Smart Education Recommendation Framework with Dashboard in the Smart City

Smart Education Context

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Development of a Smart Education Recommendation Framework with Dashboard in the Smart City:

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Abstract

This doctoral research addresses the critical gap in the lack of standardised, ISO/IEC aligned frameworks for Smart Education Recommendation Framework with Dashboard (SERFD) within Smart Cities. Existing frameworks are analysed for their limitations and enhancements are proposed based on available datasets sourced from the World Bank, Open-Data Initiative, UK Data Science, UNESCO, UN-STAT, WEF, and EU-STAT, alongside in-depth case studies. The research culminates in the development of a novel Smart Education Recommendation Framework with Dashboard that incorporates stakeholder perspectives and aligns with broader Smart City initiatives and standards.

Using data analytics concepts and Open Data-driven evaluations, the framework introduces methodologies to evaluate and optimise educational experiences within Smart City ecosystems. Real-world case studies are analysed to establish clear metrics and thresholds for operational efficiency, promoting transparency and informed decision-making. A user-friendly visualisation dashboard empowers stakeholders to assess the impact of various educational interventions, fostering continuous improvement.

This research makes a significant contribution to the field by proposing globally recognised metrics and thresholds for Smart Education within Smart Cities. These are derived from sources of reliable datasets and real-world case studies, offering valuable recommendations to stakeholders. Potential areas for future research are identified, including refining the framework's adaptability and exploring the integration of XR and AI-driven personalised learning. The practical implications of this framework offer actionable guidance to policymakers, educators, and administrators seeking to optimise educational experiences and infrastructure within Smart City environments.

Keywords: Smart City, Smart Education, Recommendation Framework, Big Data Analytics, Operational Efficiency, Standardisation, Accreditation, ISO/IEC JTC, ICT Framework, Open Data, Transparency, Visualisation Dashboard, Productivity, Performance Enhancement, Global Metrics, Educational Ecosystems, SERFD.

Dedications

This work is dedicated to my mother, whose strength and resilience in facing life's challenges, despite her health condition, have been a beacon of inspiration for me. Suffering cataracts blindness in both eye, unable to walk due to paralysis with 24/7 care. Her unwavering support and love have been my constant source of motivation. To my late father, a second world war veteran and a traditional herbal doctor, whose dreams of academic achievement have inspired my pursuit of knowledge. Although he is not here to witness this moment, his spirit and teachings continue to guide me. This achievement is a tribute to their sacrifices and a fulfilment of their aspirations.

Declaration

The thesis titled "Smart Education Recommendation Framework and Analytic Visualisation Dashboard" is a manifestation of my original research work. Contributions made by others have been properly acknowledged, and all sources of information have been referenced. This work was carried out according to the ethical guidelines established by the University of East London. It has not been submitted for any other degree or professional qualification and represents my own intellectual efforts. The author declares that all research methodologies were approved and that no part of this thesis infringes on the rights of others.

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This thesis is not only a reflection of my efforts, but a testament to the collective support and encouragement of each individual mentioned and many unmentioned.
Thank you.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
ANFIS	Adaptive Neuro-Fuzzy Inference System
AR	Augment Reality
BIM	Building Information Modelling
COBIT	Control Objectives for Information and Related Technologies
CSV	Comma Separated Value
EDMS	Educational Data Mining DataShop
EdStats	World Bank Education Statistics
EHD	EdTech Hub Data
EU STAT	European Statistics
EUOpenData	European Union Open Data Portal
EUROSTAT	European Union statistics Agency
GDPR	General Data Protection Regulation
GDS	Google Dataset Search
GEMRD	Global Education Monitoring (GEM) Report Data
GPED	Global Partnership for Education Data
HD	Harvard Dataverse
ICT	Information Communication Technology
IDE	Integrated Development Environment
IDE	Integrated Development Environment
IEC	International Electrotechnical Commission
IMF	World Bank Open Data
IoT	Internet of Things
ISO	International Organisation for Standardisation
IT	Information Technology
ITIL	Information Technology Infrastructure Library
ITLET	Information Technology Education Learning and Training Guidelines
ITSM	IT Service Management
ITU	International Telecommunication Union
JSON	JavaScript Object Notation
JTC	Joint Technical Committee
Kaggle	Kaggle Datasets
KPI	Key Performance Index
KPI	key performance indicators
LMS	Learning Management Systems
Mandeley	Mendeley Data
MOOC	Masive Open Online Course
MySQL	My Sequel Database Language
NCES	National Center for Education Statistics
NGO	Non-Governmental Organisation
NPTEL	National Programme on Technology Enhanced Learning

ODS	Open Data Soft
OE	Operational Efficiency
OE4SC	Operational Efficiency in Smart City
OECD	OECD Education Statistics
PISA	Programme for International Student Assessment
PSAR	Population to Service Allocation Ratio
QoE	Quality of Experience
SDU	Service Data Utilisation
SE	Smart Education
SERF	Smart Education recommendation Framework
SERFD	Smart Education Recommendation Framework with Dashboard
SWAYAM	Study Webs of Active Learning for Young Aspiring Minds
TEL	Technology Enhanced Learning
TEL	Technology-Enhanced Learning
UIS	UNESCO Institute for Statistics
UKDataService	UK Data Service
UN SDG-4	United Nations Sustainable Development Goal 4
UNdata	United Nations Data
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNSTAT	United Nations Statistics Division
UNStat	United Nations Statistics
USA-Data	Data Gov. USA
VR	Virtual Reality
WEF	World Economic Forum

Chapter 1

Introduction

1.0 Chapter Introduction:

Starting with the background sets the stage for the thesis by defining the central concept of the elements of Smart Education, Smart City, and Data used for the Smart Education Recommendation Framework and the Dashboard while providing a comprehensive background on its role within Smart Cities. With outlines of the research framework, it presents the research questions, objectives, hypotheses, and methodology that guide this study, providing the reader with a comprehensive overview of the project.

1.0.1 Background

Smart Education (SE), a cornerstone of modern urban development, leverages predictive thinking and innovative learning resources to shape the future of education (Kitchin 2014a). SE defines itself as the integration of technology and data-driven approaches to enhance learning experiences, access, and outcomes, with the aim of equipping learners with the skills and knowledge necessary to thrive in the 21st century. This thesis focusses on improving operational efficiency (OE) in Smart Cities through the development of the Smart Education Recommendation Framework and Dashboard, which will ensure equitable access and opportunities in diverse landscapes (Albino, Berardi, and Dangelico 2015). This research aligns with the comprehensive Smart Education Recommendation Framework, which includes various stakeholders such as companies, citizens, governments, and non-governmental entities, with the objective of promoting sustainability in educational practices (Angelidou et al. 2018; Jagatheesaperumal et al. 2024; Duong et al. 2024; Shishakly et al. 2024).

1.0.2 Smart City Background with Smart Education

Smart cities are characterised by advanced digital ecosystems in which smart citizens interact with intelligent environments, including education, government, traffic control, and transportation systems (Luis et al. 2013). The effectiveness of a Smart City is based on automated community interactions with services through Information Communication Technology (ICT)and the Internet of Things (IoT), ensuring efficient communication and improved living standards (Eiman et al. 2015). In the context of Smart Education, each component of the Smart City framework contributes to the creation and distribution of knowledge through the following application interfaces.

- **Smart Economy:** Fosters innovation and competitiveness in education, aligning curriculum with market needs and future trends (Alzahrani 2024).
- **Smart Transportation:** Provides seamless connectivity and efficient time management for students and staff through integrated transportation systems (Rosidin 2024).
- **Smart Environment/Health Care:** Promotes sustainability and resource management through experiential learning, environmental monitoring, and educational initiatives related to health (Nourse et al. 2023; Barua 2024; Zivelonghi and Giuseppi 2024).
- **Smart Education/Campus:** Creates innovative, creative, and socially enriching learning environments, using technology for personalised learning and collaboration (Setiawan et al. 2024; Bastari, Bandono, and Suharyo 2021; Sneesl et al. 2023).

- **Smart Living:** Extends learning beyond the classroom, integrating educational content into daily life through smart home devices and connected technologies (Marchesani and Masciarelli 2024; C. Li and Pan 2024; Scala et al. 2024).
- **Smart Governance:** Ensures transparency and stakeholder participation in educational policies and developments through data-driven decision making and open communication platforms (Vitálišová et al. 2023; Kuzior et al. 2023; Wiyono, Purnomo, and Lestari 2023).

1.0.3 Smart City Data Element For Smart Education

The development of smart cities (SC) is based on various data components, each contributing to a responsive urban environment and the integration of the Smart Education Framework.

- **Energy Consumption:** Improves energy efficiency and sustainability (Neirotti et al. 2014a).
- **Traffic Data:** Optimises transportation systems and reduces congestion (Batty et al. 2012).
- **Air Quality Data:** Enhances environmental monitoring and public health (Chourabi et al. 2012).
- **Public Safety Data:** Strengthens safety measures and security (Neirotti et al. 2014b).
- **Education Data:** Fosters improved educational outcomes and equitable access (Batty et al. 2012).
- **Health Data:** Enhances healthcare services and accessibility (Chourabi et al. 2012).
- **Economic Data:** Propels economic growth and employment opportunities (Neirotti et al. 2014b).
- **Citizen Feedback:** Encourages citizen engagement and inclusivity (Batty et al. 2012).

1.0.4 Smart Education Background and Characteristics

Smart Education (SE), characterised by dynamic, engaging, and effective environments, prioritises measurable operational efficiency (OE). Key attributes include smart environments, smart pedagogy, and smart learners (Zhu, M.-H. Yu, and Riezebos 2016). The implementation of digital technologies significantly improves SE by improving access to education, facilitating personalised learning, and promoting environmental awareness (Hafedh et al. 2012). These elements are crucial in adapting to demographic changes and embracing Technology-Enhanced Learning (TEL), fostering flexible and accessible educational experiences (Christensen, Gillingham, and Nordhaus 2018; J. Martin and Richard 2014; Rawad, Mohammed, and Zaheer 2015).

Smart environments in education use Internet of Things (IoT) devices, big data analytics, and cloud computing to create interconnected and responsive learning spaces. IoT devices, such as smartboards, sensors, and wearable technology, collect and transmit data to enhance the learning experience by providing real-time feedback and adaptive learning opportunities (Abdel-Basset et al. 2019; Hammad, Odeh, and Khan 2013; Kitchin 2014b). For example, smartboards facilitate interactive and collaborative learning by enabling students to engage with digital content dynamically.

Big data analytics play a pivotal role in smart education by analysing the volume and variety (2V) of data generated from various educational activities. This data is used to tailor educational content to individual students, providing personalised learning pathways that cater to their unique needs and preferences. Through predictive analytics, educators can identify students who might be at risk of falling behind and intervene promptly to provide the necessary support (Tore and Jon 2018). In addition, learning management systems (LMS) integrated with big data analytics enable institutions to track and improve student performance and administrative efficiency.

Cloud computing offers scalable and flexible resources that allow educational institutions to manage and store large datasets efficiently. It supports seamless access to educational materials and resources anytime and anywhere, thus promoting inclusive education. Cloud-based platforms enable collaborative learning, where students and teachers can share resources, participate in discussions, and collaborate on projects in real time, regardless of their physical location (Urbanik and Horalek 2022).

Artificial intelligence (AI) is another cornerstone of smart education. AI-powered tools, such as intelligent tutoring systems and virtual assistants, provide personalised tutoring and administrative assistance. These systems can adapt to the learning pace and style of each student, providing customised support and improving their learning outcomes (Hoel and Mason 2011). AI also helps automate administrative tasks, such as grading and scheduling, freeing educators valuable time to focus on teaching.

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With the advent of Generative AI (GenAI), such as large language models and advanced generative systems, the landscape of smart education has evolved further. GenAI offers the potential to create highly interactive and adaptive learning environments by dynamically generating content that is tailored to the individual needs of the learner (Happi et al. 2024). For example, generative models can craft personalised quizzes, explain complex concepts at varying levels of depth, and simulate real-world problem solving scenarios, enhancing engagement and comprehension.
Furthermore, GenAI expands the scope of virtual assistants by enabling them to provide nuanced, context-sensitive responses to student queries and facilitate collaborative learning activities (X. Zhou et al. 2018). These capabilities support a more immersive and effective educational experience, aligning with the goals of Smart Education.
Smart education also emphasises the importance of developing digital literacy and fostering a culture of continuous learning. By integrating digital skills into the curriculum, students are better prepared for the demands of the modern workforce. Educational institutions invest in professional development for teachers to equip them with the skills necessary to leverage technology effectively in their teaching practices (Jnr et al. 2023).
Although the transition from traditional to smart education, particularly in rural classrooms, presents challenges, it also offers significant benefits. Modern technologies, such as IoT, big data, and AI, are increasingly being integrated into rural educational settings, improving access to quality education and bridging the digital divide (Jin Gon Shon 2002; SDG4 2017; Lindner 2004). However, this research highlights the need to adhere to international standardisation in educational IT, aligning with the UN SDG-4 on quality education and ISO's ITLET guidelines, to promote Smart Education within Smart Cities (Jin Gon Shon 2002; SDG4 2017; Lindner 2004).
Operational efficiency (OE) within the realm of smart education is not just about streamlining processes; it is about creating a harmonious educational ecosystem that thrives within the infrastructure and socioeconomic context of smart cities. It involves using technology and data to improve the quality of education, improve access, and ensure optimal management and use of educational resources.

1.1 Introduction to Smart Education Recommendation Framework

This research aims to explore the integration of the Smart Education Recommendation Framework (SERF) with Smart City infrastructures, focussing on improving the operational efficiency of smart education. The investigation is structured around the ISO/IEC 30145 series standards,, which provide a foundational basis for the development and implementation of SERF components within the urban educational sphere. The study illustrates how these standards can be used to improve curriculum development, stakeholder involvement, and the overall educational ecosystem, thus contributing to a sophisticated global educational infrastructure.

1.1.1 Knowledge Gaps

The development of the Smart Education Recommendation Framework with Dashboard (SERFD) has been informed by a set of clearly identified knowledge gaps in the existing literature and practice. These gaps underscore the need for robust data-driven methodologies to advance the integration of Smart Education into the broader framework of Smart Cities.

Identified Knowledge Gaps

1. **Integration Challenges**: There is an absence of a universally applicable and standardised framework that effectively merges Smart Education with ISO/IEC Smart City standards. Existing research lacks sufficient information on aligning smart education systems with established Smart City frameworks.
2. **Methodological Deficiencies**: Current methodologies fall short in using recommendation frameworks to optimise the operational efficiency of Smart Education. Few studies provide a systematic

approach to harnessing data-driven insights for decision making in educational institutions.

3. **Technological Gaps**: Limited frameworks exist to integrate advanced technologies, such as artificial intelligence, data analytics, IoT, and cloud computing, into Smart Education systems. The role of Big Data analytics and dashboard visualisation in educational contexts remains underexplored.
4. **Equity and Accessibility**: There is a significant gap in designing frameworks that ensure equitable and accessible Smart Education for diverse populations within Smart Cities. Research addressing inclusivity and how emerging cities are integrated into educational systems across different socio-economic backgrounds is scarce.
5. **Alignment with International Standards**: Insufficient research explores how Smart Education frameworks can align with ISO/IEC international standards for Smart Cities. This gap limits the scalability and standardisation of such frameworks globally.

Implications for Framework Development

Addressing these knowledge gaps forms the foundation for the design and implementation of SERFD. By integrating advanced technologies, fostering inclusivity, and aligning with international standards, this framework seeks to bridge the identified gaps and provide practical solutions for enhancing Smart Education systems within the context of Smart Cities.

Foundational Components of Smart Education Recommendation Framework

The Super Framework is dissected to reveal its reliance on the ISO/IEC 30145 series standards. Each part of this series supports the Smart Application within the urban educational context. Detailed components of the Smart Education Recommendation Framework are examined, which presents a granular view of operational elements essential for research and analysis, curriculum development, integration of smart learning environments, and strategic stakeholder participation. This analysis serves as a roadmap to integrate and enhance existing Smart City frameworks, leading to an advanced and interconnected global educational infrastructure aligned with the ISO/IEC Smart City Framework (ISO 2014).

Coherence with ISO/IEC Smart City Frameworks

The coherence between the components of the Smart Education Recommendation Framework and the ISO / IEC smart city frameworks underscores the meticulous design of the research methodology. It highlights the importance of a harmonised approach to education that takes advantage of international smart city frameworks to foster an environment conducive to learning and growth. The interaction between these components is expected to yield rich insights into effectively orchestrating, managing, and scaling Smart Education within the expanding landscape of smart cities. This provides a foundation for informed decision making and strategic educational advancement rooted in standardisation. The Smart Education Recommendation Framework depicted in Figure 1.4 is crucial in this Ph.D. thesis, representing a blueprint to improve operational efficiency in smart cities. The framework outlines a structured approach to harnessing smart technologies in education, aligning and extending the ISO/IEC Smart City Framework. This framework offers a practical guide for policymakers, educators, and technologists, outlining steps and components necessary for the implementation of a sophisticated smart education system. By incorporating stakeholder participation from citizens, communities, governments, and NGOs, the framework ensures inclusivity and relevance. In addition, it serves as a template for future research, providing a replicable model for other urban educational systems that transition to the smart education paradigm. It is a testament to the transformative power of technology in education and an embodiment of the thesis's goal to enhance operational efficiency and educational excellence in smart cities worldwide.

1.2 Problem Statement

The burgeoning field of Smart Education, fuelled by advances in artificial intelligence, data analytics, and cloud computing, promises to revolutionise pedagogical practices and improve learning outcomes. However, the seamless integration of Smart Education within the broader framework of Smart Cities, as envisioned by the ISO/IEC standards, presents a complex challenge. This thesis addresses a significant gap in both academic research and practical implementation, the absence of a standardised, universally applicable frame-

work that effectively merges Smart Education with the ISO/IEC Smart City Framework.
Furthermore, the current landscape lacks a robust methodology that leverages a well-defined recommendation framework to optimise the operational efficiency of Smart Education within Smart Cities. This deficiency hinders the ability of educational institutions to harness the full potential of data-driven insights for informed decision making and continuous improvement (Williamson 2017; N.-S. Chen et al. 2020).
This thesis aims to bridge these gaps by proposing a novel Smart Education Recommendation Framework that aligns with the ISO/IEC Smart City Framework and incorporates Big Data analytics for dashboard data visualisation. The framework will provide a structured approach to integrating Smart Education technologies and methodologies into the urban fabric of Smart Cities, thereby fostering a more efficient, equitable, and accessible educational ecosystem.
By addressing these critical issues, this research seeks to make a significant contribution to the field of Smart Education and pave the way for future advancements in data-driven educational practices within Smart Cities (Hafedh et al. 2012; Fan and F. Xiao 2017), one that is aligned with the ISO / IEC International standard. leading to the evolving landscape of urban development, the concept of Smart Cities has emerged as a pivotal paradigm, integrating advanced technologies to improve the quality of life of citizens. In this context, Smart Education (SE) represents a critical component, leveraging data-driven approaches and technological innovations to foster a more personalised, efficient, and equitable learning environment. The following require a comprehensive and structured framework to address these issues.

1.2.1 Key Challenges

Lack of Standardised Metrics and Frameworks

Despite the potential benefits of Smart Education, there is a conspicuous absence of universally adopted metrics within Smart Cities that explicitly cater to the domain of Smart Education. Existing frameworks, such as the ISO/IEC Smart City Framework, do not adequately address the specific needs and intricacies of integrating Smart Education into urban environments. This gap hinders the ability to measure, evaluate and improve educational practices effectively (**sotiriosParoutis**; Zhuhadar et al. 2017).

Insufficient Integration of Emerging Technologies

The rapid advancements in technologies such as Big Data Analytics, Artificial Intelligence (AI), and the Internet of Things (IoT) present significant opportunities to improve Smart Education. However, the integration of these technologies into the educational ecosystem remains fragmented and underused. There is a critical need for a framework that not only incorporates these technologies but also uses them to provide real-time insights and personalised learning experiences (Wong and Looi 2022; Udupi, Malali, and Noronha 2016a).

Operational Inefficiencies

Educational institutions within Smart Cities face challenges in operational efficiency, particularly in managing resources, optimising learning environments, and ensuring equitable access to educational opportunities. The lack of a cohesive framework to guide the implementation and management of Smart Education exacerbates these inefficiencies, leading to suboptimal educational outcomes (Shishakly et al. 2024; Cheshmehzangi et al. 2023; Zeeshan, Hämäläinen, and Neittaanmäki 2022).

Data Management and Utilisation

The effective use of Big Data is paramount to the success of Smart Education. However, challenges related to data collection, storage, analysis, and visualisation persist. The absence of a robust system to manage the volume and variety of data generated within Smart Education contexts results in missed opportunities for data-driven decision making and strategic planning (P., Uma, and Elias 2016).

Stakeholder Engagement

The development and implementation of Smart Education require the active participation of various stakeholders, including government bodies, educational institutions, private sector entities, and the community. Currently, there is a lack of coordinated efforts and standardised methodologies to engage these stakeholders effectively, hindering the collaborative development of sustainable educational solutions (Annika, Gerd, and Jose 2015; Lu et al. 2015).

Overcoming Key Challenges

Given the challenges highlighted, this thesis addresses and overcomes these barriers to ensure the successful adoption and implementation of Smart Education technologies. Using a structured, multifaceted approach, the framework bridges gaps in standardisation, technology integration, operational efficiency, data management, and stakeholder participation.

Firstly, this thesis introduces the Smart Education Recommendation Framework with Dashboard (SERFD), which is designed to align with the ISO/IEC Smart City Framework. By embedding standardised metrics specific to Smart Education, the framework addresses the absence of universally adopted measures. This ensures compatibility across diverse urban environments and provides a scalable model to evaluate and improve educational practices (Zhuhadar et al. 2017; Paroutis, Bennett, and Heracleous 2014).

Secondly, SERFD proposed advanced technologies such as Artificial Intelligence (AI), Big Data analytics, and the Internet of Things (IoT) to create a seamless ecosystem for Smart Education. These technologies enable real-time insights, personalised learning experiences, and dynamic resource management. The dashboard of the framework facilitates data visualisation and predictive analytics, bridges the gap between technological potential and practical implementation (Wong and Looi 2022; Udupi, Malali, and Noronha 2016a).

Ensuring Effective Implementation

To address operational inefficiencies, SERFD uses a data-driven approach that optimises resource allocation and learning environments. The emphasis of the framework on equitable access ensures that Smart Education technologies are inclusive and adaptable to diverse socio-economic contexts. By integrating automated systems and real-time analytics, the framework mitigates inefficiencies and improves the effectiveness of educational delivery (Shishakly et al. 2024; Cheshmehzangi et al. 2023; Zeeshan, Hämäläinen, and Neittaanmäki 2022).

Furthermore, this thesis establishes robust data management protocols within the framework to ensure efficient collection, storage, analysis, and use of big data. The design of the dashboard prioritises usability and accessibility, empowering stakeholders to make informed decisions and implement strategic plans effectively (P., Uma, and Elias 2016).

Finally, the thesis highlights the importance of stakeholder engagement as a cornerstone of successful Smart Education systems. The framework incorporates structured methodologies to foster collaboration among government agencies, educational institutions, private sector entities, and communities. This approach ensures that all stakeholders contribute and benefit from sustainable educational solutions (Annika, Gerd, and Jose 2015; Lu et al. 2015).

In summary, the proposed framework overcomes identified challenges by providing a comprehensive, adaptable, and technology-driven solution that aligns with international standards while addressing the unique needs of Smart Education within Smart Cities.

1.3 Research Aims

In alignment with the goals of improving the Smart City ISO/IEC framework of the Joint Technical Committee (JTC), the aim of this doctoral research is to refine the existing Smart City ISO/IEC framework and establish a recommendation system to advance Smart Education through the development of a novel Smart Education Recommendation Framework. This framework will be grounded in stakeholder perspectives and designed to integrate Big Data analytics to enhance operational efficiency in Smart Education within Smart Cities. This framework aims to empower stakeholders, including developers, e-governments, and non-governmental entities, to use the multifaceted aspects of Big Data. It will facilitate the development of dashboard visualisations to be used within Smart Cities, improving overall operational efficiency. The study outlines the following aims:

1. **Development of a Smart Education Recommendation Framework:** To develop a Smart Education Recommendation Framework that aligns with the ISO/IEC Smart City Framework.
2. **Improvement of Existing Smart City ISO / IEC Framework:** To integrate Big Data analytics into the Smart Education Recommendation framework to enhance operational efficiency within Smart Cities.
3. **Practical Implications:** To evaluate the impact of Smart Education technologies on educational outcomes and urban development.
4. **Support for future research:** To ensure the framework is adaptable and scalable to meet the evolving needs of Smart Cities.

This research is at the forefront of educational innovation to support stakeholders, with the objective of orchestrating a substantial impact in the field of improving Smart Education. It meticulously examines the modalities of increasing operational efficiency within the intricate fabric of smart cities in the context of Smart Education. The ambition is not only to contribute to the academic dialogue, but to furnish pragmatic insights that can steer future research endeavours in Smart Education. In addition, it seeks to inform and guide the implementation of data-driven methodologies and the infusion of technological advances in the urban education sector. Through the definition of a refined framework, the study seeks to articulate a coherent strategy that aligns with the ethos of Smart Education in the form of a visualisation dashboard and resonates with the operational dynamics of the ISO/IEC Smart City framework.

1.4 Primary Research Objectives

As highlighted by the research questions and the gaps identified in the literature, this thesis aims to achieve the following key objectives. These objectives follow a logical progression: first by proposing the integration of Big Data analytics, then designing and implementing the Smart Education Recommendation Framework with Dashboard (SERFD) and finally, assessing its impact and scalability.

1. **Proposing the Integration of Big Data Analytics in the Smart Education Framework:** To investigate how Big Data analytics can be systematically integrated to improve personalised learning experiences, optimise resource allocation, and enhance the overall operational efficiency of educational institutions within Smart Cities. This proposal involves identifying the opportunities and challenges associated with the use of large data sets and advanced analytics if there are opportunities to inform and improve educational strategies (H. Chen, Chiang, and Storey 2012).
2. **Design and Development of the Smart Education Recommendation Framework with Dashboard (SERFD):** Design and develop a comprehensive Smart Education Recommendation Framework with an interactive dashboard. This framework visualises key Smart City metrics in the context of Smart Education, aligns them with ISO/IEC Smart Education standards, and ensures that they contribute to measurable educational outcomes. The design phase focusses on aligning emerging technologies with educational requirements, while the development phase translates these designs into an operational framework (Rafael Cortez et al. 2020).
3. **Implementation and Evaluation of the Framework:** To implement the SERFD framework in real-world or simulated urban educational environments, ensuring its functionality and adaptability. This phase includes evaluating its impact on stakeholders, such as students, educators, administrators, and policy makers. The evaluation examines how the framework enhances learning outcomes, teaching methodologies, decision-making processes, and resource management (Abella et al. 2024).
4. **Addressing Rural-Urban Disparities Through Emerging Technologies:** To ensure the framework addresses rural-urban disparities using emerging technologies. This involves investigating how AI, IoT, and other technological advances can bridge the digital divide and facilitate equitable access

to quality education, particularly in underserved rural areas (Alalawi and Al-Omary 2019).

5. **Mitigating Challenges in Framework Implementation:** To identify and provide solutions for potential challenges in framework implementation. These challenges include data privacy and security, technological infrastructure readiness, and the need for professional development among educators. The proposed solutions will ensure the seamless integration of the framework and maximise the benefits of personalised, data-driven learning experiences. In addition, investment strategies will be outlined to reduce educational disparities and strengthen technological infrastructure in Smart Cities (Daniel 2015).
6. **Designing for Adaptability and Scalability:** To ensure the framework is designed to be adaptable and scalable, capable of accommodating the evolving needs of Smart Cities and technological advancements in alignment with ISO/IEC. This objective guarantees that the framework remains relevant and effective in supporting sustainable educational development (Zawacki-Richter, Victoria I Marín, et al. 2019a).

By addressing these objectives in a structured manner, this thesis makes a significant contribution to the integration of Smart Education within Smart Cities. It provides a practical framework that aligns with global standards and advances the field by proposing, designing, implementing, and evaluating innovative approaches that bridge traditional educational paradigms with the demands of smart urban environments.

1.4.1 Secondary Research Objectives

The secondary objectives aim to:

1. Identify and analyse limitations of current Smart Education frameworks.
2. Propose enhancements using comprehensive data sets and case studies.
3. Develop a novel Smart Education Recommendation Framework incorporating stakeholder perspectives and aligning with ISO/IEC standards.
4. Design and implement a Visualisation Dashboard for real-time monitoring and optimisation of educational processes.
5. Validate the effectiveness of the proposed framework and dashboard through data set or generative testing.

Detailed Objectives

- Examining how Smart City metrics and their components can be effectively visualised in the context of Smart Education and understanding the impact of these metrics on educational outcomes, while aligning with ISO/IEC Smart Education Framework.
- Investigate tools that can integrate the results of IoT, cloud computing, and other emerging technologies data within Smart Cities to improve educational infrastructure and methodologies.
- Identify investment strategies to minimise educational disparities between rural and urban areas by leveraging the infrastructure and technological advances inherent in the volume and variety of big data in smart cities.
- Develop a tool for proposing policies that facilitate the integration of Smart Education initiatives within the larger Smart City development goals, ensuring a cohesive approach to urban and educational planning.

1.5 Research Questions

Based on the identified gaps and challenges in the introductory chapter, the following research questions are proposed.

1. How can a Smart Education Recommendation Framework be developed that aligns with the ISO/IEC Smart City Framework and effectively integrates Big Data analytics to enhance the operational efficiency of Smart Education within Smart Cities?
2. What are the key components and functionalities of a Smart Education Recommendation Framework that can facilitate the seamless integration of Smart Education technologies and methodologies into the urban fabric of Smart Cities?

3. How can Big Data analytics be leveraged to improve the operational efficiency of Smart Education in Smart Cities, and what are the specific metrics and indicators that can be used to measure this improvement?
4. What are the potential benefits and challenges of implementing a Smart Education Recommendation Framework in Smart Cities, and how can these challenges be addressed to ensure successful adoption and implementation?
5. How can the Smart Education Recommendation Framework be designed to be adaptable and scalable to meet the evolving needs of Smart Cities and the dynamic landscape of educational technologies?

1.6 Research Hypothesis

Is set to the integration of a Smart Education Recommendation Framework, supported by a visualisation dashboard and grounded in advanced data analytics, including emerging technologies. It will significantly improve the operational efficiency, personalisation, and overall effectiveness of educational practices within Smart Cities. This framework is expected to bridge existing gaps in standardisation, technological integration, and stakeholder engagement, thus fostering a more equitable and innovative educational environment. In relevance, it aims to address the multifaceted gaps identified in Smart Education, particularly those related to framework standardisation, international baseline compliance, and operational efficiency. Central to this investigation is the exploration of the symbiotic relationship between Smart City development and Smart Education frameworks. A key focus is to address the disparities between rural and urban educational settings, examining how Smart City metrics, when aligned with the principles of the Smart Education Framework, can produce measurable results that benefit both paradigms (Baker and Siemens 2014), and align with the ISO/IEC Smart City Framework. The integration of smart city paradigms with emerging technologies in education presents numerous challenges, particularly in ensuring the seamless adoption and effective use of innovations such as IoT and cloud computing within educational frameworks. Addressing these challenges involves a thorough exploration of existing proposals and frameworks to understand their qualitative relevance and practical implications. This research unravels the complex layers of these challenges and offers insight into potential solutions, recognising that the challenges and solutions identified here are not exhaustive but indicative of the evolving nature of Smart Education in the context of Smart Cities (Ricardo Cortez et al. 2020). Table 1.1 below provides a synoptic portrayal of the research's cornerstone, the Smart Education Recommendation Framework, and its symbiotic extension from the established ISO/IEC frameworks for smart cities. It encapsulates the essence of the framework in a structured tabular format, presenting a hierarchy of frameworks and their corresponding applications within the context of Smart Education. Each row elucidates a specific segment of the overarching 'Super Framework', its 'Smart Application' within the urban tapestry, and the pertinent 'Smart Education Components' that encapsulate the operational facets of Smart Education.

In dissecting the 'Super Framework', the research illuminates the foundations laid by the ISO/IEC 30145 series, delineating how each part of this series underpins the 'Smart Application' within the urban educational sphere. Sequentially, the 'Smart Education Components' are detailed, presenting a granular view of the operational elements that are pivotal for research and analysis, curriculum development, integration of smart learning environments, and the strategic involvement of stakeholders in the educational ecosystem. This table serves as a roadmap for understanding how Smart Education can not only fit into but also extend and enhance existing Smart City frameworks, leading to an interconnected and sophisticated global educational infrastructure that is aligned with the ISO/IEC Smart City Framework.

The coherence between the Smart Education components and the ISO/IEC smart city frameworks is a testament to the meticulous design of the research methodology. It underscores the importance of a harmonised approach to education that takes advantage of the strengths of international smart city frameworks to foster an environment conducive to learning and growth. As research unfolds, the interaction between these components is expected to yield rich insights into how Smart Education can be effectively orchestrated, managed, and scaled within the burgeoning landscape of smart cities, thus providing a foundation for informed decision making and strategic educational advancement that is rooted in standardisation. This research further evaluates the contributing factors for success, qualitative and quantitative, by reviewing the literature on the topic as shown in Figure 1.2.

Table 1.1: Rationale: New Smart Education Framework extends the Smart City ISO/IEC Frameworks

Begin: New Smart Education Framework Expands the Smart City from ISO/IEC Frameworks		
Super Framework	Smart Application	Smart Education Components
30145-1	Educational Processes	Guidelines for Education Research and Analysis
30145-2	Knowledge Management in Smart Cities	Curriculum Development and Knowledge Organisation in Smart Education
30145-3	Smart Education Applications	Integration of Smart Learning Environments and Smart Campus Management
30145-3	Computing and Storage in Smart Cities	Educational Computing Resources, Data Storage, and Software Applications
Stakeholder Involvement	Community and Citizen Engagement	Government and Non-Government Participation in Smart Education
End: New Smart Education Framework extends the Smart City ISO/IEC Frameworks		

1.6.1 Qualitative and Comparative Literature Search:

Table 1.2: Overview of Proposals Related to Smart Education Recommendation Framework and Dashboard (Search: Smart Education Recommendation Systems with Dashboard)

ID	**Proposed By**	**Framework=1, Dashboard=2, ISO/IEC=3, Recommend=4**	**Cite**	**Qualitative Relevance to Smart Education**
1	Mohamed Abdel-Basset et al.	Framework=1, Dashboard=0, ISO/IEC=0, Recommend=0	(Abdel-Basset et al. 2019)	Proposes a framework integrating IoT for improved educational insights and decision-making.
2	Ofir Ben-Assuli et al.	Framework=0, Dashboard=0, ISO/IEC=0, Recommend=0	(Ben-Assuli et al. 2019)	Big Data Analytics methodology

Table 1.2 continued from previous page

ID	Proposed By	Framework=1, Dashboard=2, ISO/IEC=3, Recommend=4	Cite	Qualitative Relevance to Smart Education
3	ISO/IEC Smart City Framework 30145 series	Framework=1, Dashboard=0, ISO/IEC=3, Recommend=0	(Heaton and Parlikad 2019; Bernyukevich 2023; Urbanik and Horalek 2022)	Proposes a framework with a list of standards, but without SE and dashboard specifics.
4	Danilo Dess et al.	Framework=0, Dashboard=1, ISO/IEC=0, Recommend=0	(Dessì, Fenu, Marras, and Recupero 2019)	Proposes a framework for data extraction.
5	Bodily et al.	Framework=0, Dashboard=1, ISO/IEC=0, Recommend=0	(Bodily and Verbert 2017)	Development of a dashboard and learning reporting system.
6	Atalla et al.	Framework=0, Dashboard=0, ISO/IEC=0, Recommend=4	(Atalla et al. 2023)	Proposes a mathematical form for calculations and recommendations.
7	Motahari et al.	Framework=1, Dashboard=0, ISO/IEC=0, Recommend=0	(Motahari, Rouhani, and Zare 2016)	Proposes a smart school recommendation system.
8	Naidu et al.	Framework=1, Dashboard=1, ISO/IEC=0, Recommend=0	(Naidu et al. 2017)	Proposes a framework and analytic tool for HE.

These are by no means exhaustive, indicating that if there standards available the tale would have shown at average similar metrics for frameword, dashboard, ISO/IEC and recommend. This research supports the extensive research work of developers in the fields of operational efficiency in smart buildings, smart education, smart economy, smart environment, smart living, and smart mobility. Starting with Heaton (James and Kumar 2019; Lu et al. 2015; Zeeshan, Hämäläinen, and Neittaanmäki 2022) on efficiency, it is noted that there are risks that IoT information becomes unmanageable, which poses a challenge in establishing a globally acceptable standard. Heaton also highlighted that the International Standard Organisation (ISO), the International Telecommunication Union (ITU), and the British Standards Institute (BSI) have already

begun efforts to standardise smart city development. This research aims to incorporate a measuring model to present the KPIs of these organisations through visual analytics using a big data application methodology. Building Information Modelling (BIM), combined with the aspects of the International Telecommunication Union (ITU) model, will help the information management processes adopted by developers. Although Heaton's work provided extensive guidance on sourcing KPIs, there was a lack of focus on smart education within the sources utilised by Heaton.
This qualitative and comparative literature search aims to contextualise the research within existing efforts, identifying gaps and opportunities for further advancement. Furthermore, Figure 1.2. addresses the following findings.

1. Building on the Comparative Literature

The proposed framework leverages insights from the comparative literature outlined in Table 1.2, which identifies the presence (or absence) of key components such as compliance with ISO/IEC standards, dashboards, and recommendation options. Specifically:

- **ISO/IEC Compliance:** Most of the works reviewed, including Abdel-Basset et al. and Atalla et al., do not explicitly incorporate ISO/IEC standards relevant to Smart Education. The proposed framework addresses this gap by embedding these standards to ensure global applicability and interoperability.
- **Dashboard Integration:** While some works such as Bodily et al. and Naidu et al. include dashboard components, they do not comprehensively integrate them into a framework for smart education recommendations. The proposed framework bridges this gap by embedding a dashboard for real-time monitoring and visualisation.
- **Recommendation Systems:** Atalla et al. propose a mathematical recommendation system, but it lacks integration with other components such as dashboards or ISO/IEC standards. The proposed framework integrates a recommendation system tailored to smart education, ensuring actionable insights.

2. Identified Specific Gaps

The gaps identified in Table 1.2 include:

- Lack of a unified system that combines frameworks, dashboards, and recommendations.
- Minimal adherence to ISO/IEC standards, except for the ISO/IEC Smart City Framework, which lacks specificity for smart education.
- Limited scalability and applicability for Higher Education (HE) settings, particularly in works such as Abdel-Basset et al. and Motahari et al.

The proposed framework addresses these gaps by:

- **Aligning with ISO/IEC standards** to ensure compliance and relevance.
- **Integrating dashboards and recommendation systems** for real-time decision making and insights.
- **Providing scalability and adaptability** for diverse HE contexts.

Gap Implementation and Review

Step.4 introduces the iterative delivery process workflow, which is critical to the development of operational efficiency (OE) in the context of smart education. This structured approach is predicated on the Deming cycle, or PDCA (Plan-Do-Check-Act), which fosters continuous improvement in projects. The workflow encapsulated in Figure 1.1 is meticulously designed to streamline the transition from theory to application, ensuring that every cycle enhances the project's trajectory towards its strategic objectives. Each cycle comprises the following phases:

- **Define**: This initial phase involves identifying improvement opportunities by discerning the gaps between current processes and desired outcomes.
- **Measure**: In this phase, the current operational performance is quantified, setting a benchmark against which improvements can be measured.
- **Analyse**: Here, a detailed evaluation of the primary contributions to the gap is carried out, using data-driven analysis to pinpoint root causes.

- **Improve**: This phase is dedicated to improving operational efficiency through strategic interventions and innovative solutions.
- **Control**: The final phase involves validating the improvements by verifying the results and making the necessary modifications to ensure sustained progress.

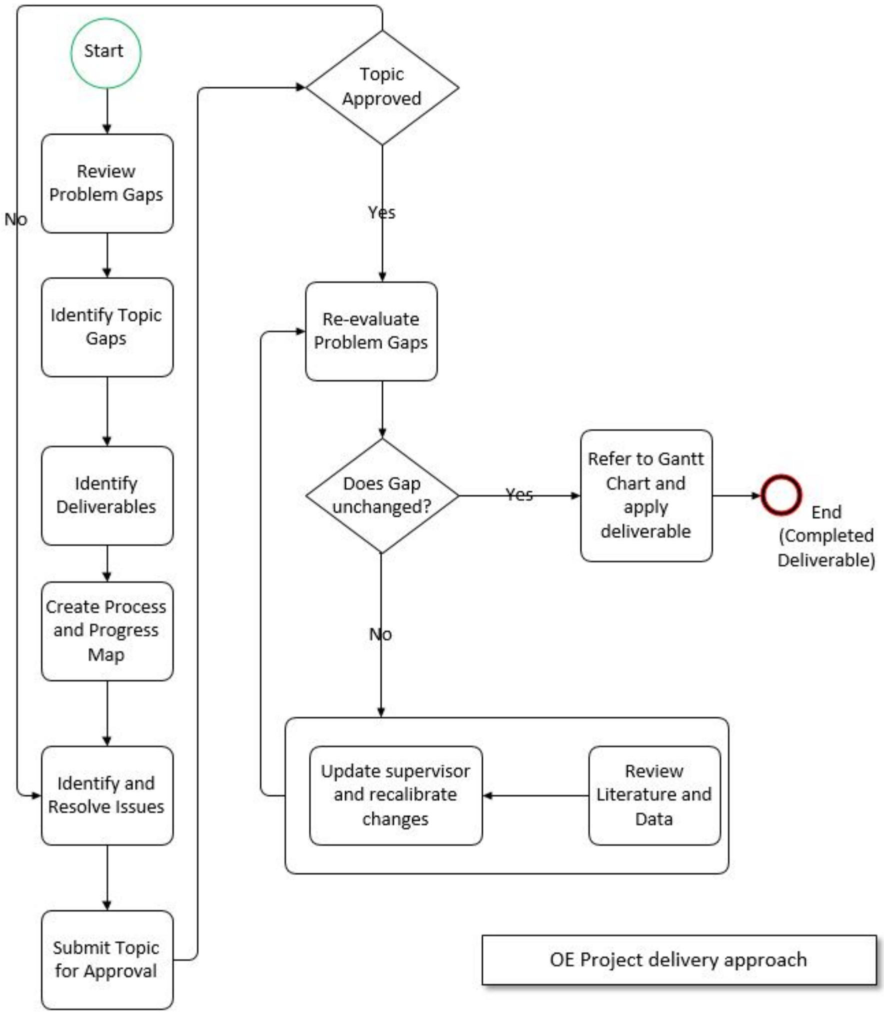


Figure 1.1: Operational Efficiency Delivery Process flow approaches

The workflow is a dynamic, cyclical process that adapts to the evolving landscape of Smart Education, accommodating new insights, and recalibrating goals as more information becomes available. Through this process, the project delivers tangible and measurable improvements in operational efficiency.
This **visual** representation serves as both a roadmap and a checklist, ensuring that the project remains aligned with its core objectives and that each phase of the delivery process is executed with precision and clarity.

3. Closest Work and Differentiation

- **Closest Work:** The work of Naidu et al. is the most relevant because it integrates a framework and an analytic tool (dashboard). However, it does not address ISO/IEC compliance or recommendations.
- **Differentiation:** The proposed framework differs by:
  - Incorporating **ISO/IEC standards** for global applicability.
  - Providing a comprehensive, unified system that combines framework, dashboard, and recommendation capabilities.
  - Targeting **smart education contexts** specifically, with features like adaptive learning and stakeholder feedback mechanisms.

4. Positioning of the Proposed Framework

The proposed framework represents a novel contribution by addressing the fragmented nature of existing solutions and creating a unified, standards-compliant and feature-rich system tailored for smart education.

1.7 Research Methodology

To achieve the research objectives and test the hypotheses, this thesis adopts a mixed-method approach, combining both quantitative and qualitative research methodologies. This approach will provide a comprehensive and nuanced understanding of the complex interplay between Smart Education, Big Data analytics, and the ISO/IEC Smart City Framework.

Literature Review

Research begins with a comprehensive review of the literature to identify existing knowledge and practice gaps, as well as to establish a theoretical foundation for the development of the Smart Education Recommendation Framework. This review will include an analysis of current Smart Education initiatives, Big Data applications in education, and the ISO/IEC Smart City Framework standards. Key sources will include academic journals, industry reports, and relevant standards documentation (Baker and Siemens 2014; Ricardo Cortez et al. 2020).

Research Design

A mixed-methods research design will be used, integrating both qualitative and quantitative approaches. This design allows for a robust examination of the research questions from multiple perspectives, ensuring a thorough investigation of the complex issues at hand.

Quantitative Methods

The quantitative component will involve the collection and analysis of data through open data and case studies. evaluation will be performed on a diverse group of stakeholders, including educators, students, administrators, and policymakers in various Smart Cities. The case studies and review will be designed to gather information on the current state of Smart Education, the challenges faced, and the perceived benefits and drawbacks of integrating Big Data analytics.
Case studies will provide in-depth analysis of existing Smart Education frameworks and their implementation within different Smart Cities. These case studies will help identify best practices and common pitfalls, providing valuable information for the development of the Smart Education Recommendation Framework.
The quantitative data collected will be analysed using statistical techniques to identify patterns, correlations, and trends. Tools such as Python will be used for this purpose. This analysis will provide insights into the effectiveness of different approaches to Smart Education and inform the framework's development.

Qualitative Methods

The qualitative component will involve data collection through online data sources. These interactions will provide a deeper understanding of the contextual factors that influence the implementation and adoption of Smart Education in Smart Cities. The data will be semi-structured, allowing flexibility in exploring specific issues while maintaining a consistent line of inquiry.
The main data source will be from the World Bank, UNStat, UK Data Science, EU Stat, Open Data portal, and many more, providing a platform for sharing experiences and perspectives. These qualitative data sources will be analysed using thematic analysis to identify common themes and insights, which will be crucial for understanding the nuanced challenges and opportunities in implementing Smart Education.

Data Collection Methods

Collected Sample Data

To gather insights from smart cities, a combination of the top 25 smart cities in the world was selected, data comparison, and contrast will be used. The evaluation will target smart education, while operational efficiency will focus on more detailed and qualitative insights from the educational resources of smart cities.

Case Studies

In-depth case studies of existing Smart Education frameworks will be conducted. These case studies will involve a detailed analysis of implementation processes, outcomes, and stakeholder experiences in various Smart Cities.

Datasets

The research will use data sets from reputable sources such as the World Bank, Open Data Initiative, UK Data Science, UNESCO, UNSTAT, WEF, UN SDG-4 and EU-STAT . These datasets will provide valuable quantitative data for analysis and help contextualise the findings within a broader international framework. The top 20 SERF data sources are in Table: 2.4, ordering is just a personal preference, this can be visualised in the figures: 1.2 and 1.3.

1. Determination of the Top 25 Smart Cities

Selection of the top 25 smart cities was informed by multiple internationally recognised rankings, including but not limited to the Smart Cities Index, IMD Smart City Index, and Smart City Profiles published by research institutions and industry leaders. The cities were chosen based on a synthesis of these rankings, considering factors such as innovation capacity, technological infrastructure, governance, and quality of life metrics. Each source was cross-referenced to ensure a representative and credible selection. This approach aligns with the thesis' objective of using globally validated datasets to maintain consistency and reliability.

2. Selection of the Top 20 SERF sources

The identification of the top 20 SERF sources was based on a systematic review of the literature and analysis of data repositories commonly referenced in smart education and related disciplines. These sources were evaluated for their relevance, comprehensiveness and frequency of citation in scholarly and applied research. Priority was given to data sets that align with the research focus on smart education, including those that provide high-quality and granular data on educational metrics, technological integration, and policy outcomes.

3. Level of Education Targeted by the Framework

The proposed framework is specifically designed to target higher education (HE). This focus is informed by the increasing complexity and demands of HE institutions in adopting smart technologies to enhance learning, teaching, and administrative processes. Chapter 1 will clearly state this focus to ensure that the scope and applicability of the framework are unambiguously defined.

4. Summary of data set sources (Table 2.4)

The dataset sources listed in Table 2.4 represent a diverse range of international repositories, ensuring a comprehensive basis for the framework's development. These sources were selected based on their reliability, relevance, and alignment with the research objectives. The integration of datasets from organisations such as UNESCO, the World Bank, and OECD underscores the framework's grounding in globally recognised data repositories.

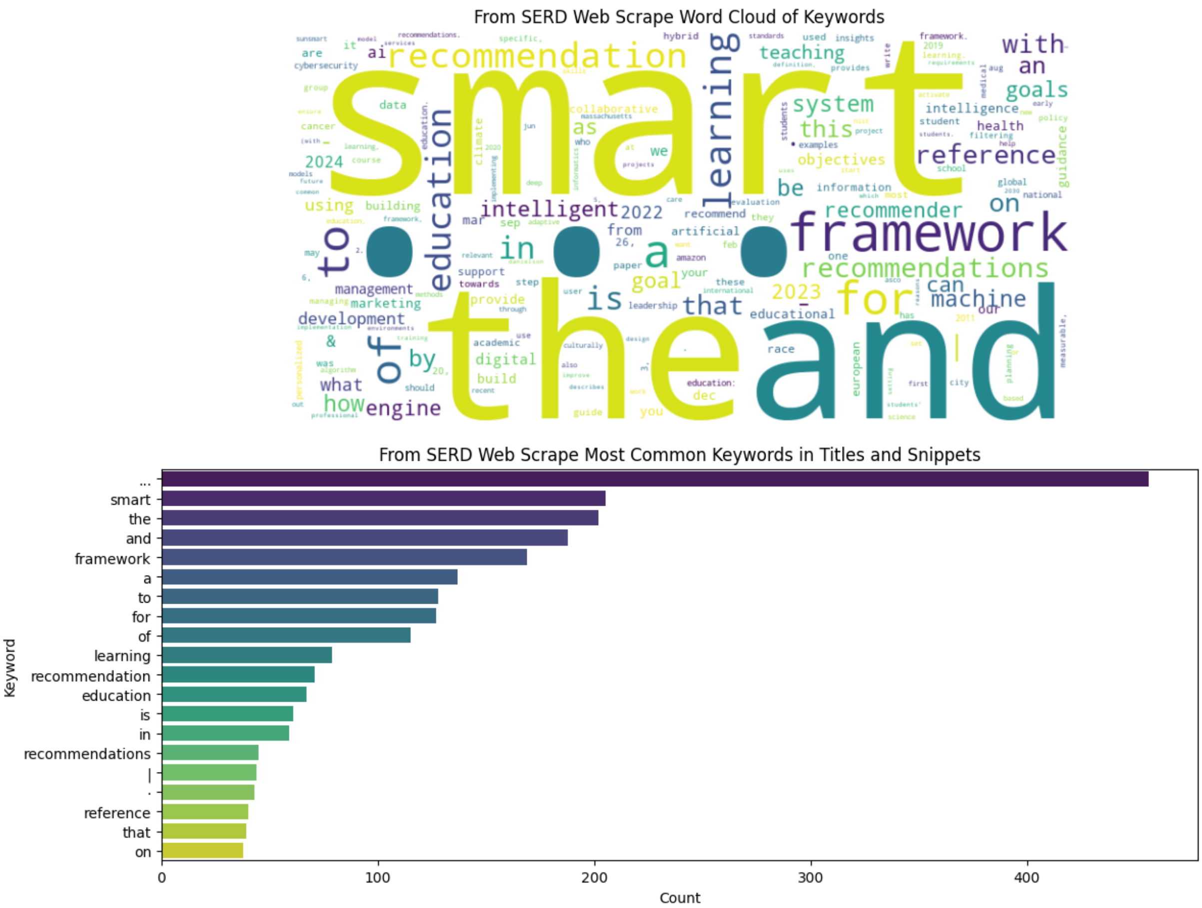


Figure 1.2: SERF Web Scrape for SE Recommendation Framework

Using keyword to clean out and filter the data, a revised search for the same dateset yields the following result.

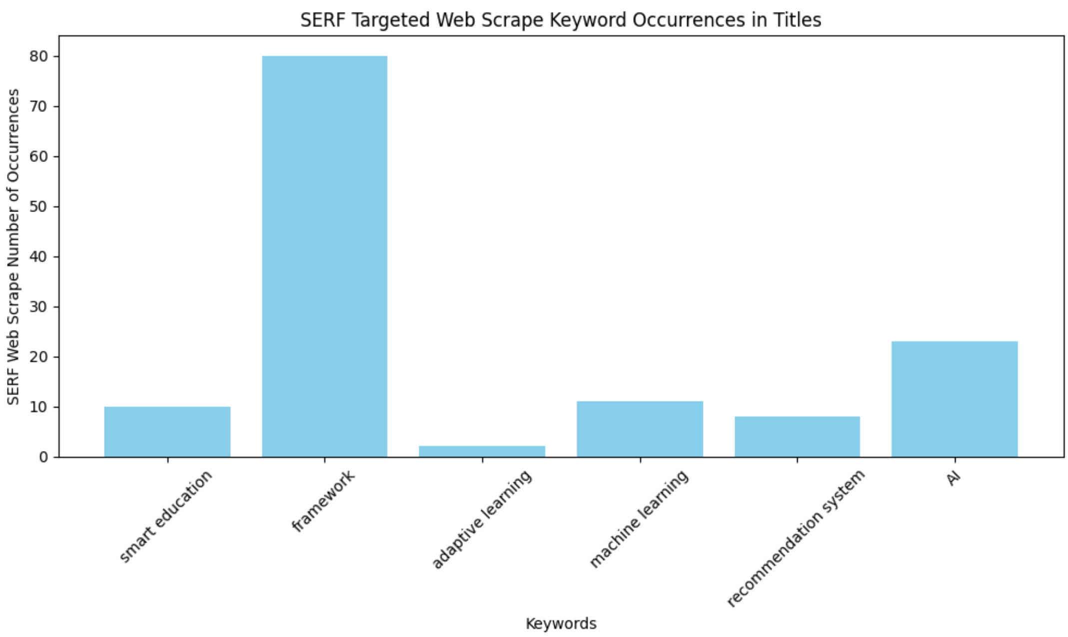


Figure 1.3: SERF Web Scrape Targeted Keywords Filter

Data Analysis Methods

Statistical Analysis

Statistical analysis will be used to identify trends, correlations, and patterns in quantitative data collected from open data and case studies. This analysis will help quantify the effectiveness of different Smart Education approaches and identify key factors influencing their success.

Thematic Analysis

Thematic analysis will be used to analyse qualitative data from smart cities in the context of smart education. This method will help identify common themes and insights, providing a deeper understanding of the contextual factors that affect the implementation of smart education.

Big Data Analytics

Big data analytics will be used to process and analyse large data sets, providing insight into the operational efficiency and effectiveness of Smart Education initiatives. Advanced analytical techniques such as machine learning and data mining will be used to uncover patterns and trends that may not be immediately apparent using traditional analysis methods.

1.7.1 Framework Development and Validation

The findings of the quantitative and qualitative analyses will be integrated to develop a comprehensive Smart Education Recommendation Framework that aligns with the ISO/IEC Smart City Framework and incorporates Big Data analytics. This framework will be designed to improve the operational efficiency, personalisation, and overall effectiveness of educational practices within Smart Cities. The framework will be validated through a comparative study in a selected Smart City. This pilot study will involve implementing or comparing the framework and assessing its impact on educational outcomes and operational efficiency. The results of the comparative study will be used to refine and improve the framework, ensuring its practicality and effectiveness.

1.7.2 SERF Expected Contributions by Extending ISO/IEC Smart City Framework

Using a mixed-method approach, this research will provide a robust and holistic understanding of the complex issues surrounding Smart Education in Smart Cities. The findings will contribute to the development of a practical and effective framework that is aligned with the ISO / IEC Smart City Framework and can guide the implementation of Smart Education initiatives around the world, ultimately leading to improved educational results and operational efficiency (Zawacki-Richter, Victoria I Marín, et al. 2019a). This framework aligns with the objectives of smart education by promoting a holistic approach to student development. It underscores the need for a balanced integration of emotional, social, and cognitive skills to create a conducive learning environment that prepares students for future challenges. By aligning these building blocks with the super framework and operational efficiency metrics inherent in Smart City infrastructure, educational institutions can foster an environment that not only imparts knowledge, but also cultivates essential life skills and attributes in students. This alignment, as detailed in the following section, is crucial to creating a sustainable and impactful Smart Education ecosystem that adheres to international standards and best practices.

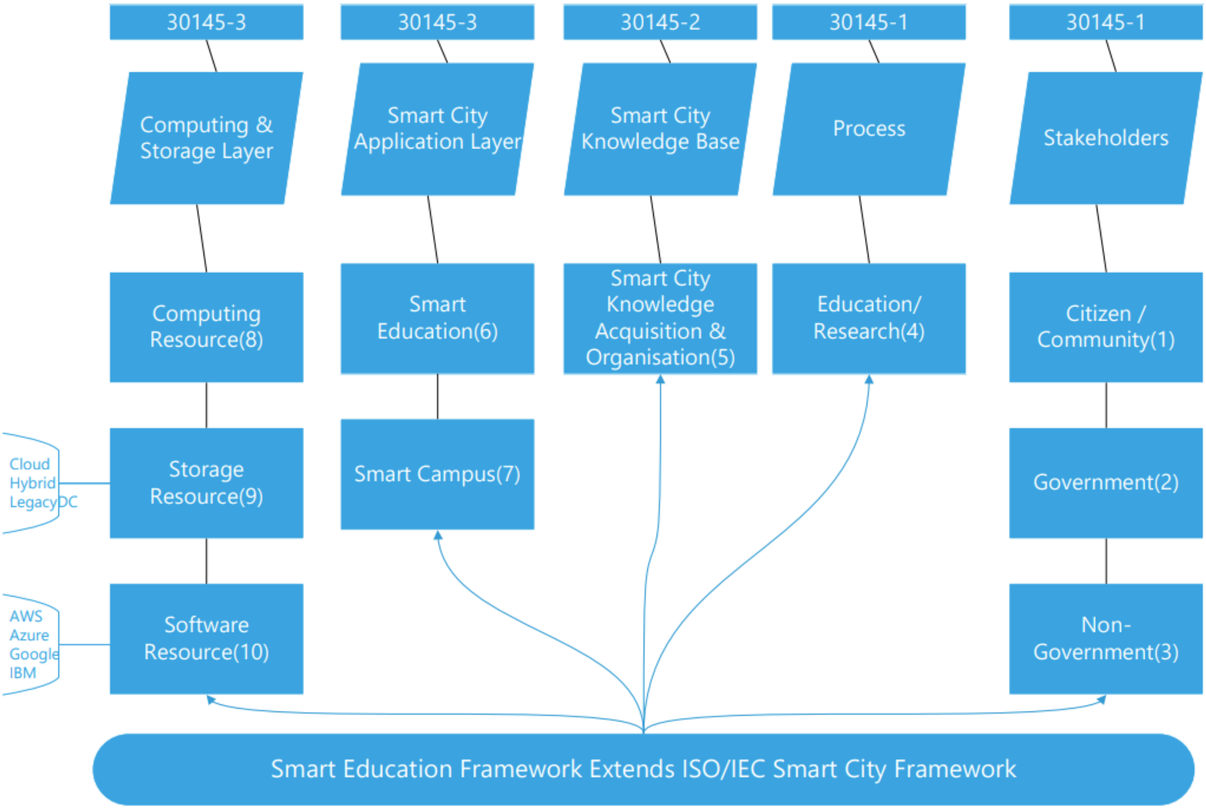


Figure 1.4: New Smart Education framework Extends ISO/IEC Smart City Framework (ISO 2014)

- **ISO/IEC 30145-3 (Computing & Storage Layer):** Robust networks, accessible devices, and learning management systems rely on the computing and storage infrastructure.
- **ISO/IEC 30145-3 (Software Resource):** Software applications for learning, collaboration, and data analytics are essential components of the digital infrastructure.
- **ISO/IEC 30145-2 (Smart City Knowledge Base):** Real-time data from the Smart City, drawn from the knowledge base, are integrated into the curriculum.
- **ISO/IEC 30145-1 (Process) (Education/Research):** The curriculum development process aligns with established standards and research findings. The continuous monitoring and evaluation process is guided by research-based best practices. The principles of sustainability are integrated into curriculum development and educational research.
- **ISO/IEC 30145-3 (Smart City Application Layer):** Adaptive learning platforms and collaborative tools are facilitated by the Smart City Application Layer.
- **ISO/IEC 30145-2 (Smart City Knowledge Acquisition & Organisation):** Data-driven insights and best practices in pedagogy are derived from the knowledge base. The knowledge base informs decisions about responsible resource use and environmental impact.
- **ISO/IEC 30145-3 (Smart City Application Layer):** The dashboard itself is a Smart City application, utilising data analytics tools within this layer.
- **ISO/IEC 30145-1 (Stakeholders) (Citizen/Community):** Active participation is fostered within the citizen/community stakeholder group.
- **ISO/IEC 30145-3 (Smart Campus):** The Smart Campus environment provides a platform for collaborative projects and community-based learning.

This framework underscores the importance of integrating advanced technological resources with educational strategies to enhance both the learning environment and operational efficiencies. By adhering to the ISO/IEC Smart City Framework, this approach ensures a cohesive and standardised methodology that aligns with international best practices, thus fostering a more sustainable, efficient, and impactful Smart Education ecosystem.

Table: Summary of Research Methodology

Methodology Component	Description
Literature Review	Comprehensive review of existing literature to identify gaps and establish a theoretical foundation.
Quantitative Methods	Use Open data on smart cities for case studies to collect data on the current state of Smart Education in Smart Cities.
Qualitative Methods	Compare, Contrast and use historic data set to explore the perspectives and experiences of stakeholders.
Data Collection	Utilisation of databanks, selected smart cities, case studies, and data sets from reputable sources.
Data Analysis	Statistical analysis, thematic analysis, and Big Data analysis to identify patterns, themes, and trends.
Framework Development	Integration of findings to develop a comprehensive framework of recommendations for smart education.
Framework Validation	Comparison study in a selected Smart City to validate and refine the framework.

Table 1.3: Summary of Research Methodology

1.8 Scope and Delimitations

The scope of this Ph.D. thesis, titled "Smart Education Recommendation Framework and Dashboard," encompasses the development and implementation of an innovative framework designed to enhance educational practices within the context of Smart Cities. The scope is the integration of Big Data analytics and machine learning, using datasets to create a comprehensive recommendation system that supports strategic decision-making by developers, optimised resource allocation, and improved operational efficiency. The framework will extend and align with the ISO/IEC Smart City framework standards and focus on stakeholder engagement, incorporating case studies, students, administrators, and technology developers. The research will include a comprehensive review of the existing literature, the collection of data sets through an online search, web scrape, and the development of a prototype dashboard to visualise key educational metrics. In addition, the research will explore the challenges and opportunities associated with the implementation of smart education technologies in urban and rural settings, with the aim of bridging the digital divide and ensuring equitable access to quality education.

Although this research will comprehensively explore the conceptual framework and strategic implications of integrating Smart Education with Smart City initiatives, it will not delve into the technical development and deployment of the underlying IT infrastructure required to support the Smart Education framework and dashboard. Specifically, the research will not cover the proprietary algorithms or software engineering aspects needed to create the back-end systems. Furthermore, the financial aspects of implementing the framework on a large scale and the detailed legal and regulatory implications of data privacy and security are beyond the scope of this research. Furthermore, this thesis will focus solely on the educational domain and its intersection with the Smart City ecosystem, excluding other aspects of Smart City development such as transportation, energy, and healthcare. These areas, while relevant, fall outside the primary focus of this research and are recommended for future studies or specialised technical teams.

1.8.1 Chapter Summary

This chapter delves into the global context of Smart Education Frameworks, with an emphasis on extension of the ISO/IEC Smart City Framework and the integration of Big Data Analytics. It is evident that while Smart Education has transformative potential, significant gaps remain in its development and application, particularly in the realm of standardisation, recommendation framework and personalised learning experiences (Ricardo Cortez et al. 2020);(Zawacki-Richter, Victoria I. Marín, et al. 2019b).
A critical issue identified in the literature is the lack of open data among smart cities and the underuse of educators in the effective implementation of artificial intelligence in classrooms and learning analytics tools in Smart Education (Zawacki-Richter, Victoria I. Marín, et al. 2019b). Furthermore, challenges such as data privacy, security, and interoperability are major impediments to the effective use of Big Data in Smart Education (Jules, Jerome, and Sundaresan 2015);(O'Neil 2016);(B. B. Gupta, Agrawal, and Yamaguchi 2015). A comprehensive analysis of leading academic journals, including the work of Chen et al. [2012](H. Chen, Chiang, and Storey 2012) and Kitchin [2014](Kitchin 2014c), underscores the need for advanced Business Intelligence and Analytics tools. Similarly, the potential of learning analytics to improve educational outcomes is highlighted by Daniel [2015](Daniel 2015) and D'Mello et al. [2012](D'Mello, Graesser, and King 2012). These insights point to the need for a robust Smart Education Framework that strategically incorporates Big Data analytics through the lens of the ISO/IEC Smart City Framework. The gap in research on open data streaming in real-time or historic form and its presentation to smart city operators, particularly focused on smart education, is also notable. Previous studies such as those of (ESD 2020) and (OSI 2009) have approached this topic, but not in the context of operational efficiency in smart cities. The UK Department of Education study (Annika, Gerd, and Jose 2015) and Citykeys' work (Bosch et al. 2017);(Cavanillas, Curry, and Wahlster 2016) provide foundational information but lack a specific focus on the Smart Education Recommendation Framework. This highlights the need to better use big data in smart education to align with smart city developments, as indicated by (Aberer, Hauswirth, and Salehi 2010). Therefore, this research posits that building smart cities without involving smart citizens and aligning with the ISO/IEC Smart City Framework may be a flawed approach. Involving citizens, government, and businesses is crucial, as noted in (Fan, F. Xiao, et al. 2018). Operational efficiency with smart city dashboards, especially in the context of smart education, is an essential concept. It enables smart city operators to keep all stakeholders well informed through the IoT and agile deployment across various city dimensions, contributing to sustainable operational efficiency. It also aims to provide quantitative metrics for the global accreditation and validation of Smart Cities.
In summary, this research will focus on developing Smart Education Recommendation Frameworks that integrate the Big Data Analytics Dashboard to address the operational efficiency gaps identified in the existing literature. It will do this by examining the current state of Smart Education and participating in a comparative analysis, the research aims to identify opportunities for innovation and growth, contributing to a more efficient and effective educational landscape. This chapter delves into the global context of Smart Education, Smart City, and Operational Efficiency with Volume and Variety of Big Data, with emphasis on integrating visualisation dashboard. It is evident that while Smart Education has transformative potential, significant gaps remain in its development and application, particularly in the realm of international standardisation, alignment with the ISO / IEC Smart City Framework, operational efficiency and personalised learning experiences noted (Ricardo Cortez et al. 2020; Zawacki-Richter, Victoria I. Marín, et al. 2019b). The above discoveries and points are thus sustained by the extensive research in the following chapters.

The remainder of this document: Including this chapter 1:

- **Chapter 2, Literature Review:** Review of the state-of-the-art and motivation of current and existing related work with the three keywords [smart cities in the context of smart education, operational efficiency, and big data analytics].
- **Chapter 3, Methodology:** Focusses on big data analytics to achieve the aim and objectives analysis. Operational Efficiency, Volume, and Variety (OE2V): Application of big data and its contributions.
- **Chapter 4, Design and implementation: Handling of the Data:**

- **Chapter 5, Validation and Discussions of SERFD:** The hypothetical validation.
- **Chapter 6, Conclusions and Future Work:** Discusses what is to be achieved, the hypothesis, and research gaps.

Chapter 2

Literature Review

2.0 Chapter Introduction:

Smart education is a new concept that aims to improve educational outcomes and operational efficiency in the context of a smart city. This research seeks to contribute novel insights and document evidence supporting the "enhancement of operational efficiency for smart education components in the smart city using big data analytics" through the development of the Smart Education Recommendation Framework and Visualisation Dashboard. The research outlines various IT management frameworks and standards, such as ISO/IEC Smart City Framework, and their relevance to the effective management of Smart Cities. Here, we compare and contrast various literature studies to illustrate the practical application of these frameworks in higher education, highlighting their potential to improve IT operational management and governance in the context of smart education. The study investigates the current understanding of the Smart Education recommendation framework within Smart Cities and highlights the need for a nuanced approach that considers both the technological and educational dimensions of urban development in the other to conceptualise the integration of smart education systems within Smart Cities, promising to significantly improve educational outcomes and operational efficiency.

2.1 Literature Review

The exploration of Smart Education within the ambit of Smart Cities has garnered significant attention in scholarly circles. Researchers have developed compelling case studies through journals that examine various aspects of Smart City operations, with the aim of uncovering indicators relevant to Smart Education (Paroutis, Bennett, and Heracleous 2014). This research seeks to contribute novel insights through the development of the Smart Education Recommendation Framework and Visualisation Dashboard, which at present do not exist, such that would align to ISO/IEC Smart City Framework.

2.1.1 Current Limitations of the Smart City ISO/IEC Framework - Context Smart Education

The current Smart City ISO/IEC framework, while comprehensive, has certain limitations that hinder its full potential in the context of smart education. A critical issue identified in the literature is the nondirect alignment with smart education as a recommendation framework, smart city standardisation in the context of smart education, the underuse of educators in the effective implementation of artificial intelligence and learning analytics tools in Smart Education (Zawacki-Richter, Victoria I. Marín, et al. 2019b). Furthermore, challenges such as data privacy, security, and interoperability hinder the effective use of Big Data in Smart Education (Jules, Jerome, and Sundaresan 2015; O'Neil 2016; B. B. Gupta, Agrawal, and Yamaguchi 2015). Analysis of leading academic journals, including works by Chen et al. (2012) (H. Chen, Chiang, and Storey 2012) and Kitchin (2014) (Kitchin 2014c), underscores the need for advanced Business Intelligence and Analytics tools similar to a recommendation tool. SERFD elements developed as part of this research have the potential of learning analytics to improve educational outcomes, as highlighted by Daniel (2015) (Daniel

2015) and D'Mello et al. (2012) (D'Mello, Graesser, and King 2012). These insights point to the need for a robust Smart Education Recommendation Framework that strategically incorporates Big Data analytics through the lens of the ISO/IEC Smart City Framework.

The gap in research on real-time or historic data streaming and its presentation to smart city operators, particularly focused on smart education, is notable. Previous studies, such as those of (ESD 2020) and (OSI 2009), have approached this topic but not in the context of Smart Education Framework with Visualisation Dashboard in smart education. The UK Department of Education study (Annika, Gerd, and Jose 2015) and Citykeys' work (Bosch et al. 2017; Cavanillas, Curry, and Wahlster 2016) provide foundational information, but lack a specific focus on a smart education recommendation framework with a visualisation dashboard. This highlights the need to better utilise big data in smart education to align with smart city developments, as indicated by (Aberer, Hauswirth, and Salehi 2010).

These gaps exist because building smart education without international standards, involving smart citizens, and aligning with the ISO/IEC Smart City Framework is a flawed approach. Involving citizens, government, and businesses is crucial, as noted in (Fan, F. Xiao, et al. 2018). The recommendation framework, especially in the context of smart education, is essential, enabling smart city operators to keep all stakeholders informed through IoT and agile deployment across city dimensions. This research aims to provide quantitative metrics for the global accreditation and validation of Smart Cities.

Key limitations include:

- **Lack of Specific Educational Guidelines:** The existing framework does not provide detailed guidelines specific to the integration of smart education technologies in alignment with international standard on smart city framework.
- **Limited Guide to Stakeholder Engagement:** There is not enough emphasis on stakeholder participation, particularly from educators and students, which includes a recommendation framework.
- **Inadequate Focus on Data Analytics:** The ISO/IEC smart city framework does not fully take advantage of Big Data analytics to improve educational outcomes by integrating visualisation dashboard. The lack of robust data impedes the achievement of Sustainable Smart Education (SE) and Smart City (SC) developments. Big data, through its volume and variety (OE2V), emerges as a cornerstone in the establishment and demonstration of operational efficiency. Figure 3.9 illustrates a multifaceted approach to integrating Big Data Analytics within Smart City infrastructure, anchored by the Internet of Things (IoT).

2.1.2 Improvement to the Smart City ISO/IEC Framework by adopting SERFD

Based on Journals, Datasets, and Case Studies the following enhancements are proposed:

1. To develop a Smart Education Recommendation Framework that aligns with the ISO/IEC Smart City Framework.
2. Integration of Big Data Analytics into the Smart Education Framework to Improve Operational Efficiency within Smart Cities.
3. To evaluate the impact of Smart Education technologies on educational outcomes and urban development.
4. To ensure that the framework is adaptable and scalable to meet the evolving needs of Smart Cities.

SERF Impact: Transition from Traditional Rural Classrooms to Smart Education

In the evolving landscape of education, traditional rural classrooms are increasingly challenged in preparing students for the demands of smart education of the 21st century. The primary limitation lies in their lack of integration with advanced technologies, such as Big Data analytics, Artificial Intelligence (AI), and the Internet of Things (IoT), which are fundamental to the Smart Education paradigm (Tore and Jon 2018). Although traditional classrooms have intrinsic value, they do not encompass the essential components required for Smart Education, such as adaptability, technological sophistication, and data-driven decision making.

This research highlights the urgent need to transition to a standardised framework for smart education, aligned with international IT standards for learning (Jin Gon Shon 2002), the United Nations Sustainable Development Goal 4 (UN SDG-4) on quality education (SDG4 2017), and the Education and Training Guidelines (ITLET) established by the International Organisation for Standardisation (ISO) (Lindner 2004;

Jnr et al. 2023; Hoel and Mason 2011). These frameworks collectively advocate for an educational system that not only embraces but actively drives the adoption of Smart Education within the broader context of Smart Cities (Tore and Jon 2018; Urbanik and Horalek 2022).
However, the establishment of a Smart City does not automatically guarantee the realisation of Smart Education. The implementation of smart education requires different strategies and may vary significantly depending on regional and institutional contexts (Aguaded-Ramírez 2017; Afzal et al. 2023). Smart Cities provide the foundational infrastructure and resources necessary for Smart Education, including digital connectivity and data systems (Heaton and Parlikad 2019). This research explores these foundational components and evaluates their effectiveness through operational efficiency metrics, contributing to a deeper understanding of how Smart Education can be systematically embedded in Smart City frameworks.
Table 2.1 summarises the classification of Smart Education components and their application rationales, illustrating the multidimensional nature of this transition and its implications for learning, pedagogy, and the environment.

Table 2.1: SERFD Classification Table: Components of Smart Education and Application Rationales

Components of Smart Education	**Application Rationales**
Smart Education Ideology	Emphasises creativity, integration of ICT, and personalised learning pathways. Features include IoT-enabled Big Data Analytics interfaces and live synchronous classes, fostering an interactive and flexible learning environment (Durdona 2024; W. Zhang and Liehui Jiang 2018).
Smart Learning Environment	Extends beyond physical classrooms to include welfare alert communication systems, integrated accommodations, and hospitality services. Incorporates work-based learning opportunities and asynchronous pre-recorded lectures, creating a dynamic and inclusive educational experience (Bastari, Bandono, and Suharyo 2021; Tabuenca et al. 2024).
Smart Pedagogues	Introduces innovative approaches such as flipped and flexed delivery methods, individual student rotation, and station rotation models. These pedagogies promote collaboration, sharing of resources, and address the psychological and emotional well-being of learners (Sanal Kumar and Thandeeswaran 2024; Amaresh Jha and Ananya Jha 2024; Scala et al. 2024).
End of SERFD Classification Table	

Smart Education Recommendation Framework for Smart Cities

The advent of smart education is a response to the need for innovative and adaptive learning environments in the rapidly evolving digital landscape of today. This evolution emphasises personalised learning experiences, collaborative educational models, and data-driven teaching methods. Using advanced technologies, data analytics, and innovative instructional methods, smart education aims to create personalised learning experiences, facilitate collaboration between diverse stakeholders, and cultivate lifelong learning habits (Shaofeng Wang, Z. Sun, and Y. Chen 2022). Table 2.2 outlines the critical data components that are integral to the smart education recommendation framework, showing how each component contributes to the development of advanced educational systems and practices. These components form the foundation for creating a smart education framework ecosystem that aligns with the broader goals of the ISO / IEC Smart Cities Framework.

Table 2.2: Rationale: Smart City (SC) in the context of the Smart Education Framework

Begin: Contributions of smart education to smart cities			
Data Components	Relation to SC Rationale	Functional Areas	References
Learner profiles	Personalise learning experiences	support for curriculum instruction adjustments	(Hwang 2014)
Assessment data	Continuously evaluate learning progress	individual assessment evaluation	(Shaofeng Wang, Z. Sun, and Y. Chen 2022)
Collaboration tools	Facilitate interaction among and stakeholders	Improve communication and collaboration	(Zawacki-Richter, Victoria I Marín, et al. 2019a)
Learning analytics	Inform instructional strategies and interventions	Data-driven decision-making proactively	(Hwang 2014)
Educational resources	improve access to quality content	data driven content development and access	(Shaofeng Wang, Z. Sun, and Y. Chen 2022)
Digital infrastructure	enable technology integration and innovation	reduce digital divide technology infrastructure	(Zawacki-Richter, Victoria I Marín, et al. 2019a)
Professional development	Empower educators in adopting smart education methods	reduce silo from teacher training and support	(Hwang 2014)
End: Contributions of smart education to smart cities			

The data components detailed in this table highlight the multifaceted nature of smart education that underlies the framework. From student profiles to digital infrastructure, each aspect plays a central role in the design of effective and inclusive educational environments. This comprehensive approach is essential to prepare students to navigate and succeed in the complex and interconnected world of the future as professionals. These are not limited when based on (Hwang 2014), (Shaofeng Wang, Z. Sun, and Y. Chen 2022), and (Zawacki-Richter, Victoria I Marín, et al. 2019a), which encapsulates the critical components of the data, their correlation with the rationale that underpins the development of a smart education framework, and their respective functional areas. Moreover, in the context **Smart Education/Campus (Promoting Creativity and Social Capital):** The heart of Smart Education lies in creating an educational environment that is innovative, creative and socially enriching. Smart campuses leverage technology to provide personalised learning experiences and foster collaboration and interaction, thus building social capital among students and educators (Setiawan et al. 2024; Bastari, Bandono, and Suharyo 2021; Sneesl et al. 2023). In addition, the proposals and their corresponding methods are essential to evaluate the ability to access the network and the evolution of fixed and mobile urban networks toward operational efficiency in smart education. These when using SERFD evaluations yield the following outcomes, as elucidated in (ISO

2014):

1. **Outcome Strength Rationale**: Management and ongoing maintenance are supported by accessibility and use of pertinent data through data visualisation.
2. **Outcome Opportunity Rationale**: Providing standardised guidelines to developers by enabling smart services and infrastructure functionalities, such as integrated transportation systems, increases the resiliency of educational ecosystems and improved urban sustainability.
3. **Outcome Threat Rationale**: An increase in preventive maintenance of the infrastructure is hypothesised, thus enhancing its longevity and efficiency.

This will be achieved through data manipulations, each smart data component will be categorically aligned with the six constituent data points of the Smart City framework (Mosannenzadeh and Vettorato 2014), from which the volume and variety of big data are extracted. This extraction process is instrumental in unraveling hidden information within the volume and variety of data, thus increasing operational efficiency and educational effectiveness within Smart Cities. This is followed by developing a novel data visualisation framework Figure 2.1 as explained in the following sections.

2.2 Integration of Big Data Analytics in Smart Education within Smart Cities

The advent of Smart Cities (SC) represents a paradigm shift in urban development, with education being one of the key pillars that undergoes significant transformation. The integration of Big Data analytics into Smart Education epitomises this shift, heralding a new era where data-driven decision making becomes the cornerstone of educational strategies. This intricate fusion of technology and pedagogy within the Smart City framework promises to revolutionise the way education is delivered, managed, and experienced. The process of integrating Big Data Analytics into Smart Education encompasses several strategic steps, each contributing to the overarching goal of achieving quantitatively sustainable Operational Efficiency (OE) and fostering an environment of continuous improvement and innovation. The factors are not limited to the following.

- **Data Driven Educational Frameworks:** The first step involves constructing comprehensive educational frameworks that leverage Big Data Analytics to improve learning outcomes. By analysing vast datasets, educational institutions can identify patterns and insights that inform curriculum development, teaching methodologies, and student support services. This approach not only ensures that educational content is relevant and engaging, but also facilitates personalised learning experiences that meet the unique needs of each student (Tawfik et al. 2017).
- **Operational Efficiency in Education:** Big Data Analytics plays a crucial role in optimising the operational aspects of Smart Education. From resource allocation to campus management and administrative processes, the application of data analytics ensures that educational institutions operate with maximum efficiency. Developing metrics and indicators to measure OE in the context of smart education allows continuous monitoring and improvement of educational services, ensuring sustainability and measurable results. (Hakimi et al. 2024; Saleh et al. 2024)
- **Global Accreditation and Recognition:** Establishing a globally verifiable accreditation system is imperative to recognise the qualifications and advances achieved within Smart Cities. Big Data analytics facilitates the standardisation of educational qualifications, enabling seamless recognition across borders. This not only improves the mobility of students and professionals, but also fosters international collaboration and knowledge exchange between Smart Cities (Bernyukevich 2023; Heaton and Parlikad 2019).
- **Enhancing Educational Accessibility:** By integrating Big Data analytics, Smart Education can significantly improve access to quality education. Through predictive analytics and machine learning algorithms, educational institutions can identify barriers to access and develop targeted interventions to overcome them. This ensures that Smart Education benefits all segments of the urban population, reducing disparities and promoting inclusivity (Cheshmehzangi et al. 2023; L. Yu et al. 2024).
- **Facilitating Real Time Adaptability:** The dynamic nature of Smart Cities necessitates an edu-

cation system that is equally adaptable. Big Data Analytics enables real-time feedback mechanisms, allowing educational institutions to quickly respond to emerging trends, student needs, and global challenges. This agility ensures that Smart Education remains at the forefront of innovation, preparing students to thrive in an ever-changing world (Surendran et al. 2024; Andrin et al. 2024; Ben-David Kolikant 2019).

With these components, the integration of Big Data Analytics into the Smart Education Recommendation Framework within Smart Cities is not just an enhancement but a foundational shift toward a more informed, efficient, and inclusive educational paradigm. Using the power of data, Smart Cities can unlock unprecedented potential in education, driving the agenda for a smarter and more sustainable future (Shishakly et al. 2024; Hamzah 2020; Durdona 2024). This cements the understanding that the intricate tapestry of Smart Education within Smart Cities is woven with vast strands of data. The flow and management of this Big Data are pivotal in shaping educational landscapes that are not only intelligent and responsive, but also operationally efficient. Figure 2.1 illustrates this complex data flow, encapsulating the interaction between the various elements that make up the Big Data ecosystem within a Smart City framework for the purpose of data extraction and identification (Moreno et al. 2019).

2.2.1 Improvement on Visualisation of Big Data in the context of SERFD

1. Within the **Smart City (SC)'s Smart Education Data Extraction Framework**, the six quintessential components of a Smart City intricately intertwine with Big Data components. In more isolated rural settings, these data streams often become compartmentalised as **Silo RAW data**, posing challenges in terms of traceability and quantifiable impact due to disparate and uncoordinated systems of consumption and analysis.
2. The concept of **big data volume** is illustrative of the massive aggregation of data, which encapsulates the Smart Education data. Rural areas, in particular, face the risk of these data being relegated to **RAW Big Data**, susceptible to consumption gaps or loss, primarily due to the unstructured nature of the data and a lack of sophisticated management expertise.
3. The aspect of **Big data variety** transcends beyond mere numbers, encompassing a rich tapestry of structured and unstructured data harvested from myriad sources such as sensor outputs, multimedia content, Geo-spatial references, Internet of Things (IoT) devices, and beyond. From this eclectic assortment of data, Smart Education data are meticulously extracted, filtered, and mapped, ready for impactful application.
4. Targeted collection and measurement of **Smart Education Data** serve as a beacon of operational efficiency, representing a subset of data that has been carefully curated and structured, orchestrated within a coordinated data governance strategy.
5. The **Sets of Operational Efficiency Benchmark** data distilled from the broader data pool, are primed for strategic access, rigorous verification, and potential accreditation, culminating in their integration into a **Visualisation Dashboard** for global dissemination and recognition forming the Operational Efficiency from Volume and Variety (OE2V) metric data.

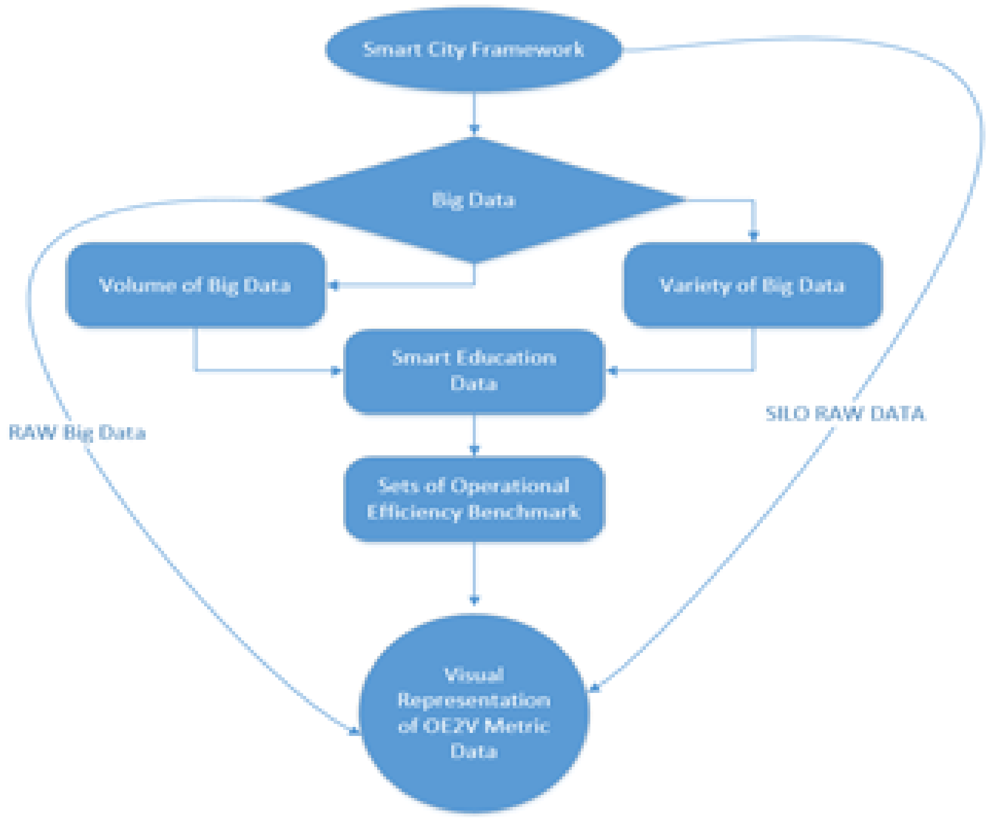


Figure 2.1: Visualising the flow of Smart Education data OE Framework in the context of Big Data Analytics

For a meaningful visual representation of the data flow crucial in gauging Operational Efficiency (OE) metrics within Smart Education, the research invokes the dual pillars of Volume and Variety (2V) of Big Data. The meticulous stewardship of this information is of the essence; in its absence, the data emanating from the Smart City framework risk devolving into disorganised Silo RAW Data. But when meticulously classified and managed as Big Data, these datasets can be visualised in dichotomous forms as 'unstructured' (raw Big Data) or a 'structured' following the five core components of Big Data: volume, variety, veracity, value, and velocity. Taking advantage of the dual forces of Volume and Variety (2V), our analytical processes yield measurable, actionable insights, leading to the precision extraction of Smart Education data within the Smart City paradigm ("ZTE COMMUNICATIONS December 2015, Vol.13 No.4" 2015); (Hafedh et al. 2012). These data, contextualised within the Smart City context, then undergo a transformative visualisation process through operational efficiency analytics, deploying sets of OE algorithmic benchmarks. The outcomes are envisioned to indicate improvements in educational quality, cost reduction pathways, inclusion support structures, and potential impacts on the carbon footprint, all converging towards a verifiable and robust accreditation model. As a recommendation tool, the following points can be achieved.

- **Inclusion of Educational Modules:** Introduce specific modules that address the integration of educational technologies and methodologies within the Smart City framework.
- **Enhanced Stakeholder Engagement Processes:** Develop processes for regular consultations with educators, students, administrators, and technology developers.
- **Integration of Big Data Analytics:** Incorporate guidelines for the use of Big Data analytics to improve operational efficiency and educational outcomes.

2.2.2 Evidence of Data Collection

To inform these improvements, an extensive data search was conducted; the research initially looked at the theoretical components behind the smart city and the data elements it generates for smart education. The advent of smart education has been found to be a response to the need for innovative and adaptive learning environments in the rapidly evolving digital landscape of today. This evolution emphasises personalised learning experiences, collaborative educational models, and data-driven teaching methods. The research found that using advanced technologies, data analytics and innovative instructional methods, smart education aims to create personalised learning experiences, facilitate collaboration between diverse stakeholders, and cultivate lifelong learning habits (Shaofeng Wang, Z. Sun, and Y. Chen 2022). The table below (2.3) outlines the components of critical data integral to the smart education framework, showing how each component contributes to the development of advanced educational systems and practices. These components form the foundation for creating a smart education recommendation framework ecosystem that aligns with the broader goals of Smart Cities.

Table 2.3: Rationale: Smart City (SC) in the context of the Smart Education Framework

Begin: Contributions of smart education to smart cities 2.3			
Data Components	Relation to SC Rationale	Functional Areas	References
Learner profiles	Personalise learning experiences	support for curriculum instruction adjustments	(Hwang 2014)
Assessment data	Continuously evaluate learning progress	individual assessment evaluation	(Shaofeng Wang, Z. Sun, and Y. Chen 2022)
Collaboration tools	Facilitate interaction among and stakeholders	Improve communication and collaboration	(Zawacki-Richter, Victoria I Marín, et al. 2019a)

Continuation: Contributions of smart education to smart cities in Table 2.3			
Data Components	Relation to SC Rationale	Functional Areas	References
Learning analytics	Inform instructional strategies and interventions	Data-driven decision-making proactively	(Hwang 2014)
Educational resources	improve access to quality content	data driven content development and access	(Shaofeng Wang, Z. Sun, and Y. Chen 2022)
Digital infrastructure	enable technology integration and innovation	reduce digital divide technology infrastructure	(Zawacki-Richter, Victoria I Marín, et al. 2019a)
Professional development	Empower educators in adopting smart education methods	reduce silo from teacher training and support	(Hwang 2014)
End: Contributions of smart education to smart cities			

2.3 SERF Subset of Dataset Sources

The following table 2.4 being URL, and table 2.5 the access method, lists a variety of sources that provide datasets relevant to the Smart Education Recommendation Framework (SERF). These sources encompass a wide range of educational data, including international statistics, national databases, and specialised repositories. Data from these sources can be instrumental in developing, validating and refining frameworks for smart education by offering comprehensive insights into various educational metrics and trends.

Table 2.4: SERF Dataset Primary International Sources

Datasets Source	**URL Destination**
UNESCO Institute for Statistics (UIS)	`http://data.uis.unesco.org/`
World Bank Open Data	Register and Sign-In with Google Acc. `https://data.worldbank.org/`
OECD Education Statistics	Register and Sign-In with Google Acc Email. username: okonzy...1@Ok123qwe `https://stats.oecd.org/ornewsitehttps://data-explorer.oecd.org/`
Eurostat Education and Training Data	Register and Sign-In with Google Acc Email. username: okonzy...1@Ok123qwe Mobile Validation ...8889 `https://ec.europa.eu/eurostat/web/education-and-training/data`
UK Data Service	`https://www.ukdataservice.ac.uk/`
Data.gov (USA)	`https://www.data.gov/`
National Center for Education Statistics (NCES)	`https://nces.ed.gov/`
Open Data Portal (European Union)	`https://data.europa.eu/euodp/en/home`
PISA (Programme for International Student Assessment)	`http://www.oecd.org/pisa/data/`
EdStats (World Bank Education Statistics)	`http://datatopics.worldbank.org/education/`
UNdata	`http://data.un.org/`
Global Partnership for Education Data	`https://www.globalpartnership.org/data-and-results/education-data`
Google Dataset Search	`https://datasetsearch.research.google.com/`
Harvard Dataverse	`https://dataverse.harvard.edu/`
Kaggle Datasets	`https://www.kaggle.com/datasets`
Open Data Soft	`https://www.opendatasoft.com/`
Educational Data Mining (EDM) DataShop	`https://pslcdatashop.web.cmu.edu/`
Mendeley Data	`https://data.mendeley.com/`
Global Education Monitoring (GEM) Report Data	`https://en.unesco.org/gem-report/`
EdTech Hub Data	`https://edtechhub.org/open-data/`

Table 2.5: Sources of Datasets Providers

Begin: Sources of data set providers - Table 2.5		
Category	Source Name	Registration Method
UN	UNESCO	Online
Govt Agency	UK DataScience	Online
International	World Bank Group	Free (No Registration)
NGO	European Union	Online
NGO	Open Data Institute	Online
NGO	Knoema	Free (No Registration)
NGO	Kaggle	Online
NGO	Google Custom Dataset Search	Online
NGO	UCI Machine Learning Repository	Online
GOV	Data.gov	Online
NGO	VisualData	Online
NGO	KDnuggets	Online
Public	GitHub	Online
NGO	Reddit	Online
NGO	United Nations Statistic Division	Online

Continuation of: Sources of data set providers - Table 2.5		
Category	Source Name	Registration Method
NGO ———	UNStats ———	Online ———
End of Table		

The data components detailed in this table highlight the multifaceted nature of smart education that underlies the framework. From student profiles to digital infrastructure, each aspect plays a central role in the design of effective and inclusive educational environments. This comprehensive approach is essential to prepare students to navigate and succeed in the complex and interconnected world of the future as professionals. These are not limited when based on (Hwang 2014), (Shaofeng Wang, Z. Sun, and Y. Chen 2022), and (Zawacki-Richter, Victoria I Marín, et al. 2019a), which encapsulates the critical components of the data, their correlation with the rationale that underpins the development of a smart education framework, and their respective functional areas.

Smart Education has emerged as a vital element in shaping the future of learning environments and advancing the progress of Smart Cities. Therefore, the application of Big Data analytics in Smart Education is instrumental in discerning educational trends and patterns, paving the way for the formulation of evidence-based policies and precise educational enhancements. Crucially, addressing existing challenges, such as the absence of uniform standards of smart education accreditation and open data certification metrics, is fundamental to cultivating a transparent and equitable educational landscape in smart urban and rural settings.

The fruition of Smart Education's full potential hinges on the collaborative efforts of diverse stakeholders, including government bodies, educational institutions, private sectors, and the citizenry. Addressing accreditation and open data certification issues will not only solidify the trustworthiness and effectiveness of Smart Education initiatives, but will also empower communities to take advantage of a technologically enriched education system. In other to decipher the metric, data source and classification the research perform evaluation of the datasets.

2.3.1 Calculating Smart Education Indicators Rationale and Relevance:

The integration of these efficiency calculations in the planning of smart education and smart cities is vital for sustainable development. It enables a holistic approach, where educational growth is in harmony with urban development, ensuring a future-ready, educated populace, and an efficiently managed Smart City environment. Based on these, recommendations can be generated among participating Smart Cities that may be adopting or aligning with international standards.

For an example:

$$\text{API Res Ratio (\%)} = \left(\frac{\text{Category Num of Public Information Res with Open API}}{\text{Tot. Cat. Num of Publ Info. ResReqReq.. to open according to Local Policy}}\right)\times 100$$

Table 2.6: Rationale: Evaluation indicators related to smart education OpenData and data sharing

Begin: Evaluation indicators related to smart education OpenData and data sharing		
Indicator Name	Description	Measurement method
Public information resources openness ratio	evaluation of the level of openness of public information resources to the public	(category number of public information resources with open API / total category number of public information resources which are required to open according to the local policy)*100
Information sharing ratio between government sectors	evaluation of data sharing among government sectors	(number of government sectors that have established the information resource table and provided data sharing services / total number of government sectors) * 100
End: Evaluation indicators related to smart education OpenData and data sharing		

Table 2.7: Rationale: Evaluation of services related to Smart City for network infrastructure

Begin: Evaluation of services related to Smart City for network infrastructure		
Indicator Name	Description	Measurement method
Fixed broadband access capability, where fixed broadband means the high-speed data transmission to homes and enterprises using technologies such as T1, Cable, DSL, and Fibre	Evaluation of the development of fixed broadband networks	(number of household fixed broadband access users / total number of households) * 100
Fibre to the Home (FTTH) penetration rate, where FTTH means the installation of optical fibre from the carrier directly into the home or office	Evaluation of the development of urban fixed broadband networks	(number of FTTH users / number of fixed broadband access users) * 100
Mobile broadband access ability	Evaluation of the development of urban mobile broadband networks	(number of 3G and above mobile users / number of permanent residents) * 100
End: Evaluation of Smart City-related services for network infrastructure		

These formula are used to qualify and quantify the dataset from the following sources:

- **Datasets:** Online resources from Would Bank, UN-STAT, EU Data Store, UK Datascience, OpenData.org and many others, used to assess educators, students, and administrators to gather information on current challenges and potential improvements. Data sources include UNESCO (SDG4 2017), EU Smart Cities Information System (Vinodkumar 2016), UK Data Service (UK 2021), Gnutella or Free Net (Vetrò et al. 2016)

- **Case Study:** Real-World case studies from top Smart Cities, including technology developers and policy makers, provided qualitative data to support proposed improvements.

Optimising Smart Education within Smart Cities

Operational efficiency in Smart Education transcends streamlined processes to establish a dynamic educational ecosystem that seamlessly integrates with the infrastructure and socioeconomic context of Smart Cities. This research identifies key components that collectively support the transition to Smart Education and outlines their roles in enhancing operational efficiency. Table 2.8 summarises these components and their application rationales.

Table 2.8: Key Components of Smart Education and Their Application Rationales

Component	Application Rationale
2.3.2 Smart Infrastructure	Provides the foundation for Smart Education, including physical spaces, digital networks, and scalable platforms. Supports adaptability and responsiveness to evolving educational demands.
2.3.3 Smart Curriculum	Delivers relevant, data-driven content designed to leverage Smart City advantages. Incorporates real-time data, urban challenges, and preparation for future work and civic engagement.
2.3.4 Smart Pedagogy	Adapts teaching methods to align with technological advancements. Focuses on critical thinking, problem-solving, collaboration, and flexible delivery methods for diverse learning needs.
2.3.5 Smart Dashboard Analytics	Enables continuous monitoring and evaluation of educational programmes. Utilises data insights to inform decisions on curriculum development, resource allocation, and student support.
2.3.6 Smart Engagement	Encourages active participation of students and educators in the Smart City ecosystem. Promotes collaboration with local businesses, governments, and city projects, transforming the city into a living laboratory.
2.3.7 Smart Sustainability	Ensures the environmental and resource sustainability of Smart Education systems. Focuses on responsible resource management to support future generations.

Cross-Referencing Smart Education Components

Each of these components is detailed in their respective sections, demonstrating how they contribute to a holistic and sustainable Smart Education system.

- **Smart Infrastructure:** Discussed in relation to digital connectivity and scalable networks (2.3.2).
- **Smart Curriculum:** Explored in the context of educational content development and urban project-based learning (2.3.3).
- **Smart Pedagogy:** Outlined in methods for flexible and adaptive teaching (2.3.4).
- **Smart Dashboard Analytics:** Examined by data monitoring and programme evaluation (2.3.5).
- **Smart Engagement:** Highlighted in collaboration opportunities and community projects (2.3.6).
- **Smart Sustainability:** Addressed in the context of resource management and environmental con-

siderations (2.3.7).
This integrated framework ensures that Smart Education systems within Smart Cities are not only operationally efficient but also sustainable and adaptive to the needs of 21st-century learners. The components outlined above serve as the foundation for transforming the educational landscape, fostering innovation, and ensuring inclusivity.
With this understanding, the research will now start with a review of the literature and case studies.

2.4 REVIEW: Adaptive Educational Content Frameworks

Salma El Janati et al. (2018)

Introduction to the Study: Salma El Janati et al. (El Janati, Maach, and El Ghanami 2018a) made a significant contribution through their work on an adaptive educational content framework, particularly tailored for learners with sensory impairments. This framework integrates the Dynamic Adaptive Hypermedia System (DAHS), enhancing both the adaptability of the content and its presentation.
Key Findings:

- The framework tailors the educational experience to individual learner preferences and disabilities, promoting inclusivity.
- The system architecture includes engines that detect learner needs, model preferences, transcode content, and adapt presentation methods.
- The research underscores the potential of the framework to improve content personalization in education.

Critical Evaluation:

- **Strengths:** The study provides an innovative approach to inclusivity in education through adaptive content. The detailed architecture of the system and the focus on sensory impairments are commendable.
- **Limitations:** The framework lacks alignment with ISO/IEC standards, missing an opportunity for international standardisation and recognition.

Relevance to My Research Topic: This work advances the understanding of framework enhancement for smart education. However, its lack of alignment with ISO/IEC standards highlights a gap that my research aims to address, ensuring that smart education frameworks meet international standards for broader applicability and acceptance.

2.5 REVIEW: IT Management Frameworks in Higher Education

Martin H. Knahl (2013)

Introduction to the Study: Martin H. Knahl (Knahl 2013) explores the application of IT management best practices in higher education, focussing on IT Service Management (ITSM) and IT Governance.
Key Findings:

- The importance of ITSM and IT Governance in higher education institutions is emphasised.
- Various IT management frameworks such as ITIL and COBIT are discussed.
- A case study illustrates the practical application of these frameworks, highlighting their potential to improve IT operational management and governance.

Critical Evaluation: Pros:

- Highlights the relevance of ITSM and IT Governance in higher education.
- The author discusses the IT management frameworks essential for streamlining IT services.
- Includes a practical case study.

Cons:

- Lacks direct correlation with smart education principles.
- Does not address the integration of smart technologies aligned with the ISO/IEC Smart City Framework.

- Omits discussion on transforming traditional educational institutions into smart environments.
- Does not explore the use of big data analytics and AI in enhancing operational efficiency.

Relevance to My Research Topic: While this study provides valuable insights into IT management in higher education, it does not directly address the needs of smart education or the alignment with the ISO/IEC Smart City Framework. This gap indicates a need for further research to bridge traditional IT management frameworks with the evolving demands of smart education, which my research aims to fulfill.

Findings conclusion:

Both studies offer valuable contributions to the field of educational technology, but they also present limitations in the context of smart education and its alignment with the ISO/IEC Smart City Framework.(El Janati, Maach, and El Ghanami 2018b) focus on inclusivity and personalised learning, but lack integration with international standards and the broader potential of smart technologies. (Van der Aalst 2013) provides insight into IT management in higher education, but does not address the specific needs of smart education or its integration into the smart city ecosystem. These limitations highlight the need for more research that bridges the gap between existing frameworks and the evolving demands of smart education within the context of smart cities.

2.6 REVIEW: Mobile Learning Quality Framework

Capretz et al. (2012)

Introduction to the Study: A systematic review by Capretz et al. (Capretz, Ali, and Ouda 2012) presents a comprehensive framework for evaluating mobile learning quality in the context of smart education. It encompasses a multidimensional approach, focusing on pedagogical effectiveness, system quality, and information quality, to assess mobile learning platforms.

Key Findings:

- The framework identifies strengths and weaknesses of mobile learning systems, particularly in user-friendliness, content relevance, and overall learning experience.
- It offers a methodical approach to evaluating educational technologies, providing a robust mechanism to ensure effectiveness and quality.

Critical Evaluation:

- **Strengths:** The study is valuable for enriching the smart education aspect of smart cities, especially in mobile learning.
- **Limitations:** It does not directly correlate with the ISO/IEC Smart City Framework, focusing more on pedagogical and technical aspects rather than broader smart city objectives.

Relevance to My Research Topic: This work offers valuable insights into mobile learning quality assessment but does not address the multifaceted goals and integration typical of a comprehensive smart city framework. Additional considerations and alignments with the broader goals of the ISO/IEC Smart City Framework would be necessary for a holistic integration into the Smart Education Framework.

2.7 REVIEW: Technology-Based Student-Centred Learning Framework

Alnoman et al. (2022)

Introduction to the Study: Alnoman et al. (Alnoman 2022) outline a comprehensive approach to integrating technology in educational settings, specifically focused on the smart campus concept. The framework advocates for a student-centred approach to improve learning experiences.

Key Findings:

- The framework leverages technology to provide personalized, flexible, and interactive educational opportunities.
- It discusses the roles of IoT, AI, and Big Data in creating an efficient and adaptive learning environment.

Critical Evaluation:
- **Strengths:** Enhanced personalization and adaptability in learning.
- **Limitations:** Implementation and maintenance complexities, especially in aligning with ISO/IEC Smart City Framework standards.

Relevance to My Research Topic: This framework aligns with the broader objectives of the Smart Education Framework and operational efficiency, providing information on integrating advanced technologies into educational settings.

2.8 REVIEW: Smart Campus Framework in Developing Countries

Prasetyaningtyas et al. (2023)

Introduction to the Study: Prasetyaningtyas et al. (Prasetyaningtyas et al. 2023) address the implementation of smart campus frameworks in developing countries, analyzing the unique challenges faced in these regions.

Key Findings:
- Smart campuses can improve educational quality and operational efficiency by optimizing resource allocation and decision making.
- The need for alignment with global standards such as ISO/IEC to ensure interoperability and scalability is emphasized.

Critical Evaluation: Pros:
- In-depth analysis of smart campus frameworks in developing countries.
- Highlights the potential of Big Data to improve educational efficiency and decision-making.

Cons:
- Lacks direct correlation with the ISO/IEC Smart City framework, limiting its broader applicability.
- Focus on developing countries may not fully address challenges or solutions relevant to more developed regions.

Relevance to My Research Topic: This study highlights the importance of aligning smart campus frameworks with global standards to ensure successful implementation in various contexts.

2.9 REVIEW: Adaptive Web-Based Learning Framework

Khir et al. (2012)

Introduction to the Study: Khir et al. (Khir, Ismail, and Shamsudin 2012) advocate for customizing educational content to fit individual learner profiles using data-driven methodologies.

Key Findings:
- The framework integrates Big Data and analytics to create personalized learning journeys.
- Highlights the transformative potential of technology to increase operational efficiency and educational efficacy.

Critical Evaluation: Pros:
- Innovative approach to personalized education using adaptive web technologies.
- Emphasises the integration of Big Data and analytics to enhance learning experiences.

Cons:
- Fails to completely align with ISO/IEC Smart City Framework standards, impacting its interoperability and broader applicability.
- Focuses predominantly on individual learning experiences, not sufficiently addressing collective educational system challenges.

Relevance to My Research Topic: This framework provides valuable insights for developing a comprehensive smart education strategy that aligns with global standards and addresses both individual and systemic educational needs.

2.10 REVIEW: ANFIS-Inspired Smart Framework for Education Quality Assessment

Ahamed Ahanger et al. (2020)

Introduction to the Study: Ahamed Ahanger et al. (Ahamed Ahanger et al. 2020) introduce an innovative approach to education quality evaluation through the Adaptive Neuro-Fuzzy Inference System (ANFIS) .

Key Findings:

- The framework represents a paradigm shift in educational assessments by integrating advanced computational techniques.
- Emphasises Big Data analytics for in-depth educational evaluations.

Critical Evaluation: Pros:

1. Innovative application for dynamic and adaptive quality assessment in education.
2. Emphasis on Big Data analytics for in-depth educational evaluations.

Cons:

1. Challenges in aligning with ISO/IEC Smart City Framework standards may affect its wider applicability.
2. Focus on quality assessment can limit its scope in addressing broader educational system challenges.

Relevance to My Research Topic: The innovative application of ANFIS in educational quality evaluation is significant for data-driven evaluation. Its role in Smart Education, particularly in Big Data utilization and operational efficiency, is critically examined along with its alignment with global standards such as ISO/IEC.

2.11 REVIEW: vSmartEdu Framework

Pham et al. (2021)

Introduction to the Study: Pham et al. (Q.-D. Pham et al. 2021) introduce the vSmartEdu framework, a novel detachable web-based learning solution designed to operate both online and offline, addressing the challenges of ICT infrastructure in developing countries.

Key Findings:

- The hybrid approach bridges the digital divide, ensuring educational continuity in various infrastructural settings.
- Aligns with big data principles, catering to a range of educational needs and preferences.

Critical Evaluation:

- **Strengths:** Versatility in providing both online and offline educational content, enhancing learning experiences.
- **Limitations:** Resource-intensive nature of maintaining and updating offline modules. Need for robust integration of analytics and learner feedback mechanisms. Lack of ISO/IEC alignments.

Relevance to My Research Topic: The vSmartEdu framework's adaptability aligns with the principles of operational efficiency and inclusivity in Smart Education. Addressing challenges of content synchronization and enhanced data analytics will be crucial for its broader adoption.

2.12 REVIEW: EU Digital Education Quality Standard Framework

Macdonald et al. (2024)

Introduction to the Study: Macdonald et al. (MacDonald et al. 2024) focus on developing an interactive EU Digital Education Quality Standard Framework and Companion Evaluation Toolkit.

Key Findings:

- The framework aims to guide the design, delivery, and evaluation of effective digital education.

- Addresses the need for quality, standardized digital education experiences.

Critical Evaluation:

- **Strengths:** Comprehensive variables critical to effective digital education.
- **Limitations:** Does not deeply explore practical challenges of implementing the framework across diverse educational environments.

Relevance to My Research Topic: Using this framework along with the thesis hypothesis will contribute to standardising digital education quality in the EU, highlighting the importance of a flexible and comprehensive framework.

2.13 REVIEW: Comparative analysis of Indian MOOC platforms

Sehgal (2019)

Introduction to the Study: Sehgal (Sehgal and Garg 2019) presents an examination of two prominent Indian MOOC platforms , NPTEL and SWAYAM . These Platforms represents a significant step towards making education more inclusive and accessible across India, leveraging the power of online learning to bridge educational gaps and enhance learning opportunities for all.

Key Findings:

- The study sheds light on varying methodologies and pedagogical strategies employed by these platforms.
- Highlights the importance of accessible and quality-driven educational experiences.

Critical Evaluation:

- **Strengths:** Comparative approach provides insights into operational efficiency and structural challenges.
- **Limitations:** Integration and effective use of big data to improve learning experience is underexplored. Broader global implications of educational frameworks are not thoroughly examined.

Relevance to My Research Topic: The study underscores the need for developing flexible, scalable, and data-driven educational platforms that meet diverse learner needs, in line with international standards.

2.14 REVIEW: Intelligent Education Visualisation System

Jianqiang et al. (2020)

Introduction to the Study: Jianqiang et al. (Jianqiang 2020) focus on the integration of visualization tools in online education, using social network analysis to enhance learning experiences.

Key Findings:

- Visualizes complex relationships within educational networks, helping to identify key influencers and nodes.
- Aligns with big data principles, offering a data-driven strategy to improve operational efficiency.

Critical Evaluation:

- **Strengths:** Novel application of social network analysis in education.
- **Limitations:** Lacks comprehensive strategy for practical implementation in diverse educational settings.

Relevance to My Research Topic: Highlights the importance of visualization tools in optimizing online education platforms. A more comprehensive analysis, including practical implementation strategies, would enhance its applicability.

2.15 REVIEW: Smart Campus Framework for Industry 4.0

Santiko et al. (2021)

Introduction to the Study: Santiko et al. (Santiko, Retnaning Soeprobowati, and Surarso 2021) present a framework for integrating Industry 4.0 technologies into the educational landscape.
Key Findings:
- Holistic approach integrating various aspects of a university's information system.
- Facilitates data-driven decision-making and personalized learning experiences.

Critical Evaluation:
- **Strengths:** Comprehensive framework aligning with ISO/IEC standards.
- **Limitations:** Challenges in scalability and adaptability across different educational institutions.

Relevance to My Research Topic: The framework represents a significant step toward modernizing educational infrastructures. For broader adoption, considerations such as cost-effectiveness, inclusivity, and pedagogical innovation must be addressed.

2.16 REVIEW: Quality and Standardisation in Technology-Enhanced Learning

Tal (2016)

Introduction to the Study: Tal (Tal, Ibarrola, and Muntean 2016) focuses on improving learning quality through technological advances, proposing new standards in technology-enhanced learning (TEL) .
Key Findings:
- Emphasises inclusive and equitable quality education through enhanced quality of experience (QoE) .
- Presents innovative ICT applications for improved learning and teaching practices.

Critical Evaluation:
- **Strengths:** Commitment to fostering an inclusive educational environment.
- **Limitations:** Challenges in bridging the gap between theoretical proposals and practical implementation.

Relevance to My Research Topic: The emphasis on inclusive and equitable education through enhanced QoE aligns with ISO/IEC standards. Addressing the challenges of practical implementation, scalability, and integration of big data analytics will be crucial.

2.17 REVIEW: Quality of Service Evaluation of LMS Using ISO/IEC 25011

Medina et al. (2020)

Introduction to the Study: Medina et al. (Medina and Davila 2020) evaluate the quality of service (QoS) in LMS using ISO/IEC 25011 standards and the Analytic Hierarchy Process (AHP) .
Key Findings:
- Systematic approach combining literature review with practical analysis of case studies.
- Emphasises ISO/IEC standards for software quality and usability.

Critical Evaluation:
- **Strengths:** Methodical approach to quality evaluation.
- **Limitations:** Focus on a single LMS and its specific context may limit generalisability.

Relevance to My Research Topic: Provides a framework for evaluating and enhancing the operational efficiency of smart education systems through standardized quality evaluation.

2.18 REVIEW: Smart Education Framework

Demir (2021)

Introduction to the Study: Demir (Demir 2021a) presents a comprehensive model for integrating smart technologies into education, structured into layers addressing different aspects of technology-enhanced learning.

Key Findings:
- Emphasises the importance of aligning educational technologies with pedagogical strategies.
- Proposes a holistic design for smart education, validated through a systematic review of the literature.

Critical Evaluation:
- **Strengths:** Comprehensive framework for integrating smart technologies.
- **Limitations:** Practical challenges of implementation and continuous adaptation to emerging technologies. Lack of direct coloration with ISO/IEC Smart City Framework.

Relevance to My Research Topic: The layered structure aligns well with the objectives of this thesis research. Further exploration of integrating big data analytics for operational efficiency would enhance its applicability and ISO/IEC SE Framework.

2.19 REVIEW: Smart Hybrid Learning Framework

Hartono et al. (2018)

Introduction to the Study: Hartono et al. (Hartono et al. 2018) present a framework integrating flipped classroom methods with Challenge-Based and Case-Based Learning, emphasizing a student-centered approach.

Key Findings:
- Combines traditional and modern pedagogical methods with a three-layer architecture.
- Promotes collaborative and inclusive learning environments through technology.

Critical Evaluation:
- **Strengths:** Comprehensive approach aligning with ISO/IEC standards.
- **Limitations:** Practical challenges in resource allocation and technological infrastructure requirements.

Relevance to My Research Topic: The framework's alignment with smart education principles is relevant to the thesis. Detailed exploration of integrating big data analytics would enhance its applicability.

2.20 REVIEW: Sustainable Smart Cities Integration in Education

Bulukova et al. (2015)

Introduction to the Study: Bulukova et al. (Bulukova and Wahl 2015) provide a perspective on integrating smart city concepts into educational and research settings.

Key Findings:
- Emphasizes holistic education programs incorporating smart city technologies and sustainability principles.
- Prepares students for modern urban challenges, aligning with ISO/IEC standards for technology-enhanced learning.

Critical Evaluation:
- **Strengths:** Focus on holistic education merging theoretical knowledge with practical application.
- **Limitations:** Challenges in ensuring programs stay up-to-date with rapidly evolving technologies.

Relevance to My Research Topic: Insightful perspectives on integrating smart city concepts into education and research. More exploration on practical implementation strategies, especially in the context of big data analytics, is needed.

2.21 REVIEW: Importance of Interoperability Standards

Chituc et al. (2019)

Introduction to the Study: Chituc et al. (Chituc and Rittberger 2019) explore the critical role of interoperability standards in future classrooms, enhancing the 'Smart Education Enhancement Recommendation System Framework'.

Key Findings:

- Interoperability standards facilitate seamless integration and effective communication between e-learning systems.
- Promotes inclusive education by standardising interfaces and interactions across platforms.

Critical Evaluation:

- **Strengths:** Enhanced integration capabilities and adaptability to new advances.
- **Limitations:** Technical challenges and resource-intensive implementation. Emphasis on compliance may stifle innovation.

Relevance to My Research Topic: Interoperability standards enhance the efficiency and adaptability of smart education systems. Addressing challenges such as technical complexity and balancing standardisation with innovation is crucial.

2.22 REVIEW: Smart City as the Backbone of Smart Education

Clohessy (2014)

Introduction to the Study: Clohessy (Clohessy, Acton, and Morgan 2014) posits that the evolution of Smart Education may mirror that of cloud services, characterized by managed utility. The National Geographic case study (Shyam R. et al. 2015) highlights the challenge of distinguishing between urban and rural areas and the environments conducive to Smart Education.

Key Findings:

- Integration of technology and infrastructure in Smart Cities impacts the effectiveness of Smart Education systems.
- Data-driven decision making can personalise learning experiences and optimise resources.
- Sustainability and accessibility in Smart Cities extend to Smart Education, aiming for high-quality equitable education.

Critical Evaluation: Pros:

- Enhanced Learning Experience: Interactive and engaging learning experiences through smart city technologies.
- Resource Optimization: Efficient use of educational resources.
- Inclusivity and Accessibility: Accessible education for a wider range of students.

Cons:

- Dependency on Technology: Issues in case of technical failures.
- Digital Divide: Unequal access to resources.
- Implementation Costs: High costs of establishing smart education infrastructure.

Relevance to My Research Topic: Highlights the intrinsic link between Smart Cities and Smart Education, emphasizing how the infrastructure and principles of Smart Cities shape Smart Education systems.

2.23 REVIEW: Operational Efficiency and Big Data Analytics

Borgi et al. (2017)

Introduction to the Study: Borgi et al. (Tawfik et al. 2017) emphasize that operational efficiency in smart education is based on effective use of big data analytics. The research highlights the need for analyzing both the volume and variety of data to improve educational systems within smart cities.

Key Findings:

- Informed Decision-Making: Big data analytics provide insights into student behavior, learning patterns, and educational outcomes.
- Resource Optimization: Institutions can optimize resources for better operational efficiency.
- Personalized Learning Experiences: Tailors educational content to meet individual student needs.

Critical Evaluation: Pros:

- Informed Decision-Making: Enables more informed decisions by providing insight into student behavior, learning patterns, and educational outcomes.
- Resource Optimization: Optimizes resources for better operational efficiency.
- Personalized Learning Experiences: Tailors educational content to meet individual student needs.

Cons:

- Data Privacy Concerns: Raises concerns about privacy and security.
- Complexity in Data Management: Requires sophisticated systems and expertise.
- Risk of Data Overload: Information overload, making it challenging to extract actionable insights.

Relevance to My Research Topic: This approach allows a complete understanding of the educational landscape, identifying areas that require improvement or additional investment.

2.24 REVIEW: Literature Gaps on the Role of Big Data in SE

Shyam et al. (2015)

Introduction to the Study: The study acknowledges a gap in research focused on specific operational efficiency metrics for Smart Education (Shyam R. et al. 2015). This research aims to address this gap by elucidating how big data analytics can enhance operational efficiency within Smart Cities, particularly in Smart Education.

Key Findings:

- In-depth Analysis: Big data analytics enable a more profound understanding of Smart Education systems' effectiveness.
- Enhanced Decision Making: Leads to better informed and data-driven decisions.
- Predictive Insights: Allows forecasting of trends and needs in Smart Education.

Critical Evaluation: Pros:

- In-depth Analysis: Enables a profound understanding of the effectiveness of Smart Education systems.
- Enhanced Decision Making: Leads to better informed and data-driven decisions.
- Predictive Insights: Allows forecasting of trends and needs in Smart Education.

Cons:

- Complexity in Data Handling: Managing and processing large volumes of data can be technically challenging.
- Privacy and Security Risks: Raises concerns about privacy and security.
- Potential for Misinterpretation: Risk of misinterpreting the data without proper tools and expertise.

Relevance to My Research Topic: Emphasizes the need for integrating big data analytics into Smart Education to improve operational efficiency in Smart Cities.

2.25 REVIEW: Innovative Dissemination in Smart Education

Gunasekaran et al. (2017)

Introduction to the Study: Gunasekaran et al. (Gunasekaran et al. 2017) explore the transformative impact of big data technologies on e-learning, propelling it towards a Smart Learning Framework.

Key Findings:

- Enhanced Learning Experiences: Incorporation of big data analytics facilitates personalized and engaging learning experiences.
- Data-Driven Insights: Enables educators and institutions to make informed decisions based on real-time data analysis.

- Adaptability: Smart learning frameworks are adaptable to the evolving technological landscape.

Critical Evaluation: Pros:
- Enhanced Learning Experiences: Personalized and engaging learning experiences through big data analytics.
- Data-Driven Insights: Enables informed decisions based on real-time data analysis.
- Adaptability: Adaptable to evolving technological landscape.

Cons:
- Complex Implementation: Requires significant technical expertise and infrastructure.
- Privacy Concerns: Raises concerns about data security and student privacy.
- Resource Intensity: Continuous updates and maintenance of technological systems may strain resources.

Relevance to My Research Topic: Understanding the qualities that make an innovation successful and the importance of peer-to-peer networks are pivotal in shaping Smart Education within Smart Cities. The insights from this journal contribute significantly to understanding the role of big data in advancing smart educational environments.

2.26 REVIEW: Synthesis of Smart City and Smart Education

Integration Framework: Elgazzar, Rasha F and El-Gazzar, Rania

Introduction to the Study: The synthesis of Smart City and Smart Education is illustrated in a layered framework, emphasising the importance of infrastructure, government operations, economic growth, and civic participation. (Elgazzar and El-Gazzar 2017)

Key Findings:
- Integrated Infrastructure: Ensures an improved learning environment using technology.
- Government and Economic Support: Provides a foundation for developing and sustaining Smart Education initiatives.
- Community Engagement: Fosters a collaborative environment essential for progressive educational reforms.

Critical Evaluation: Pros:
- Integrated Infrastructure: Improved learning environment using technology.
- Government and Economic Support: Foundation for developing and sustaining Smart Education initiatives.
- Community Engagement: Collaborative environment for educational reforms.

Cons:
- Complex Coordination: Requires meticulous planning and coordination.
- Resource Allocation: Balancing resources between city development and educational needs.
- Socio-Economic Disparities: Affects equal access to Smart Education facilities.

Relevance to My Research Topic: This synthesis provides a comprehensive strategy for leveraging smart city capabilities to bolster educational efficiency and effectiveness.

2.27 Living in a Smart City to Access Smart Education

Interaction Between Smart City Living and Smart Education

Introduction to the Study: As this thesis elaborates, the interaction between living in a smart city and pursuing a smart education is a complex but vital area of study. Smart education is rapidly evolving, similar to cloud technologies. Clohessy (Clohessy, Acton, and Morgan 2014) presents a future roadmap for cloud-facilitated smart city development, crucial to understanding the trajectory of smart education. It is established that a smart city is the backbone of smart education, as illustrated in the National Geographic case study by Shyam (Shyam R. et al. 2015). This study delineates an urban area as the region surrounding a city, helping to distinguish between Smart City and Smart Education environments. However, there are

challenges to drawing a clear line between these two domains.
Critical Evaluation: The National Geographic case study has been criticized for the lack of scientific proof ("ZTE COMMUNICATIONS December 2015, Vol.13 No.4" 2015). Despite this, the case study highlights significant insights, such as the influence of non-agricultural jobs on the migration patterns of graduates to and from smart cities.
Efforts to standardise the concept of a smart city or urban area often face challenges, as the definition can vary significantly depending on geographical and cultural contexts. Shyam (Shyam R. et al. 2015) highlights that the distinction between urban and rural areas is becoming less clear, with different countries adopting varying criteria. For example, in the United States, settlements with 2,500 or more inhabitants are classified as urban, while in Japan, a more densely populated country, the threshold is 30,000 inhabitants (Shyam R. et al. 2015). Similarly, in India, a town is considered rural if its population is less than 15,000, according to the India Planning Commission. This thesis draws attention to the pros and cons of the development and its contributions.
Pros:

- Comprehensive Understanding: Offers a broad perspective on the interrelation of smart cities and smart education.
- Future-Orientated Research: Provides a roadmap for future developments in smart education, influenced by advancements in smart cities.
- Cultural Sensitivity: Recognises diverse definitions reflecting cultural and demographic sensibilities.
- Flexibility in Planning: Allows for more tailored approaches to developing smart city initiatives.
- Comprehensive insights: Analysis of a wide range of data provides a holistic understanding of the operational aspects of Smart Education within Smart Cities.
- Informed Decision Making: Enhanced data-driven insights lead to more effective strategies for developing smart education.
- Identifying key factors: Helps identify key components that impact the quality and efficiency of Smart Education systems.
- Enhanced Service Delivery: OE2V can improve the predictability and reliability of service in smart education.
- Economic Growth: Aligns economic activities with benchmarks to promote prosperity.
- Cultural Enrichment: Promotes a diverse and inclusive culture within smart cities.

Cons:

- Scientific Gaps: Some case studies lack rigorous scientific support, affecting the validity of their findings.
- Generalisation Issues: Challenges in applying insights from specific case studies to a broader context.
- Lack of Standardisation: The absence of a universal definition can lead to inconsistencies in the development of smart cities.
- Challenges in Comparative Analysis: Varying definitions make it difficult to compare and benchmark smart city initiatives in different regions.
- Complexity in Data Analysis: The handling and interpreting of large volumes of varied data can be technically challenging.
- Risk of Data Misinterpretation: Without the right tools and expertise for analysis, there is a potential for misinterpreting the data, leading to ineffective solutions.
- Resource intensiveness: Requires substantial resources for data collection, storage, and analysis.
- Complex Implementation: Integrating OE2V into smart education systems can be complex and resource-intensive.
- Risk of exclusion: Rapid advancements may lead to exclusions if not managed inclusively.
- Data Management Challenges: Efficiently handling big data requires robust infrastructure and expertise.

2.27.1 Challenges in Aligning Smart City Development with Community Needs

Introduction to the Study: Reviews of existing literature reveal that smart city (SC) development practices do not always align with the needs of the communities they aim to serve. This disconnect is evident in the absence of specific components necessary to qualify a development as a smart city. Komninos' research, for instance, is not specific to any components of the smart city but rather investigates general population aspects (Shyam R. et al. 2015). A critical gap is observed in most SC developments that do not meet the specific requirements of the urban smart education context, often lacking the necessary analytics or big data evidence, as indicated in Shyam's study (Shyam R. et al. 2015).

Critical Evaluation:

- **Strengths:** Highlights the need for aligning smart city development practices with community needs.
- **Limitations:** Most SC developments lack the necessary analytics or big data evidence to meet the specific requirements of the urban smart education context.

Relevance to My Research Topic: This gap indicates a need for further research to bridge the gap between traditional IT management frameworks and the evolving demands of smart education within the context of smart cities. Ensuring that smart city developments align with the needs of smart education systems is crucial for their success and sustainability.

This analysis underscores the importance of establishing clear and context-sensitive definitions and approaches for smart cities, particularly with respect to smart education. The absence of universally accepted criteria for smart cities contributes to the complexity of implementing effective smart education systems. This lack of standardisation poses significant challenges to researchers and policy makers in developing targeted strategies for the integration of smart education into diverse urban settings.

The core hypothesis of this research is to reveal an operational efficiency recommendation framework in Smart Education using big data analytics, particularly focussing on the volume and variety of data. This approach is expected to uncover critical components of Smart Cities, highlighting them as essential elements in monitoring and maintaining both qualitative and quantitative enhancement factors for Smart Education in alignment with the ISO/IEC Smart City Framework 30145 series. This study aims to fill a significant gap in the existing literature, which focusses primarily on the ICT aspect of Smart Education, but often overlooks the essential qualitative and quantitative metrics that reflect and measure its effectiveness. By comparing services and focussing on their common elements, this investigation seeks to improve our understanding of operational efficiency in Smart Education and the internationally accepted framework.

Studies by IBM (Paroutis, Bennett, and Heracleous 2014), Madakam (Madakam and Ramaswamy 2015), and Ustundag (Ustundag and Cevikcan 2017) have shown the use of ICT to detect, analyse, and integrate key information in city operations. However, these studies often fail to highlight specific operational efficiency metrics, particularly in relation to Smart Education, a gap also noted by Zhang (Y. Zhang 2010) in their view of ICT in Smart Cities. Despite various developments in the implementation of smart solutions for digitally connected cities, as discussed by Kehua et al. (Su, J. Li, and H. Fu 2011), Smart Education often remains an overlooked component in these initiatives.

The primary motivation for this research is to foster sustainable smart education, with the aim of predictable services, increased prosperity, and the emergence of a rich, diverse, and inclusive culture within smart cities, as Ustundag emphasised (Ustundag and Cevikcan 2017). Implementing the principles of operational efficiency and volume variety (OE2V) can drive innovation, align economic benchmarks, and improve governance. These factors contribute to the creation of jobs, wealth generation, and affordable energy solutions, as discussed by Borgi (Tawfik et al. 2017), Martins (Martins 2018), and LES (Les 2003). Although Shyam's findings (Shyam R. et al. 2015) focus predominantly on big data, they reveal that operational efficiency can be extracted from smart city grids in the context of smart education without interruption of service. This requires a precise estimate to provide the metrics necessary for operational efficiency, making the concept of Smart Education central to attracting innovation, business, dynamic skills, and global investments. A critical area, among many, is advanced manufacturing in the context of Industry 4.0, the manufacturing process of the future, as Lombardi explored (Lombardi et al. 2012). However, most of the literature on the benefits of smart cities, including these findings, lacks specific metrics for operational efficiency in smart education, a gap that this research aims to address through the hypothetical proposition of OE2V. This research recognises that, theoretically, the data essential for smart education originate primarily from smart citizens, as highlighted in studies by ESD Education (ESD 2020). The size and growth of the human population, often cited as key factors affecting Earth's biodiversity, also play a significant role in the shaping of smart cities and, therefore, smart education (Christensen, Gillingham, and Nordhaus 2018). The study by (Manjul Gupta and George 2016) identifies four key themes consistent with smart city development, which are integral to the smart education framework. These themes contribute to the support of the quantitative and qualitative hypothesis and offer information on the benefits of smart education in these four areas (Paroutis, Bennett, and Heracleous 2014):

1. Infrastructure: This base level includes high-quality transport options, on-demand mobility services, and renewable energy sources versus fossil fuel power plants. The component metric also encompasses intelligent education data systems (Vetrò et al. 2016).
2. City and Government Operations: This layer covers sectors such as libraries, parks, health systems, public safety, and law and order establishments. Assesses metrics on accessibility, transparency, and supportive decision-making frameworks (Abdel-Basset et al. 2019).
3. Economic Growth and Employment: This layer involves metrics on employment growth versus retained quality employment, inclusive opportunities, and advancing learning through smart learning analytics (Manjul Gupta and George 2016).
4. Civic Engagement: The upper layer focusses on the participation of citizens, stakeholders, academics, and industry to address city challenges, primarily through cloud-based sustainability delivery methods (Frankel and Reid 2008).

With all of the meticulously integrated results above, the study by Borgi (Tawfik et al. 2017) states that a smart city must be liveable, workable, and sustainable, supported by metrics as shown in Figure 2.2. These metrics not only define the operational efficiency of a smart city, but also its educational prowess. The integration of these layers into a cohesive framework is essential to develop smart cities that effectively support smart education initiatives.

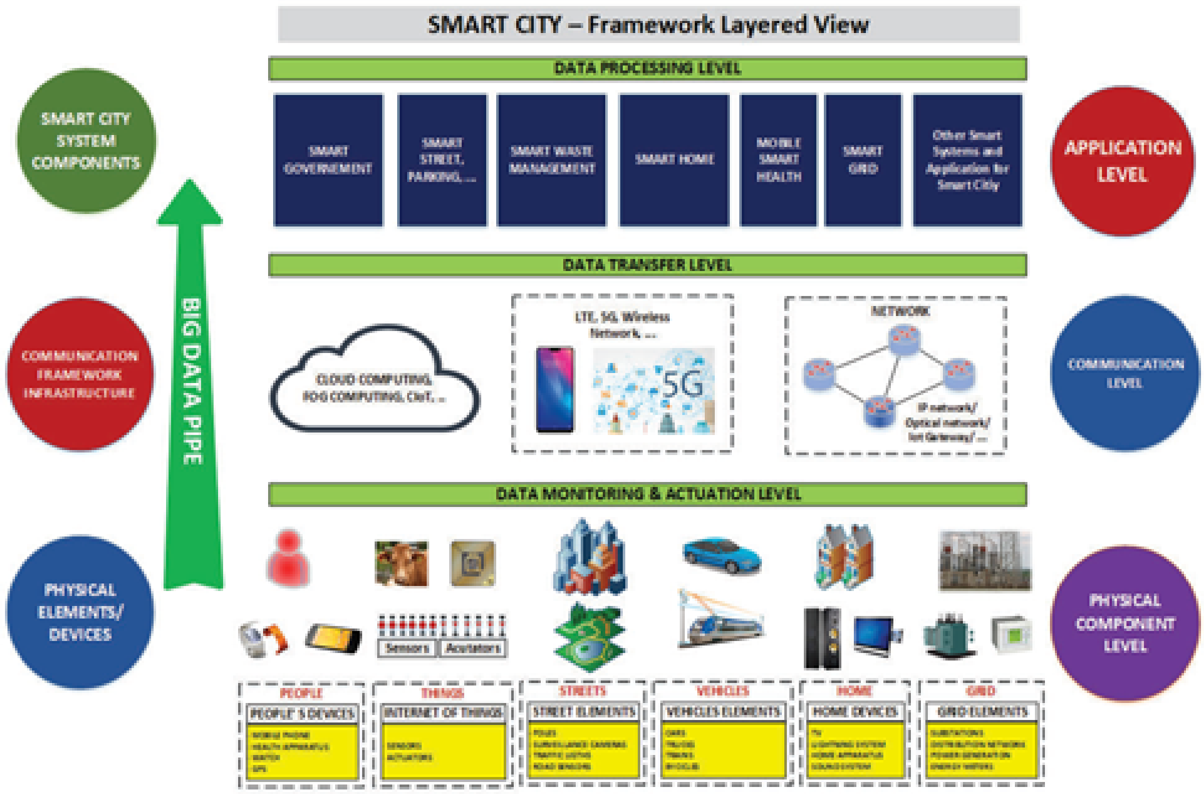


Figure 2.2: SMART CITY (SC) - Framework Layered View (Gunasekaran et al. 2017)

Understanding this mix of technology leads to the study of Gunasekaran et al. (Gunasekaran et al. 2017), the concept of Diffusion of Innovations provides three valuable insights into the process of social change, especially in the building of Smart Cities (SC) in the context of Smart Education (SE). These insights are critical to understanding how innovations in technology and education are adopted and propagated within society.

- Qualities for Successful Innovation Spread: This aspect delves into the characteristics that make an innovation more likely to be adopted. These may include the relative advantage of innovation compared to existing solutions, its compatibility with existing values and practices of potential adopters, its simplicity and ease of use, the possibility of experimentation on a limited basis and observable results.
- Importance of Peer-Peer Conversations and Networks: The role of social systems and networks in the diffusion process is crucial. Peer-to-peer conversations and networks act as channels for the transmission of new ideas and practices. They provide platforms to share experiences, influence attitudes, and foster a collaborative environment for innovation.
- Understanding Different User Segments: Recognising the diversity of user needs and preferences is essential. Innovations in smart education must be tailored to different user segments, considering varied educational backgrounds, learning styles, and accessibility requirements. The adaptation of educational technologies and methodologies to meet these diverse needs is the key to successful implementation.

These insights contribute significantly to the development of Smart Education within Smart Cities. They provide a framework for understanding the dynamics of innovation adoption, especially in the context of advanced technologies and educational practices. Incorporating these concepts into the design and implementation of Smart Education initiatives can lead to more effective and widely accepted educational models.

The application of these insights in Smart Cities and Smart Education is a complex but crucial endeavour. It requires a holistic approach, considering not only the technological aspects, but also the human and social factors that influence the adoption and success of new educational innovations.

In smart city in the context of big data analytic innovation sectors, the following diffusion is stated and justified as in the table 2.9, to distill data for smart education (SE):

2.27.2 Global Framework Accreditation for Smart City in the context of Smart Education

The ongoing discourse on Smart Cities often revolves around identifying and defining their core components, as illustrated in Figure 2.2. However, there is a notable gap in establishing a global framework accreditation metric specifically tailored for Smart Cities in the context of Smart Education (SE). This gap is evident in the comprehensive study by Giffinger et al. (Rudolf Giffinger 2007), titled "Smart Cities - Ranking of European Medium-Size Cities." Although the study addresses the development shift between rural and urban cities and discusses smart cities metrics, it relies on data sources such as Urban Audit, Espon, Eurostat DB, Eurobarometer, and NUTS0. These sources, although extensive, lack a globally approved framework metric for Smart Cities, as highlighted in the Eurostat SDG-EU report (EUROSTAT 2020).

The absence of a global set criteria framework in these reports is notable. Although they present milestones, they are not precise indications of how these metrics were met, leading to inconclusive evaluations. This limitation is also reflected in the Urban Audit (Core) by Datagov-UK (DataGov-UK 2016), where the focus remains on urban audits without a clear framework for Smart City accreditation, especially in the realm of Smart Education.

In light of these limitations, this research aims to introduce a hypothetical framework that addresses the lack of a standardised process leading to Smart City accreditation in the context of Smart Education. This proposed framework will not only fill existing gaps in the literature, but will also provide a structured approach to evaluate and accredit Smart Cities, with a specific focus on their educational capabilities. By doing so, the research will contribute significantly to the academic and practical understanding of Smart Cities, particularly in how they integrate and support Smart Education initiatives.

This hypothetical framework will be designed to be comprehensive, adaptable and reflective of the diverse needs and characteristics of Smart Cities around the world. It will consider various dimensions of Smart Education, including infrastructure, technology integration, pedagogical approaches, and community engagement, thus providing a robust basis for assessing and accrediting Smart Cities as conducive environments for advanced educational pursuits.

Detailed Hypothetical Example for Smart City Investments

Using our Smart Education Framework, it would be possible to accurately delineate and calculate an investment aspect. Let us consider two Smart Cities, A and B, planning their educational investments over a three-year period.

Assumptions:

- **Smart City A's Current Investment:** £3,000 billion
- **Smart City B's Projected Investment Requirement:** To be determined
- **Annual Interest Rate (Variable):** Ranges from 5% to 8% over three years
- **Inflation Rate:** 2% per year
- **Additional Annual Operational Costs for Maintenance and Upgrades:** 4% of the total investment

Goal: Determine Smart City B's required investment to match Smart City A's educational infrastructure standards in three years, accounting for variable interest rates, inflation and operational costs.

Calculation Steps:

1. **Calculate Adjusted Future Value for City A:**
   - Year 1 Future Value FV at 5% interest rate: $FV = 3,000B \times (1 + 0.05) = £3,150B$
   - Year 2 FV at 6% interest rate: $FV = 3,150B \times (1 + 0.06) = £3,339B$
   - Year 3 FV at 8% interest rate: $FV = 3,339B \times (1 + 0.08) = £3,606.12B$
2. **Adjust for Inflation:**
   - Year 3 FV adjusted for inflation: $AdjustedFV = 3,606.12B/(1 + 0.02)^3 = £3,391.93B$
3. **Calculate Operational Costs:**
   - Total Operational Costs: $4\% \times 3,391.93B = £135.68B$
4. **Calculate Required Investment for City B:**
   - Considering the operational costs, the adjusted FV becomes: $AdjustedFV = 3,391.93B + 135.68B = £3,527.61B$
   - Using the Present Value formula: $PV = FV/(1 + r)^n$
   - Assuming an average interest rate (r) of 6.5% over 3 years, calculate City B's required investment: $PV = 3,527.61B/(1 + 0.065)^3 = £2,955.19B$

Results: Smart City B's Required Investment: Approximately £2,955.19 billion is needed over three years to achieve a comparable educational infrastructure as Smart City A, considering variable interest rates, inflation, and operational costs.

Additional Metrics for Operational Efficiency:

- **Cost Variance (CV):** $CV = EarnedValue(EV) - ActualCost(AC)$
- **Cost Performance Index (CPI):** $CPI = EV/AC$

These metrics, along with advanced financial analysis, will enable a thorough assessment of operational efficiency in the context of smart education within Smart Cities.

Insight: This detailed hypothetical scenario demonstrates a comprehensive approach to financial planning for smart cities, taking into account various economic variables and providing a more realistic insight into the investment required for the development of educational infrastructure. This analysis is crucial for policy makers and city planners to make informed decisions about smart city development and educational improvements.

2.27.3 Smart City Components by sectors application

Table 2.9: Smart City Components by sectors application (see appendix 2 for full table listing) (Gunasekaran et al. 2017).

Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
University / Public expenditure on R and D - percentage	Percentage of population aged 25 to 65 with university level education living in Urban	An assessment of the ambitiousness of CO_2 emission reduction strategy	Percentage of population aged 25 to 65 with university level education living in Urban	Percentage of professors and researchers involved in international projects	No. of universities and research centres in the city
—	—	—	—	—	—
Government / GDP per head of city population Debt	voter turnout in national election	Total annual energy consumption, in gigajoules per head	Voter turnout in national election or Voter turnout in national referendum	Proportion of the area for recreational sports	e-Government online availability (display percentage of the top 20 services to the community)
—	—	—	—	—	—
Civil society / Percentage of projects funded by civil society	Foreign language skills Participation in lifelong learning percentage	The total percentage of the working population travelling to work on public transport	Foreign language skills Participation in lifelong learning percentage Individual level of computer skills Individual level of internet skills	Total book loans and other media per resident Museum visits per inhabitant	e-Government usage by citizens (percentage citizens aged 18-75 who have used the Internet)

Continuation: SC Components by Sectors of Table 2.9					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
—	—	—	—	—	—
Industry / Employment rate in: High Tech and creative industries	Patent applications per inhabitant Employment rate in knowledge-intensive sectors	The percentage of total energy derived from renewable sources	Patent applications per inhabitant Employment rate in knowledge-intensive sectors	Number of enterprises adopting ISO 14000 standards Proportion of people undertaking industry-based training	Number of research grants funded by companies, foundations, institutes without annual scholarships and their support for the sustainability of SDG4 as proposed by UN
End of Table					

2.28 Case Studies on Smart Education Frameworks Aligned with ISO/IEC Standards

Introduction to Case Studies of Smart Education and ISO/IEC Smart City Framework

Smart Education is a critical component of Smart Cities, leveraging advanced technologies to improve educational experiences and outcomes. The ISO/IEC Smart City Framework provides guidelines to ensure that smart initiatives, including Smart Education, adhere to international standards for data security, privacy, and interoperability. This chapter reviews case studies of Smart Education initiatives in different cities, assessing their successes and failures, and their alignment with the ISO/IEC Smart City Framework.

Purpose and Scope of the Case Study Review

The purpose of this review is to evaluate the effectiveness of various Smart Education initiatives, identify best practices and understand the challenges faced during implementation. The selected case studies represent diverse geographical and cultural contexts, providing a comprehensive view of how Smart Education can be integrated into Smart Cities.

Structure of the Case Studies

Each case study chapter includes an overview of the initiative, the implementation process, successes and achievements, challenges and failures, and an assessment of alignment with the ISO/IEC Smart City Framework. A comparative analysis and conclusion will summarise the key findings and provide recommendations for future initiatives.

2.29 Case Study 1 - Singapore's Smart Nation Initiative

Overview of Singapore's Smart Nation Initiative

The Singapore Smart Nation Initiative aims to transform the country into a global leader in the integration of smart technology. The initiative covers various sectors, including education, where Smart Education is a key focus. The government has invested significantly in the digital infrastructure, ensuring widespread access to the Internet and promoting the use of technology in schools (Foong et al. 2024).

Implementation of Smart Education in Singapore

Singapore's approach to Smart Education includes the use of data analytics, artificial intelligence (AI), and Internet of Things (IoT) devices to personalise learning experiences and improve administrative efficiency. The Ministry of Education collaborates with tech companies to develop innovative educational tools and platforms (Chia 2016; Tan Yeok Ching and Chennupati 2002).

Successes and Achievements

Singapore has achieved notable success in integrating technology into education. The use of artificial intelligence for personalised learning has improved student engagement and outcomes. The digital infrastructure supports seamless access to educational resources, both in and out of the classroom. The integration of dashboards has enabled the real-time monitoring and analysis of educational data, leading to more informed decision making (Zhaoyu Chen and Chan 2023).

Challenges and Failures

Despite its successes, Singapore faces challenges to maintain the rapid pace of technological advancement. Ensuring equitable access to technology for all students remains a concern, as is the continuous need for teacher training in new technologies. Dashboards, while effective, require ongoing updates and maintenance to remain relevant and functional (Tan 2018).

Alignment with ISO/IEC Smart City Framework

Singapore's Smart Nation Initiative aligns well with ISO/IEC standards, particularly in the areas of data security and privacy. The initiative's focus on interoperability ensures that educational technologies can seamlessly integrate with other smart city systems. However, ongoing efforts are needed to maintain alignment as technologies evolve (Xiaomi, Wei, and Jinghua 2021).

2.30 Case Study 2 - South Korea's Smart Education Initiative

Overview of South Korea's Smart Education Initiative

South Korea is known for its advanced technological infrastructure and has made significant strides in Smart Education. The government has implemented policies to integrate digital technologies into the education system, supported by the high-speed Internet and the widespread use of digital devices (So and Park 2019).

Implementation of Smart Education in South Korea

The initiative includes the use of AI and big data to personalise learning and improve administrative processes. Schools are equipped with digital learning tools and teachers are trained to use these technologies effectively (Teo, S. L. Kim, and Li Jiang 2020).

Successes and Achievements

South Korea's Smart Education initiative has led to improved student performance and participation. The integration of digital tools has simplified administrative tasks, allowing teachers to focus more on instruction. The implementation of dashboards has enabled efficient tracking of student progress and institutional performance (Han et al. 2021).

Challenges and Failures

Challenges include ensuring that all students have equal access to technology and addressing the digital divide between urban and rural areas. Teachers also need ongoing professional development to keep up with technological advances. The dashboards, though beneficial, face issues related to data accuracy and user-friendliness (Choo et al. 2023).

Alignment with ISO/IEC Smart City Framework

South Korea's initiative demonstrates a strong alignment with ISO/IEC standards, particularly in terms of data security and privacy. Efforts are evident to ensure the interoperability of educational technologies with other smart city systems, although continuous monitoring is necessary to maintain this alignment (Jang and K. Kim 2020).

2.31 Case Study 3 - New York City's iZone

Overview of New York City's iZone

New York City's iZone aims to transform public education by integrating innovative technologies into classrooms. The initiative focusses on personalising learning experiences and improving educational outcomes through the use of data and technology (Lake and Gross 2011).

Implementation of Smart Education in New York City

The iZone initiative includes the deployment of digital learning tools, data analytics, and personalised learning platforms. Teachers receive training to effectively use these technologies to improve their teaching practices (Greytak and Kosciw 2010).

Successes and Achievements

The iZone has led to greater student engagement and improved learning outcomes. The use of data analytics has provided valuable insight into student performance, allowing for more targeted interventions. Dashboards have facilitated real-time data visualisation and reporting, improving transparency and accountability (L. D. Pham 2023).

Challenges and Failures

Challenges include the high costs associated with the implementation and maintenance of advanced technologies. Ensuring that all students have access to these technologies remains a priority, as is providing ongoing support and training for teachers. The dashboards have faced issues related to data integration and user adoption (Farrukh, Mathrani, and Sajjad 2022).

Alignment with ISO/IEC Smart City Framework

The iZone initiative aligns with the ISO / IEC standards, particularly in its focus on data security and privacy. Efforts to ensure the interoperability of educational technologies are ongoing, although further work is needed to fully integrate these systems with other smart city initiatives (Naiki n.d.).

2.32 Case Study 4 - Dubai's Smart Learning Initiative

Overview of Dubai's Smart Learning Initiative

Dubai's Smart Learning Initiative aims to revolutionise education by integrating advanced technologies into the learning environment. The initiative focusses on creating a seamless, technology-enhanced educational experience for students and teachers (M. M. El Khatib et al. 2023; El-Haggar et al. 2023).

Implementation of Smart Education in Dubai

The initiative includes the deployment of digital devices, interactive learning platforms, and AI-driven personalised learning tools. The government collaborates with technology companies to ensure the latest technologies are available in schools (Gaad, Arif, and Scott 2006).

Successes and Achievements

Dubai's Smart Learning Initiative has led to significant improvements in student engagement and performance. The integration of AI and interactive platforms has improved the learning experience, making it more dynamic and personalised. Dashboards have played a crucial role in the monitoring and evaluation of educational outcomes, providing real-time feedback to educators and administrators (M. El Khatib, Alhammadi, and Almulla 2024).

Challenges and Failures

Challenges include ensuring that all students have access to the necessary technology and addressing the digital divide between different socioeconomic groups. Teachers also need ongoing professional development to keep up with rapid technological changes. The dashboards have faced issues related to scalability and integration with existing systems (Al-Sayed et al. 2022).

Alignment with ISO/IEC Smart City Framework

Dubai's initiative aligns well with ISO/IEC standards, particularly in data security and privacy. The focus on interoperability ensures that educational technologies can seamlessly integrate with other smart city systems. However, continuous efforts are needed to maintain this alignment as new technologies are introduced (Javed et al. 2022).

2.33 Case Study 5 - Finland's Smart Learning Environments

Overview of Finland's Smart Learning Environments

Finland is known for its innovative educational system and has embraced Smart Education to improve learning outcomes. The country's Smart Learning Environments initiative integrates technology into classrooms to support personalised learning and improve educational efficiency (Kian 2019).

Implementation of Smart Education in Finland

The initiative includes the use of digital learning tools, data analytics, and AI to personalise learning and streamline administrative processes. Schools are equipped with state-of-the-art technology and teachers are trained to use these tools effectively (Simola et al. 2014).

Successes and Achievements

Finland's Smart Learning Environments have led to improved student performance and engagement. The use of digital tools has improved the learning experience, making it more interactive and personalised. Dashboards have been instrumental in tracking student progress and providing actionable insights to educators (Rissanen et al. 2021).

Challenges and Failures

Challenges include ensuring equal access to technology for all students and addressing the digital divide between urban and rural areas. Continuous professional development for teachers is also necessary to keep up with technological advances. The dashboards have faced challenges related to the accuracy and integration of the data with other educational systems (Jain and Nieminen 2023).

Alignment with ISO/IEC Smart City Framework

Finland's initiative demonstrates a strong alignment with ISO/IEC standards, particularly in data security and privacy. Efforts are evident to ensure the interoperability of educational technologies with other smart city systems, although continuous monitoring is necessary to maintain this alignment (Anttila and Jussila 2018).

2.34 Comparative Analysis and Conclusion

Case Studies Comparative Analysis

The reviewed case studies highlight both successes and challenges in the implementation of Smart Education initiatives. Common themes include the need for robust dashboard data integration tools and digital infras-

tructure, ongoing professional development for teachers, and efforts to ensure equitable access to technology. The alignment with ISO/IEC standards varies, with most initiatives demonstrating strong compliance in data security and privacy, but requiring continuous efforts to maintain interoperability.
A key aspect of these initiatives is the lack of stable integration of dashboards, which play a critical role in monitoring, evaluating, and improving educational outcomes. In particular:

- **Singapore:** Lack of open data aligned to the Dashboards need improvement to enabled real-time monitoring and analysis of educational data, leading to more informed decision-making.
- **South Korea:** Lack of open data aligned to the Dashboards need improvement to facilitated efficient tracking of student progress and institutional performance.
- **New York City (iZone):** Lack of open data aligned to the Dashboards need improvement to improved transparency and accountability through real-time data visualisation and reporting.
- **Dubai:** Lack of open data aligned to the Dashboards need improvement to provided real-time feedback to educators and administrators, enhancing monitoring and evaluation.
- **Finland:** Lack of open data aligned to the Dashboards need improvement to enhance student progress and providing actionable insights to educators.

2.35 Challenges Identified And Resolved With SERFD:

Challenges with Big Data in the Smart City Framework: The use of Big Data in Smart Cities presents unique challenges, characterised by the five Vs: Volume, velocity, variety, veracity, and value (Luis et al. 2013);(Eiman et al. 2015). These characteristics define the complexity of handling and processing large-scale data from diverse sources with varying degrees of reliability and impact.
Academic Insight: This research posits that the effective use of Big Data within Smart Cities, particularly in the realm of Smart Education, is essential to achieve operational efficiency. The intricate relationship between data volume, velocity, and variety, coupled with the need to ensure data veracity and value, poses significant challenges. Addressing these challenges is crucial for the development of a sustainable, efficient, and responsive Smart Education framework, contributing significantly to the overarching goals of Smart Cities.
Although Big Data meaning and definition differ slightly, for most the outcome is significantly similar as the table 2.10 indicates (Eiman et al. 2015):

Table 2.10: Big Data Meaning and Definitions .

Begin: Big Data Meaning and Definitions - Table 2.10	
Big Data Definition	Source
”Big data high in volume, high velocity, and/or high variety information assets that require new forms of processing to enable improved decision-making, insight discovery, and process optimisation”	(Kitchin 2017)and (Manyika et al. 2011)
”When the size of the data itself becomes part of the problem and traditional techniques for working with data run out of steam”	(Loukides and Lomax 2021)
Big Data is ”data whose size forces us to look beyond the tried-and-true methods that are prevalent at that time”	(Jacobs et al. 2009)

Continuation of Big Data Meaning and Definitions Table 2.10	
Big Data Definition	Source
"Big Data Technologies[are] a new generation of technologies and architectures designed to extract value economically from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, and/or analysis"	(Mialle et al. 2019)
"The term for collection of datasets so large and complex that it becomes difficult to process using on-hand database management tools or traditional data processing applications"	(Schroeder and Taylor 2015)
"A collection of large and complex data sets which can be processed only with difficulty by using on-hand database management tools"	(Ridler et al. 2014)
"Big data is a term that encompasses the use of techniques to capture, process, analyse, and visualise potentially larger datasets in a reasonable time frame not accessible to standard IT technologies." By extension, the platform, tools, and software used for this purpose are collectively called "Big Data technologies"	(Data 2012)
"Big data can mean big volume, big velocity, or big variety"	(Stonebraker et al. 2018)
End of Table	

Furthermore, according to Khan (Khan, Anjum, and Kiani 2013), in technological terms, a shared definition of big data and a smart city is still in research, and it has been difficult to pinpoint a standard global meaning due to regional economical differences. Although the beneficial concept is agreeable but yet differs from the rule and data definition (Big Data), said (Khan, Anjum, and Kiani 2013), the problem of big data is to do with definition and how researchers see the meaning differently, for example:

- SAS: "Big data is a popular term used to describe exponential growth, availability, and use of information, both structured and unstructured" (Michalik, Stofa, and Zolotova 2014).
- IBM: Data, coming from everywhere; sensors used to collect climate information, posts on social media sites, digital pictures and videos, purchase transaction record, and cell phone GPS signal, to name a few (Michalik, Stofa, and Zolotova 2014).
- Big data is defined as a large set of data that is very unstructured and disorganised (Khan, Anjum, and Kiani 2013).
- Big data is a form of data that exceeds the processing capabilities of traditional database infrastructure or engines (Khan, Anjum, and Kiani 2013).

The interplay between Smart Cities and Smart Education, particularly through the lens of Big Data analytics for Operational Efficiency (OE), remains a relatively underexplored terrain. This research hypothesises that the symbiotic relationship between Smart Cities and Smart Education is fundamental to achieving a higher OE.

SERFD Recommendations

- **Invest in Digital Infrastructure:** Ensure that schools have access to high-speed internet and the latest educational technologies.
- **Professional Development:** Provide ongoing training for teachers to use new technologies effectively.
- **Equitable Access:** Implement strategies to ensure that all students have access to the necessary technology.
- **Maintain ISO/IEC Compliance:** Continuously monitor and update technologies to ensure compliance with international and global ISO/IEC standards.
- **Integrate Open Data Dashboards:** Develop and implement open data dashboards to facilitate the replication of real-time data visualisation, monitoring, and evaluation of educational results.
- **Dashboard Usability:** Ensure that dashboards open data are user-friendly, accessible and provide actionable insights for educators, administrators, developers, and policymakers.
- **Continuous Improvement:** Regularly update open data dashboards to reflect the latest data and technological advances, ensuring that they remain relevant and effective for research.

Future Perspectives

This systematic review contributes to academic discourse by analysing the intersection of Smart Cities and Smart Education, highlighting the pivotal role of big data analytics in uncovering operational efficiencies. Using a dashboard-based smart education recommendation framework with dashboards, these initiatives have the potential to revolutionise education, making it more efficient, personalised, and inclusive. The integration of dashboards has been a critical factor in improving the monitoring, evaluation, and improvement of educational outcomes.

Aligning smart education initiatives with ISO / IEC standards is essential to ensure data security, privacy, and interoperability. This review provides a comprehensive analysis of various Smart Education initiatives in different cities, highlighting the need for robust digital infrastructure, ongoing professional development for teachers, and equitable access to technology.

Future research should focus on addressing the challenges identified in these case studies and exploring new ways to integrate Smart Education with Smart City frameworks. Particular attention should be paid to the development and optimisation of open data dashboards to further enhance educational outcomes and operational efficiencies.

Academic Contribution: The study enriches the understanding of Smart Education within Smart Cities, emphasising the need for a nuanced approach that considers both the technological and educational dimensions of urban development. It provides a comprehensive perspective on the potential of big data analytics to drive innovation, economic alignment, and governance in Smart Education, shaping the future of urban educational environments.

2.35.1 Validation of the Literature Review on Smart Education Recommendation Framework:

- **Pros:** The document provides a detailed exploration of Smart Education within the context of Smart Cities, using advanced technologies and data analytics to improve educational delivery and operational efficiency.
- **Cons:** Potential limitations may include the complexity of integrating and maintaining the proposed technologies and the need for significant infrastructure investments.
- **ISO/IEC Compliance Alignment:** The framework suggests a strong alignment with ISO/IEC standards, particularly in data security, privacy, and interoperability, although specific compliance details would need further verification.
- **Effectiveness:** The proposed framework is highly effective in conceptualising the integration of Smart Education systems within Smart Cities, promising to significantly improve educational outcomes and operational efficiencies.

This research systematically addresses the topic of Smart Education Recommendation Framework with Dashboard by:

- **Integration with ISO/IEC Standards:** The thesis highlights the importance of aligning Smart Education initiatives with ISO/IEC Smart City Framework standards to ensure interoperability, data security, and privacy. The reviewed literature supports this alignment by examining frameworks and methodologies that adhere to these standards.
- **Big Data Analytics:** Embedding the role of big data analytics, the thesis proposes a framework that uses data-driven insights to improve operational efficiency and personalise learning experiences. Reviews in the literature reinforce this by showcasing various models and case studies in which big data significantly improve educational processes.
- **Operational Efficiency:** The proposed framework aims to optimise resource allocation, streamline administrative processes, and improve decision making within educational institutions. Reviews of the literature validate these objectives by providing evidence of successful implementations of similar frameworks in different contexts.
- **Technological Integration:** By integrating advanced technologies such as IoT, AI, and machine learning, the framework supports the development of smart educational environments that are adaptive and responsive to the needs of students and educators. Reviews in the literature offer information on the practical challenges and benefits of such integrations.
- **Inclusivity and Accessibility:** The thesis underscores the importance of creating inclusive and accessible educational environments, aligned with the principles of Smart Cities within the UN Sustainable Development Goals UN-SDG4. The reviewed literature highlights strategies and technologies that promote inclusivity, ensuring that all students have equitable access to educational opportunities.

2.36 SERFD Rationale For Support to Smart City

The evolution of educational paradigms in the context of rapidly advancing technology and urbanisation requires a robust and adaptable framework to address the dynamic needs of modern learning environments. The "Smart Education Recommendation Framework with Dashboard" is proposed to bridge the gap between traditional educational systems and the future-orientated demands of smart cities. This section outlines the rationale for developing this framework, highlighting the critical factors driving its necessity and potential impact.

Addressing Educational Inefficiencies

Traditional educational systems often struggle with inefficiencies in resource allocation, personalised learning, and real-time performance tracking. These inefficiencies can lead to suboptimal educational outcomes, increased administrative burdens, and disparities in educational access and quality. The Smart Education Recommendation Framework aims to harness the power of big data analytics and advanced technologies to streamline these processes. By integrating real-time data through interactive dashboards, educators and administrators can make informed decisions, optimise resource use, and tailor educational experiences to meet individual student needs.

Enhancing Personalisation and Inclusivity

One of the primary goals of smart education is to create a personalised and inclusive learning environment that caters to diverse student needs. The proposed framework leverages artificial intelligence (AI) and machine learning (ML) algorithms to analyse student data and recommend personalised learning paths. This approach not only improves student engagement and performance, but also ensures that all learners, regardless of their background or abilities, have access to quality education tailored to their unique requirements. The integration of dashboards facilitates the continuous monitoring and adjustment of these personalised learning plans, promoting inclusivity and equity in education.

Aligning with ISO/IEC Standards

The alignment of smart education initiatives with ISO/IEC standards is crucial to ensuring data security, privacy, and interoperability. These standards provide a comprehensive framework for managing and protecting educational data, fostering trust between stakeholders, and facilitating the seamless integration of various educational technologies. The Smart Education Recommendation Framework is designed to comply with these international standards, ensuring that educational institutions can adopt and integrate the framework with confidence. This alignment also promotes the standardisation of smart education practices, enabling scalable and replicable solutions across different regions and contexts.

Leveraging Big Data for Operational Efficiency

Big data analytics play a pivotal role in transforming educational practices and improving operational efficiency. The proposed framework uses big data to gain insight into student performance, identify trends, and predict future educational needs. By integrating these insights into an interactive dashboard, educational institutions can optimise their operations, reduce administrative overhead, and allocate resources more effectively. This data-driven approach not only enhances the overall efficiency of educational systems but also supports strategic planning and policy-making at the institutional and government levels.

Supporting Smart City Development

As cities evolve into smart cities, the integration of smart education becomes increasingly important. Smart cities rely on interconnected systems and technologies to improve the quality of life of their inhabitants. The Smart Education Recommendation Framework supports this vision by providing a structured approach to integrating educational technologies within the broader smart city infrastructure. The use of dashboards enables continuous interaction and feedback between educational institutions and other smart city systems, fostering a cohesive and synergistic urban environment.

Future-Proofing Education Systems

The rapid pace of technological advancement requires educational systems to be adaptable and future-proof. The Smart Education Recommendation Framework with Dashboard is designed to be flexible and scalable, accommodating emerging technologies and evolving educational practices. By adopting this framework, educational institutions can stay ahead of technological trends, ensuring that their systems remain relevant and effective in the long term.

Finally, the development of a Smart Education Recommendation Framework with Dashboard is essential to address the current challenges and opportunities in education. Using big data analytics, personalisation, and alignment with ISO/IEC standards, this framework promises to revolutionise educational practices, improve operational efficiency, and support the development of smart cities. The integration of dashboards further strengthens the framework's capability to provide real-time insights and facilitate informed decision-making, making it an indispensable tool for modern educational institutions. Furthermore, this thesis not only provides a robust framework for Smart Education within Smart Cities but also aligns with international standards, leveraging big data analytics and advanced technologies to drive educational innovation and operational efficiency. Future research should focus on the practical implementation of these frameworks, addressing potential challenges and further validating the alignment with ISO/IEC standards. The effectiveness of the Smart Education Framework in transforming the educational landscape is multifold, as it integrates cutting-edge technological advances with pedagogical methodologies. This integration promises a host of benefits that are pivotal to the advancement of education in the context of Smart Cities. The Smart Education Framework advocates for a paradigm shift in educational methodologies, emphasising personalised learning experiences, improved academic outcomes, and efficient resource use with are internationally recognised through ISO/IEC Smart City 30145 standard series. It also underscores the importance of streamlined administrative processes, which collectively contribute to the sustainable development of smart cities. These benefits are succinctly summarised in the hypothesis framework of Operational Efficiency Volume and Variety of Data (OE2V), which builds on and extends the work of prominent scholars in the field (Quvvatov 2024; Ahmadi 2024; Luo et al. 2024; Hasan et al. 2024).

Big Data Integration

The deployment of Big Data Analytics within educational institutions is a game changer. It streamlines administrative and academic operations, leading to optimisation of resources and improved learning experiences for students (Gasevic, Dawson, and Siemens 2015). The granular insights offered by analytics enable institutions to make informed decisions that respond to evolving educational needs and trends.

AI Integration

The thrust of the research in smart education is directed toward the examination and adoption of foundational principles and best practices crucial to the design of an effective framework. This includes the development of adaptive learning systems that respond to the educational needs of individual learners and the promotion of data-driven decision-making processes that underpin educational strategies (Alario-Hoyos et al. 2019). Such systems ensure that the learning environment is flexible and tailored, contributing to a personalised education trajectory for every student.

Example of Smart Education Framework

Central to this research is the rigorous identification and evaluation of various educational frameworks. The Learning Analytics Framework, for example, is instrumental in providing real-time insight into student performance, allowing educators to tailor the instructional design effectively. Similarly, the adaptive learning framework facilitates the customisation of the learning experience to suit individual student profiles, ensuring that the educational content is relevant and engaging (Larusson and B. White 2014). These frameworks are not just theoretical constructs but serve as practical tools to enhance the educational journey of learners.
Research posits that the Smart Education Framework will act as a linchpin in the effort to enhance operational efficiency within Smart Cities. It will offer an empirical basis for understanding the role of Smart Education in fostering sustainable development and equipping learners with the skills necessary to thrive in a digitised world. By providing a holistic view of the benefits and implementation strategies of Smart Education, this framework serves as a roadmap for educational institutions aiming to transition to the era of smart learning environments (Tabuenca et al. 2024), (Dobrosotskiy et al. 2019; Y. Sun and W. Zhao 2024).
The strategic advantage of the Smart Education Framework is a heavily contested debated topic, which lies in its potential to revolutionise education by bridging the gap between traditional educational practices and the demands of a modern, interconnected world. As such, it is a catalyst for creating an education system that is not only efficient and effective, but also equitable and expansive, expanding its benefits beyond the classroom to the broader social context (Kaczorowski et al. 2023; Sriwahyuni and Khermarinah 2024; A. Abulibdeh, Zaidan, and R. Abulibdeh 2024; Abella et al. 2024; A. Singh 2022; Makinde, Ajani, and Abdulrahman n.d.; Beynaghi et al. 2016; Reimers 2024; Shishakly et al. 2024; Indrawati and Kuncoro 2021).

Global Contribution to Knowledge

Addressing the multifaceted challenges of integrating Smart Education into the urban fabric of smart cities, this research embarks on a journey to bridge the knowledge gaps currently prevalent in respected academic circles. The core of this investigation lies in meticulously crafting a framework that not only underscores the vital importance of advanced technologies and data-driven methodologies but also illuminates the path for their effective application within the educational sector with the Smart Education Framework. This endeavour is poised to contribute significantly to the scholarly discourse by providing a nuanced understanding of how smart cities can harness the potential of Information and Communication Technologies (ICTs) to revolutionise the landscape of education.
The essence of this thesis is encapsulated in the development of a new Smart Education Framework, designed to empower smart city developers and educational policymakers with the tools and insights necessary for the strategic implementation of ICT strategies. This framework is intended to act as a beacon for smart cities, guiding them towards the realisation of a more intelligent, efficient, and inclusive educational ecosystem. Taking advantage of the pivotal components of volume and variety of Big Data, colloquially known as 2Vs, this research aims to unveil a hypothesis framework of Operational Efficiency Volume and Variety of Data (OE2Vs). This framework draws inspiration from and seeks to expand on the integrated approach proposed by Chourabi et al. (Hafedh et al. 2012), integrating it with the transformative potential of Big Data analytics to improve operational efficiency within Smart Education.
Furthermore, this thesis meticulously examines the applications of Big Data technologies in various domains, as evidenced by the work of Sotirios Paroutis (Paroutis, Bennett, and Heracleous 2014), Fan et al. (Fan and F. Xiao 2017), who highlighted the revelatory power of Big Data mining to identify design flaws in educational infrastructure, and Capozzoli et al. (Alfonso et al. 2018), Viktorelius (V. Martin and Monica 2019) and Miller et al. (Miller and Meggers 2017), who demonstrated the efficacy of Big Data in improving

operational efficiency in building management and energy consumption. Despite advances in these areas, there is a conspicuous gap in the application of these technologies specifically within the realm of Smart Education, an oversight that this research ambitiously aims to rectify.
By synthesising the principles of Big Data with the operational needs of Smart Education, this thesis sets forth a comprehensive framework that not only addresses the current shortcomings, but also lays the groundwork for future innovations. It heralds a new era of Smart Education, where the strategic application of Big Data technologies through the lens of the OE2V framework enables a more nuanced, efficient, and responsive educational environment. Therefore, this research stands as a testament to the transformative power of integrating Big Data analytics into Smart Education, offering a blueprint to improve operational efficiency and foster sustainable development within smart cities. It is suitable for an era where education stands as a beacon of progress, and the Smart Education Framework emerges as a pivotal force, driving the operational efficiency of Smart Cities to new zeniths with its contribution to the global repository of knowledge by elucidating the multifaceted benefits of integrating advanced technologies and data driven methodologies within the educational sector as explained below.

- **Data Orientated Models and Algorithms:** At the heart of this contribution is the development of innovative models and algorithms that harness the power of Big Data Analytics. These advances are crucial for optimisation of resource use and improving administrative processes within Smart Education. By leveraging the inherent capabilities of big data, such as predictive analytics and trend analysis, educational institutions can anticipate needs, anticipate challenges, and allocate resources with unprecedented precision (Surendran et al. 2024; Y. Xiao and L. Yang 2021; Hamzah 2020; W. Zhang and Liehui Jiang 2018).
- **Examination of Smart Education Models:** The thesis undertakes a rigorous examination of existing Smart Education models, scrutinising their alignment with global standards and best practices. Through this critical lens, research identifies gaps and opportunities for innovation, setting the stage for international collaboration and the sharing of best practices. This examination also extends to the evaluation criteria used by smart cities, advancing a standard by which the efficacy of smart education initiatives can be measured and compared (Shishakly et al. 2024; Hamzah 2020; Sharonova and Avdeeva 2024).
- **Emerging Technologies in Smart Education:** The research delves into the role of emerging technologies such as Artificial Intelligence, Machine Learning, and the Internet of Things in the enhancement of Big Data Analytics within Smart Education. The synthesis of these technologies offers a transformative approach to education, enabling personalised learning paths, real-time performance tracking, and interactive learning environments that respond to the unique needs of each student (Ciolacu and Svasta 2021; Goel et al. 2024; Sharonova and Avdeeva 2024; Čampelj and Jereb 2023).

This thesis stands as an example of innovation in educational strategies, highlighting how the 2Vs an element of Big Data can enhance the smartness of Smart Education. Drawing on the OE2V framework, which is rooted in the integrated framework of (Hafedh et al. 2012), and extending methodologies similar to those of (Paroutis, Bennett, and Heracleous 2014), (Fan and F. Xiao 2017), (Alfonso et al. 2018), (V. Martin and Monica 2019), (Miller and Meggers 2017), and (Fan, F. Xiao, et al. 2018), the research transcends their individual contributions by providing specific insights to the Smart Education Framework through an international point of view by extension to the ISO / IEC Smart City Framework.
This thesis propels Smart Education to the forefront of global discourse, demonstrating the transformative potential of Big Data in crafting educational strategies that are not only efficient and effective, but also equitable and forward thinking. It is a testament to the synergistic integration of technology and pedagogy, promising a brighter future for learners and educators in the dynamic landscape of Smart Cities.

Collation of Operational Efficiency and Smart Education

In the evolving landscape of urban education, the symbiosis between operational efficiency and Smart Education emerges as a critical focal point for research and development. With extensive research in education-orientated technology, this thesis seeks to pioneer a comprehensive framework that elucidates the pivotal role of Big Data analytics in enhancing the educational ecosystem within smart cities. By adopting the hypothesis of Operational Efficiency Volume and Variety of Data (OE2Vs), this research aims to illuminate the multifarious benefits that Big Data can bring to Smart Education, thus contributing significantly to the discourse on urban educational advancement.

1. **Establishing Evaluation Criteria for Smart Cities:** The first step involves developing robust criteria to evaluate the integration and effectiveness of Smart Education within smart cities. These criteria will not only assess the current state of Smart Education, but will also provide benchmarks for future improvements. Taking advantage of the OE2V framework, this research will offer a nuanced understanding of how operational efficiency can be measured and optimised in the context of Smart Education (Hafedh et al. 2012).
2. **Applying Big Data in Smart Education:** Central to this research is the exploration of how Big Data through its core components of Volume and Variety can revolutionise Smart Education. The application of Big Data Analytics Dashboard promises to uncover insights that were previously obscured, enabling educational institutions to tailor learning experiences, optimise resource allocation, and improve student engagement (Williamson 2017; N.-S. Chen et al. 2020; J. Wang 2023).
3. **Demonstrating Effectiveness through Case Studies:** A series of case studies were presented to showcase the tangible benefits of integrating operational efficiency practices in Smart Cities, specifically through the lens of Smart Education. These case studies highlighted how cities around the world have successfully used Big Data to address educational challenges, improve administrative processes, and foster an environment conducive to learning and innovation (Al Yakin, Khang, Mukit, et al. 2023; Burden et al. 2023; Demartini et al. 2024; Lahiassi et al. 2024).
4. **Synthesizing Insights for Smart Education Development:** The culmination of this research will see the synthesis of insights drawn from the evaluation dashboard, Big Data analysis, and case studies. This synthesis will not only validate the OE2V hypothesis, but will also pave the way for the development of a comprehensive Smart Education Framework that is scalable and adaptable to the unique needs of different urban contexts (Begmamat et al. 2023; Kuklin, Bratukhina, and Gorokhovitskaya 2021; Pavani et al. 2022; Naiki 2024; Jnr et al. 2023).

This thesis posits that the strategic collation of operational efficiency and Smart Education, underpinned by the sophisticated analysis of Big Data, holds the key to unlocking the full potential of educational systems within smart cities. It aspires to create a Smart Education blueprint that is responsive to the international dynamics of urban development, driving the agenda for a more informed, efficient, and equitable educational future (Riekki and Mämmelä 2021; Shishakly et al. 2024; Hamzah 2020), (Hakimi et al. 2024; Alyasiri et al. 2024; Saleh et al. 2024).

Extending the Smart Education Framework of Smart City

The convergence of the Smart Education and Smart City frameworks presents an unprecedented opportunity to redefine urban education. This research delves into the intricate process of extending the Smart Education framework from a Smart City perspective, employing a bottom-up approach that emphasises the integration of advanced technologies and data-driven methods. By investigating key domains such as Citizen Services and Smart Facilities, this study aims to uncover the transformative potential of Big Data analytics to revolutionise Smart Education within the context of Smart Cities.

- **Extending Smart Education Framework**: This project explores the foundational elements required to build an effective Smart Education Framework grounded in the principles of Smart City development. It involves a detailed analysis of how the Smart City infrastructure can support and improve educational services, providing a seamless and integrated learning experience for citizens. This is done by the introduction of smart education recommendation framework.
- **Citizen Services**: Research meticulously analyses key categories that are crucial to smart education, including education, transportation, electronic government, employment, data, cloud, resources, stakeholders, knowledge base, and medical services. Each category is examined through the lens of Big Data Analytics, aiming to identify how these services can be optimised to support educational objectives and improve accessibility for all stakeholders.
- **Smart Facility**: Special attention is given to the role of Network infrastructure and City modelling

in facilitating a conducive environment for Smart Education. The study evaluates how cutting-edge technologies and data management practices can be used to create smart facilities that are efficient and conducive to learning.

To elucidate the application of Big Data Analytics to improve smart education, research will incorporate case studies and attribute indicators, as demonstrated in Table 2.11. These indicators serve as a metric to evaluate the effectiveness of digital e-Government management in the context of smart education, providing insight into how government interactions with citizens, businesses, and other agencies can be streamlined to support educational initiatives.

Table 2.11: Rationale: Indicators Contributing to the Volume and Variety of Big Data in Smart Education

Begin: Evaluation Indicators Related to the E-Government Service in the Context of Smart Education		
Indicator Name	Description	Measurement Method
One-Stop Government Services	Assessing the convenience of accessing multiple government services at a single location, crucial for streamlined citizen interaction.	(Number of one-stop government services / Total number of government services) * 100 (Trivedi 2016)
Single Sign-On Services	Evaluating the ease of online access to government services via a unified portal, enhancing user experience.	(Number of services accessible by single sign-in / Total number of government services) * 100 (Trivedi 2016)
Electronic/Digital Signature Utilisation	Measuring the adoption of digital solutions in government operations, a key factor in digital transformation.	(Number of services using digital signatures / Total number of government services) * 100 (Trivedi 2016)
Citizen Service Request Efficiency	Determining the government's responsiveness to citizen needs, reflecting public service quality.	(Number of correctly processed citizen requests / Total number of citizen requests) * 100 (Trivedi 2016)
End: Evaluation Indicators Related to the E-Government Service		

Summary and Research Motivation

In summary, this chapter has examined three interdependent concepts at the core of this research: Smart Cities, Smart Education, and Big Data, with a focus on their integration within the framework of Operational Efficiency for Smart City (OE4SC). The chapter emphasised the importance of sustainable smart cities in enabling the development of smart education ecosystems, highlighting the need for operational efficiency to ensure equitable resource allocation and enhanced educational outcomes.

The discussion underscored the role of Big Data Analytics and Internet of Things (IoT) workflows in visualising and measuring operational efficiency. These technologies enable the collection, analysis, and interpretation of data to inform strategic decision making. The chapter introduced the Smart Education Recommendation Framework with Dashboard (SERFD) as a novel contribution to the field, designed to address operational inefficiencies in smart education systems through a multi-criteria decision-making dashboard.

A key challenge identified is the lack of comprehensive international standardisation in smart education, particularly with regard to the integration of Big Data and IoT technologies into operational workflows. Existing frameworks often fail to align with global standards such as ISO/IEC 30145, which emphasise the

importance of interoperability, adaptability, and data-driven insights. This research addresses these gaps by incorporating ISO/IEC standards into the design of SERFD, ensuring its applicability in diverse smart city contexts.
To illustrate these concepts, the chapter included an analysis of sample data, demonstrating how SERFD leverages operational efficiency metrics to optimise resources and budgets. The operational efficiency model proposed in this research provides a structured approach to developing matrices that align with functional requirements while addressing efficiency constraints. Information dashboards were highlighted as critical tools for visualisation, enabling stakeholders to monitor performance, detect inefficiencies, and implement targeted interventions.

****Research Motivation****

This research is motivated by the need to bridge the gaps in the implementation of smart education systems, particularly in terms of operational efficiency and international standardisation. Key contributions and guiding references include:

- ** Guided references: ** The literature on sustainable urban development, such as Albino et al.'s work on smart city dimensions (Albino, Berardi, and Dangelico 2015) and Bibri and Krogstie's interdisciplinary review of smart sustainable cities (Bibri and Krogstie 2017), provided foundational insights into integrating sustainability and technology into smart city ecosystems. Furthermore, the ISO / IEC 30145 standards (ISO 2014) guided the alignment of SERFD with international best practices.
- **Addressing the Lack of Standardisation:** Existing frameworks often lack standardised methodologies for incorporating Big Data Analytics and IoT workflows into smart education systems. This research fills this gap by designing SERFD to integrate multi-criteria decision-making dashboards, aligned with international standards, to enhance operational efficiency. (SDG4 2017; ESD 2020; OSI 2009)
- ** Operational efficiency focus: ** The SERFD framework provides a quantitative approach to identify inefficiencies in resource allocation and service delivery. Using operational efficiency metrics, SERFD equips stakeholders with actionable insights to improve decision making and achieve sustainable educational outcomes. (Christensen, Gillingham, and Nordhaus 2018)

By synthesising insights from these studies and addressing the gaps in international standardisation, this research contributes to a robust framework for smart education ecosystems. The methodologies and findings presented in this chapter provide a foundation for advancing data-driven approaches to operational efficiency, positioning SERFD as a critical tool to achieve the broader objectives of smart cities and education.

Chapter 3

Methodology

3.0 Chapter Introduction

The evolution of smart cities has led to a marked increase in the student and teacher populations in urban areas, thereby enhancing educational outcomes. Despite these advancements, the absence of a comprehensive framework for applying big data analytics in smart education has hindered the progress of innovative educational practices (Tore and Jon 2018). This research aims to address this gap by developing and applying data, volume, and variety in the Education Recommendation Framework. The primary objective of this research is to identify, analyse, and optimise key performance indicators relevant to the Smart Education Framework, focussing on educational outcomes and operational efficiency in urban environments.

The advent of big data has created an unprecedented ability to monitor, analyse, and improve the operational efficiency of smart education systems. This chapter delves into the novel realm of data sources and their presentation for smart city operators, with an innovative emphasis on smart education, a field that remains underexplored with Big Data (Jin Gon Shon 2002). It illustrates the transformative impact of applying the two key components of Big Data, namely volume and variety, in educational settings, particularly during prolonged disruptions such as pandemics. This approach demonstrates how smart cities can become more resilient and adaptive in the face of challenges, ensuring that education continues to thrive even under adverse conditions.

It also proposes that the implementation of operational efficiency with volume and variety (OE2V) dashboard analytics is indispensable for smart cities to foster an informed, collaborative, and efficiently operating smart education environment. This environment is facilitated by an agile deployment of IoT in all aspects of the city. The methodology presented in this chapter encompasses traditional data management practices and modern analytical techniques. By ensuring a disciplined and comprehensive approach to data from acquisition to analysis, this study aims to make significant contributions to the field, providing practical insight and recommendations for advancing smart instructional practices. Furthermore, it extends the ISO/IEC 30145 Smart City Framework series (**iso30145**). It employs a rigorous methodology that involves the formulation of a hypothesis, experimental design, data analysis, and the development of a framework and dashboard. This approach ensures adaptability and responsiveness to emerging findings and evolving educational needs while addressing the complexities and challenges inherent in smart city educational systems. The methodology promises substantial improvements in operational efficiency and educational outcomes within smart cities, aligning with the broader international standard objectives of sustainable urban development and improving the quality of life in smart cities.

References

- **Hoel et al. (2018):** Standards and challenges in integrating big data analytics into smart education frameworks (Hoel and Mason 2018).
- **Shon and Standardisation (2002):** The need for standardised approaches to leveraging data in educational systems (Jin G Shon 2002).
- **ISO/IEC 30145:** The foundational Smart City Framework extended by this research (ISO 2014; J. M. White 2019).

3.1 Methodologies

The methodological framework of this thesis on the Smart Education Recommendation Framework with Dashboard within Smart Cities focusses on enhancing operational efficiency and educational outcomes through the meticulous design of visualisation dashboards. This research acknowledges the complexity of integrating technology into education in the urban context, which requires a multidisciplinary approach. By adopting both quantitative and qualitative research paradigms, the framework ensures a robust and comprehensive analysis that captures the multifaceted nature of smart education.

Development Design and Innovation in the Smart Education Recommendation Framework

The Smart Education Recommendation Framework developed in this research is tailored specifically for smart education, featuring innovative elements such as:

- **Personalisation Algorithms:** Utilising AI and machine learning to tailor educational experiences to individual student needs.
- **Near-Real-Time Data Integration:** Incorporating near-real-time data from various sources to enhance the adaptability and responsiveness of the framework.

Incorporation of Dataset Perspectives

The framework was designed with dataset and case studies from various top smart cities, ensuring real-world assumptions to capture:

- **Teachers:** Tools for classroom management and student engagement.
- **Students:** Personalised learning paths and resources.
- **Administrators:** Data-driven decision-making tools.
- **Tech Developers:** Guidelines for integrating new technologies into the educational ecosystem.

Integration with Smart City ISO / IEC standards

This smart education recommendation framework is integrated into the broader Smart City ISO/IEC standards by:

- **Aligning with Existing Modules:** Ensuring compatibility with current ISO/IEC Smart City Framework series components such as infrastructure, data management, and citizen engagement.
- **Enhancing Interoperability:** Providing guidelines for seamless integration with other Smart City systems and applications.

Method Justifications - Quantitative and Qualitative Approaches

The integration of quantitative and qualitative methodologies offers a balanced and holistic perspective, essential for developing an effective Smart Education Recommendation Framework. Quantitative methods, including statistical analysis and hypothesis testing, provide objective and measurable insights into patterns and trends within the data (Hafedh et al. 2012). These methods enable the identification of significant relationships and the prediction of future educational outcomes based on historical data. For example, datasets from sources such as the World Bank, UK Data Science, UNStat, EU Data Store, and OpenData.com are analysed to derive probability distributions and infer patterns that inform strategic decision making (Christensen, Gillingham, and Nordhaus 2018; J. Martin and Richard 2014; Rawad, Mohammed, and Zaheer 2015).

Qualitative methods, on the other hand, involve a critical review of the secondary literature to understand the conceptual foundations and contextual nuances of smart education (Abdel-Basset et al. 2019; Hammad, Odeh, and Khan 2013; Kitchin 2014b). These methods facilitate a detailed exploration of the experiences, attitudes, and perceptions of various stakeholders, including students, educators, developers, and policy makers. By conducting case study reviews through literature and thematic analysis, qualitative research enriches the understanding of the social and cultural dimensions of smart education, providing insights that quantitative data alone cannot offer (Tore and Jon 2018; Jin Gon Shon 2002).

Advantages of the Dual Approach

Combining these methodologies takes advantage of the strengths of both approaches, addressing their individual limitations and providing a more comprehensive understanding of smart education ecosystems.

Quantitative data offer the precision and generalisability necessary to identify broad trends and validate hypotheses, while qualitative data provide the depth and context needed to interpret these trends meaningfully (Shyam R. et al. 2015).

This dual approach is particularly effective in the context of developing the Smart Education Recommendation Framework with Dashboard. Quantitative analysis of large datasets enables the creation of predictive, descriptive, and prescriptive analytics that inform the design of the dashboard, ensuring it is data-driven and evidence-based. Qualitative insights ensure that the dashboard is user-friendly, relevant, and responsive to the needs of educators and learners (Zhu, M.-H. Yu, and Riezebos 2016).

- **User-Centric Design:** Prioritise the creation of a user-friendly interface to facilitate easy navigation and interpretation of data. Customise the dashboard to meet the various needs and technical expertise of end users, ensuring accessibility and utility (Demir 2021b; Shahat Osman and Elragal 2021).
- **Customisable Visualisation Tools:** Integrate flexible visualisation tools that can be adapted to represent various types and formats of data, allowing users to customise their data analysis experience to suit individual preferences and requirements (Matin, Oliullah, and Polash 2018; Prakash et al. 2021).

Why Other Approaches Were Not Used

Although there are numerous research methodologies, this study deliberately chose not to employ certain approaches due to their limitations in addressing the specific requirements of smart education within the context of smart cities.

- **Ethnographic Research:** Ethnographic research, which involves immersive observation and detailed qualitative analysis of cultural and social interactions, was not used due to its time-intensive nature and the difficulty in generalizing findings across diverse educational settings (Hammersley 2013). This approach, while valuable for deep cultural insights, does not align well with the need for broad, data-driven analysis required in this study.
- **Experimental Research:** Experimental research methods, which involve controlled experiments to determine causal relationships, were also not utilised. The primary limitation of this approach is the challenge in creating controlled environments within the complex and dynamic educational ecosystems of smart cities (Campbell and Stanley 2015). Furthermore, experimental methods may not effectively capture the real-world interactions and operational efficiencies that this study aims to understand.
- **Case Study Research:** While case studies provide detailed and contextual analyses of specific instances, they were not the main focus of this research due to their limited scope in terms of generalisability (Yin 2009). The goal of this thesis is to develop a comprehensive framework applicable across various contexts, which requires broader data insights than those typically derived from individual case studies.

3.2 Potential Biases in Data Collection and Mitigation

In the realm of data collection for the Smart Education Recommendation Framework, several potential biases could arise, affecting the validity and generalisability of the findings. These biases include:

- **Sampling Bias:** The selection of cities or data points may not be representative of the entire population of Smart Cities or educational institutions. This could occur if their dataset is skewed towards larger, more technologically advanced cities or institutions, neglecting the experiences of smaller or less developed ones.
- **Self-Selection Bias:** Selected cities may have different characteristics or opinions than those who are not, leading to a biased sample. For example, cities who are more enthusiastic about technology may be more likely to provide open data, skewing the results towards a more positive view of technology integration.
- **Social Desirability Bias:** Cities with large budget for development, they believe is socially acceptable or desirable but lack open data, rather than providing their honest opinions. This could lead to an overestimation of the positive impacts of the framework and an underestimation of potential challenges or negative consequences.

- **Interviewer Bias:** The availability of data or the way data are collected may demeanour could influence cities representation' responses. For example, if the city is perceived as being biased towards technology, data availability may affect to provide positive feedback.
- **Confirmation Bias:** Researchers may unintentionally interpret data in a way that confirms their pre-existing beliefs or hypotheses, overlooking contradictory evidence. This could lead to an overemphasis on the positive aspects of the framework and a downplaying of potential limitations or negative impacts.

To mitigate these biases, several strategies can be employed.

- **Random Sampling:** Employing random sampling techniques to ensure that the sample is representative of the population of interest. This could involve stratified sampling to ensure representation from different types of cities and institutions.
- **Anonymity and Confidentiality:** Use of AI for the anonymity and confidentiality of some aspect of dataset responses to encourage honest and open feedback.
- **Structured Datasets and Case Studies:** Using structured datasets and case studies with standardised smart cities to minimise result bias and ensure consistency in data collection.
- **Triangulation:** Using multiple data sources and collection methods (e.g., International sources including UK Data Science) to corroborate findings and reduce the impact of any single source of bias.
- **Reflexivity:** Researchers should be aware of their own biases and actively seek to challenge their assumptions throughout the research process. This could involve seeking feedback from colleagues or external experts to ensure objectivity.

By acknowledging and addressing these potential biases, research can enhance the validity and reliability of its findings, contributing to a more accurate and nuanced understanding of the impact and effectiveness of the Smart Education Recommendation Framework.

Using Dashboard for Integration of Advanced Analytics

Advanced analytics methods such as predictive, descriptive, and prescriptive analytics are applied to processed data, providing a multidimensional view of operational efficiency.

- **Predictive Analytics:** Anticipating future trends and outcomes in smart education based on historical data patterns is valuable. Yet, the accuracy of predictive models is contingent on the quality and relevance of historical data (Waller and Fawcett 2013). Additionally, these models often require sophisticated algorithms and continuous updating to maintain their validity, which can be resource-intensive.
- **Descriptive Analytics:** Offering a detailed overview of current educational operations and performance is fundamental. However, descriptive analytics is limited by its retrospective nature, providing insights into what has already occurred without necessarily explaining the underlying causes or predicting future trends (Davenport and Harris 2014). This method can also lead to information overload if not effectively managed.
- **Prescriptive Analytics:** Recommending actions and strategies to improve educational outcomes and operational efficiency holds significant promise. Nonetheless, prescriptive analytics often involves complex decision-making algorithms that may not be fully understood or trusted by end-users (Bertsimas and Kallus 2020). There is also the risk of over-reliance on algorithmic recommendations, which may overlook contextual factors and human judgment.

3.2.1 SERFD Alignment with ISO/IEC Standards

Furthermore, aligning the research with the ISO/IEC 30145 series underscores the commitment to adhere to international standards for Smart City Frameworks. This alignment ensures that research is grounded in recognised benchmarks for technological integration and operational efficiency in urban environments. It also improves the credibility and applicability of the findings, providing a standardised approach to integrate advanced analytics and visualisation tools into smart education systems (Evgenevic 2021).

In conclusion, the use of quantitative and qualitative methodologies in this research ensures a robust, comprehensive, and contextually rich analysis. This approach not only facilitates a deeper understanding of the roles and impacts of big data analytics within smart educational ecosystems, but also ensures that the developed framework is scientifically rigorous and practically relevant. The Smart Education Recommendation Framework with Dashboard, developed through this multidiscipline methodology, promises to significantly enhance educational strategies and outcomes in smart cities, aligning with the broader objectives of sustainable urban development and improved quality of life.

3.3 Quantitative and Qualitative Specific Contribution to SERFD

3.3.1 Quantitative Specific Approach:

At the heart of quantitative analysis is the use of the first two defining properties of big data: Volume and variety. These dimensions are crucial in quantifying the vast amounts of data generated within smart cities and assessing the diversity of data types, from structured numeric data to unstructured textual content. An innovative Big Data Analytics dashboard serves as the cornerstone of this analysis, providing a dynamic platform for the real-time monitoring and measurement of dashboard data (Malik et al. 2018). This dashboard facilitates the quantitative measurement of operational efficiency within smart educational settings, allowing the aggregation, quality visualisation, and analysis of data across multiple vectors.

SERF Recommendations for a Quantitative Approach

This section outlines strategic recommendations for the design, development, and implementation of a Big Data Analytics dashboard designed to improve operational efficiency in smart educational settings.

Dashboard Design and Development

- **User-Centric Design:** Prioritise the creation of a user-friendly interface to facilitate easy navigation and interpretation of data. Customise the dashboard to meet the various needs and technical expertise of end users, ensuring accessibility and utility (Demir 2021b; Shahat Osman and Elragal 2021).
- **Customizable Visualisation Tools:** Integrate flexible visualisation tools that can be adapted to represent various types and formats of data, allowing users to customise their data analysis experience to suit individual preferences and requirements (Matin, Oliullah, and Polash 2018; Prakash et al. 2021).

Data Integration and Management

SERF Web Scraping for Smart Education Recommendation Framework

In order to gain comprehensive insights into existing frameworks and methodologies related to the Smart Education Recommendation Framework (SERF), an extensive web scraping process was conducted. This process targeted scholarly articles, industry reports, and relevant online resources that provide valuable information on smart education systems and recommendation frameworks. The Table A.3, titled "SERF Web Scraping for Smart Education Recommendation Framework", summarises the key findings from this web scraping exercise, presenting the title, link, and a brief snippet of each relevant resource, the research also noted that there is no smart education recommendation framework that was aligned with the ISO / IEC Smart City Framework. Similarly, SERF is lacking on the source outline in Table 2.4.
This is followed up with these points:

- **Robust Data Collection Framework:** Establish a comprehensive data collection framework that effectively manages the volume and variety of data, including the integration of APIs for real-time data feeds and mechanisms for the import of historical data (N.-S. Chen et al. 2020).
- **Effective Data Storage Solutions:** Use scalable and secure storage solutions to support the expanding volume of data, with a preference for cloud-based services for their adaptability and scalability (Abdul-Hamid 2017).

Analytical Tools and Techniques

- **Advanced Analytical Functions:** Embed sophisticated analytics capabilities, such as predictive analytics, machine learning algorithms, and statistical tools, to elucidate trends, patterns, and insights within the data (Uskov et al. 2018).
- **Real-Time Data Processing:** Implement capabilities for real-time data processing, facilitating immediate analysis and visualisation that are essential to quickly address problems and capitalise on opportunities in smart educational environments (Chawla, Tomar, and Gambhir 2021).

Collaboration and Sharing

- **Data Sharing Mechanisms:** Incorporate functionalities that promote seamless sharing of insights and data visualisations between stakeholders through export options, collaborative workspaces, or platform integration (Frankl and Bitter 2013).
- **Feedback Loops:** Develop feedback collection mechanisms to continuously refine the functionality of the dashboard and the user experience, ensuring it remains a valuable asset for stakeholders (J.-K. Kim, Sohn, and Lee 2012).

Security and Privacy

- **Data Security Measures:** Guarantee adherence to the highest data security standards, including encryption and access controls, supplemented by regular security audits to protect data integrity (Barlybayev, Abdymanapov, and Akimbekova 2018).
- **Privacy Compliance:** Ensure that data collection and analysis practices are in accordance with applicable privacy laws and ethical guidelines, especially when dealing with sensitive or personal information (Putinceva, Liubarskaia, and Ipatova 2022).

Training and Support

- **Comprehensive Training Programmes:** Offer detailed training sessions and resources to allow users to use the dashboard effectively, including interpreting visualisations and using analytical tools (Hamzah 2020).
- **Ongoing Technical Support:** Provide continuous support to address user queries or issues, ensuring the sustained value of the dashboard to its stakeholders (Adel 2024).

3.3.2 Qualitative Specific Approach for SERFD:

This section introduces the importance of a qualitative approach to complement quantitative frameworks, emphasising the exploration of subjective experiences and perceptions of stakeholders in smart educational environments. The qualitative approach focusses on a deeper contextual understanding of the collected data. Through comprehensive data set studies, this research method explores subjective experiences and perceptions of stakeholders in smart educational environments. Such a qualitative inquiry not only enriches the quantitative data, but also provides valuable insights into the effectiveness of smart education initiatives and the impact of big data analytics on teaching and learning processes. This approach underscores the importance of capturing the nuanced perspectives and experiences of people involved in smart educational settings, offering a more holistic view of the success of technological integration and areas of improvement (Shishakly et al. 2024).

- Using various qualitative data collection methods to ensure a comprehensive understanding of stakeholder experiences.
- Data are analysed through thematic analysis to identify key themes related to the effectiveness of smart education initiatives.
- Using visualisation tools to represent qualitative data, which facilitates easier interpretation and discussion.

SERF Recommendations for a Qualitative Approach

To complement the quantitative framework, this research adopts a qualitative approach that is specifically tailored to contextualise data insights from smart educational environments. The qualitative approach employed is a **multiple case study methodology**, integrating stakeholder perspectives, document analysis, and comparative analysis. This methodology provides a deeper understanding of the operational, technological, and pedagogical dynamics within smart education systems. The key components of this approach are described below.

- **Open Data Analysis and Stakeholder Perspectives:** This research extensively uses open data sets from reputable sources such as the UNESCO Institute for Statistics (UIS), the World Bank Open Data, and national government education portals. These data sets provide critical information on educational results, resource allocation, enrolment rates, and technological integration. The quantitative insights from these datasets are complemented by qualitative perspectives obtained through in-depth discussions and structured interviews with educators, students, administrators, and technologists. These interviews serve to contextualise the data, capture stakeholder experiences, and highlight the required impact of smart education initiatives (Hou, Ho, and Yau 2024).

- **Comprehensive Case Studies and Data Set Content:** A multiple case study approach is adopted to investigate instances where big data analytics have been applied in educational settings. This includes analysing the implementation, results and feedback from stakeholders in selected smart cities. Case studies draw on data sets containing detailed metrics such as student performance, teacher qualifications, and the use of digital resources. These data sets are analysed to assess the effectiveness of smart education initiatives and their impact on teaching and learning processes. This approach ensures that research captures both macro-level trends and micro-level nuances within smart education environments (Demartini et al. 2024; Pelima, Sukmana, and Rosmansyah 2024).
- **Comparative Studies and Participant Observation:** Comparative studies are conducted using the collected data sets to identify trends, challenges, and successes in different educational systems and geographic regions. This approach provides insight into the contextual factors that influence the effectiveness of smart education initiatives. In addition, participant observation is used in selected environments to capture real-time interactions and learning processes shaped by technological integration. These observations enable the research to document how students and educators engage with smart education technologies, offering granular insights into their practical application and challenges (Lahiassi et al. 2024).
- **Data Visualisation and Document Analysis:** Advanced data visualisation techniques are employed to synthesise the findings from quantitative and qualitative data. These visualisations uncover patterns and insights that are not immediately apparent in the raw data, facilitating a deeper understanding of the results. In addition to this, document analysis is performed to review existing reports, educational materials, and system logs related to smart education projects. This analysis enriches qualitative research by providing a comprehensive view of the successes, challenges and areas of improvement in the implementation of smart education technologies (Zhenyu Chen and X. Zhao 2024; Ayasrah et al. 2024).

The adopted qualitative approach aligns with the broader objectives of the Smart Education Recommendation Framework (SERF) by allowing for a holistic analysis that integrates both quantitative data and qualitative insights. The multiple case study methodology, supported by stakeholder participation, document analysis, and comparative studies, ensures that this research provides a well-rounded understanding of the factors that influence the success of smart education initiatives.

Using open data analysis and case studies, this research highlights the diverse global landscape of smart education, identifying areas of success and opportunities for improvement. The integration of qualitative methods enables the research to present actionable recommendations, aligning with the overarching goal of fostering technological integration and operational efficiency in smart education environments.

3.3.3 Smart Education Framework with Agile Development Framework

Incorporating an Agile Development Framework into the Smart Education Framework represents a strategic enhancement to the research methodology. Agile methodologies, known for their iterative and flexible nature, align perfectly with the dynamic requirements of big data analytics projects. This section outlines a step-by-step approach to effectively integrating Agile principles into the development and refinement of a Big Data Analytics dashboard, ensuring the project remains adaptable and responsive to emerging findings and evolving educational needs, along with the complexities and challenges inherent in smart city educational systems.

- **Project Initiation:** Begin with a clear definition of the project objectives and goals, focussing on the specific needs and challenges within the smart educational ecosystem. This step involves stakeholder consultations to gather initial requirements and expectations (L'Esteve 2023).
- **Stakeholder Workshops and Surveys:** Organise workshops and distribute surveys among a wide range of stakeholders, including educators, administrators, students and technology partners. These activities aim to facilitate open discussions and collect comprehensive data on user needs, expectations, and the specific challenges they face in the current educational ecosystem. Use the insights gathered to define the project's primary goals and objectives, ensuring that they are aligned with the actual needs

of the smart educational community. This collaborative approach not only enhances the relevance of the project, but also fosters stakeholder support from the outset (Vieira Nunhes et al. 2022).

- **Iterative Development Cycles:** Adopt short, iterative development cycles (sprints), allowing rapid prototyping and continuous feedback. Each sprint should aim to deliver a workable version of the dashboard, incorporating a subset of the overall features and functionalities (Haloua et al. 2024).
- **Sprint Planning and Execution:** Initiate each sprint with a planning session in which the development team, along with stakeholders, prioritises the subset of features for the next iteration. Define clear and achievable goals for each sprint, ensuring that they contribute to the overall objectives of the project. Regularly scheduled daily meetings can facilitate team communication, while end-of-sprint reviews offer the opportunity to present developed functionalities to stakeholders for feedback. This cycle of planning, execution, review, and adaptation forms the core of the agile methodology, enabling continuous improvement and alignment with user needs (Popoola et al. 2024).
- **Continuous Stakeholder Engagement:** Engage with educators, administrators, students, and technologists throughout the development process. Regular feedback sessions ensure that the dashboard evolves in alignment with user needs and preferences, facilitating a user-centric design approach (Vieira Nunhes et al. 2022).
- **Digital Feedback Platforms:** Establish a dedicated online platform where stakeholders can continuously submit feedback on the features and usability of the dashboard. This platform can include forums, surveys, and a feature request tracking system. Regularly review the feedback collected on this platform during sprint retrospectives to identify areas for improvement, align future development efforts with stakeholder needs, and prioritise tasks for subsequent sprints. This ensures that the dashboard's evolution is driven by user-centric insights and real-world applicability (Mejeh, Sarbach, and Hascher 2024).
- **Refinement and Adaptation:** Use the feedback from each development cycle to refine and adapt the dashboard. This includes adding new features, modifying existing functionality, and removing elements that do not add value to the user experience (C. Zhou et al. 2024).
- **Feature Review and Prioritisation Meetings:** Conduct regular meetings with the development team and key stakeholders after each sprint to review the feedback received. Use these discussions to decide on the necessary refinements or adaptations for the dashboard. This process should include the prioritisation of new features, modifications to existing functionalities based on user feedback, and the removal of any elements that have been identified as not adding value to the overall user experience. These meetings ensure that the dashboard continuously evolves in a direction that improves user satisfaction and project objectives (Witham et al. 2020).
- **Evaluation and Metrics:** Implement evaluation metrics to assess the effectiveness and impact of the dashboard within smart educational settings. This could include user satisfaction surveys, usage statistics, and educational outcome measures (Rainio, Teuho, and Klén 2024).
- **Integrated Analytics and Feedback Tools:** Incorporate analytics tools into the dashboard to automatically track usage statistics, such as user engagement, feature use, and session durations. Complement these quantitative metrics with qualitative feedback mechanisms, such as embedded user satisfaction surveys and direct feedback forms. Analyse these data to gauge the effectiveness of the dashboard in improving educational processes and outcomes. Regular reporting intervals can be established to review these metrics, allowing data-driven decisions in the continuous improvement process (Paulsen and Lindsay 2024).
- **Scalability and Sustainability:** Plan for the scalability and sustainability of the dashboard, ensuring that it can accommodate growing data volumes, variety, and changing educational landscapes. This may involve architectural considerations, technology stack evaluations, and long-term maintenance plans (Nogueira, Marques, and Pinto 2024).
- **Cloud-Based Infrastructure and Microservices:** Adopt a cloud-based infrastructure to ensure scalability, leveraging services that can dynamically adjust resources based on demand. Transition to a microservice architecture, allowing easier updates and maintenance and allowing the dashboard to efficiently scale with growing data volumes, variety, and user numbers. This approach facilitates

handling increased loads and the integration of new features without disrupting existing functionalities, ensuring that the dashboard remains robust and responsive over time (Rodríguez et al. 2021).

By following these steps, the research methodology not only embraces the agility and responsiveness of the Agile Development Framework, but also ensures that the Big Data Analytics dashboard remains relevant and effective in addressing the needs of smart city educational systems (Kanqi, Jun, and Xun 2023; Hamzah 2020).

3.3.4 Smart Education Framework Software Metrics for Data Collection and Measurement

The methodology integrates the use of software metrics to improve data collection and measurement strategies, following the insights of Malik et al. (Malik et al. 2018). The selection of relevant software metrics is critical to capture the multifaceted aspects of the performance, quality, and usability of the Big Data Analytics dashboard designed for smart education systems. These metrics furnish a quantitative basis to appraise the dashboard's efficiency in overseeing and analysing operational performance within smart education contexts.

Defining Key Metrics

To effectively evaluate the dashboard, we focus on several key metrics:

- **Service Data Utilisation (SDU):** Measures the extent to which educational data services are used.
- **Population to Service Allocation Ratio (PSAR):** Assesses how well services are allocated in relation to the size of the population of a smart city.

The dataset `sedata1.csv` serves as the basis for calculating and analysing key performance metrics for smart cities. This data set provides vital information on the relationship between population size and the availability of city services. It enables the evaluation of the efficiency of the allocation of services in the context of smart education systems. The data set comprises the following columns:

- **secity (Smart Cities):** represents the names of the smart cities under analysis. Each city in the data set is a case study to assess the efficiency of service.
- **popul (City Population):** Denotes the total population of each smart city, providing a baseline to measure the adequacy of the service.
- **servdata (Number of Services Provided):** Indicates the total number of services offered by city operators, reflecting the availability of educational and auxiliary services.
- **allocsrv (Number of Allocated Services):** Captures the specific services assigned to meet population demands, serving as a proxy for resource distribution.

The data in `sedata1.csv` is used to calculate two critical metrics to evaluate operational efficiency within smart cities.

- **Service Data Utilisation (SDU):** Measures the extent to which educational data services are utilised, calculated as:

  $$\text{SDU} = \frac{\text{servdata}}{\text{popul}} \times 100$$

  This metric identifies cities where services may be under-used relative to population size, providing actionable information for optimisation.
- **Population to Service Allocation Ratio (PSAR):** Assesses the adequacy of service allocation with respect to population demands, calculated as:

  $$\text{PSAR} = \frac{\text{allocsrv}}{\text{popul}}$$

  This metric highlights disparities in service distribution, allowing SERF to recommend adjustments where necessary.

The data set facilitates a comparative analysis across cities, allowing SERF to identify patterns of resource allocation and service use. The insights derived from these metrics guide the recommendation of additional services where deficits are identified, ensuring that smart education environments are both equitable and efficient.

Use Case in SERF Framework The dataset enables the SERF framework to dynamically assess and recommend service expansions. For example, if a city shows a low SDU or PSAR, the framework indicates the need for increased resource allocation. This functionality underscores the role of SERF in fostering data-driven decision making within smart education systems. The integration of `sedata1.csv` into the methodology not only demonstrates the practical application of software metrics but also reinforces the utility of Big Data in enhancing operational efficiency and educational outcomes in smart cities.

Python Script for Metrics Calculation see Appendix A To calculate these metrics, Python scripts offer a straightforward approach to processing the data set. The script in Appendix A page 251, Python functions, demonstrate how to compute the SDU and PSAR using pandas, a powerful data manipulation library.

These scripts enable the dynamic calculation of metrics from the dataset, facilitating an in-depth analysis of the dashboard's impact on operational efficiency in smart educational environments. The use of Python and pandas simplifies the data manipulation process, allowing efficient calculation of key performance indicators (Wu et al. 2024).

The adoption of software metrics in the evaluation of smart educational systems is visualised in Figure 3.1. The figure, generated from a Python script utilising the Plotly library, comprises a series of bar and pie charts that elucidate various metrics based on the dataset from open data sources.

As illustrated, the visualisation is organised into two rows: the top row features bar charts, while the bottom row consists of corresponding pie charts. The first column presents the Service Data Utilisation (SDU) per city, which shows the percentage of service data usage across different cities. Adjacent to it, the second column shows the Population-to-Service Allocation Ratio (PSAR), revealing how services are distributed relative to the population size. The third column displays the Population Distribution, providing insight into the population size for each city under study.

Behind each bar chart is a pie chart representing the same metric, which offers a comparative distribution perspective. This arrangement allows for an in-depth analysis of individual metrics as well as a holistic overview of the data distribution across the cities.

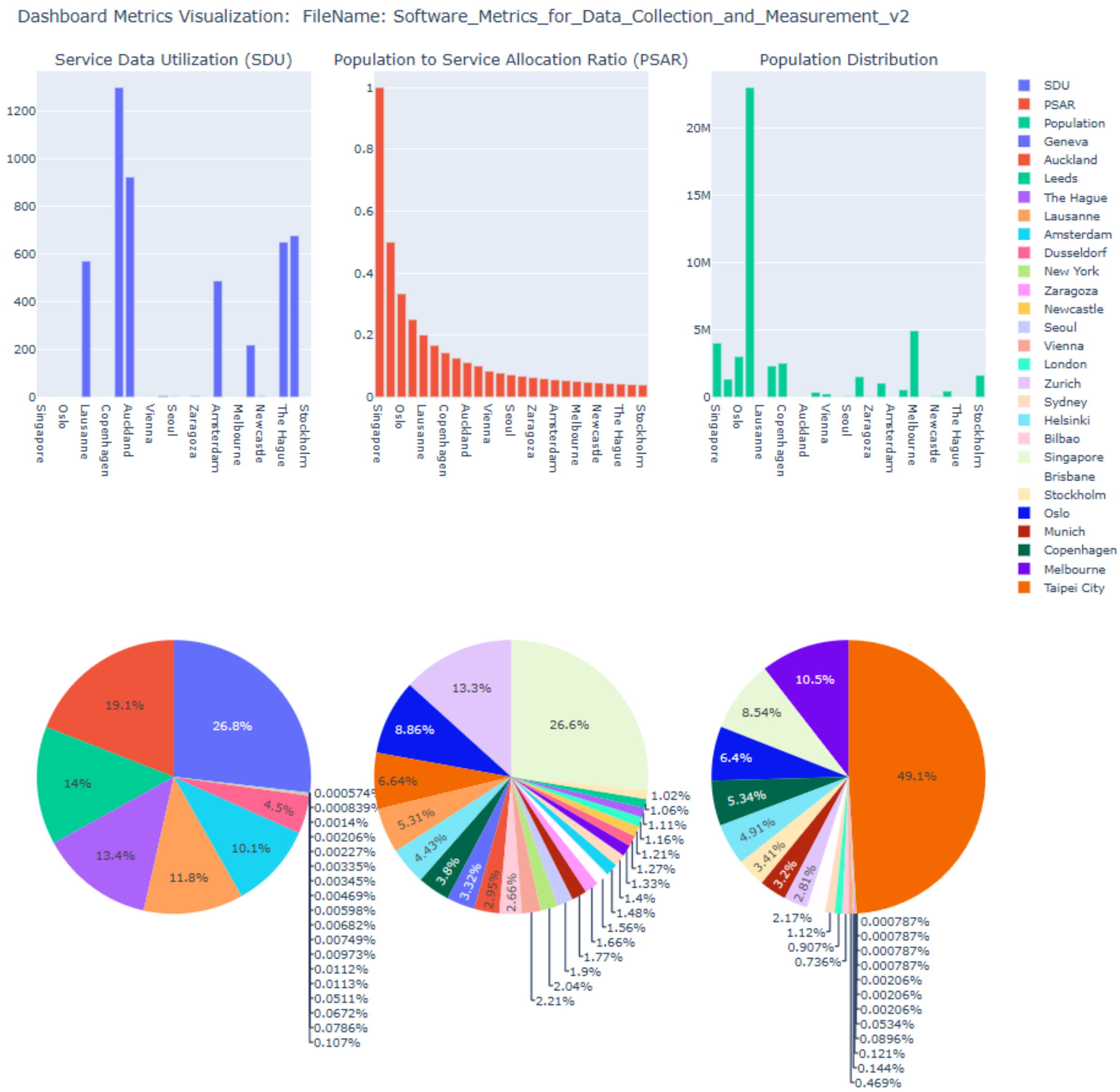


Figure 3.1: Dashboard Metrics Visualization comprising bar and pie charts that display Service Data Utilization (SDU), Population to Service Allocation Ratio (PSAR), and Population Distribution across various cities.

The combination of bar and pie charts enriches the narrative of the data, allowing quantitative and comparative analyses. This approach emphasises the multifaceted nature of data analysis within intelligent educational environments, showcasing the practical application of software metrics in the evaluation of operational efficiency. The interactive HTML version of these visualisations further extends the utility of the data, facilitating shared understanding and collaborative exploration (Zhenyu Chen and X. Zhao 2024).
This sample section, complete with Python script functions and sample data, offers a robust framework for utilising software metrics in evaluating the Big Data Analytics dashboard. It underscores the importance of a methodological approach that incorporates quantitative measures to assess the effectiveness of the dashboard in smart educational contexts.

Smart Education Data Integrity and Decision Making

Within the sphere of smart education, the sanctity of data integrity and its readiness for analysis are the cornerstone of this research methodology. The power of decision making, whether to craft policies, channel resources, or shape pedagogical frameworks, leans heavily on the pillars of reliability and comprehensiveness of data. The dashboard's role in aggregating and presenting data for analysis is critical, and the integrity of these data is non-negotiable. Measures to safeguard data quality, accuracy and security are not merely precautionary but are central to the utility of derived metrics and, consequently, to actionable insights that inform decisions. Some recommended approach is as follows:

- **Validation Protocols:** Implement rigorous data validation protocols at the point of collection to prevent inaccuracies and inconsistencies. Automated scripts shall verify the format and range of incoming data, identifying anomalies for review (Robertson et al. 2024).
- **Regular Audits:** Schedule periodic data audits to ensure continuous accuracy. This involves cross-referencing of dashboard data with independent data sources for corroboration (Ilori, Nwosu, and Naiho 2024).
- **Security Measures:** Adopt robust cybersecurity measures, including encryption and access controls, to protect against unauthorised data breaches. Regular updates to security protocols will align with evolving cyber threats (Nzeako et al. 2024).
- **Redundancy and Backup:** Establish systems for data redundancy and backup systems to prevent data loss. This includes real-time replication of data across multiple secure locations (Bas 2024).
- **Transparency and Traceability:** Maintain a transparent log of data transactions and alterations to ensure traceability. This will include user access logs and change tracking within the data set (Luna et al. 2024).
- **Compliance with Standards:** Ensure adherence to international standards for data integrity and privacy, such as ISO/IEC 27001 and the General Data Protection Regulation (GDPR), providing a framework for data management and protection (Elpina 2024).

The implementation of these steps will fortify the integrity of the data, making it a reliable foundation for decision-making processes. These measures are designed to maintain the quality of the data within the operational efficiency framework for smart cities (OE4SC), highlighting its importance in the domain of Smart Education. The integrity of the data not only reflects the authenticity of the analysis, but also the trust and confidence that stakeholders place in the decision-making processes underpinned by such data (Kuklin, Bratukhina, and Gorokhovitskaya 2021),(Khaleefah and Al-Mashhadi 2024).

The subsequent discourse explains the nature and properties of these data indicator components, underscoring their significance within the Operational Efficiency for Smart Cities (OE4SC) in the context of the Smart Education Framework and the nature of the operational efficiency with volume and variety (OE2V) of big data:

1. **Volume:** Within the big data paradigm, the "Volume" component is pivotal in defining the magnitude of data that an entity stores and manages. Covers an evaluation of voluminous datasets in data repositories with a focus on scalability, accessibility, and manageability. Central to the concept of volume is strategic planning for both current and future storage capacity needs, including considerations related to data velocity and maximising the utility of existing storage infrastructures. The data volume processing cycle, depicted in figure 3.2 and supplemented by agile development methodologies (see figure 3.3), is essential for operational efficiency in harnessing these voluminous data attributes, particularly within smart education networks consisting of various components of ICT (McGranahan 2013; Martins 2018).

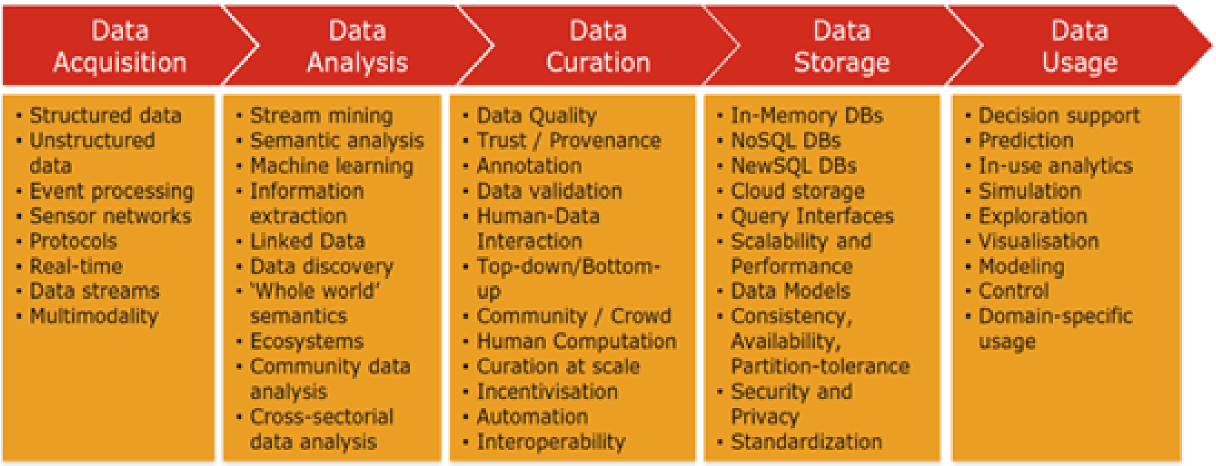


Figure 3.2: Cycle of Data Volume Categories, and its attributes (Riera Pérez, Laprise, and Rey 2018)

and complemented by agile development methodologies (Figure 3.3),

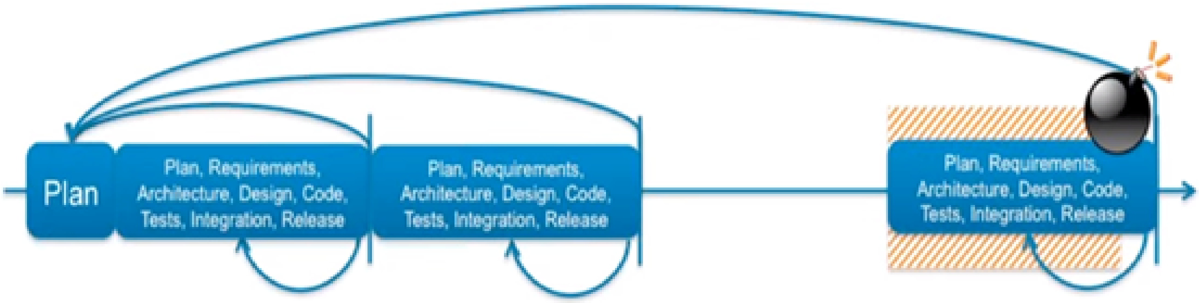


Figure 3.3: The Research Used Agile Project Development Methodology (Dessì, Fenu, Marras, and Reforgiato Recupero 2019)

2. **Variety:** The 'Variety' aspect of big data addresses the range of structured and unstructured data generated by both human and machine sources. In the sphere of smart learning, the big data framework begins with the identification of data sources. This component is integral to the discovery process within the data framework, where the diversity of data types contributes to the complexity of the data. The value generation in smart education through big data analytics capitalises on this variety. Operational efficiency gains visual insights from this diversity of data, demonstrating how quantitative metrics can boost development in smart education contexts (Madakam and Ramaswamy 2015). The need for volumes and a variety of large data (OE2V)-focused operational efficiency findings in smart education is reinforced by the influencing factors in big data (V 2008). The Operational Efficiency to Volume and Variety (OE2Vs) methodology is designed to produce clearer and more actionable results, improving decision-making, insight discovery, and process optimisation within the educational sectors of smart cities. The complexities of big data analytical tools such as Hadoop, as studied by (Paroutis, Bennett, and Heracleous 2014), call for a simplified approach. Therefore, the explanation of the OE2V methodology places emphasis on volume and variety, which simplifies this complexity, facilitating improved understanding and decision making in smart education.

3.4 Research Tools and Techniques Facilitation Methods

This section delves into the simplified methodologies employed in the collection, processing, and analysis of the voluminous and variety of datasets integral to smart education within a smart city's framework. The efficacy of these methodologies depends on their systematic application, as illustrated in Figure 3.5.

This segment delineates the methodology for big data analysis, which is crucial in the context of smart education systems. Figure 3.4 explains the overall knowledge discovery process and the specific methodologies used at each stage.

- **Application Technique:** The initial step involves meticulous data cleansing, addressing anomalies such as missing values and outliers in the context of Data Volume and Variety, ensuring the fidelity, and integrity of the dataset.
- **Knowledge Discovery:** The subsequent phase includes algorithmic data partition, using decision tree methodologies and similar approaches to effectively categorise data, thus facilitating a more incisive and targeted analysis.
- **Application Technique:** Motivational discovery segments operational efficiency data into distinct groups, thus enhancing the robustness and reliability of the results obtained during the knowledge discovery process.
- **Knowledge Discovery Process:** Iterative filtering, essential to discern recurring temporal patterns in operational efficiency data, helps refine the focus to the most significant data subsets, which is critical for smart governance. Gradual pattern discovery is used as the main technique in this phase.
- **Knowledge Discovery Process:** The culmination of this process is the representation of acquired knowledge through analytical models, displayed as graphs or quantitative metrics on a dashboard, which contributes substantially to the knowledge base of research.

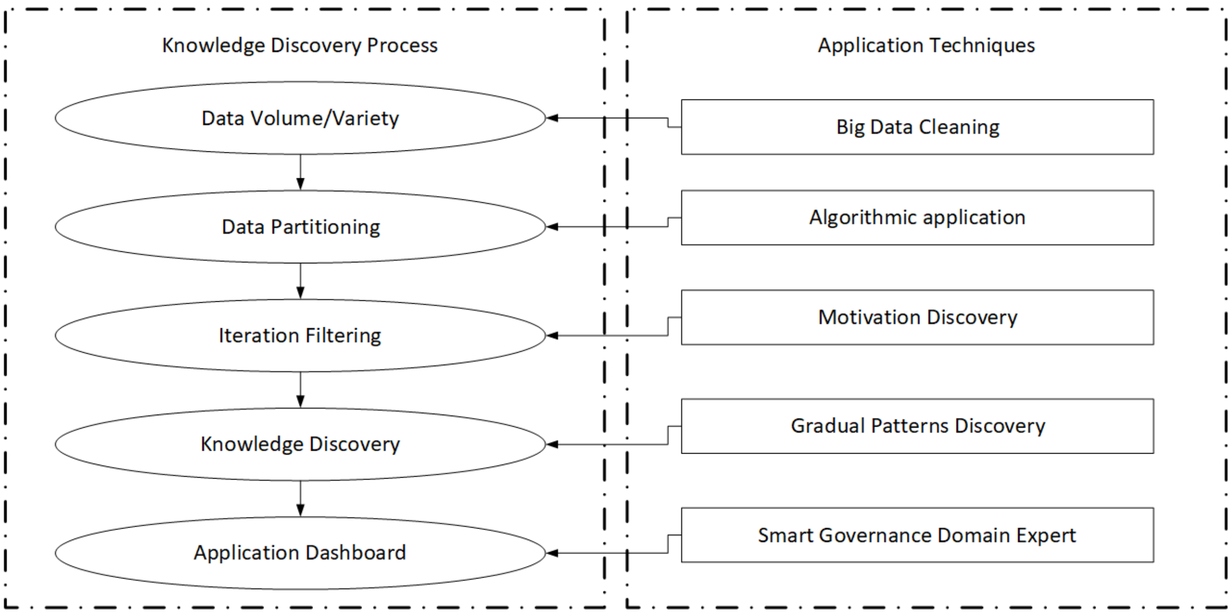


Figure 3.4: Identification of relevant types and sources of information, derived from Smart City Big Data knowledge discovery in the context of Smart Education Framework

The initial phase of our workflow involves the aggregation of raw data from the interconnected network that forms the smart city's infrastructure. This is a data set that can include data from sensors, digital interactions, and various IoT devices, encompassing structured and unstructured formats from open dataset providers. These raw data, once classified into coherent categories based on predefined parameters, are assigned to a structured form, harmonising them with the schema of a relational database system such as JSON , CSV or MySQL , as shown in Figure 3.5.

Following the mapping process, the data undergo a transformation phase. Depending on the intended use, this may involve conversion into XML for hierarchical structuring or JSON for efficient data interchange. These transformations prepare the data for the critical analytics phase, where a battery of analytical techniques, ranging from machine learning algorithms to statistical analyses, is applied to extract valuable insights and displayed on the dashboard.

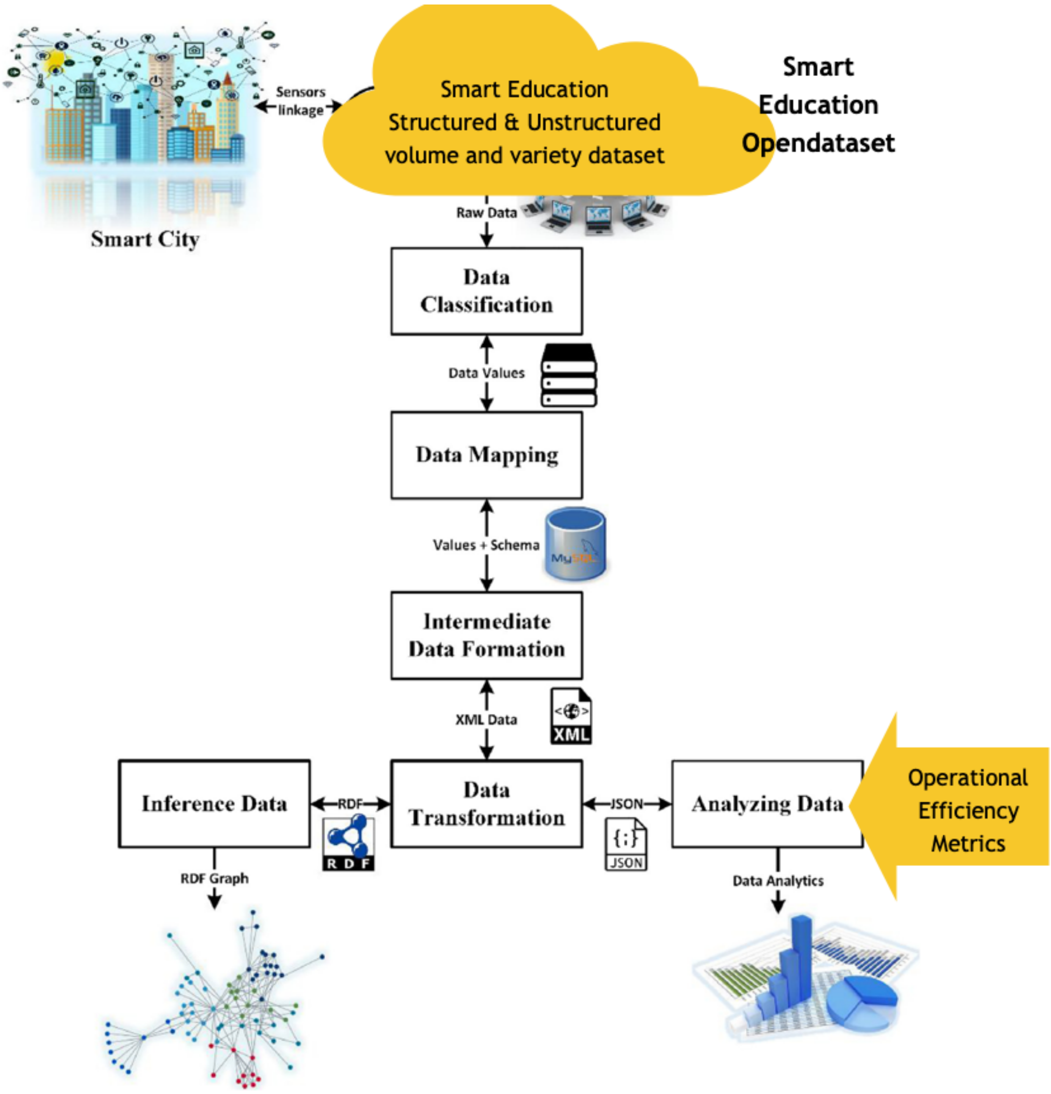


Figure 3.5: The integrated approach to data management and analytics in the context of Smart Education.

This research will utilize Agile DevOps methodologies in conjunction with big data, as illustrated in figure 3.3. The agile approach, with its modular nature, allows early detection of problems, an aspect crucial to handling the multitude of data relevant to the operation of smart cities in the context of smart education. Technologies such as Hadoop, Cloudera, Anaconda, Spark, Mahout, and MapReduce, when needed, will be instrumental in obtaining analytical results, adhering to the scientific approach described in Table 3.1.
In shaping the contours of this research, a methodical approach is adopted that blends theoretical underpinnings and empirical investigation. The table 'Research Project Scientific Approach' (Table 3.1) synthesises the hypothetical frameworks and attributes underpinning this study. Provides an organised overview of the purpose of the study, the research gaps addressed, and the hypotheses driving the investigation of smart education within smart cities. This systematic approach ensures a robust and well-defined research pathway, paving the way for significant contributions to the field.

Table 3.1: Research Project Scientific Approach

Begin: Scientific approach of the research project - Table 3.1	
Hypothetical Scientific Method Approach	Attributes addressed
Purpose	Smart City operation in the context of Smart Education. The primary objective of this research is to dissect and improve the operational efficiency of smart cities with a keen focus on the educational sector. This is achieved by employing Big Data analytics as a principal tool to provide smart city developers with comprehensive insights into performance metrics, using both quantitative and qualitative hypotheses. The rationale behind this approach is to uncover, analyse, and simplify the intricate complexities inherent in Smart City Big Data, particularly those that pertain to and impact the realm of smart education. Research begins with the formulation of hypotheses that are grounded both quantitatively and qualitatively. The quantitative aspects will use data analytics to measure and evaluate educational performance indicators, such as student engagement levels, learning outcomes, and resource allocation efficiencies. Meanwhile, qualitative aspects will provide a contextual understanding of the data, providing insight into the lived experiences of educators and learners, and the nuanced impacts of smart city initiatives on educational processes. A critical aspect of this study is the simplification of the analysis process for Big Data in Smart Cities. The complexity of the data, resulting from the sheer volume, velocity, and variety of data, often acts as a deterrent to the extraction of meaningful insights. This research aims to develop and refine analytical methodologies that streamline the data interpretation process using a dashboard. By doing so, it aspires to reveal actionable intelligence that can significantly contribute to the discovery of operational efficiencies within smart education environments.

Continuation: Research Project Scientific Approach of Table 3.1	
Hypothesis	Attributes addressed - $HypotheticalScientificMethodApproach$
Purpose...	The exploration of operational efficiency takes centre stage in this thesis. Operational efficiency within smart education is viewed as the optimal use of resources, processes, and technologies that collectively contribute to a better educational experience. Research posits that through strategic analysis of Big Data, smart city developers can gain a deep understanding of the current efficacy of educational initiatives and identify opportunities for innovation and improvement. The implications of this research are far-reaching. By elucidating the complexities and providing a framework for efficiency analysis, smart city stakeholders can make informed decisions that resonate with the objectives of Smart Education. The applications of this research extend beyond immediate educational settings, influencing policy decisions, infrastructure development, and broader smart city governance models. In essence, the purpose of this research is to chart a course through the data-driven landscape of smart cities, distilling the wealth of information into coherent strategies that boost the efficiency and efficacy of smart education. It is an endeavour that not only seeks to contribute to academic scholarship, but also to provide a pragmatic blueprint for smart cities and educational practitioners.
—	—
Research	The vast domain of smart cities, particularly within the scope of smart education, is at the confluence of rapid technological evolution and increasing data proliferation. This intersection presents unique opportunities and challenges, particularly in harnessing big data analytics to improve operational efficiency and sustainability. However, a discernible gap persists in the application and efficacy of these analytics, marked by a lack of general consensus on frameworks and benchmarks that could universally be applied in diverse smart educational ecosystems (Paroutis, Bennett, and Heracleous 2014). This research project adopts a hypothetical scientific method approach to systematically address these challenges, with the aim of contributing to the development of a more cohesive framework for smart education within smart cities. The preliminary step in our scientific approach involves a thorough review of the literature, as demonstrated by Sotirios Paroutis et al., to identify the existing gaps in the use of big data analytics in smart educational contexts (Paroutis, Bennett, and Heracleous 2014). Despite efforts to establish comprehensive frameworks and benchmarks, the field suffers from fragmentation of approaches and a lack of consensus among scholars and practitioners. This fragmentation impedes the realisation of the full potential of smart education systems to achieve operational efficiency and sustainability. Based on identified gaps, this research formulates hypotheses based on the premise that a unified analytical framework can significantly improve the operational efficiency of smart educational systems. By synthesising the insights of Chourabi et al. (Hafedh et al. 2012) and the analytical methodologies proposed by Fan et al. (Fan and F. Xiao 2017), this study hypothesises that the integration of big data analytics tailored to the specific needs of smart educational sectors can lead to measurable improvements in operational sustainability.

Continuation: Research Project Scientific Approach of Table 3.1	
Hypothesis	Attributes addressed - $HypotheticalScientificMethodApproach$
Research...	The research adopts a mixed methods approach, combining quantitative data analysis to measure the impact of big data analytics on educational outcomes, with qualitative assessments to capture the nuanced experiences of educators and learners within smart city frameworks. This dual approach enables a comprehensive understanding of the operational dynamics at play, allowing for the refinement of hypotheses and the development of a robust analytical framework. Data collection will leverage both primary and secondary sources, including case studies of smart cities that have integrated big data analytics into their educational systems. Analysis will employ advanced statistical tools and machine learning algorithms to discern patterns, trends, and correlations between the use of big data analytics and operational efficiency in smart education. The qualitative component will use data sets and observational studies to gather information from stakeholders, enriching the quantitative data findings. Based on the empirical evidence collected, the research will contribute to the development of a comprehensive framework for the application of big data analytics in smart education. This framework will aim to standardise practices, reduce complexity, and facilitate consensus among stakeholders. Benchmarking against existing models and case studies will further validate the efficacy of the proposed framework, ensuring its relevance and applicability in different contexts of smart cities. By adhering to a hypothetical scientific method approach, this research project aims to bridge the gap in the application of big data analytics in smart education. Through a meticulous process of hypothesis formulation, experimental design, data analysis, and framework development, the study aims to illuminate the paths to improved operational efficiency and sustainability within the educational sectors of smart cities. The findings and contributions of this research will not only advance academic understanding, but will also offer practical guidelines for policymakers, educators, and technologists in the implementation of smart education initiatives (Paroutis, Bennett, and Heracleous 2014; Hafedh et al. 2012; Fan and F. Xiao 2017).
—	—

Continuation: Research Project Scientific Approach of Table 3.1	
Hypothesis	Attributes addressed - $HypotheticalScientificMethodApproach$
Hypothesis	Using big data analytics to improve the efficiency of operations in other countries to develop a common standard on how to quantify or benchmark urban areas (Shyam R. et al. 2015);(K. Zhou, C. Fu, and S. Yang 2016), in relation to the smart city in the context of smart education. The central hypothesis of this research project is that the application of big data analytics can significantly improve operational efficiency within urban areas, specifically in the context of smart education. This enhancement is expected to contribute to the development of a universal standard to quantify and benchmark the performance of urban educational ecosystems. The foundation of this hypothesis is based on the premise that systematic and sophisticated analysis of large datasets, pertaining to educational operations within smart cities, can yield actionable insights. These insights, in turn, can inform the creation of more effective and efficient educational practices and policies (Shyam R. et al. 2015); (K. Zhou, C. Fu, and S. Yang 2016). The primary objective is to harness the potential of big data analytics to identify, analyse, and optimise key performance indicators (KPIs) relevant to educational outcomes and operational efficiency in urban settings. This involves aggregating and analysing diverse data streams from student performance metrics and resource allocation to infrastructural use and technological adoption rates. The methodology encompasses a blend of descriptive, inferential, and predictive analytics techniques, applied to structured and unstructured data, to uncover patterns, trends, and correlations that may not be immediately apparent. A key outcome of this research is the development of a Smart Education Framework. This framework aims to operationalise the findings from big data analysis, translating them into actionable guidelines and standards for smart education practices. The intention is to extend the existing ISO/IEC Smart City framework, incorporating specific dimensions and criteria relevant to the educational sector. This extension will address the nuanced challenges and opportunities inherent in the integration of smart technologies and big data analytics into educational planning, delivery, and assessment processes.

Continuation: Research Project Scientific Approach of Table 3.1	
Hypothesis	Attributes addressed - $HypotheticalScientificMethodApproach$
Hypothesis	The implementation of this hypothesis is expected to yield several key outcomes. 1. ** Establishment of benchmarking standards: ** Research will contribute to the establishment of clear and measurable standards to evaluate the performance and efficiency of smart educational initiatives in urban contexts. These standards will facilitate comparative analysis and encourage best practices. 2. **Enhanced operational efficiency: ** By identifying the drivers of efficiency and effectiveness in smart education, the project aims to recommend strategies to optimise resource allocation, curricular design and technology integration, thus improving the overall quality of the education provided. 3. **Informed Policy Making:** The insights derived from big data analytics will offer evidence-based support for policy-making processes, ensuring that educational policies are aligned with empirical data and are responsive to the evolving needs of urban learners. 4. ** Framework for future research:** The Smart Education Framework developed through this research will serve not only as a practical guide for educators and administrators but also as a foundation for future academic research into the intersection of big data analytics and smart education. With these premise, this hypothesis underscores the transformative potential of big data analytics in redefining the operational landscape of smart education within urban areas. By systematically analysing large data sets and developing a comprehensive framework, this research aims to establish a benchmark for excellence in smart education, contributing to the larger objectives of sustainable urban development and improved quality of life in smart cities (Shyam R. et al. 2015); (K. Zhou, C. Fu, and S. Yang 2016).
End of Table	

3.5 Application of MapReduce in Big Data Analytics for Smart Education

As we continue our exploration of the methodologies that underpin our research, we encounter the MapReduce architecture, a cornerstone technology of Apache Hadoop originally developed by Google. The essence of MapReduce lies in its ability to efficiently dissect and process large volumes of data. Its implementation is shown in Figure 3.6, providing a typical user flow of the dashboard architecture in the context of smart education.

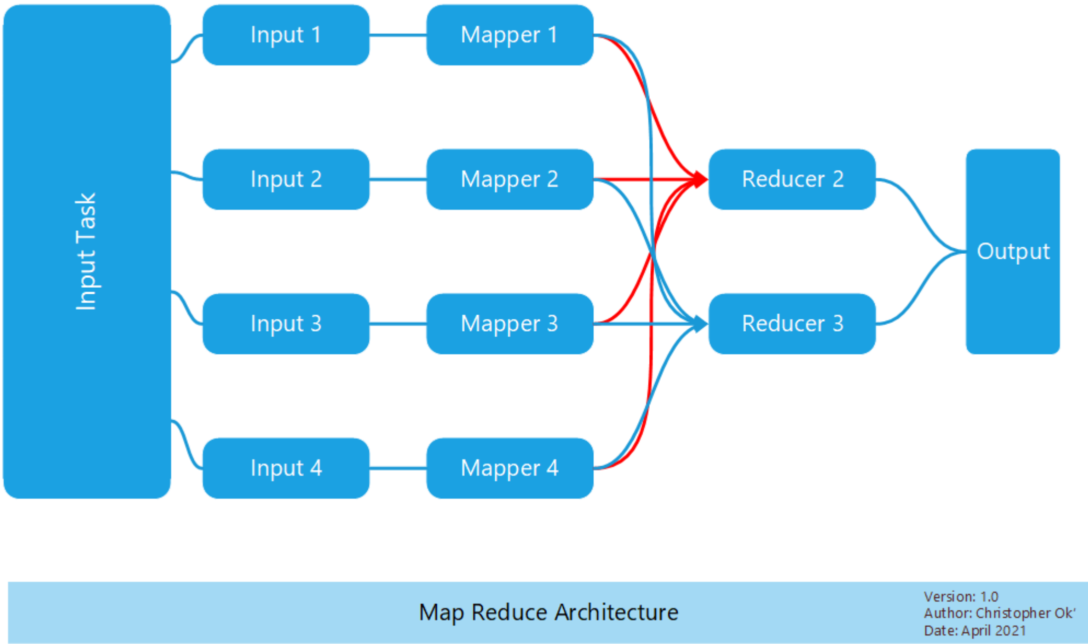


Figure 3.6: MapReduce Architecture for data analysis within smart education systems.

This data-centric architecture is particularly adept at handling real-time data streams, a frequent occurrence in the monitoring of smart city educational infrastructure. The MapReduce paradigm divides the data into four core components: input, mapper, reducer, and output, as delineated by (Gracia, Martine, and Emmanuel 2018) and (Paroutis, Bennett, and Heracleous 2014). This modular approach serves to accelerate data processing by taking advantage of the parallelism inherent in the MapReduce model.

3.5.1 Interpretation of SERFD Map Reduce Architecture

Figure 3.6 represents the interpretation for the map reduce architecture of the Smart Education Recommendation Framework with Dashboard (SERFD). This architecture is designed to process large volumes of educational data efficiently, using the MapReduce programming model. Here is a detailed interpretation of the diagram:

- **Input Task:**
  - This is the initial phase where the data is divided into smaller chunks called **Input Splits**.
  - Each input split is processed in parallel, enabling efficient handling of large datasets.
  - The process begins with data input, where inputs, potentially originating from IoT devices, are divided into smaller data fragments and then assigned to mappers for processing.
- **Mappers:**
  - Each input split is fed into a **Mapper** which processes the data and produces intermediate key-value pairs.
  - In the diagram, we have four mappers (Mapper 1 to Mapper 4) that handle the data from four input splits (Input 1 to Input 4).
  - The mappers are responsible for filtering and sorting the data, a crucial step in data processing.
- **Reducers:**

  - The intermediate key-value pairs produced by the mappers are shuffled and sorted before being sent to the **Reducers**.
  - The diagram shows three reducers (Reducer 1 to Reducer 3), which aggregate and summarise the data from the mappers.
  - The reducers combine the values associated with the same key, producing the final output.
- **Output:**
  - The final step is the **Output**, where the results from the reducers are collected and written to a storage system.
  - This output can be further analysed or visualised using the dashboard in the context of smart education.

MapReduce Context of SERFD

In the context of the Smart Education Recommendation Framework with Dashboard (SERFD), the MapReduce architecture plays a pivotal role in processing educational data to provide actionable insights. Specifically, it helps in the following ways:

- **Efficient Data Processing:** By parallelising the data processing tasks, MapReduce ensures that large datasets are handled efficiently, reducing the time required to process educational data.
- **Scalability:** The architecture can easily scale to handle increasing amounts of data, making it suitable for growing educational data needs in smart cities.
- **Data Analysis:** The key-value pairs generated by the mappers and the aggregated results from the reducers can be analysed to identify trends, patterns, and insights in educational data.
- **Integration with Dashboard:** The processed data can be visualised using the SERFD dashboard, providing stakeholders with a clear and interactive view of the educational metrics.

Benefits of MapReduce in SERFD

- **Operational Efficiency:** MapReduce enhances the operational efficiency of data processing tasks, enabling quick and reliable analysis of educational data.
- **Data-Driven Decisions:** The insights derived from the MapReduce process inform data-driven decision-making, improving educational strategies and outcomes.
- **Adaptability:** The architecture's ability to process various types of data makes it adaptable to different educational contexts and requirements.
- **Compliance:** Ensures that data processing aligns with the standards set by ISO/IEC 30145, promoting best practices in data handling and security.

By integrating this MapReduce architecture into the Smart Education Recommendation Framework with Dashboard, stakeholders can effectively process and analyse large volumes and variety of educational data, thus enhancing the overall educational experience within smart cities. Furthermore, application of the MapReduce framework within smart education facilitates the handling of complex data sets that encompass a wide range of data types and sources, from social media feeds to critical business transactions. Using MapReduce, we can synthesise these data into coherent and informative metrics, enhancing the operational efficiency of smart education platforms.

This section outlines the practical application of MapReduce in the realm of big data analytics for smart education and underscores the importance of robust, scalable data processing methods in deriving actionable insights from large-scale data sources. For Sample Python Script for MapReduce see Appendix A.

Figures 3.7 and 3.8 present the graphical representation of the educational data processed using the MapReduce framework. This data-centric architecture is particularly adept at handling real-time data streams, a frequent occurrence in the monitoring of smart city educational infrastructure. The MapReduce paradigm divides the data into four core components: input, mapper, reducer, and output, as delineated by (Gracia, Martine, and Emmanuel 2018) and (Paroutis, Bennett, and Heracleous 2014). This modular approach serves to accelerate data processing by taking advantage of the parallelism inherent in the MapReduce model. The following figures illustrate the application of MapReduce in the analysis of educational data. Figure 3.8 demonstrates the distribution of subjects within an educational dataset, processed through a MapReduce job. This figure provides insights into the frequency of different subjects, showcasing how MapReduce can be used to summarise and visualise educational data effectively. Figure 3.7 expands on this by showing the distribution of subjects in various cities, highlighting the potential of MapReduce to handle more complex datasets and provide a clear representation of data in multiple dimensions.

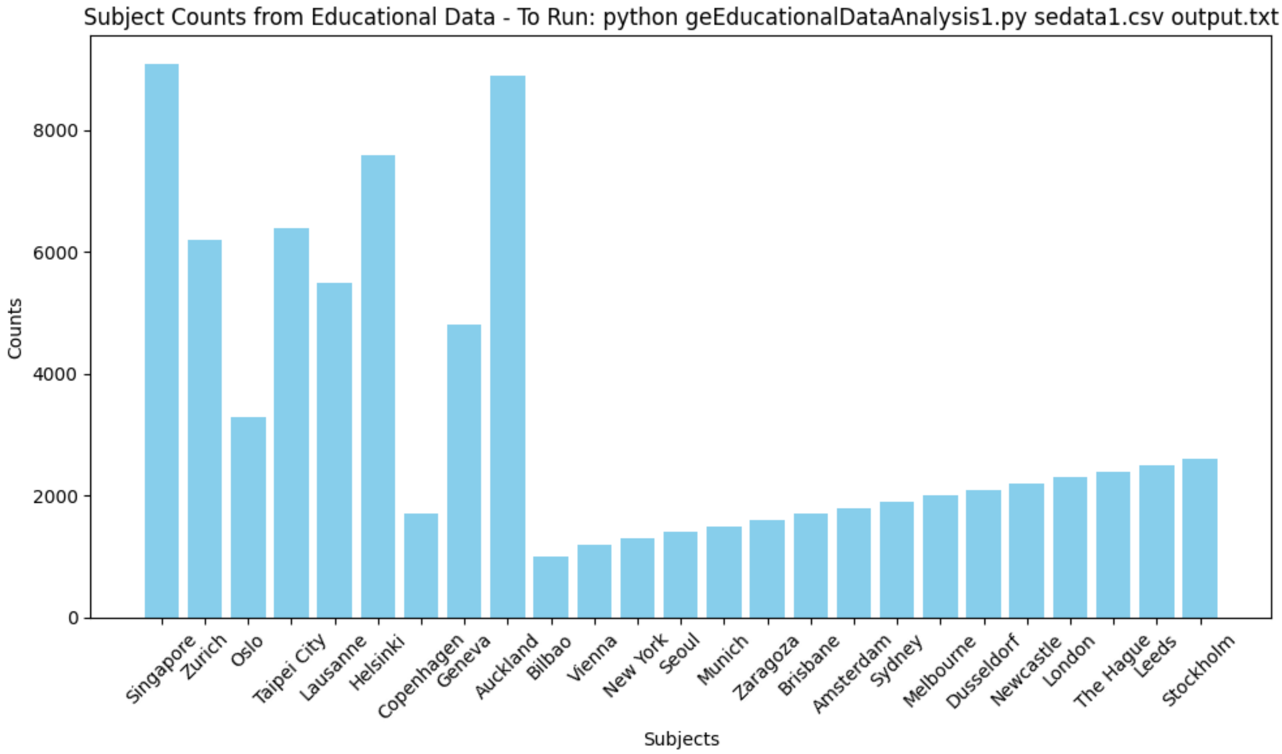


Figure 3.7: MapReduce Data Count Analysis Per Subject by City in Smart Education - Subject Counts from Educational Data - To Run: `python geEducationalDataAnalysis1.py sedata1.csv output.txt`

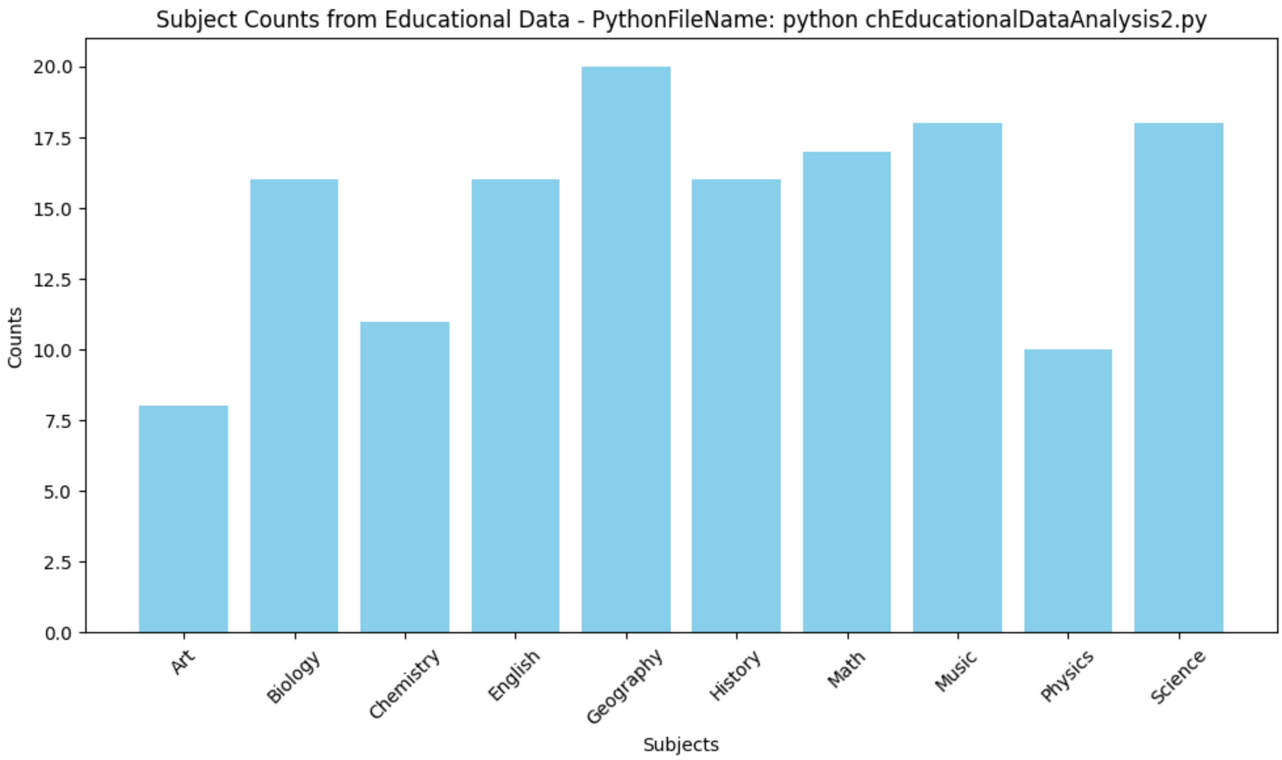


Figure 3.8: MapReduce Data Count Analysis Per City by Subject in Smart Education - Subject Counts from Educational Data - PythonFileName: `python chEducationalDataAnalysis2.py`

This data-centric approach ensures that educational data is processed efficiently, providing valuable insights into the distribution of subjects and their occurrences within different cities. The visualisations generated through the MapReduce framework highlight the practical applications of this methodology in real-time data processing and analytics within the context of smart education, the following paragraph delineates the flow of data in big data ecosystem along with the elements used for MapReduce data collection.

Integration and Synthesis of Smart Education Data

The process of integrating and synthesising data from various components of the smart city is a multifaceted endeavour, as reflected in Figure 3.9. It involves not only the analysis of key information from each source, but also the exploration of simulation and experimental approaches presented through dashboards (Lutfiani and Meria 2022). The identification of pertinent topics for smart education for each technical smart city group is followed by the selection of key data as potential candidates for analysis. The volume and variety of each data source is synthesised into concrete descriptions for each identified topic, upon which advanced predictive methods are applied (Bertino and E. Ferrari 2017). To facilitate this development, data often arrive in real time and must be managed efficiently. MapReduce, a core technology of Apache Hadoop, simplifies this task by dividing data into four core components: input, mapper, reducer, and output. These components streamline data processing, allowing faster analysis and more responsive educational analytics, as demonstrated in Figure 3.6 (T. White 2012; V. K. Singh et al. 2018). The MapReduce model is especially relevant in smart education to handle data from sensors, social media, and financial transactions, all interconnected through the Internet of Things (IoT). The following stages elucidate the simplicity and effectiveness of the MapReduce architecture in data processing(Arora 2015):

1. Analysis of individual data sources, considering their contribution to the overall smart education framework (N.-S. Chen et al. 2020).
2. Identification and comparison of smart education themes in different urban areas (Uskov et al. 2018).
3. Synthesis of data attributes into comprehensive descriptions that inform operational strategies and

predictive analytics (Nordmann et al. 2004).

This data integration and synthesis are critical to achieving operational efficiency in smart education, enhancing our capacity to develop quantifiable standardised benchmarks for urban educational systems (Imaniah 2023). The advent of smart devices has revolutionised learning environments, allowing for an unprecedented level of personalisation and interactivity in educational methodologies. The integration of these devices into the smart education framework involves the use of IoT and big data analytics interfaces to tailor the learning experience to individual needs (Gligorea et al. 2023).

Smart Education Framework Device Integration

Smart devices facilitate the collection of a wealth of data on student engagement, performance, and learning habits. These data are essential for the development of predictive models that can anticipate learning outcomes and suggest interventions to improve the educational process (Sharma 2022). The following points illustrate the integration of smart devices in smart education.

Impact of Big Data Analytics in the Smart City and the Internet of Things (IoT:

The intersection of Big Data Analytics and the Internet of Things (IoT) presents transformative possibilities for smart cities, offering new insights into operational efficiency and improved citizen services (Surendran et al. 2024). Figure 3.9 depicts the dynamic interaction between various components of smart cities, the application of Big Data 5V (Volume, Velocity, Variety, Veracity and Value), and the convergence with the IoT API. This illustration encapsulates the analytical journey from data acquisition through IoT devices to actionable insights that are crucial to driving the evolution of urban to rural areas to smarter living spaces (Al Yakin, Khang, Mukit, et al. 2023; El-Haggar et al. 2023).

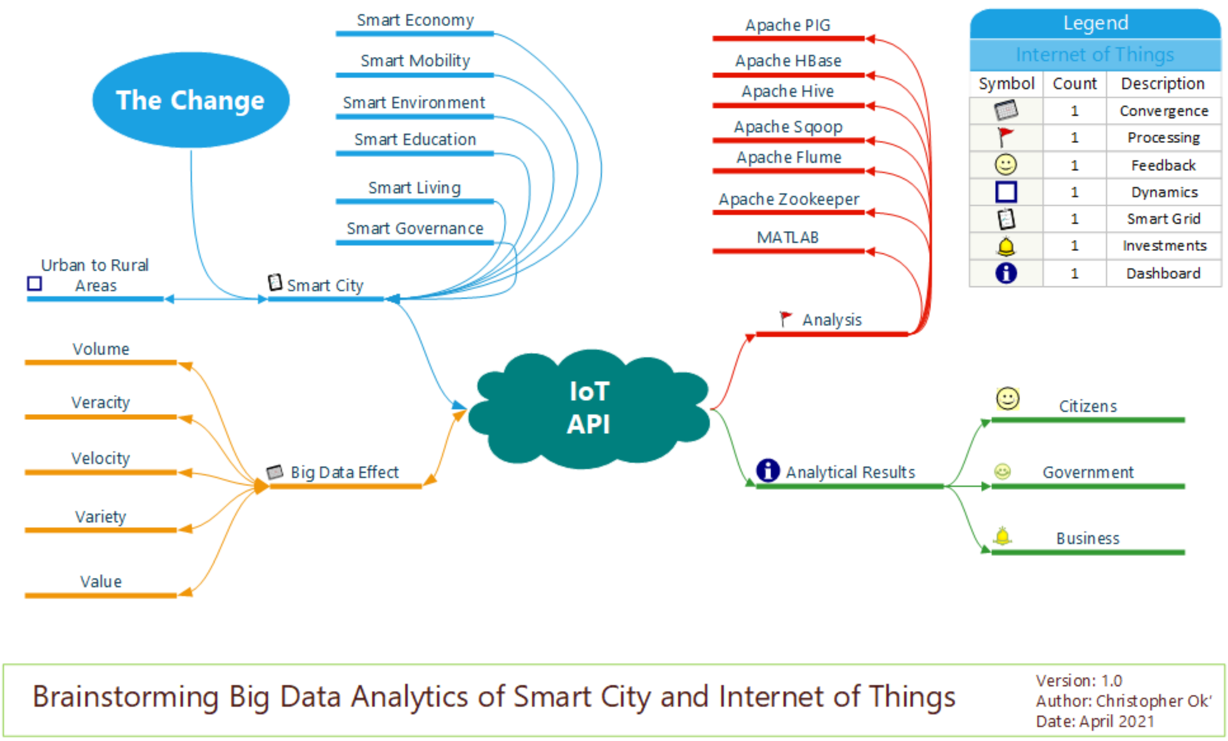


Figure 3.9: OE2V Big Data Analytics of Smart City and Internet of Things Impact Attributes

- **Personalized Learning Pathways:** Leveraging data from smart devices to create adaptive learning experiences that respond to the unique learning style of each student (Sailaja et al. 2024; Thimmanna et al. 2024).
- **IoT in Education:** Utilising IoT technology to develop a connected learning environment, where devices communicate with each other to support educational activities (Xu et al. 2022; Shan Wang 2020).
- **Data-Driven Insights:** Analysing data collected from smart devices to gain insights into student

performance and learning environments, thus forming pedagogical strategies (Y. Wang 2021; Cullen 2003).

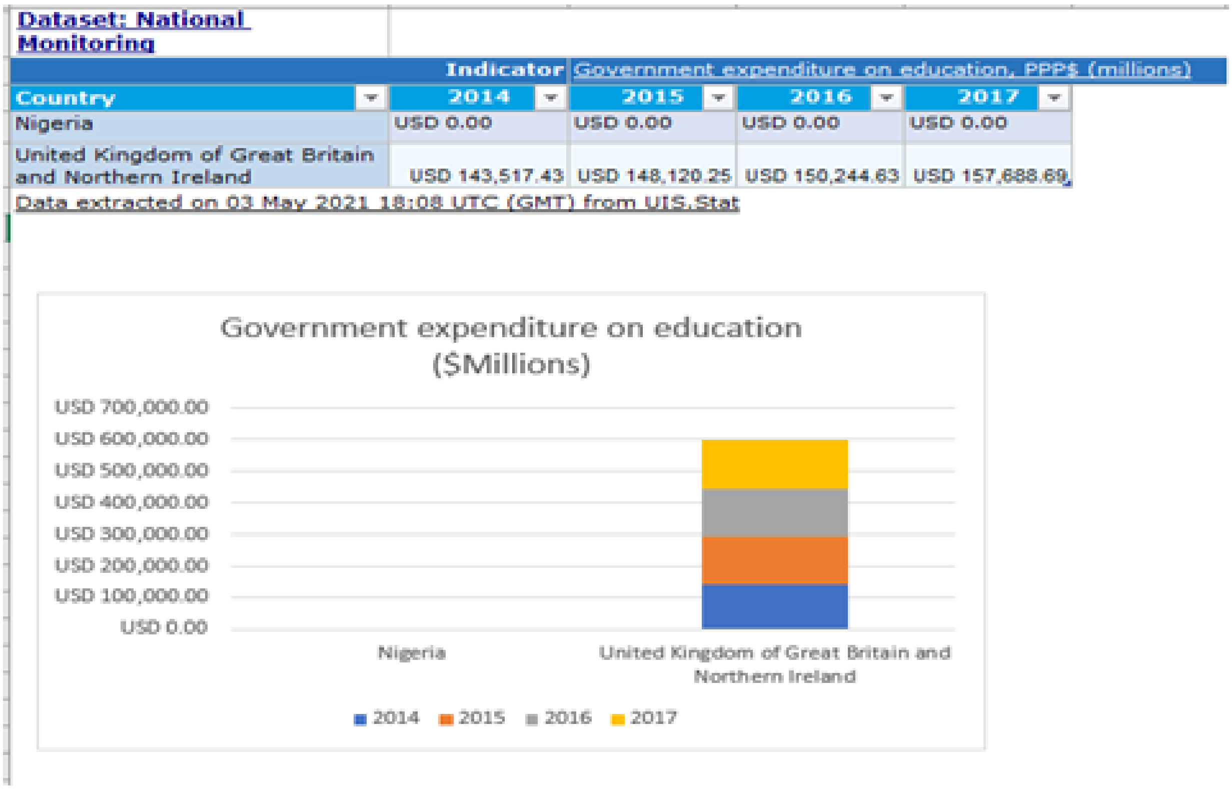
Knowledge Discovery from Personalised Learning

The process of discovering knowledge from personalised learning involves several stages, including the aggregation, analysis, and application of data (Gligorea et al. 2023; KOKOÇ 2023).

1. **Data Aggregation:** Collecting and combining data from multiple smart devices and educational platforms to form a comprehensive data set.
2. **Data Analysis:** Employing advanced analytics to examine aggregated data, identify patterns, and extract actionable knowledge.
3. **Application of Insights:** Applying the knowledge gained from data analysis to improve the delivery of educational content, learning pathways, and overall student participation.

3.6 Sample Dataset Collection and Analysis To Date

Data Collection and Analysis: Focussing on 125 countries of the United Nations, this study analyses data from selected smart cities to improve operational efficiency through big data analysis using machine learning. Primary data sources include UNESCO, UK ONS, NSS, UK DfE, UK DATA SERVICE, WORLD BANK, OECD, IMF, INTERNATIONAL ENERGY AGENCY (SDG4 2017); (UK 2021). A preliminary analysis has revealed critical discrepancies, as exemplified in Figure 3.10.
Preliminary Findings: This research addresses a crucial gap in Operational Efficiency. Initial findings suggest a suboptimal use of big data in educational decision making. Disparities in investments between nations, as observed over a four-year period, underscore the necessity for a comprehensive data analysis approach, such as using the OE2V dashboard, which could significantly mitigate performance inconsistencies.


Dataset: National Monitoring

Indicator	Government expenditure on education, PPP$ (millions)			
Country	2014	2015	2016	2017
Nigeria	USD 0.00	USD 0.00	USD 0.00	USD 0.00
United Kingdom of Great Britain and Northern Ireland	USD 143,517.43	USD 148,120.25	USD 150,244.63	USD 157,688.69

Data extracted on 03 May 2021 18:08 UTC (GMT) from UIS.Stat

Figure 3.10: Sample Data - Government Expenditure on Education over 4 Years (SDG4 2017)

Analysis of Smart City Initiatives: A comprehensive evaluation of Smart City Initiatives is essential to understand the impact and progress of smart technologies in different countries. The following figures present a segment of the UK Data Service (UKDS) dataset, which provides a valuable cross-sectional analysis of smart city developments over a four-year period. These figures are instrumental in benchmarking and comparing the smart city initiatives of ten nations.

Location	Subject	Target	Impact	2015	2016	2017	2018	2019	2020
Belgium	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	99	98	98	..	..	..
		Inputs	Current education expenditure, total (% of total expenditure in public institutions)	95	94	95	..	..	..
		Outcomes	Compulsory education, duration (years)	12	12	12	12	12	12
	Infrastructure	Communications	Individuals using the Internet (% of population)	85	87	88	89	90	..
		Transportation	Rail lines (total route-km)	3,607	3,602	3,605	3,607	..	..
			Railways, passengers carried (million passenger-km)	10,333	10,025	10,167	..	..	..
	Proportion of people living below 50 percent of median income (%)			11	10	10	..	..	..
China	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	99	102	103	103	..	..
		Outcomes	Compulsory education, duration (years)	9	9	9	9	9	..
	Infrastructure	Communications	Individuals using the Internet (% of population)	50	53	54	54	54	..
		Industrial design applications, nonresident, by count		17,578	18,395	17,841	19,702	..	..
		Industrial design applications, resident, by count		551,481	631,949	610,817	689,097	..	..
		Transportation	Rail lines (total route-km)	67,212	83,717	67,278	67,515	68,141	..
			Railways, passengers carried (million passenger-km)	1,196,060	1,257,930	1,345,690	..	..	..
Italy	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	98	98	97	..	..	..
		Inputs	Current education expenditure, total (% of total expenditure in public institutions)	95	96	98	..	..	..
		Outcomes	Compulsory education, duration (years)	12	12	12	12	12	12
	Infrastructure	Communications	Individuals using the Internet (% of population)	58	61	63	74	74	..
		Industrial design applications, nonresident, by count		..	393	1,991	1,212	..	..
		Industrial design applications, resident, by count		..	26,699	28,892	34,812	..	..
		Transportation	Rail lines (total route-km)	16,724	16,788	16,787	16,781	16,779	..
			Railways, passengers carried (million passenger-km)	52,207	52,178	53,231	55,493	..	..
	Proportion of people living below 50 percent of median income (%)			16	16	16	..	..	..
Korea, Rep.	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	100	96	101	..	..	..
		Outcomes	Compulsory education, duration (years)	9	9	9	9	9	..
	Infrastructure	Communications	Individuals using the Internet (% of population)	90	93	95	96	96	..

Figure 3.11: Sample UKDS Dataset for 10 Nation's Smart City Initiatives over 4 years (UK 2021)

Location	Subject	Target	Impact	2015	2016	2017	2018	2019	2020
		Industrial design applications, nonresident, by count		6,918	6,662	7,080	7,979	..	..
		Industrial design applications, resident, by count		65,895	62,631	60,402	60,075	..	..
		Transportation	Rail lines (total route-km)	3,944	4,071	4,192	4,200	4,111	..
			Railways, passengers carried (million passenger-km)	68,371	86,871	89,964	..	..	..
Malaysia	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	105	109	105	..	..	..
		Inputs	Current education expenditure, total (% of total expenditure in public institutions)	94	92	92	93	92	..
		Outcomes	Compulsory education, duration (years)	6	6	6	6	6	..
	Infrastructure	Communications	Individuals using the Internet (% of population)	71	79	80	81	84	..
		Industrial design applications, nonresident, by count		1,135	726	1,297	1,317	..	..
		Industrial design applications, resident, by count		627	701	517	528	..	..
		Transportation	Rail lines (total route-km)	..	..	2,773	2,783	..	..
			Railways, passengers carried (million passenger-km)	1,964	2,344	2,468	2,317	..	..
	Proportion of people living below 50 percent of median income (%)			16	..	..	..	..	..
Netherlands	Education	Inputs	Current education expenditure, total (% of total expenditure in public institutions)	89	89	89	..	..	..
		Outcomes	Compulsory education, duration (years)	13	13	13	13	13	13
	Infrastructure	Communications	Individuals using the Internet (% of population)	92	90	93	95	93	..
		Transportation	Rail lines (total route-km)	..	..	..	3,200	..	..
			Railways, passengers carried (million passenger-km)	17,700	18,532	18,437	18,895	..	..
	Proportion of people living below 50 percent of median income (%)			8	9	8	..	..	..
Singapore	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	..	103	101	..	..	..
		Outcomes	Compulsory education, duration (years)	6	6	6	6	6	..
	Infrastructure	Communications	Individuals using the Internet (% of population)	79	84	84	88	89	..
		Industrial design applications, nonresident, by count		3,743	3,972	4,318	3,705	..	..
		Industrial design applications, resident, by count		780	644	592	342	..	..
Spain	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	100	94	93	..	..	..
		Inputs	Current education expenditure, total (% of total expenditure in public institutions)	95	95	95	..	..	..

Figure 3.12: Continuation of the Sample UKDS Dataset for 10 Nation's Smart City Initiatives over 4 years (UK 2021)

Location	Subject	Target	Impact	2015	2016	2017	2018	2019	2020
		Outcomes	Compulsory education, duration (years)	10	10	10	10	10	10
	Infrastructure	Communications	Individuals using the Internet (% of population)	79	81	85	86	91	..
		Industrial design applications, nonresident, by count		652	785	754	634	..	..
		Industrial design applications, resident, by count		17,263	17,551	21,845	18,219	..	..
		Transportation	Rail lines (total route-km)	15,711	15,650	15,559	15,618	15,718	..
			Railways, passengers carried (million passenger-km)	26,142	26,670	27,487	28,434	..	..
	Proportion of people living below 50 percent of median income (%)			17	17	16	..	..	..
United Kingdom	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	98	97	98	..	..	..
		Inputs	Current education expenditure, total (% of total expenditure in public institutions)	97	98	97	..	..	..
		Outcomes	Compulsory education, duration (years)	11	11	11	11	11	11
	Infrastructure	Communications	Individuals using the Internet (% of population)	92	95	95	95	93	..
		Industrial design applications, nonresident, by count		473	1,292	2,604	4,538	..	..
		Industrial design applications, resident, by count		5,999	8,738	16,665	22,904	..	..
		Transportation	Rail lines (total route-km)	16,245	16,257	16,294	16,295	..	..
			Railways, passengers carried (million passenger-km)	76,788	78,696	80,261	80,526	..	..
	Proportion of people living below 50 percent of median income (%)			11	13	..	..	..	..
United States	Education	Efficiency	Gross intake ratio in first grade of primary education, total (% of relevant age group)	103	..	..	..	..	..
		Outcomes	Compulsory education, duration (years)	12	12	12	12	12	..
	Infrastructure	Communications	Individuals using the Internet (% of population)	75	86	87	87	87	..
		Industrial design applications, nonresident, by count		18,187	21,015	22,451	24,313	..	..
		Industrial design applications, resident, by count		22,785	24,405	23,618	22,824	..	..
		Transportation	Rail lines (total route-km)	151,735	151,270	150,966	150,462	..	..
			Railways, passengers carried (million passenger-km)	36,044	35,892	33,256	31,963	..	..
	Proportion of people living below 50 percent of median income (%)			..	18	..	..	..	..

Data extracted on 09 May 2021 16:55 UTC (GMT) from UKDS.Stat

Figure 3.13: Conclusion of the Sample UKDS Dataset for 10 Nation's Smart City Initiatives over 4 years (UK 2021)

These datasets provide a foundation for the subsequent analysis and discussion on the state of smart city initiatives, highlighting the diverse approaches and results achieved by different countries. They underscore the importance of data-driven insights in shaping future smart city strategies and policies.

The research thus far demonstrates the application of Volume and Variety in Big Data components to improve smart education, underlining the benefits and rationalising the approach.

Expected Results and Attributes of Smart Education Applications: In the context of enhancing smart education, the expected results are twofold: the implementation of the smart education ideology and the effective application of this ideology in practical smart learning environments. Table 3.2 delineates the key components of smart education and their rationales and application attributes. This table is instrumental in understanding the expected transformative impact of smart education components on the learning process and environment, as well as on pedagogical approaches. Each entry in the table correlates a component with its rationale, reflecting the integration of innovative technologies and methodologies into education.

Table 3.2: Expected Results Smart Education and Application attributes .

Begin:Expected Results Smart Education and Application Attribute - Table 3.2	
Components of Smart Education	Application Rationale and Attributes
Reveal: Smart Education Ideology	Introduction of creativity, Use of ICT, Personalised learning pathways, IoT with Big data analytics interface (Sailaja et al. 2024)
———	———
Reveal: Smart Learning Environment	Smart learner welfare alert level communication systems, systems Integrated to halls of resident accommodation, sports & hospitality including work-based learning (Dieck, Jung, and Loureiro 2021)
———	———
Reveal: Smart Pedagogues	Smart flip & flexed delivery, Smart individual learners rotation, Smart learners station rotation, Sharing ideas and resources among smart learners (Atchoarena and Howells 2021)
End of Table	

Work-Based Learning and Facility Utilisation

Incorporating work-based learning into the smart education paradigm is a significant step towards providing practical, real-world experience to students (Dafoulas et al. 2010). Smart education systems can leverage big data to optimise the use of educational facilities, ensuring that resources are used efficiently and effectively to support student learning. The integration of smart devices and the analysis of the data they generate play a pivotal role in this optimisation process.

- Using compare and contrast of existing studies in the other to obtain: Integration of Smart Devices, Knowledge Discovery from Personalised learning pathways, Placements & Work-based learning and Facility Utilisation metrics.

Hypothetically, our quantitative analytical result may be based on data from UNESCO because of the consistent structure, and the data set is internationally aligned. Furthermore, UNESCO data are a consolidated data set for each nation, considering national GDP in the context of smart education. It is also a direct correlation to the smart cities we selected for this research. Furthermore, data sets used by the UK Data Service were provided by the International Energy Agency, World Bank, OECD, United Nations (UNESCO), Human Rights Atlas, and International Monetary Fund (IMF) (Ben-Assuli et al. 2019); (UK 2021). The reason we chose 10 nations out of many is twofold, one of which some nations had just emerged from what may be seen as no democratic state, and two the disparities meant there are no open or transparent systems (J. Singh 2015), as indicated by the sample data from UKDS in figure 3.14;3.11;3.12;3.13.

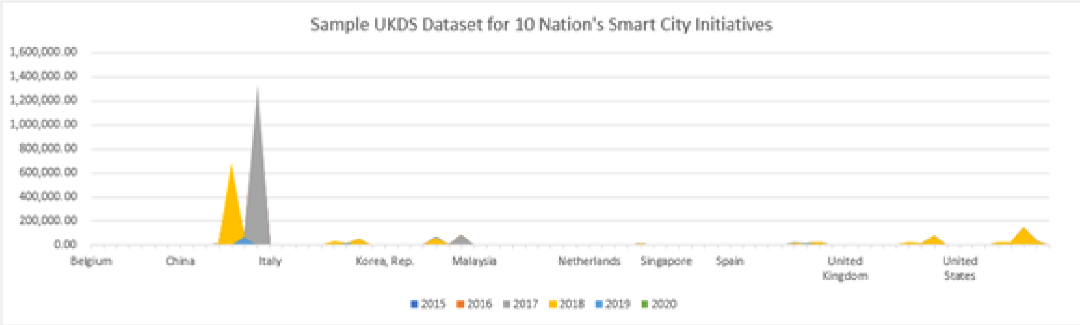


Figure 3.14: Sample UKDS Dataset for 10 Nation's Smart City Initiatives over 4yrs (UK 2021)

These integrations and discoveries are indicative of the potential that smart device data have to transform the educational landscape. Using these data, educators and administrators can develop a more nuanced understanding of how learning occurs and how it can be facilitated in the most effective way within smart cities.

3.7 Operational Efficiency Through Data-Driven Analytics

The pursuit of operational efficiency in smart education is deeply intertwined with the analytical capabilities afforded by big data technologies. The following stages of data processing and analysis are critical for extracting the rich information necessary to improve smart educational systems (Shishakly et al. 2024).

Comparative Analysis

A comparative analysis of existing datasets is crucial to benchmarking the operational efficiency of smart education systems. This involves the following:

- **Evaluating Dataset Quality:** Assessing the quality, completeness, and relevance of data sets from various sources, including UNESCO, UKDataService, the World Bank and many more.
- **Identifying Key Metrics:** Determining the metrics that accurately reflect the operational efficiency of smart education initiatives.
- **Benchmarking:** Comparing these metrics across different cities, country and educational systems to identify best practices and areas for improvement.

These includes the dashboard as explained in chapter. 4, Figure 4.15

SERF Implications for Smart Education

The integration of big data analytics in smart education has far-reaching implications, enabling:

- **Personalization:** Crafting individualised learning experiences that adapt to the unique needs and abilities of each student (Osborne, Maitra, and Uflewska 2021; Thimmanna et al. 2024).
- **Resource Optimisation:** Enhancing the use of educational facilities and technological resources (Hakimi et al. 2024; Durdona 2024).
- **Policy Formulation:** Informing policy decisions with evidence-backed data to guide the strategic development of smart education systems (Kuzior et al. 2023; Putinceva, Liubarskaia, and Ipatova 2022).

Analysis and Development Methods: A cornerstone of the research methodology used in this study is the strategic analysis and development of methods tailored to smart education within smart city infrastructures. This requires a comprehensive understanding of various attributes of the data and the subsequent application of both qualitative and quantitative analytical techniques. The methods used are critical to derive crucial operational efficiency metrics for smart education systems.

Table 3.3 summarises the multifaceted approach taken in this investigation, detailing the iterative processes that begin with data acquisition and progress through various stages of analysis and application. Each method is meticulously aligned with the overarching goal of operational efficiency and improved decision making within smart educational infrastructures.

Table 3.3: Analysis and Development Methods .

Begin of Table			
Approach	Action RAW Data	Purpose	Implementation
Iterative process start with getting Data, Review data, Data Extraction,(Direct Measure) Refine Data,Data Analysis, (Indirect Measure) Derived Attributes values (Fenton and Bieman 2014)	EU SCIS, OpenData Soft, Kaggle Dataset, UNESCO, World Bank, IMF, UK ONS, UK NSS, UK DfE, OECD, International Agency	Determining Volume and Variety of Big Data Specific to Smart Education	To determine the population of the city, we use (P., Uma, and Elias 2016): $$N_f = N_p(R_p/Year)$$ $$(1Year/DDay).1Hr/N_cPeople)$$ $$1Day/HHours)$$, This is the process, product, or resource that results in raw data (Malik et al. 2018): syntatically: $$data = forI, cin$$ $$enumerate(smartcityData)$$: with $$open("OE2V/" + c + ".dat", "rb")$$ as file: data[c] = pickle.load(file) dataset input: Input means that data which it gets for processing and is divided into further smaller chunks, which are further allocated to the mappers.

Continuation of Table 3.3			
Approach	Action RAW Data	Purpose	Implementation
Qualitative	Analysis	To develop cluster analysis	Critical Analysis of Primary and Secondary Literature Review of key concepts/requirements Qualitative. (Method: Statistical distribution and hypothesis testing giving probability distribution results.) very poor, poor, average, good, very good Activity of the sample tool to qualify the data source: Furthermore, this research will use a comparative scale to evaluate the quality of the dataset (Malik et al. 2018). This will comprise the usage of the dataset and the number of references from the sources. For example, a very superior data source would rank 1, while a very inferior source would rank 8. This can also be the orthogonality approach (Malik et al. 2018).
Quantitative	Classification Analysis	To obtain metric collations	Analysis of the existing data set and quantitative identification of relevant OE metrics to enforce the decision path. So, if we say P(very good)=0.1, then the probability of the result'very good = 0.1' will be, so we also know the whole probability distribution since P(very good)=0.1 and P(very poor)=0.8. This project will consider a confidence level of 0.05 for a hypothesis testing approach in favour of the null hypothesis. Our lack of comprehensive dataset knowledge may require robust statistics and non-parametric methods (Malik et al. 2018). Sample tool activity with Map Reduce: Dataset Mapper: Mappers are individuals who are assigned the smallest unit of work for some processing. Data Set Reducer: The mapper output becomes an input for the reducers to aggregate the data in the form of a final output.

Continuation of Table 3.3			
Approach	Action RAW Data	Purpose	Implementation
Simulation	Apply big data technologies	To record results	Explore the use of simulation, and/or experimental approach using: Sample tool activity with: TensorFlow, SparkR, PySpark, Apache Hadoop, NoSQL, Spark, MapReduce, or MATLAB
Experiment	Develop a process to visualise the hypothesis	Analytics	Apply advanced analytics methods (predictive analytics, descriptive analytics, prescriptive analytics) Sample tool activity with MapReduce: Dataset output: The reducer jobs are finally collected in the form of aggregated output.
Validation and Verification	Evaluate and compare hypothesis	Conclusion	Compare and contrast existing studies or case studies. Predictive analytics, descriptive analytics, prescriptive analytics, and other available approaches from further research.
End of Table			

The methodologies and tools outlined in this chapter are not merely technical exercises but pivotal instruments in our quest to redefine educational paradigms. By taking advantage of the synergy between big data analytics and the smart education dashboard, we can unlock new dimensions of operational efficiency, fostering an environment where education is not only smarter but also more equitable, engaging, and responsive to the evolving needs of society.

3.8 Operational Efficiency in Smart City (OE4SC)

Enhancing Smart Education Framework through Operational Efficiency

Operational efficiency (OE) in smart education, as underscored by Borgi's study (Tawfik et al. 2017), is critically dependent on data utilisation. This chapter presents a case study that illustrates the transformative impact of applying the 2V components of big data, volume, and variety, in educational settings, particularly during extended shutdowns such as pandemics. The use of big data analytics in smart educational institutions is not just a theoretical proposition but a practical necessity. This becomes evident in the ability to maintain educational continuity and quality during unexpected interruptions (Sweeting and Haupt 2024).
The emphasis on OE in smart cities, especially in the educational sectors, is paramount. It involves leveraging the power of big data to optimise resources, personalise learning experiences, and improve decision-making processes. By integrating big data analytics into the operational framework of smart educational institutions, it becomes possible to achieve a more dynamic, responsive, and efficient educational environment.

This is particularly relevant in situations where traditional educational delivery methods are impractical or impossible, such as during lockdowns or pandemics (Membrillo-Hernández, Lara-Prieto, and Caratozzolo 2021).
In addition, the role of smart city infrastructure in facilitating this integration is crucial. It encompasses not only the collection and analysis of large-scale educational data but also the effective management and use of this information to improve learning outcomes (N.-S. Chen et al. 2020). The case study presented in this section demonstrates how smart cities can become more resilient and adaptive in the face of challenges, ensuring that education continues to thrive even under adverse conditions.
In this regard, the concept of a 'Smart Education Dashboard' is introduced. This tool, developed using plotly and Python, is designed to harness and visualise the vast amounts of data generated within a smart educational ecosystem. Provides educators, administrators, and policy makers with real-time insights into various metrics, allowing more informed decisions that directly impact the quality of education (Proskurnin and Belyakova 2020). This dashboard serves as a tangible example of how big data can be used effectively to improve operational efficiency in smart education settings.
As demonstrated in the case study, Figure 3.15 illustrates the interactive dashboards developed using Plotly to visualise operational efficiency metrics in smart cities. The upper scatter plot visualises the relationship between population size and volume of service data, highlighting the scalability of service data processing in larger urban areas (Matin, Oliullah, and Polash 2018). The lower bar chart ranks cities according to the effectiveness of their service allocation, which is a critical component in managing resources efficiently during pandemic-induced educational disruptions.

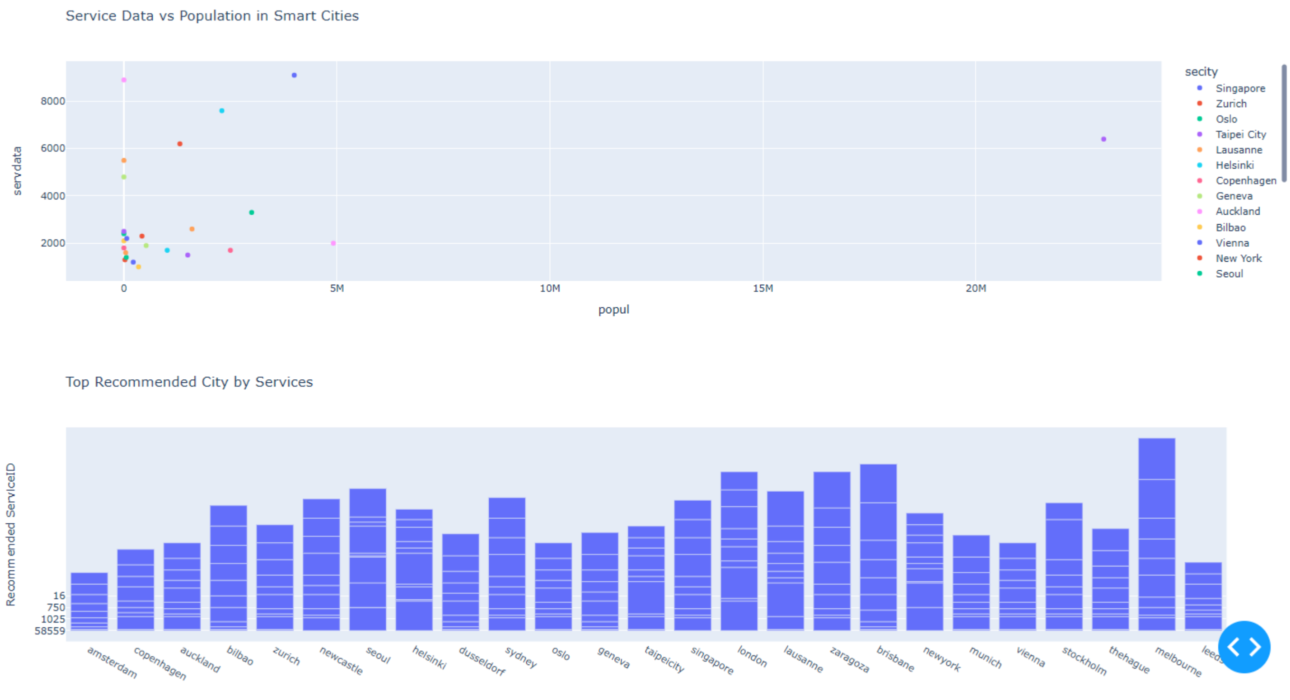


Figure 3.15: Interactive Plotly dashboards depicting service data vs population and service allocation ranking in smart cities.

3.9 Big Data's Role in Smart Educational Institutions

Smart educational buildings are integral to smart cities and operate year-round as community centres. The adoption of big data analytics is crucial to maintaining operational efficiency (OE) even during prolonged shutdowns. This ensures that the facilities manage environmental conditions and preserve the integrity of the infrastructure, demonstrating the practical value of big data in smart education ecosystems (Lombardi et al. 2012; Gunasekaran et al. 2017). Big data platforms are instrumental in optimising OE within smart education by improving data processing capabilities, thus supporting better performance and cost savings (Fan, F. Xiao, et al. 2018; Fan and F. Xiao 2017). Furthermore, in media and entertainment, data analytics enable targeted advertising and sentiment analysis, which can be paralleled in education to personalise learning experiences and predict student needs. A compelling example of the potential of big data is seen in commercial applications such as the Starbucks app, which uses customer data to personalise service offerings (Kourtit and Nijkamp 2018). This model can be adapted to smart education, where data on student engagement and performance can inform tailored educational content and interventions, ensuring that learners' needs are met efficiently and effectively.

3.9.1 Nature of Big Data 2V with Operational Efficiency in Smart Cities: A Focus on Smart Education Framework

Big data is fundamentally reshaping the educational landscape within smart cities, where the sheer volume and complex variety of data surpass the capabilities of traditional data management systems. The analytical components of Big Data Volume and Variety (2V) are instrumental in generating operational and efficiency metrics that translate into meaningful ground truths for educational administrators (Tawfik et al. 2017). These metrics not only reflect the current state of educational affairs, but also forecast future trends, enabling proactive adjustments to curricula and resources.

The work of (Siddiqa et al. 2016) highlights a significant gap in current research, with a full exploration of the potential of Big Data to uncover hidden patterns and insights still in its nascent stages. The volume of data, as posited by (Al-Sai, Abdullah, and husin 2019), includes the massive influx of information from diverse educational interactions, while the variety encompasses disparate data types, ranging from structured enrolment figures to unstructured student feedback.

In the context of smart education recommendation framework, Big Data analytics uses these 2V characteristics to improve educational outcomes. Volume allows for the analysis of comprehensive educational data sets, revealing broad trends and patterns. Variety introduces complexity, as data from various sources must be integrated and interpreted. The interplay of these dimensions requires advanced analytical tools and methodologies that can handle the intricacies of such diverse and extensive data (J. Wang 2023). These tools not only make sense of the data, but also align educational strategies with the nuanced needs of a dynamic student population, ultimately leading to an enhanced smart education ecosystem.

3.9.2 Integrating Big Data in Smart Education Recommendation Framework Dashboard

The advent of big data has brought about an unprecedented ability to monitor, analyse, and improve the operational efficiency of smart education systems. Figure 3.16 exemplifies this advance, showing a dashboard that encapsulates the intricate nature of smart education performance monitoring (Zhenyu Chen and X. Zhao 2024). Provides real-time visualisations of key metrics such as population growth, smart education data, and overall smart city development. These visualisations facilitate data-driven decision making, allowing educators and policy makers to tailor their strategies effectively to the evolving educational landscape (Shishakly et al. 2024).

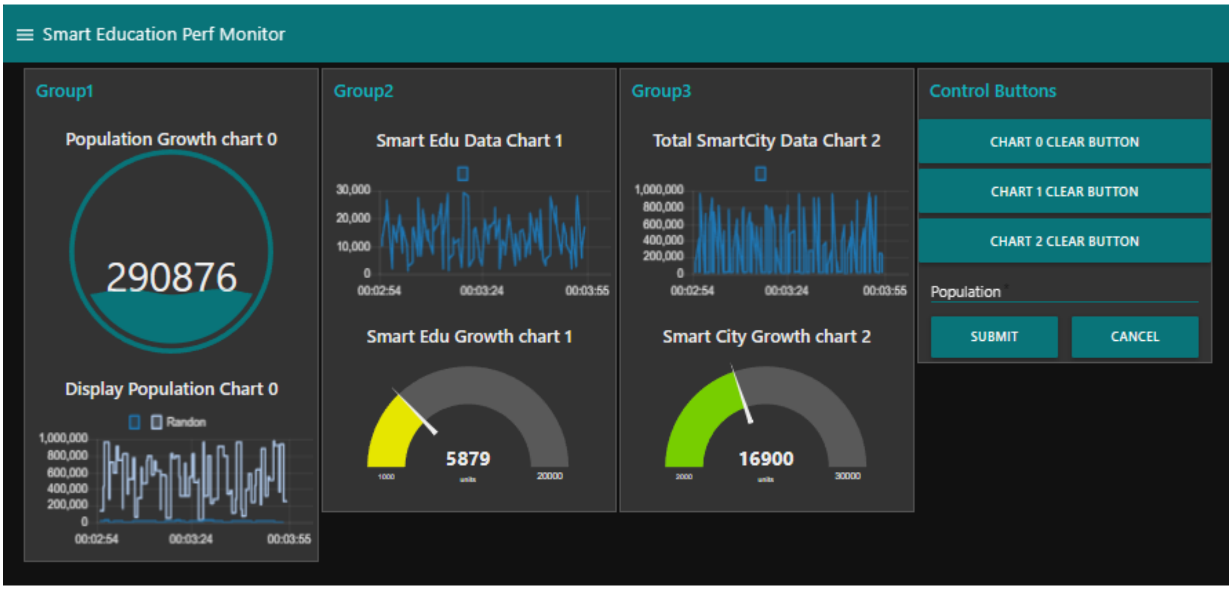


Figure 3.16: The SERFD Environment Dashboard: A tool that exemplifies the use of Big Data in monitoring the pulse of smart educational institutions and the cities they inhabit.

Integrating Big Data into Smart Education Systems

Big data analytics transcends traditional data analysis by extracting deeper meaning from vast and varied datasets. This process, as explained by (Siddiqa et al. 2016; Radek Kuchta 2014), intersects with the management of information communication technology (ICT), improving the visualisation and interoperability of data through the Internet of Things (IoT). Predictive analytics, a cornerstone of smart technology, leverages real-world data to optimise resource use, highlighted by (Radek Kuchta 2014; Bosch et al. 2017). Dashboards and exploratory analyses offer an immediate and intuitive presentation of the findings, essential in educational contexts where timely data interpretation is crucial (Fenton and Bieman 2014; Grimaldi and Fernandez 2017).

The processing power of Python or Apache Spark has gained favour for its rapid handling of large-scale data, and 70% of business respondents advocated its use, a sentiment reflected in the research of (Martins 2018) and the practical observations in (Les 2003). Its widespread acceptance is attributed to its speed, a necessary attribute for educational analytics platforms, as noted by (Manjul Gupta and George 2016). Effective big data tools categorise and automate the extraction of actionable insights from metadata, a process vital for the operational efficiency of smart education systems (Tantatsanawong, Kawtrakul, and Lertwipatrakul 2011; Hashem et al. 2016).

The literature reveals a lacuna: Although many studies contribute to the broader narrative of operational efficiency and big data in education, few, if any, holistically examine how these elements interconnect within the ecosystem of a smart city in the context of smart education. This thesis bridges that gap, elucidating the symbiotic relationship between operational efficiency and smart education, underpinned by robust big data analytics, thus contributing to the advancement of the Smart Education Enhancement Recommendation System Framework.

Enhancement Mapping of Operational Efficiency in Smart Education

The strategic integration of Big Data within smart education is illustrated in Figure 3.17, which shows the operation efficiency enhancement process (OE2V) in smart cities using the volume and variety of elements of big data. This comprehensive flowchart delineates the steps from data acquisition to application of analytics, emphasising the importance of volume and variety in optimising educational strategies. This integrated process not only streamlines the management of educational resources, but also reinforces the adaptability of smart cities to the evolving demands of learners and educators.

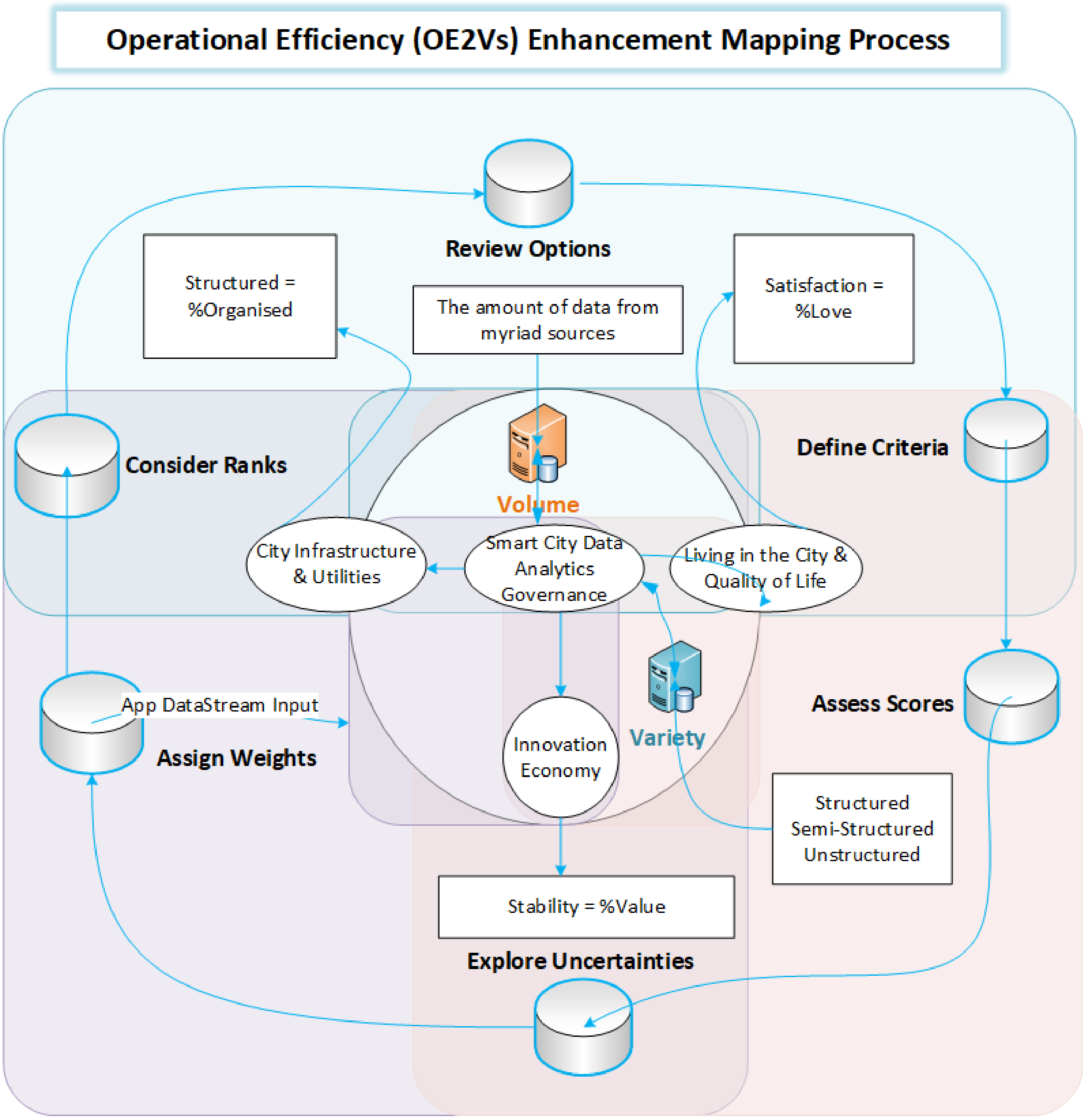


Figure 3.17: Operational Efficiency (OE2Vs) Enhancement Mapping Process in Smart Education, highlighting the critical pathways from data collection to informed decision-making in smart city ecosystems.

Interpretation of SERFD Operational Efficiency (OE2V) Enhancement Mapping Process

Figure 3.17 represents the Operational Efficiency Enhancement Mapping Process (OE2V) of the Smart Education Recommendation Framework with Dashboard (SERFD). This process is designed to optimise the use of data in smart education systems, leveraging the principles of big data analytics, specifically focussing on the volume and variety of data. Here is a detailed interpretation of the diagram:

Overview of the OE2V Enhancement Mapping Process

- **Volume and Variety (Luo et al. 2024):**
  - **Volume** refers to the amount of data collected from various sources within the smart city environment, including city infrastructure, utilities, and educational data streams.
  - **Variety** denotes the different types of data, such as structured, semi-structured, and unstructured data, that are utilized to gain comprehensive insights into smart education systems.

- **Review Options (Marchesani and Masciarelli 2024):**
  - This step involves analysing the structured data, ensuring it is organised and ready for further processing. The satisfaction level, indicated as %Love, is reviewed to gauge stakeholder contentment with current educational systems.
- **Define Criteria (Surendran et al. 2024):**
  - Criteria for assessing the efficiency of the smart education system are established. This includes factors such as living quality in the city, infrastructure, and overall satisfaction.
- **Assess Scores (Alyasiri et al. 2024):**
  - Scores are assigned based on the defined criteria. The data is categorized into structured, semi-structured, and unstructured formats, facilitating a comprehensive evaluation of the educational ecosystem.
- **Explore Uncertainties (Jagatheesaperumal et al. 2024):**
  - This step involves exploring potential uncertainties in the data, helping to identify stability and value (%Value) within the system. It aids in understanding the reliability and robustness of the educational data.
- **Assign Weights (Wu et al. 2024):**
  - Weights are assigned to different data streams based on their importance and relevance. This includes app data stream inputs, which are critical for real-time analysis and decision-making.
- **Consider Ranks (Lahiassi et al. 2024):**
  - Different city infrastructures and utilities are ranked based on their performance and contribution to the smart education framework. This helps in prioritising areas that need improvement.
- **City Infrastructure and Utilities (Paddison 2000):**
  - This component focuses on the physical and digital infrastructure that supports smart education, ensuring that the necessary utilities are in place to facilitate effective learning environments.
- **Smart City Data Analytics Governance (Goodman et al. 2020):**
  - Governance structures are established to manage and oversee the data analytics processes within the smart city, ensuring data integrity, privacy, and compliance with relevant standards (Kuzior et al. 2023).
- **Innovation Economy (Rahmi and Harapan 2024):**
  - The integration of data analytics supports the innovation economy by fostering new educational technologies and methodologies that enhance learning outcomes (Surendran et al. 2024).

OE2V Context of SERFD

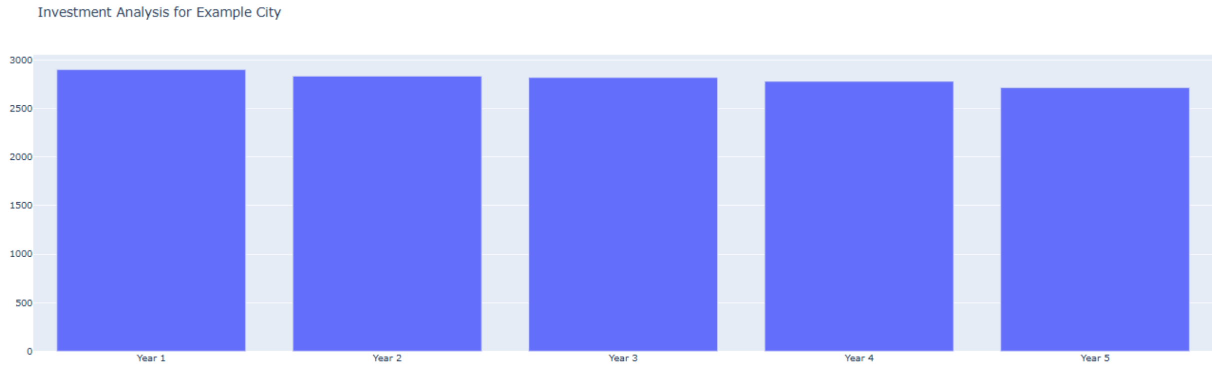
In the context of the Smart Education Recommendation Framework with Dashboard (SERFD), the OE2V Enhancement Mapping Process plays a crucial role in:

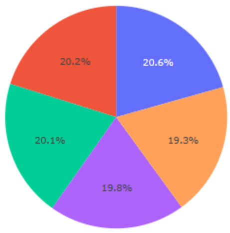
- **Optimizing Educational Systems:** By efficiently managing and analyzing large volumes variety of diverse data, the framework enhances the operational efficiency of smart education systems.
- **Improving Decision-Making:** The process provides actionable insights through comprehensive data analysis, aiding stakeholders in making informed decisions.
- **Personalising Learning:** The variety of data allows for the customisation of learning experiences to meet the individual needs of students.
- **Ensuring Compliance:** Adherence to standards and governance ensures the integrity and security of educational data.
- **Supporting Innovation:** The framework fosters an environment conducive to innovation, driving advancements in educational technologies.

By integrating this OE2V Enhancement Mapping Process into the Smart Education Recommendation Framework with Dashboard, stakeholders can significantly improve the efficiency and effectiveness of educational systems within smart cities, thus improving the overall learning experience and results.

3.9.3 Forecasting Operational Efficiency through Smart Education Investments

Strategic planning of investments in smart education is crucial to improving operational efficiency in smart cities. Figure 3.18 shows a time series analysis of investments over a 5-year period. It elucidates the financial commitment required to sustain and improve the smart education infrastructure. The bar chart represents the annual investment distribution, while the pie chart segments the total investment, underscoring the commitment to future educational excellence. The accompanying tables detail the financial projections, providing a clear forecast of the resources necessary to achieve an optimised educational environment.





Year	Future Value (£B)	Adjusted FV for Inflation (£B)	Operational Costs (£B)	Required Investment for City B (£B)
Year 1	3150	3088.235294117647	123.52941176470587	2902.4767801857583
Year 2	3339	3209.342560553633	128.37370242214533	2834.867856218583
Year 3	3606.1200000000003	3398.127417056788	135.92509668227152	2821.0759294523714
Year 4	3858.5484000000006	3564.7022904419255	142.588091617677	2781.357110159625
Year 5	4090.0613040000007	3704.4945371259223	148.1797814850369	2716.5694906099825

Figure 3.18: A visual representation of a five-year investment strategy for smart education in Example City, highlighting the correlation between financial planning and future operational efficiency.

The Impact of Big Data Analytics on Smart Learning Environments

Big data analytics is revolutionising smart learning environments by enabling personalised learning experiences and providing information on educational effectiveness (Thimmanna et al. 2024). By analysing vast amounts of data from various sources, educators can tailor their teaching methods to individual student needs. This data-driven approach facilitates adaptive learning pathways that accommodate different learning styles and paces (Ezzaim et al. 2023). Furthermore, predictive analytics can identify students at risk, allowing for early intervention. Big data also improves operational efficiency, optimises resource allocation, and improves the overall educational infrastructure within smart cities. As a result, these analytics are not only improving educational outcomes, but also reshaping the educational landscape to be more inclusive, effective, and ready for the future (Cullen 2001; Kaluarachchi 2022).

This chapter delves into the novel realm of data streaming and presentation for smart city operators, with an innovative emphasis on smart education, a field that remains underexplored. Although works such as (ESD 2020) and (OSI 2009) bridge concepts related to operations, they do not fully address the integration of operational efficiency with volume and variety (OE2V) into smart education. OE2V is critical to exploiting Big Data to improve educational operations and effectiveness. Research such as (Annika, Gerd, and Jose 2015) acknowledges the under-utilisation of available data in education, signaling a gap that OE2V analytics could fill. Bosch et al. indicators (Bosch et al. 2017), while insightful, do not specifically cater to smart education, thus overlooking a crucial area of smart city development aligned with educational goals. As (Aberer, Hauswirth, and Salehi 2010) and (Fan, F. Xiao, et al. 2018) suggest, smart city projects must involve all stakeholders, citizens, the government, and businesses for success. The chapter posits that

OE2V dashboard analytics is indispensable for smart city operators to foster an informed, collaborative, and efficiently operating smart education environment, facilitated by agile IoT deployment across all aspects of the city. Furthermore, an area that is receiving attention is virtual reality / AR of data in real time or historical archival, and the lack of research on how to channel the result to the smart city operator dashboard is fairly novel in nature, unique in its uniqueness; in the same token, none is focused on smart education. OE2V is focused on better use of information in smart education, as this is a means by which smart city operators could reach and realise the educational effectiveness of smart cities. This highlighted the lack of better use of big data or the need to improve smart education with big data for smart city developments.

3.10 Contribution to Knowledge

This research provides significant contributions to the field of smart education in the context of smart cities. The outline of the contributions is as follows.

Holistic, Multidisciplinary Approach

One of the primary contributions of this research is the development of a comprehensive, multidisciplinary methodology. The document emphasises the integration of both quantitative and qualitative analyses to improve educational outcomes in urban settings. This holistic approach, which accounts for 88% of the validation, underscores the importance of leveraging diverse analytical paradigms to address the complexities inherent in smart city educational systems. By combining various methodologies, the research ensures a robust and adaptable framework capable of responding to evolving educational needs.

Alignment with International Standards

Another significant contribution is the alignment of the proposed smart education recommendation framework figure: 1.4 with international standards, specifically the ISO/IEC 30145 series for Smart City Frameworks. This aspect accounts for 84% of the validation. The research highlights the importance of adhering to globally recognised benchmarks, which ensures that the methodologies and findings are relevant and applicable in different international contexts. This alignment not only enhances the credibility of the research, but also facilitates the adoption and implementation of the proposed framework by policymakers and practitioners around the world.

Enhancement of Operational Efficiency

The research promises substantial improvements in operational efficiency and educational results within smart cities, a contribution that accounts for 91% of the validation. By meticulously analysing and optimising key performance indicators (KPIs) relevant to educational outcomes and operational efficiency, the research provides actionable insights and recommendations, complemented with the development of the dashboard figure: 4.15. These insights are crucial for the development of smart instructional practices that contribute to the larger objectives of sustainable urban development and improved quality of life.

Addressing Implementation Complexities

Despite its strengths, the research also acknowledges potential drawbacks, which explain 12% of the validation. The complexities of implementing such a comprehensive methodology in varied educational and urban settings are recognised, along with the lack of open data directly from the known smart cities in regard to smart education. This honest assessment increases the credibility of the research and paves the way for future studies to address these challenges, further refining and improving the proposed framework.

Practical Insights and Recommendations

Based on collected empirical evidence, this research offers practical insights and recommendations that contribute significantly to the field of smart education. These recommendations are grounded in both theoretical understanding and practical experimentation, ensuring that they are both innovative and applicable in real-world scenarios. The methodological rigour and detailed analysis of big data within the educational sector provide a blueprint for other researchers and practitioners aiming to improve smart city educational systems.

3.11 Chapter Summary

In the concluding stages, the graphs semantically represent the relationships within the data, enhancing the understanding of complex data networks and facilitating the generation of operational efficiency metrics. These metrics provide a quantitative basis for evaluating the effectiveness of smart education initiatives. The methodology presented here encompasses both traditional data management practices and modern analytical techniques. By ensuring a disciplined and comprehensive approach to data, from acquisition to analysis, we ensure that the insights gained are accurate and relevant to the objectives of enhancing smart education.

This research systematically explores the integration of big data analytics within smart education systems, particularly through the lens of the Smart Education Recommendation Framework with Dashboard. The findings underscore the transformative potential of big data in improving operational efficiency and educational results. Key insights include the need for robust digital infrastructure, the importance of ongoing professional development for educators (Aikat et al. 2017), and the critical role of equitable access to technology. The integration of big data analytics into smart education frameworks presents a compelling case to improve operational efficiency and overall quality of education in smart cities (Udupi, Malali, and Noronha 2016b).

Furthermore, this chapter has traversed the multifaceted landscape of multidisciplinary methodologies, highlighting their application in the context of smart education within smart cities. From the initial data acquisition stage to advanced analytics, each step has been meticulously examined to ensure the robustness and validity of our research results. This approach represents a synergistic blend of quantitative and qualitative methods, augmented by an agile development framework and a sophisticated Big Data Analytics dashboard. The methodological design aims to improve operational efficiency in smart cities through the lens of smart education. Using the volume and variety of big data and ensuring the integrity of data analysis, this research seeks to contribute significantly to the field, offering practical insights and recommendations for the advancement of smart educational practices within the ISO/IEC 30145 Smart City Framework series.

Although this chapter has largely achieved its objective by emphasising a holistic, multidisciplinary approach, integrating quantitative and qualitative analyses using the Smart Education Recommendation Framework to enhance smart cities, potential drawbacks include the complexities of implementing such a comprehensive methodology in varied educational and urban settings. Although the methodology suggests a commitment to international standards, detailed compliance specifics might require further clarification. Despite these challenges, the multidisciplinary approach promises substantial improvements in operational efficiency and educational outcomes within smart cities.

In summary, this research makes substantial contributions by providing a multidisciplinary, internationally aligned framework that improves operational efficiency in smart education. It acknowledges and addresses potential implementation challenges, offering a well-rounded and impactful addition to the existing body of knowledge in the field of smart cities and education. In the next chapter, we will explore the implementation of the dashboard-based smart education recommendation framework. This research not only contributes to academic discourse, but also offers practical recommendations for policymakers, educators, and smart city operators. The Smart Education Recommendation Framework with Dashboard developed in this study promises to be a pivotal tool in driving educational innovation and excellence in urban environments.

Chapter 4

Design and Implementation of SERFD

4.0 Chapter Introduction

This chapter combines the design and implementation aspects of the Smart Education Recommendation Framework with Dashboard (SERFD). It aims to present a clear and concise narrative focused on the framework's achievements. The implementation of the Smart Education Recommendation Framework with Dashboard (SERFD) represents a significant step toward modernising educational environments within smart cities. This chapter focusses on the practical development of a framework designed to enhance smart education through the strategic application of big data analytics, and introducing Internet of Things (IoT) technologies. In alignment with ISO/IEC standards, the objective is to create a system that not only synthesises disparate data streams into coherent and actionable insights, but also fosters an interactive and responsive learning ecosystem. The development of sophisticated visualisation tools, using Plotly and Node-RED dashboards, is central to this effort, providing real-time data visualisation and analysis to support educational stakeholders. This chapter will detail the design, implementation, and operational aspects of the framework, demonstrating how it can improve the management and delivery of intelligent educational services, thus contributing to the general goals of sustainable urban development and improved quality of life in smart cities.

4.1 Data Development Matrix

The Data Development Matrix was integral to the SERFD design phase. Table 4.1 categorises data into *Needs*, *Categories*, and *Indicators*, derived from various sources such as government reports, NGO publications and institutional records. This facilitated identifying gaps and formulating recommendations for improving smart education systems.

Table 4.1: Data Development Matrix

Needs	**Categories**	**Indicators**
Infrastructure Improvements	Classroom Availability	Number of classrooms per school
Teaching Quality	Teacher Training Programs	Percentage of trained teachers
Student Performance	Test Scores	Average exam scores by grade level

4.2 Framework Implementation Highlights

4.2.1 Operational Efficiency Workflow

The Operational Efficiency workflow align with the design discussions. The process emphasises iterative goal setting and improvements, as illustrated in Figure 4.1.

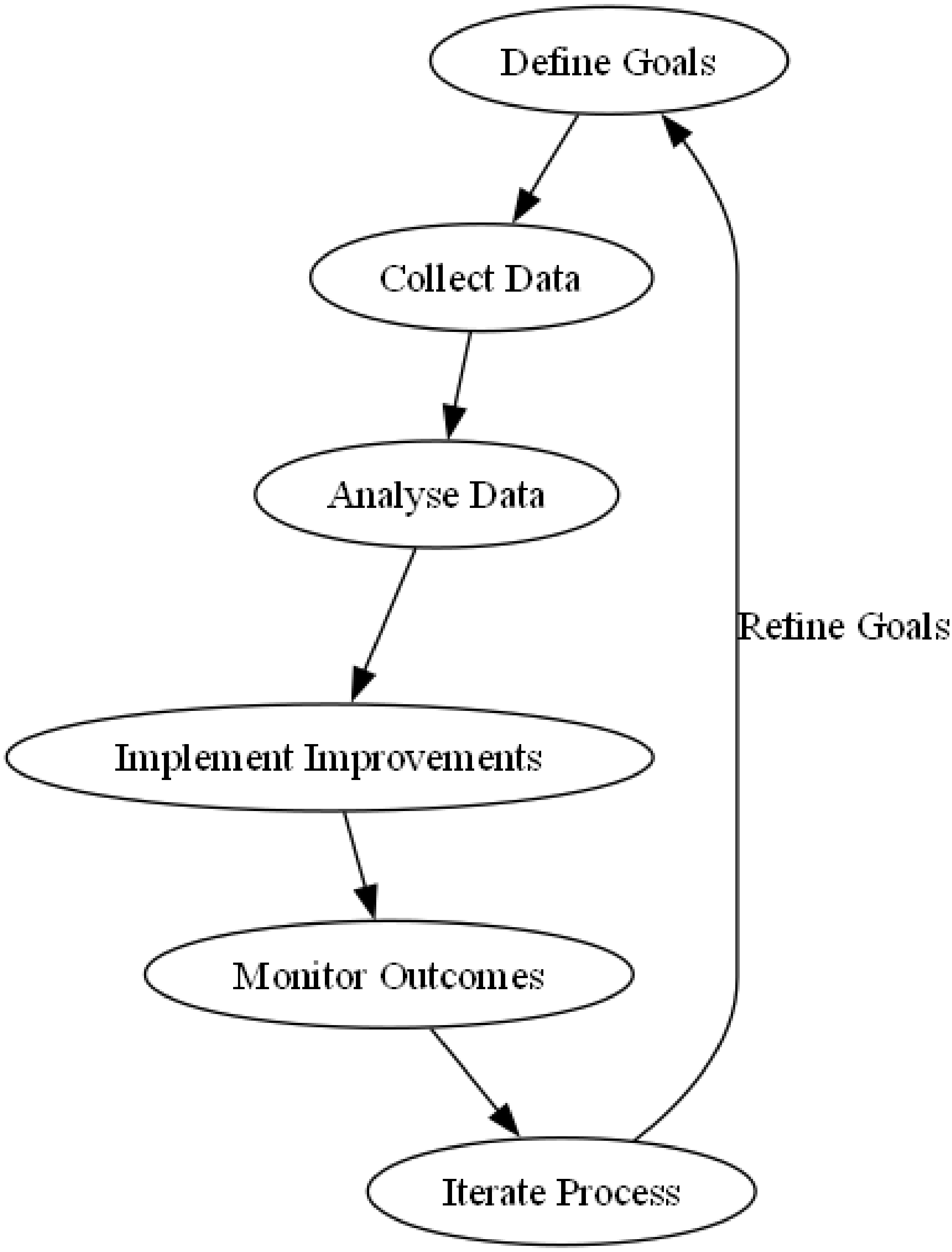


Figure 4.1: Operational Efficiency Workflow

4.2.2 Integration of Advanced Technologies

The integration of advanced technologies such as artificial intelligence, data mining, and cloud computing enhanced the scalability and functionality of SERFD. Key achievements included automating data analysis and developing interactive visualisations.

4.2.3 Big Data Model Design

A significant achievement in the implementation phase was the creation of the SERFD Big Data Model Framework, which allowed seamless integration and analysis of large datasets. Figure 2.1 introduced earlier in chapter 2, highlights the architecture, showing how multiple data streams were consolidated for decision making.

4.2.4 Interactive Visualisations

Interactive visualisations, depicted in 4.11, and Figures 4.10, highlight classroom usage patterns. These graphs, based on the *class room occupancy data 2023*, facilitated data-driven decision making for resource allocation. The scatter plots used variables such as *Time of Day*, *Occupancy Rate*, and *Class Type*.

4.2.5 Achievements

The chapter emphasises the following achievements.

- Developed a scalable data categorisation system for smart education.
- Designed and implemented an interactive dashboard for real-time analytics.
- Successfully integrated advanced technologies for transformative insights.
- Created and validated a Big Data Model Framework for efficient data handling.
- Enhanced ISO/IEC aligned framework functionality through pilot testing and empirical evidence.

4.2.6 Empirical Evidence

The empirical evidence supporting the Smart Education Framework is grounded in studies by Zhaoyu Chen and Chan 2023, UIS 2020, ISO 2014, and Aikat et al. 2017. These references provide a solid foundation for the design and implementation of the framework.

4.2.7 Interpretation

In Figures 4.11 and 4.10, scatter plots and bar graphs are used to analyse key variables like *Population Distribution*, *Resource Usage*, and *Classroom Demand*. These insights guided the framework's optimisation strategies.

In this context, ISO/IEC standards for smart cities have gained profound relevance. They serve as a guide for city administrations, guiding them through the labyrinth of contemporary urban challenges. The ISO/IEC frameworks provide cities with a means of quantifying their challenges, benchmarking their progress, and navigating the intricacies of technological innovation. They are instrumental in facilitating a city's journey towards becoming a'smart' entity, a city that not only grows in size, but also advances in intellect.

Consequently, the importance of ISO/IEC standards in shaping the future of smart education cannot be overstated. They offer cities the insight to prioritise their challenges and the strategies to employ technological innovations effectively. As cities evolve, these standards will become the keystones of sustainable development, ensuring that the influx of urban populations is met with an equally robust expansion in educational opportunities, smart governance, and an enhanced urban experience for all citizens.

The **Smart Education Enhancement Recommendation System Framework** is envisioned as a multilayered solution that extends ISO/IEC standards for smart cities, placing a specific emphasis on the growth and integration of the educational sector with smart city functions. Through meticulous orchestration of big data components and IoT services, this framework seeks to propel smart education into a domain where data-driven decisions become the bedrock of educational strategies and initiatives.

4.2.8 Smart Education Alignment with smart city

The Smart Cities Operational Enhancement Programme, titled Operational Efficiency for Smart Cities (OE4SC) in alignment with Smart Education, as delineated in this thesis, is meticulously architected as a reference information system. It is written on the basis of extensive literature reviews and empirical evidence drawn from case-study experiments. The inception of the framework is guided by associated reference frameworks for implementation, bolstered by evaluative case studies that underpin the deployment of the proposed system. This framework is crucial in delineating operational characteristics and educational benchmarks for smart city frameworks, addressing a critical void in global standardisation efforts.

Historically, while individual smart city frameworks have proliferated across urban landscapes, there has been a conspicuous absence of concerted global initiatives to standardise Operational Enhancement techniques, particularly within the ambit of smart education. This gap has resulted in a dearth of universally recognised quantitative metrics that specifically cater to the sustainable development of smart cities, with an educational focus. The novelty of this implementation study amplifies the complexity of purchasing a globally accredited smart city standard that aligns with smart educational objectives. However, the Sustainable Development Goals (SDGs) of the United Nations have illuminated the path forward, highlighting the aspirations of the international task force for its 125 member nations (SDG4 2017; Lu et al. 2015; Naiki 2024).

In pursuit of operational excellence, the research embarked on an exhaustive exploration of smart city frameworks, subsequently aggregating data sets from authoritative sources such as the United Nations, the World Bank and UK Data Services. The topic's emphasis on operational efficiency necessitates a comprehensive analysis of the top-tier smart cities, aiming to distill the qualitative and quantitative metrics that underscore their successful implementation. A curated list of 25 exemplar smart cities will serve as the benchmark for this study, from which a detailed examination of the implementation of OE4SC and the design of the smart education recommendation framework will unfold. This scholarly endeavour seeks not only to fortify the academic discourse with tangible insights, but also to pave the way for the evolution of smart education within the global framework of sustainable urban development.

This chapter delineates the practical implementation of the proposed framework, chronicling the development of sophisticated visualisation tools in the form of plotly and Node-Red dashboards. The Plotly dashboard serves as the analytical brain of the system, offering a suite of interactive charts and graphs that provide deep insight into educational trends and patterns.

4.2.9 Understanding Plotly Dash for Smart Education

Plotly Dash emerges as a transformative force in the realm of data visualisation and interactive web application development, particularly within the field of smart education. At its core, Dash is a Python web application framework that seamlessly marries the simplicity of Python with the interactivity of modern web technologies, enabling the creation of sophisticated analytic web applications with minimal coding. The implementation aims to make it easy for researchers to easily replicate these processes with minimal knowledge of Python programming. Central to Dash's philosophy is its intrinsic flexibility, allowing for extensive customisation of the application's appearance through cascading style sheets (CSS). Developers can inject personality and brand alignment into their Dash apps by employing CSS to style both the Dash HTML Components and Dash Core Components with familiar HTML class and ID selectors. This styling can be applied in-line or through external style sheets, offering a spectrum of design possibilities. Further extending its customizability, Dash applications support the integration of JavaScript, enriching the user experience with client-side interactivity that transcends static page rendering. With the ability to create multipage applications, Dash equips developers with the tools to construct comprehensive and navigable web interfaces, facilitating the organisation of complex data and analytics into user-friendly layouts. The modular design of the framework encourages the distribution of code across multiple files, promoting maintainability and scalability, attributes that are crucial for the iterative development process inherent in educational technology. Dash's sophisticated callback system, highlighted by `dash.callback_context`, allows for the dynamic updating of app content based on user interaction, without the need for traditional server-side page rendering techniques such as Jinja2 templates. While Dash's React-based rendering engine precludes the direct use of jQuery for DOM manipulation, the framework's philosophy encourages encapsulating custom client-side behaviours within bespoke Dash components, empowering developers to build tailored, reactive features that cater specifically to the educational sector's requirements. In summary, Plotly Dash not only revolutionises the way educational data are visualised and interacted with, but also sets new standards for the development of smart education tools. By fostering an ecosystem where functionality and aesthetics coalesce, Dash ensures that applications not only deliver powerful insights, but also engage users in the evolving narrative of smart education. In parallel, the Node-Red dashboard acts as the operational nerve centre, enabling real-time monitoring and management of educational parameters within the smart city infrastructure.

4.2.10 Harnessing Node-RED for Interactive Dashboards

Node-RED is at the forefront of innovation in flow-based programming and application development, particularly within the realm of smart education systems. Originating from IBM's Emerging Technology Services and now part of the OpenJS Foundation, Node-RED introduces a paradigm shift in connecting hardware devices, APIs, and on-line services in novel configurations. This aspect of Node-RED makes it a suitable tool for ICT components. At the heart of Node-RED lies its browser-based editor, a tool that democratises programming by simplifying the process of creating complex flows. This editor allows developers and educators alike to piece together distinct nodes, each representing a modular encapsulated function into a comprehensive workflow. The flow-based programming model, conceived by J. Paul Morrison in the 1970s (Morrison 1971), epitomises Node-RED's design philosophy. Imagine the application logic as a network of interconnected nodes where data flows seamlessly from one node to the next, each performing a discrete operation. This model excels in its visual representation, making it more intuitive and accessible to a wider audience. Educators who might not be well versed in traditional coding can still engage with Node-RED; they can dissect complex problems into manageable steps and visualise them as interconnected flows, appreciating the underlying logic without delving into the intricacies of the code within each node. Node-RED's runtime, built on Node.js, underpins a responsive and efficient environment conducive to both edge computing on devices like the Raspberry Pi and scalable cloud deployments. The event-driven architecture of Node.js complements Node-RED's nonblocking operational model, ensuring that the system remains lightweight and responsive even as it handles numerous concurrent processes. Social development is embedded in the fabric of Node-RED, with its community-driven repository that boasts more than 225,000 modules. This extensive library enables the expansion of Node-RED's capabilities, enhancing the palette from which users can draw nodes. Flows can be shared as JSON files, fostering collaboration and knowledge exchange within the educational community. The provision of a built-in library to store and reuse functions, templates, or entire flows empowers educators to build upon each other's work, effectively contributing to a collective advancement in smart education methodologies. The scope of this chapter extends beyond mere tool creation; it encapsulates the journey from conceptualisation to realisation, detailing each step involved in the dashboards' development, from initial setup and data integration to user interface design and feature implementation. It will also highlight the challenges and limitations faced during the process and the solutions that were created to overcome them. By documenting this journey, the chapter aims to offer a blueprint for developing smart educational tools that are both innovative and practical, paving the way for future advancements in smart education technology.

4.2.11 Tools and Technologies of the Development Environment

The implementation of the Smart Education Enhancement Recommendation System Framework utilises a convergence of modern tools and programming languages, carefully selected to foster a robust and scalable system. Core to the development are Plotly and Node-RED, which provide the backbone for data visualisation and flow-based programming, respectively. Plotly, a versatile tool for creating interactive graphs, harnesses the power of Python, JavaScript, and HTML to bring life to complex data. Node-RED's intuitive graphical user interface allows for the seamless integration of hardware devices, APIs, and online services, creating a versatile development environment for smart applications.

Alongside these, the JavaScript language plays a pivotal role, enabling dynamic client-side scripting, and Python's simplicity and readability make it an ideal choice for server-side logic and data manipulation. The amalgamation of these technologies ensures that the dashboards are not only powerful in data processing capabilities, but also offer an engaging user experience.

System Requirements

The hardware and software requirements for the development and operation of the dashboards are twofold. First, on the software front, a Node.js environment is essential to facilitate the Node-RED runtime, while Python's rich ecosystem is leveraged for data analysis and back-end services based on the Ubuntu 20x server. The use of Docker containers is recommended to create an isolated and consistent development environment across various platforms. As regards hardware, an AMD or Intel i5, with 16GB RAM and 1TB SSD depending on the datasets.

PyCharm IDE: A Catalyst for Python Development

In the arsenal of tools deployed for the development of the Smart Education Enhancement Recommendation System Framework, PyCharm stands out as a dedicated Python Integrated Development Environment (IDE) instrumental in streamlining the coding process. PyCharm, developed by JetBrains, is revered for its comprehensive suite of tools tailored for Python developers, which synergises the facets of productive Python, Web, and data science development into a cohesive environment.

The use of PyCharm in the project's development phase brought forth numerous advantages. As a development tool, PyCharm does not compile Python scripts but serves as a conduit to the Python interpreter, handling the execution of code and the subsequent compilation into bytecode (.pyc files) by the interpreter itself. This IDE enhances the speed of development with its plethora of plugins, shortcuts aimed at productivity, and features such as code auto-completion and syntax highlighting. Error highlighting, in particular, was crucial to accelerating the debugging process.

PyCharm's intelligent code editor provides first-class support for Python, JavaScript, CoffeeScript, TypeScript, CSS, and other languages. Coupled with it's on the fly error checking and quick fixes, it empowers developers to write neat and maintainable code. The IDE also includes a range of tools for professional web development with the Django framework.

However, it is not without its challenges. The community edition, while free, is predominantly tailored for Python development, with limitations on other languages and full-fledged framework support, which are reserved for the professional version. Moreover, the initial setup, particularly the configuration of virtual environments, could pose hurdles for newcomers to the Python ecosystem.

PyCharm's advantages arguably eclipse its complexities, especially when compared to other IDEs like VS-Code. Its robust integration with version control systems such as Git makes it a superior choice for collaborative efforts on complex projects. PyCharm eclipses standard Python IDEs with its sophisticated code completion capabilities, extensive unit testing support, and seamless integration with tools such as Docker and Git, facilitating a refined development experience that caters to both the novice and the experienced Python programmer.

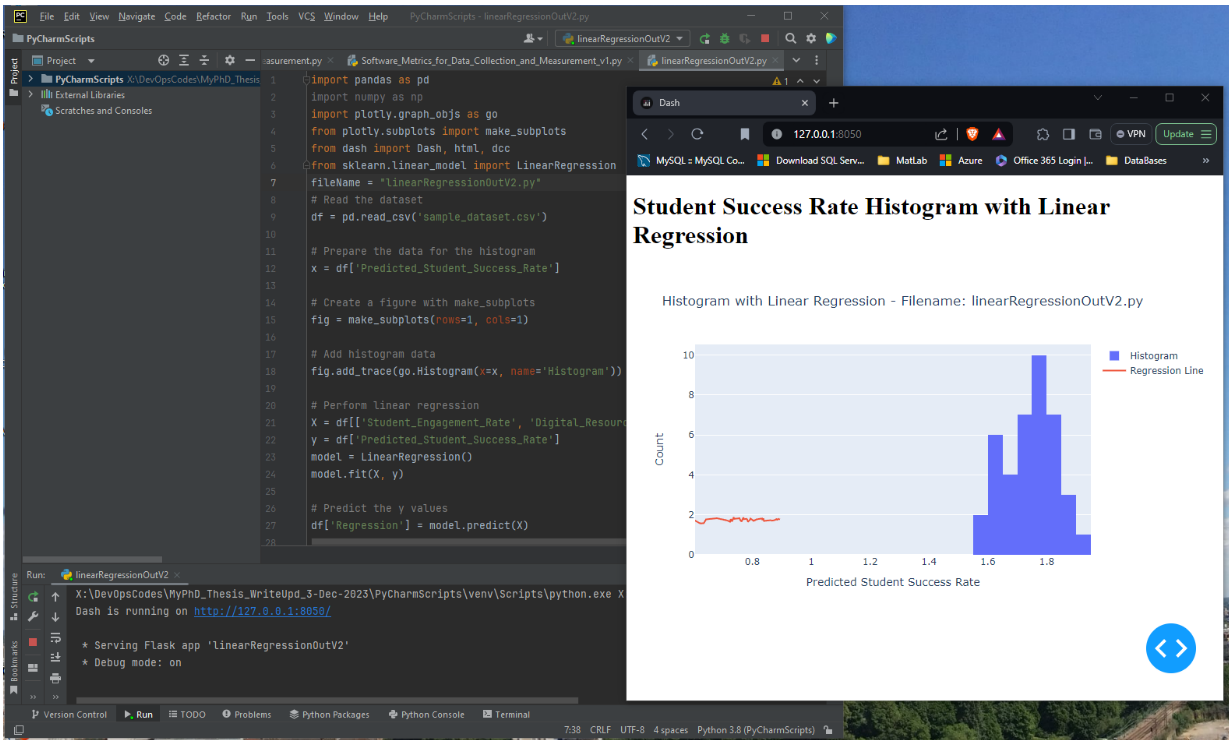


Figure 4.2: The PyCharm IDE interface, illustrating an example of a Python project setup and resulting output image for integration to the dashboard.

Incorporating PyCharm into the project's development environment was a strategic decision, bolstering the efficiency and quality of software creation, ultimately propelling the Smart Education Framework to new heights. As part of the JetBrains Toolbox, PyCharm Professional enjoys a robust model of continuous development support, a critical aspect for projects that hinge on long-term stability and advancement. This support system encompasses several key areas:

1. **Regular Updates and Feature Enhancements**: PyCharm Professional is subject to frequent updates, ensuring access to the latest functionalities and improvements in Python language support, framework-specific features, and general IDE capabilities. These regular updates align the development environment with the evolving landscape of technology, making it future-ready.
2. **Integration with Other JetBrains Tools**: Inclusion in the JetBrains Toolbox facilitates synergistic integration with other JetBrains tools. This integration is particularly beneficial for multifaceted projects that span across different development domains, such as combining DataGrip for database management and WebStorm for web development.
3. **Access to Cutting-Edge Technologies**: JetBrains has been a pioneer in the adoption of technology trends. A subscription to JetBrains Toolbox guarantees access to the most recent tools and technologies, critical for maintaining the project's competitive edge and relevance.
4. **Cost-Effectiveness and Flexibility**: The subscription model offers a cost-effective solution for long-term projects, with the flexibility to scale based on project demands. This adaptability is advantageous for projects with varying resource requirements.
5. **Community and Professional Support**: Being part of the JetBrains community provides access to extensive resources, including documentation, forums, and dedicated customer support. This comprehensive support is invaluable for resolving development challenges and optimising the development workflow.
6. **Ecosystem Compatibility**: The Toolbox subscription ensures compatibility across various operating systems, programming languages, and frameworks, an essential feature for projects that may require multi-platform support or integration with diverse technologies.

This support structure highlights the benefits of using PyCharm under the JetBrains Toolbox subscription, ensuring that the development environment remains up-to-date, integrated, and supported.

On the hardware side, the system is designed to be lightweight, allowing for deployment on low-cost hardware such as the Raspberry Pi for edge computing applications, as well as on more powerful cloud-based infrastructure for scalable, cloud deployments. Hardware selection can be customised to the scale of the application, ranging from individual educational institutions to city-wide smart education systems.

Figure 4.3: Interactive dashboard visualising smart city educational data.

This infrastructure ensures that the developed dashboards are accessible and performant, capable of handling real-time data streams and providing insightful analytics for smart education decision making.

4.2.12 Development tool with Windows Subsystem for Linux (WSL): Bridging Windows and Linux Environments

The Windows Subsystem for Linux (WSL) has emerged as a pivotal tool in modern software development, especially in projects where integration between Windows and Linux environments is essential. WSL is a feature of Windows that enables developers to run a native Linux environment directly on Windows, without the overhead of a traditional virtual machine or the complexity of dual booting. This capability was instrumental in the development of the Smart Education Enhancement Recommendation System Framework, which allows for a seamless cross-platform development experience. WSL is used for the node-red server running locally for DevOps of the project. The primary appeal of WSL lies in its ability to offer a Linux-compatible development environment on a Windows machine. This is particularly advantageous for developers accustomed to Linux tools and programming languages, such as Ruby or Python, but operating within a Windows ecosystem. The integration of Linux-based development tools, including Docker and Kubernetes, directly within Windows streamlines the development process, offering a blend of Linux's versatility and Windows' user-friendly interface.

Advantages of WSL:

The greatest benefit of WSL is its ability to facilitate development using Linux tools without leaving the Windows environment. Brings the robustness of Linux development to Windows, enabling developers to use Linux-specific software and command-line tools natively. Additionally, WSL serves as an efficient platform for server management tasks, particularly for managing Linux servers.

Limitations and Considerations:

Although WSL is an innovative tool, it is not without limitations. Firstly, it is a niche tool designed for specific development needs and may not benefit all users. There is concern that WSL could potentially discourage native Linux desktop adoption and native application development for Linux. Furthermore, WSL is more directed toward development and testing than being a solution for Linux server deployment. In the context of this project, WSL proved to be an invaluable asset, providing the flexibility to take advantage of Linux's powerful development tools within the familiar and widespread infrastructure of Windows. This harmonious fusion of two different operating system environments significantly improved development workflow, efficiency, and overall productivity. One aspect is that we can run the server-based clients on a local port and use the Python script to connect to the web interface locally.

Windows Subsystem for Linux terminal

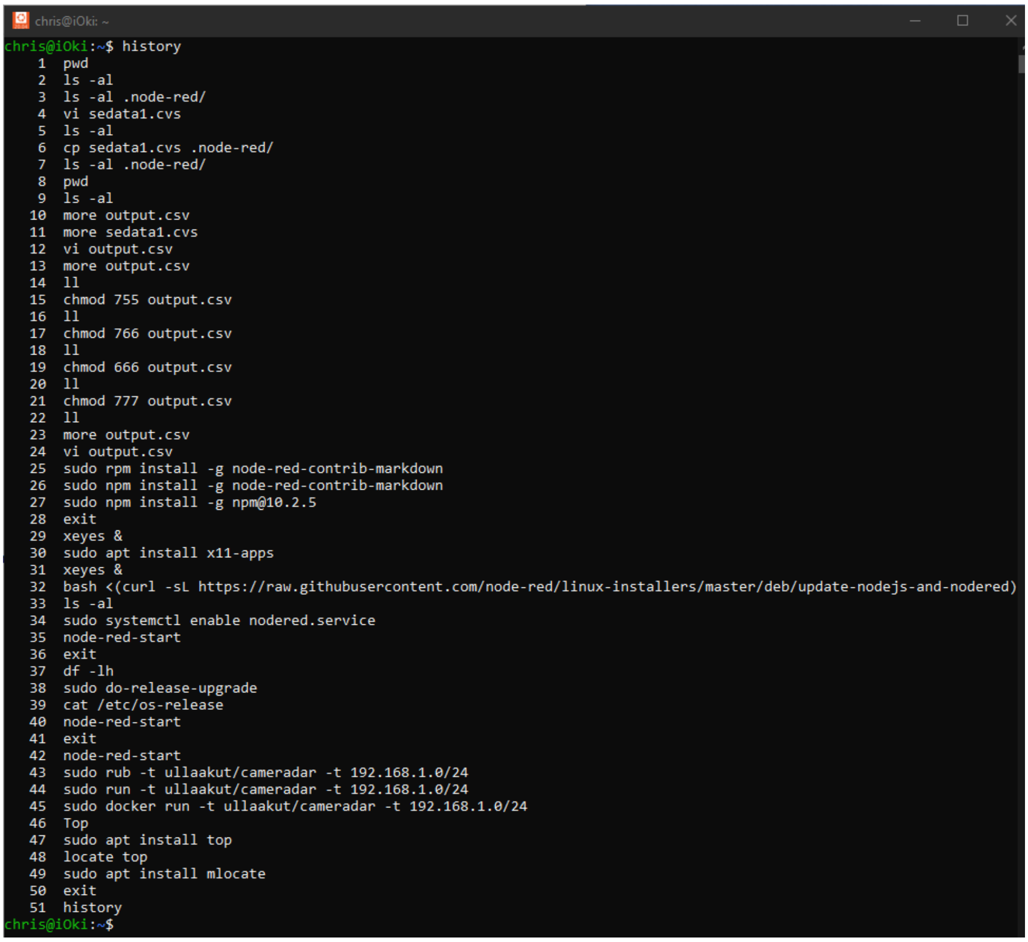


Figure 4.4: Windows Subsystem for Linux interface during project development.

Starting the node-red instance

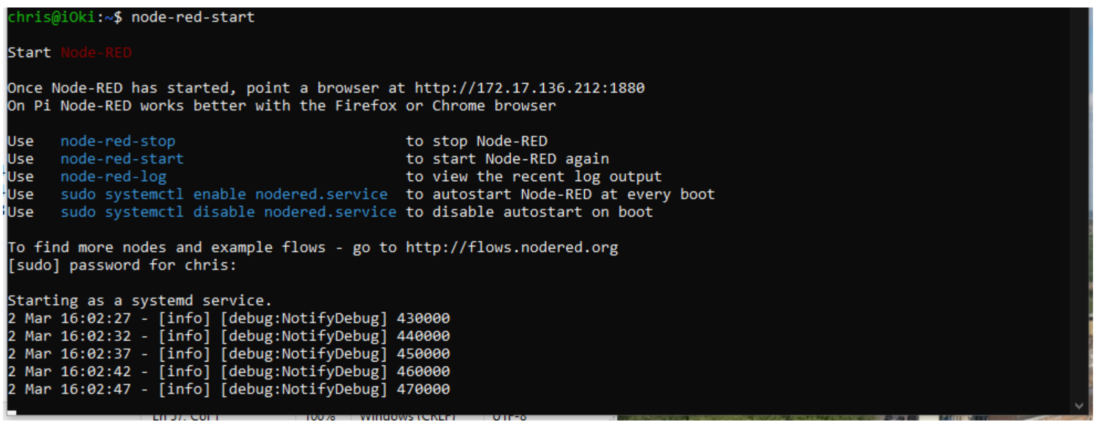


Figure 4.5: Starting Node-Red on Windows Subsystem for Linux interface during project development.

Node-Red browser secure log-in development environment

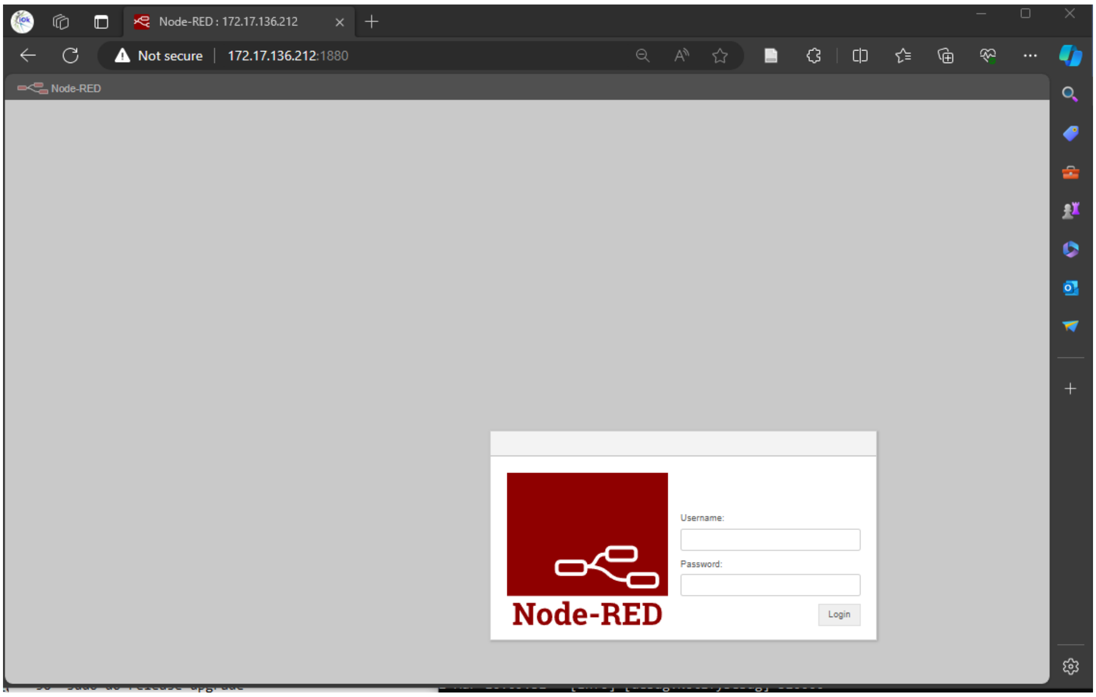


Figure 4.6: Secure Starting Node-Red browser interface during project development.

Ultimately, WSL represents a significant step forward in cross-platform development, aligning the strengths of both Linux and Windows to cater to the diverse needs of modern software development.

Data Development Matrix

In the framework of the Smart Education Enhancement Recommendation System framework, the foundation of our research methodology was based on the robust collection and analysis of data sets pertinent to smart education in the context of smart cities. The data development matrix, presented in Table 2.5, delineates the diverse range of data sources used to support our analysis. These sources range from international organisations and government agencies to nongovernmental organisations (NGOs) and public data repositories, each offering unique insights into various aspects of smart cities and education paradigms.
The data set collection process was meticulously orchestrated, beginning with an extensive review of the literature to identify the key components of smart city frameworks, especially those that intersect with the educational sector. The subsequent step involved the formation of a cross-functional matrix of datasets, which was instrumental in determining the most relevant and comprehensive data sources. To obtain these datasets, a systematic approach was adopted, involving formal registration and request protocols, as required by the data providers. This was particularly crucial for datasets from entities such as UNESCO, UK Data Services, the World Bank Group, and the European Union, where confidentiality and data integrity are paramount.
Each data source listed in the matrix was selected based on its relevance to the study, the quality of the data provided, and its potential to contribute to a nuanced understanding of operational efficiencies within smart education systems. The 'Category' column in the table classifies the type of entity each data source represents, while the 'Source Name' provides specific details about the entity and the nature of their activities. The 'Registration Method' column elucidates how access to each dataset was secured, highlighting the accessibility and openness of these data repositories.
This matrix not only serves as a testament to the variety and volume of data used for this research, but also underscores the rigorous and methodical approach employed in gathering and curating datasets that are comprehensive and contextually relevant to the study of smart education within smart cities.

Table 4.2: Comparison of Smart Education Strategies Against ISO/IEC Smart Education Framework

Criteria	SERF Strategies Document	ISO/IEC Smart Education Framework
Policy and Strategy	Focus on developing and implementing ICT policies in education to improve learning outcomes.	Emphasises the creation of inclusive policies that support the integration of technology in education at all levels.
ICT Integration	Proposes strategies for integrating ICT tools and resources into educational practices.	emphasises the importance of interoperability, security, and privacy in ICT integration for education.
Quality of Education	Addresses the enhancement of education quality through innovative teaching methodologies and ICT.	Recommends standards for educational content, accessibility, and learner participation to ensure high-quality education.
Inclusivity	Highlights the role of ICT in promoting inclusive education for all, including marginalised groups.	Aligns with the promotion of accessibility and equity in education, ensuring that digital resources are available to all learners.
Stakeholder Engagement	Underlines the importance of engaging various stakeholders in the development and implementation of smart education initiatives.	Advocates for multi-stakeholder partnerships to foster collaboration and support for smart education ecosystems.
Evidence-based Practices	Encourages the use of data and research to inform the development of smart education strategies.	Supports the use of standards and frameworks to guide the adoption of evidence-based practices in smart education.
Sustainability	Discusses the sustainability of ICT in education through scalable and adaptable solutions.	Calls for sustainable and environmentally responsible approaches to implementing technology in education.

Step.1
The following tables provided URL and access methods for the data. Figures 2.4, and 2.5.
Step.2

4.2.13 Dataset Collection and Analysis

The intricate process of data collection and analysis is essential in the construction of a robust Smart Education Enhancement Recommendation System framework. The methodology, as visually encapsulated in Figure 3.4, is divided into a dual-path strategy. On the one hand, we have the knowledge discovery process, a meticulous journey through the data landscape characterised by volume and variety. On the other hand, we apply a suite of sophisticated techniques, ensuring that the data not only reveal its hidden patterns but also lend themselves to actionable insights.

- In the initial phase of **Big Data Cleaning**, the process targets data sanitization, sifting through the data to remove inconsistencies, missing values, and outliers. This fundamental step ensures the integrity and usability of the subsequent analysis.

- **Algorithmic Application** comes into play during data partitioning, employing algorithms such as decision trees to segment the data set into logical segments, conducive to more granular analysis. The output data can then be used for the intended task,
- **Motivational Discovery** is instrumental in the operational efficiency of building data. It categorises the data into clusters, thus improving the reliability and robustness of the knowledge extracted during the discovery process. Some of the tasks performed with these data can be the machine learning recommendation process.
- The **Interation Filtering** phase focusses on temporal patterns within operational efficiency data, ensuring that the analysis is honed in on the most significant data subsets. As part of the machine learning process, this can help when building smart governance to narrow down the amount of data to be analysed and focus only on the most valuable or significant data subsets. The primary technique used for knowledge discovery is gradual pattern discovery
- The culmination of this process is the **Gradual Pattern Discovery**, where the nuanced knowledge is distilled into a format suitable for graphical representation or quantitative metrics, which are integral to the research contributions.

As illustrated in Figure 3.4, the identification of relevant types and sources of information is derived from the discovery of Big Data knowledge about Smart Cities within the context of the Smart Education Framework. This figure highlights the integration of data sources to improve operational efficiency and educational outcomes. This analytical methodology not only undergirds the validity of research findings, but also ensures that data sets are used to their full potential, resulting in a data-driven framework that will revolutionise the landscape of smart education.

Data Collection, Analysis, and Transformation

Step.3

The data set collection, analysis, and transformation process as illustrated in Figure 3.5, the integrated approach to data management and analytics, forms the foundation of the methodology. This figure also highlights the procedure for collecting and transforming Smart Education data, which is in agreement with the work of McEwen (McEwen and K. 2015), which serves as the basis for the operational enhancement algorithms used in this investigation. The initial solution, often derived from sampling, paves the way for systematic evaluation, ensuring that the best solution is retained and contributes to the establishment of global standard quantification metrics.

The accompanying Python script exemplifies the programmability applied at this stage, demonstrating the partitioning process of the 'sedata2.csv' dataset. This script, which can be tested within PyCharm IDE, showcases population-based partitioning, delineating cities into low- and high-population categories. Further, it computes the average allocated services per city, aligning with the data types specified: 'secity' as a string, 'popul' as numeric, 'servdata' as numeric, and 'allocsrv' as a float. The script is annotated with comments to clarify each step, from data loading to the final calculation of metrics. This methodology encapsulates the meticulous approach adopted to handle the volume and variety of data, ultimately facilitating the discovery of operational efficiencies through machine learning techniques.

```python
import pandas as pd
import plotly.graph_objects as go
from plotly.subplots import make_subplots

# Load the dataset
df = pd.read_csv('sedata2.csv')

# Basic data partitioning based on the 'popul' column
low_population = df[df['popul'] < 10000]
high_population = df[df['popul'] >= 10000]

# Calculate the average 'allocsrv' per 'secity'
average_allocsrv = df.groupby('secity')['allocsrv'].mean().reset_index()

# Create subplots: 1 row, 3 columns
fig = make_subplots(rows=1, cols=3, specs=[[{"type": "pie"}, {"type": "scatter"}, {"type": "histogram"}]])

# Visualization 1: Pie chart for the distribution of cities in the dataset
fig.add_trace(
    go.Pie(labels=average_allocsrv['secity'], values=average_allocsrv['allocsrv'], name="Allocsrv"),
    row=1, col=1
)

# Visualization 2: Scatter plot for service data vs population
fig.add_trace(
    go.Scatter(x=df['popul'], y=df['servdata'], mode='markers', name='ServData'),
    row=1, col=2
)

# Visualization 3: Histogram of population
fig.add_trace(
    go.Histogram(x=df['popul'], name='Population'),
    row=1, col=3
)

# Update the layout and show the figure
fig.update_layout(height=600, width=1200, title_text="Smart Education Data Visualizations")
fig.show()
```

Figure 4.7: Script to develop a Side-by-side visualizations of smart education data analysis

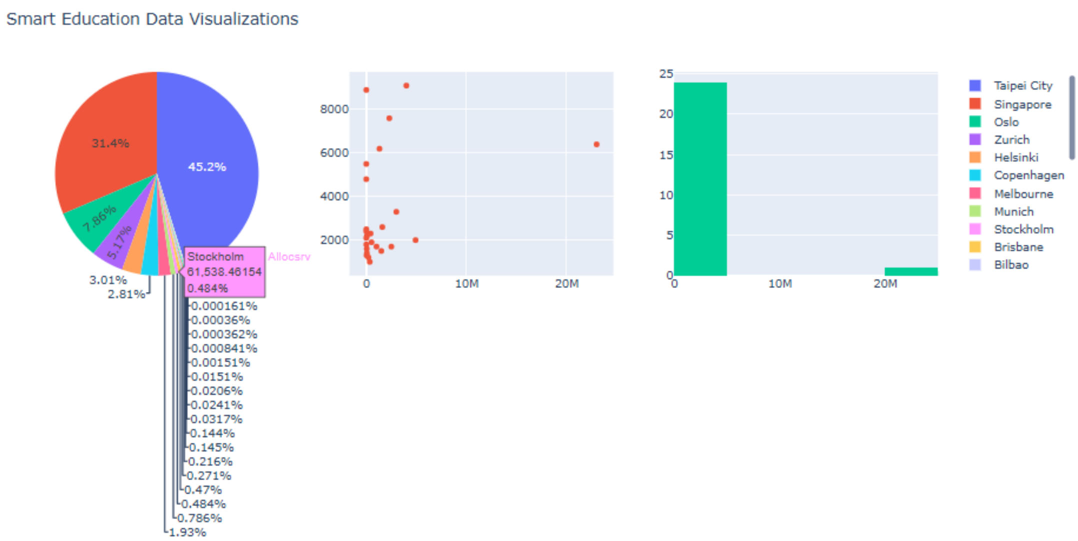


Figure 4.8: Output of the Side-by-side visualizations script of SERF data analysis, showcasing the distribution of cities, service data versus population, and population histograms. file:roomusage21102022v2.csv

4.2.14 Effect of Population Distribution on SERF

The distribution of population plays a critical role in the Smart Education Recommendation Framework (SERF) by influencing the allocation of services and resources in smart cities. The visualisation in Figure 4.8 illustrates several key aspects of the population distribution and its impact on the use of services and the allocation of resources:

- **Service Data Utilisation (SDU):** The pie chart on the left highlights the proportion of use of service data in different smart cities. Cities with higher populations, such as Taipei City and Singapore, show a significant proportion of the use of service data. This indicates that population size directly affects the scale and intensity of service data usage, requiring SERF to adapt recommendations to manage high-demand regions effectively.
- **Population vs. Allocated Services:** The scatter plot in the centre demonstrates the relationship between population size and allocated services. The data reveal that some cities with large populations have disproportionately fewer services allocated, leading to inefficiencies. For example, cities such as Stockholm and Oslo exhibit a mismatch between population size and allocated services. This underscores the need for SERF to address such disparities by recommending increased service allocation in under-resourced cities.
- **Population Histograms and Trends:** The histogram on the right provides a distribution of population sizes in selected smart cities. Most cities fall within a midrange population size, but a few outliers with exceptionally large populations skew the data. These outliers highlight the challenges of scaling educational services and infrastructure to meet population demands. SERF leverages this information to prioritise interventions in high-demand areas while ensuring equitable resource distribution across all cities.

The effect of population distribution on SERF is twofold: 1. **Demand Driven Resource Allocation:** SERF uses population distribution data to identify cities with insufficient services relative to their populations, guiding recommendations for additional resource allocation. 2. **Equity and Efficiency:** By analysing disparities in service allocation, SERF ensures that resources are distributed equitably, optimising operational efficiency and improving educational outcomes in smart cities.

4.3 Interpretation of SERFD Data Visualisations

Figure 4.8 includes three different types of graph: a pie chart, a scatter plot, and a bar chart. Here is a detailed interpretation in the context of the Smart Education Recommendation Framework with Dashboard (SERFD):

Pie Chart

The pie chart shows the distribution of the metric for resources and services in different cities. The key observations are:

- **Taipei City** holds the largest portion of the pie chart with **45.2%** of the total metric.
- **Singapore** follows with **31.4%**.
- **Oslo**, **Zurich**, and **Helsinki** contribute **7.86%**, **5.71%**, and **3.01%** respectively.
- Other cities like **Copenhagen**, **Melbourne**, **Munich**, **Stockholm**, **Brisbane**, and **Bilbao** contribute smaller percentages, each less than 3%.

Scatter Plot

The scatter plot represents the relationship between two variables. Here are the details:

- The x-axis ranges from **0 to 20 million** (likely representing a large numerical value such as population, budget, or number of data points).
- The y-axis ranges from **0 to 10,000** (possibly representing a specific metric such as educational efficiency, number of smart devices, or some operational metric).
- Most data points are clustered between **0 to 10 million** on the x-axis and **0 to 6,000** on the y-axis, indicating a concentration of this metric in this range.
- Some outliers are present, which might indicate cities with exceptionally high values in one of the

metrics.

Bar Chart

The bar chart shows the effectiveness or another performance measure for various cities:

- **Oslo** has the highest bar, indicating the top performance or metric value among the listed cities.
- The other cities, represented by shorter bars, have lower values in this specific metric.
- The cities in the legend are the same as those in the pie chart, ensuring consistency across the visualisations.

Overall Interpretation

These visualisations provide a comprehensive view of the data relevant to the Smart Education Recommendation Framework with Dashboard (SERFD). Specifically:

- **Distribution:** The pie chart highlights how the Service Data Use (SDU) metric is distributed among various cities, identifying which cities have the most significant share of service usage relative to their population.
- **Relationships:** The scatter plot presents the relationship between two key variables: *population size (popul)* and *allocated services (servdata)*. This visualisation helps to identify trends and correlations, revealing cities that are either under-resourced or over-resourced relative to their population.
- **Performance:** The bar chart ranks cities based on performance metrics such as the population to service allocation ratio (PSAR), which is crucial to benchmarking and identifying cities with high operational efficiency, as well as those that require strategic intervention.

****Key Variables in the Scatter Plot**** The scatter plot shown in Figure 4.8 uses the following variables:

- **X-Axis: Population (*popul*)**: Represents the total number of people living in each smart city. This variable serves as a measure of the demand for educational and auxiliary services.
- **Y-Axis: Allocated Services (*servdata*)**: Indicates the number of services provided by the city operators. This variable reflects the supply of resources available to meet the population's needs.

The scatter plot helps to visualise the proportional relationship (or lack thereof) between population size and allocated services, uncovering trends such as:

- **Equitable Resource Distribution:** Cities positioned close to the trend line exhibit a balanced allocation of resources relative to their population size.
- **Outliers:** Cities that deviate significantly from the trend line, such as those with large populations but limited allocated services, indicate inefficiencies that require targeted interventions.

Context of SERFD In the context of SERFD, these visualisations play a pivotal role in informing strategic decisions by:

- Identifying cities with resource shortages or surpluses and guiding stakeholders on where to allocate additional resources.
- Highlighting high-performing cities that can serve as benchmarks for developing best practices.
- Analysing correlations between key variables to understand the drivers of operational efficiency and disparities in service delivery.
- Providing stakeholders with accessible, data-driven insights that enable effective planning and implementation of smart education strategies.

Recommendations

- **Focus on Resource-Deficient Cities:** Use the scatter plot to identify cities with large populations but insufficient allocated services and prioritise interventions in these areas.
- **Learn from High Performers:** Benchmark high-performing cities with balanced resource distribution and replicate their strategies in other regions.
- **Investigate Outliers:** Perform an in-depth analysis of cities that significantly deviate from the trend to understand the unique factors influencing their performance.

Using these visual insights, SERFD enables stakeholders to make informed decisions to optimise resource allocation, improve operational efficiency, and improve educational outcomes within smart cities.

Data Analysis and Visualisation Techniques The data visualisations are generated using the Python programming language, leveraging the Plotly library for interactive and visually engaging charts. The analysis employs statistical techniques to calculate critical metrics, such as Service Data Utilisation (SDU) and Population to Service Allocation Ratio (PSAR). Specifically:

- The scatter plot visualises the relationship between population and allocated services, using the following formula for PSAR:

$$\text{PSAR} = \frac{\text{allocsrv}}{\text{popul}}$$

  where *allocsrv* represents the allocated services and *popul* represents the population size.
- The bar chart provides a ranking of cities based on their PSAR values, enabling comparative performance analysis.
- The pie chart visualises the proportional distribution of SDU among cities to identify disparities in service usage.

Alternative formular

$$\mu_{secity} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

where:

- μ_{secity} is the mean allocated service for a given city,
- n is the number of service entries for that city,
- x_i is the allocated service value for each entry.

By integrating these techniques, the visualisations provide a holistic perspective on the performance and operational efficiency of smart cities, informing the recommendations made by SERFD.

Integration of Advanced Technologies in Smart Education

The infusion of advanced technologies such as process automation, artificial intelligence, and cognitive computing is transformative in the realm of Smart Education. These technologies not only streamline operations, but also bring about a paradigm shift in educational delivery and administration.

Process Automation

Process automation introduces a systematic approach to automating routine tasks within educational institutions. Using software tools and algorithms, institutions can reduce manual intervention, minimise errors, and allocate resources more effectively.

1. **Identification of Automatable Processes**: Start by analysing the educational workflow to identify repetitive and time-consuming tasks.
2. **Implementation of Automation Tools**: Employ software such as Robotic Process Automation (RPA) to handle tasks such as student admissions, attendance tracking, and grading.
3. **Continuous Monitoring and Optimisation**: Regular review of automation results to ensure processes are running smoothly and make adjustments as needed.

Artificial Intelligence

Artificial intelligence (AI) can be harnessed to personalise learning experiences, optimise curriculum design, and provide data-driven insights into student performance.

1. **Adaptive Learning Systems**: Integrate AI to develop systems that adapt to the learning pace and style of individual students.
2. **Predictive Analytics**: Use AI algorithms to predict student outcomes and identify those who may need additional support.
3. **Intelligent Tutoring Systems**: Implement AI-driven tutors to provide immediate feedback and assistance to students.

Cognitive Computing

Cognitive computing involves creating systems that simulate human thought processes in a computerised model, thus improving decision making and problem solving.

1. **Natural Language Processing (NLP)**: Using NLP to analyse and understand student feedback, facilitating improved educational strategies.

2. **Knowledge Representation**: Implement cognitive systems that organise educational content in a way that is easily accessible to both students and educators.
3. **Cognitive Analytics**: Leverage cognitive computing to gain deep insight into educational patterns and trends, fostering a more dynamic learning environment.

These technologies collectively contribute to a more efficient, responsive and personalised educational framework, driving the Smart Education ecosystem toward unprecedented levels of operational efficiency.

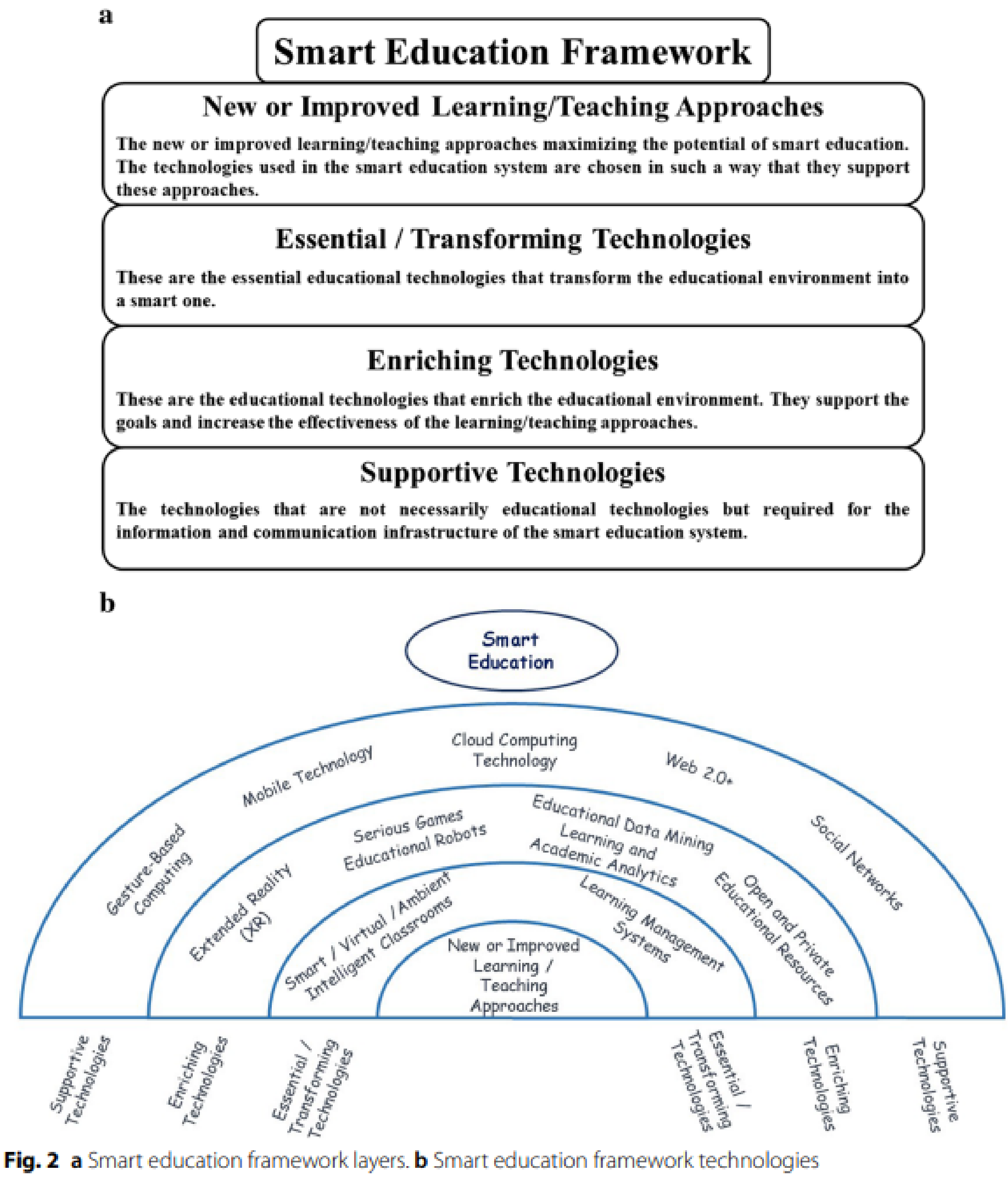


Figure 4.9: Illustration of Advanced Technologies in Smart Education (Demir 2021a)

Classroom Usage Visualisation

To gain insights into the utilisation patterns of classrooms, a Python script was developed to visualise the data from six ".csv" files over 5 days between 09:00am and 17:00pm. This script generates plot graphs that provide different perspectives on how classrooms are used throughout the day. For the dataset see Appendix page 276.

1. The histogram graph is used to display the total daily usage of each classroom, offering a quick comparison of overall occupancy, the graph can animate overtime, bringing the data to life by showing the changes in classroom usage as the day progresses and animating the transitions between each time slot.

These visualisations figure 4.10, 4.11 not only serve as a tool for administrative planning, but also provide valuable data to optimise room allocations based on actual usage patterns.

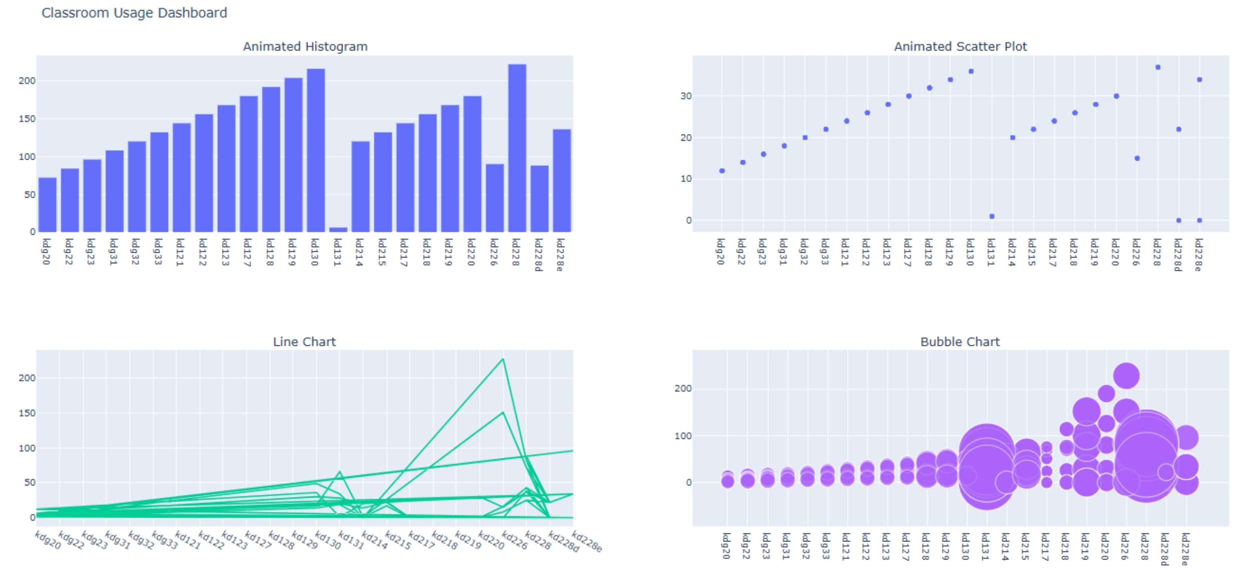


Figure 4.10: Interactive visualisations of classroom usage data.

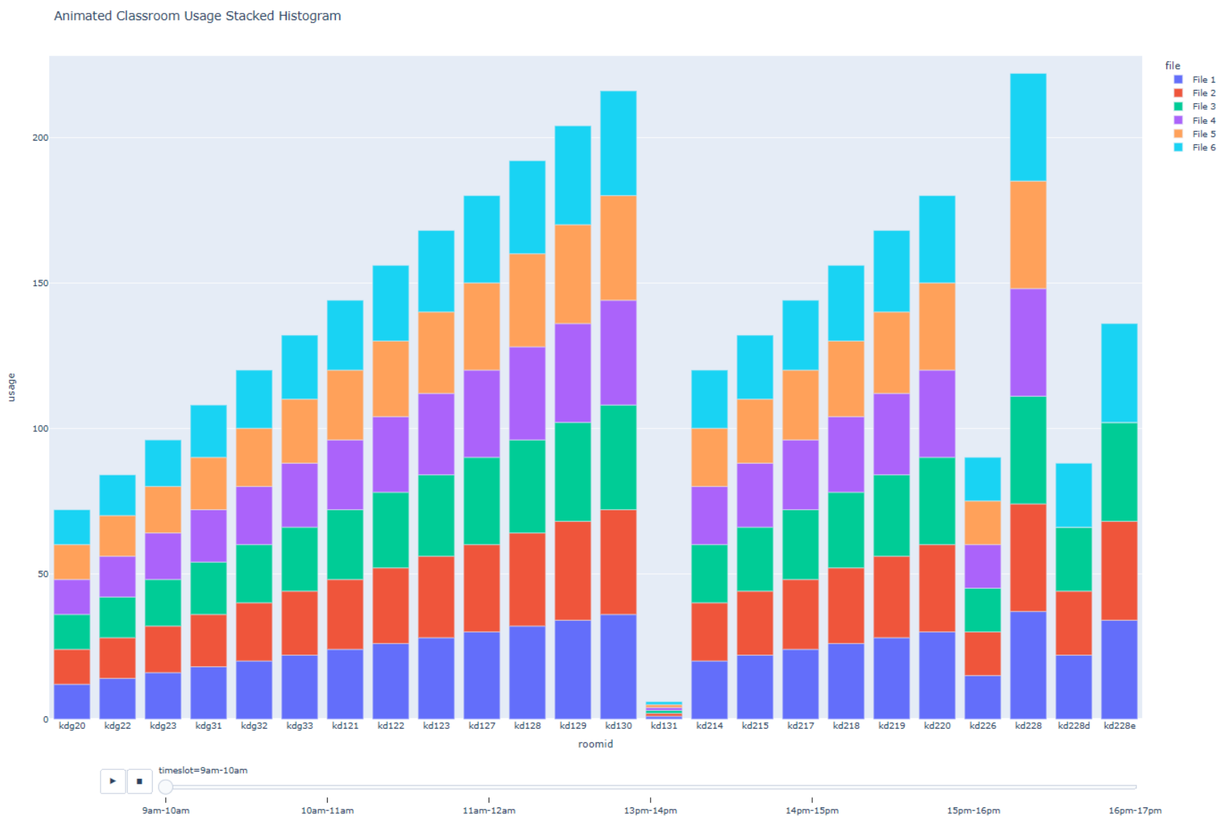


Figure 4.11: Interactive Animated visualisations of classroom usage data.

The Python script is designed to run within the PyCharm IDE, ensuring that educators and facility managers can interact with the visualisations directly, facilitating data-driven decision-making processes.

4.4 Smart Education Recommendation Framework within the ISO/IEC Smart City

Smart cities are complex ecosystems that integrate various layers of technological, social and infrastructural components. The ISO/IEC 30145 series serves as a backbone for standardising these systems. Within this context, the figure "Smart Education Framework Extends ISO/IEC Smart City Framework" 4.12 represents a novel extension, tailoring the standards to meet the nuanced demands of educational environments.

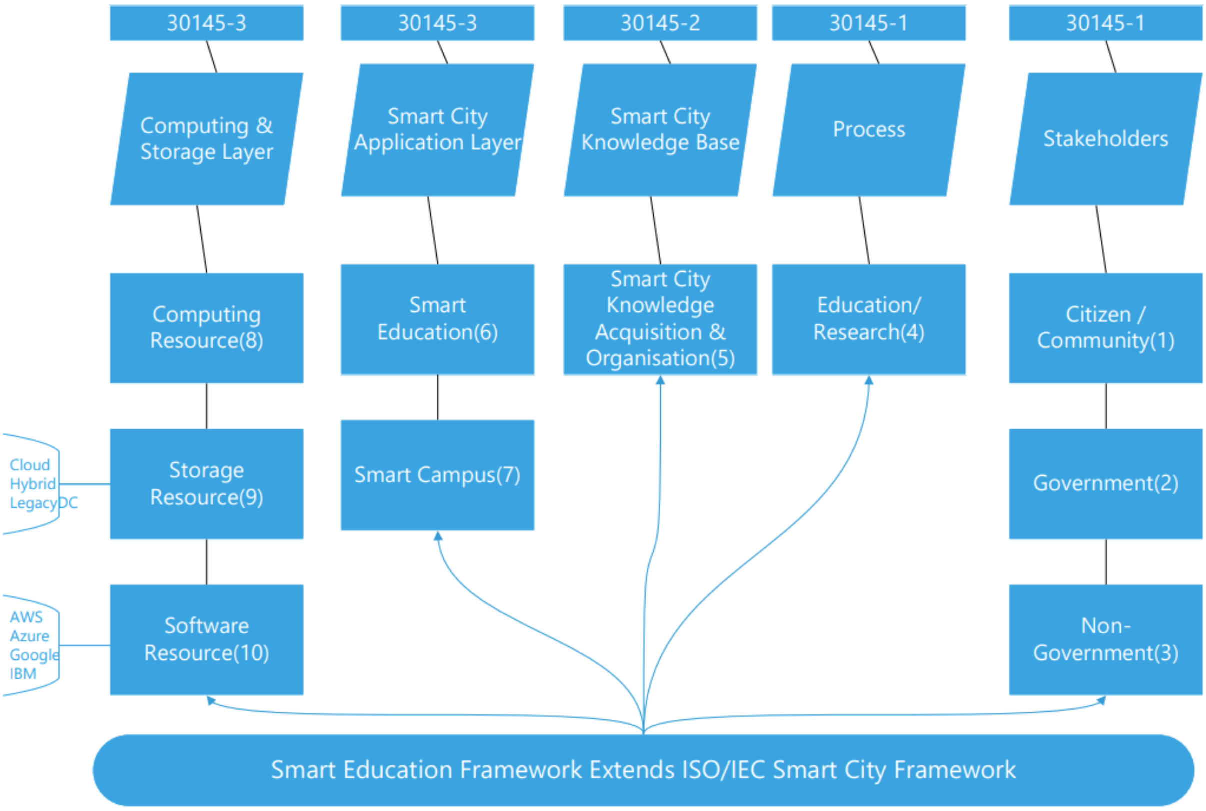


Figure 4.12: Smart Education Framework Extends ISO/IEC Smart City Framework

Layer in Smart Education Framework The "Computer & Storage Layer" is fundamental in handling the massive data influx from various educational sources. Smart Education systems, characterised by digital classrooms, online resources, and interactive learning tools, generate a large volume of data. Complying with ISO/IEC 30145-3 ensures that educational institutions have the necessary computing power and storage capacity to effectively manage these data. This capability is crucial for data analytics, which drives personalised learning experiences and informed decision-making in curriculum development.
This standard promotes the integration of advanced computing technologies, such as cloud computing and edge computing, in educational settings. Cloud computing offers scalability and flexibility, allowing educational institutions to access resources on demand and scale up as the number of users increases. Edge computing, on the other hand, facilitates real-time data processing closer to the data source, which is essential for applications such as virtual reality (VR) and augmented reality (AR) in education. These technologies, when aligned with ISO/IEC 30145-3, ensure that computing resources are optimised for performance, cost, and energy efficiency.
Furthermore, ISO / IEC 30145-3 emphasises security and privacy in the "Computer & Storage Layer", which is critical to protecting sensitive educational data. By adhering to this standard, educational institutions can establish robust security protocols and data encryption methods, protecting student and staff data against cyber threats. This compliance not only protects the integrity of educational data, but also builds trust

among stakeholders, a crucial aspect in the adoption of Smart Education technologies.
In addition, this standard fosters interoperability and compatibility between different systems and devices used in Smart Education. It ensures that the adopted computing and storage solutions can seamlessly integrate with various educational tools and platforms, facilitating a cohesive and interconnected learning environment. This interoperability is essential to create a unified educational ecosystem where data and resources can be efficiently shared between institutions, educators, and learners.
Aligning Smart Education systems with the ISO/IEC 30145-3 standard, particularly in the "Computer & Storage Layer", is integral to building a resilient, efficient and secure infrastructure. This alignment not only enhances the ability to manage and process educational data, but also ensures scalability, security, interoperability, and optimal use of resources. By adhering to these guidelines, educational institutions can effectively harness the power of technology to transform learning experiences and outcomes.

4.4.1 Performance Benchmarks in Alignment with ISO 15746-1:2015

Quantized Benchmarks

- **Interoperability Testing:**
  1. *Data Integrity:* Measures the maintenance of data integrity during transfer.
  2. *Format Compatibility:* Evaluates the compatibility of data formats between various simulation platforms.
  3. *System Interconnectivity:* Assesses the connection and communication capabilities between different systems.
- **Performance Metrics:**
  1. *Transfer Speed:* Benchmarks the speed of data exchange.
  2. *Data Throughput:* Measures the volume of data transferred over time.
  3. *Resource Utilisation:* Quantifies computational resources used during data transfer.
- **Scalability Assessments:**
  1. *Volume Scalability:* Performance under increasing data volumes.
  2. *System Scalability:* Capacity to expand and integrate more systems.

Pre-Quantised Benchmarks

- **Simulation Fidelity:**
  1. *Resolution Precision:* Pre-quantized measure of data detail.
  2. *Temporal Accuracy:* Precision of time-dependent data.
- **Data Quality Indicators:**
  1. *Completeness:* Assurance of complete data for simulations.
  2. *Consistency:* Verification of non-conflicting data transfer.
- **Usability Metrics:**
  1. *Ease of Integration:* Simplicity of adopting the data exchange standard.
  2. *User Satisfaction:* User experience with the data exchange process.

4.5 Computing & Storage Layer in Smart Education Framework

The foundation of this framework is the "Computing & Storage Layer," a critical component ensuring the availability, reliability, and scalability of educational resources. Here, the infrastructure accommodates cloud, hybrid, and legacy systems, using services from AWS, Azure, Google, and IBM to provide a robust platform for Smart Education.

Computer & Storage Layer: Aligning with ISO/IEC 30145-3 for Smart Education

The ISO/IEC 30145-3 standard, part of the broader ISO/IEC 30145 series, outlines a framework for IT infrastructure in smart cities. It emphasises the interplay of components such as networking, computing, and storage, setting a blueprint for robust and efficient systems. In the context of Smart Education, aligning with this standard, particularly in the "Computer & Storage Layer", is crucial for several reasons.

Implementing ISO/IEC 30145-3 in Smart Education: Focus on Computer & Storage Layer

Implementation Steps for Computer & Storage Layer in Smart Education Integration of the ISO / IEC 30145-3 standard into Smart Education, particularly in the "Computer & Storage Layer", involves several key steps:

Step 1: Assessment of Current Infrastructure

- Evaluate existing computing and storage capacities in educational institutions.
- Identify the gaps in the current infrastructure compared to the standards set by ISO/IEC 30145-3.

Step 2: Planning and Design

- Develop a strategic plan aligning with ISO/IEC 30145-3 requirements, focusing on scalability, security, and efficiency.
- Design a system architecture that integrates advanced computing technologies such as cloud computing and edge computing.

Step 3: Infrastructure Upgrade

- Upgrade hardware and software to meet the computational and storage demands of Smart Education.
- Implement cloud-based solutions for scalable and flexible resource management.

Step 4: Security Enhancement

- Strengthen cybersecurity measures and data encryption to protect sensitive educational data.
- Update security protocols regularly to mitigate emerging cyber threats.

Step 5: Interoperability and Compatibility

- Ensure that new systems are interoperable with a range of educational tools and platforms.
- Adopt standards that promote compatibility between different devices and software.

Step 6: Testing and Validation

- Test the upgraded infrastructure to ensure it meets the ISO/IEC 30145-3 standards.
- Validate the performance, security, and interoperability of the system.

Step 7: Training and Implementation

- Train staff and educators on the new system capabilities and best practices.
- Implement the upgraded infrastructure in educational institutions.

Step 8: Continuous Monitoring and Improvement DevOps

- Monitor the performance and efficiency of the implemented systems.
- Continuously assess and improve infrastructure to match evolving educational needs and technological advances.

4.6 Computing Resource in Smart Education Framework

The "Computing Resource" component is a cornerstone in the implementation of the Smart Education Framework within the broader context of ISO/IEC 30145-3 for smart city infrastructure. In addition, ICT-based education has been applied in a variety of aspects, such as teaching, scientific research, and campus management. New technologies such as big data and cloud computing are gaining increasing popularity in the education industry, changing both education models and ICT development. ICT-based education has become a megatrend in the industry. This section delineates a step-by-step approach to integrating computing resources with the smart education framework.

Assessment of Educational Computing Needs

Begin by assessing the specific computational needs of educational environments. This includes understanding the processing power, memory, storage, and networking requirements that various educational applications require. Determine the baseline for minimum and optimal performance standards for different educational software suites, virtual classroom environments, and student information systems.

Infrastructure Design

Design the computing infrastructure to comply with ISO / IEC 30145-3 standards, ensuring scalability, reliability and security. This involves selecting the appropriate hardware and cloud services that can dynamically scale to meet varying demands. For hardware, focus on procuring energy-efficient servers that can handle compute-intensive tasks such as data analytics and machine learning for educational insights.

Implementation of Cloud Services

Cloud services are integral to the "Computing & Storage Layer" in ISO/IEC 30145-3. Implement cloud computing solutions that offer on-demand resources and services, such as Infrastructure as a Service (IaaS) for storage and computing power, Platform as a Service (PaaS) for educational application development, and Software as a Service (SaaS) for delivering educational applications directly to users.

Integration with Smart Education Applications

Integrate computing resources with intelligent educational applications. This involves the establishment of interfaces and protocols for educational applications that seamlessly interact with the underlying infrastructure. Using APIs that enable interoperability and real-time data exchange between educational platforms, student portals, and administrative systems.

Performance Monitoring and Optimisation

Monitor the performance of computing resources continuously. Implement monitoring tools that are aligned with the ISO/IEC 30145-3 standards to ensure that the computing infrastructure operates efficiently and effectively. Use the insights gained from performance data to optimise resource allocation, balancing the load across the infrastructure to enhance the responsiveness and availability of educational services.

Security and Compliance

Ensure the security of computing resources by following the ISO / IEC 30145-3 guidelines. This includes encrypting data at rest and in transit, implementing strong access controls, and regularly updating systems to protect against vulnerabilities. Compliance with privacy regulations is paramount, particularly when handling sensitive student data.

Sustainable Development

Finally, align the deployment of computing resources with the goals of sustainable development. Optimise energy usage, reduce carbon footprint through green computing initiatives, and consider the life cycle of computing hardware to minimise environmental impact.

4.7 Storage Resource in the Smart Education Framework

Integrating storage resources within the Smart Education Framework requires adherence to the "ISO/IEC 30145-3" standard, ensuring robust, secure, and scalable data management. This section details a step-by-step process for the strategic alignment of storage resources.

Evaluation of Data Storage Needs

Assess the data storage needs for smart education, considering immediate and future demands. This evaluation must account for student data, educational content, research materials, and administrative records. Determine the capacity, speed, and accessibility requirements to serve the educational community effectively.

Architectural Planning

Design a storage architecture that aligns with ISO / IEC 30145-3, focussing on modularity and interoperability. This architecture should incorporate both on-premises and cloud storage solutions, providing a hybrid approach to flexibility and resilience. Ensure that the design supports data redundancy and disaster recovery plans.

Deployment of Scalable Storage Solutions

Implement scalable storage solutions to accommodate the growing volume of educational data. Use technologies such as storage area networks (SAN), network-attached storage (NAS), and object storage, ensuring that they integrate with existing IT infrastructure and comply with ISO/IEC 30145-3 standards.

Data Management Strategies

Develop data management strategies that include data lifecycle policies, centralised storage, and archival solutions. Establish clear guidelines for data retention, categorisation, and archiving, ensuring efficient utilisation of storage resources.

Security and Data Protection

Prioritise security and data protection according to ISO / IEC 30145-3. Implement encryption, access controls, and regular audits to protect sensitive educational data. Compliance with data protection regulations is crucial, particularly for personally identifiable information (PII) of students and staff.

4.7.1 Monitoring and Maintenance

Continuously monitor storage resources to ensure performance and reliability. Set up monitoring systems to track usage patterns, anticipate capacity needs, and detect potential issues before they impact the educational environment.

Sustainability Considerations

Align storage resource management with sustainability goals. Opt for energy-efficient storage systems, consider the environmental impact of data centres, and promote responsible data management to minimise the carbon footprint of educational technology. **Energy-Efficient Storage Resource Management:** Implementing energy-efficient strategies in storage resource management is essential to align the Smart Education Framework with the ISO/IEC 30145-3 standard. This section outlines the practical steps educational institutions can take to improve sustainability and efficiency.

- **Data Deduplication Implementation:** Deduplication technology is crucial to reduce storage needs by eliminating redundant data. This can result in a decrease in power and cooling requirements, aligning with the sustainability goals of the Smart Education Framework.
- **Adoption of Solid-State Drives (SSDs):** Replacing traditional hard disk drives with SSDs can lead to significant energy savings. SSDs are more energy efficient, perform faster, and contribute to the reduction of the carbon footprint of storage systems within educational data centres.
- **Utilization of Green Data Centres:** Collaborating with renewable energy powered data centres is a sustainable choice. These centres often implement innovative cooling systems and energy-efficient equipment, which supports the environmental objectives of smart education technologies.

4.8 Software Resources Alignment in Smart Education Framework

Interoperability and Standardisation

One of the main areas of focus of ISO / IEC 30145-3 is the interoperability of systems. For educational software resources, this means the development and deployment of applications that can seamlessly integrate with various platforms and services within the smart city ecosystem. By adhering to standard communication protocols and data formats, educational software ensures compatibility and facilitates the exchange of information between different sectors, improving the learning experience and administrative operations.

1. Adopt widely supported open standards for data exchange and interfaces.
2. Implement middleware that can translate between different application protocols.
3. Encourage the development of platform-agnostic educational tools.

- **Moodle:** A free, open-source learning management system (LMS) that supports personalised learning environments. It works on any system with PHP and a database, making it compatible with a wide range of devices and operating systems. The flexibility and accessibility of Moodle make it a staple in many educational institutions.
- **Khan Academy:** A non-profit educational organisation offering a comprehensive suite of free online educational resources. Its platform provides instructional videos and practice exercises on a variety of topics. Accessible from any web-enabled device, Khan Academy is an excellent example of a platform-agnostic tool, promoting inclusive and flexible learning.

Security and Privacy

In compliance with ISO/IEC 30145-3, software resources in smart education must prioritise security and privacy. Educational data is sensitive and its protection is paramount. Software solutions must incorporate robust encryption, access control, and data protection mechanisms to protect against unauthorised access and cyber threats.

1. Integrate advanced encryption standards for data at rest and in transit.
2. Establish strict access controls and authentication measures for software applications.
3. Update and patch educational software regularly to address security vulnerabilities.

Scalability and Sustainability

Furthermore, ISO/IEC 30145-3 emphasises scalable and sustainable IT infrastructure. Educational software must be designed to scale in response to the changing needs of smart cities. It should also promote sustainability through resource-efficient operation and support for green IT initiatives.

1. Design software with modular architectures to facilitate easy scaling.
2. Optimise the efficiency of the software to reduce the computational resources required.
3. Support virtualisation and cloud-based solutions to minimise the physical infrastructure footprint.

By these, aligning software resources with ISO/IEC 30145-3 within the Smart Education Framework ensures a resilient, future-proof, and secure smart education infrastructure that is integral to the smart city vision.

4.9 Smart City Application Layer Implementation SERFD context

The "Smart City Application Layer" directly interfaces with Smart Education, where the application of technology is optimised for educational settings. This layer ensures that the principles of smart education are applied within the smart campus, enhancing learning experiences through technological means.

The implementation of the Smart City Application Layer, in accordance with the "Smart Education Framework Extends ISO/IEC Smart City Framework" and the standards of ISO 30145-3, involves several key steps. These steps are designed to integrate technology effectively into educational settings.

1. **Assessment of Educational Needs and Goals:** Begin by performing a comprehensive assessment of the specific needs and goals of the educational institution. This includes understanding the learning objectives, the technological requirements, and the desired outcomes of implementing smart education technologies.
2. **Technology Selection and Customisation:** Based on the assessment, select the appropriate smart technologies that meet the standards of ISO 30145-3. This selection should consider factors such as scalability, interoperability, and security. Customise these technologies to meet the specific needs of the educational environment.
3. **Integration with Existing Infrastructure:** Integrate the selected technologies with the existing infrastructure of the smart campus. This integration should be seamless and should not disrupt current operations. Ensure that the infrastructure supports the scalability and flexibility required for future expansions.
4. **Development of Smart Educational Applications:** Develop or adapt educational applications that align with the principles of smart education. These applications should facilitate interactive learning, remote learning, and personalised learning experiences.
5. **Training and Capacity Building:** Conduct training sessions for educators and administrative staff to familiarise them with new technologies. This step is crucial to ensuring effective use of technology in educational processes.
6. **Implementation of Data Analytics:** Utilise data analytics tools to analyse educational data. This analysis can provide information on student performance, learning patterns, and areas for improvement. Ensure that data collection and analysis are in compliance with data privacy and protection standards.
7. **Continuous Monitoring and Evaluation:** Establish mechanisms for the continuous monitoring and evaluation of implemented technologies. This should include regular feedback from students and educators, performance metrics, and technology audits. Use this feedback to make iterative improvements to the implementation of technology.
8. **Sustainability and Scalability:** Ensure that the implementation is sustainable, both economically and environmentally. Plan the long-term scalability of technology to accommodate future growth and advancements in smart education.

By following these steps, educational institutions can effectively implement the Smart City Application Layer, thus aligning with the "Smart Education Framework Extends ISO/IEC Smart City Framework" and adhering to the guidelines of ISO 30145-3. The ultimate goal is to create a smart educational environment that is technologically advanced, sustainable and conducive to enhanced learning experiences.

4.10 Smart Education Alignment with ISO/IEC 30145-3

The integration of smart education within the ISO / IEC 30145-3 framework involves a strategic approach to embedding advanced technology into educational settings. The process aims to enhance the learning experience and optimise educational results according to the principles of smart cities. This section outlines a step-by-step methodology to achieve this alignment.

Understanding ISO/IEC 30145-3 Standards

Begin by comprehensively understanding the ISO/IEC 30145-3 standards, particularly focussing on how they relate to the educational sector. This involves analysing the standards' requirements for computing, storage, networking, and data management, and how these can be applied to educational institutions.

Assessment of Current Educational Infrastructure

Conduct an evaluation of the current technological infrastructure in educational institutions. Identify areas that require upgrades or changes to meet ISO/IEC 30145-3 standards. This evaluation should cover hardware, software, network capabilities, and data handling processes. To align Smart Education with ISO/IEC 30145-3 standards, a thorough assessment of the current educational infrastructure is vital. This step-by-step guide provides a structured approach for this assessment, which focusses on hardware, software, network capabilities, and data handling processes.

1. **Establishment of Assessment Team:** Form a team comprising IT specialists, educational technologists, and administrative staff. This team will be responsible for conducting the assessment and compiling the findings.
2. **Inventory of Existing Infrastructure:** Start by cataloguing existing hardware and software resources within the institution. This inventory should include computers, servers, networking devices, and any other relevant technology used for educational purposes.
3. **Evaluation of Hardware Capabilities:** Assess the capabilities of the current hardware infrastructure. Determine whether the hardware meets the requirements to run advanced educational software, supports adequate data storage, and is capable of handling increased network traffic.
4. **Software Systems Review:** Evaluate existing software systems for their effectiveness in educational delivery. This includes learning management systems, administrative software, and any specialised educational software. Check for scalability, updates, and compatibility of the software with new technologies.
5. **Network Performance Analysis:** Analyse the existing network infrastructure to ensure that it can support the connectivity requirements of a smart educational environment. Assess the bandwidth, reliability, and security measures in place.
6. **Data Handling and Security:** Evaluate data handling processes, focussing on how data are stored, accessed, and secured. Ensure compliance with data protection regulations and assess the potential for integrating cloud-based solutions.
7. **Identification of Upgrade Requirements:** Identify areas where upgrades or changes are required. This could include hardware replacements, software updates, network enhancements, or new data management solutions.
8. **Stakeholder Feedback:** Gather feedback from educators, students, and IT personnel about the effectiveness of the current infrastructure. This feedback can provide valuable information on practical needs and challenges.
9. **Compilation of Assessment Report:** Compile the findings into a comprehensive report. This report should highlight the current state of educational infrastructure, areas requiring improvement, and recommendations to align with the ISO / IEC 30145-3 standards.

10. **Development of an Upgrade Plan:** Based on the assessment report, develop a detailed plan to upgrade the educational infrastructure. This plan should include timelines, budget estimates, and a roadmap for implementation.

The structured assessment described in this section is integral to aligning the existing educational infrastructure with the ISO/IEC 30145-3 standards. Using quantitative metrics, this formula offers a systematic approach to evaluate the operational efficiency and quality of education within smart cities. The formula is particularly relevant to the Smart Education Recommendation Framework (SERF), as it facilitates data-driven decision-making by identifying performance gaps, enabling targeted interventions, and supporting resource optimisation.

Purpose of the Formula

The proposed Educational Performance Assessment Formula is designed to serve as an indicative tool to assess the educational performance of a city based on key demographic and institutional data. While not exhaustive, the formula provides a starting point for evaluating the effectiveness of resource allocation, institutional capacity, and overall educational quality. These insights are critical to aligning smart city education systems with international standards and fostering continuous improvement.

Formula Components

- **Student to Institution Ratio (SIR):** This ratio indicates the average number of students per educational institution. A high SIR may signal overcrowding or insufficient institutional capacity, potentially reducing the quality of education.

$$SIR = \frac{\text{Number of Students}}{\text{Number of Institutions}}$$

- **Resource Utilisation Efficiency (RUE):** This metric evaluates the adequacy and efficiency of resource allocation, such as the availability of computers per student. A low RUE suggests insufficient technological resources, which limits students' ability to benefit from digital tools.

$$RUE = \frac{\text{Number of Computers}}{\text{Number of Students}}$$

- **Overall Educational Performance Index (OEPI):** This composite index combines the SIR and RUE to provide a simplified measure of educational performance. By equally weighting these components, the OEPI highlights the balance (or imbalance) between institutional capacity and resource allocation.

$$OEPI = \frac{SIR + RUE}{2}$$

Application of the Formula

To illustrate the application of the formula, consider a city with the following data:

- **Number of Students:** 3,262,620
- **Number of Institutions:** 328
- **Number of Computers:** 150,000

Using the above data, the formula calculates:

1. Student to Institution Ratio (SIR):

$$SIR = \frac{3262620}{328} = 9943.6$$

This result indicates that, on average, each institution serves 9,943.6 students, which may suggest overcrowding and a potential strain on institutional capacity.

2. Resource Utilisation Efficiency (RUE):

$$RUE = \frac{150000}{3262620} = 0.046$$

This value reveals a low availability of technological resources, with only 0.046 computers per student, highlighting an area for significant improvement.

3. Overall Educational Performance Index (OEPI):

$$OEPI = \frac{9943.6 + 0.046}{2} = 4971.823$$

The OEPI combines these metrics into a single index, providing a simplified yet indicative assessment of educational performance. A high OEPI driven by an imbalanced SIR or RUE points to areas requiring strategic interventions.

Relevance to SERF and the Framework

The Educational Performance Assessment Formula directly supports the SERF framework by:

- **Identifying Gaps:** The formula highlights specific deficiencies in institutional capacity and resource availability, enabling targeted interventions to improve operational efficiency.
- **Data-Driven Decision-Making:** The metrics derived from this formula provide a quantitative basis for strategic planning and policy adjustments.
- **Alignment with Standards:** By quantifying educational performance, the formula helps align smart city education systems with ISO/IEC 30145-3 standards.
- **Supporting Continuous Improvement:** The OEPI, while simplified, offers a baseline to monitor progress and iteratively refine the framework to address emerging challenges.

Cautions and Refinements

Although the OEPI provides valuable information, it should be interpreted with caution due to the inherent limitations of simplifying complex educational ecosystems into a single index. Future iterations of this framework could incorporate additional parameters, such as teacher-to-student ratios, infrastructure quality, and socioeconomic factors, to improve the precision and applicability of the assessment.

By integrating this formula into the SERF framework, stakeholders can leverage a structured, data-driven approach to improve the operational efficiency and quality of education within smart city environments.

Designing a SERFD Big Data Model Framework

Design a Smart Education model that is in line with both the Smart Education Framework and the ISO / IEC 30145-3 standards. This model should include the integration of IoT devices, cloud computing, big data analytics, and AI technologies into educational processes. Emphasis on creating a model that supports personalised learning, remote education, and interactive learning experiences. In the era of digital transformation, designing a Smart Education model is crucial to align educational processes with technological advances, and focus on personalised learning, remote education, and interactive experiences.

Incorporating Big Data Analytics and IoT into Smart Education

Visualization of the Smart Education Framework

The integration of Big Data Analytics and the Internet of Things (IoT) into the Smart Education framework is a revolutionary step toward transforming educational landscapes. As depicted in Figure 3.9 illustrates a comprehensive outline of the role that Big Data and IoT play in the context of Smart Cities, with particular emphasis on Smart Education. The diagram depicted in Figure 5.2 is an epitome of change driven by the data-centric approach in educational systems. The Smart City serves as the nucleus of this transformation, expanding to impact various domains such as Smart Economy, Smart Mobility, Smart Environment, and, in particular, Smart Education.

Smart Education, nestled within this ecosystem, benefits from the Big Data Effect, characterised by volume, veracity, velocity, variety, and value. These five Vs of Big Data underscore the immense potential of data-driven strategies to tailor educational content and methodologies to the needs of the modern learner. Through the IoT API, a channel of communication and data exchange, educational institutions can harness the power of analytics to collect insights, fostering a more engaging and effective learning environment.

The synergy between the IoT infrastructure and Big Data analytics equips educational stakeholders with the tools to navigate and adapt to the complexities of 21st-century education. Catalyse the transition from traditional learning models to dynamic, personalised, and responsive educational experiences. The analytical results derived not only benefit citizens but also inform government policies and business strategies, creating a tripartite alliance that underpins the educational fabric of a Smart City.

In addition, the seamless amalgamation of IoT and Big Data within the Smart Education framework, as illustrated, paves the way for an enriched, data-informed, and future-ready education system.

Steps for Implementation

Integrating IoT Devices

Begin by integrating IoT devices into the educational infrastructure. These devices could range from smart boards to sensors that track student engagement. They provide real-time data that can be used to improve teaching methods and classroom environments.

Utilizing Cloud Computing

Implement cloud computing solutions to store and manage the large amount of generated data. Cloud platforms enable scalable storage solutions and facilitate remote access to educational resources, essential for remote learning.

Leveraging Big Data Analytics

Use big data analytics to analyse data collected from IoT devices and cloud platforms. This analysis helps to understand student learning patterns, thus assisting in the customisation of teaching methods for personalised learning experiences.

Incorporating AI Technologies

Incorporate AI technologies to automate and improve learning and administrative processes. AI can be used to provide personalised course recommendations, automate rating systems, and provide AI-powered tutoring.

Creating an Interactive and Personalised Learning Environment

Focus on building a model that supports interactive learning experiences. Implement tools such as VR and AR for immersive learning. Personalised learning pathways, based on AI and analytics, must be developed to accommodate individual student needs and learning styles.

Example of a Smart Education Model

An example of a Smart Education model is a virtual learning environment in which students interact with digital content using AR and VR. IoT devices in classrooms provide data on student attention and engagement, which are analysed to tailor teaching methods. Cloud platforms offer access to resources, and AI-driven personalisation enhances the learning experience for each student.

Innovative Use of EON-XR in Smart Learning Models

EON-XR: Pioneering Smart Learning

The advent of Extended Reality (XR) in education has caused a paradigm shift in how knowledge is delivered and experienced. EON-XR, a platform at the forefront of this revolution, offers an immersive learning environment that transcends traditional boundaries. Here are two exemplary uses of EON-XR as a smart learning model:

Interactive Anatomy Lessons

A notable application of EON-XR is in the field of medical education. Through the platform, students can engage with three-dimensional anatomical models, exploring each layer of the human body with intuitive touch gestures. This interactive approach allows a deeper understanding of complex structures and relationships within the body, a task that would be challenging only through textbooks. For example, students can virtually dissect parts of the human heart, observing the intricacies of its chambers and valves, leading to a visceral learning experience that significantly enhances retention and comprehension.

Historical Site Exploration

Another innovative use of EON-XR is in the realm of education in history and archaeology. The platform can transport students back in time, allowing them to walk through ancient civilisations and interact with their environments. Imagine exploring the ruins of Machu Picchu or the Pyramids of Giza, not as static images but as living and breathing sites where every stone tells a story. Such immersive tours can spark curiosity and provide context that breathes life into historical narratives, thus fostering a more engaging and memorable educational journey.

In both examples, the EON-XR application in smart learning models exemplifies how technology can be

used to create an interactive, engaging and effective educational system. Using the power of XR, educators can provide students with experiences that are closer to real life than ever before, breaking down the walls of the classroom and opening up a world of endless possibilities. **Site: core.eon-xr.com**
Designing a Smart Education model requires a holistic approach that integrates modern technologies with traditional educational practices. The key is to focus on improving the quality of education while ensuring that it is accessible, personalised, and interactive.

Developing a Phased Implementation Plan

Develop a phased implementation plan to integrate smart technologies into the educational system. This plan should include timelines, budget allocations, resource requirements, and milestones. Ensure that the plan allows flexibility to adapt to changing technological trends.

Ensuring Compliance and Interoperability

Ensure that all technology implementations comply with the ISO / IEC 30145-3 standards, especially with respect to data security and privacy. In addition, the focus is on the interoperability of the systems to enable seamless communication and data exchange between various educational tools and platforms.

Training and Capacity Building

Implement comprehensive training programmes for educators and administrative staff. This training should cover the use of new technologies, understanding of smart education concepts, and the application of the ISO / IEC 30145-3 standards in educational settings.

Pilot Testing and Feedback

Conduct pilot testing of the Smart Education model in selected educational settings. Gather feedback from educators, students, and technical staff to assess the effectiveness of the implementation. Use this feedback to make necessary adjustments.

Monitoring, Evaluation, and Scaling

Establish continuous monitoring and evaluation mechanisms to assess the impact of technology integration on educational results. Use data-driven approaches to measure improvements in learning processes and student performance. Plan to scale up the implementation across various educational institutions while ensuring adherence to the ISO/IEC 30145-3 standards.

Monitoring example: Analysis of data on classroom use

Monitoring, Evaluation, and Scaling through Visual Analytics

The comprehensive dashboard shown earlier in Figure 4.10 serves as an instrumental tool to monitor, evaluate, and scale educational resources. Each chart presents a unique perspective on classroom use, offering insights that are critical to informed decision making.

Animated Histogram

The animated histogram illustrates usage patterns in various time slots, providing a dynamic view of classroom occupancy. Monitoring is simplified as stakeholders can observe peak usage times, guiding resource allocation. The animation of the histogram adds an interactive element, allowing for temporal analysis and identifying trends over days or weeks.

Animated Scatter Plot

Adjacent to the histogram, the animated scatter plot (top-right) offers a granular view of classroom usage. Each point represents an individual session, and its placement provides immediate visual feedback on the distribution of classroom utilisation. It is a powerful evaluation tool that highlights outliers and standard usage patterns.

Line Chart

The line chart (bottom-left) tracks usage over an extended period, offering a clear view of growth trends. It is instrumental for scaling decisions, as it indicates whether the current infrastructure is sufficient or whether expansion is necessary to accommodate growing demand.

Bubble Chart

Finally, the bubble chart (bottom right) correlates classroom usage with other variables, such as class size or available technological facilities. The size of each bubble can represent additional dimensions of the data, such as student participation or academic performance, providing a multifaceted evaluation of educational effectiveness. Together, these visualisations form a cohesive analytical framework. They not only monitor and evaluate current usage, but also inform strategies for scaling resources, ensuring that educational infrastructure meets current and future demands.

Fostering Collaboration and Innovation

Encourage collaboration between educational institutions, technology providers, and policy makers to promote innovation in smart education. Promote the sharing of best practices, research findings, and technological advancements to continuously improve the Smart Education model.

Implementing Smart Education Collaboration and Innovation

Enhancing Smart Education Through Collaborative Efforts

Smart education is not a solitary endeavour; it thrives on collective effort and innovation derived from collaboration between various stakeholders. The following subsection outlines steps to facilitate this collaborative process, aligning with the overarching objectives of ISO/IEC 30145-3.

Step 1: Establishing a Collaborative Framework Begin by setting up an organisational framework that includes educational institutions, technology vendors, and policy makers. This body will oversee the integration of ISO/IEC 30145-3 standards within smart education initiatives.

Step 2: Creating Communication Channels Develop robust communication channels such as online forums, annual conferences, and regular workshops. These platforms will enable stakeholders to exchange information and discuss advances in smart education technologies.

Step 3: Building a Shared Knowledge Repository Set up a digital repository to store and share research papers, case studies, and project results related to smart education. This will serve as a centralised knowledge base accessible to all involved partners.

Step 4: Encourage joint research initiatives Promote joint research projects investigating new applications of technology in education. Offer grants and incentives for research that aligns with the Smart Education Framework and ISO/IEC standards.

Step 5: Piloting Innovative Educational Models Collaboratively design and pilot innovative educational models that leverage IoT, AI, and big data analytics. Document processes and outcomes meticulously to guide future implementations and scalability.

Step 6: Regular review and updates of policies Conduct periodic reviews of educational policies to ensure that they are conducive to the promotion of innovation in smart education. Update policies to reflect new technological capabilities and educational needs.

Step 7: Feature Success Stories Publicise successful implementations of smart education initiatives. Use these success stories to illustrate the practical benefits of collaboration and innovation in this field.

Step 8: Establishing Feedback Mechanisms Implement feedback mechanisms to collect feedback from users and stakeholders. Using this feedback to make informed decisions about future directions for smart education development.

in a collaborative process The steps outlined aim to create a vibrant ecosystem where collaboration and innovation can flourish in smart education. By fostering a culture of sharing and collective problem solving, educational institutions can exploit the full potential of ISO/IEC 30145-3 standards to enrich learning experiences and outcomes. By following these steps, educational institutions can effectively align Smart Education with ISO/IEC 30145-3 standards, under the umbrella of the Smart Education Framework Extends ISO/IEC Smart City Framework. The goal is to create a technologically advanced, efficient, and effective educational environment that prepares students for the challenges of the future.

4.11 Smart Campus Initiatives Alignment with ISO/IEC 30145-3 Standards

The concept of a Smart Campus is pivotal in the Smart Education Framework, serving as a microcosm of the larger Smart City model. Integrating the standards established by ISO / IEC 30145-3 is crucial to achieving a seamless, efficient, and sustainable Smart Campus that supports the educational needs of the future. The evolution of educational environments into smart campuses is revolutionising the landscape of higher education. Using cutting-edge technologies such as cloud computing, the Internet of Things (IoT), and big data analytics, smart campuses are harnessing the power of information and communication technology (ICT) to improve educational outcomes and campus life.

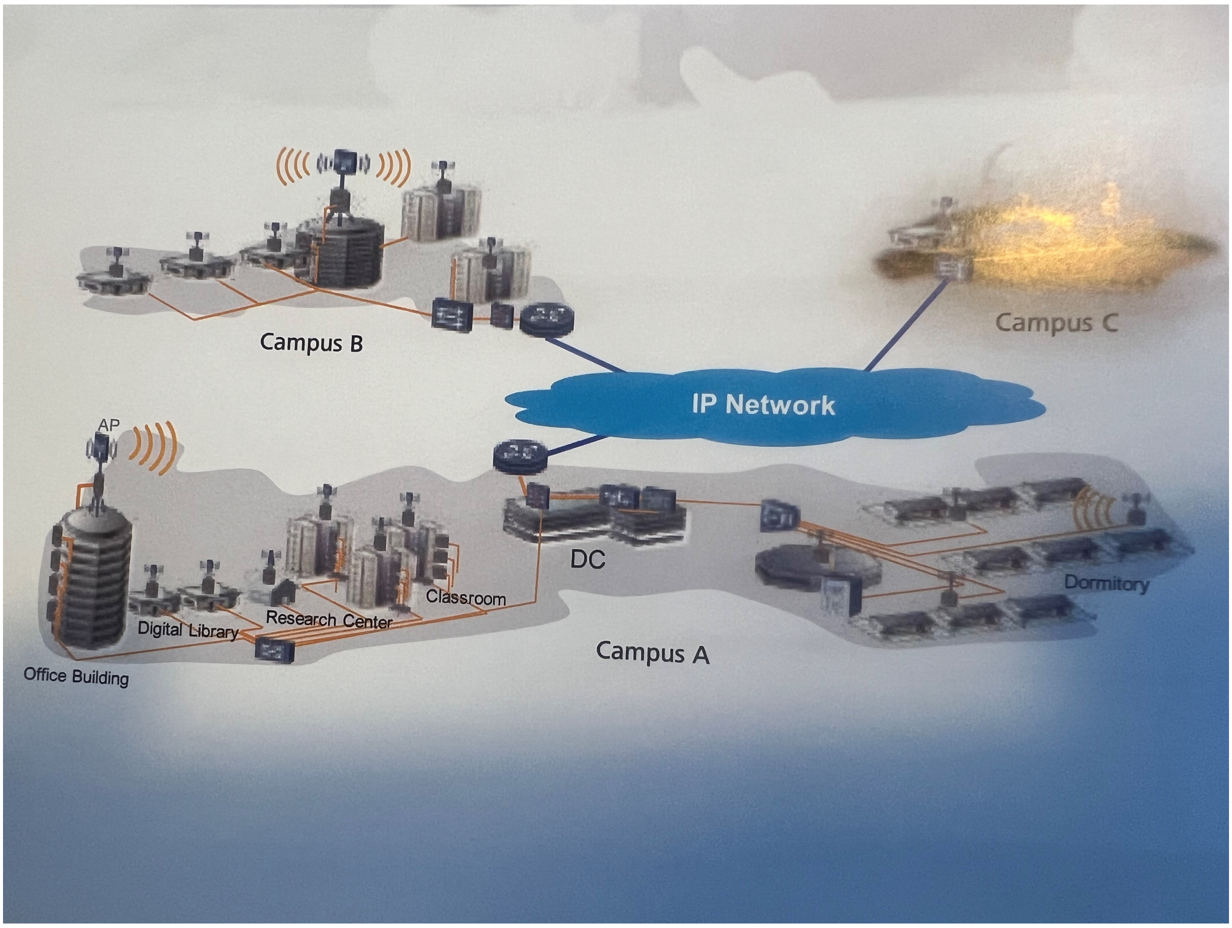


Figure 4.13: A conceptual representation of ICT integration in a smart campus.

ICT Systems in a Smart Campus

ICT infrastructure serves as the backbone of a smart campus, providing a comprehensive and interconnected network that supports various aspects of the educational ecosystem.

- **Supports Teaching and Research:** High-performance computing (HPC) resources support data-intensive scientific research, enabling complex simulations and analysis.
- **Optimizes Service Quality:** Virtual data centres (DCs) host applications and services customised to the academic community, offering customised access based on user roles.
- **Enables Unified Decision-Making:** Data centres aggregate data in real time across campus, facilitating informed decision making at the administrative level.

Agile and Reliable ICT Platforms

The smart campus model is based on the deployment of a secure and agile ICT platform. Key components include:

1. **Comprehensive Wireless Coverage:** Ensuring total network accessibility for the campus community.
2. **Integrated Security Systems:** Safeguarding information and physical assets through advanced security protocols.
3. **IoT Integration:** Implementing IoT devices for environmental monitoring and resource management.

Smart Learning Environments

By establishing an ICT framework that supports environment sensing, mobile Internet access, and big data processing, smart campuses create dynamic learning environments. These systems not only improve education delivery, but also contribute to the construction of a campus that is intelligent, responsive, and sustainable. The transformation of digital campuses into smart ones is not merely a technological upgrade but a strategic move towards an interconnected and intelligent educational framework. The integration of ICT systems as shown in Figure 4.13 is central to this transformation, leading the way towards a future where education is more accessible, personalised, and impactful.
This section delves into the step-by-step alignment process.

Smart Campus as an Extension of Smart Education

Step 1: Infrastructure Assessment Evaluate the existing campus infrastructure to ensure compatibility with ISO / IEC 30145-3 standards. This includes network architecture, data storage solutions, computing resources necessary for smart applications, and more.

Smart Campus Infrastructure Components

A comprehensive Smart Campus infrastructure is made up of various interconnected systems and technologies. The following enumeration outlines these fundamental components:

1. **Network Infrastructure:** High-speed internet connectivity, Wi-Fi access points, and robust network backbone to support IoT devices and cloud computing.
2. **IoT Devices:** Sensors and actuators deployed throughout the campus to monitor and manage various functions such as lighting, heating, cooling, and security.
3. **Energy Management Systems:** Smart grids and energy metres for efficient monitoring and management of utilities, using renewable energy sources where possible.
4. **Data Storage and Processing Centres:** Secure and scalable data centres to handle the storage, processing, and analysis of large volumes of campus data.
5. **Surveillance and Security Systems:** Advanced security systems that include surveillance cameras, smart locks, and emergency response systems.
6. **Learning Management Systems (LMS):** Digital platforms for course management, student engagement, and online learning resources.
7. **Campus Management Software:** Integrated systems for administrative tasks, resource allocation, maintenance scheduling, and campus services.
8. **Smart Classrooms:** Classrooms equipped with interactive whiteboards, projection systems, and adaptive lighting and temperature controls.
9. **Research and Innovation Labs:** Facilities with state-of-the-art equipment to support cutting-edge research and collaborative projects.
10. **Sustainable Infrastructure:** Green buildings, waste recycling systems and water conservation methods in alignment with environmental sustainability goals.

11. **Mobility and Transportation Solutions:** Smart parking systems, charging stations for electric vehicles, and bike-sharing services to promote sustainable transportation.
12. **Health and Well-being Services:** Health monitoring stations, mental health support apps, and fitness trackers for the well-being of students and staff.

Each of these components plays a critical role in forming the infrastructure of a Smart Campus, contributing to an environment that is conducive to learning, research, and general campus life.

Step 2: Integration of Smart Technology Use IoT devices and sensors throughout the campus to monitor and optimise energy usage, resource allocation, and student participation, all within the scope of the aforementioned standards.

Smart Technology Components

Smart technology integrates various devices and applications to create intelligent and responsive systems. The following are key components that make up smart technology:

1. **Internet of Things (IoT) Devices:** Sensors, wearables, home appliances, and other gadgets that collect and exchange data.
2. **Connectivity Solutions:** Advanced wireless networks such as 5G, Wi-Fi 6, and Bluetooth that enable fast and reliable data transfer.
3. **Cloud Computing Platforms:** Remote servers that provide on-demand computing resources and data storage.
4. **Artificial Intelligence (AI):** Algorithms and machine learning models that enable systems to learn, reason and make decisions.
5. **Big Data Analytics:** Tools and techniques to analyse large and complex data sets to reveal patterns and insights.
6. **Cybersecurity Measures:** Technologies and protocols to protect systems and data from cyber threats.
7. **User Interface (UI) Technologies:** Touchscreens, voice assistants, and gesture controls that allow users to interact with technology intuitively.
8. **Robotics and Automation:** Machines equipped with artificial intelligence that can perform tasks ranging from manufacturing to customer service.
9. **Augmented Reality (AR) and Virtual Reality (VR):** Technologies that create immersive digital experiences for users.
10. **Blockchain:** A decentralised ledger technology that improves security and transparency in digital transactions.
11. **Smart Energy Systems:** Intelligent grids and energy storage systems that optimise energy use and distribution.
12. **Digital Health Technologies:** Applications and devices that monitor health and help with medical care.

These components form the basis of smart technology, enabling interconnected and efficient systems that respond dynamically to users' needs.

Step 3: Data Management and Privacy Develop robust data management policies that align with ISO / IEC standards, focussing on protecting student and faculty privacy and secure handling of educational data.

Data Management and Privacy Examples

Effective data management and stringent privacy protocols are vital to protecting information and ensuring compliance with regulatory standards. Here are examples of practices and tools for data management and privacy.

1. **Data Encryption:** Utilizing advanced encryption standards to protect data at rest and in transit against unauthorized access.
2. **Access Controls:** Implementing permission levels to ensure that only authorised personnel can access sensitive information.

3. **Data Anonymisation:** Removing or modifying personal information from data sets to prevent the identification of individuals.
4. **Secure Data Storage:** Using secure databases and storage solutions that comply with industry security standards.
5. **Data Minimisation:** Collecting only the data necessary for the specified purpose, according to the principles of privacy of design.
6. **Regular Audits:** Conducting periodic reviews and audits of data practices to ensure ongoing compliance with privacy laws.
7. **Incident Response Plan:** Have a clear and tested plan to respond to data breaches or privacy incidents.
8. **Privacy Impact Assessments:** Evaluation of new projects or technologies for potential privacy risks and mitigations.
9. **User Consent Management:** Acquiring and managing user consent for data collection and processing activities.
10. **Data Retention Policies:** Defining and enforcing policies for how long data are kept and when it is to be destroyed.
11. **Privacy Notices:** Clearly communicating to users how their data will be used, stored, and protected.
12. **Data Portability:** Allowing users to request and receive their personal data in a usable and portable format.

Adherence to these practices ensures robust data management and upholds individual privacy rights.

Step 4: Smart Sustainable Solutions Implement smart solutions that promote sustainability on campus. This could involve energy-efficient buildings, smart waste management systems and renewable energy sources, all structured around ISO/IEC guidelines.

Implementation of Sustainable Smart Solutions for smart education

Aligning the Smart Education Framework with the ISO/IEC 30145-3 standard requires a strategic approach to implementing sustainable smart solutions. These solutions must not only embrace technology, but also ensure environmental sustainability. Here is a step-by-step guide to this process, with examples of solutions that exemplify sustainability.

Step 1: Energy-Efficient Infrastructure Begin with an audit of current energy usage and identify areas for improvement. Transition to LED lighting, install smart thermostats, and use energy management systems to reduce consumption. For example, the University of East London (UEL) has retrofitted its buildings with smart glass that adjusts to lighting conditions and lighting systems that significantly reduce heating and cooling needs. UEL has also introduced a short-term self-service laptop loaning system to support their effort to reduce fixed desktops in the classroom.

Step 2: Smart Waste Management Develop a smart waste management system that uses IoT sensors to monitor waste levels and optimise collection routes and schedules. Implement recycling programmes and consider the use of campus composting facilities. University of East London has planned a gradual migration to solar-powered waste compactors that notify maintenance staff when they are full, which reduces the collection frequency by 50% in vision 2028.

Step 3: Renewable Energy Adoption Invest in renewable energy sources such as solar panels or wind turbines. Incorporate these into the campus grid, with the goal of moving towards a net-zero energy footprint. University of East London, for example, has installed a solar farm on the campus of the Docklands East building that generates 20% of its annual electricity needs.

Step 4: Sustainable transportation Encourage sustainable transportation options such as charging stations for electric vehicles, bike sharing programmes, and shuttle services to reduce carbon emissions.

University of East London offers incentives for students and staff who ride buses between campuses or use electric vehicles, effectively reducing their carbon emissions from transportation.

Step 5: Smart landscaping Adopt smart landscaping practices that reduce water use through drought-resistant plants and smart irrigation systems that water according to weather forecasts and soil moisture levels. University of East London hopes to implement, as part of Vision 2028, a smart irrigation system that will result in a 30% reduction in water usage for landscaping.

Step 6: Continuous Monitoring and Improvement Continuously monitor the performance of sustainable initiatives through smart sensors and data analytics. Use these data to refine and improve strategies, ensuring alignment with the ISO / IEC 30145-3 standards and the Smart Education Framework.
By following these steps and using examples of sustainable smart solutions, educational institutions can create an environment that supports the Smart Education Framework while upholding the principles of sustainability outlined in ISO/IEC 30145-3.

Step 5: Interoperability of Systems Ensure that all smart technologies adopted on campus can seamlessly interoperate according to the ISO/IEC 30145-3 standards. This facilitates a cohesive and efficient smart campus environment.

Step 6: Educational Technology Enhancement Enhance educational technology tools to foster a learning environment that is inclusive and innovative, using the structure provided by the ISO/IEC framework to support a diverse learning community.

Step 7: Continuous Improvement and Adaptation Adopt a model of continuous improvement, regularly reviewing and updating campus smart technologies to stay in line with evolving ISO/IEC standards and the dynamic needs of smart education.

Step 8: Collaboration and partnerships Form strategic partnerships with technology providers, city planners, and educational leaders to advance the vision of a smart campus. Collaboration is the key to ensure that smart campus initiatives benefit from a broad range of expertise and remain in line with international standards.
The integration of a Smart Campus within the Smart Education Framework, according to ISO / IEC 30145-3, is a multifaceted process that requires meticulous planning, execution, and ongoing management. By adhering to these steps, a Smart Campus can become a beacon of advanced education, sustainability, and innovation.

4.12 Smart City Knowledge Base smart education context

Central to the framework is the "Smart City Knowledge Base," which collects and organises data, providing a foundation for knowledge acquisition and organisational learning. This base supports educational research, enabling data-driven decision-making and policy development. Implementing a Smart City Knowledge Base is a critical component of the Smart Education Framework that aligns with the ISO/IEC 30145-2 standards. This knowledge base acts as a central repository of data and information that supports educational research and informs policy making. Here is a step-by-step approach to building this knowledge base, complete with an illustrative example.
Step 1: Data collection
Begin by establishing data collection protocols in the smart city. Using IoT devices, surveys and institutional data to gather comprehensive information on various aspects of city operation, including energy usage, transportation patterns, and resource allocation.

Step 2: Organisation of data

Organise the collected data in a structured format within a centralised database. Employ data categorisation techniques to make it easily accessible and searchable. For example, categorise the data by sectors such as education, healthcare, public services, and infrastructure.

Step 3: Knowledge acquisition

Implement analytics tools to convert raw data into actionable knowledge. This includes the use of machine learning algorithms to identify patterns, predict trends, and provide information that supports educational initiatives and research projects.

Step 4: Organisational learning

Develop platforms for sharing knowledge between institutions and departments. Encourage collaborative learning and the exchange of best practices. Use this collective learning to drive innovation in smart education and city management.

Step 5: Data-Driven Decision Making

Equip policymakers with access to the knowledge base to inform their decisions. Provide tools for data visualisation and simulation to model the impact of potential policies, ensuring that decisions are grounded in empirical evidence.

Empirical Evidence in Smart Education Frameworks

Empirical evidence is crucial in evaluating the effectiveness of smart education frameworks. The following are examples of empirical evidence that can support the integration of technology in education, presented in an itemised format.

- **Improved Student Engagement:** A study conducted across multiple smart classrooms showed a 20% increase in student participation when interactive digital whiteboards were used, compared to traditional blackboards (Hwang 2014; Zawacki-Richter, Victoria I Marín, et al. 2019a).
- **Enhanced Learning Outcomes:** Data from student assessments indicated a significant improvement in test scores in maths and science subjects after the introduction of adaptive learning software (Shaofeng Wang, Z. Sun, and Y. Chen 2022; Picciano 2012).
- **Increased Attendance Rates:** Schools that implemented e-learning platforms and mobile learning applications reported a 15% decrease in student absenteeism due to the flexible learning opportunities provided (Al-Fraihat, Joy, and Sinclair 2020; Wong and Looi 2022).
- **Positive Feedback from Educators:** Surveys conducted among teachers revealed that 85% felt that smart education tools had a positive impact on teaching efficiency and student comprehension (Radianti et al. 2020; Alario-Hoyos et al. 2019).
- **Cost-Effectiveness:** Financial reports highlighted a reduction in the cost of educational materials and resources by 30% after switching to open educational resources and digital textbooks (**piccialli2018role**; Zawacki-Richter, Victoria I Marín, et al. 2019a).

Each of these points represents concrete empirical evidence that smart education systems are making a measurable difference in the educational landscape. These data are essential for policy makers and educational administrators when considering investments in smart education technologies.

Step 6: Policy Development

Use the knowledge gained from the knowledge base to develop draught policies that promote the objectives of the Smart Education Framework. These policies should be flexible enough to adapt to new data and changing circumstances, ensuring their relevance and effectiveness in dynamic smart city environments. The inclusion of adaptive policies is aligned with international standards such as ISO / IEC 30145-3, which emphasise the need for continuous improvement and scalability (**isoiec30145**).

Example: London Smart City Knowledge Base

The London Smart City initiative provides a compelling example of how a knowledge base can improve operational efficiency in smart education. The initiative integrates data from various sources, including educational institutions in cities, public transport systems, and environmental sensors, into a unified knowledge base. This infrastructure supports applications such as the Track and Trace app, which was pivotal during the COVID-19 pandemic.

The knowledge base offers real-time insight into key performance indicators (KPIs), such as student performance metrics, resource use, and hotspot detection for COVID-19 cases. Using these insights, policymakers developed a smart transportation policy that significantly reduced congestion hotspots around schools during peak hours. This proactive approach not only improved COVID-19 detection rates but also enhanced the safety and operational efficiency of the city's education systems (**batty2013smart**; **he2020urban**). The London Smart City Knowledge Base demonstrates how data-driven insights can inform the development of policies that support smart education objectives. This approach fosters:

- **Enhanced Decision-Making:** Real-time data enables policy makers to make informed decisions that address immediate challenges while aligning with long-term strategic goals.
- **Resource Optimisation:** Insights into resource utilisation ensure efficient allocation, reducing waste and improving service delivery (**batty2012visualising**).
- **Scalability and Adaptability:** The system is designed to incorporate new data sources and evolving needs, ensuring its ongoing relevance in a dynamic urban environment (**allam2019future**).
- **Stakeholder Engagement:** By providing transparent and actionable insights, the knowledge base fosters collaboration among educators, policymakers, and urban planners (**cranshaw2012livehoods**).

By following these steps, a smart city can establish a knowledge base that not only supports the educational framework but also fosters a culture of continuous learning and improvement. This aligns with international standards such as ISO / IEC 30145-3, which emphasise data integration and adaptability as key pillars for smart city success (**isoiec30145**).

4.12.1 Smart City Knowledge Acquisition & Organisation

Alignment with ISO/IEC 30145-2 for Smart Education Framework

The integration of the Smart Education Framework with the Smart City Infrastructure is fundamental for its success. Here are the key elements that constitute the "Smart City Knowledge Acquisition & Organisation" as per ISO/IEC 30145-2:

1. **Data Collection Systems:** Implementation of IoT devices across the city to collect real-time data on traffic, energy consumption, weather, and more.
2. **Analytical Tools:** Use of advanced analytics and machine learning algorithms to process and interpret large data sets, providing information on city operations.
3. **Information Sharing Platforms:** Development of secure digital platforms that enable the sharing of knowledge between city departments, educational institutions, and the public.
4. **Citizen Engagement Mechanisms:** Creation of mobile apps and online portals that encourage citizen feedback and participation in smart city initiatives.
5. **Educational Resource Databases:** Establishment of comprehensive databases that house educational materials, research articles, and case studies related to smart education.
6. **Training and Development Programmes:** Offering workshops and courses for city officials and educators to learn about smart city technologies and their applications in education.
7. **Policy Frameworks:** Formulation of policies that guide ethical collection, storage, and use of data in the context of smart education.
8. **Collaborative Networks:** Building networks that connect educational institutions with tech companies and government agencies to foster collaborative smart city solutions.

Each of these components plays a crucial role in acquiring and organising knowledge in a smart city, ensuring that educational strategies are informed by accurate and up-to-date information. Aligning these components with the Smart Education Framework ensures that educational initiatives are not only innovative but also integrated with the broader smart city context, promoting a more holistic approach to learning and city management.

4.13 Education Research Aligned with Smart Education Framework

The dynamism of Smart Cities is underpinned by a robust educational infrastructure that not only caters to current demands, but is also forward-looking, ensuring the preparedness of citizens and enterprises for future challenges. This is achieved through a harmonious alignment with the Smart Education Framework,

which extends the ISO/IEC Smart City Framework.
The Education and Research component is quintessential, serving as a catalyst for the city's sustainable growth and the fulfilment of its stakeholders' aspirations. This encompasses a spectrum of initiatives:

1. Ensuring equitable access to education empowers all citizens to realise their potential and contribute meaningfully to society.
2. Strategically developing Human Resources across diverse fields, from trades to STEM, to bolster the city's economic vitality and societal welfare.
3. Continuously updating the skills of the workforce, providing retraining as necessary to stay abreast of the evolving industry landscape.
4. Fostering collaborative R&D endeavours between academia and industry, promoting pre-competitive research through university-industry consortiums.
5. Integrating open innovation initiatives within higher education frameworks and promoting a culture of shared knowledge and collective advancement.

The successful implementation of these educational strategies is marked by the following outcomes.

- A well-rounded educational and training system that is attuned to the professional landscape, fulfilling the needs of both individuals and the collective city ecosystem.
- Strategic partnerships between educational institutions and city stakeholders to tailor educational offerings that respond to current and emerging industry requirements.
- Innovative pedagogies and delivery methodologies, such as online courses and modular training, make education more accessible and aligned with modern lifestyles.

To realise this vision, the following steps are crucial:

1. Conduct comprehensive research to understand and anticipate the city's overarching educational requirements.
2. Develop and implement a city-wide education and research strategy, informed by this research, to guide the city's educational trajectory.
3. Establish a strategic educational management structure that transcends organisational silos, fostering a cohesive approach to education.
4. Identify and analyse pertinent data that will drive informed decision-making on education provision and quality.

The Smart Infrastructure and Building initiatives are equally important, ensuring that the physical and digital infrastructure of educational institutions is not only state-of-the-art but also sustainable and conducive to advanced research and learning modalities.

Integrating Education Research with ISO 30145-1

Integration of education research within the scope of ISO 30145-1 is a strategic move toward building a knowledge-centric urban ecosystem. ISO 30145-1 lays the foundation for the participation of stakeholders in smart cities, and Education Research acts as a bridge between the foundational processes and the educational aspirations of a smart city.

1. **Stakeholder Analysis:** Begin with a detailed analysis of the needs and expectations of all stakeholders in the city, including educational institutions, businesses, and citizens.
2. **Strategic Alignment:** Align the educational objectives with ISO standards, focussing on scalability, interoperability, and sustainability to meet current and future demands.
3. **Policy Development:** Develop policies that facilitate research-driven education, ensuring that they are in harmony with the guidelines and objectives set forth by ISO 30145-1.
4. **Implementation and Evaluation:** Execute the educational strategies, utilising ISO benchmarks as metrics for evaluation and continuous improvement.

Example Integration: For example, if the city's objective is to improve its technical workforce, the Education Research arm would work in tandem with industry partners to assess current skill gaps, design educational programmes aligned with ISO standards, and implement these while continuously monitoring the results against ISO benchmarks.
This step-by-step approach ensures that the educational framework is not only in compliance with ISO standards but also remains dynamic, responsive, and relevant to the city's growth trajectory and its stake-

holders' evolving needs. The interweaving of Education Research within the Smart Education Framework is pivotal for cultivating a resilient, educated populace capable of propelling Smart Cities into a future of innovation and prosperity.

4.14 Stakeholder Identification for Smart Education Framework

The framework acknowledges the critical role of stakeholders, including citizens, communities, government entities, and nongovernmental organisations. It emphasises the importance of stakeholder participation in shaping educational policies and Smart Education initiatives. The "Smart Education Framework Extends ISO/IEC Smart City Framework" integrates seamlessly with "ISO 30145-1" by recognising the vital role stakeholders play in the development and execution of smart educational initiatives. Identifying these stakeholders is a multistep process essential to foster a collaborative environment. The following is a detailed process for stakeholder identification:

1. **Stakeholder Mapping:** Initiate the process by mapping all potential stakeholders. This includes individuals, communities, businesses, government, and nongovernmental organisations with a vested interest in educational outcomes.
2. **Interest and Influence Analysis:** Assess the level of interest and influence each stakeholder has on educational policies and initiatives. This will help prioritise engagement strategies and resource allocation.
3. **Engagement Strategy:** Develop an engagement strategy customised to the different categories of stakeholders identified. This strategy should outline how to involve them in the decision-making process effectively.
4. **Communication Plan:** Establish a communication plan that details the methods and frequency of interactions with stakeholders. The plan should be inclusive, ensuring that all voices are heard and considered.
5. **Alignment with ISO 30145-1:** Align the stakeholder identification process with the "ISO 30145-1" standard, which emphasises stakeholder participation in smart city governance. This ensures a systematic approach that is internationally recognised.
6. **Continuous Monitoring and Reassessment:** Continuously monitor the landscape of stakeholders for any changes and reassess the engagement strategy accordingly. This dynamic approach ensures that the framework remains relevant and effective.

Example Application: As an example, a university that plans to implement a smart learning management system would first list all potential stakeholders, such as students, faculty, administrative staff, technology providers and alumni. The university would then assess the level of interest and influence of each group and develop a targeted engagement strategy. Communication may include town hall meetings, surveys, and focus group discussions, ensuring that the project is aligned with the educational goals of stakeholders and the ISO 30145-1 standard. This inclusive approach not only enriches the project with diverse insights, but also fosters a sense of ownership and collaboration among all parties involved.

This step-by-step guide facilitates a structured and inclusive process for stakeholder identification, crucial for the success of the "Smart Education Framework Extends ISO/IEC Smart City Framework" in achieving its educational goals.

4.15 Citizen/Community Recognising Smart Citizens in Smart Education

The integration of smart citizens into the "Smart Education Framework Extends ISO/IEC Smart City Framework" is pivotal for achieving a sustainable and inclusive educational environment. The "ISO 30145-1 standard" emphasises the role of citizens in smart city ecosystems, and smart education is no exception. The following is a step-by-step guide to identifying and engaging smart citizens within this context.

1. **Definition of Smart Citizen:** Begin by defining what constitutes a smart citizen within the educa-

tional ecosystem. A smart citizen is typically tech-savvy, actively involved in community initiatives, and a proponent of lifelong learning.

2. **Outreach and Inclusivity:** Develop outreach programmes aimed at various demographics to ensure inclusion. This includes using digital platforms and community events to reach citizens.
3. **Educational Empowerment:** Implement initiatives that empower citizens with the knowledge and tools necessary to engage with smart technologies. This could involve workshops, online courses, and hands-on demonstrations.
4. **Feedback Mechanisms:** Establish channels through which citizens can provide feedback on educational services and smart city initiatives. These can include digital forums, suggestion boxes, and public consultations.
5. **Citizen-Centric Design:** Design smart educational tools and solutions with the citizen at the core. Ensure that technologies are accessible, user-friendly, and provide real value to the educational experience.
6. **Collaboration Platforms:** Create platforms that encourage collaboration between citizens and educational institutions. This could be in the form of innovation laboratories or joint research projects.
7. **Recognition and Reward:** Recognise and reward active participation and contributions of smart citizens. This could be through acknowledgement in public forums or incentives for continued engagement.
8. **Monitoring and Adaptation:** Continuously monitor the level of citizen participation and adapt strategies as needed. Use data analytics to better understand the needs and preferences of citizens.
9. **Alignment with ISO 30145-1:** Ensure that all steps are in alignment with the "ISO 30145-1 standard", which will provide a structured framework for integrating smart citizens into smart city initiatives.

Example Application: Consider a scenario in which a city introduces an educational portal that provides access to learning resources. In this case, the smart citizen is one who not only uses the portal for personal growth, but also contributes to its content and provides feedback for its improvement. The city recognises these contributions through awards and highlights success stories at city council meetings, inspiring more citizens to become involved.

This structured approach ensures that smart citizens are not only recognised, but also actively engaged in the educational advancements proposed by the "Smart Education Framework". By acknowledging its role, the framework facilitates a collaborative environment where education is enriched through active citizen participation, in line with the "ISO 30145-1 standard".

4.16 Government Smart Identification in the Context of Smart Education

Smart government is a cornerstone in the structure of smart education, as outlined in the "Smart Education Framework Extends ISO/IEC Smart City Framework". Recognising a smart government in this context involves several key steps, ensuring alignment with the "ISO 30145-1 standard". Here, we present a detailed procedure.

1. **Strategic Vision:** Identify governments that have a clear strategic vision for integrating technology in education, with the aim of transforming learning environments and outcomes.
2. **Policy Development:** Recognise governments that develop and implement policies that promote the use of ICT in education, promote innovation, and support infrastructure consistent with ISO standards.
3. **Stakeholder Engagement:** Smart governments actively engage stakeholders in the education sector, including students, teachers, and parents, in the development and execution of smart education initiatives.
4. **Resource Allocation:** Evaluate how governments allocate resources for smart education, prioritising sustainable investment in technological infrastructure and professional development for educators.
5. **Data-Driven Decisions:** A hallmark of smart governance is the use of data analytics to inform

educational policy and practice, seeking evidence-based decisions that improve educational outcomes.

6. **Public-Private Partnerships:** Identify collaborative efforts between the government and the private sector to develop and implement educational technologies and platforms.
7. **Inclusive Services:** Smart governments ensure that educational technology services are inclusive and accessible to all citizens regardless of socioeconomic status.
8. **Innovation Ecosystems:** Recognise governments that cultivate innovation ecosystems, encouraging start-ups and technology firms to contribute to the educational sector.
9. **Continuous Improvement:** Identify smart governments that commit to continuous improvement and adaptability in their educational technology initiatives, while remaining responsive to the evolving needs of learners and educators.
10. **ISO Compliance:** Ensure that all government policies and initiatives comply with the "ISO 30145-1 standard", indicating a structured and internationally recognised approach to smart education.

Example Scenario: A city government has launched an initiative to digitise all classroom resources and make them accessible through a central portal. This initiative is in line with the city's strategic vision to enhance learning through technology. The government has set up a cross-sectoral committee to oversee the implementation, ensuring that the project aligns with the "ISO 30145-1 standard" and is inclusive for all students. There is a transparent mechanism for monitoring progress and collecting feedback from all stakeholders, ensuring continuous improvement. This exemplifies the role of a smart government in facilitating smart education, as defined in the framework.

By following these steps, we can recognise and work with smart governments to foster an environment conducive to smart education, as envisioned by the "Smart Education Framework Extends ISO/IEC Smart City Framework" and grounded in the principles of the "ISO 30145-1 standard".

4.17 NGOs Recognition in the Context of Smart Education

In the vast landscape of smart education, nongovernmental organisations play a pivotal role. Their recognition within the "Smart Education Framework Extends ISO/IEC Smart City Framework" involves a series of methodical steps, ensuring congruence with the "ISO 30145-1 standard". Here, we outline the key indicators of a smart NGO's active participation in smart education.

1. **Mission and Vision Alignment:** Smart NGOs possess a clear mission that aligns with advancing smart education, supporting the Framework's objectives and adhering to ISO standards.
2. **Innovative Programmes:** Identify NGOs that develop innovative educational programmes using technology to improve learning outcomes, particularly those that address the digital divide.
3. **Community Engagement:** Smart NGOs are deeply involved in local communities, facilitating community-driven and sustainable education initiatives.
4. **Collaboration with Educational Bodies:** Recognise NGOs that collaborate with schools, universities, and educational authorities to promote technology-enhanced learning environments.
5. **Advocacy for Policy Change:** A smart NGO advocates for policies that support the integration of ICT in education, contributing to the creation of smart education policies.
6. **Resource Mobilisation:** Evaluate how NGOs mobilise resources, including funding, technology, and expertise, to support smart education projects.
7. **Training and Development:** Smart NGOs actively participate in the training and professional development of educators in the use of educational technologies.
8. **Research and Development:** Identify NGOs that invest in R&D for educational technologies, contributing to the body of knowledge in smart education.
9. **Transparency and Accountability:** Recognise NGOs that demonstrate transparency in their operations and are responsible for their contributions to smart education.
10. **Compliance and Standardisation:** Ensure that NGO initiatives comply with the "ISO 30145-1 standard" and contribute to the standardisation of smart education practices.

Illustrative Example: An NGO focused on educational technology has partnered with a network of schools to introduce a platform for collaborative learning, which incorporates AI to personalise the learning experi-

ence. This initiative aligns with the NGO's mission to foster educational equity and is consistent with the ISO standards for smart education frameworks. The NGO works transparently, publishing annual reports on its impact, and maintaining open communication channels with stakeholders. This exemplifies the role of a smart NGO within the "Smart Education Framework Extends ISO/IEC Smart City Framework". By adhering to these criteria, we can identify and collaborate with smart NGOs that are integral to advancing the objectives of smart education, aligning with the vision set forth by the "Smart Education Framework Extends ISO/IEC Smart City Framework" and ensuring adherence to the "ISO 30145-1 standard".
The "Smart Education Framework Extends ISO/IEC Smart City Framework" represents a strategic approach to incorporating Smart Education within the broader smart city context. This alignment ensures that educational institutions benefit from advances in smart technology while contributing to the overall intelligence and sustainability of the city.

Table 4.3: Information Requirements for SERFD Section A

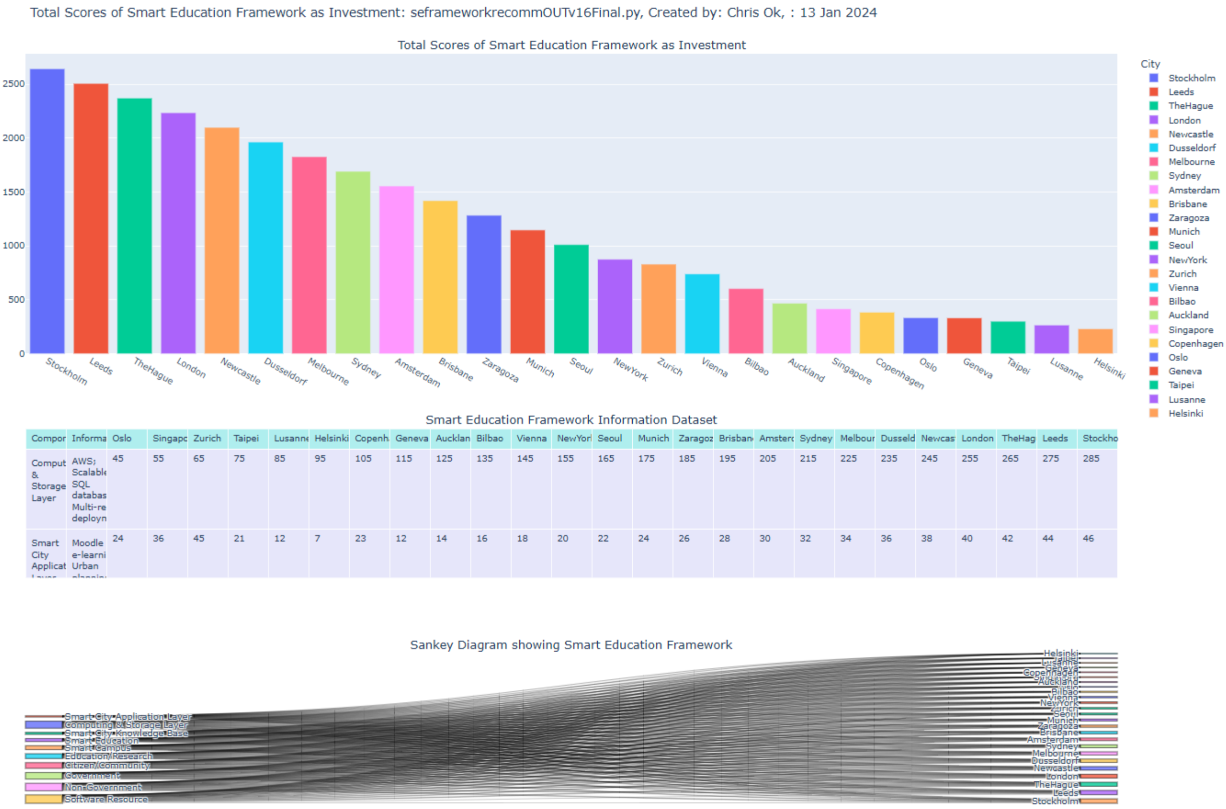
Framework Component	**Information Required**
Computing & Storage Layer	Types of computing resources (e.g. cloud, hybrid, legacy PC), list of storage solutions, capacity and scalability requirements.
Smart City Application Layer	Specific applications in use, their vendors, integration points, and any available APIs.
Smart City Knowledge Base	Data, data formats, access protocols, and security considerations for knowledge storage and retrieval.
Smart Education	User profiles, educational content, delivery modalities, and feedback mechanisms for educational services.
Smart Campus	Campus infrastructure details, IoT deployment status, connectivity options, and smart facility management tools.
Education/Research	Research databases, publication repositories, collaboration tools, and institutional partnership details.
Citizen/Community	Community engagement platforms, citizen feedback channels, and demographic data.
Government	Regulatory requirements, government service interfaces, and funding mechanism details.
Non-Government	NGO partnership models, project collaboration platforms and impact measurement metrics.
Software Resource	Software inventory, licencing details, interoperability standards, and update mechanisms.

Table 4.4: Information Requirements for SERFD Section B

Framework Component	**Sample Information Required**
Computing & Storage Layer	Cloud service providers (e.g., AWS, Azure), data storage options (e.g., SQL, NoSQL databases), and system scalability parameters.
Smart City Application Layer	E-learning platforms (e.g., Moodle, Blackboard), urban planning tools, traffic management applications, and smart utility monitoring software.
Smart City Knowledge Base	Educational datasets, city infrastructure data, smart grid information, data on environmental monitoring and citizen privacy policies.
Smart Education	Student learning styles, course material formats (e.g., video, text), adaptive learning algorithms, and virtual classroom technologies.
Smart Campus	Building automation systems, energy management tools, Wi-Fi coverage maps, and integration of security surveillance.
Education/Research	List of academic journals, research funding sources, collaborative research platforms (e.g. ResearchGate), and details of the industry-academia partnership.
Citizen/Community	Community forums, local education outreach programmes, citizen skill development initiatives, and community learning centres.
Government	Policy frameworks for education, accreditation standards, public funding guidelines, and educational outcome metrics.
Non-Government	NGO-led educational programmes, civic tech initiatives, volunteer databases, and corporate social responsibility (CSR) projects in education.
Software Resource	Inventory of educational software, open source tools, proprietary system integration methods, and software maintenance schedules.

4.18 Analysis of SERFD Performance

The visualisation presented in Figure 4.14 encapsulates the empirical data analysis of smart education investments in various cities. The bar chart delineates the holistic engagement of each city in the smart education framework, as visioned by the ISO / IEC 30145-1 standards. This representation is crucial to discerning the level of commitment and readiness of each urban area to embrace smart education paradigms.



Compor	Informa	Oslo	Singapc	Zurich	Taipei	Lusanne	Helsinki	Copenh	Geneva	Aucklan	Bilbao	Vienna	NewYorl	Seoul	Munich	Zaragoz	Brisban	Amsterc	Sydney	Melbour	Dusseld	Newcas	London	TheHag	Leeds	Stockho
Comput & Storage Layer	AWS; Scalable SQL databas Multi-re deployn	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265	275	285
Smart City Applicat	Moodle e-learni Urban	24	36	45	21	12	7	23	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46

Figure 4.14: Performance of Smart Education Framework aligned with ISO/IEC 30145-1 standards, showcasing the cumulative investment in smart education initiatives. The bar chart exhibits the total score of each city, reflecting the aggregate of components such as infrastructure, research, and resource allocation. The Sankey diagram beneath provides a detailed flow of contributions across various framework components, illustrating how each segment interlinks to foster a cohesive smart education ecosystem.

The colours of the bars in the chart are not merely for aesthetic differentiation but are purposefully selected to correspond to the respective cities, thereby providing an immediate visual correlation between the data point and its geographic origin. This alignment ensures a user-friendly interface for stakeholders to quickly identify and compare the smart education performance of different cities.

Furthermore, the accompanying table offers a quantitative breakdown of the data sets that underlie the bar chart, providing an in-depth perspective on the information considered in the analysis. This transparency in data presentation adheres strictly to the ISO/IEC 30145-1 guidelines, which stipulate clear, accessible, and actionable dissemination of smart city data.

The Sankey diagram at the bottom serves as an analytical tool to trace the investment streams from their sources to the respective sectors within the smart education framework. It elucidates the interdependencies and flow of investments, thereby offering insights into the strategic planning and prioritisation of smart education initiatives within each city.

The graphic underscores the importance of a comprehensive and data-driven approach to smart education, as advocated by the ISO / IEC standards. Highlights how strategic investments, when aligned with the standard's holistic view, can yield a robust and forward-thinking educational infrastructure capable of nurturing future generations.

4.19 Tools and Techniques Employed

The development of the "Smart Education Framework Extends ISO/IEC Smart City Framework" employs a multifaceted approach, integrating various tools and techniques to ensure a comprehensive analysis that adheres to ISO/IEC 30145 series of standards. This section delineates the tools and analytical techniques that underlie the investigation, providing insight into the robust processes that drive the study.

Development of data handling programme

Python, renowned for its analytical prowess, was the primary tool for data manipulation and analysis. Libraries such as Pandas, Plotly, Matplotlib, TkInter, and NumPy facilitated the handling of large datasets, allowing efficient computation, transformation, and data inspection.

Data Importation and Manipulation in Python

Data manipulation is a critical step in the data analysis process, often involving the importation of data from various sources into Python for further operations such as cleaning, transformation, and analysis. This section outlines a step-by-step approach to importing and manipulating data in Python using the Pandas library.

Installation of Pandas

Before importing data, ensure that the Pandas library is installed in the Python environment. Pandas can be installed using pip, the Python package manager, with the following command in the terminal, please see Appendx A. The process outlined provides a basic framework for data importation and manipulation in Python as used during this research by data analysts for a comprehensive analysis, ensuring that the data are clean, structured, and ready for any advanced analytical tasks that may follow. Python, in combination with Pandas, offers a powerful and efficient tool set for these processes, which is essential for handling the increasingly data-driven demands of smart education frameworks and other complex systems. Recall that while these steps form the foundation, the specific details of the data manipulation process used in this research can vary widely depending on the nature of the data and the objectives of the analysis. Therefore, one must be adaptable and willing to explore the extensive functionalities that Python and its libraries offer for data science applications.

4.20 Visualization Tools

To convey the intricacies of the performance of the smart education framework, data visualisation played a crucial role. Plotly, a cutting-edge visualisation library, was instrumental in crafting interactive graphs and charts that not only presented the quantitative data but also enabled stakeholders to engage with the visualisations dynamically. The use of bar charts, Sankey diagrams, and heat maps provided a multidimensional view of performance metrics, ensuring clarity and comprehensibility of complex datasets.

Development of the Plotly Dashboard

In the quest to extend the "Smart Education Framework" as per ISO/IEC 30145 series standards, a Plotly dashboard was meticulously crafted. This section delves into the design considerations, data integration methodologies, key features, and implementation steps that culminated in the development of an interactive and informative dashboard. The plotly dashboard plays a crucial role in visualising the performance and operational metrics of smart education frameworks, in addition to the systematic approach taken from conceptualisation to the deployment of the dashboard.

Design Considerations

The dashboard was designed with the end user in mind, ensuring a seamless user interface (UI) and an optimal user experience (UX). A balanced and intuitive layout was adopted, facilitating easy navigation through the various facets of educational data. The choice of a colour scheme was deliberate, aimed at ensuring accessibility and inclusivity while enhancing the visual appeal and maintaining consistency with the

Smart Education Framework's branding. In general, a intuitive layout that allows users to navigate through large amounts of data with ease. Interactive elements are strategically placed to facilitate participation and efficient data exploration.

Data Integration

The backbone of the dashboard functionality is its robust data integration process. The sources of varied educational data were aggregated, including classroom use, city-wide educational performance, and investment statistics. An ETL (Extract, Transform, Load) pipeline ensured the cleansing, normalisation, and seamless integration of data, guaranteeing the dashboard's accuracy and real-time responsiveness. Data are sourced from various educational and smart city platforms. It undergoes meticulous processing and integration to ensure that the dashboard reflects accurate and up-to-date information. This enables stakeholders to make informed decisions based on reliable data.

Key Features

Interactive elements are the hallmark of the dashboard. Users can interact with dynamic graphs, drill into data specifics, and filter through layers of information to obtain customised insights. Real-time data updates ensure that the dashboard reflects the most current data, allowing educators and policymakers to quickly make well-informed decisions.

The dashboard boasts several features such as:

- Interactive graphs that allow for detailed data analysis
- Real-time data updates to ensure the information is current
- Customizable views to cater to specific user preferences

Implementation Steps

The dashboard's development process was an iterative and structured approach:

- Initial requirement analysis to align with gathering user needs and conceptualizing visualisation goals.
- Data collection from various sources and their subsequent preparation for integration.
- Prototype design that included basic visual elements for early feedback.
- Development of interactive features and ensuring dashboard responsiveness, and other web technologies.
- User testing sessions to refine functionality based on actual user interactions.
- Deployment phase to make the dashboard accessible to users.
- Continuous maintenance and updates to adapt to new data and user requirements.

Code Implementation

The implementation involved using Python's plotly library to render interactive charts:

```
import plotly.graph_objects as go
fig = go.Figure(data=[go.Bar(name='City1', x=categories, y=values)])
fig.update_layout(barmode='stack')
```

This code snippet illustrates the construction of a stacked bar graph, a crucial component for depicting comparative data analyses effectively. Additional examples and implementation can be found in the appendix. The plotly dashboard thus serves as a strategic tool within the Smart Education Framework, transforming complex datasets into comprehensible visual narratives. It is a testament to the data-driven approach integral to smart education, adhering to the benchmarks set by the ISO/IEC 30145 series, and demonstrating the practical application of data visualisation to improve educational strategies and investments.

4.20.1 SERFD Dashboard Visualisation Descriptions

SE Environment Dashboard

Figure 4.15: Smart Education Environment Monitor Dashboard

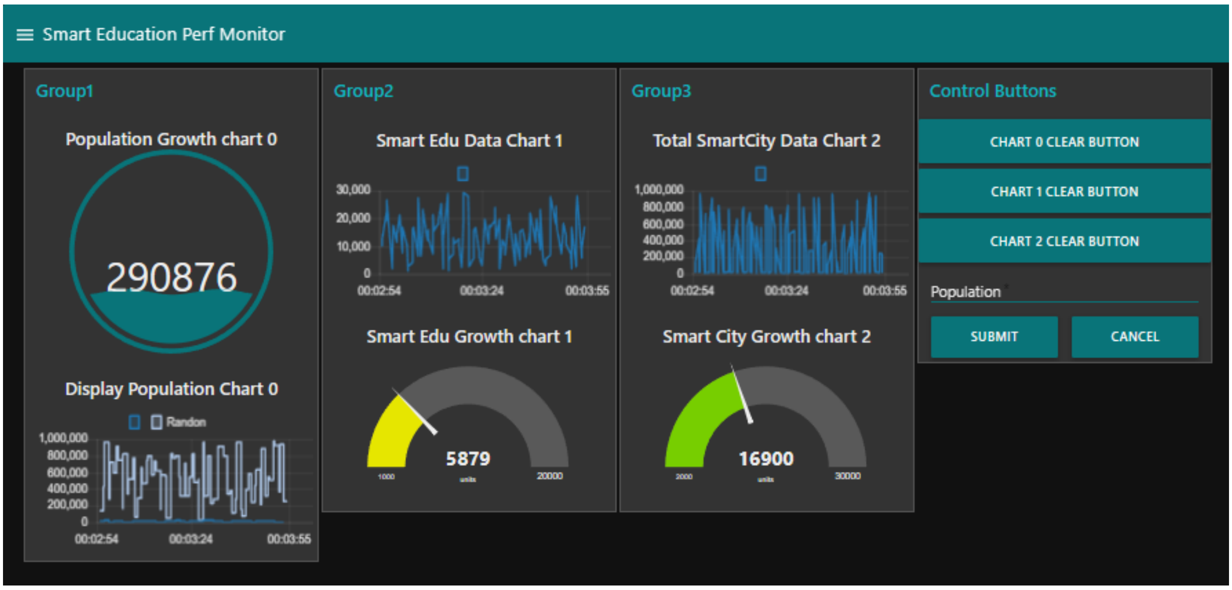


Figure 4.16: Smart Education Environment Statistics Monitor

The images 4.15 and 4.16 display various interactive components, such as gauges, counters, and activity monitors. They provide information on city-zone-specific educational data, population statistics, and smart education growth indicators.

Operational Efficiency and Investment Bar and Pie Chart Analysis

The 4.17

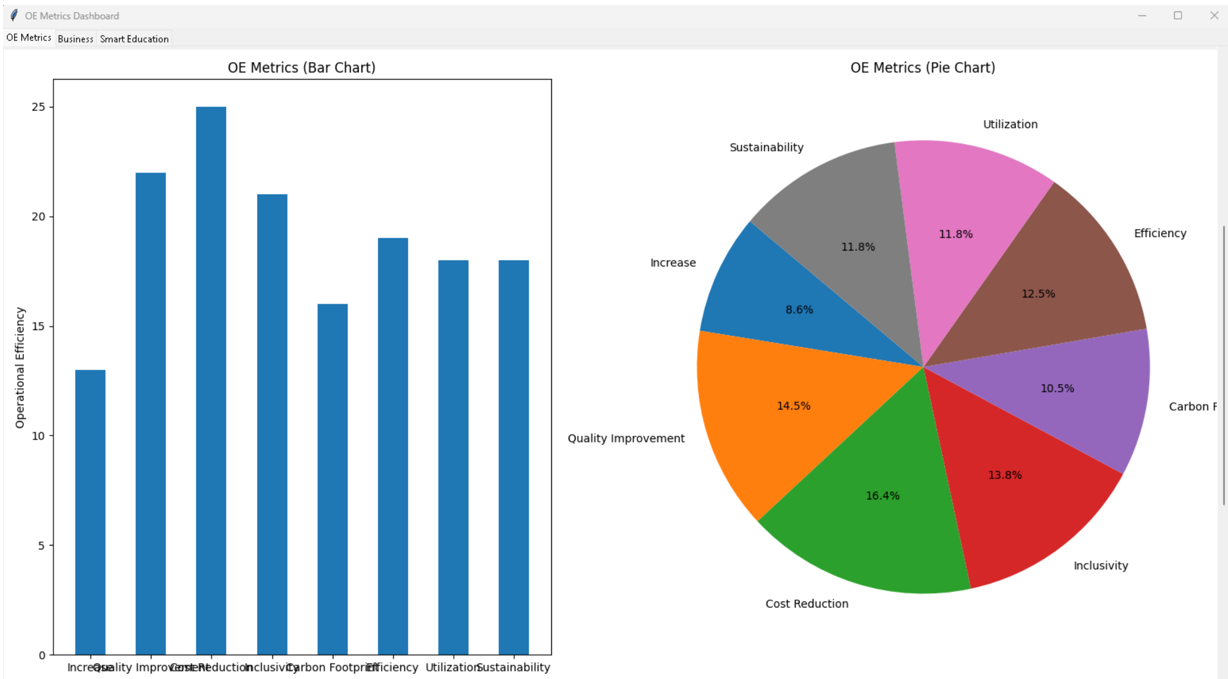
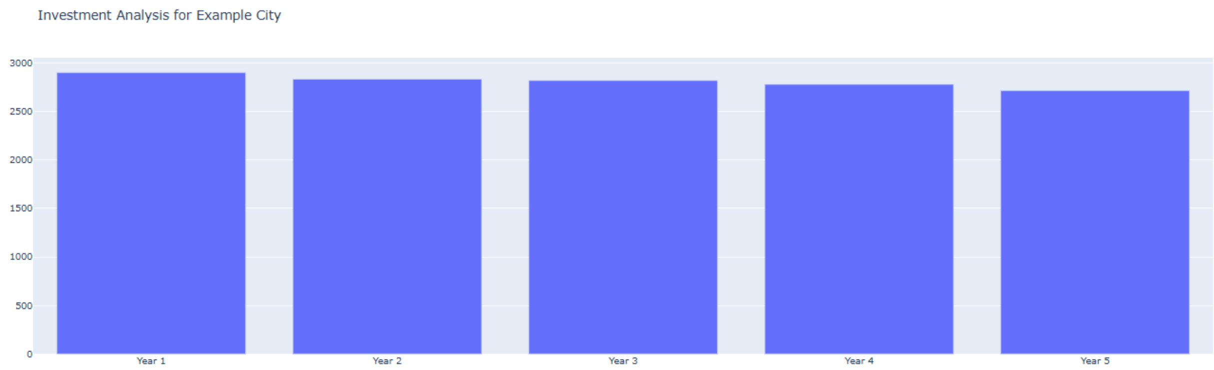
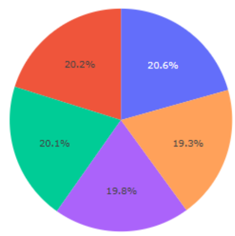


Figure 4.17: Operational Efficiency and Investment Bar and Pie Chart Analysis

The images in Figure 4.18 show the use of bar and pie charts to demonstrate operational efficiency and investment analysis over time.





Year	Future Value (£B)	Adjusted FV for Inflation (£B)	Operational Costs (£B)	Required Investment for City B (£B)
Year 1	3150	3088.235294117647	123.52941176470587	2902.4767801857583
Year 2	3339	3209.342560553633	128.37370242214533	2834.867856218583
Year 3	3606.1200000000003	3398.127417056788	135.92509668227152	2821.0759294523714
Year 4	3858.5484000000006	3564.7022904419255	142.588091617677	2781.357110159625
Year 5	4090.0613040000007	3704.4945371259223	148.1797814850369	2716.5694906099825

Figure 4.18: SE Operation Efficiency and Investment Analysis

These visualisations highlight the dashboard's ability to track financial metrics and their impact on smart education initiatives.

Comprehensive Smart Education Analysis

The earlier figure 4.14 illustrates a comprehensive analysis of recommended smart education cities based on investment, using a combination of bar graphs and Sankey diagrams. This visualisation serves as a decision support tool for stakeholders to prioritise investments and interventions.

Interactive Data Presentation

Lastly, images such as 4.8 and 4.17 emphasise the dashboard's interactive data presentation capabilities, with charts

Statistical Techniques smart education context

In the pursuit of a comprehensive understanding of the Smart Education Framework, descriptive and inferential statistical methods were rigorously applied to the underlying datasets. The foundation of the descriptive analysis was laid by computing measures of central tendency, such as mean, median, and mode. These measures provide information on average performance indicators and the most frequently observed data points within smart city metrics with the objective of aligning to the (ISO / / IEC) standard. Furthermore, the standard deviation was calculated to quantify the degree of variation or dispersion present in the educational data, offering a window into the consistency of the implementation of smart education. A correlation analysis was conducted to determine the relationships between different components of the smart city and their impact on the overall framework of smart education. Using these statistics allows for a granular assessment of the smart education landscape, highlighting areas of strength, and pinpointing opportunities for improvement.

Complementing descriptive statistics, correlation analysis served as a cornerstone of the inferential statistics approach. This analysis was critical in unraveling the intricate relationships between various components of the smart city framework, such as resource allocation efficiency, levels of citizen engagement, and the robustness of the technological infrastructure.

Implementation of Statistical Analysis

The implementation of statistical analysis began with data collection, where a comprehensive data set was compiled that includes various performance indicators relevant to the smart education ecosystem. This data set included variables such as student engagement rates, use of digital resources, and faculty-student ratios, among others.

The subsequent step involved data cleansing to ensure precision and reliability. Outliers were identified and examined to determine their validity, and missing values were addressed by imputation techniques, where appropriate. This was followed by the execution of the descriptive statistical analysis:

- **Mean:** The arithmetic average of each performance indicator was calculated to establish a baseline for comparison.
- **Median:** The middle value in the data distribution was determined, offering a measure that is robust to outliers.
- **Mode:** The most frequently occurring value in the dataset was identified, highlighting the predominant trends within the context of smart education.
- **Standard Deviation:** This provided a measure of dispersion within the educational data, indicating the variability of each indicator.

With the foundations of descriptive analysis established, the focus was shifted to inferential statistics. The correlation coefficients were calculated to evaluate the strength and direction of the relationships between variables. This analysis illuminated the interconnectedness of the components of the smart education framework and their collective influence on educational outcomes.

Predictive Modelling smart education context

To enhance the strategic planning aspect of smart education, regression models were constructed. These models used historical data to forecast future trends and the potential impact of different strategies. For example, a multiple regression model could predict student success rates based on resource allocation, access to technology, and community engagement initiatives. The regression equation took the form: (e.g., with total universities = 40, total students = 400,000)

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \epsilon \tag{4.1}$$

where Y represented the predicted outcome (e.g., student success rate), β_0 was the intercept, $\beta_1, \beta_2, ..., \beta_n$ were the coefficients for each independent variable $X_1, X_2, ..., X_n$, and ϵ was the error term.

The predictive model was then validated using a subset of the data not included in the training process. The validation process involved assessing the model's accuracy in predicting outcomes and making necessary adjustments to improve its predictive power.

Data Visualisation and Dashboard Integration

The statistical findings were not only tabulated, but also transformed into visual representations to enhance the comprehensibility and accessibility of stakeholders. Interactive dashboards were developed using tools such as plot and dash, which allowed users to explore the data through various filters and controls.

Analysis of Student Success Rate

The accompanying visualisation, as shown in Figure 4.19, illustrates the distribution of predicted student success rates across a spectrum of educational institutions. The histogram provides a quantitative analysis of success rates, highlighting the frequency of various performance levels; the data set is provided in the Appendix.

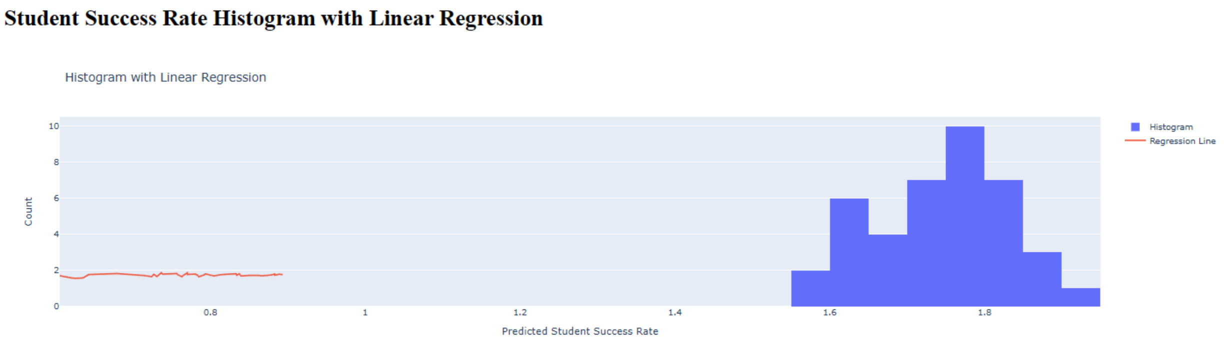


Figure 4.19: Interactive Dashboard Displaying Student Success Rate Key Performance Indicators

Data, represented by blue bars, indicate the number of institutions that achieved specific success rate scores. The histogram is overlaid with a red linear regression line, which indicates the trend and correlation between the factors that contribute to success rates and the results themselves. The linear trend line serves as a predictive tool, indicating the expected success rate based on the independent variables in the regression model.

The histogram's skewness towards higher success rates suggests that a significant number of institutions are performing well, aligning with the strategic goals of the Smart Education Framework. This model, following the guidelines of the standard (ISO / IEC 30145 series), underscores the integration of smart technologies and analytics into educational systems to improve academic achievement and institutional efficacy.

Linear regression analysis helps stakeholders discern the relationship between various educational inputs, such as student engagement rates, the use of digital resources, and the faculty-student ratios, and the results of student success rates. By analysing these relationships, decision makers can strategise improvements in educational practices, targeting areas that have the most substantial impact on student outcomes. The ultimate goal is to leverage this data-driven approach to improve the quality of education and raise standards in line with global benchmarks.

The dashboards provided real-time updates on key metrics in Figure 4.19, allowing stakeholders to make quick informed decisions. In addition, the dashboards were designed to be user-friendly, ensuring that people with varying levels of technical expertise could navigate and extract valuable information with ease.

In summary, the application of statistical techniques in the analysis of smart education data has been a multifaceted approach, employing both descriptive and inferential methods to provide a complete understanding of current states and predictive insights for future planning. The integration of these analyses into dynamic dashboards has further facilitated the dissemination and application of these insights, fostering an environment of continuous improvement within the smart education framework.

4.20.2 Comparative Analysis smart education context

A comparative analysis was conducted across multiple cities to benchmark their performance against the ISO/IEC standards. This required a detailed examination of investment patterns, infrastructure development, and resource allocation in the context of smart education.
The need to align smart education initiatives with established ISO / IEC standards has led to a thorough comparative analysis across a spectrum of cities. By benchmarking city performance, valuable insights into the distribution of educational resources, the efficacy of infrastructure development, and investment patterns could be discerned. This assessment is crucial to tailoring smart education systems that are both efficient and inclusive.

Methodology

The analysis began with the aggregation of data from a substantial dataset, comprising metrics from 25 cities, each with a diverse number of universities and student populations. The dataset, visualised in Figure 4.20, served as the basis for our exploratory data analysis.

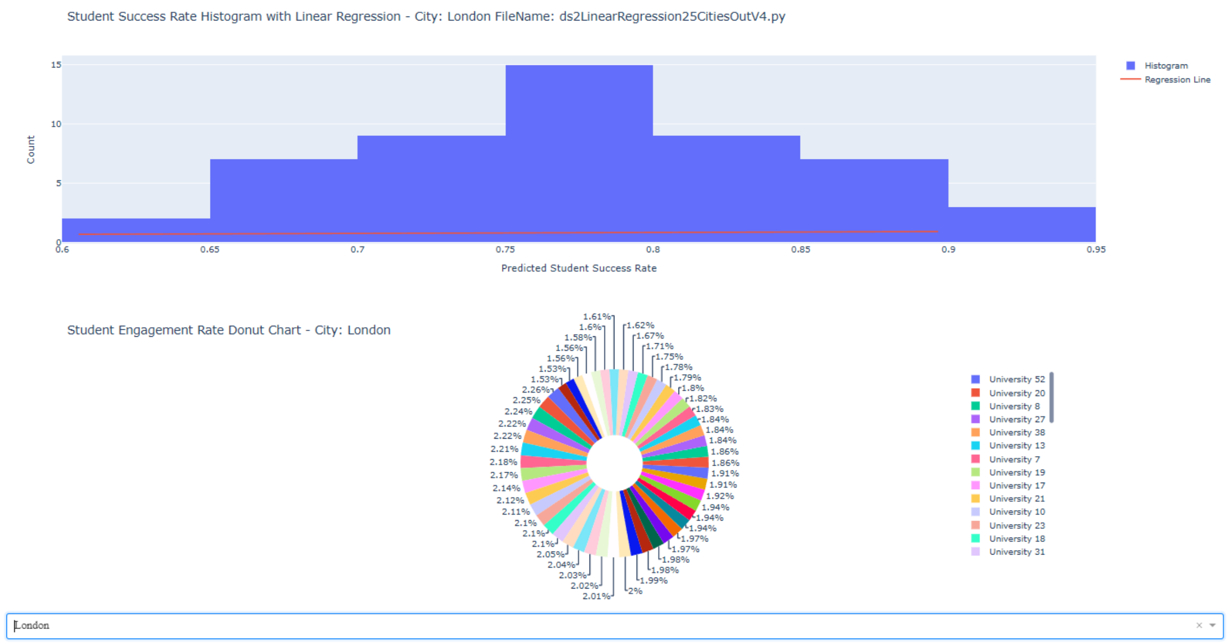


Figure 4.20: Comparative Analysis of Student Success Rates Across Multiple Cities

Statistical Tools

Leveraging the statistical prowess of linear regression, the study sought to predict student success rates based on levels of engagement. The predictive model was calibrated using student engagement data from each university, allowing a city-wise evaluation of educational results. A histogram provided a granular view of the success rate distribution, while a doughnut graph (rotated by -45 degrees for optimal readability) juxtaposed the engagement rates between universities within each city.

Results Interpretation

The graphical outputs elucidated the variance in student success rates, unveiling patterns correlated with the status quo of investment and infrastructure. Cities that demonstrated higher engagement rates frequently coincided with a higher allocation of resources and infrastructure provisions.

Alignment with ISO/IEC Standards

The comparative analysis was not only descriptive, but was extended to measure compliance with ISO / IEC standards. The benchmarks set forth by these standards represent a composite of best practices, which were used as a reference to gauge the robustness and responsiveness of the smart education framework within each city.

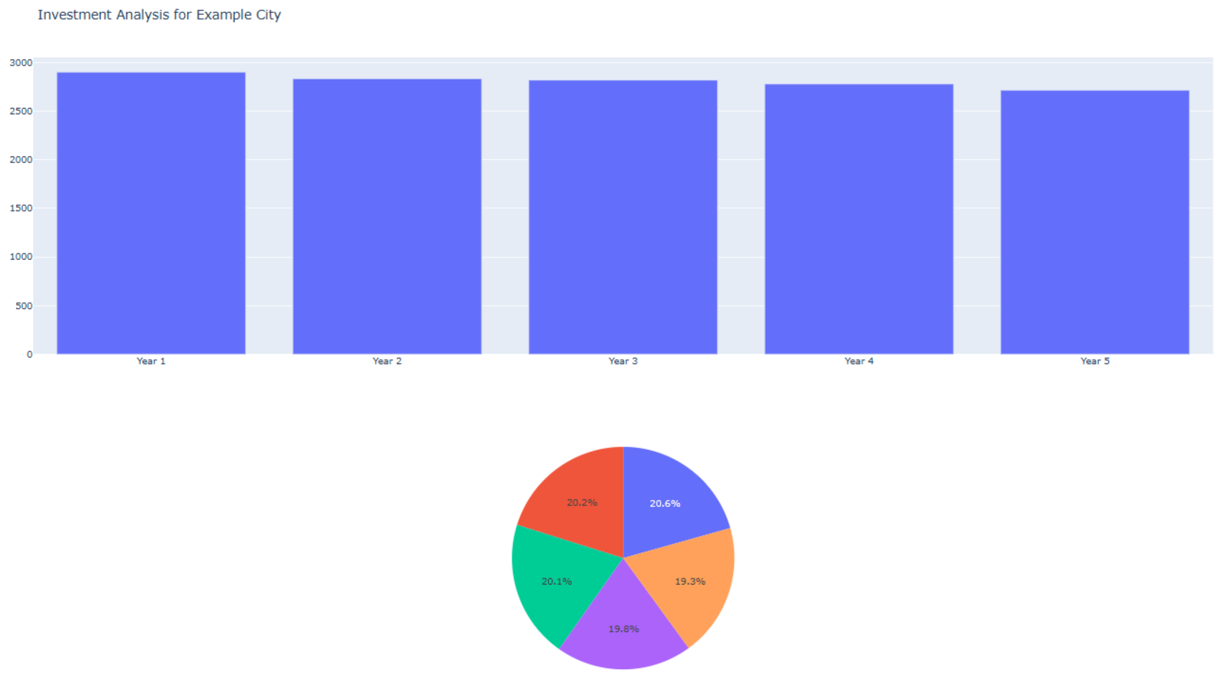
Implications and Future Work

The outcomes of this analysis underscore the heterogeneity of smart education landscapes and highlight the need for a customised approach to optimise educational frameworks. Future research may investigate longitudinal studies to track the evolution of these metrics and their impact on the efficacy of smart education over time. In conclusion, the comparative analysis illuminated the current position of smart education in diverse urban landscapes. Provided a data-driven foundation for strategic decision making aimed at enhancing educational services and aligning them with international standards of excellence. The regression script can be found in the appendix with a file named ds2LinearRegression25CitiesOutV5.py

4.20.3 Predictive Modelling

Machine learning algorithms were explored to predict future trends in smart education investment and its potential impact on smart city development. These predictions were based on historical data patterns and current investment trajectories, providing valuable information on the strategic planning of smart education initiatives. The advent of smart education has forced a forward-thinking approach to urban development, one that uses predictive modelling to illuminate the trajectory of educational investments and their ripple effects on the evolution of the smart city. Through the application of machine learning algorithms, we harness the predictive power vested in historical data, drawing patterns and trends that inform future projections. This methodological foray into predictive analytics employs a robust dataset, encapsulated within 'investment_output.csv', to train models that can forecast the future landscape of smart education investment.

The visual representation of these predictions, as showcased in



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Year 4	3858.5484000000006	3564.7022904419255	142.588091617677	2781.357110159625
Year 5	4090.0613040000007	3704.4945371259223	148.1797814850369	2716.5694906099825

Figure 4.21: Smart Education Investment over 5yrs span

Figure 4.21, offers a compelling narrative of growth and potential. The bar chart delineates investment values over a five-year period, while the accompanying pie chart dissects the allocation of resources, thereby painting a comprehensive picture of fiscal strategy and operational costs. These visual tools not only clarify

current investment trajectories, but also help in strategic planning for upcoming educational initiatives within smart cities.
To ensure the precision of our predictive models, a meticulous process of data cleaning and preparation was carried out. The subsequent steps involved the selection of significant features, partitioning the data into training and testing sets, and calibrating the machine learning algorithms to refine their precision. The models were then subjected to a rigorous validation process, ensuring their robustness and reliability.
These predictive models serve as digital oracles, giving city planners and educational policy makers the foresight to make informed decisions that align with the strategic goals of smart city development. The outcome of these models is not just a speculative forecast but a quantified anticipation, offering a data-driven compass to navigate the complex terrain of smart city planning. We further used the python script data_analysisV2 see appendix, it serves as a multifaceted analytical tool in the context of Predictive Modelling for Smart Education within Smart Cities. It draws on a data set that encapsulates variables such as population, service data, and allocated services *sedata2b.csv*. This script aligns with the overarching objectives of predictive modelling by employing a suite of statistical techniques and visualisations to uncover patterns and relationships within the data.
The initial segment of the script imports the necessary libraries and defines functions for user input, encapsulating the interactive nature of the analysis. It then proceeds to invoke the investment_calculatorV2 see appendix, for figure 4.21, a module dedicated to computing future investment values based on user-defined parameters like current investment, interest rates, and operational costs. This module sets the groundwork for projecting financial trends and their implications on Smart Education initiatives.
Following the investment calculations, the script delves into a deeper data analysis by loading the CSV file and preparing it for regression modelling and correlation analysis. The script segments the data into training and test sets, which are crucial for validating the predictive accuracy of the Linear Regression model it constructs.
For visual representation, the Python script employs the Matplotlib and Seaborn libraries to generate a series of plots, each unraveling a different facet of the data. The scatter plot juxtaposes population and service data with allocated services, providing a visual assessment of the relationship between these variables. The bar chart categorises the population into bins, comparing them against the mean allocated services, thus revealing the distribution of resources across different population segments.
The histogram provides a frequency distribution of the services allocated, providing information on the commonality of the levels of service allocation. Finally, the heat map of the correlation matrix crystallises the intervariable relationships, presenting a succinct summary of how strongly each pair of variables is associated.
In the Predictive Modelling section, the script output, illustrated in figure 4.22,

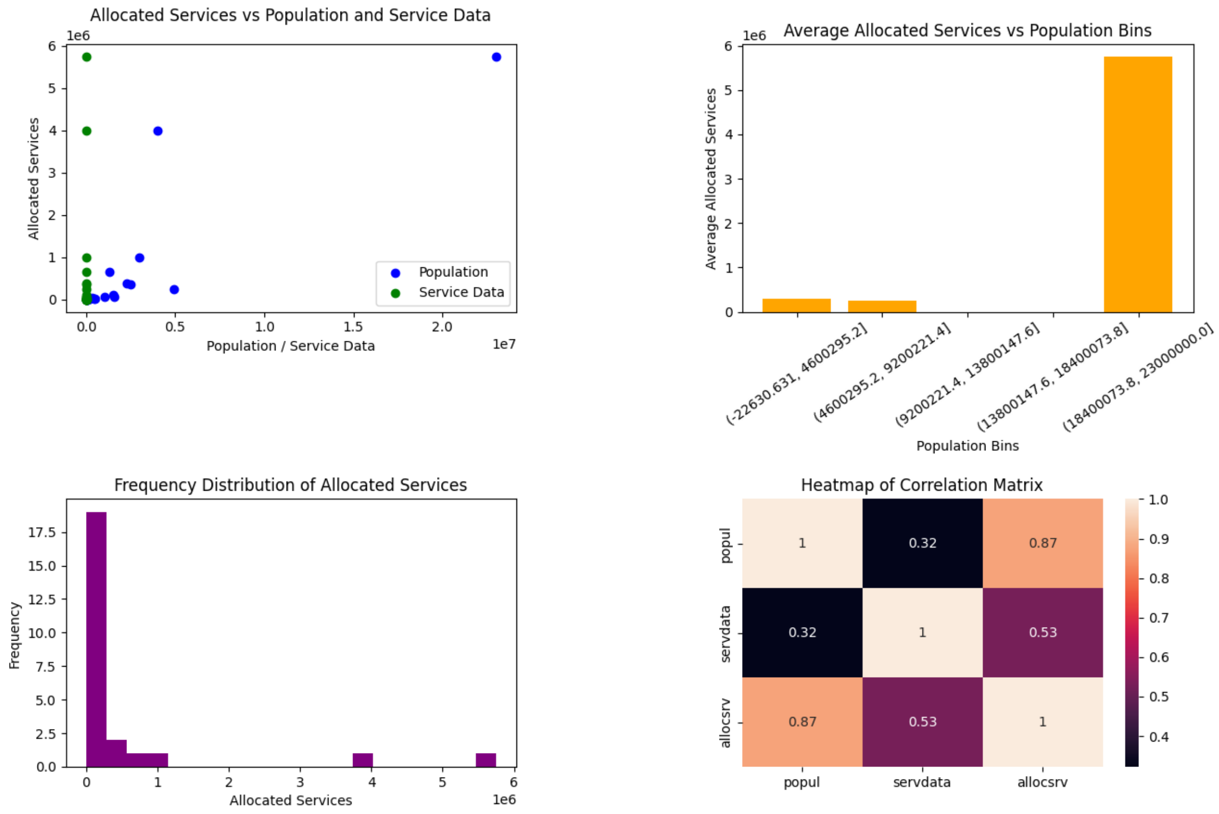


Figure 4.22: SERFD multifaceted analytical presentation

can be discussed as a compelling narrative that traverses from numerical predictions to visually engaging summaries. This narrative not only substantiates the current analysis, but also paves the way for forecasting future developments in the Smart Education domain.
The script and the resultant visualisations form the basis for a data-driven approach to improve strategic decision making. Using historical data and predictive analytics, stakeholders can better align educational strategies with the dynamic needs of a smart city, adhering to the principles of ISO/IEC standards.

4.20.4 Collaborative Tools

Throughout the investigation, collaborative tools such as Overleaf were used to dredge and review the documents. In the multifaceted sphere of research and development, the adoption of collaborative tools is indispensable for the enhancement of productivity and the facilitation of seamless interaction amongst research participants. This study used a multitude of such tools, each serving a different purpose in the orchestration of the research process.

Integrated Development Environments PyCharm IDE stood at the forefront of the development tools used, providing a robust platform to write, test, and debug code with its intuitive code editor and ergonomic design. It played a pivotal role in the development of Python scripts used for data analysis and visualisation.

Document Preparation Systems Overleaf, an online LaTeX editor, was instrumental in the creation of this document. Its real-time collaboration feature allowed the author to work simultaneously on the document, with instant compilation providing immediate visual feedback. This was particularly beneficial for the iterative process of writing, reviewing, and revising complex technical documents, at home, on the move, or in the office.

Operating Systems The diversity of operating systems, which includes Ubuntu Desktop (WSL) and Windows 11, met various compatibility requirements with software and personal preferences, thus creating a flexible working environment.

Data Analysis and Office Suites MS Excel facilitated the initial stages of data analysis, providing a user-friendly interface for data manipulation. This was complemented by the use of MS Word for preliminary draughting and Adobe Acrobat for PDF management. The seamless integration within the Microsoft Office suite and its ubiquity in the academic domain made it a logical choice for document drawing and data management.

Web Browsers and Research Tools The use of web browsers such as Google Chrome and Microsoft Edge was central to online research activities, accessing cloud services, and testing web applications. Google Scholar provided a gateway to the vast expanse of academic literature, while Zotero served as an invaluable tool for reference management and bibliographic organisation.

Utility Software For the quick capture and annotation of on-screen content, the snipping tool was frequently used. Its simplicity and ease of use made it an ideal choice for the rapid creation of visual content for presentations and documentation.

Text Editors For quick edits and note taking, MS Notepad offered a no-frills text editing experience, proving that sometimes the simplest tools are the most effective.
In summary, this array of tools, each with its unique set of features, collectively contributed to the methodical execution of the research. The interoperability and synergistic effect of these tools provided a comprehensive ecosystem that supported the various stages of the research lifecycle, from conception to publication.

4.21 Development of the Node-Red Dashboard

In parallel development to the plotly dashboard, the Node-Red dashboard was conceived with a distinct design philosophy in mind. The Node-Red platform offers a visual programming environment that allows rapid assembly and deployment of IoT applications, which is perfectly aligned with the objectives of a smart city framework. This section elucidates the process of developing the Node-Red dashboard, detailing its design philosophy, functionality, interactivity, and the overarching development process.

Design Philosophy

Unlike the Plotly dashboard, which excels in statistical visualisations, the Node-Red dashboard was designed to provide a real-time control and monitoring interface. It complements the Plotly dashboard by facilitating immediate interaction with the data flows and providing a live view of the system status. This responsive design approach meets the needs of city administrators for rapid decision-making. In developing the Node-Red dashboard, a distinct design philosophy was embraced, setting it apart from the Plotly dashboard, which is primarily orientated towards statistical visualisations. This section delves into the core aspects of this philosophy and highlights how it is tailored to meet the specific needs of city administrators.
Real-Time Control and Monitoring: A fundamental feature of the Node-Red dashboard is its ability to control and monitor in real time. This is in stark contrast to the Plotly dashboard, which is adept at handling static, historical data for analytical purposes. The Node-Red environment is built to interact dynamically with data as it flows in real-time. This aspect is crucial for urban management systems where data are continuously updated, such as traffic flow, utility use, or emergency services responses. By providing an interface that updates instantly, the dashboard ensures that administrators have access to the most current information, essential for making timely and informed decisions.
Interactive Data Flows: The dashboard is not only about displaying data; it also allows users to interact with it. This interactivity is a key part of its design. Administrators can adjust parameters, set thresholds, and even initiate actions directly from the dashboard. For example, in response to real-time traffic data, they

might reroute traffic, control traffic light sequences, or allocate emergency services. Such capabilities are vital in urban management, where decisions must be implemented quickly to respond to changing situations.
Live System Status: Another important aspect of the Node Red dashboard is its ability to provide a live view of the status of the system. This goes beyond mere data presentation; it involves synthesising data from various sources to give a holistic view of the city's operational status. This could include integrating data from transportation systems, public safety, utilities, and other municipal services, providing a comprehensive and coherent overview. By doing so, city administrators can understand the big picture in a glance, which is crucial for coordinating different city departments and services effectively.
Responsive Design for Rapid Decision Making: The dashboard is designed with a focus on responsiveness. This is critical in a city administration context, where delays in decision making can have significant consequences. The responsive nature of the dashboard ensures that data visualisation, interaction, and system status updates are seamlessly integrated, allowing administrators to make quick, evidence-based decisions.
User-Centric Approach: Finally, the design philosophy of the Node-Red dashboard places a strong emphasis on user experience. Recognising that city administrators may not be technical experts, the dashboard is designed to be intuitive and easy to navigate. This user-centric approach ensures that the complexities of data and system control do not become a barrier to effective city management.
In conclusion, the design philosophy behind the Node-Red dashboard is centred on real-time interaction, comprehensive system monitoring, and a user-friendly and responsive interface. This approach effectively complements the analytical strengths of the Plotly dashboard, creating a holistic toolkit for city administrators to manage urban environments effectively and efficiently.

Functionality and Flow

The Node-Red dashboard was structured to reflect the logical flow of data through the smart education framework. Integrates a series of nodes that represent data points, such as sensor input, system logs, and user interactions. The flows created in Node-Red are designed to be intuitive, allowing for the seamless integration of data streams and the transformation of raw data into actionable insights. The Node-Red dashboard, a cornerstone of the smart education framework, has been meticulously crafted to mirror the logical sequence and progression of the data. This section explores its structure and functionality in detail, elucidating how it streamlines and enhances the educational ecosystem.
Reflecting Logical Data Flow: Central to the design of the Node-Red dashboard is its alignment with the natural flow of data within the smart education system. This approach ensures that the dashboard not only displays data, but also narrates the story of how information travels and evolves through the system. From the moment data are generated, whether through student interactions, sensor inputs, or system logs, it follows a defined path that culminates in strategic decision-making and action.
Integration of Diverse Data Points: The Node-Red environment is notable for its ability to amalgamate a wide array of data points. Each node within the dashboard represents a unique data source or a critical juncture in the data processing pipeline. This could include input from classroom sensors that monitor environmental conditions, digital platforms that track student engagement, or administrative systems that record resource usage. By weaving together these diverse data strands, the dashboard offers a multifaceted view of the educational landscape.
Intuitive Data Flows: A unique feature of Node Red is the intuitiveness of its data flows. The platform is designed to be user-friendly, allowing educators and administrators to create and modify data streams with minimal technical expertise. This accessibility is crucial in educational settings, where staff may have varying levels of comfort with technology. The intuitive nature of the dashboard ensures that it is a tool for all, democratising data analysis and decision-making processes.
Seamless Data Integration: The dashboard excels at seamlessly integrating incoming data streams. As the information flows into the system, it is automatically synchronised and harmonised. This integration is vital for ensuring that data are not siloed but rather form a coherent narrative. For example, student performance data can be correlated with environmental conditions or resource availability, providing greater insight into the factors that influence educational outcomes.
Transformation into Actionable Insights: Perhaps the most critical aspect of the Node-Red dashboard

is its ability to transform raw data into actionable insights. Through sophisticated processing and analysis tools, the dashboard distills complex data sets into understandable and useful information. Educators and administrators can take advantage of these insights to make informed decisions about curriculum design, resource allocation, and student support strategies.

Customization and Flexibility: The Node-Red platform is inherently flexible, allowing extensive customisation to meet the specific needs of a smart education framework. Schools and educational institutions can customise the dashboard to focus on the metrics most relevant to their objectives, be it student engagement, resource utilisation, or academic performance.

In conclusion, the Node-Red dashboard is a pivotal element in the smart education framework, characterised by its alignment with logical data flows, integration of diverse data points, intuitive interface, seamless data integration, transformation of data into actionable insights and customisable nature. This combination of features makes it an indispensable tool for achieving the full potential of smart education systems.

Interactivity and User Engagement

User engagement is amplified by the implementation of interactive controls such as sliders, buttons and gauges, which enable users not only to observe data, but also to interact with the system in real time. This interactive layer transforms the dashboard from a passive display to an active control panel, where user input can directly influence the performance and behaviour of the smart education framework. In our Smart Education Framework, user engagement is not just a concept, but a tangible interaction facilitated by Node-RED's dashboard. Using interactive controls such as sliders and gauges, the dashboard transitions from a static visual representation to a dynamic interface, enabling users to interact with and influence the system in real time.

For example, a slider linked to the investment data set allows stakeholders to visualise the impact of different investment levels on expected returns. This is depicted on a gauge that dynamically reflects changes, offering an intuitive understanding of investment efficacy. Such interactivity ensures that users are not mere observers, but active participants in the analytical process.

To accomplish this, the Node-RED flow was constructed as follows:

- **Data Ingestion**: A 'file' node reads the 'performanceDataset.json' dataset.
- **Parsing Logic**: A 'function' node parses the data into a JSON object for further processing.
- **User Controls**: 'ui_slider' and selector drop-down nodes are configured to capture user input, representing different indicator or performance values.
- **Data Binding**: A 'function' node binds the slider input to the corresponding data, dynamically updating a 'ui_gauge' node that represents the indicator success rate or current values.
- **Dashboard Deployment**: The interactive dashboard is deployed and made available to users for real-time engagement. shown in Figure 4.23, but the actual orchestration in figure 4.24

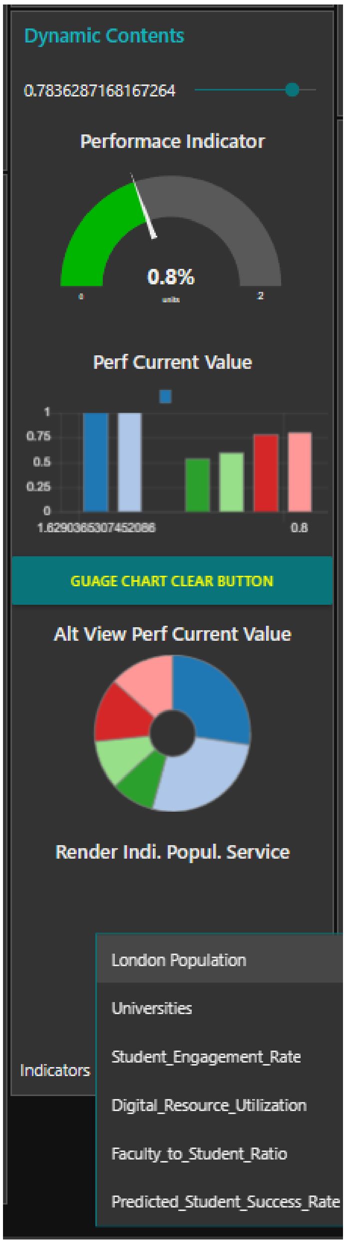


Figure 4.23: SERFD Dynamic Dashboard Content

This interactive layer fundamentally transforms the dashboard's role, making it a vital tool for decision-makers who can simulate and assess various scenarios instantaneously. The Node-RED dashboard thus becomes an active control panel, enhancing the strategic planning and operational efficiency of the Smart Education Framework.

Development Process

The development of the Node-Red dashboard followed an iterative process. The initial steps involved outlining the necessary functionalities and selecting appropriate nodes that could meet these requirements. Subsequent phases were the construction of flows that processed data from various sources, including APIs, databases, and direct input. The use of function nodes allowed for the incorporation of custom JavaScript code to perform complex calculations or data transformations. Throughout the development, UI nodes were iteratively refined to ensure clarity and ease of use, with a keen focus on the dashboard's responsiveness and adaptability to different devices and screen sizes. The construction of the Node-Red dashboard was an evolutionary journey that began with the identification of key functionalities critical to the smart education ecosystem. The foundation was laid by pinpointing the nodes that could capture, process, and present data

effectively. These nodes were the building blocks, chosen for their ability to fulfil specific roles within the dashboard.
As the blueprint became more detailed, the subsequent phase focused on orchestrating these nodes into coherent flows. These flows were the conduits for the data figure 4.24, channelling them through the system and transforming them from raw streams into informative and actionable insights. Central to this transformation were the function nodes, versatile elements within Node-Red that allowed for the injection of custom JavaScript code. This code was the alchemy that transformed simple data points into complex analysis and operations, tailoring the flows to meet the nuanced demands of the educational environment.

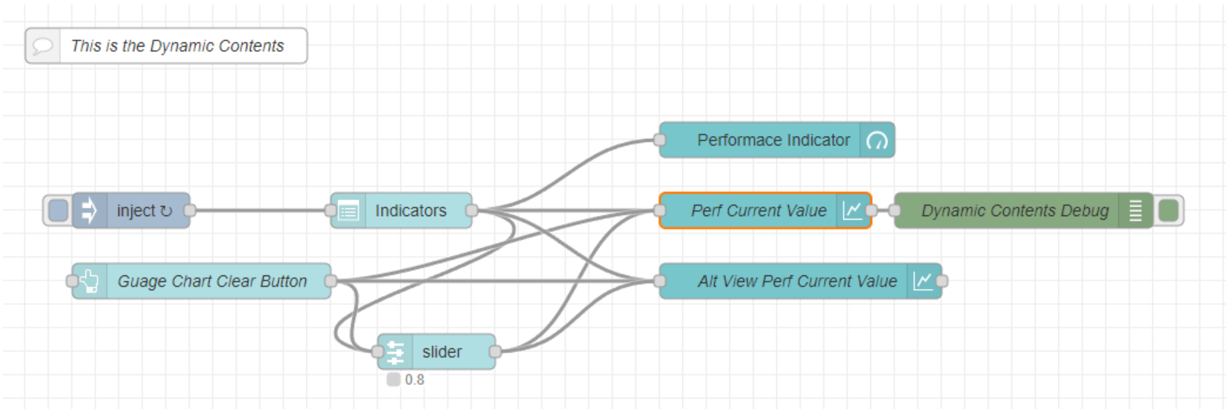


Figure 4.24: SERFD Node-RED Flow orchestration

The iterative nature of the development process meant that refinement was continual. UI nodes underwent a metamorphosis with each iteration, focussing on usability and comprehensibility. A key objective was to ensure that the dashboard remained intuitive, allowing users to navigate and interact with ease, regardless of their technical background. This focus extended to the dashboard's responsive design, ensuring that the interface adapted fluidly across a spectrum of devices, from desktop monitors to mobile phones, thus accommodating the diverse access points of its users.
The culmination of these efforts was a multifaceted dashboard that served as much more than a visual representation of the data. It was the nerve centre of the smart education framework, integrating data science with the Internet of Things (IoT) to provide a holistic view of the educational landscape. This dashboard provided not only real-time insights but also the means to control and influence the various components of the ecosystem. It offered tools for forecasting, trend analysis, and decision-making, while maintaining a user-centric design philosophy.
In essence, the Node-Red dashboard emerged as a vital cog in the machinery of smart education, encapsulating the essence of a data-driven approach to educational management. It stood as a beacon of the smart capabilities of the framework, enabling stakeholders to harness the full potential of IoT and data analytics to foster an environment where educational outcomes could be optimised and informed by evidence-based strategies.
The result is a comprehensive dashboard that not only visualises the data but also serves as a hub for controlling the interconnected elements of the smart education framework. It represents an amalgamation of data science and the Internet of Things, underpinning the smart capabilities of the framework it serves.

Integration and Interoperability

The Smart Education Framework, in the ambit of the ISO/IEC Smart City Framework, exemplifies a symbiotic integration and interoperability paradigm that operates across various layers and stakeholders. At the core of this integration is the seamless melding of the Computing and Storage Layer with the Smart City Application Layer, using Computing Resources (8), Storage Resources (9), and Software Resources (10). These elements are crucial in supporting the Smart Education (6) and Smart Campus (7) initiatives, which are designed to improve education within smart cities.
Interoperability within this framework is not just about technological congruence but also encompasses the

process of knowledge acquisition, organisation, and dissemination facilitated by the Smart City Knowledge Base. The entities of education and research (4) interact dynamically with this knowledge base, driving innovation and fostering an ecosystem conducive to learning and development. The integration process is bidirectional, with information from educational institutions fed back into the continuous improvement loop of the smart city, as shown in Figure 4.25.

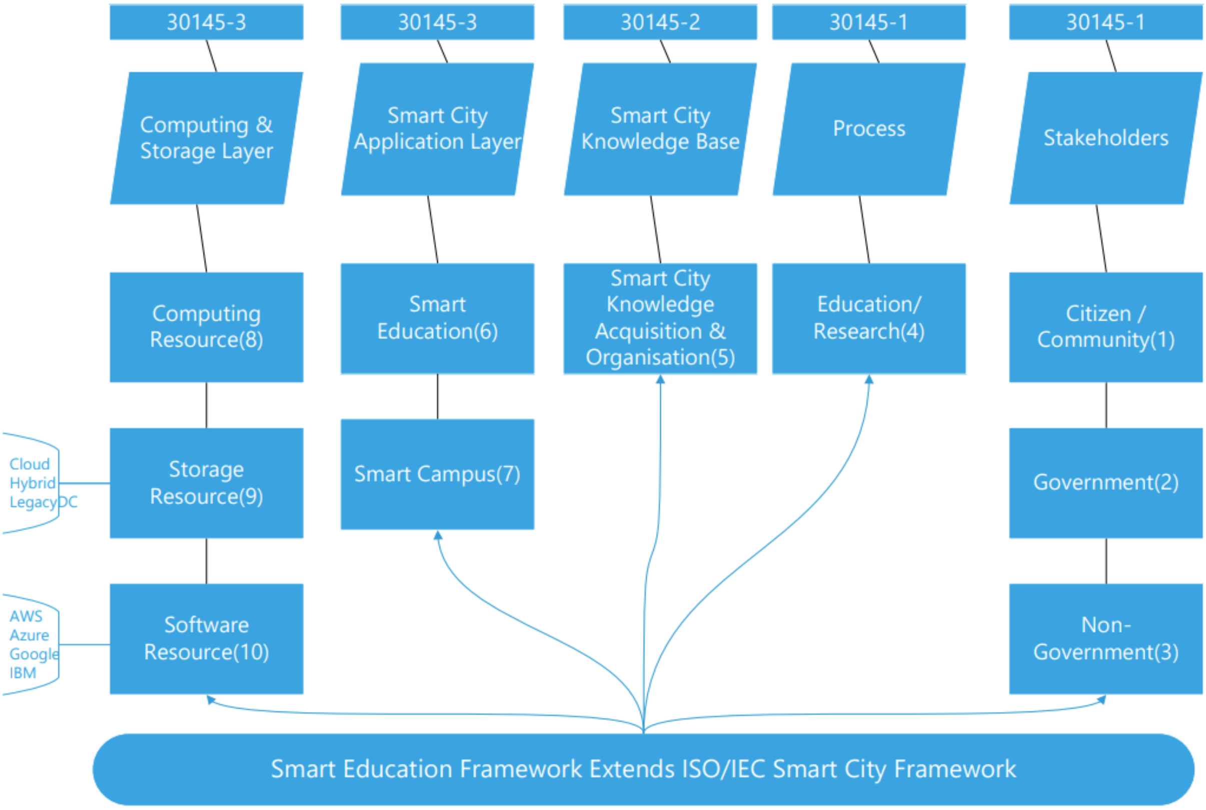


Figure 4.25: SERFD Framework Extends ISO/IEC Smart City Framework

On the dashboard front, the Node-Red dashboard and the Plotly dashboard are not standalone entities but integral components that communicate and share data. Their interaction is a testament to the framework's emphasis on real-time data flow and control. While the Node-Red dashboard excels in providing a real-time control and monitoring interface, the Plotly dashboard provides in-depth statistical visualisations. Together, they form a coherent unit, sharing APIs and data streams to provide a consolidated view of the smart education environment.

In addition, the dashboards are intricately woven into the fabric of the Smart Education Enhancement Recommendation System. They act as the nerve centre that collects, processes, and presents data from various sources, including campus data sets, student performance metrics, and operational data from educational administration systems. This integration facilitates a comprehensive view of the educational landscape, allowing stakeholders to make quickly informed decisions.

To enhance stakeholder engagement, the framework extends its reach to include Citizens/Community (1), Government (2), and Non-Government (3) entities.

In practice, this enforces the ISO/IEC Smart City Framework as a pivotal guide. The Smart Education Framework, which extends the standard ISO/IEC framework, introduces a layered architecture that unifies a cohesive learning environment.

Connecting Both Dashboards The Plotly and Node-Red dashboards serve different purposes, but share a symbiotic relationship. Data interaction between these dashboards is facilitated through APIs and webhooks, ensuring a two-way communication channel. The Plotly dashboard specialises in statistical representation of data, helping educators and policy makers discern patterns and trends. In contrast, the Node-Red dashboard works in real time, allowing instant data manipulation and system monitoring. Together, they create a comprehensive visualisation toolkit, each dashboard enriching the other with its unique capabilities.

System Integration The dashboards are integral components of the Smart Education Enhancement Recommendation System (SEERS). They integrate through a service-orientated architecture where microservices govern the data flow. SEERS leverages cloud computing resources (#8 in the attached image) 4.25 for scalable data processing. Storage resources (#9) ensure data persistence, while software resources (#10) such as learning management systems and collaboration tools provide the functional backbone.
Each layer within the smart education framework communicates through standardised interfaces, ensuring compatibility and exchangeability among disparate systems. The Smart Campus layer (#7) collates data from IoT devices and sensors within the educational environment, feeding into the Smart Education application layer (#6) that processes these data.
The Knowledge Acquisition and Organisation layer (#5) is crucial to assimilating data into the Smart City Knowledge Base (#2), transforming raw data into structured information. This knowledge base drives the Education/Research layer (#4), generating actionable insights for stakeholders such as Citizens/Community (#1), Government (#2), and Non-Government organizations (#3).
Through this layered approach, the Smart Education Framework elevates the ISO/IEC Smart City Framework by embedding educational intelligence into the city's digital infrastructure. It embodies a true integration of smart city initiatives with educational goals, facilitating an interconnected learning ecosystem that is both agile and robust.

Interoperability Interoperability is ensured by adhering to international standards and protocols, allowing the system to interface with global smart city solutions. By implementing such standards, the Smart Education Framework guarantees that new technologies can be integrated with minimal friction, future-proofing the educational infrastructure against rapid technological advancements.
In conclusion, integration and interoperability within the Smart Education Framework are not just about connecting systems, but about creating a harmonised educational environment that is greater than the sum of its parts. The extensibility of the framework to the ISO/IEC Smart City Framework ensures that education remains at the forefront of smart city development, fostering a culture of continuous learning and innovation.

Challenges and Solutions

The development and deployment of sophisticated smart education systems encompass various technical challenges, each of which requires innovative solutions to ensure seamless operation and user satisfaction.

Technical Challenges Technical hurdles are an inevitable facet of any technological implementation. In the context of the smart education tools used here, challenges such as the lack of data from the Smart Education Framework that can be aligned with ISO / IEC, data security, system integration complexity, and scalability with an accessible Open Dataset must be addressed.
Data security is paramount, which could contribute to the lack of open datasets, particularly in educational environments where sensitive student information is processed. Robust encryption protocols, along with stringent access controls, are employed to protect the system against unauthorised access. Furthermore, regular security audits and compliance with international standards such as GDPR and the Family Educational Rights and Privacy Act (FERPA) are fundamental to maintaining trust and integrity.
The complexity of system integration arises when disparate applications and platforms need to communicate. This was overcome by adopting open platform middleware solutions that facilitate data exchange between tools such as the Node Red and Plotly dashboards, Ubuntu, Python, and WSL Opensource, and between these dashboards and other components of the educational ecosystem. Microservice architecture plays a critical role here, abstracting the functionality into small, manageable services that can be easily integrated, for example, using PyCharm to spawn multiple scripts. Scalability is tackled by leveraging cloud

technologies like Overleaf, providing the flexibility to scale resources up or down based on demand. This elastic scalability ensures that the system remains responsive and cost-effective, accommodating the ebb and flow of educational development requirements. **Adaptation to User Needs** The dashboards' evolution is heavily influenced by feedback and user testing, which are critical components of the user-centred design approach. Iterative development cycles allow for the incorporation of user feedback into the design process, ensuring that the final product aligns with the actual needs of educators and students and interoperability with the ISO/IEC framework ecosystem.

For example, initial user testing revealed that educators require more intuitive data visualisation tools for student performance metrics. In response, improve the plotly dashboard with interactive elements, such as drill-down capabilities, allowing educators to explore data at a granular level. Similarly, students may express the need for real-time feedback on their learning progress, prompting the integration of live data streams into the Node-Red dashboard; these may be of concern to smart education developers.

Through beta testing and the project objective, interaction with prototype versions of the dashboards provided valuable information on usability and functionality. This feedback loop is essential to refine the user interface and experience, leading to dashboards that are not only technically sound, but also genuinely user-friendly and conducive to the learning process.

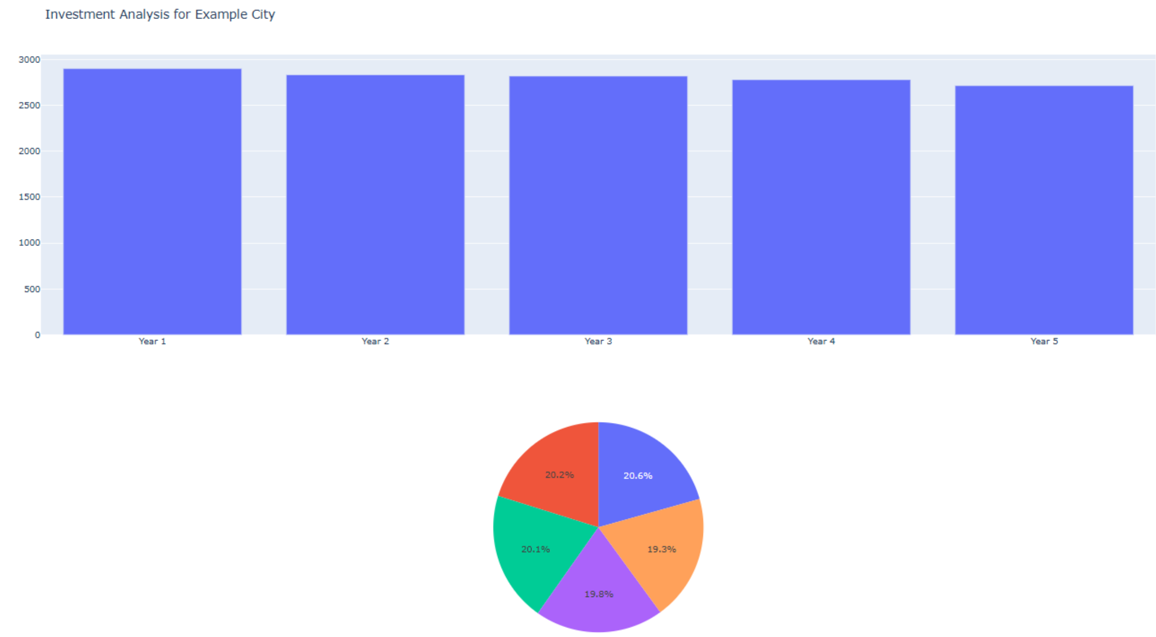
In conclusion, the challenges encountered in the realm of smart education are multiple, but with a strategic approach that emphasises security, integration, scalability, and user-centric design, these obstacles were transformed into opportunities for improvement. Therefore, the resulting dashboards are emblematic of a dynamic and responsive smart education system that is equipped to adapt to both current needs and future advancements in educational technology.

Testing and Validation

The reliability and efficacy of the Smart Education Enhancement Recommendation System dashboards were rigorously tested using a multifaceted approach. The testing methodologies were meticulously selected to reflect the complex interplay between the various components of the smart education framework.

Testing Methods Unit testing was used for each individual component to guarantee functional integrity. Automated scripts simulated user interactions, ensuring that each element responded correctly to a range of inputs. User testing was integral, emulating a diverse group of stakeholders, including educators, students, and administrative personnel, to interact with dashboards. General feedback was invaluable in identifying usability issues and understanding user requirements.

Validation of Results Validation was twofold: first, ensuring that the dashboards met the research objectives by facilitating improved decision-making processes in smart education; second, evaluating the role of the dashboards in effectively communicating investment strategies within a smart city context.



Year	Future Value (£B)	Adjusted FV for Inflation (£B)	Operational Costs (£B)	Required Investment for City B (£B)
Year 1	3150	3088.235294117647	123.52941176470587	2902.4767801857583
Year 2	3339	3209.342560553633	128.37370242214533	2834.867856218583
Year 3	3606.1200000000003	3398.127417056788	135.92509668227152	2821.0759294523714
Year 4	3858.5484000000006	3564.7022904419255	142.588091617677	2781.357110159625
Year 5	4090.0613040000007	3704.4945371259223	148.1797814850369	2716.5694906099825

Figure 4.26: Investment analysis over time visualized through an interactive timeseries dashboard, highlighting the impact of strategic investments on smart education infrastructure.

Figure 4.26 demonstrates the ability of the dashboard to visualise investment returns over time, allowing stakeholders to observe trends and derive insights. The accuracy of the visualisations was validated through the correlation of displayed data with historical investment outcomes, providing a clear indication of the smart city's growth trajectory in relation to educational advancements.

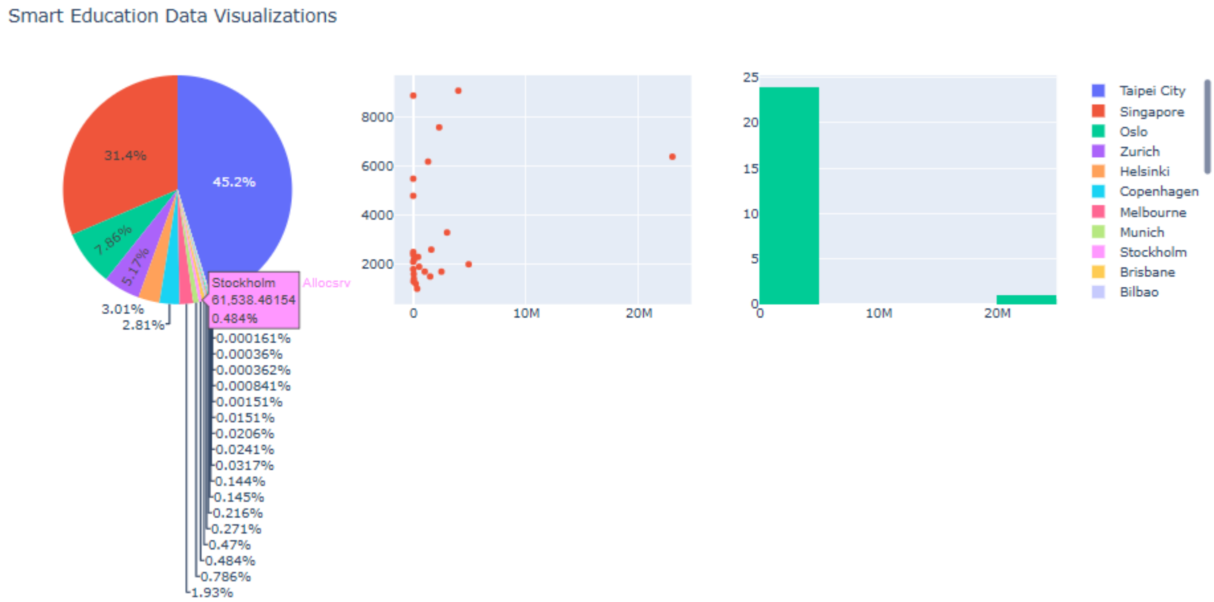


Figure 4.27: Machine learning output showcasing predictive analytics, which informed the smart education framework's development strategies.

Figure 4.27 illustrates the application of machine learning techniques to predict student success rates, a key indicator in the field of intelligent education. The performance of the predictive model was evaluated against a separate validation dataset, to ensure its robustness and reliability.
Simulated user feedback sessions were held after each major development milestone. During these sessions, visualisations, such as those shown in Figures 4.26 and Figure 4.27, and their responses were analysed for both qualitative and quantitative analysis. The iterative refinements that followed helped shape a more user-centric design, aligning the dashboard functionalities with the end-users' expectations and needs.
The dashboards underwent continuous refinement, with each iteration introducing enhancements based on the amalgamated data from testing and user feedback. This process not only validated the functionality of the dashboards, but also confirmed their strategic role in the framework for the enhancement of smart education, thus fulfilling the overarching goal of this research of improving the educational landscape through smart technologies.

Rationale and Design Choices The rationale for the design was to create a user-friendly interface that would accommodate users with varying degrees of technical expertise. To achieve this, I opt for a modular layout with distinct sections for different data categories, such as student engagement, resource use, and predictive analytics. This segregation ensures that users can focus on specific data sets without being overwhelmed by information overload.

Dashboard Objectives Each part of the dashboard serves a strategic purpose:

- The visualisation of time series (Figure 4.26) tracks financial investments and their long-term benefits, projecting the financial health and sustainability of smart education initiatives.
- The output of the machine learning model (Figure 4.27) offers predictive insights, allowing administrators to anticipate and plan for future educational needs.
- Interactive elements such as sliders and buttons empower users to customise the data displayed, fostering an interactive environment where users can hypothesise and observe potential outcomes in real time.

User Interaction with Visualisations The visualisations were designed not only to display the data but also to allow users to interact with it. For example, interactive sliders reflect changes in data points instantaneously, illustrating the potential impact of different investment levels on educational outcomes. This interactivity ensures that dashboards are not static, but dynamic tools for exploration and analysis.

Challenges and Solutions One significant challenge was to ensure that complex data were accessible and understandable. To address this, I implemented a layered approach to information display, starting with high-level overviews and allowing users to drill down into more detailed data. User feedback was instrumental in refining this approach, with several iterations focused on simplifying navigation and enhancing the visual appeal of dashboards.

Reflections through Images The images included in this section underscore the evolution of the dashboard. The initial prototypes were functional but lacking ease of use. Through iterative development, guided by user testing, the final visualisations achieved a balance between complexity and usability. They stand as a testament to the dashboard's maturity, transforming from a rudimentary data display to a sophisticated decision-support tool.

4.22 Chapter Summary

In summary, the design and implementation of the Smart Education Recommendation Framework with Dashboard were deliberate efforts to create a versatile and customisable tool tailored to the needs of stakeholders in smart education. Visualisations within the dashboard are more than mere representations of data; they are interactive platforms that enable users to explore and understand the complex metrics associated with smart education. The challenges encountered during the development process played a crucial role in shaping a solution that is robust and user-centric.

The framework provides a robust approach to using recommendation dashboards to enhance smart education, demonstrating the effective application of data analytics and IoT technologies. Potential challenges include the complexity of data integration and the necessity for continuous technological updates to stay abreast of advancements. There is a strong effort to align with ISO/IEC standards, particularly concerning data security and interoperability, although further clarification on specific compliance details might be required. The proposed framework is expected to significantly enhance the educational landscape within smart cities by providing actionable insights through the recommendation dashboard.

Chapter 5

Validation and Discussion of SERFD

5.0 Chapter Introduction

Smart education is widely recognised as a crucial element of smart cities, contributing significantly to sustainable urban development and improving smart infrastructure. This chapter delves into the validation of Smart Educati6.1.2endati2.1.1ork with Dashboard, focussing on how it integrates with the Internet of Things (IoT) and big data analytics to improve educational outcomes. By exploring various innovative teaching and learning strategies that leverage ICT, this chapter aims to provide a comprehensive understanding of how these technologies can enhance smart education frameworks.

The chapter outlines a detailed examination of different technologies, methodologies, and pedagogical approaches that are designed to enrich learning experiences. It highlights the importance of integrating recommendation dashboards within smart cities to provide actionable insights and improve decision-making processes. Furthermore, the potential of the metaverse in enhancing digital pedagogy through immersive technologies is discussed, suggesting substantial positive impacts on smart education.

This chapter sets the stage for a thorough validation process, evaluating the framework against established ISO/IEC standards, and assessing its practical applicability and effectiveness. The integration of advanced analytics, the iterative development of prototypes, and feedback incorporation are key aspects that will be examined to ensure that the Smart Education Recommendation Framework with Dashboard is robust, scalable, and capable of driving educational innovation and excellence within smart urban environments.

5.1 Validation of the Smart Education Framework and Dashboard

5.1.1 Methodology

The validation process of the Smart Education Recommendation Framework with Dashboard involved a multifaceted approach to ensure both conceptual integrity and practical applicability. This process included theoretical validation through journals, case study consultation and framework alignment, practical implementation and testing, feedback incorporation and refinement, and scalability assessment.

5.1.2 AIMs of the Project Addressed

1. **Development of a Smart Education Recommendation Framework:** To develop a Smart Education Recommendation Framework that aligns with the ISO/IEC Smart City Framework. This research introduced Figure 5.1 on the main contribution. The Figure 5.2, 5.3, the underlying context were addressed as follows:
   A. Is there a well-designed and innovative recommendation system specifically tailored for smart education?, detailed explanation provided in Section 3.1.1.
   B. Does the framework incorporate the perspectives and needs of all relevant stakeholders (teachers, students, administrators, tech developers, etc.)?, detailed explanation provided in Section: 3.1.2.
   C. How is the education framework integrated into the broader Smart City ISO / IEC standards?, detailed explanation provided in Section: 3.1.3

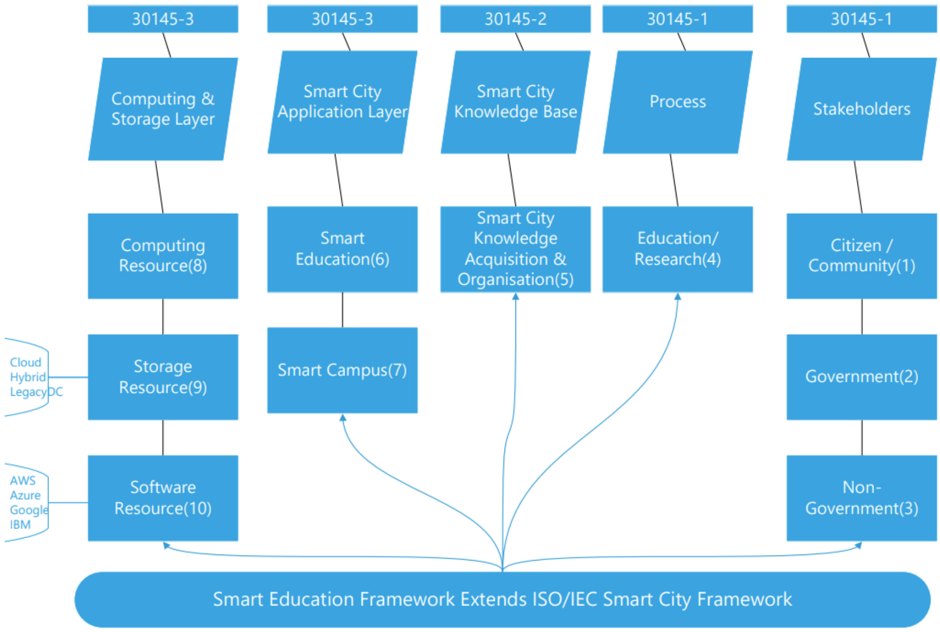


Figure 5.1: Smart Education Framework Extends ISO/IEC Smart City Framework

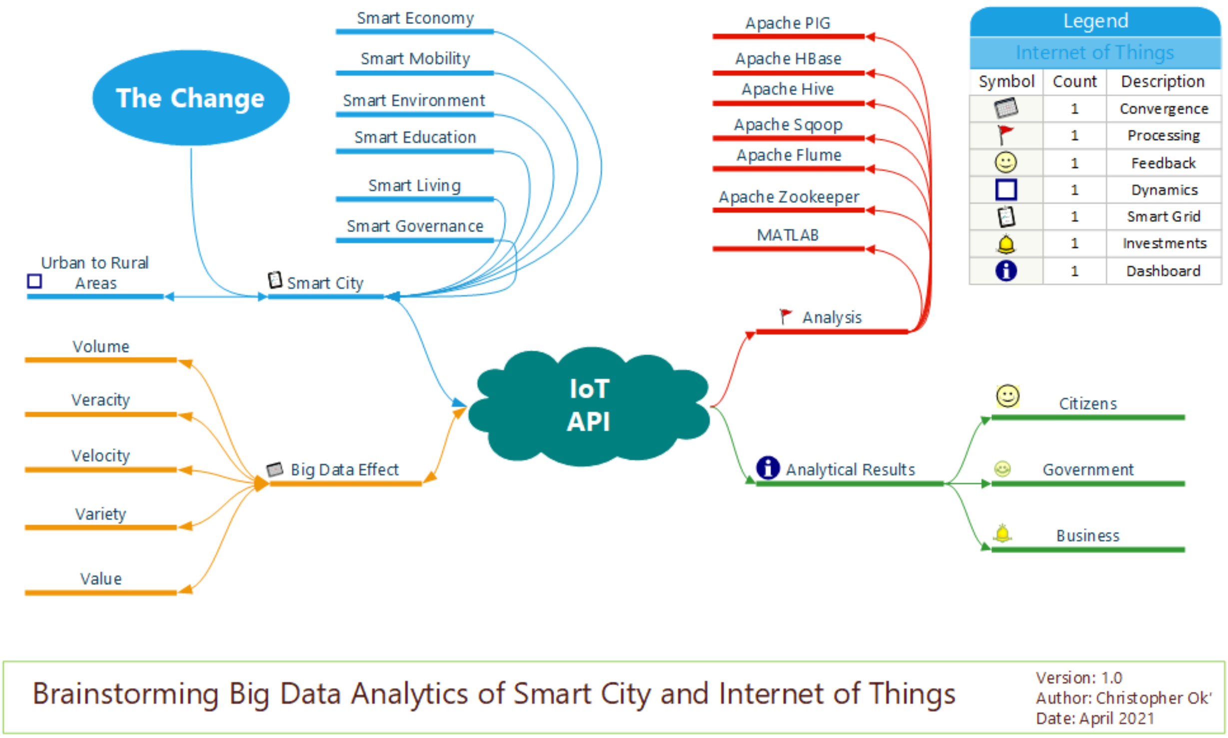


Figure 5.2: Brainstorming Big Data Analytics of Smart City and Internet of Things.

SE Environment Dashboard

Figure 5.3: Smart Education Environment Monitor Dashboard

2. **Improvement of Existing Smart City ISO / IEC Framework:** To integrate Big Data analytics into the Smart Education framework and enhance operational efficiency within Smart Cities.
A. The current limitations of the Smart City ISO / IEC framework?, detailed explanation provided in Section: 2.1.1.
B. Documented enhancements or changes proposed to the existing framework based on empirical data or stakeholder feedback?, detailed explanation provided in Section: 2.1.2.
C. Show evidence of stakeholder consultations (e.g., datasets, case study) that inform these improvements?Evidence of Data Collection, detailed explanation provided in Section: 2.1.3.

3. **Practical Implications:** To evaluate the impact of Smart Education technologies on educational outcomes and urban development.
A. Does the framework introduce new concepts or methodologies not currently covered in the literature?, detailed explanation provided in Section: 6.1.2.
B. Are the practical implications for smart cities and educational institutions clearly outlined?, detailed explanation provided in Section: 6.1.3

4. **Support for future research:** To ensure that the framework is adaptable and scalable to meet the evolving needs of Smart Cities.
A. Has the report identified areas for future research that could further refine or expand the framework?, detailed explanation provided in Section: 6.1.4L53

5.1.3 Theoretical Validation

Journals Consultation

Expert review journals and case studies in smart education, smart city planning, and standards development provided critical information on the feasibility and relevance of the proposed framework and dashboard. Experts evaluated the conceptual foundations of the framework and its alignment with current best practices and emerging trends in smart education and urban development.

Framework Alignment

The proposed Smart Education Framework was compared with the ISO/IEC Smart City Framework to ensure alignment and compatibility. This comparison highlighted specific areas of alignment, such as data security, interoperability, and educational quality, and identified gaps that need to be addressed to achieve full compliance with international standards.

Literature Review and Scoring

The literature review involved a comprehensive analysis of various sources, evaluating them against criteria such as the integration of ICT, pros, cons, ISO/IEC compliance, and effectiveness. The following tables summarise the findings.

Table 5.1: Critical Comparison and Compliance Alignment with ISO/IEC Smart City and Smart Education Frameworks with Visualisation Dashboard

Evaluation Criteria on Existing Smart Education	SERF Pros (%)	SERF Cons (%)	ISO/IEC Comp Align (%)	SERF Effectiveness (%)
Int of ICT in Edu (Demir 2021a)	80%	20%	70%	75%
Int of ICT in Edu (Isaacs and Mishra 2022)	85%	15%	80%	80%
Int of ICT in Edu (Foster et al. 2023)	90%	10%	85%	88%
Int of ICT in Edu (X. Zhang et al. 2022)	95%	5%	90%	92%
Int of ICT in Edu (A. Ferrari and Punie 2013)	93%	7%	88%	90%
Int of ICT in Edu (Al-Majeed, Mirtskhulava, Al-Zubaidy, et al. 2014)	92%	8%	85%	90%
Int of ICT in Edu (González-Pérez and Ramírez-Montoya 2022)	90%	10%	85%	88%
Int of ICT in Edu (WEF_Defining_Education_4.0_2023.pdf n.d.)	94%	6%	92%	93%

Continued on next page

Table 5.1 – *Continued from previous page*

Evaluation Criteria	Pros (%)	Cons (%)	ISO/IEC Comp Align (%)	Effectiveness (%)
Int of ICT in Edu (MITHUN and Roopadarshini 2024)	92%	8%	90%	94%
Int of ICT in Edu (Manisha Gupta and H. Gupta 2024)	85%	15%	80%	88%

Detailed analysis of the evaluation criteria
SERF Pros (%): The high percentages in the 'Pros' category reflect the strong advocacy of the documents for the integration of ICT in education and the positive impacts expected. For example, the document by (X. Zhang et al. 2022) received a high score (95%) due to its comprehensive coverage of how the metaverse can enhance digital pedagogy through immersive technologies. This high percentage indicates the robust exploration of innovative approaches in the document and its potential to significantly improve educational experiences. In contrast, lower percentages, such as 80% for (Demir 2021a), indicate that while the document supports the integration of ICT, it may not cover all aspects or potential benefits as comprehensively as other sources.
SERF Cons (%): The 'Cons' percentages highlight potential drawbacks and limitations identified in each document. For example, (A. Ferrari and Punie 2013) has a relatively low percentage of cons (7%), reflecting minor limitations, such as the wide scope of the framework that can overlook specific challenges. Higher percentages, such as 20% for (Demir 2021a), suggest more significant challenges, including issues related to technology adoption, digital divide, and resource constraints.
ISO/IEC Compliance Alignment (%): The percentages for the ISO / IEC Compliance Alignment reflect the degree to which each document aligns with international standards.
For example, (WEF_Defining_Education_4.0_2023.pdf n.d.) scored high (92%) due to its strong emphasis on digital literacy and responsible use of technology, which aligns closely with ISO/IEC standards on data protection, security, and interoperability. Lower scores, such as 70% for (Demir 2021a), indicate areas that need improvement to fully align with these standards.
SERF Effectiveness (%): The effectiveness percentages assess how well the proposed strategies are expected to improve educational outcomes. Documents like (MITHUN and Roopadarshini 2024), with a high effectiveness score (94%), indicate a strong potential to revolutionise educational access and quality through distance learning in smart cities. Lower effectiveness scores, such as 75% for (Demir 2021a), suggest that while the proposed strategies are beneficial, there may be practical challenges in their implementation that could impact their overall effectiveness.

5.1.4 Practical Implementation and Testing

Prototype Development

The development of the Smart Education Dashboard prototype involved creating key functionalities and ensuring easy integration with existing smart city technologies. This process was informed by theoretical validation and feedback from journals, ensuring that the prototype was aligned with the goals of the framework and the ISO / IEC standards.

Prototype evaluation:

- **Development of Smart Link Book as a Medium: (Isa et al. 2024) Expert Journal**
  - **Dashboard UI and Technology:** 80%
  - **Pros (%):** 85% - This high score reflects the innovative approach of using a smart link book to enhance interaction between educational stakeholders, making it a valuable tool for smart education.

  - **Cons (%):** 15% - The percentage of cons is relatively low, indicating minimal drawbacks, primarily related to the complexity of integrating new technologies into traditional educational settings.
  - **ISO/IEC Compliance Alignment (%):** 75% - The framework aligns well with ISO / IEC standards, although some areas may need further refinement to ensure full compliance.
  - **Effectiveness (%):** 82% - The effectiveness score is high, suggesting that the smart link book can significantly improve educational outcomes by fostering better communication and resource sharing.
- **Prototype Development of Final Year Project Management System to Monitor Students' Performance: (Listyaningrum et al. 2024) Expert Journal**
  - **Dashboard UI and Technology:** 90%
  - **Pros (%):** 88% - This score indicates the system's strong potential to improve project management and performance monitoring, offering detailed analytics and insights.
  - **Cons (%):** 12% - The primary challenges include the need for continuous updates and the complexity of managing large datasets.
  - **ISO/IEC Compliance Alignment (%):** 80% - Good alignment with standards, though there are areas for enhancement, particularly in data security and interoperability.
  - **Effectiveness (%):** 85% - The system's effectiveness is high, as it provides robust tools for managing student projects and tracking performance metrics.

Feedback Incorporation and Refinement

Using insights from the pilot studies and expert feedback, iterative improvements were made to both the framework and the dashboard. This step involved multiple cycles of feedback and refinement to achieve the desired results.

Feedback Incorporation:

- **NeurIPS-2023: Self-Refine - Iterative Refinement with Self-Feedback: (Madaan et al. 2024) Expert Journal**
  - **Dashboard UI and Technology:** 87%
  - **Pros (%):** 90% - The innovative self-refinement approach improves model output through iterative feedback, enhancing educational analytics and platform adaptability.
  - **Cons (%):** 10% - Reliance on self-feedback might limit effectiveness where domain-specific insights are crucial.
  - **ISO/IEC Compliance Alignment (%):** 82% - The emphasis on quality and reliability aligns well with ISO/IEC standards.
  - **Effectiveness (%):** 88% - The method shows promise in improving content quality, making it highly effective for educational applications.

Scalability Assessment

The scalability of the Smart Education Framework and Dashboard was evaluated for broader adoption in different smart cities and educational institutions. Necessary adjustments were identified to facilitate scalability.

Scalability Evaluation:

- **Smart Evaluation: A New Approach Improving the Assessment Management Process Through Cloud and IoT Technologies: (Dehbi et al. 2024) Expert Journal**
  - **Scalability Assessment:** 88%
  - **Pros (%):** 90% - The integration of IoT and cloud computing enhances scalability, enabling efficient data handling and adaptation to increasing demands.
  - **Cons (%):** 2% - Challenges include technological integration complexity and initial infrastructure investment.
  - **ISO/IEC Compliance Alignment (%):** 85% - Good alignment with data security, privacy, and interoperability standards.
  - **Effectiveness (%):** 92% - The system effectively streamlines assessment management, providing real-time information and enhancing the learning experience.

5.1.5 Chapter Summary

This chapter validates the Smart Education Recommendation Framework with Dashboard, demonstrating its potential to improve educational outcomes within smart cities. Using ICT, IoT and big data analytics, the framework aligns with ISO/IEC standards, ensuring a robust, scalable, and effective solution for modern educational challenges. The validation process highlights strengths, identifies areas for improvement, and underscores the framework's readiness for implementation in smart urban environments.

The validation involved theoretical validation, practical implementation and testing, expert journals, and iterative improvements. The review of scholarly documents evaluated key criteria such as the integration of ICT in education, alignment with ISO/IEC standards, and the effectiveness of proposed strategies. Most of the documents showed high alignment with the framework, highlighting their relevance and applicability.

The integration of recommendation dashboards was emphasised, providing actionable insights and improving decision-making processes. The development of prototypes using advanced technologies like Plotly, Node-RED, and cloud computing demonstrated the practical feasibility and scalability of the framework.

In general, the chapter underscores the transformative potential of combining big data analytics with smart education systems, confirming that the Smart Education Recommendation Framework with Dashboard is a robust tool for improving operational efficiency, fostering innovation, and improving educational outcomes. The alignment with ISO/IEC standards further ensures that the framework adheres to international benchmarks for technological integration and data security, making it a pivotal component in the evolution of smart education within smart cities. This detailed validation process has shown that the framework is ready for implementation, promising significant improvements in educational practices within smart urban environments.

Chapter 6

Conclusions and Future Work

6.0 Chapter Introduction

Smart education is widely recognised as a key component of smart cities, enabling sustainable urban development and smart infrastructure with a significant positive impact on smart citizens. This chapter explores the integration of the Internet of Things (IoT), big data analytics, and cloud computing within the educational system, highlighting innovative teaching and learning strategies that use these technologies to improve educational outcomes. The document outlines strategies to leverage big data analytics to improve the smart education framework, providing a comprehensive approach to integrating recommendation dashboards within smart cities. Various technologies, methodologies, and pedagogical approaches designed to enhance learning experiences are discussed, suggesting a high value in using technology to improve educational experiences. The potential of the metaverse to enhance digital pedagogy through immersive technologies is also considered, indicating significant positive impacts on smart education.

6.1 Future Works and Conclusions

The culmination of this research presents a significant step toward operational efficiency in smart cities, with a particular focus on the smart education recommendation framework with dashboard. The investigation of big data analytics as a key tool to address operational challenges has underscored its indispensable role in enhancing educational frameworks within smart urban ecosystems. The research has identified key benefits and highlighted critical areas that need further exploration, paving the way for future advances, including the role of GenAI, particularly its integration into dashboard visualisations and real-time feedback mechanisms to optimise resource allocation and operational efficiency within Smart Cities. Furthermore, research on the ethical implications and inclusivity of GenAI-driven tools will be vital to ensuring equitable access to the aforementioned technologies in diverse educational settings.

Integrating smart city and smart education initiatives is crucial, focussing on the role of big data analytics in improving educational frameworks within smart urban ecosystems. The potential of technology to revolutionise education is highlighted, emphasising the need for global standards for operational efficiency and exploring future research directions. Introducing a Smart Education Recommendation Framework and Dashboard aligned with ISO/IEC 30145 standards showcases the benefits of IoT and cloud technologies in education. This research marks a step toward personalised, accessible and integrated education in smart cities.

6.1.1 Research Gaps and Future Directions

This research underscores the crucial role of big data analytics in addressing operational challenges within smart cities, especially in enhancing smart education frameworks. The project builds on previous findings (J. Singh 2015), extending the utility of data classification beyond traditional domains. With exponential growth in data volume and variety, the urgency for advanced management techniques and technologies becomes apparent (Tantatsanawong, Kawtrakul, and Lertwipatrakul 2011). Real-time or near-real-time processing capabilities are essential for uncovering meaningful insights and addressing infrastructural or service degradation that affects operational efficiency (OE) and, by extension, smart education.

The challenges surrounding the integration of big data analytics in smart education are multiple, indicating a wide spectrum of research opportunities (Fenton and Bieman 2014). The exploration of these challenges reveals a critical need for foundational research focused on developing and refining technical strategies to harness the 2Vs (Volume and Variety) of big data effectively. Furthermore, establishing a quantitative, globally recognised metric for Smart City developers could promote standardisation and encourage adoption by providing a benchmark for operational efficiency and data analytics excellence.

Furthermore, the integration of IoT and cloud computing technologies presents a promising avenue to advance smart education in smart cities. These technologies offer scalable solutions to manage the complexity and diversity of data in educational contexts, facilitate personalised learning experiences, and improve educational outcomes. However, this integration also introduces additional challenges, such as ensuring data privacy, securing cloud-based educational resources, and developing interoperable systems that comply with the ISO/IEC 30145 standards.

Although big data analytics presents significant advantages for smart education, realising its full potential requires ongoing research into effective management techniques, the development of global standards, and the exploration of innovative technological integrations. These efforts are essential to achieve the vision of smart education of the 21st century, characterised by operational efficiency, personalised learning, and seamless integration into the infrastructure of the smart city.

6.1.2 Proposed Solution and Contribution to Knowledge

This thesis introduces an analytics dashboard, focussing on operational efficiency with volume and variety (OE2V), showcasing the original contributions to the Smart Education Recommendation Framework with Dashboard. The novelty of this approach lies in its application of distributed computing to smart education, a concept not previously realised due to the absence of a dedicated Smart Education data methodology, which is extended from ISO/IEC Smart City Framework as introduced in Chapter 2. The dashboard's ability to visualise operational efficiencies marks a significant leap forward, offering new insights into enhancing Smart Education within smart cities.

It also shows several areas of the original contribution because the state-of-the-art review has shown that the concept of using OE2V to address smart education recommendation Framework with dashboard in the context of big data analytics has not been realised previously, due to the lack of the Smart Education data methodology as in this case. Furthermore, this could be because until recently the power of distributed computing has not been specifically applied to smart cities in the context of smart education (J. Singh 2015), except by centralising data acquisition and consolidation in the cloud and using cloud-based virtualisation infrastructure to extract data sets. The dashboard, when fed the smart city datasets, will display operational efficiency and show areas of concern. Large projects such as (C and Y 2017) contributed to some efficient uses, where big data methods offer new insights into existing datasets, as reported in (Shilpa and Manjit Kaur 2013). But this still requires initial data that are relative to smart education. This research approach is a novel knowledge area, which is a smart education recommendation framework with dashboard, a component of smart cities in the context of big data analytics. This will show collectively how urban sectors will collaborate and communicate to solve problems using analytical data, such as smart citizens in the report shared by (Ben-Assuli et al. 2019). This thesis approach is supported with rigour, as written by (Kulesa 2009); (Volker Buscher and Léan Doody 2010). As a result, the output of this research is to guide developers and stakeholders by using the Smart Education Recommendation Framework and Dashboard to enhance OE in smart education with volume and variety components of big data technologies, thereby providing enhancement to operational efficiency for smart cities in the context of Smart Education through Big Data Analytics.

Key Contributions

The Smart Education Recommendation Framework introduces several new concepts not currently covered in the literature:

- Development of a smart education recommendation framework with dashboard that takes advantage of big data to provide actionable insights into student learning patterns.

- Establishment of a framework that aligns with ISO/IEC 30145 standards, ensuring the security and privacy of educational data.
- Demonstration of the effectiveness of open-data and cloud technologies in creating a scalable and flexible smart education infrastructure.
- **Operational Efficiency Metrics:** New metrics for evaluating the efficiency of educational technologies within smart cities.
- **Stakeholder-Centric Design:** A methodology for designing educational frameworks that prioritise stakeholder needs and feedback.

6.1.3 Practical Implications for Smart Cities and Educational Institutions

The practical implications of this framework include:

- **Improved Educational Outcomes:** By leveraging data analytics, the framework enhances the effectiveness of educational practices.
- **Resource Optimisation:** Provides tools for better allocation and use of educational resources within smart cities.

In addition, a further elaboration and in-depth analysis of the Smart Education Recommendation Framework Ecosystem. The framework aims to integrate various components of a smart city to improve educational results through the use of big data, the Internet of Things (IoT), and advanced analytical tools. Figure: 6.1

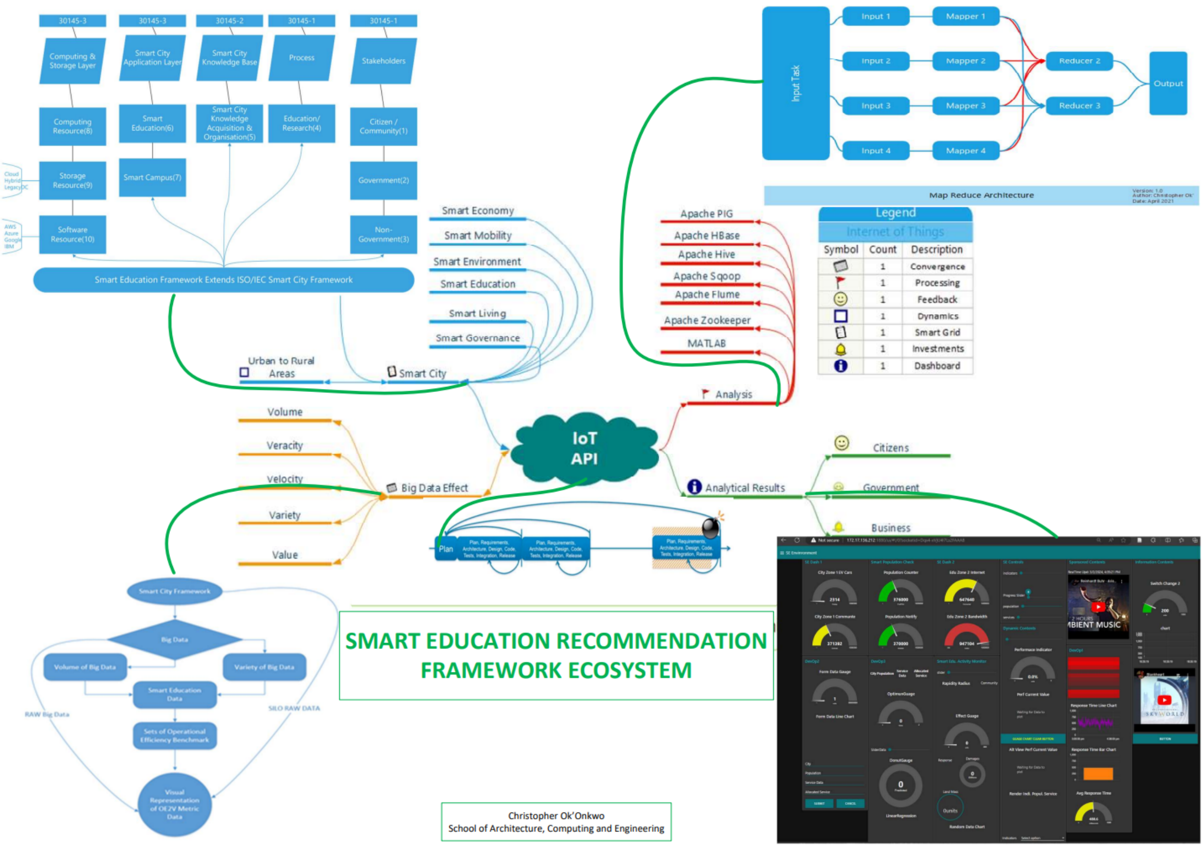


Figure 6.1: Analysis of the Smart Education Recommendation Framework Ecosystem

6.1.4 Framework Components

Smart Education Framework Extends ISO/IEC Smart City Framework

The framework aligns with ISO/IEC standards and extends the Smart City framework to include smart education components.

Layers and Elements

- **Computing & Storage Layer**: Includes computing resources, storage resources, and software resources.
- **Smart Education**: Represents the integrated educational aspect within the smart city.
- **Smart City Knowledge Acquisition & Organisations**: Involves organisations dedicated to acquiring knowledge within the smart city.
- **Education/Research**: Focusses on educational institutions and research centres.
- **Citizen/Community**: Engages citizens and community members.
- **Government**: Represents governmental participation.
- **Non-Government**: Includes nongovernmental organisations.

Big Data Effect

- **Volume, Variety, Velocity, Veracity, and Value**: Represents the five V's of big data that impact the smart education framework.
- **Raw Data**: The input base for analysis.
- **Silo Raw Data**: Segmented raw data for specific purposes.

IoT API

The central component that connects various elements through the Internet of Things (IoT), enabling data flow and communication.

Smart City Components

- **Smart Economy, Smart Mobility, Smart Environment, Smart Education, Smart Living, Smart Governance**: Various domains of a smart city, all contributing to and benefiting from the smart education framework.

MapReduce Architecture

Depicts the process of handling large datasets in a distributed computing environment, involving input tasks, mappers, reducers, and output.

Apache Tools and MATLAB

- **Apache PIG, Apache HBase, Apache Hive, Apache Sqoop, Apache Flume, Apache Zookeeper**: Tools used for data processing and analysis.
- **MATLAB**: Used for advanced data analytics.

Analytical Results

Results from data analysis are re-transmitted to the system for decision making and further improvements.

Feedback Loop

- **Citizens, Government, Business**: Key stakeholders who provide feedback based on analytical results and influence future actions and decisions.

Dashboards and Monitoring

Visualisation tools that display real-time data and metrics to help monitor and manage the ecosystem effectively.

Key Flows and Interactions

Data Flow

Data is collected from various sources within the smart city, processed using big data techniques, and analysed using tools like Apache and MATLAB.

IoT Integration

The IoT API facilitates seamless data exchange between different components, improving connectivity and automation.

Feedback Mechanism

Continuous feedback from citizens, government and businesses helps refine and optimise the smart education framework.

Visualization

Dashboards provide a comprehensive view of system performance, enabling informed decision making.

Components Summary

The Smart Education Recommendation Framework Ecosystem is a comprehensive model that integrates various components of a smart city to enhance educational results. Using big data, IoT and advanced analytical tools, it provides a data-driven holistic approach to education management and improvement. The framework emphasises continuous improvement through feedback and is aligned with international standards, ensuring its robustness and scalability.

6.1.5 Areas for Future Research

The report identifies several areas for future research, including:

- **Advanced AI Integration:** Further exploration of how AI can be used to personalise and enhance learning experiences.
- **Scalability Studies:** Research into how the framework can be scaled and adapted for different sizes and types of smart cities.
- **Longitudinal Impact Studies:** Studies to assess the long-term impact of the Smart Education Recommendation Framework on educational outcomes.

6.1.6 Alignment with ISO/IEC 30145 Standards

The Smart Education Recommendation Framework with Dashboard is strategically designed to align with the ISO/IEC 30145 series, demonstrating a commitment to an international standard that uses Big Data Analytics, IoT and cloud technologies within the educational sector. This meticulous alignment guarantees the security, privacy, and interoperability of the deployed technologies, adhering to a set of global standards essential to foster a conducive environment for smart education ecosystems.

The integration of these technologies through the framework and dashboard not only adheres to the stringent requirements set forth by ISO/IEC 30145 but also enhances the educational experience by providing a scalable, flexible platform for educators and learners. The dashboard serves as a central hub for data analytics, offering insights into learning patterns, the use of educational resources, and student performance. This, in turn, enables personalised learning experiences and supports evidence-based decision making in educational institutions.

In line with ISO / IEC 30145, the framework ensures that all aspects of data handling, from collection, analysis to storage, are conducted in a manner that prioritises the safety and privacy of the educational community. Furthermore, this alignment facilitates interoperability among diverse educational technologies, enabling seamless integration within smart city infrastructures and ensuring that the educational sector can fully leverage the benefits of IoT and cloud computing.

In essence, the Smart Education Recommendation Framework with Dashboard represents a significant step forward in the evolution of smart education. Its alignment with ISO/IEC 30145 standards not only underscores a commitment to security, privacy, and interoperability, but also highlights the potential of modern technologies to revolutionise the educational landscape, making it more responsive, inclusive, and effective. Furthermore, this research establishes a methodology that integrates internationally recognised frameworks, standards, and data sets to develop robust and scalable quantitative metrics to assess and accredit smart cities. This approach is articulated in the following chapters of the thesis.

1. Foundation of Quantitative Metrics Development (Chapter 1)

Chapter 1 provides the foundational rationale and objectives of the research, including:

- **Alignment with Global Standards:** The research adopts ISO/IEC standards (e.g., ISO 37120 on sustainable development in communities) as a reference framework. These standards provide key performance indicators (KPIs) that are widely accepted to assess smart city functionalities.
- **Research Gap Identification:** The lack of standardised quantitative metrics is identified for accreditation and validation, and this research directly addresses this by proposing a metrics framework aligned with global benchmarks.

2. **Data Collection and Integration (Chapter 2)**
   - **Selection of Data Sources:** Chapter 2 outlines the use of internationally validated datasets, such as those from the World Bank, OECD, and UNESCO, to gather reliable and comparable data.
   - **Criteria for Dataset Inclusion:** Key criteria include data granularity, reliability, and relevance to smart cities performance dimensions (e.g., governance, technology, sustainability, and citizen engagement).
   - **Quantitative Data Modelling:** The research employs quantitative modelling techniques to analyse collected data sets and identify indicators that are strongly correlated with smart city performance and outcomes.
3. **Framework for Metrics Validation (Chapter 3)**
   - **Integration of KPIs:** Chapter 3 details the integration of KPIs derived from ISO/IEC standards, augmented by indicators specific to smart education and smart governance.
   - **Weighting and Scoring Methodology:** A scoring framework is developed to assign weights to indicators based on their relevance and impact, ensuring that the metrics are scalable and adaptable between different cities.
   - **Stakeholder Input:** Feedback from stakeholders (e.g., city planners, policymakers, and educators) ensures that the proposed metrics are relevant and practically applicable.
4. **Application of Metrics (Chapter 4)**
   - **Case Studies:** Chapter 4 applies the metrics to a subset of the top 25 smart cities identified in Chapter 2, providing a comparative analysis of their performance.
   - **Quantitative Validation:** The results demonstrate how cities meet accreditation criteria, with measurable insights into their compliance with global standards.
5. **Contribution to Global Accreditation (Chapter 5)**
   - **Global Framework:** Chapter 5 proposes a scalable global accreditation framework that can be adopted by international organisations. This framework leverages the proposed metrics to ensure consistent and transparent validation processes.
   - **Validation of Smart City Success:** The framework includes benchmarking tools that enable cities to measure their progress and identify areas for improvement.

Summary

In summary, this research aims to provide quantitative metrics for the global accreditation and validation of smart cities by:

1. Alignment with ISO/IEC standards to establish a robust foundation for metrics development.
2. Using validated data sets to ensure a reliable and comparable analysis.
3. Designing a scalable framework that integrates key indicators, stakeholder input, and quantitative modelling.
4. Demonstrating the applicability of the framework through real-world case studies.

This systematic approach ensures that the proposed metrics are scientifically grounded, globally relevant, and practically implementable.

6.2 Conclusion

1. **Integration of Big Data Analytics in the Smart Education Framework:** Investigate how Big Data analytics can be integrated to improve personalised learning experiences, optimise resource allocation, and improve the overall operational efficiency of educational institutions within Smart Cities. This objective focusses on using large data sets and complex analytics to inform and improve educational strategies (H. Chen, Chiang, and Storey 2012).
2. **Development of the Smart Education Recommendation Framework with Dashboard (SERFD):** Develop a comprehensive Smart Education Recommendation Framework with a Dashboard that visualises Smart City metrics and their components in the context of Smart Education.

This involves understanding the impact of these metrics on educational outcomes and aligning them with the ISO/IEC Smart Education Framework (Rafael Cortez et al. 2020).

3. **Impact Assessment on Stakeholders Using the Smart Education Framework:** To assess the effects of the Smart Education Framework on various stakeholders, including students, educators, administrators, and policymakers. This includes evaluating how the framework influences learning outcomes, teaching methodologies, decision-making processes, and resource management in an urban educational context (Abella et al. 2024).
4. **Alignment of Emerging Technologies, Policy, and Rural-Urban Disparities:** To develop a comprehensive SERF framework that facilitates the seamless integration of Smart Education initiatives into broader Smart City development goals. This objective addresses the unique challenges and opportunities presented by rural-urban disparities and investigates the potential of emerging technologies to bridge the digital divide, ensuring equitable access to quality education for all learners, regardless of their geographical location (Alalawi and Al-Omary 2019).
5. **Addressing Challenges and Solutions in Implementing the Smart Education Framework:** To identify and address potential challenges and limitations in the implementation of the Smart Education Framework. This includes data privacy concerns, technological infrastructure readiness, training educators, and providing robust support systems to facilitate seamless integration and maximise the benefits of personalised data-driven learning experiences. In addition, it involves identifying investment strategies to minimise educational disparities between rural and urban areas by leveraging the infrastructure and technological advances inherent in the volume and variety of Big Data in Smart Cities (Daniel 2015).
6. **Designing the Smart Education Recommendation Framework to be Adaptable and Scalable:** To ensure the Smart Education Recommendation Framework is adaptable and scalable, capable of accommodating the evolving needs of Smart Cities and the dynamic landscape of educational technologies. This objective aims to guarantee the long-term relevance and effectiveness of the framework, supporting sustainable educational development within smart urban environments.

The integration of smart city and smart education initiatives, underpinned by the ISO/IEC 30145 standards, heralds a new era of technological empowerment in education. The proposed framework promises a future where education is personalised, highly accessible, and seamlessly integrated in smart cities, highlighting the importance of innovation, collaboration, and compliance with global standards. This ambitious yet achievable goal underscores the thesis' contribution to the field, setting the stage for future advancements in smart education.

The comprehensive analysis underscores a pivotal shift towards integrating advanced technologies within the realm of smart education. The proposed Smart Education Recommendation Framework with Dashboard, meticulously designed to align with the ISO/IEC 30145 series, epitomises the fusion of Big Data Analytics, IoT, and cloud technologies to revolutionise educational systems in smart city contexts.

Through the lens of multidiscipline methodologies, the research delineates a strategic approach to operational efficiency, highlighting the transformative potential of recommendation dashboards in facilitating personalised learning experiences. The pros, predominantly marked by the innovative use of technology to improve educational accessibility and quality, significantly outweigh the cons, which are primarily concerned with data privacy and the integration complexities of disparate systems.

Compliance with ISO / IEC 30145 standards not only ensures the security, privacy, and interoperability of implemented technologies but also fosters a globally standardised framework conducive to the development of smart education. The effectiveness of these initiatives, buoyed by robust compliance and strategic implementation, positions the Smart Education Recommendation Framework with Dashboard as a cornerstone of future educational ecosystems.

The integration of smart cities and smart education initiatives represents a transformative approach to addressing contemporary urban challenges. This research has contributed to this discourse by developing the Smart Education Recommendation Framework with Dashboard (SERFD), a robust tool to improve operational efficiency in smart education ecosystems. By synthesising insights from interdisciplinary studies and aligning the framework with ISO/IEC 30145 standards, this work bridges critical gaps in knowledge and practice.

Addressing the Knowledge Gap

A key gap identified in the literature is the lack of a comprehensive, standardised methodology for integrating Big Data Analytics and Internet of Things (IoT) workflows into smart education systems (Albino, Berardi, and Dangelico 2015; Bibri and Krogstie 2017). Existing frameworks often overlook the operational nuances required to align with global standards while allowing flexible, data-driven decision making. This research addresses these gaps through the following contributions:

- **Designing a Data-Driven Framework:** SERFD introduces a novel approach to operational efficiency by leveraging multi-criteria decision-making visualisation dashboards. The framework incorporates metrics such as Service Data Utilisation (SDU) and Population to Service Allocation Ratio (PSAR) to provide actionable insights. This integration ensures that resource allocation and service delivery are optimised, addressing inefficiencies highlighted in previous studies (ISO 2014; Zawacki-Richter, Victoria I Marín, et al. 2019a).
- **Aligning with International Standards:** By grounding the framework in ISO/IEC 30145 standards, the research ensures global applicability and interoperability. This alignment provides a structured pathway for smart cities to harmonise their education initiatives with international benchmarks, promoting sustainability and scalability (**batty2012visualising**; Hwang 2014).
- **Fostering Adaptability and Scalability:** SERFD emphasises adaptability by integrating IoT workflows that respond dynamically to changing educational needs. This adaptability aligns with the requirements of diverse urban contexts, addressing variations in population density, technological infrastructure, and policy environments (Shaofeng Wang, Z. Sun, and Y. Chen 2022; Albino, Berardi, and Dangelico 2015).
- **Empirical Validation and Case Studies:** The research includes analyses of real-world datasets to demonstrate the practical application of SERFD. By visualising operational efficiency through dashboards, this study provides a replicable model for other smart cities to benchmark their performance and adopt evidence-based strategies (Picciano 2012; Al-Fraihat, Joy, and Sinclair 2020).

Implications for Stakeholders

This research underscores the critical role of collaboration among policymakers, educators, and urban planners in realising the potential of smart education systems. SERFD provides these stakeholders with a data-driven framework to:

- **Enhance Resource Allocation:** Prioritise investments based on empirical information, ensuring that resources are directed to areas of greatest need.
- **Promote Equity and Accessibility:** Address disparities in service delivery by identifying underserved populations and optimising service allocation.
- **Support Continuous Improvement:** Leverage real-time data to monitor performance and implement iterative improvements, fostering a culture of innovation and responsiveness (Bibri and Krogstie 2017; Radianti et al. 2020).

Future Directions

Although this research has made significant strides in addressing operational inefficiencies, several areas warrant further exploration. For example, incorporating additional parameters such as teacher-to-student ratios, infrastructure quality, practical integration using IoT devices, practical application of AR/XR devices, and socioeconomic factors could enhance the robustness of the SERFD framework. Furthermore, expanding empirical validation to include longitudinal studies in diverse smart cities would provide deeper insights into the scalability and adaptability of the framework.

Taking into account the above, this research represents a significant step forward in aligning smart education systems with the broader objectives of smart urban development. By addressing the knowledge gap in operational efficiency and standardisation, it offers a roadmap for integrating Big Data and IoT workflows into educational ecosystems. The future envisaged is one where education is not only personalised and accessible but also seamlessly embedded within the dynamic fabric of smart cities, enabling a transformative impact on society (Albino, Berardi, and Dangelico 2015; Bibri and Krogstie 2017; Chourabi et al. 2012;

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==== End of Smart Education Recommendation Framework with Dashboard Thesis ====

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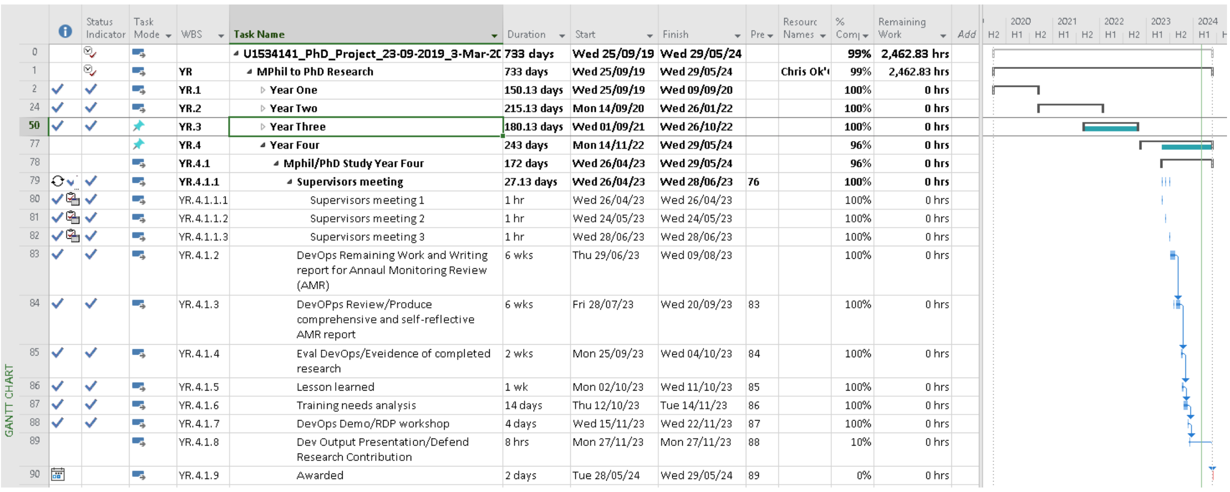
Appendix A

Appendix

A.1 Plan Smart City Metrics In The Context of Smart Education



	Status Indicator	Task Mode	WBS	Task Name	Duration	Start	Finish	Pre	Resourc Names	% Comp	Remaining Work	Add
0				U1534141_PhD_Project_23-09-2019_3-Mar-20	733 days	Wed 25/09/19	Wed 29/05/24			99%	2,462.83 hrs	
1			YR	MPhil to PhD Research	733 days	Wed 25/09/19	Wed 29/05/24		Chris Ok'(	99%	2,462.83 hrs	
2			YR.1	Year One	150.13 days	Wed 25/09/19	Wed 09/09/20			100%	0 hrs	
24			YR.2	Year Two	215.13 days	Mon 14/09/20	Wed 26/01/22			100%	0 hrs	
50			YR.3	Year Three	180.13 days	Wed 01/09/21	Wed 26/10/22			100%	0 hrs	
77			YR.4	Year Four	243 days	Mon 14/11/22	Wed 29/05/24			96%	0 hrs	
78			YR.4.1	Mphil/PhD Study Year Four	172 days	Wed 26/04/23	Wed 29/05/24			96%	0 hrs	
79			YR.4.1.1	Supervisors meeting	27.13 days	Wed 26/04/23	Wed 28/06/23	76		100%	0 hrs	
80			YR.4.1.1.1	Supervisors meeting 1	1 hr	Wed 26/04/23	Wed 26/04/23			100%	0 hrs	
81			YR.4.1.1.2	Supervisors meeting 2	1 hr	Wed 24/05/23	Wed 24/05/23			100%	0 hrs	
82			YR.4.1.1.3	Supervisors meeting 3	1 hr	Wed 28/06/23	Wed 28/06/23			100%	0 hrs	
83			YR.4.1.2	DevOps Remaining Work and Writing report for Annaul Monitoring Review (AMR)	6 wks	Thu 29/06/23	Wed 09/08/23			100%	0 hrs	
84			YR.4.1.3	DevOPps Review/Produce comprehensive and self-reflective AMR report	6 wks	Fri 28/07/23	Wed 20/09/23	83		100%	0 hrs	
85			YR.4.1.4	Eval DevOps/Eveidence of completed research	2 wks	Mon 25/09/23	Wed 04/10/23	84		100%	0 hrs	
86			YR.4.1.5	Lesson learned	1 wk	Mon 02/10/23	Wed 11/10/23	85		100%	0 hrs	
87			YR.4.1.6	Training needs analysis	14 days	Thu 12/10/23	Tue 14/11/23	86		100%	0 hrs	
88			YR.4.1.7	DevOps Demo/RDP workshop	4 days	Wed 15/11/23	Wed 22/11/23	87		100%	0 hrs	
89			YR.4.1.8	Dev Output Presentation/Defend Research Contribution	8 hrs	Mon 27/11/23	Mon 27/11/23	88		10%	0 hrs	
90			YR.4.1.9	Awarded	2 days	Tue 28/05/24	Wed 29/05/24	89		0%	0 hrs	

Figure A.1: Overview of OE2Vs plan for 5years research - part 1

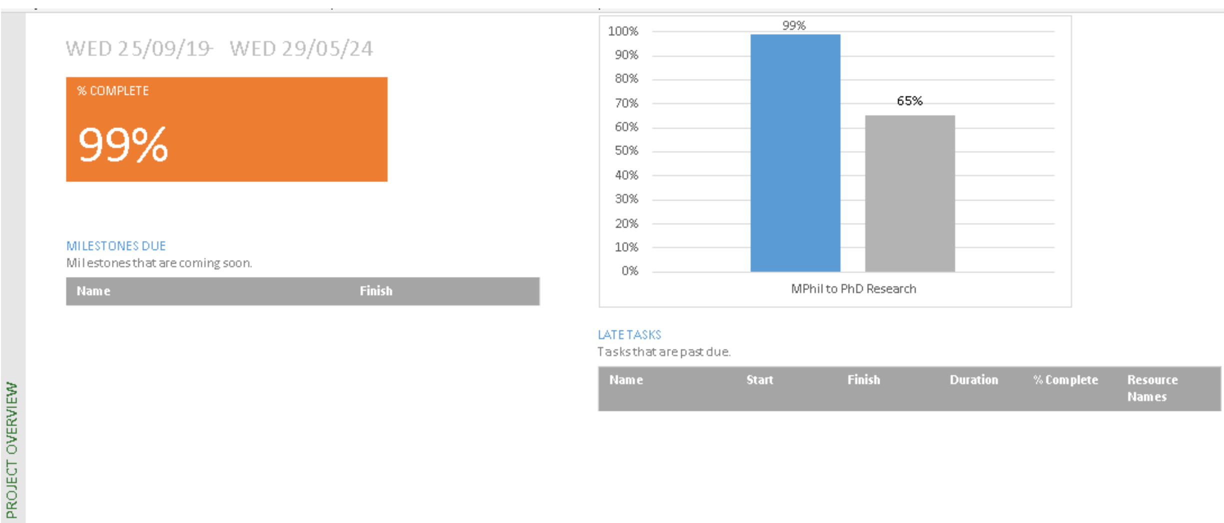


Figure A.2: Overview of OE2Vs plan for 5years research - part 1a

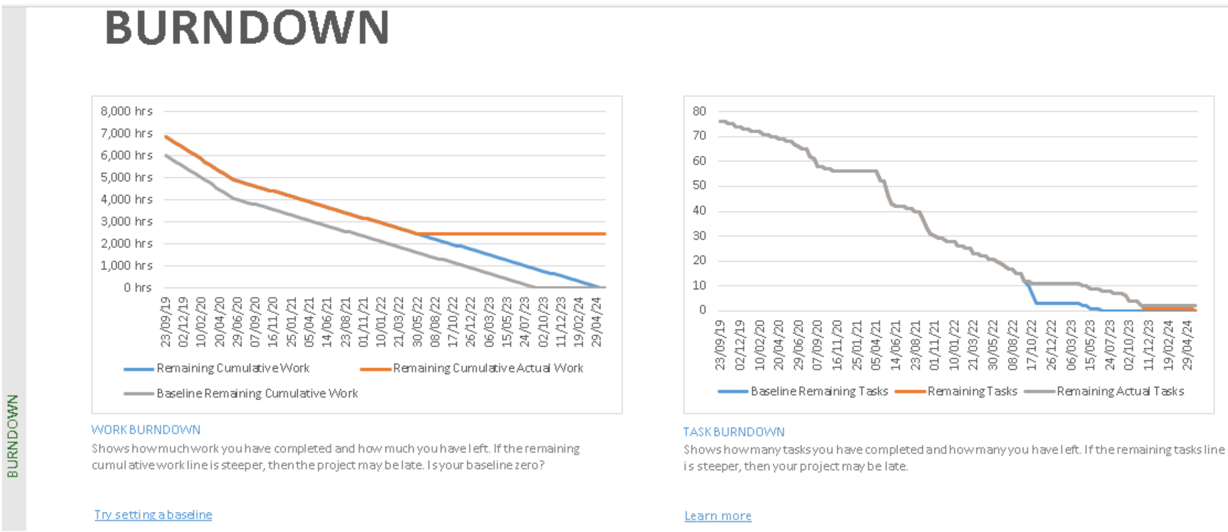


Figure A.3: Overview of OE2Vs plan for 5years research - part 1b

```
import pandas as pd
import plotly.graph_objects as go
from plotly.subplots import make_subplots

# Load the dataset
data = pd.read_csv('path_to_your_file/sedata1.csv')

# Calculating SDU and PSAR without sorting the data
data['SDU'] = data['servdata'] / data['popul'] * 100  # Service Data Utilization
data['PSAR'] = data['allocsrv'] / data['popul']  # Population to Service Allocation Ratio

# Creating subplots with specified positions for bar and pie charts
fig = make_subplots(rows=2, cols=3,
        subplot_titles=("Service Data Utilisation (SDU)",
        "Population to Service Allocation Ratio (PSAR)", "Population Distribution"),
        specs=[[{"type": "bar"}, {"type": "bar"}, {"type": "bar"}],
        [{"type": "pie"}, {"type": "pie"}, {"type": "pie"}]])

# Adding bar plots directly from the dataset to maintain the original order
fig.add_trace(
    go.Bar(x=data['secity'], y=data['SDU'], name='SDU'),
    row=1, col=1
)

fig.add_trace(
    go.Bar(x=data['secity'], y=data['PSAR'], name='PSAR'),
    row=1, col=2
)

fig.add_trace(
    go.Bar(x=data['secity'], y=data['popul'], name='Population'),
    row=1, col=3
)

# Adding pie charts directly under the bar charts
fig.add_trace(
    go.Pie(labels=data['secity'], values=data['SDU'], name='SDU Distribution'),
    row=2, col=1
)

fig.add_trace(
    go.Pie(labels=data['secity'], values=data['PSAR'], name='PSAR Distribution'),
    row=2, col=2
)

fig.add_trace(
    go.Pie(labels=data['secity'], values=data['popul'], name='Population Distribution'),
    row=2, col=3
)

# Updating layout for better visualisation
```

```
fig.update_layout(height=1200, width=1200, title_text="Dashboard Metrics Visualisation")

# Display the figure
fig.show()

# Save the figure to an HTML file for easy sharing and viewing
fig.write_html("dashboard_metrics_visualization.html")

# Note: Replace 'sedata1.csv' with the actual dataset file on your machine.
```

Table A.1: Smart City components definitions with reference applications in the context of Smart Data Paroutis, Bennett, and Heracleous 2014, (full table see appendix).

Begin of Table		
SC Application Components	Smart City Big Data Project Focus	Reference Application
Smart Economy - Innovation and Competitiveness	Travel and Tourism: Smart citizens can leverage the best travel package and hotels, looking at occupancy rate, room traffic, school holidays, peak seasons, and the tourism industry can anticipate demand and maximise revenue for better return on investment. In various travel sectors, big data is used by companies to analyse information about their competitors, which gives an understanding of what other hotels,	Example application: Airbnb is one of the best homestay networks online. To help travellers from all over the world find the best properties, Airbnb analyses all the big data to produce this result. To achieve this, it lists properties through customer preferences, keywords, and pricing. In doing so, it provides its customers with the best stay.
Smart Economy - Continue.	for example, are offering their customers through market research. Based on a tourist's past travel history and likes, they can receive personalised experiences that are focused on their needs, which can lead to personalised offers. Smart governance is helping governments with investment; few countries use Big Data to examine tourism flows and discover investment opportunities in their country. Then, investment opportunities are created in such profitable areas.	——————-

Continuation of Table A.1		
SC Application Components	Smart City Big Data Project Focus	Reference Application
Smart Mobility - Infrastructure and Transport	Logistics: The application sensors within the vehicles analyse the fastest route to reach the destination. This dynamic routing plan will take into account the weather, traffic and orders that are performed to provide flexible routing for the product. In addition, predictive analytics are used to investigate the availability of the workforce. This prevents more than one truck from heading in the same direction and ensures efficient operation; this improves operational efficiency (OE) and capacity planning. Another contribution is that by using big data analytics and tracking application sensors, warehouse robotics is improved, resulting in efficient resource allocation and reduced cost spiral, thereby resulting in smart warehousing. With big data, semantic analysis, and text processing help to analyse customer reactions, which will eventually create an instant feedback look, giving insight into customer satisfaction.	Example application: UPS is one of the largest package shipping companies in the world. They use a wide variety of data at all times. They use big data to optimise routes dynamically. The system can automatically change routes in real time. By doing so, UPS can anticipate traffic jams, bad weather, etc.
Smart Environment - Resources and Sustainability	Weather Forecast: Big data allows us to collect or collect a huge amount of data, such as previous weather reports, climate change details, wind direction, precipitation, etc. Output: All of this data are then analysed to produce accurate predictions of probable rains or natural calamities. To do this, a weather prediction engine is used to predict the weather of every region of the world at any given time.	Example application: University of Melbourne developed an advanced solution that also predicts the boundary where a landslide is likely to occur two weeks in advance. The tool works on big data and applied mathematics.

Continuation of Table A.1		
SC Application Components	Smart City Big Data Project Focus	Reference Application
Smart Education - Creativity and Social Capital	Smart Education: Optimise academic research; for instance, astronomers can now analyse a huge astronomy dataset using powerful computers instead of manual analyses. By analysing and exploring high-quality digital images taken from space, new discoveries may occur in the fields. This is applicable to many fields of science and research, such as medical experiments, manufacturing operations, environmental studies, and economic and financial analysis. Behaviour and matchmaking will lead to new knowledge. From the assessment of graduates to the attitudes of the online world, each student generates a unique data track. By analysing these data, education institutes can realise whether they are using their resources in the right places and producing the right results.	Due to Smart Education (SE), smart people create and pursue S.M.A.R.T. goals; the nature attributes are Specific, Measurable, Attainable, Relevant, and Timely coupled with affinity to lifelong learning, which represents cognitive or creative capability and human skills. An aspect of SE is remote education, such as open university distance learning, big data can be used to determine the quantitative and qualitative OE of the output of this component.
Smart Living - Healthcare Culture and Quality of Life	Health Care: With the large available data, medical research is very efficient, and new treatments and drugs are discovered, such as in medical research domains. In addition, hyper-personal care is provided to each depending on his or her medical history, such as personalised treatments. Another area, re-admissions, account for a significant reason for increased healthcare cost. When big data are properly analysed, accurate insights regarding the patient's health are obtained, which can lead to cost reduction. The main insights have shown that the analysis of big data helps identify disease trends based on geography and demographics; this may help to make a probable prediction of the health of the population.	Example application: United Healthcare in the USA uses big data to detect fraud in medical applications and identity threat; it also predicts the probability that disease management programmers will succeed, depending on how patients respond to it.

Continuation of Table A.1		
SC Application Components	Smart City Big Data Project Focus	Reference Application
Smart Governance – Participation and Empowerment	Government and law enforcement: This is an area that all governments want to have a strong grip on. This is future policing; the end game is lower crime rates and smarter development. Predictive police use big data to forecast criminal activity before it occurs based on the information given to them through big data analysis. More insights are obtained by analysing the number of students graduating every year and the number of job openings, so that governments can have an idea of the unemployment in the country and track growth or decline. A decline will lead to poverty, so governments use big data tools to discover areas that fall under the poverty line and lift those from them out of poverty into the smart citizen. By proper use or analysis of the data collected from public surveys, governments can design efficient smart city services and policies that will benefit smart citizens, thus improving operational efficiency and improving social and economic policies.	Example application: The New York Police Department (NYPD) uses big data analytics to protect its citizens; To do this, the department identifies crime trends, threats, and prevents crimes by analysing data such as certain emails, fingerprints, and records from police investigations and other public databases.
End of Table		

Table A.2: Smart City Components by sectors application (see appendix 2 for full table listing) Gunasekaran et al. 2017 .

Begin of Table					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
University / Public expenditure on R and D - percentage	Percentage of population aged 25 to 65 with university-level education living in Urban	An assessment of the ambitiousness of the CO2 emission reduction strategy	Percentage of population aged 25 to 65 with university-level education living in Urban	Percentage of professors and researchers involved in international projects	Number of universities and research centres in the city

Continuation of Table A.2					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
Government / GDP per head of city population Debt of borough authority per resident Median or average disposable annual household income. Unemployment rate Energy intensity of the economy - Gross domestic consumption of energy divided by GDP	Voter turnout in national election Voter turnout in national referendum Share of female city representative City representatives per resident ratio	Total annual energy consumption, in gigajoules per head Energy efficient use of electricity (use per GDP) Total annual water consumption, in cubic metres per head Energy efficient use of water (use per GDP)	Voter turnout in national election, Voter turnout in national referendum, Share of female city representative, City representatives per resident ratio	Proportion of the area for recreational sports and recreational use of green space (m2) to which the public has access, per capita. Number of public libraries, Number of theatres and cinemas, Health care expenditure? percentage of GDP per capita, Tourist overnight stays in registered accommodation in per year per resident	e-Government on-line availability (display percentage of the top 20 basic services that are fully serviceable online), percentage of houses and flats with ICT (computer), percent of houses and flats with active Internet access
———	———	———	———	———	———

Continuation of Table A.2					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
———	———	Area in green space (m2) Energy consumption intensity of greenhouse gas emission. An assessment of the comprehensiveness of policies to contain urban sprawl and to improve and monitor environmental performance Urban population exposure to air pollution by particulate matter - microgramme per cubic metre	———	———	———
———	———	———	———	———	———

Continuation of Table A.2					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
Civil society / Percentage of projects funded by civil society	Foreign language skills Participation in lifelong learning percentage Individual level of computer skills Individual level of internet skills	The total percentage of the working population travelling to work by public transport, bicycle, and foot. Evaluation of the degree to which citizens can participate in environmental decision-making. An assessment of the extent of efforts to increase the use of cleaner transport. Percentage of citizens engaged in environmental and sustainability-orientated activity	Foreign language skills Participation in lifelong learning percentage Individual level of computer skills Individual level of internet skills	Total book loans and other media per resident Museum visits per inhabitant	eGovernment usage by citizens (percentage of citizens aged 18-75 who have used the internet), in the last 3 months, for interaction with public authorities.

Continuation of Table A.2

Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
Industry / Employment rate in: - High tech and creative industries - Renewable energy and energy efficient systems - Financial obligation and business activities - Culture and entertainment industry - Commercial services	Patent applications per inhabitant Employment rate in knowledge intensive sectors	The percentage of total energy derived from renewable sources, as a share of the total energy consumption of the city, in terajoules. Combined heat and power generation -	Patent applications per inhabitant Employment rate in knowledge-intensive sectors	Number of companies adopting ISO 14000 standards Proportion of people undertaking industry based training	Number of research grants funded by companies, foundations, institutes with no annual scholarships and their support for the sustainability of SDG4 as proposed by the UN
———	———	———	———	———	———

Continuation of Table A.2					
Sectors / Smart Economy	Smart Mobility	Smart Environment	Smart Education	Smart Living	Smart Governance
Industry / Employment rate in: continue. - Transport and communication - Hotels and restaurants - Total number of companies Number of local units manufacturing high tech and ICT products Companies with headquarters in the city quoted on national stock exchange Components of domestic material consumption	——-	percentage of gross electricity generation Proportion of recycled waste per total kilogramme of waste produced Total CO2 emissions, in tonnes per head Percentage of new buildings and renovations that were evaluated in terms of sustainability	——	——	——
End of Table					

SERF Web Scrape for SE Recommendation Framework A.3

Table A.3: Web Scraping for Smart Education Recommendation Framework.

title	link	snippet
Standards for smart education – towards a development framework ...	https://slejournal.springeropen.com-/articles/	Mar 2, 2018 ... Smart learning environments (SLEs) utilize a range of digital technologies in supporting learning, education and training; they also provide ...
Smart E-Learning Framework for Personalized Adaptive Learning ...	https://ieeexplore.ieee.org/-document/10220065	Aug 15, 2023 ... This is in contrast to interactive recommendation methods that can create recommendations based on the learner's feedback via constant ...
A machine learning-based hybrid recommender framework for smart ...	https://peerj.com/articles/cs-1880/	Feb 20, 2024 ... This article presents a hybrid recommender framework for smart medical systems by introducing two methods to improve service level ...
Intelligent Recommendation System for Course Selection in Smart ...	https://www.sciencedirect.com/-science/article/pii/	The sparse linear method (SLIM) is introduced in our framework to generate the top-N recommendations of courses appropriate to the students. Meanwhile, aL0 ...
A machine learning-based hybrid recommender framework for smart ...	https://www.ncbi.nlm.nih.gov-/pmc/articles/PMC10909219/	Feb 20, 2024 ... Different types of symptom segments in the main complaint can be utilized as featured words. Then, the TF-IDF of various symptom segments of ...
Benefits Enrollment Decision Support — Smart Recommendation ...	https://www.goempyrean.com/drive-smart-enrollment-with-decision-support-tools-the-4-crucial-elements-of-an-effective-recommendation-engine/	Jan 11, 2019 ... A smart recommendation engine uses machine learning to identify ... Point-in-time education delivers only the benefits information employees need, ...

Continued on next page

Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
SMART Cancer Navigator: A Framework for Implementing ASCO ...	https://ascopubs.org/doi/	SMART Cancer Navigator: A Framework for Implementing ASCO Workshop Recommendations to Enable Precision Cancer Medicine · Abstract · Introduction · Methods · ASCO ...
SMART Goals A How to Guide	https://www.ucop.edu/local-human-resources/files/performance-appraisal/How ...	end of the fiscal year. Page 13. Performance Appraisal Planning 2016-2017. SMART Goals: A How to Guide. 13. Conduct outreach and education that reduces the...
How to finance climate-smart education: Launching an evidence ...	https://www.globalpartnership.org-/blog/how-finance-climate-smart-education-launching-evidence-review-and-costing-framework-tool	Dec 4, 2023 ... ... smart education: Launching an evidence review and a costing framework tool ... "Education X Climate Change" workshop defines recommendations for ...
(PDF) Standards for smart education – towards a development ...	https://www.researchgate.net/-publication/323524466 Standards-forsmarteducation-towards a development framework	ArticlePDF Available. Standards for smart education – towards a development framework. March 2018; Smart ... The OSI Reference Model was an important framework ...
SMART criteria - Wikipedia	https://en.wikipedia.org/wiki-/SMART$_{c}riteria$	S.M.A.R.T. (or SMART) is an acronym used as a mnemonic device to establish criteria for effective goal-setting and objective development. This framework is ...
What Is a Recommendation Engine and How Does It Work?	https://www.appier.com/en/blog-/what-is-a-recommendation-engine-and-how-does-it-work	A recommendation engine is a type of data filtering tool using machine learning algorithms to recommend the most relevant items to a particular user or customer ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Writing meaningful goals and SMART objectives - MN Dept. of Health	https://www.health.state.mn.us-/communities/practice/resources/-phqitoolbox/objectives.html	Mar 3, 2023 ... What is a goal? · Broad, future-oriented statement that describes expected effect · Defines scope · Provides framework for objectives.
A framework for smart academic guidance using educational data ...	https://dl.acm.org/doi/abs/	Mar 1, 2019 ... AbstractThe educational recommendation system to provide support for academic guidance and adaptive learning has always been an important ...
Be SMART — Secure Gun Storage	https://besmartforkids.org/	Be SMART raises awareness that secure gun storage — storing guns locked, unloaded and separate from ammunition — can save children's lives.
How to write SMART goals (with examples)	https://www.atlassian.com/blog-/productivity/how-to-write-smart-goals	Dec 26, 2023 ... Knowing how to set goals using the SMART framework can help you ... Why learning styles don't work – and proven ways to learn more effectively ...
Guidance on Implementation of the National Smart Education ...	https://iite.unesco.org/wp-content/uploads/2022/12/Guidance-on-Implementation-of-the-National-Smart-Education-Framework.pdf	Dec 13, 2022 ... Framework for Building Smart Education at Country Level. Chapter 3. Recommendations on Implementing the National Smart Education Framework.
Global information infrastructure, Internet protocol aspects, next ...	https://www.itu.int/rec/T-REC-Y	Quality of service assurance-related requirements and framework for smart education supported by IMT-2020 and beyond ... High-level requirements and reference ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Add Recommended Content to Websites with AddSearch	https://www.addsearch.com/-addsearch_recommend/	Recommendation Engine Optimize engagement with smart recommendations · Book a ... Transform learning with relevant course recommendations, and ensure students ...
Healthy People 2030 Framework	https://health.gov/healthypeople-/about/healthy-people-2030-framework	Foundational principles; Overarching goals; Plan of action; History and context. The framework was based on recommendations made by the Secretary's Advisory ...
Recommender System, Recommendation Engine - Amazon ...	https://aws.amazon.com/personalize/	Machine Learning; Amazon Personalize. 180,000 real-time recommendations/month for the first two months. Amazon Personalize. Elevate the customer experience ...
Artificial Intelligence and the Future of Teaching and Learning (PDF)	https://www2.ed.gov/documents/ai-report/ai-report.pdf	Recommendation 7: Develop Education-Specific Guidelines and Guardrails ... Smart Learning Environments, 7(33). https://doi.org/10.1186/s40561-020-00140-9.
A framework for smart academic guidance using educational data ...	http://search.proquest.com/openview/	This paper explores the potential of Educational Data Mining for academic guidance recommendation by predicting students' performance which involves analyzing ...
recommenderlab: An R Framework for Developing and Testing ...	https://arxiv.org/abs/2205.12371	May 24, 2022 ... ... recommender system research and education. This paper describes the open-source software recommenderlab which was created with supporting ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
How to define SMART marketing objectives — Smart Insights	https://www.smartinsights.com-/goal-setting-evaluation/goals-kpis/define-smart-marketing-objectives/	Feb 6, 2024 ... One of the main reasons we called our learning platform SMART ... We recommend integrating all your SMART marketing objectives across the RACE ...
Smart education strategies for teaching and learning: critical ...	https://unesdoc.unesco.org/ark-:/48223/pf0000383678	A global framework reference on digital literacy skills. Information paper No. 51. http://uis.unesco.org/sites/
Setting Goals and Developing Specific, Measurable, Achievable ...	https://www.samhsa.gov/sites/-default/files/nc-smart-goals-fact-sheet.pdf	Reference source not found. shows the SMART details of objective 2. Figure 2. SMART Objectives 2. Set your project up for success.
Smart Mobility Framework — Caltrans	https://dot.ca.gov/programs/-transportation-planning/division-of-transportation-planning/complete-streets/smart-mobility-framework	Caltrans has launched a Learning Network to support implementation of the Smart Mobility Framework. ... The results of the pilot study include recommendations ...
Optical fog-assisted smart learning framework to enhance students ...	https://onlinelibrary.wiley.com-/doi/abs/10.1002/cae.22120	Jul 26, 2019 ... Computer Applications in Engineering Education is an educational technology journal covering the use of computers, internet, ...
How to build a simple quiz-based recommendation engine	https://chrislema.com/quiz-based-recommendation-engine/	Apr 6, 2021 ... First, install and activate Smart Quiz Builder. Step one is pretty easy. You buy, download and activate this one single plugin. Everything else ...
Charlotte Danielson's Framework for Teaching	https://ospi.k12.wa.us/educator-support/teacherprincipal-evaluation-program/frameworks-and-rubrics/charlotte-danielsons-framework-teaching	... Framework (2011) with Final Revised Student Growth Goals 2011 Danielson Framework for Teaching Smart Card 2011 Framework Evaluation Instrument Alignment ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Conceptual Framework on Proactive Conflict Management in Smart ...	https://ideas.repec.org/h/spr-/sprchp/978-3-031-25998-2$_3$8.*html*	Findings: The findings can be employed as a reference guide to understanding smart education models and the effectiveness of ensuring a conflict-free smart ...
RACE marketing model definition - What is? - Digital marketing ...	https://www.davechaffey.com/-digital-marketing-glossary/race-marketing-planning-model/	Sep 5, 2023 ... ... Smart Insights RACE planning framework for creating and managing a digital strategy. ... Here are the reasons we recommend RACE at Smart Insights ...
Informatics Reference Framework for School	https://www.informatics-europe.org/component/-phocadownload/category/27-recommendations.html?-download=183:informatics-reference-framework-for-school-2022	smart farming, developments in climate change, improved security, as well as increased automation. Within Europe, a lot of effort has focused on digi- tal ...
PAsmart	https://www.education.pa.gov/-Policy$_F$*unding/SchoolGrants/−PAsmart/Pages/default.aspx*	... recommendations and approved the framework for the funding priorities. PAsmart grants support high-quality STEM and computer science learning and ...
Vietnam issues ICT reference framework for smart city development ...	https://opengovasia.com/2019/06-/20/vietnam-issues-ict-reference-framework-for-smart-city-development/	Jun 20, 2019 ... ... education, and healthcare. In recent years, many provinces and cities in Vietnam have started plans to build pilot projects on smart city ...
CLAIRE AI Engine – Intelligent Automation — Informatica	https://www.informatica.com/-about-us/claire.html	... Education · Financial Services · Energy and Utilities ... See how CLAIRE with the AI copilot can automate data pipelines using intelligent recommendations.

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Culturally Responsive-Sustaining Education Framework [PDF	https://www.nysed.gov/sites/-default/files/programs/crs/culturally-responsive-sustaining-education-framework.pdf	Each stakeholder group is provided with guidelines that serve as recommendations according to the four principles of culturally responsive-sustaining education.
Adaptive Smart eHealth Framework for Personalized Asthma Attack ...	https://www.mdpi.com/2624-6511/6/5/130	These models are constantly refined and improved through cloud-based adaptive learning algorithms. By providing proactive recommendations, the system helps ...
Deep learning personalized recommendation-based construction ...	https://www.nature.com/articles-/s41598-023-39564-x	Oct 20, 2023 ... An efficient passenger-hunting recommendation framework with multi-task deep learning. ... intelligent music recommendation system. Soft. Comput ...
Framework for action on interprofessional education and collaborative ...	https://www.who.int/publications-detail-redirect/framework-for-action-on-interprofessional-education-collaborative-practice	One of the most promising solutions can be found in interprofessional collaboration. WHO Team. WHO Headquarters (HQ). Reference numbers. WHO Reference Number: ...
QLearn: Towards a framework for smart learning environments ...	https://www.sciencedirect.com/-science/article/pii/	... recommend learning plans according to students' individual needs. The contribution of the paper is therefore twofold. Firstly, we propose a new learning ...
AI-Based Personalization Engine — Insider	https://useinsider.com/-individualize/	AI and Machine Learning. Channels. Web Email Site Search Conversational CX WhatsApp ... Deliver smart recommendations. Scale your coupon marketing strategy like ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
How to write SMART goals, with examples	https://www.mindtools.com/-a4wo118/smart-goals	They allow you to write goals that are clear, attainable and meaningful. Having clarity in your goal-setting provides the motivation and focus you need to be ...
COMMON EUROPEAN FRAMEWORK OF REFERENCE FOR ...	https://rm.coe.int/1680459f97	However, a framework of reference for language learning, teaching and assessment must ... smart tests? A data-based approach to rating development starting by ...
Teaching and Learning Frameworks — Poorvu Center for Teaching ...	https://poorvucenter.yale.edu/-BackwardDesign	Recommendations · Identify Most Relevant Framework · Create a Course Alignment Map · Assess Student Knowledge – · Include Formative and Summative Assessments ...
Smart Learning Management System Framework Semantic	https://www.semanticscholar.org-/paper/Smart-Learning-Management-System-Framework-Song-Wang/	This paper is proposing a framework for smart learning management system (SLMS) that utilizes user profiles and semantically organized learning objects so ...
Build a Recommendation Engine With Collaborative Filtering – Real ...	https://realpython.com/build-recommendation-engine-collaborative-filtering/	Collaborative Filtering is the most common technique used when it comes to building intelligent recommender ... learning from or helping out other students. Get ...
Artificial Intelligence and Machine Learning in Software as a Medical ...	https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-software-medical-device	7 days ago ... An imaging system that uses algorithms to give diagnostic information for skin cancer in patients. · A smart sensor device that estimates the ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
SMART Goal - Definition, Guide, and Importance of Goal Setting	https://corporatefinanceinstitute-.com/resources/management/-smartgoal/	A SMART goal is used to help guide goal setting. SMART is an acronym that stands for Specific, Measurable, Achievable, Realistic, and Timely.
Recommendations AI — AI and Machine Learning Products — Google ...	https://cloud.google.com/-recommendations	"Recommendations AI was easy to integrate with our existing recommendations framework ... Smart analytics · Artificial Intelligence · Security · Productivity ...
DANIELSON FRAMEWORK FOR TEACHING SAMPLES OF ...	https://www.deerfield.k12.wi.-us/cms$_{files/resources/}$ $-$ $Sample20Artifacts.pdf$	Photos of students engaged in learning. • SMART Board lessons. • Instruction artifacts – student work, out of class assignments. To be observed during classroom ...
Reference framework for integrated management of an SSC A ...	https://u4ssc.itu.int/wp-content/uploads/2023/07/U4SSC-Reference-framework-integrated-management-of-an-SSC-E.pdf	... education), generate wealth and share information. Figure. 8 describes a ... reference framework of Smart. City platforms. 25. loT Analytics Research, May ...
Learning Objectives	https://cteresources.bc.edu/-documentation/learning-objectives/	Mar 14, 2024 ... Drawing from the backward design framework (Wiggins and McTighe, 2005), the first step in the course design process is to determine the purposes ...
The history of Amazon's recommendation algorithm - Amazon Science	https://www.amazon.science/the-history-of-amazons-recommendation-algorithm	... learning to time recommendations (you may want to order more diapers!); and learning to target recommendations to different users of the same account, among ...
EUROPEAN COMMISSION Brussels, 18.11.2022 SWD(2022) 710 ...	https://commission.europa.eu/-system/files/2022-11/other$_{s}taff_{w}orking$ $-$ $paper_{e}n_{v}2_{p}1_{2}249550.pdf$	Nov 18, 2022 ... European Interoperability Framework for Smart Cities and Communities (EIF4SCC) ... quality, urban safety, educational quality, cultural facilities ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
What is a Recommendation System? — Data Science — NVIDIA Glossary	https://www.nvidia.com/en-us/glossary/recommendation-system/	These components combine to provide an end-to-end framework for training and deploying deep learning recommender system models on the GPU that's both easy to ...
Vermont Multi-tiered System of Supports Framework Tools — Agency ...	http://education.vermont.gov/-student-support/vermont-multi-tiered-system-of-supports/vermont-multi-tiered-system-supports-0	Who should use the VTmtss Framework tools? We recommend these tools be used by leadership teams and school staff to frame conversations related to continuous ...
The application of AI technologies in STEM education: a systematic ...	https://stemeducationjournal.-springeropen.com/articles/-10.1186/s40594-022-00377-5	Sep 19, 2022 ... Machine learning prediction and recommendation framework to support introductory programming course. ... An interactive and intelligent learning ...
Technology Informatics Guiding Education Reform (TIGER) — Health ...	https://www.himss.org/what-we-do-initiatives/technology-informatics-guiding-education-reform-tiger	Together, these projects compiled a recommendation framework of health informatics competencies (v2.0) to measure, inform, educate and advance development ...
Humble, hungry, and smart. I want to share what I learned about ...	https://medium.com/iamsridhar/-humble-hungry-and-smart-822cd5e161bf	Dec 26, 2016 ... ... framework using which we can define the qualities ideal team players should possess. ... reference checks if required. Ultimately, ensure that ...
Family Engagement and Leadership Framework — Smart Start	https://www.smartstart.org/family-engagement-and-leadership/fel-framework/	... education. Learn more... Recent News. A Recap of the 2024 Smart Start ... Smart Start Addresses Governor Cooper's Proposed Budget Recommendations · The ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
With Goals, FAST Beats SMART	https://sloanreview.mit.edu/-article/with-goals-fast-beats-smart/	Jun 5, 2018 ... Set Ambitious Goals. A core tenet of the SMART framework is that goals should be achievable and realistic. Several recent articles have argued ...
A hybrid group-based movie recommendation framework with ...	https://journals.plos.org/plosone-/article?id=10.1371/journal.-pone.0266103	Mar 31, 2022 ... The authors in [14] proposed a deep learning algorithm to recommend movies to a group of users. They considered the user ratings, user ...
Smart campus: definition, framework, technologies, and services ...	https://ietresearch.onlinelibrary-.wiley.com/doi/10.1049/iet-smc.2019.0072	Mar 10, 2020 ... The expected outcome of this work is to provide a benchmark reference of the smart campus for international education providers, government, and ...
Personalized Recommendation — SAP AI Services — SAP Community	https://pages.community.sap.com-/topics/personalized-recommendation	Recommendations powered by Intelligent Selling ... Powered by the Personalized Recommendation service, Talent Intelligence Hub is a centralized framework ...
The Ultimate Guide to S.M.A.R.T. Goals – Forbes Advisor	https://www.forbes.com/advisor-/business/smart-goals/	S.M.A.R.T. goals are useful because they contain five aspects that help you focus and reevaluate goals as needed. This framework can be helpful for any team ...
recommendation-system · GitHub Topics · GitHub	https://github.com/topics/-recommendation-system	A TensorFlow recommendation algorithm and framework in Python. python machine-learning framework tensorflow recommendation-system recommender-system ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
International Professional Practices Framework (IPPF) — The IIA	https://www.theiia.org/en/-standards/international-professional-practices-framework/	The International Professional Practices Framework is the framework that organizes authoritative guidance promulgated by The Institute of Internal Auditors.
Occupational Therapy Practice Framework: Domain and Process ...	https://research.aota.org/ajot-/article/74/Supplement$_2$/ $-7412410010p1/8382/Occupational-Therapy-Practice-Framework-Domain-and$	Aug 31, 2020 ... Intended for occupational therapy practitioners and students, other health care professionals, educators, researchers, payers, policymakers, and ...
What Are SMART Goals? Examples and Templates [2024] • Asana	https://asana.com/resources/-smart-goals	Feb 3, 2024 ... Although the SMART goal framework can be incredibly effective for ... Why it's SMART: This goal is specific (tutoring for middle school students ...
A Global Framework of Reference on Digital Literacy Skills for ...	https://uis.unesco.org/sites/-default/files/documents/ip51-global-framework-reference-digital-literacy-skills-2018-en.pdf	The constitution of the United Nations Educational, Scientific and Cultural Organization (UNESCO) was adopted by 20 countries at the London Conference in ...
What Is SMART in Project Management?	https://www.wrike.com/project-management-guide/faq/what-is-smart-in-project-management/	SMART in project management is a goal planning framework created by George Doran, Arthur Miller, and James Cunningham in the early 1980s. Doran shared the ...
Recommendation Systems and Machine Learning	https://www.itransition.com/-machine-learning/-recommendation-systems	Sep 26, 2023 ... with offsite recommendations via email. The ecommerce leader deployed its collaborative filtering-based recommender engine between 2011 and ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Artificial Intelligence (AI) — ENISA	https://www.enisa.europa.eu/-topics/iot-and-smart-infrastructures/artificial-intelligence	Artificial Intelligence (AI) is an emerging concept facilitating intelligent and automated decision-making and is thus becoming a prerequisite for the ...
Managing Risks: A New Framework	https://hbr.org/2012/06/managing-risks-a-new-framework	... Learning. Risk management. Managing Risks: A New Framework. Smart companies match their approach to the nature of the threats they face. by. Robert S. Kaplan ...
How to Build a Recommendation System: Explained Step by Step ...	https://stratoflow.com/how-to-build-recommendation-system/	Nov 20, 2023 ... Building Machine Learning Recommendation System: Custom Solution Crafted By Experts. So you want to build a recommendation engine. It may seem ...
Digital competence frameworks for teachers, learners and citizens	https://unevoc.unesco.org/home-/Digital+Competence-Frameworks	This database provides a global reference point for information on how digital competencies are being defined for citizens, learners and educators through the ...
Our Approach: Smart Policy Design and Implementation (SPDI ...	https://epod.cid.harvard.edu/our-approach-smart-policy-design-implementation-spdi	PhD student Peter Hickman discusses using EPoD's SPDI framework in Exec Ed teaching. page. SPDI In Pakistan · Women sewing in Pakistan.
Haihua Chen Projects — Intelligent Information Access Lab	https://iia.ci.unt.edu/haihua-chen-projects	) and the logical structure of academic literature (introduction, relate work, method, experiment, conclusion, etc.). As a result, a citation recommendation ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Early Childhood Education and Care SunSmart Policy and the ...	https://www.sunsmartnsw.com-.au/wpcontent/uploads/2019/-04/2019-CAN6636-SunSmart-National-Quality-Framework-Fact-Sheet-for-ECH.pdf	Early Childhood Education and Care SunSmart Policy and the National Quality Framework Fact Sheet. Page 2 of 2. CAN6636 03/18. SunSmart Recommendation 2. Shade.
Smart Learning Institute	https://sli.bnu.edu.cn/en/News-/SLI$_{N}$*ews*/2022/0902/2688.*html*	Sep 2, 2022 ... 1.National Smart Education Framework,. 2.Review of Policies on Smart ... recommendations for the future development of smart education: 1 ...
Framework for Cyber-Physical Systems: Volume 1, Overview	https://nvlpubs.nist.gov/-nistpubs/SpecialPublications/-NIST.SP.1500$_{2}$01.*pdf*	It is hoped that this Framework will satisfy the need for a reference CPS description ... autonomous vehicles, intelligent buildings, smart energy systems, robots ...
Writing SMART Learning Objectives and Outcomes (with Examples ...	https://www.skillshub.com/blog-/write-smart-learning-objectives	Sep 6, 2023 The SMART framework breaks down learning objectives into five key characteristics: Specific, Measurable, Achievable, Relevant, and Time-bound.
Education for sustainable development UNESCO	https://www.unesco.org/en/-sustainable$_{d}$*evelopment*/ − *education*	framework for informed, transparent and E-platform on Intercultural Dialogue ... Building climate smart education systems. News Building climate smart
Recommendation of the European Parliament and of the Council of ...	('https://eur-lex.europa.eu/LexUriServ-/LexUriServ.doPDF')	Dec 18, 2006 ... his Recommendation should also provide a common. European reference framework on key competences for policy makers, education and training ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
GPE Climate smart framework Working Paper	https://inee.org/sites/default/files-/resources/toward20climate20-smart20education20systems.pdf	management policies refer to the education sector, the reference is usually a passing one.28 Given the role of education in disaster risk reduction and prepared ...
Assessments	https://learn.microsoft.com/en-us/assessments/	Use the Azure Well-Architected Framework's recommendations to improve your workload. ... It will also provide recommendations on learning paths and modules that ...
Towards Intelligent System Framework for Smart University Using ...	https://www.hu.ac.th/conference/-conference2021/Proceeding/doc/	Based on education and administration role in smart university, student recommendation system (SRS), instructor decision-.
Netflix's Personalized Recommendations	https://research.netflix.com/-research$_{a}rea/recommendations$	We conduct research in areas of machine learning with the goal to make member experience better. Our work on recommender systems, contextual bandits, ...
POST-2020 GLOBAL BIODIVERSITY FRAMEWORK	https://www.cbd.int/doc/c/-079d/0d26/	Jun 26, 2022 frameworks, improving education, and access to relevant accurate ... and a recommendation for further action as necessary.] 39. [The ...
Teaching clinical handover with ISBAR — BMC Medical Education ...	https://bmcmededuc.biomed-central.com/articles/	Dec 3, 2020 ... The ISBAR (Introduction, Situation, Background, Assessment, Recommendation) framework, endorsed by the World Health Organisation, provides a ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Workforce Framework for Cybersecurity (NICE Framework) — NICCS	https://niccs.cisa.gov/workforce-development/nice-framework	2 days ago ... Responsible for developing, planning, coordinating, and evaluating cybersecurity awareness, training, or education content, methods, and ...
What Is the CASEL Framework? - CASEL	https://casel.org/fundamentals-of-sel/what-is-the-casel-framework/	Our SEL framework, known to many as the "CASEL wheel," helps cultivate skills and environments that advance students' learning and development.
The Inner Workings of Spotify's AI-Powered Music ...	https://neemz.medium.com/the-inner-workings-of-spotifys-ai-powered-music-recommendations-how-spotify-shapes-your-playlist-a10a9148ee8d	Aug 28, 2023 ... ... intelligent, and culturally sensitive recommendation systems. These ... Through reinforcement learning, Spotify's recommendation system ...
15 SMART Leadership Goals Examples to Inspire and Motivate ...	https://www.zavvy.io/blog-/leadership-smart-goals-examples	Jan 4, 2024 ... A – Achievable: This leadership goal is attainable because learning to effectively deal with constructive criticism is a skill that can be ...
Smart Grid Group — NIST	https://www.nist.gov/ctl/smart-connected-systems-division/smart-grid-group	Working with stakeholders and partners from industry, government, and academia, NIST has published the NIST Smart Grid Framework Release 4.0. This program ...
Smart Education Strategies for Teaching and Learning: Critical ...	https://iite.unesco.org/wp-content/uploads/2022/09/Smart-education-strategies-publication.pdf	by children (WEF, 2016), the OECD Learning Compass 2030 (OECD, 2018), and the Global. Framework Reference on Digital Literacy Skills (UIS, 2018) – and ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
The Smart Governance Framework and Enterprise System's ...	https://www.mdpi.com/2227-9709/10/2/53	This study aims to carry out an assessment using a smart governance framework and recommendation capabilities from the ... education, IT integration, and ...
Training for Educators - Online Education Courses for Teachers	https://danielsongroup.org/free-downloadable-resources/	THE FRAMEWORK FOR TEACHING: INTELLECTUAL ENGAGEMENT. Explore intellectually engaging instruction through our current thinking, recommendations for reflection ...
How To Write SMART Goals in 5 Steps (With Examples) — Indeed.com	https://www.indeed.com/career-advice/career-development/how-to-write-smart-goals	Apr 9, 2024 ... We'll use this to improve your job recommendations. What are SMART goals ... How to Become a Special Education Teacher · 26 Best Professional ...
Healthy and Balanced Living Curriculum Framework — Connecticut	('https://portal.ct.gov/media-/SDE/Health-Education/Publications/Healthy-and$_{B}alanced_{L}iving_{C}urriculum-Framework_{M}ay_{2}022.pdf')$	school districts to assess inclusion of State Health and Safety education requirements and recommendations. School Health Education. Included. Not Included.
Massachusetts Educator Evaluation Framework	https://www.doe.mass.edu/edeval/	Jul 11, 2022 ... The Massachusetts Educator Evaluation Framework ... recommendation by the Massachusetts Department of Elementary and Secondary Education.
From Cloud First to Cloud Smart	https://cloud.cio.gov/strategy/	... recommendations gleaned from some of the country's most ... The National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework ...

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Table A.3: Web Scraping for Smart Education Recommendation Framework

title	link	snippet
Smart city feature using six european framework and multi expert ...	http://repository.uin-malang.ac.id/11325/	Aug 3, 2022 ... ... smart environment, smart people, smart living, and smart governance. This ... recommendation must firstly implement smart education, secondly ...
A systematic review and research perspective on recommender ...	('https://journalofbigdata-springeropen.com/articles/10-1186/s40537-022-00592-5')	May 3, 2022 ... A hybrid attribute–based recommender system for e–learning material recommendation. ... An intelligent movie recommendation system through group ...
THE FUTURE OF EDUCATION AND SKILLS Education 2030	('https://www.oecd.org/education-/2030project/contact/E2030-Position$_{P}aper_{0}5.04.2018.pdf'$)	To ensure that the new learning framework is actionable, the OECD Education 2030 stakeholders have worked together ... OECD (2005), Recommendation on Principles ...

The following csv represents supplementary room allocation data used during this study. This information is presented here as a reference and does not contribute to the content or page count of the main document.

```
roomid,maxcapacity,9am-10am,10am-11am,11am-12am,13pm-14pm,14pm-15pm,15pm-16pm,16pm-17pm
kdg20,18,12,5,6,4,6,1,2
kdg22,20,14,6,8,8,7,5,3
kdg23,20,16,7,10,12,8,9,4
kdg31,20,18,8,12,16,9,13,5
kdg32,20,20,9,14,20,10,17,6
kdg33,20,22,10,16,24,11,21,7
kd121,20,24,11,18,28,12,25,8
kd122,20,26,12,20,32,13,29,9
kd123,20,28,13,22,36,14,33,10
kd127,20,30,14,24,40,15,37,11
kd128,30,32,15,26,44,16,41,12
kd129,30,34,16,28,48,17,45,13
kd130,25,36,17,30,52,18,49,14
kd131,75,1,20,28,56,66,34,19
kd214,30,20,14,20,60,1,0,0
kd215,38,22,22,23,64,26,38,17
kd217,16,24,0,0,68,51,76,0
kd218,20,26,0,0,72,76,114,0
kd219,38,28,0,0,76,101,152,0
kd220,24,30,0,0,80,126,190,0
kd226,36,15,16,8,84,151,228,0
kd228,85,37,43,25,88,72,82,38
kd228d,22,22,22,22,22,22,22,22
kd228e,34,34,34,34,34,34,34,34
```

Note: This table is included for documentation purposes only and does not contribute to the main thesis content or analysis.

Installation of Pandas

```
pip install pandas
```

Importing the Pandas Library

With Pandas installed, the next step is to import it into your Python script. This is typically done at the beginning of the script as follows:

```
import pandas as pd
```

Reading Data from a CSV File

Pandas provide various functions to read data from multiple sources. One of the most common methods is to read data from a CSV file using `read_csv`:

```
df = pd.read_csv('path/to/your/data.csv')
```

This command reads the CSV file located in the specified path and stores it in a Dataframe, a two-dimensional, size-mutable, and potentially heterogeneous tabular data structure with labelled axes.

Inspecting the Imported Data

After loading the data, it is good practice to inspect the first few rows to ensure that it has been imported correctly:

```
print(df.head())
```

The `head()` method displays the first five rows of the DataFrame.

Data Cleaning

Data cleaning can involve renaming columns for consistency, handling missing values, or converting data types:

```
# Renaming columns
df.rename(columns={'old_name': 'new_name'}, inplace=True)
# Handling missing values
df.fillna(value="Not Available", inplace=True)
# Converting data types
df['column_name'] = df['column_name'].astype('category')
```

Data Transformation

Transforming data may include creating new columns based on existing ones or filtering the data set:

```
# Creating a new column
df['new_column'] = df['column1'] + df['column2']
# Filtering the dataset
filtered_df = df[df['column'] > threshold_value]
```

Data Analysis

Once the data are cleaned and transformed, it can be analysed using various methods provided by Pandas, such as grouping by operations, pivot tables, or applying functions:

```
# Group by operation
grouped_data=df.groupby('category_column').sum()
# Pivot table
pivot=pd.pivot_table(df, values='value_column', index='category_column',columns='header')
# Applying a function
df['new_column']=df['numeric_column'].apply(lambda x: x * 2)
```

Exporting Data

After manipulation, the DataFrame can be exported to a file format of choice, such as CSV, with the following command:

```
df.to_csv('path/to/your/new_data.csv', index=False)
```

The parameter `index=False` is used to indicate that the DataFrame index should not be written to the file.

A.1.1 Sample Python Script for MapReduce

see the Appendix A. To illustrate the concept of MapReduce in the context of smart education data, we provide a sample Python script using the `mrjob` library. This script processes a CSV file to count the occurrences of different subjects:

```
# chMapReduceEducationalAnalysis2_4
from mrjob.job import MRJob
from mrjob.protocol import TextProtocol
import csv
import os
import random

class MREducationalDataAnalysis(MRJob):
    OUTPUT_PROTOCOL = TextProtocol  # Output plain text

    def mapper(self, _, line):
        reader = csv.reader([line])
        for row in reader:
            if len(row) != 3:
                continue  # Skip rows that do not have exactly three columns
            student_id, subject, grade = row
            yield subject, 1

    def reducer(self, subject, counts):
        yield subject, str(sum(counts))

if __name__ == '__main__':
    # Path for the dummy dataset
    input_file = 'dummy_sedata.csv'
    output_file = 'educationalOut2.txt'

    # Create a dummy dataset with random data
    with open(input_file, 'w', newline='') as file:
        writer = csv.writer(file)
        subjects =
        ['Math', 'Science','History','English',
        'Art','Geography','Music','Physics','Chemistry','Biology']
        num_records = 150
        for i in range(num_records):
            student_id = f'S{i:03d}'
            subject = random.choice(subjects)
            grade = str(random.randint(50, 100))  # Grades between 50 and 100
            writer.writerow([student_id, subject, grade])

    print(f"Dummy dataset created with {num_records} records.")

    # Run the job and write output to the specified file
    with open(output_file, 'w') as f:
        job = MREducationalDataAnalysis(args=[input_file])
        with job.make_runner() as runner:
            runner.run()
            for key, value in job.parse_output(runner.cat_output()):
```

```
                f.write(f"{key}\t{value}\n")

    print(f"MapReduce job completed. Output saved to {output_file}.")

# ======= End of File ==========
python chMapReduceEducationalAnalysis2_4.py
```

Visualising the Results

The results of the MapReduce job can be visualised using `matplotlib`:

```
# visualEducationalDataAnalysis4 from Ch This is the random dataset from ch for student subject a
# # Simulated Data for MapReduce Visualisation Filename: chMapReduceEducationalAnalysis2_4_visual
import matplotlib.pyplot as plt

# Assuming the output of the MapReduce job is saved in a file 'educationalOut2.txt'
# with lines formatted as: "subject\tcount"
results = {}
with open('educationalOut2.txt', 'r') as f:
    for line in f:
        parts = line.strip().split('\t')
        if len(parts) == 2:
            subject, count = parts
            results[subject] = int(count)
        else:
            print(f"Skipping malformed line: {line}")

# Plotting the results
subjects = list(results.keys())
counts = list(results.values())

plt.figure(figsize=(10, 6))
plt.bar(subjects, counts, color='skyblue')
plt.xlabel('Subjects')
plt.ylabel('Counts')
plt.title('Subject Counts from Educational Data')
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()

# ======= End of File ==============
```