**Czech University of Life Sciences Prague**

**Faculty of Economics and Management**

**Department of Information Technologies**

# Bachelor Thesis

## The Role of ICT and Big Data in Smart Digital Campus

**Ebru Kader Sagir**

# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

# BACHELOR THESIS ASSIGNMENT

Ebru Kader Sagir

Informatics

Thesis title

**The Role of ICT and Big Data in Smart Digital Campus**

---

**Objectives of thesis**

This thesis aims to identify ICT and big data including their positive and negative effects on a smart digital campus. The thesis will cover the impact on different aspects of life such as the education system, environmental transformation, etc. Consideration will be given to the different aspects.

Partial Objectives:
- Identify the essential elements and the most significant deficiencies in the area of a smart campus and from the user point of view
- Identify a cutting edge smart campus and propose a smart campus framework.

**Methodology**

In the theoretical part, open source public observation data in the AR/VR area will be used for the research methods. Nowadays, absorbent learning provides educators or teachers with a high level of performance, and with a use of technologies and data as never before. Educators can learn data-based information from their students through post-performance, feedback, etc. and these can help them to measure learning and identify areas for improvement. Based on the content in the theoretical part and the results of the practical part conclusions will be formulated.

**The proposed extent of the thesis**

40 – 50 pages of text

**Keywords**

colleges and universities, ICT, big data, smart campus, data integration, IoT

---

**Recommended information sources**

AHMED, Hanan, A.A. RAMADAN, E.H. ELKORDY and Ahmed A. ELNGAR. Introduction to Industrial Internet of Things (IIoT). In: JHA, Sudan, Usman TARIQ, Gyanendra Prasad JOSHI a Vijender Kumar SOLANKI. Industrial Internet of Things [online]. Boca Raton: CRC Press, 2022, 2022-2-28, p. 1-18 [cit. 2022-10-13]. ISBN 9781003102267. Available at: doi:10.1201/9781003102267-1

MISRA, Sudip, Anandarup MUKHERJEE and Arijit ROY. Introduction to IoT [online]. Cambridge University Press, 2021 [cit. 2022-10-13]. ISBN 9781108913560. Available at: doi:10.1017/9781108913560

RAJ, Pethuru and Anupama C. RAMAN. The Internet of Things [online]. Boca Raton: Taylor & Francis, CRC Press: Auerbach Publications, 2017 [cit. 2022-10-13]. ISBN 9781315270395. Available at: doi:10.1201/9781315273095

VENERI, Giacomo and Antonio CAPASSO. Hands-On Industrial Internet of Things. Packt Publishing, 1st edn, 2018.

VERMESAN, Ovidiu. Artificial Intelligence for Digitising Industry [online], River Publishers; 1st edition, 2021, p. 1-541 [cit. 2022-10-13]. Available at: doi:10.13052/rp-9788770226639

---

**Expected date of thesis defence**

2022/23 SS – FEM

**The Bachelor Thesis Supervisor**

Věra Motyčková, MA

**Supervising department**

Department of Information Technologies

Electronic approval: 14. 11. 2022

**doc. Ing. Jiří Vaněk, Ph.D.**

Head of department

Electronic approval: 24. 11. 2022

**doc. Ing. Tomáš Šubrt, Ph.D.**

Dean

Prague on 26. 06. 2023

**Declaration**

I declare that I have worked on my bachelor thesis titled "The Role of ICT and Big Data in Smart Digital Campus" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 30/11/2023 _____

**Acknowledgement**

I would like to thank Motyčková Věra and all other persons, for their advice and support during my work on this thesis.

# The Role of ICT and Big Data in Smart Digital Campus


## Abstract

The use of ICT and big data in higher education has the potential to transform the way we learn and work. A smart digital campus leverages technologies to enhance teaching and learning, improve student outcomes, and support research and innovation. These technologies have the potential to improve the learning experience and make education more accessible to students. A smart digital campus is one that uses ICT and Big Data to optimize various aspects of campus operations, such as student engagement, campus security, and resource allocation. This thesis investigates the role of ICT and big data in developing a smart digital campus, focusing on how these technologies can be used to support the delivery of personalized and adaptive learning experiences. This thesis also aims to identify ICT and big data including their positive and negative effects on a smart digital campus. The thesis will cover the impact on different aspects of life such as the education system, environmental transformation, etc. Consideration will be given to the different aspects. The results of this study will provide a comprehensive understanding of the potential and challenges of ICT and big data in smart digital campuses. The findings will also provide recommendations for higher education institutions on how to effectively leverage these technologies to enhance teaching and learning, improve student outcomes, and support research and innovation



**Keywords:** Colleges and universities, ICT, big data, smart campus, data integration, IoT

# Jakou roli hrajou ICT a big data v chytrých digitálních kampusech

**Abstrakt**

Využití ICT a velkých dat ve vysokoškolském vzdělávání má potenciál změnit způsob, jakým se učíme a pracujeme. Inteligentní digitální kampus je ten, který využívá technologie ke zlepšení výuky a učení, zlepšení výsledků studentů a podpoře výzkumu a inovací. Tyto technologie mají potenciál zlepšit studijní zkušenost a učinit vzdělávání pro studenty dostupnější. Chytrý digitální kampus je takový, který využívá ICT a velká data k optimalizaci různých aspektů provozu kampusu, jako je zapojení studentů, zabezpečení kampusu a alokace zdrojů. Tato práce zkoumá roli ICT a velkých dat při vývoji chytrého digitálního kampusu a zaměřuje se na to, jak lze tyto technologie využít k podpoře poskytování personalizovaných a adaptivních vzdělávacích zkušeností. Tato práce si také klade za cíl identifikovat ICT a velká data včetně jejich pozitivních a negativních dopadů na inteligentní digitální kampus. Práce se bude zabývat dopadem na různé aspekty života, jako je vzdělávací systém, transformace životního prostředí atd. Pozornost bude věnována různým aspektům

**Klíčová slova:** Vysoké školy a univerzity, ICT, velká data, chytrý kampus, datová integrace, IoT

# Table of content

# 1 Introduction

The integration of information and communication technologies (ICT) and big data has transformed many industries and sectors, and education is no exception. Smart digital campuses, which are educational institutions that use technology, data analytics, and other tools to improve the quality and effectiveness of education, have become increasingly prevalent in recent years. The role of ICT and big data in smart digital campuses is multifaceted and complex, with the potential to impact various aspects of the educational experience. By leveraging the power of ICT and big data, educators and education policymakers can gain insights that can inform decisions on how to improve the education system, personalize learning and tailor instruction to individual students' needs, enhance campus security, optimize resource allocation, and much more. However, the integration of ICT and big data in education also bring with it a range of challenges and potential risks, such as cost, accessibility, security concerns, and the potential for disruption to traditional teaching methods. This thesis aims to explore the role of ICT and big data in smart digital campuses, examining the potential benefits and challenges of their integration into education. Through a comprehensive review of the literature and empirical data, this thesis aims to provide a nuanced understanding of the role of ICT and big data in smart digital campuses and offer insights and recommendations for how to effectively leverage their potential in education. The multifaceted and complex role of ICT and big data in smart digital campuses has paved the way for revolutionary changes in the educational landscape. These advancements have the potential to impact every facet of the educational experience, providing educators and education policymakers with invaluable insights to inform decisions on how to improve the education system holistically.

**Significance of the research**

The research holds utmost importance in the modern world as it helps provide improved educational services to the citizens (Sanogo, 2019). It is due to the importance of such services that is considered to be much better than that of traditional campuses. This is because traditional campuses provide educational services in a traditional manner such as books and without electrical services. On the other hand, smart campuses provide educational services with the help of technology which is mostly associated with online mediums. For instance, an E-book is a measure that is used by smart campuses to provide convenient services. Due to this, it is crucial that the students need to connect to a Wi-Fi

network of the campus. This is where the role of the project materialises that is responsible for tracking the location of the students while they use the university's services. The output provided by the project can help provide information regarding the places which are preferred by the students during accessing the services of the campus.

**The rationale of the research**

The primary purpose of the project is to manage the challenges of identifying the preferences of the students (Nikolopoulou, 2022). To be more precise, smart campuses in the modern world provide top-quality services to students to ensure that they can be provided with the best services. For this, such campuses need to know about the preferences of the students in order to ensure that they can be provided with the best services. In this modern world, this issue holds the utmost importance as this can help to identify the preferences of the students within the campus. Due to all this, the research can effectively identify the places the students often like to visit. For instance, the project is to collect the latitude and longitude of the students and compare them with the map of the smart campus. The project is also responsible for collecting the max and mean temperature for the specific time period. Along with this, the project also helps to identify the snow and precipitant value both of which are responsible for helping the project during the winter terms and the temperature of the places in which the project is likely to visit. As a result, it can help the campus to customize the services to the students to improve their overall experience.

**Justification of the research**

The primary purpose of the research can be helpful for identifying the preferences of the students during various semesters. The purpose of this is to improve the services of the campuses so that the students can develop their overall skills. To be more precise, the target population of the project is to provide students with improved services that can be helpful for the development of smart campuses (Sari *et al.,* 2017). As a result, it can help the modern universities of today to improve their service to the students which can be crucial for their career success. However, the campuses can provide them with such services if they understand the preferences of the students so that they can provided with improved services.

# 2 Objectives and Methodology

## 2.1 Objectives

This thesis aims to identify ICT and big data including their positive and negative effects on a smart digital campus. The thesis will cover the impact on different aspects of life such as the education system, environmental transformation, etc. Consideration will be given to the different aspects.

Partial Objectives:

- Identify the essential elements and the most significant deficiencies in the area of a smart campus and from the user point of view
- Identify a cutting-edge smart campus and propose a smart campus framework

## 2.2 Methodology

In the theoretical part, open source public observation data in the AR/VR area will be used for the research methods. Nowadays, absorbent learning provides educators or teachers with a high level of performance, and with a use of technologies and data as never before. Educators can learn data-based information from their students through post-performance, feedback, etc. and these can help them to measure learning and identify areas for improvement. Based on the content in the theoretical part and the results of the practical part conclusions will be formulated.

# 3 Literature Review

## 3.1 Smart Campuses

A smart digital campus is a term used to describe a campus that is equipped with advanced technology and systems to support the learning, research, and operational needs of the campus community.

The notion of Smart Campus has developed much in the modern which is largely due to its importance. The word Smart is a perfect implication of such a measure that is responsible for developing the skills of the students to an extensive margin. It is mostly due to the incorporation of technologies like IoT, AI, ICT and Big Data along with others that are responsible for improving the quality of teaching. For this, it helped to develop the knowledge of the students that helped them to advance their careers. (Muhamad *et al.*, (2017))

Smart campuses refer to the devices, applications, and technologies which are essential to creating new experiences, improving efficiency, and providing advanced applications and services to campus users who are student staff, visitors, and staff performing multiple tasks in campus buildings. The development of a smart campus in general means the achievement of certain objectives, such as providing very high-quality and efficient services, improving environmental sustainability, reducing operation costs, and making communication and education generally easier and better. Smart city campuses are similar to the services provided by smart cities, being adopted to campus needs. ( Ikrissi and Mazri (2020))

integrating the Internet of Things (IoT) is a fundamental aspect of the smart campus and is equipped with the advanced infrastructure to support and enhance the teaching process, research, and student experience. The smart campus is characterised by three approaches, the academic ventures are particularly technology-driven, a unique adoption of the smart city concept, and the implementation of an organisation or business process. Educational institutions are increasingly embracing the idea of a smart campus which aims to increase communication, increase efficiency among students, and focus on advanced learning to provide facilities to students for educational purposes. (Srhir *et al.*, (2023))

### 3.1.1 Advantages of Smart Campus

There are several advantages of Smart campuses and, one of the advantages of Smart Campus is associated with cybersecurity which is considered to be a modern concept. The purpose is associated with the development of security measures that are a crucial factor for maintaining the privacy of the students. On the other hand, the integration of technologies like Big Data along with the concept of ICT is also responsible for reinforcing security so that crucial information of the user cannot be stolen under any circumstances. Adding to this, the interactive learning method provided by Smart Campus is also responsible for improving the knowledge base of the learners and thus affecting their career growth (Sánchez-Torres *et al.*, (2018)),

Students can choose any university while opting to study overseas. The availability of a plethora of devices and the reach of the Internet has made the smart campus a smart choice and application, which required human intervention previously. This article has contended that a smart device supports teaching, scientific exploration, and smart services through the implementation of IoT, cloud computing, and geographic information systems. A smart campus takes advantage of advanced technology implications to improve the performance of processes and activities. A smart campus serves as a major gateway to information for university students, with the help of quality education and improving user experience. ( Cavus *et al*., (2022))

The analysis of classroom teaching quality in colleges and universities is of higher significance to achieve educational goals. Through smart campuses, school education management can be strengthened and the significance of the educational decision-making process can be to improve the efficiency of the decision-making process. With the continuous improvement of information technology, society has an increasing demand for resources in the advancement of education ventures, and the emergence of information platforms for educational institutions has made the development of resource-sharing a positive aspect. The implementation of technology can be made at an advanced process in the development of the reading and writing processes for students (Huang *et al*., (2021))

### 3.1.2 Seatbacks Of Smart Campus

One of the crucial setbacks of Smart Campus is associated with energy consumption which is responsible for threatening the sustainability of the environment. This is mostly due to the usage of technology that is responsible for increasing the power consumption of Smart

Campuses. As a result, the operating cost of managing and maintaining a smart campus is much more than that of traditional campuses. However, this can be improved in the future by using an alternative power supply that can play a crucial role in reducing the overall cost. (Shalaby *et al.,* (2023))

Students face mental health issues while approaching smart education ventures. They are unable to cope with the education reforms which results in suspected depression among the students. They also face anxiety disorders and require consultation with experts on psychological disorders. Smart campuses are unable to provide these facilities to students, which results in major psychological problems. This article has stated the physical problems that are prevalent among students, to which special attention should be paid for detecting psychological issues. Thus, smart campuses are unable to provide the required guidance to students in reforming educational reforms. (Guo *et al*., (2023))

The academic underperformance of the majority of students is associated with their constant inefficient socioeconomic status and low parental involvement. The individual perceptions of students and their attitudes are determined to have insignificant importance, and they are unable to pay extra attention to the activities which need campus expertise. The students are unable to come up with strategies for developing education reforms, and the objective of the development of a culturally modified campus setup can be possible through a positive student setup. (Cue and Taylor (2020)).

### 3.1.3 Frameworks of Smart Campus

A smart campus framework is a structured model or plan that guides the implementation of technology and data analytics within educational institutions to create a technologically advanced and innovative campus environment. There are many frameworks of Smart Campus one of which includes the iCampus framework. This framework consists of six pillars which include iLeaning, iGovernance, iGreen, iHealth, iSocial and iManagement. (Dong *et al.,* (2020)),

All of these are responsible for improving the performance of the students from various perspectives and thus are maintained by the Smart Campuses for the overall development of the students. Another crucial aspect that the framework supports is the integration of technology for which it is considered to be one of the most crucial aspects for any Smart Campus all over the world.

The conceptual framework of a smart campus is identified through society, economy, environment, and governance. Every section is closely aligned with the smart central campus of smart technology and big data. The domains have been investigated further to determine the extent of their advancement in the development of the conceptual framework. The research outcomes have determined the opportunities for the development of a smart campus, where the implementation of technology is an essential aspect of educational ventures. Thus, smart campus solutions are providing opportunities for widespread digital infrastructures, campuses, and smart campus settings. Moreover, community engagement is essential to provide information on revenue generation and expert solutions can be provided in the development of education ventures. (AbuAlnaaj *et al*., (2020))

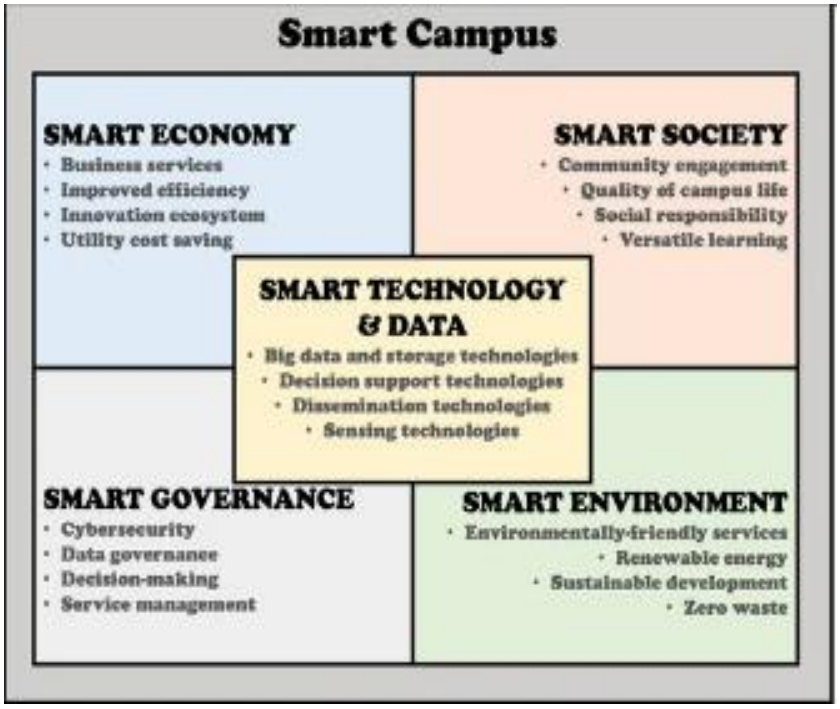


Figure 1: Conceptual framework of smart campus networks

(Source: Polin *et al*., (2023))

The consideration of the integrative nature of smart campus research, many diversified literature reviews have been conducted. The recent emergence and advancement in Information and Communication Technology, Artificial Intelligence (AI), Augmented Reality, and Virtual Reality are essential to pursue higher education and take part in the higher education domain. The potential applications of variable reality technologies to review the potential applications in smart campus aspects. The present progress and the

propositions in the literature review process have been carried out in the construction of smart city campuses. The structure of a typical review of the campus can be presented to provide an advantage to students. (Silva-da-Nóbrega *et al*., (2022)

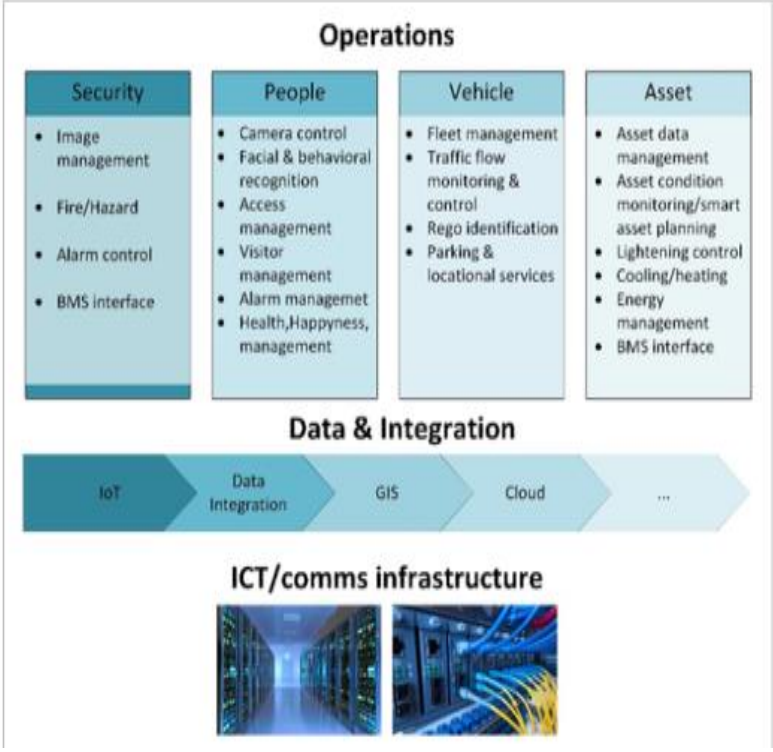


Figure 2: Integration of technology in campus networks

(Dong *et al.*, 2020)

### 3.1.4 Design and Implementation of Smart Campus Framework

The importance of implementing the Smart Campus Framework that is responsible for improving its overall effectiveness. One such technology that can be helpful in this regard is IoT or the Internet of Things. This technology mainly emphasizes interconnectivity and is responsible for holding the elements of a Smart Campus. As a result, it mitigates the communication gap for which it is responsible for increasing the effectiveness of the Smart Campus. It allows the students to communicate with the teacher in a regular manner in order to clarify any doubt which holds utmost importance in the Smart Campuses. (Pan *et al.,* (2015))

The smart adoption of universities into smart campuses has changed realities through education and critical thinking. This process applies to changing the concept of education reforms through possible technological innovations and the adoption of a management model. It can ensure that the development of smart campuses to promote the well-being of

students and ensure financial advancement. Smart Campus is a recent approach, which differs from the standard smart campus dimensions. Providing significant discussions, authorisations, and strategies can be efficient in providing core responsibilities. Thus, the students are provided with facilities in the development of smart education reforms (Silva-da-Nóbrega *et al*., (2022))

About the development of a smart environment in the development of smart campus networks. Moreover, the sources should be presented to provide solutions to the altering student environment, and the issues should be identified easily. The application of the smart blending framework is to provide facilities for the development of a synchronised learning system so that students face no problems in the long run. The integration of advanced technology is essential to maintaining educational reforms and displaying the learning activities of students. The application of synchronised manual learning is essential in the development of learning systems, where students should face no problems in the future (Wahid *et al*., (2021))

## 3.2 Information and Communication technologies (ICT)

### 3.2.1 Overview of ICT

ICT or Information and Communication Technologies are responsible for developing the concept of e-learning. This process is considered to be much better than that of the traditional learning process which is crucial for developing the knowledge of the students. It is largely due to the incorporation of technology that is responsible for affecting the overall learning process of the students. Due to this, educational institutes all over the world are integrating the concept of ICT into their operational capabilities to ensure its overall growth. (Kaware and Sain, (2015))

With the help of ICT distance education has provided an opportunity for teachers to provide virtual education features to students. The implementation of ICT is an essential aspect for teachers to provide opportunities for the development of educational ventures, and ensure that the distance education programmes are applicable. The teachers are identifying the education processes to provide a positive learning experience for students, through technological innovation. Providing real-time interactions for students is essential to come up with advanced features in the development of advanced education features. Moreover,

the students are adopting a gradual interest in virtual education through advanced forms of technology. ( Hassan and Mirza (2020))

ICT (Information and Communication Technology) conducts advanced education reforms, which provides a detailed activity in the identification of challenges and opportunities for further development. Major education institutions are provided with advanced education through the use of ICT. Thus, Research and Development facilities have been essential in the development of education reforms to determine the domain of the activities performed. Thus, the methodological approach is essential for the development of education reforms for students, and the development of a student database can be made possible through the application of ICT efficiently in the long run. (Kunev *et al*., (2020))

### 3.2.2 Advantages of ICT

The benefits of ICT in learning conditions are various as ICT has made learning really captivating and intelligent, permitting understudies to effortlessly get to data and assets more. It has additionally made it more straightforward for teachers and students alike to foster opportunities for growth in their careers, taking special care of their singular requirements and inclinations. Due to ICT, understudies can work together and speak with each other, creating significant social and relational abilities. Besides, ICT has made it feasible for understudies to learn whenever and anyplace, making schooling more open and helpful. Generally speaking, ICT has upset the manner in which we learn and can possibly work on instructive results for understudies all over the planet. (Alruwais *et al.,* (2018))

Students are self-organising education reforms with self-actualisation activities. With its help, teachers are developing guidance reforms for the students, and ensuring that they are adopting significant skills in the long run. Moreover, the development of a positive education environment can be ensured by the students, which can ensure that they are provided with enough assistance in their educational reforms. Significant education reforms have been adopted by students with the help of access to the activities, which has ensured that the drawbacks have been addressed through training facilities provided for education reforms. (Marchenko *et al*., (2021))

Shoraevna *et al*., (2021) have stated that Information and Communication Technology (ICT) has provided advantages in the development of education ventures, and students are acquiring information about the information processes required to provide

training facilities. The development of a potential learning environment is possible in the development of an education and communication channel. The students are addressing the drawbacks and the digital education sources are carried out efficiently to ensure that the students are understanding the education reforms. The education reforms are established and the communication channels are established to provide facilities to students in the development of education reforms.

### 3.2.3 Seatbacks of ICT

The he mishaps of ICT as far as information incorporate issues like the computerized partition, where not every person be it a teacher or student possesses the required knowledge. This can prompt aberrations in training and information procurement. Furthermore, the overreliance on innovation can prompt an absence of decisive reasoning abilities and a propensity to acknowledge data without scrutinizing its legitimacy. Another setback is the potential for data over-burden, where a lot of data can be overpowering and challenging to really process. Lastly, there are worries about protection and security while utilizing ICT, which can think twice about the classification of individual data and lead to wholesale fraud or other destructive results .(Buda, (2020))

The implementation of Information and Communication Technology has been a major source of advantage in the development of education reforms. Moreover, many students are facing problems coping with the present education environment, and student-centred learning cannot provide an advantage for them. Pupils are unable to adopt analytic and learning skills for the development of ideas and they are unable to acquire positive ideas about the development of education reforms. They are unable to gain access to the learning assessment, where the resources can be applicable in the development of academic skills efficiently in the long run. (Ntorukiri *et al*., (2022)),

Many administrations are unable to provide support for successful implementation of ICT for education reforms. The financial ventures are detected to have drawbacks for accessing information in the development of advanced education reforms. Teachers are unable to gain access, which has caused a serious setback in the development of education reforms. Thus, it is not possible to gain access to an improvement in education reforms for students, and the digital skills of teachers have increased with the advent of time. It is not possible for them to gain access to the strategies which are applicable to advanced academic facilities. (Samaila et al., (2021))

### 3.2.4 Understanding the role of ICT in Smart Campus

In the present advanced education environment, the development of Smart Campus has become a positive aspect in the development of education ventures. The financial strategies are efficiently conducted with the implementation of ICT for education reforms, which has ensured that the Smart campus reforms are administered efficiently. Moreover, gaining access to the development of education ventures can be an essential aspect for the students in the long run. It is essential to implement ICT in advanced education reforms to provide a data processing system for students in the development of connected devices for long-term purposes. (Fortes *et al*., (2021))

Essential strategies are implemented in the development of advanced education reforms, where the use of ICT is an essential aspect. The development of Smart Campus facilities can be made possible with the help of a relational sequence in data analysis. Thus, the implementation of ICT is essential in the development of a strategy for the development of study ventures, and the training facilities are efficiently adopted to analyse the obtained data in the long run. The drawbacks should be addressed, and the students should gain information on the action plans implemented in the long run (Pupiales-Chuquin *et al*., (2022))

## 3.3 Big Data

The role of big data is considered to be effective in the accounting segment. It is due to the fact that big data is considered to be a term that is responsible for emphasising processing larger datasets which can continue to grow over time. Adding to this, storing such a dataset is considered to be complex for which the role of big data plays a crucial role. An example of this can be observed in the accounting sector in which larger calculations are considered to be common in which the viability of the big data materializes. (Vasarhelyi *et al.,* (2015))

The new digital technologies have emerged over time and Big Data is one of them. Education institutes are adopting more smarter solutions and the implementation of integrated technology is essential to provide education reforms for the students. Moreover, students are provided with limitless opportunities in the development of smart strategies for long-term purposes. It has been ensured that the connection of smart objects has been ensured through further identification of a structural adoption for long-term purposes. The students should address drawbacks and ensure that the education ventures are applicable for

long-term purposes, with the help of ICT the education ventures can be made possible (Arena and Pau (2020))

The obtaining data in the present day is not a major issue. The efficient use of data can be provided by obtaining information about the education reforms which are applicable for long-term purposes. It is possible that the students are addressing the issues, and acquiring positive information out of the automated algorithms. The advanced data algorithms are acquired efficiently through valuable information extracted for education purposes, where the drawbacks are addressed. Thus, the implementation of big data can be significant for the students in the development of education ventures, and the issues are essentially addressed in the long run. (Ghalehkhondabi *et al*., (2020))

### 3.3.1 Advantages of Big Data

One of the crucial benefits of Big data that has altered independent direction by giving associations incredible assets to investigate enormous and complex informational collections. Benefits of Large Information in navigation incorporate better exactness and speed of direction, expanded productivity in business tasks, recognizable proof of new business valuable open doors, and the capacity to foresee future results. Enormous Information investigation can likewise assist associations with acquiring experiences into client conduct and inclinations, empowering them to offer customized items and administrations. With the right devices and skills, associations can use Large Information to acquire an upper hand and drive development. (Janssen *et al.,* (2017))

Big Data provides innovation capabilities for students in the development of education ventures, and students are coming to know about the strategies which are applicable for long-term purposes. Thus, innovative performance measures are adopted for sustainable innovation, and to ensure that the students are provided with innovative features in their academic facilities. Thus, the students are provided with advantages in their education reforms. With the help of Big Data, students are addressing the education reforms which are essential for sustainable innovation and ensure that the role of innovation can be understood further. (Ramadan et al., (2020))

The relationship between data as an input resource and its business values in digital markets is analysed. Big Data plays a major role in providing an advantage in the development of education ventures for students. It is ensured that the drawbacks are addressed, and the performance management of students can be measured. The rules and

regulations for big data management can be possible in the development of education ventures, and crucial strategies are applicable to the development of essential market ventures. Thus, significant data-sharing aspects can be provided for the students in the development of academic strategies. (Fast *et al*., (2023)).

### 3.3.2 Seatbacks of Big Data

There are a few setbacks of Big Data in lawful viewpoints. One such test is related to information security which is an urgent part of any overall set of laws. The utilization of Huge Information frequently prompts the assortment of touchy data which can be abused in the event that appropriate safety efforts are not taken. One more test is related to the exactness of the information which can prompt wrong choices. Also, the execution of Large Information in overall sets of laws requires a lot of venture which can be quite difficult for little firms. Subsequently, while Enormous Information can possibly alter the overall set of laws, its execution ought to be done cautiously (Devins *et al.,* (2017))

Students may not access Big Data for education purposes in the setting of big data analytics the perspective that the strategies should be applicable for future purposes. At times, students are unable to address academic issues with the help of Big Data, and the students are unable to implement research efforts in their education ventures. At times, it becomes impossible for students to provide facilities for processing academic ventures, where the strategies should be applicable for future purposes. It cannot become possible for students to access education reforms at times, for slow or almost no Internet access. (Vishnu and Rajput (2020))

The implementation of Big Data imposes problems to the education ventures which are held for future purposes. Thus, sustainable education ventures cannot be held. Global education initiatives cannot be provided for the students with the help of Big data analytics if many of them are unable to gain access to the Internet. The education reforms cannot be held at a balance, and potential issues are detected while implementing the strategies in the long run. It is not possible for the students to access Big Data at times, which has imposed issues in their activities. (Kumar *et al*., (2022)).

## 3.4 Understanding the Role of ICT and Big Data

### 3.4.1 The role of ICT in Smart Digital Campus

ICT plays a significant part in creating applications for educational institutes all over the world. These advances are liable for giving different instruments and stages that can be utilized for creating intelligence and connecting with applications for understudies. These applications can be utilized for different purposes like learning, correspondence, joint effort, and appraisal. In addition, ICT gives different improvements, for example, distributed computing, informed decision-making, and enormous information examination that assist in creating smart and customized applications. In general, ICT assumes a fundamental part in creating imaginative and compelling applications for educational institutes that upgrade the growth opportunities of students. For this reason, the implications of ICT hold a crucial advantage in modern educational institutes. As a result, modern educational institutes are integrating ICT into their operational capabilities which is able to develop the careers of the students. (Abuarqoub *et al.,* (2017))

The role of ICT has helped to develop the architecture of smart campuses all over the world. It is due to the ever-growing concept of digitalization that is one of the fields of ICT that is responsible for improving the overall condition of smart campuses all over the world. A critical aspect can be observed due to the incorporation of IoT which is considered to be new in the campuses all over the world. As a result, it is responsible for improving the interconnectivity all over the university which is one of the requirements of the university. It is helpful for the students are employees alike as it allows the problems to be solved with little to no difficulty. (Jurva *et al.,* (2020))

The importance of ICT through the means of energy consumption. To be more precise, ICT can play a fundamental part in lessening energy utilization within the smart campus. By executing brilliant frameworks that can screen and control energy use continuously, for example, attracting lighting and air conditioning frameworks, energy waste can be limited. Also, ICT can empower the upkeep of the technical equipment of the university, further diminishing energy utilization by forestalling hardware glitches. Moreover, cloud-based energy the executive's frameworks can give experiences into energy utilization designs, empowering grounds overseers to come to informed conclusions about energy use. In general, ICT can fundamentally diminish energy utilization within the

university grounds while further developing maintainability and cost viability.( Popoola *et al.,* (2018))

### 3.4.2 Role of Big Data in Smart Digital Campus

Big Data assumes a pivotal part in educational institutes as it helps in the assortment, examination, and translation of a lot of information created by understudies, personnel, and staff. This information can be utilized to distinguish examples, patterns, and bits of knowledge that can be applied to work on hierarchical learning. By utilizing Big Data, Smart Digital Campuses can acquire a superior comprehension of the requirements and inclinations of their understudies, foster customized growth opportunities, and further develop understudy commitment and degrees of consistency. Furthermore, it can assist in the assessment of showing adequacy, educational plan with designing, and the recognizable proof of expertise holes, which are all fundamental for hierarchical learning. (Williamson, (2018))

The role of Big Data is considered to be crucial in developing the learning capabilities of the students. It is due to the incorporation of the e-learning platform that is responsible for recording the progress of the students. As a result, the teachers are able to develop the weak links of the students so that it can lead to overall development. Moreover, the implications of Big data are also responsible for managing huge chunks of data that are a common occurrence in smart campuses. It enables such universities to effectively manage the information of the students and thus is able to provide effective services to them. Furthermore, the role of big data allows for effectively predicting trends which is used by the smart campuses to attract more students. (Cantabella *et al.,* (2019))

The importance of Big data associated with improved performance of the campuses. It can be done by using a strategy that is responsible for improving the conditions. To be more precise, it can be defined as a metric or a blueprint that is helpful for providing a stepwise approach which is crucial for developing such a strategy. For instance, Big Data emphasizes on some crucial measures that include starting with strategy, measuring data, applying analytics and reporting results all of which play a crucial role. As a result, it is responsible for solving any type of query which can be crucial for developing the overall conditions of the university. (Marr, (2015))

### 3.4.3 Theoretical Framework

Information theory is responsible for properly highlighting the research as it is associated with information exchange. This is where the role of Big Data and ICT materializes as it can be helpful for exchanging data in the most convenient manner (Ying and Sayed, (2016)).

In the case of Smart Digital Campus, it can be helpful for ensuring that students and teachers alike can be helpful for exchanging information in a formal manner. As a result, it can help to solve any problem that can be crucial for the successful development of the student in the means of career. Information Theory is the mathematical study of quantification, storage, and communication of facts. The implementation of Big Data and ICT is essential for students to come up with strategies for educational purposes. A few important measures in information theory consist of mutual information, channel distribution and determining channel capacity. It describes the explicit strategies which are applicable for long-term research purposes (Kariapper *et al*., (2020)).

With the help of this theory, students should acquire essential ideas related to the efficient implementation of this theory in their future purposes. The students are detecting the strategies which are applicable for long-term purposes of technical advancement concerning their studies.

# 4 Practical Part

## 4.1 Perspective of Empirical Research

The project is developed by considering the procedures that are usually the measures of systematic observation. In the current project, the empirical research is performed by considering some crucial factors. These include the systematic collection and analysis of the data which in the current scenario is the location of the students within the campus. The next stage of empirical research includes observing and evidence collection which in the current research is performed through the data set. The third stage of empirical research consists of experimenting which is performed by manipulating the data set in order to consume as little memory as possible.

The final stage is associated with observing the environmental data which in the current project is associated with observing with behaviour of the student from their preferred places within the smart campus.

### 4.1.1 Solution Procedure

The main idea of the project is to track the position of the students within a Smart Campus in order to get an understanding of their interests. In order to do so, the students have to be connected to the Wi-Fi of the campus so that their position can be tracked accurately. To be more precise, the project is responsible for tracking the behavior of the students within the campus. It can be identified with the help of a dataset that is considered to be essential in identifying the positions of the students within the campus. Since the data that is required for this research is supposed to be present in bulk, this project has used an existing dataset from a large location of a smart campus, where the radius of the target location has been set to 50 (*Prism data: University of Calgary's Data Repository*). This dataset has been collected from the University of Calgary's, and has been used to assess the location of the students within the campus through the live location of their devices and assess those spots, where the students have spent the most amount of their time. The use of this dataset has allowed this project to broaden its approach and scope of its function. As for the duration of the project, it is to be done for the entire year which can cover the fall and winter semesters alike. The measurement is to be performed with the help of basic data processing that plays a crucial role in identifying the position of the users. It is to be done with the help of latitude and longitude both of which play a crucial role in identifying the

exact position of the students alike. To summarize, the outcome is crucial as it allows the campus to develop its services in order to boost the experience of the students. There are total 80049 data instance in the dataset and total 19 columns, among them 6 columns are of type string, 12 columns are of type double, and only 1 column is of type integer. There is no missing or null or random value in the whole dataset. After some preprocessing we dropped few columns without any dataloss. So finally there was only 8 columns left. After some data visualization we find out that the max temp and mean temp follow a normal distribution pattern, and the duration minutes column has a exponential decrease pattern, where most of the cases lies from 0 to 60 range. Precip and snow also follow this exponential decrease pattern, where most of the cases lies between 0 and 10 degree. In terms of occurance of building name or building id, Outdoor has the maximum footprints and then MSC, MH, ST and so on, but outdoor beat them all with a huge margin. and most of the cases lies in fall term 1, winter term 1, winter term 2 and fall term 2. other don't have much footprint.

| Loct_Start | Loct_End | Academic_Day_Start | Academic_Day_End | Duration_minutes | Building_ID | Building_Name | Lat | Lon | |
|---|---|---|---|---|---|---|---|---|---|
| 10-Sep-2012 1:03:... | 10-Sep-2012 1:27:... | FALL_TERM_1 | FALL_TERM_1 | 24.4666666666667 | Outdoors | Outdoors | 51.0775 | -114.1306 | |
| 17-Sep-2012 10:54... | 17-Sep-2012 11:45... | FALL_TERM_1 | FALL_TERM_1 | 51.6833333333333 | ST | Science Theatres | 51.07933 | -114.1275 | |
| 24-Sep-2012 11:55... | 24-Sep-2012 12:49... | FALL_TERM_1 | FALL_TERM_1 | 54.1 | MFH | Murray Fraser Hall | 51.0768 | -114.1283 | |
| 26-Sep-2012 3:28:... | 26-Sep-2012 5:14:... | FALL_TERM_1 | FALL_TERM_1 | 105.766666666667 | MS | Mathematical Scie... | 51.07999 | -114.1275 | |
| 26-Sep-2012 4:56:... | 26-Sep-2012 5:13:... | FALL_TERM_1 | FALL_TERM_1 | 17.0333333333333 | ST | Science Theatres | 51.07933 | -114.1275 | |
| 10-Oct-2012 9:14:... | 10-Oct-2012 1:02:... | FALL_TERM_1 | FALL_TERM_1 | 228.066666666667 | AD | Administration | 51.07808 | -114.1274 | |
| 10-Oct-2012 10:49... | 10-Oct-2012 10:59... | FALL_TERM_1 | FALL_TERM_1 | 10.0 | MH | MacEwan Hall | 51.07866 | -114.1309 | |
| 10-Oct-2012 2:27:... | 10-Oct-2012 3:34:... | FALL_TERM_1 | FALL_TERM_1 | 66.95 | AD | Administration | 51.07808 | -114.1274 | |
| 10-Oct-2012 5:10:... | 10-Oct-2012 5:26:... | FALL_TERM_1 | FALL_TERM_1 | 16.0166666666667 | AD | Administration | 51.07808 | -114.1274 | |
| 11-Oct-2012 11:52... | 11-Oct-2012 4:49:... | FALL_TERM_1 | FALL_TERM_1 | 297.0 | AD | Administration | 51.07808 | -114.1274 | 3 |
| 12-Oct-2012 12:46... | 12-Oct-2012 2:32:... | FALL_TERM_1 | FALL_TERM_1 | 106.016666666667 | AD | Administration | 51.07808 | -114.1274 | |
| 15-Oct-2012 10:26... | 15-Oct-2012 3:51:... | FALL_TERM_1 | FALL_TERM_1 | 325.016666666667 | AD | Administration | 51.07808 | -114.1274 | |
| 15-Oct-2012 2:58:... | 15-Oct-2012 4:47:... | FALL_TERM_1 | FALL_TERM_1 | 108.95 | MS | Mathematical Scie... | 51.07999 | -114.1275 | |
| 15-Oct-2012 3:22:... | 15-Oct-2012 4:09:... | FALL_TERM_1 | FALL_TERM_1 | 46.6333333333333 | ST | Science Theatres | 51.07974 | -114.1269 | |
| 16-Oct-2012 8:59:... | 16-Oct-2012 11:52... | FALL_TERM_1 | FALL_TERM_1 | 173.7 | AD | Administration | 51.07808 | -114.1274 | |
| 16-Oct-2012 1:06:... | 16-Oct-2012 1:35:... | FALL_TERM_1 | FALL_TERM_1 | 29.0333333333333 | MSC | MacEwan Student C... | 51.07814 | -114.1323 | |
| 16-Oct-2012 1:42:... | 16-Oct-2012 3:18:... | FALL_TERM_1 | FALL_TERM_1 | 95.8 | EEEL | Energy Environmen... | 51.08095 | -114.1297 | |
| 16-Oct-2012 3:33:... | 16-Oct-2012 3:44:... | FALL_TERM_1 | FALL_TERM_1 | 11.0 | MH | MacEwan Hall | 51.07866 | -114.1309 | |
| 16-Oct-2012 3:53:... | 16-Oct-2012 4:40:... | FALL_TERM_1 | FALL_TERM_1 | 46.9 | MSC | MacEwan Student C... | 51.07814 | -114.1323 | |
| 16-Oct-2012 5:34:... | 16-Oct-2012 5:51:... | FALL_TERM_1 | FALL_TERM_1 | 16.8833333333333 | MH | MacEwan Hall | 51.07837 | -114.1305 | |

| Max_Temp_C | Mean_Temp_C | Total_Precip_mm | Snow_cm | Q_Score | T_Score | A_Score | Combined_Score | Centroid_Lat | Centroid_Lon |
|---|---|---|---|---|---|---|---|---|---|
| 21.3 | 13.1 | 0.0 | 0 | 2.484906649788 | 6.193043920506351 | 0.9807692307692311 | 15.09319109702431 | 51.0776251754386 | -114.1302850877193 |
| 24.5 | 14.5 | 0.0 | 0 | 3.931825632724331 | 6.940867630432341 | 0.9833352842730511 | 26.83549648332941 | 51.07932157039087 | -114.1271863369076 |
| 24.9 | 15.7 | 0.0 | 0 | 4.060443010546421 | 6.986566459406431 | 0.9783725076078911 | 27.75501424150581 | 51.07677460784313 | -114.1283460784313 |
| 17.4 | 12.8 | 2.4 | 0 | 4.465908118654581 | 7.656967683475031 | 0.7407407407407411 | 25.32986232733851 | 51.07998052305246 | -114.1277381558028 |
| 17.4 | 12.8 | 2.4 | 0 | 2.890371757896161 | 5.830904482095541 | 0.7142857142857141 | 12.03820117002791 | 51.07932157039087 | -114.1271863369076 |
| 12.8 | 4.899999999999991 | 1.8 | 0 | 4.779123493111531 | 8.425370257429391 | 0.9270363055529291 | 37.32793721037331 | 51.07814845682763 | -114.1272138934117 |
| 12.8 | 4.9 | 1.8 | 0 | 2.39789527279837 | 5.298317366548041 | 0.9580419580419581 | 12.17174120897381 | 51.07843682819383 | -114.1311954185021 |
| 12.8 | 4.9 | 1.8 | 0 | 2.484906649788 | 7.199678345691171 | 0.9532329988851731 | 17.05384222667651 | 51.07814845682763 | -114.1272138934117 |
| 12.8 | 4.9 | 1.8 | 0 | 2.890371757896161 | 5.769362120302181 | 1.0 | 16.67560133359741 | 51.07814845682763 | -114.1272138934117 |
| 3.100000000000001 | -0.2999999999999999 | 2.399999999999999 | 0 | 5.298317366548041 | 8.689466412356691 | 0.9756280756280751 | 44.91746801006951 | 51.07814845682763 | -114.1272138934117 |
| 17.6 | 9.5 | 0.0 | 0 | 4.682131227122221 | 7.659328588010691 | 0.8864883401920441 | 31.79122850976931 | 51.07814845682763 | -114.1272138934117 |
| 19.1 | 13.09999999999991 | 0.0 | 0 | 5.451038453556571 | 8.779608733662013 | 0.7691608858694791 | 36.81049000821531 | 51.07814845682763 | -114.1272138934117 |
| 19.1 | 13.1 | 0.0 | 0 | 4.521788577049041 | 7.686621330494621 | 0.9974916387959871 | 34.67009274440271 | 51.07998052305246 | -114.1277381558028 |
| 19.1 | 13.1 | 0.0 | 0 | 2.890371757896161 | 6.838047866557321 | 1.0 | 19.76450043262941 | 51.07958648979591 | -114.1267142857142 |
| 12.0 | 6.2 | 3.5 | 0 | 3.465735902799731 | 8.153061946801051 | 0.8833610514645 | 24.96056744446691 | 51.07814845682763 | -114.1272138934117 |
| 12.0 | 6.2 | 3.5 | 0 | 3.433987204485151 | 6.364176868744341 | 1.0 | 21.85450193434841 | 51.07815858552632 | -114.1319037828947 |
| 12.0 | 6.2 | 3.5 | 0 | 4.553876891600541 | 7.557994958530811 | 0.9644669899132141 | 33.19519710153331 | 51.08082096899225 | -114.12975 |
| 12.0 | 6.2 | 3.5 | 0 | 2.302585092994051 | 5.393627546352361 | 0.8274725274725271 | 10.27661829472631 | 51.07843682819383 | -114.1311954185021 |
| 12.0 | 6.199999999999991 | 3.5 | 0 | 3.806662489770321 | 6.843749949006221 | 0.9870902759791651 | 25.71552407531291 | 51.07815858552632 | -114.1319037828947 |
| 12.0 | 6.2 | 3.5 | 0 | 2.833213344056221 | 5.822059215580571 | 1.0 | 16.49513585946831 | 51.07846246298124 | -114.1309680651301 |

```
# list down all the column names
df.columns
```

```
['Loct_Start',
 'Loct_End',
 'Academic_Day_Start',
 'Academic_Day_End',
 'Duration_minutes',
 'Building_ID',
 'Building_Name',
 'Lat',
 'Lon',
 'Max_Temp_C',
 'Mean_Temp_C',
 'Total_Precip_mm',
 'Snow_cm',
 'Q_Score',
 'T_Score',
 'A_Score',
 'Combined_Score',
 'Centroid_Lat',
 'Centroid_Lon']
```

Figure 3: Dataset

(source: from the code)

One of the primary aspects of the project can be visualized from the dataset that is responsible for storing the position of the students. It can be reflected in the various columns that are responsible for storing elements including the tracking time, the ID and the name of the building. Moreover, it also helps to store the latitude and longitude of the building along with its temperature.

From the above diagram, it can be observed that various columns of the database are crucial for identifying the outputs. For instance, the students are to be tracked during the duration of an entire year which is denoted via the academic start and end date. The duration minutes define the time frame in which the students are to be tracked. This factor is to be tested for a particular session which depends on the time in which the student is to be connected with the campus Wi-Fi. The latitude and longitude define the exact position of the building in which the student is currently present.

```
# get all unique building ids

building_id = []

for row in df.select('Building_ID').distinct().collect():
  building_id.append(row.Building_ID)

print('\n'.join(building_id))
```

```
TRB
SB
KNB
END
PF
CHC
DC
GL
CHF
TI
OL
RU
VCF
AD
ENB
VCN
YA
MSC
EDC
ENF
CDC
ENA
ENE
```

Figure 4: Building IDs
(source: from the code)

One of the crucial aspects of coding involves the storing of building IDs that are helpful for identifying which buildings are often visited by the student. The 'print' command is helpful for displaying the ID of the building in which the student is currently present. It was initially declared as null which is to be printed via the print function that is to be stored in the dataset.

This is due to the importance of Building IDs that are considered to be the primary key of the dataset. In the current project, each of the building IDs is responsible for denoting each of the buildings. For instance, the ID of 'ST' defines the building with the name of 'Science Theaters' while the ID of 'AD' defines 'Administration' which is crucial for providing accurate outputs.

```
# get all the unique building name
building_name = []

for row in df.select('Building_Name').distinct().collect():
  building_name.append(row.Building_Name)

print('\n'.join(building_name))
```

```
Taylor Family Digital Library
Calgary Centre for Innovative Technology
MacKimmie Block
Engineering Block E
MacKimmie Tower
Mathematical Sciences
Education Classroom Block
Engineering Block B
Cascade Hall
MacEwan Hall
Family Housing Block L
Engineering Block C
Family Housing Block N
Crowsnest Hall
Kinesiology Block B
Engineering Block A
Physical Plant
Scurfield Hall
```

Figure 5: Building names
(source: from the code)

This piece of code is responsible for storing the name of each building which is denoted by the building ID. This piece of code works similarly to that of the code that prints building ID as in this code the initial value of the building name is to be printed with the help of the 'print' command. These two pieces of code are interlinked as each of the building IDs denotes a building name. For instance, the ID 'ST' defines the building name of 'Science Theatres' while the ID 'MFH' defines 'Murray Fraser Hall' along with many others.

The building names are responsible for denoting the names of each of the buildings that are denoted by the building IDs. From this list, the names of the various university buildings can be identified which includes various Engineering Blocks, Cascade and MacEwan Hall along with many others.

```
# let's explore the schema of the dataset
df.printSchema()
```

```
root
 |-- Loct_Start: string (nullable = true)
 |-- Loct_End: string (nullable = true)
 |-- Academic_Day_Start: string (nullable = true)
 |-- Academic_Day_End: string (nullable = true)
 |-- Duration_minutes: double (nullable = true)
 |-- Building_ID: string (nullable = true)
 |-- Building_Name: string (nullable = true)
 |-- Lat: double (nullable = true)
 |-- Lon: double (nullable = true)
 |-- Max_Temp_C: double (nullable = true)
 |-- Mean_Temp_C: double (nullable = true)
 |-- Total_Precip_mm: double (nullable = true)
 |-- Snow_cm: integer (nullable = true)
 |-- Q_Score: double (nullable = true)
 |-- T_Score: double (nullable = true)
 |-- A_Score: double (nullable = true)
 |-- Combined_Score: double (nullable = true)
 |-- Centroid_Lat: double (nullable = true)
 |-- Centroid_Lon: double (nullable = true)
```

Figure 6: Database Schema
(source: from the code)

This table denotes the schema of the schema which is printed with the help of the 'df.printSchema ()' command. This schema defines the datatypes of each of the elements such as string and double. In this regard, the building name and ID are both stored via the string datatype. On the other hand, the latitude and longitude of the buildings are stored with the double datatype as these are decimal datatypes.

From the schema, it can be observed that all the factors that can be of null value that is crucial for the project output. For instance, it may be possible at some time frame that the data of the user could not be tracked at any instance. This highlights that the project can sometimes fail to locate the student within the campus due to network errors or similar issues. For this, such cases of exception handling must be developed prematurely in order to ensure that the coding may not provide some errors.

```
# get all unique values in 'academic day start' column
for row in df.select('Academic_Day_Start').distinct().collect():
  acdm_day_start.append(row.Academic_Day_Start)

print('\n'.join(acdm_day_start))
```

```
# get all unique values in 'academic day end' column
for row in df.select('Academic_Day_End').distinct().collect():
  acdm_day_end.append(row.Academic_Day_End)

print('\n'.join(acdm_day_end))
```

Figure 7: Getting unique values
(source: from the code)

These two pieces of code are responsible for getting the value of academic day start and end values in the column. These two are the ranges during which the position of the students is tracked and printed similarly with the help of print functions.

Such a measure is necessary as it is responsible for reducing the size of the overall dataset that is necessary for reducing load. The main purpose is to commit as less resources in order to ensure that the project can be carried out within the best possible time frame.

```
# checking if building id and building name are alias, so that if they are alias
# then we can ignore one of those and work with only one of them
print('Number of records are same: ', len(building_id) == len(building_name))
```

```
Number of records are same:  True
```

```
# let's check if in all row academic day start and academic day end are same or not
# if it's same then again we can drop one of them without any dataloss to reduce
# the dataframe size for better performance
all(df.withColumn('same', col('Academic_Day_Start') == col('Academic_Day_End')).select('same').collect())
```

```
True
```

Figure 8: Performing comparison
(source: from the code)

It is necessary to maintain the integrity of the dataset so that it cannot contain any redundant data. In the current project, two conditions are set one of which checks if the number of records which consists of building ID and name is true for the current project. Meanwhile, the second condition is responsible for checking the number of rows consisting of academic day start and end which is true otherwise the database can consist of null data.

```
# now we are confirm that academic day start and academic day end happens in same
# term, so it's safe to drop one of them
df = df.drop('Academic_Day_End')
df.show()
```

Figure 8: Dropping table
(source: from the code)

This code highlights a condition that is responsible for negating the presence of any redundancy. For instance, the current code tracks the data of the students of a semester for

which it is likely that the start and end days are the same. Thus, it is needed to delete the end day for which the drop command is used in order to delete the entire column of the end day.

**Description of the environment**

Project environment is considered to be an element through which the project is performed. such an environment consists of both internal and external factors which can directly impact the project positively or negatively. In the case of the current project, one such crucial environment can be considered as a specific campus. However, the scope of the current project is limited which is one of the environmental factors. For instance, its scope is limited to a single campus which is likely to be increased in future projects. The size of the project is another crucial environment in which part of the current project is considered to be small as the project has not been tested in real-life scenarios.

**How the experiment was conducted**

The current project is conducted by considering various aspects which enabled the successful completion of the project. One such measure can be observed from taking consent of some students which is necessary for checking their location in real life. It is necessary as otherwise it can be considered a violation of privacy which could damage be integrity of the project. Another aspect that can be considered is to access the Wi-Fi office smart campus which can cover the entire region. It can ensure that the project can cover all the buildings that are within the Smart campus.

**How data were analyzed**

Data analysis assumes an urgent part in any venture as it assists with settling on informed choices in view of realities. It includes gathering, cleaning, changing, and displaying information to uncover examples, patterns, and experiences that can be utilized to drive business development and further develop execution. By examining information, project administrators can distinguish expected gambles, track progress, and enhance cycles to accomplish wanted results. It likewise assists in recognizing regions for development and distinguishing key execution markers that can be a success factor for the project. In the case of the current project, the data is analysed with the help of the data set that consists of all the outputs necessary for the project. This includes the terms in which the project is conducted along with the latitude and longitude of each of the buildings, max and mean temperature and precip and snow values. To summarize, all these factors are responsible for allowing the researcher to properly analyse the data in order to get accurate output.

# 5 Results and Discussion

This chapter of the research highlights the results that are gained from the coding that is performed in the previous chapter. All of the outputs are highlighted with the help of diagrams that help understand the students' position within the Smart Campus. For instance, the diagrams depict the places which are most and least preferred by the students. This test is to be performed throughout the year which involves the fall and winter semesters. On the other hand, the results also discuss the temperatures in certain areas that are most and least preferred by the students. This is denoted by max and mean which is preferred by the students in order to identify their behaviour in a proper manner. Another aspect of the results includes the latitude and longitude of the buildings on the campus. It is to identify the exact location of the students who are responsible for understanding which building they prefer within the smart campus. To summarise, the results are helpful for identifying the preferences of the students as long as they are connected to the campus Wi-Fi.

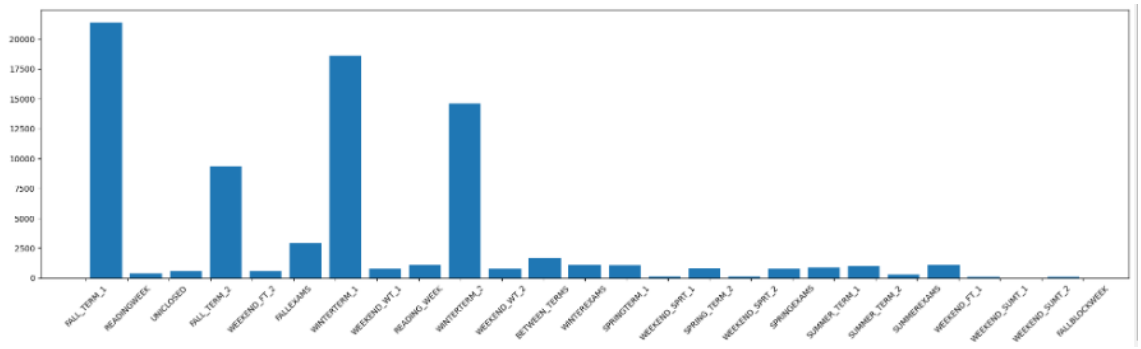


Figure 9: Tracking the students
(source: from the code)

The aforementioned figure is responsible for highlighting the position of the students within the various semesters. In the current project, it can be observed that it is helpful for identifying the number of time units during which the students visited various buildings within the Smart Campus. From the diagram, it can be depicted that during the Fall term 1, the students have been tracked for the most amount of time. This decreased by a marginal margin over the course of the semester which is also the same during the Winter terms. This value has almost dropped to null during the semester breaks due to the holiday of the students.

From the above diagram, it can be observed that during the semester the number of tests that are performed is more than 10 thousand. This is due to the increased presence of the students during that timeframe which can be reflected in the above-mentioned graph.

Another crucial aspect that can be observed from the diagram is that during the first term be it fall or winter term the students visited the campus more often. On the other hand, during the second term be it fall or winter terms the presence of the students decreased by a significant margin. Moreover, during the semester breaks the number of students has decreased by a significant margin. For this, the tests that are performed provided almost null values due to this negative presence of the students.

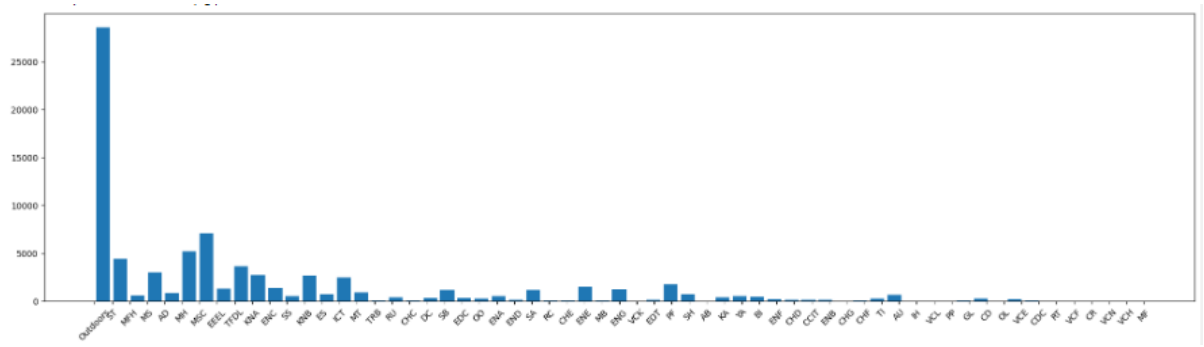


Figure 10: Duration of tracking
(source: from the code)

This table highlights the duration in which the students are being tracked constantly about their position in the Smart Campus. It can be reflected in the table which depicts that in more than 40 thousand cases the student is tracked for about an hour. This is largely associated with the sessions during which the students stay connected with the Wi-Fi of the smart campus.

The value of this table has decreased significantly over the course of time which depicts that the students do not stay connected for long periods of time. For instance, a student generally stays connected for an hour or two for which the value around these two sections is considered to be high. Contrary to this, the value of the table went to null for a significant portion of the time as students did not stay connected for that time period. From the above test, it can be observed that the shorter the duration time the more tests are performed. These are known as sessions during which the students stay connected with the Wi-Fi of the campus. The purpose is to identify how long the students stay connected with the campus network for a certain time period. From the diagram, it can be observed that the

students stay connected for about an hour with the university network. Moreover, as the time frame passed the students became less engaged with the campus network. For instance, it can be observed that within the 895th minute, the least number of the students stay connected with the university Wi-Fi. From this point on no students stay connected with the university network which can be reflected from the flat curve of the diagram that stayed 0 from this point on.

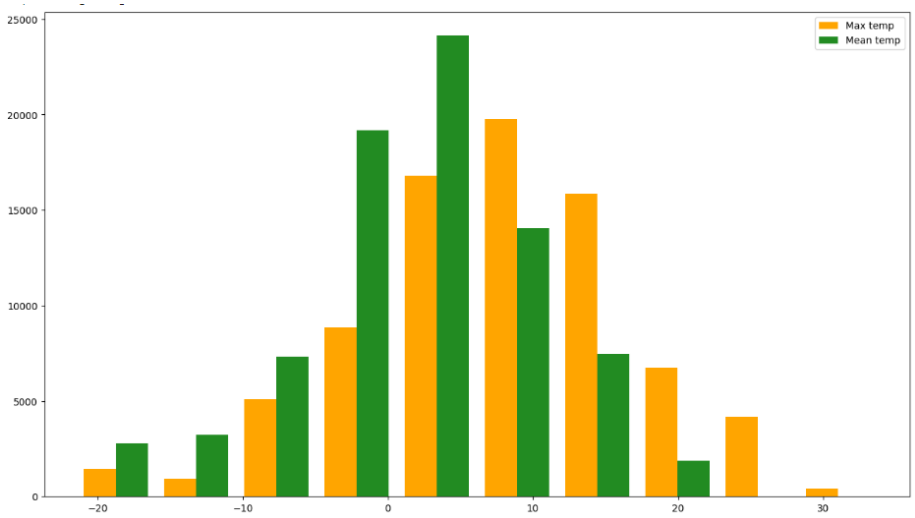


Figure 11: Max and Mean temperature
(source: from the code)

The dataset also consists of time that is responsible for depicting the temperature for a certain time period. From the table, it can be observed that students prefer those zones of smart campus which consist of marginal temperature. This ranges from about 0 to 10 for which the value of these sections is considered to be high. On the other hand, students usually avoid those zones that have lower or higher than usual temperatures.

From the diagram, it can be depicted that the students of the university prefer those areas which have about 0 to 10 degrees of temperature. To be more precise, it can be observed that more than 10 thousand students prefer this climate which is due to their behavioral aspects. In addition to this, it can also be augmented that these areas are within the campus premises which highlights that the students prefer some places. On the other hand, it can be stated that in some areas the temperatures are very cold or very hot. For this reason, the students usually avoid those places as those places come from harsh max and mean temperatures.

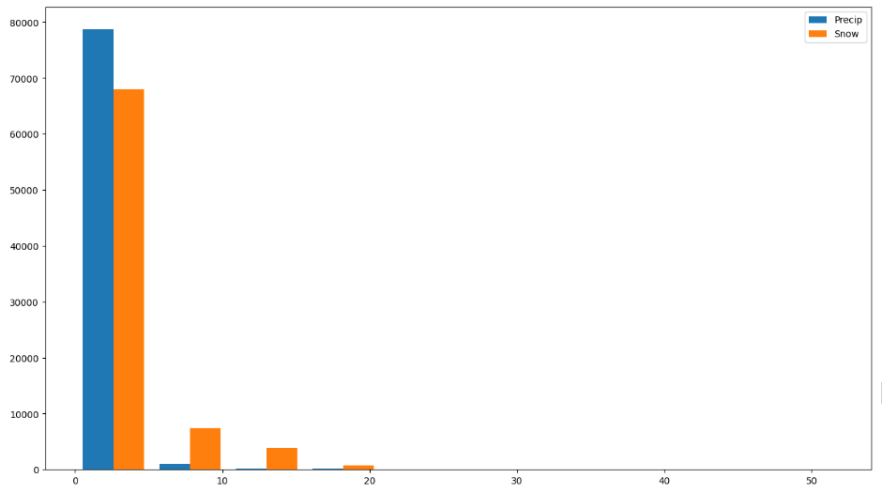


Figure 12: Precip and Snow value
(source: from the code)

This table is responsible for depicting the precip and snow values that are responsible for highlighting the position of the students within the university. From the table, it can be observed that both of these values are considered to be high when the values of both factors are nearly equal to zero. This value has degraded over the course of time and is responsible for identifying the notion that students are not being tracked for that much time period.

From the above diagram, it can be depicted that whenever the value of snow and precip is 0 provides the highest amount of value. It implies that the test was performed during the winter semester when there was snow. During that time period, about 80 thousand tests were performed which highlights that during the winter season, the students were much more engaged with the campus network. On the other hand, during the fall season, the number of tests is significantly lesser which highlights that during that time period, the students were less engaged with the university network. To summarize, the students prefer to be active during the winter season to that of the fall semester which highlights their interest.

The following diagram presents the importance of snow and precipitation in the student semester. An average value has been estimated in this matter and the tests have been performed during the winter season. A few of the places on the campus are highly preferred by the students for a higher internet connection, and they can implement the Wi-Fi services for constructive purposes. The student preferences are measured with the university, which has been measured through the duration of the activities carried out. Measuring the average

precipitation value can be carried out by the range of activities in which the students are engaged, and the strategies are applicable for long-term purposes. It is possible that the longitude with the duration of precipitation and snowfall can be measured through the action plans carried out for future purposes.

The students are measuring the range of latitude and longitude which are applicable in the long run. The preferences of students are considered, and the duration of their activities can be measured by the range of activities which are carried out for long-term purposes. The students are detecting their preferences when it comes to attaining the education sites, which can be ensured through the survey conducted.

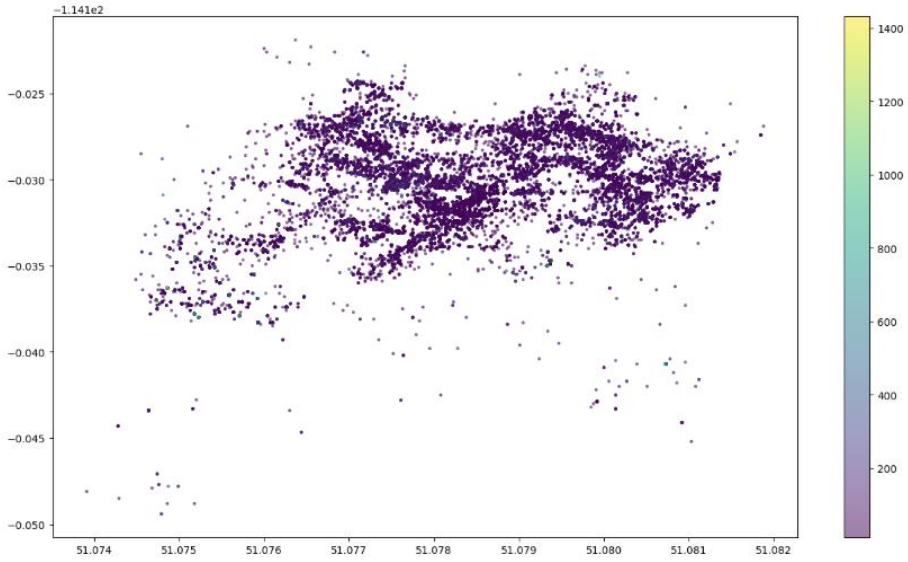


Figure 13: Longitude with duration
(source: from the code)

This diagram depicts the longitude of the places which the students visit more often while they stay connected to the Wi-Fi of the university. From this diagram, it can be observed that some of the places on the campus are preferred by the students. On the other hand, in other areas, the students do not prefer to go which is due to their personal preference. In any case, the table is responsible for highlighting the preferences of the students within the university which is measured by their duration.

The diagram has carried out a significant survey of the snow and precipitation values, having standard figures. Potential tests have been measured, which have provided crucial information on the precipitation value which is measured for research purposes.

The strategies are detected to provide essential information about the internet services, which can be provided to determine student preferences. The places which the students do not visit are as per the action plans carried out for future purposes.The drawbacks are measured as per the student preferences, where the strategies are applicable to measure the strategies for the duration of their studies.

The student preferences are considered concerning the duration of the activities carried out to determine the range of activities which the students can carry out in the long run. The strategies are applicable for measuring the range of snow and precipitation in the places, where the plans are essential to measure the range of activities in the long run.

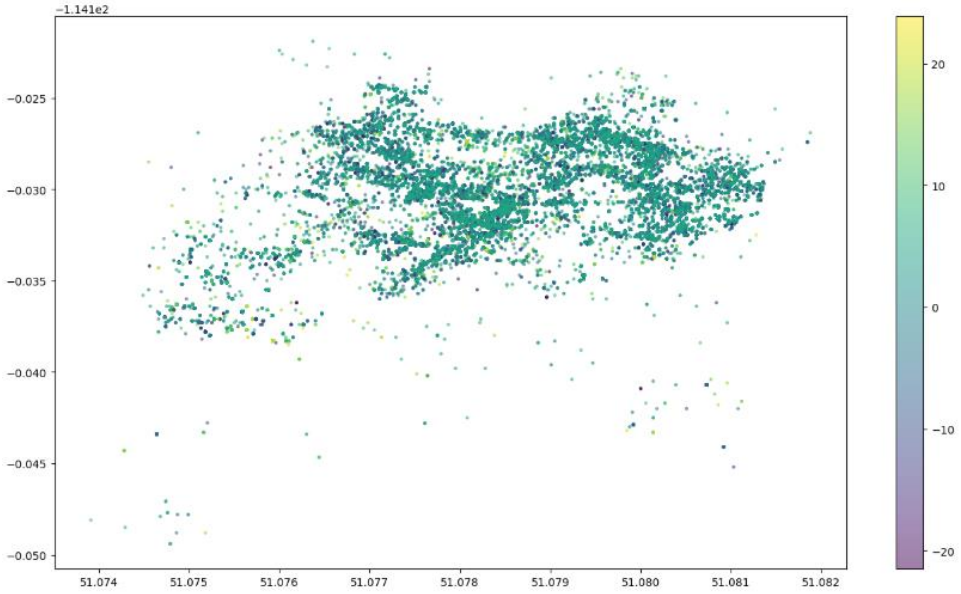


Figure 14: Longitude with mean temperature
(source: from the code)

This diagram highlights the longitudes of the buildings that the students visit more often while considering the mean temperature.The purpose is to identify the places which are preferred by the students in the context of mean temperature. From the table, it can be stated that the student usually prefers some places which consider the parameter of mean temperature.

On the other hand, it can be observed that in some other places, the students do not prefer places which may be due to the mean temperature of the location. For instance, the mean temperature of some places is considered to be marginal for the students. Contrary to

this, the mean temperature of some other places is considered to be high or low for which those locations generally are not preferred by the students which justifies their low presence.

The longitude of the building locations can be addressed, and a comparison can be carried out in the winter season in comparison to the fall season. The buildings for the winter season can be measured through the development of strategies for the future preferences of students.Their behaviour can be measured through the development of strategies for differentiating between winter and fall seasons.

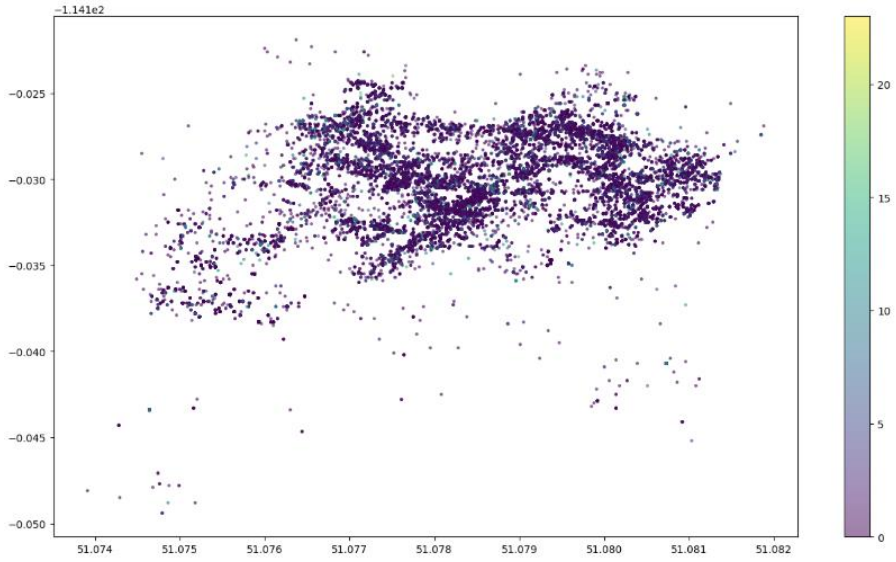


Figure 15: Longitude with snow
(source: from the code)

This chart also highlights one of the crucial aspects of the project which depicts the longitude of the building locations along with the snow value.

From the dataset, it can be observed that the snow value for the time is considered to be 0 as the test is not performed in the fall of the semester when there is no snow. In order to ensure that this plays a valuable role, it had to be performed during the winter semester.

The purpose is to identify the interests of the students and which buildings they prefer during the winter semester. It distinguishes the behaviour of the students which is likely to be different in the winter semester when compared to the fall semester. In any case, the purpose is to ensure that the position of the students can be tracked throughout the year which can be denoted by the value of snow.

The student behaviour has been distinguished, which has measured the range of activities measured in the strategies carried out. The action plans are measured as per the

strategies carried out for long-term purposes, which have determined the action plans carried out or differentiating between the two seasons. Student behaviour is an essential aspect of a range of activities which are provided with facilities in the measurement of activities to address the drawbacks which are imposing drawbacks. Moreover, the strategies are applicable in the development of strategies for student participation.

# 6 Conclusion

The case study examining the impact of the smart campus initiative at the University of Calgary’s, has provided valuable insights into the perceptions and experiences of students in this transformative educational environment. Through the application of the dataset that this study has collected from the University of Calgary’s, the use of this bulk data was quite helpful for this research to increase the accuracy and reach of the program for this project as much as possible. Therefore, it could be stated that this was very helpful in making this project as effective and efficient as possible. The findings that have been collected through the bulk information related to the live locations of the study was also used in improving the learning capacity of the program in the process as well.

The findings shed light on the positive impact of technology integration while also revealing areas for improvement, underscoring the importance of considering students' perspectives in the development of smart campus initiatives.This particular bulk data used for the findings of this project was the base of the conclusion that was developed in this research. Notably, the integration of technology, with the use of bulk data has improved access to educational resources, enabling seamless collaboration with peers and faculty members. The creation of interactive learning spaces equipped with cutting-edge technology has led to increased engagement and deeper understanding of course materials, positively influencing students' academic performance. Students' favourable views also highlight the effectiveness of data-driven decision-making, contributing to a more efficient and adaptive campus environment. The reliability of the Wi-Fi network for tracking the live location of students emerged as a concern for a subset of students, impacting their ability to complete coursework and engage effectively with digital resources. Additionally, the fast-paced academic environment resulting from technology integration raised concerns among some students, necessitating a careful balance between academic expectations and leveraging technology's benefits.

These challenges indicate the need for ongoing monitoring and improvement to ensure the seamless integration of technology and its positive impact on students' academic journeys.

The case study's findings within the University of Calgary emphasise the significance of adopting an inclusive and student-centric approach in shaping the smart

campus initiative. Engaging students as active stakeholders in the decision-making process is crucial to tailor technological implementations to their needs and expectations. Initiatives to increase awareness and education about data-driven decision-making can bridge knowledge gaps and foster student empowerment.

Addressing concerns and collaborating with students to refine technological interventions will result in an environment that aligns more closely with their requirements and preferences.

**Recommendations**

The project has its merits in that it is responsible for tracking the location of the students within the smart campus. However, the students have to stay connected with the campus network which is the primary condition. This can also be considered as a major setback of the project as it is not necessary for a student to desire to connect with the campus network. For instance, a student can connect with the help of cellular data in which tracking them cannot be made possible. It is due to the fact that it is their private network which is not a part of the campus network. Adding to this, in the modern era the usage of cellular data is considered to be common and thus is comparable to the Wi-Fi network. As a result, these students are being omitted and their presence is not being tracked within the campus premises. The inclusion of these students can play a vital role as tracking their preferences can help to properly evaluate the condition of all the students within the smart campus.

**Future Scope**

The effectiveness of the project is currently limited to the smart campus which can be expanded into the future to other broader areas. For instance, the current project can be expanded into other areas such as within a city. However, the achievement of this can be considered to be complex as it is associated with various Wi-Fi networks that are spread throughout the city.

However, the required cost is also considered to be high as an entire city needed to be covered which included numerous Wi-Fi networks. It is largely due to the complexity of Wi-Fi network increments as a bigger number of Wi-Fi organizations, the exactness of following declines, and it becomes complex to track the students due to the privacy policies that are set up by such organizations. Aside from this, the consideration of labor requirements can also be tricky due to various demands by means of cell information. As cell network use is turning out to be progressively normal, it is tantamount to Wi-Fi network utilization. This

implies that a critical number of understudies are being discarded, and their presence isn't being followed inside the ground’s premises.

To address these difficulties, it is important to foster high-level global frameworks which must be included in the planning process that can precisely help to mitigate such challenges that are considered to be complex and help to develop with a bigger number of Wi-Fi organizations.

# 7 References


AbuAlnaaj, K., Ahmed, V. and Saboor, S., 2020, March. A strategic framework for smart campus. In Proceedings of the International Conference on Industrial Engineering and Operations Management (Vol. 22, p p. 790-798).

Abuarqoub, A., Abusaimeh, H., Hammoudeh, M., Uliyan, D., Abu-Hashem, M.A., Murad, S., Al-Jarrah, M. & Al-Fayez, F., (2017), July. A survey on internet of things enabled smart campus applications. In *Proceedings of the International Conference on Future Networks and Distributed Systems* (pp. 1-7).

Alruwais, N., Wills, G. & Wald, M., (2018). Advantages and challenges of using e-assessment. *International Journal of Information and Education Technology*, *8*(1), pp.34-37.

Arena, F. and Pau, G., 2020. An overview of big data analysis. *Bulletin of Electrical Engineering and Informatics*, *9*(4), pp.1646-1653.

Buda, A., (2020). Stumbling blocks and barriers to the use of ICT in schools: A case study of a Hungarian town. *Informatics in Education-An International Journal*, *19*(2), pp.159-180.

Camacho, J., McDonald, C., Peterson, R., Zhou, X. and Kotz, D., 2020. Longitudinal analysis of a campus Wi-Fi network. *Computer Networks*, *170*, p.107103.

Cantabella, M., Martínez-España, R., Ayuso, B., Yáñez, J.A. and Muñoz, A., 2019. Analysis of student behavior in learning management systems through a Big Data framework. *Future Generation Computer Systems*, *90*, pp.262-272.

Cavus, N., Mrwebi, S.E., Ibrahim, I., Modupeola, T. and Reeves, A.Y., 2022. Internet of Things and Its Applications to Smart Campus: A Systematic Literature Review. *International Journal of Interactive Mobile Technologies*, *17*(23).

Cue, E.N. and Taylor, A.Z., 2020. Modifying harmful beliefs about academic setbacks: An attribution retraining intervention for African-American middle school students at risk for academic failure. *Journal of Education and Development*, *4*(3), p.30.

Devins, C., Felin, T., Kauffman, S. & Koppl, R., (2017). The law and big data. *Cornell JL & Public Policy*, *27*, p.357.

Dong, Z.Y., Zhang, Y., Yip, C., Swift, S. & Beswick, K., (2020). Smart campus: definition, framework, technologies, and services. *IET Smart Cities*, *2*(1), pp.43-54.

Dong, Z.Y., Zhang, Y., Yip, C., Swift, S. and Beswick, K., 2020. Smart campus: definition, framework, technologies, and services. *IET Smart Cities*, *2*(1), pp.43-54.

Fast, V., Schnurr, D. and Wohlfarth, M., 2023. Regulation of data-driven market power in the digital economy: Business value creation and competitive advantages from big data. *Journal of Information Technology*, *38*(2), pp.202-229.

Fortes, S., Hidalgo-Triana, N., Sánchez-la-Chica, J.M., García-Ceballos, M.L., Cantizani-Estepa, J., Pérez-Latorre, A.V., Baena, E., Pineda, A., Barrios-Corpa, J. and García-Marín, A., 2021. Smart Tree: An architectural, greening and ICT multidisciplinary approach to smart campus environments. *Sensors*, *21*(21), p.7202.

Ghalehkhondabi, I., Ahmadi, E. and Maihami, R., 2020. An overview of big data analytics application in supply chain management published in 2010-2019. *Production*, *30*, p.e20190140.

Guo, R., Cui, B. and Du, Y., 2023, October. Research on Mental Health Investigation and Early Warning of College Students Based on Smart Campus. In *2023 4th International Conference on Big Data and Social Sciences (ICBDSS 2023)* (pp. 104-116). Atlantis Press.

Hassan, M.M. and Mirza, T., 2020. Information and communication technology (ICT) in the distance education system: An overview. *IOSR Journal of Research & Method in Education (IOSR-JRME)*, *10*(6), pp.38-42.

Huang, X., Huang, X. and Wang, X., 2021. Construction of the teaching quality monitoring system of physical education courses in colleges and universities based on the construction of smart campus with artificial intelligence. *Mathematical Problems in Engineering*, *2021*, pp.1-11.

Ikrissi, G. and Mazri, T., 2020. A study of smart campus environment and its security attacks. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *44*, pp.255-261.

Janssen, M., Van Der Voort, H. & Wahyudi, A., (2017). Factors influencing big data decision-making quality. *Journal of business research*, *70*, pp.338-345.

Jurva, R., Matinmikko-Blue, M., Niemelä, V. and Nenonen, S., 2020. Architecture and operational model for smart campus digital infrastructure. *Wireless Personal Communications*, *113*, pp.1437-1454.

Kariapper, R.K.A.R., Nafrees, A.C.M., Razeeth, M.S. and Pirapuraj, P., 2020. Emerging smart university using various technologies: a survey analysis. *Test Eng. Manage*, *82*, pp.17713-17723.

Kaware, S.S. & Sain, S.K., (2015). ICT application in education: an overview. *International Journal of Multidisciplinary Approach & Studies*, *2*(1), pp.25-32.

Kumar, S., Sharma, D., Rao, S., Lim, W.M. and Mangla, S.K., 2022. Past, present, and future of sustainable finance: insights from big data analytics through machine learning of scholarly research. *Annals of Operations Research*, pp.1-44.

Kunev, S., Fleaca, B., Antonova, D. and Dráb, R., 2020, November. Fostering the innovative university student-centred learning by application of ICT tools together with stakeholders: a project methodology overview. In *2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE)* (pp. 1-4). IEEE.

Link, S. and Prade, H., 2016, October. Relational database schema design for uncertain data. In *Proceedings of the 25th ACM International on Conference on Information and Knowledge Management* (pp. 1211-1220).

Marchenko, G., Murzina, S., Timofeev, S. and Vodopyanova, K., 2021. Digitalization of education: advantages and problems. In *E3S Web of Conferences* (Vol. 273). EDP Sciences.

Marr, B., 2015. *Big Data: Using SMART big data, analytics and metrics to make better decisions and improve performance*. John Wiley & Sons.

Muhamad, W., Kurniawan, N.B. & Yazid, S., (2017), October. Smart campus features, technologies, and applications: A systematic literature review. In *2017 International conference on information technology systems and innovation (ICITSI)* (pp. 384-391). IEEE.

Nikolopoulou, K., 2022. Face-to-face, online and hybrid education: University students' opinions and preferences. *Journal of Digital Educational Technology*, *2*(2), p.ep2206.

Ntorukiri, T.B., Kirugua, J.M. and Kirimi, F., 2022. Policy and infrastructure challenges influencing ICT implementation in universities: a literature review. *Discover Education*, *1*(1), p.19.

Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A. & Sha, M., (2015). An internet of things framework for smart energy in buildings: designs, prototype, and experiments. *IEEE internet of things journal*, *2*(6), pp.527-537.

Polin, K., Yigitcanlar, T., Limb, M. and Washington, T., 2023. The Making of Smart Campus: A Review and Conceptual Framework. *Buildings*, *13*(4), p.891.

Popoola, S.I., Atayero, A.A., Okanlawon, T.T., Omopariola, B.I. and Takpor, O.A., 2018. Smart campus: data on energy consumption in an ICT-driven university. *Data in brief*, *16*, pp.780-793.

Pupiales-Chuquin, S.A., Tenesaca-Luna, G.A. and Mora-Arciniegas, M.B., 2022. Proposal of a Methodology for the Implementation of a Smart Campus. In Proceedings of Sixth

International Congress on Information and Communication Technology: ICICT 2021, London, Volume 2 (pp. 589-602). Springer Singapore.

Ramadan, M., Shuqqo, H., Qtaishat, L., Asmar, H. and Salah, B., 2020. Sustainable competitive advantage driven by big data analytics and innovation. *Applied Sciences*, *10*(19), p.6784.

Samaila, K., Dauda, S., Aliyu, M. and Aliero, A.A., 2021. Application of ICTs and educational software in teaching physics: advantages, challenges and proposed solutions. *Int J Res Rev*, *8*(1), pp.293-304.

Sánchez-Torres, B., Rodríguez-Rodríguez, J.A., Rico-Bautista, D.W. & Guerrero, C.D., (2018). Smart Campus: Trends in cybersecurity and future development. *Revista Facultad de Ingeniería*, *27*(47), pp.104-112.

Sanogo, T., 2019. Does fiscal decentralization enhance citizens' access to public services and reduce poverty? Evidence from Côte d'Ivoire municipalities in a conflict setting. *World development*, *113*, pp.204-221.

Sari, M.W., Ciptadi, P.W. and Hardyanto, R.H., 2017, April. Study of smart campus development using internet of things technology. In *IOP Conference Series: Materials Science and Engineering* (Vol. 190, No. 1, p. 012032). IOP Publishing.

Shalaby, A.M., Sidhu, M.S., Tan, W.C., Wei, L.Z., Yong, C.J. & Xi, L.Y., (2023). Optimized Smart Energy Management System for Campus Buildings: A Conceptual Model. *International Journal of Application on Sciences, Technology and Engineering*, *1*(1), pp.382-292.

Shoraevna, Z., Eleupanovna, Z., Tashkenbaevna, S., Zulkarnayeva, Z., Anatolevna, L. and Nurlanbekovna, U., 2021. Teachers' views on the use of Information and Communication Technologies (ICT) in education environments. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(3), pp.261-273.

Silva-da-Nóbrega, P.I., Chim-Miki, A.F. and Castillo-Palacio, M., 2022. A Smart Campus Framework: Challenges and Opportunities for Education Based on the Sustainable Development Goals. *Sustainability*, *14*(15), p.9640.

Silva-da-Nóbrega, P.I., Chim-Miki, A.F. and Castillo-Palacio, M., 2022. A Smart Campus Framework: Challenges and Opportunities for Education Based on the Sustainable Development Goals. *Sustainability*, *14*(15), p.9640.

Srhir, A., Mazri, T. and Benbrahim, M., 2023. Towards secure smart campus: security requirements, attacks and counter measures. *Indonesian Journal of Electrical Engineering and Computer Science*, *32*(2), pp.900-914.

Vasarhelyi, M.A., Kogan, A. & Tuttle, B.M., (2015). Big data in accounting: An overview. *Accounting Horizons*, *29*(2), pp.381-396.

Vishnu, V.K. and Rajput, D.S., 2020. A review on the significance of machine learning for data analysis in big data. *Jordanian Journal of Computers and Information Technology*, *6*(1).

Wahid, A., Luhriyani, S., Parenreng, J.M. and Nur, M.I., 2021, November. Smart Campus Framework: A Solution for New Normal Education System. In *2021 IEEE 5th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE)* (pp. 266-271). IEEE.

Williamson, B., (2018). The hidden architecture of higher education: building a big data infrastructure for the 'smarter university'. *International Journal of Educational Technology in Higher Education*, *15*(1), pp.1-26.

Yin, S. and Kaynak, O., 2015. Big data for modern industry: challenges and trends [point of view]. *Proceedings of the IEEE*, *103*(2), pp.143-146.

Ying, B. & Sayed, A.H., (2016). Information exchange and learning dynamics over weakly connected adaptive networks. *IEEE Transactions on information Theory*, *62*(3), pp.1396-1414.

*Prism data: University of Calgary's Data Repository* (2023) *RestPoints_2019Feb27(Radius 50, Cutoff 50, MinDuration 10, MaxDuration 1440)_ANON.tab - PRISM Data: University of Calgary's Data Repository*. Available at: https://borealisdata.ca/file.xhtml?fileId=77524&version=1.0 (Accessed: 29 November 2023).

# 8 List of pictures, tables, graphs and abbreviations

## 8.1 List of pictures



## 8.2 List of abbreviations

- ICT: Information and communication technologies
- IoT: Internet of things
- AI: Arrtifical intelligence