COVER

A review of Control Room system in AEC Industry

# Abstract **(Most important part)**

NASA Control Room concept is an innovation strategy in Construction under the digital transformation strategy of smart city paradigm. By utilizing the NASA Control Room concept in Construction Industry, a remote working platform can be provided to enhance the collaboration between different stakeholders, managed the data effectively and provided insight to managers to set-up strategies and policy to enhance the construction safety during different stages of a construction project.

Model/Construction quality data….

To achieve the most understandable and accurate display of information, a study on the available techniques of data visualization for real-time information must be made. Customizing existing platforms and designing specific boards, are among the important task to perform an accurate visualization of the information. In this paper, we conduct a literature review of data visualization, its techniques and existing dashboard platforms. We implemented a generic and dynamic dashboard based on real-time information with the aim to assess the impact of the available Data Visualization Techniques in the developed dashboard. Therefore, our Dashboard users will be able to interact with the information, based on an initial set of hints, charts, tables and reports, produced by the Dashboard itself. This will allow us to test an existing set of data visualization techniques and create a new tailored dashboard, showing that dashboards can become a unique and powerful means to provide information.

With the emerging technology IoT (Internet-of-Things), the sensory data of the environment can be captured for making effective decision. The sensor data is collected from xx-July-2020 to xx-Aug-2020 in a local factory in Hong Kong to demonstrate the entire control room concept.

This dissertation researches different ways to visualise the data, which can act as a prototype to show how different parties in the AEC industry to make decisions in an innovative way.

It shows that the BIM360 working platform and web viewer can demonstrate the real time environment and collaboration of the site in a simple way. The VR Viewer can let us identify the site constraint remotely. And the power BI dashboard can provide insight from the construction quality and safety data.

The potential development of the control room can be much further investigated.

This study reviews the functionality of a Control Room in AEC industry during the construction stage and highlights limits and requirements, paving the way to the concept of a Construction Digital Twin. A definition of such a concept is then given, described in terms of underpinning research themes, while elaborating on areas for future research.

Declaration

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Abbreviation

Acknowledgement (to different Autodesk service provider)

# Introduction

# Overview of Construction Sector

Construction sector is one of the largest sectors in the global economy. There is about $10 trillion spent on construction-related activities over the world annually, which is equivalent to 13 percent of GDP. There is also 7 percent of working population around the world working for this industry (McKinsey & Company, 2017). However, the productivity of construction sector is lagging the global productivity by over 30% and 98% of infrastructure projects are over budget or delayed around the world (Changali et al., 2015).

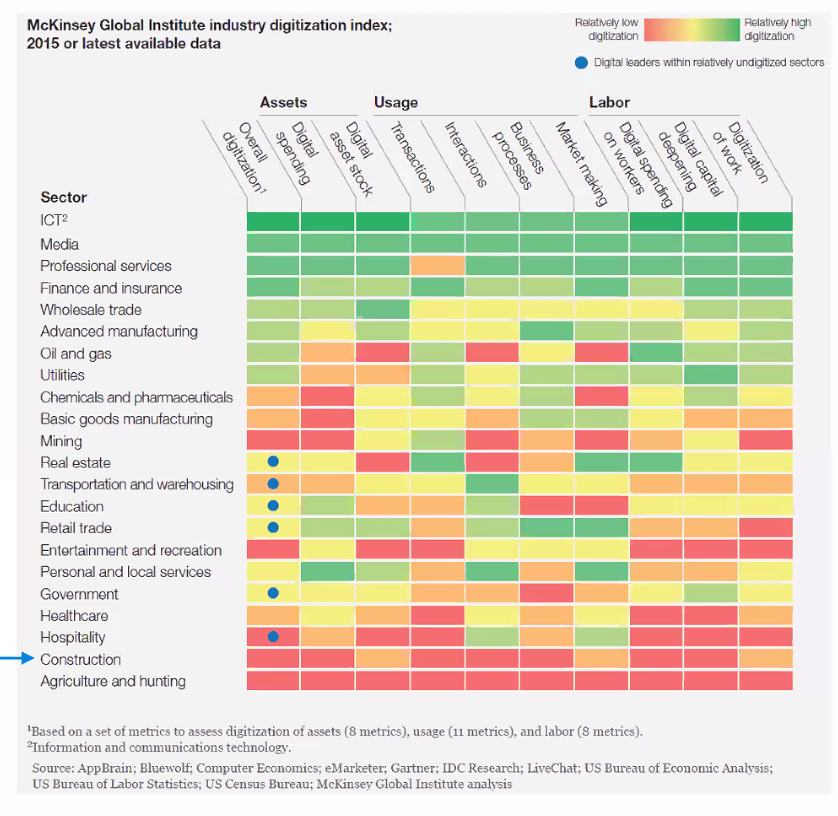
As construction sector is complex and dynamic in nature (Mohd Nawi et al., 2014), it consists of multiple disciplines and teams at various stages such as planning, design, construction, and operation. The parties are mainly client, designer, contractor, and manufacturer who are involved from the beginning until the completion of the project. Over the years, the project delivery practice among these parties are notorious for poor in collaboration such as isolation of working and inadequate co-ordination. As the project is delivered in a sequential manner, it would significantly affect the quality, safety and the progress of the works in future stages.

Apart from that, the information management in construction is not effective enough. The construction sector is labour-intensive and generates enormous amounts of information including calculation, drawings, project reports, tender documents, ...etc which are produced in the planning stage to the operation stage. According to a research in China (Xu & Luo, 2014), it has identified and discussed many consequence on the poor collaboration and information transfer among different parties, such as the loss and inconsistent of information caused by fragmentation of parties and unorganised information system. There is a comprehensive statistic shows that around 43%, 12%, 3% of the project time lost due to inconsistent information, dislocation, and ambiguity respectively on a construction project in average.

Health and safety deficiency are also one of the main concerns as compared to other sectors. The construction sector has long been recorded with the highest number of death and accident rate compared with other industry sectors globally. For example, it is about 79,000 construction workers suffered from health issue by working (new or long-standing) and 30 fatal injuries in 2018/19 (HSE, 2019). There was also about 2.1% of construction workers suffering from musculoskeletal disorder that they noticed that they got it during working. The rate is statistically significant than the rate for workers of other industries (1.2%) [ibid].

# Technology Implementation in Construction Sector

The situation in construction sector should be improved under the current digital transformation stage. However, the construction sector is notorious to adopt new technology and digitalisation compared with other industry. The digitalisation index of construction is very low as shown on below figure (McKinsey, 2015).



Although the sector has recognised the need for change and adopted many technological solutions such as Building Information Modelling, Virtual Reality, ..etc , they are fragmented point solutions and disorganised (Woodhead et al., 2018). To improve the construction project delivery by technology with a long-term advantage, a “planned IoT ecosystem” approach rather than combining different “point solutions” is recognized. This system should be with high connectivity between hardware, software and making key decisions based on data (ibid).

Besides, as the explosion of global pandemic COVID-19 is accelerating the development of digital transformation in different industry. With unprecedented consequences such as the disruption of manufacturing and supply chains, the mitigation to the impact by COVID-19 requires new approach of working and forms of collaboration such as remote working among team members to increase overall resilience of the business by using technology. To response that situation, a centralised control room system should be adopted in the construction sector.

# Smart City and Digital Transformation

Nowadays, the concept of smart city is common to all of us over the world. The smart city framework focus on connecting all the ‘things’ effectively with linking the interrelationships between multiple city systems, so that the output can be efﬁciency multiplied (Cosgrave, 2017). Besides, there are 3 elements highlighted for smart cities (Harrison et al., 2010), which are instrumented, interconnected and intelligent. Instrumentation means capturing the data from the physical world by sensors; interconnection means the data should be integrated from different source and they can communicate each other, while intelligent means the data should be visualised and provide insight for making better decision.

Apart from that, to resolve the long-established barriers in construction sector, an initiative Project 13 has been risen under the smart city paradigm to develop a new business model for the infrastructural projects. It is an industry-led response to delivery models that not just for the stakeholders as mentioned before, but also the citizens of economic infrastructure. It aims to develop a new business model to increase certainty, productivity and improve outcomes from the project life cycle. Digital transformation is a key enabler of this new business model. (Radford, Jamie; Macdonald, 2020).

Regarding to this, the building process should also have a revolutionary change to construct a smart city under this initiative. Can we build an integrated, plug-n-play solution such as a Control Room system to optimise, effectively control and get insight from the information generated to improve the project delivery in construction stage? This study will investigate it in detail.

# Scope of Research

The scope of research of this dissertation is as follows:

* How the control room works to solve the long-lasting problems of infrastructural projects in construction stages?
* What types of visualisation technique should be used to give insight and improve project delivery?
* How to make it plug-n-play for a construction professional to adopt it easily?

# Literature Review

Following from the motivation of setting a Control Room in the introduction, this section reviews what the framework for the Control Room should be from different literatures and resource on internet.

# Control Room

The control room concept was originated in 1970s, the launch of Apollo 13 program by NASA. The engineers on the ground control room needed to consider the changes swiftly to the space vehicle exposed to the extreme conditions in outer space and the astronauts inside. Later, NASA identified that they can no longer make corrective decisions based on the original modelling method because the actual module had subjected to significant changes due to the exposure under extremely hostile environment. There is a need to update the original modelling method so that the actual state of the module can be closely simulated. As a result, they use the “pairing technology” to simulate the outer space with the mathematical models so that the engineers and different professional can collaborate in the control room and make decision based on the mathematical model (Jarrett Hendricks, 2020). This actually the basis of the well-known paradigm “Digital Twin” in recent years.

# Control Room in other Industry

The same concept of control room can also apply in different industries. There is a Africa’s bank illustrated that they make a good use of this concept[[1]](#footnote-1). The head of the compliance control room of this bank suggested that the awareness of using a control room function as part of the larger compliance function has raised sharply in the financial services industry because the regulation become more strict and the day-to-day operations of the institutions become more complexed (StarCompliance, 2019).

The purpose of the Control Room in this case is to monitor the sensitive corporate information flow from a multi-service financial institution. Control rooms can act as a company’s nerve centre to monitoring the deals data such as mergers and acquisitions, equity offerings, debt offerings, …etc. The deals themselves are very complicated and generate an enormous amount of data that must be monitored closely to ensure the deal data can be organized, recorded, and analysed. It is also necessary to keep track on who's involved in the deal, what is their deal and who agree that deal, there is extremely little room for error for this deal data (ibid).

On the side of construction stage for infrastructural projects, it generates enormous amount of information (Literature). A control room should also be used to enhance project management to reduce risk of project delay, within budget, and minimise contractual implication. Health and safety of workers are very important as they are susceptible to hazardous situations. The Control Room can give insight on all aspects of health and safety to be considered before and during the construction works. In addition, there are so many researches focusing on facilities management at operational stage on the urban infrastructures but only few studies focusing on the construction stage, which is the fundamental part in the life cycle of an urban infrastructure.

# Digital Twins

The concept of Digital Twin originated from the NASA’s Apollo project. It set a basis for the control room by creating a virtual asset to represent the physical assets, which helps organisations to make better-informed decisions, leading to improved outcomes (Bolton et al., 2018). Simulation and analytics can be done by the digital twin, which established a continuous improvement to the physical asset by measuring performance, design based on data-driven observations, continuously making decision to cater for the changing market conditions (Jarrett Hendricks, 2020).

Besides, a framework of digital twin-based production management and control for a satellite assembly shop-floor is proposed by (Yi et al., 2020).

For example, construction process can be simulated with a digital twin to provide insight on how the project allocate the cost. A construction simulation is also useful to allocate subcontractors resource, since project managers can get a better understanding on what time and where they should work to improve the productivity from the digital model. Delay and poor productivity caused by lack of coordination between trades in construction projects can be improved by the digital twins (Tobias, 2020).

# Existing Solution on Market

Fragmented , not organised.

# Components of Control Room

Although there are so many existing reports or platforms to describe how to leverage building a digital twin for an infrastructure, there is a lack of clear and specific manual to describe its specific function. This section is to outline the framework of the control room, which is the collaboration and visualisation techniques.

# Cloud & Collaboration Platform

A cloud-based common data environment should be used as a centralised collaboration platform to foster the collaboration and information exchange between different disciplines. Cloud computing changes the traditional way of businesses to manage IT resources, which the services such as servers architecture, databases, analytics and business intelligence over the Internet (“the cloud” ) and ensuring data security (Microsoft, 2020). Cloud Computing also eliminates the requirement of using local hardware to handle and process data, thus no need to pay extra cost to buy hardware with high computation power (Stergiou et al., 2018).

Besides, traditional tools such as email, project management software and telephone are just one-way communication activities. They lack the real-time collaboration elements which is for connected engagement, discussion and approval process (Levine, 2016). If different parties in the project can submit updates of information on a simple and real-time manner on a single platform to create a single source of truth, it will be easier for all project team members as one and remain on the same pace as the project proceeds, so it would not make the progress delay in terms of scheduling and over-budget due to rework.

# Visualisation – Immersive Virtual Reality

Immersive Virtual Reality (VR) can give the user feel like physically presenting in a computer-generated environment simulating places in the real or imagined worlds. It is common used in the education and training purpose by its potentials of provide an interactive and motivated environment (Freina & Ott, 2015). Besides, many publications have identified that VR technologies have been implemented to enhance safety in many areas, such as risks identiﬁcation, workforce training, skill transfer, ergonomics in the AEC industry (Li et al., 2018). While VR can also be used for meeting with team members to work together within a 3D model for discussion, which is benefit for remote working (Brandon, 2020).

# Visualisation - Dashboard

Dashboard visualisation is a cognitive tool to improve our “span of control” over the business data. This help the user to identify trends, patterns, and anomalies from the data. They help manager to reason about what they observe and as a guideline for them to make effective decisions. It also let non-technological users to combine multiple data sets easily to customize a dashboard and generate data visualizations.

Besides, Key performance indicators (KPIs) is commonly used to benchmarking and compare performance by meeting both strategic goals with a dashboard in different industry. Construction industry can also make use of the objective benchmarks and to measure excellence across the industry. The analysis result can help to improve the building processes, risk identification for project delivery. It is the first priority for Project Directors, Project Engineers or any other person responsible for planning management to implement a better planning process by having a clear view of the project’s status.

# Visualisation - Real-time Web Model Viewer

As suggested by (Boje et al., 2020) , Digital twin should be based on a semantic web approach to accelerate digitalization by narrowing the gap between the physical and virtual world. Semantic web approach is to enable IT systems to process information by connecting web sites and data resources such as IoT devices so that the relationships and dependencies between pieces of data can be recognised (Keil et al., 2019). As a result, a web site approach to link the digital model data and the data from IoT device will be investigated.

# Open API

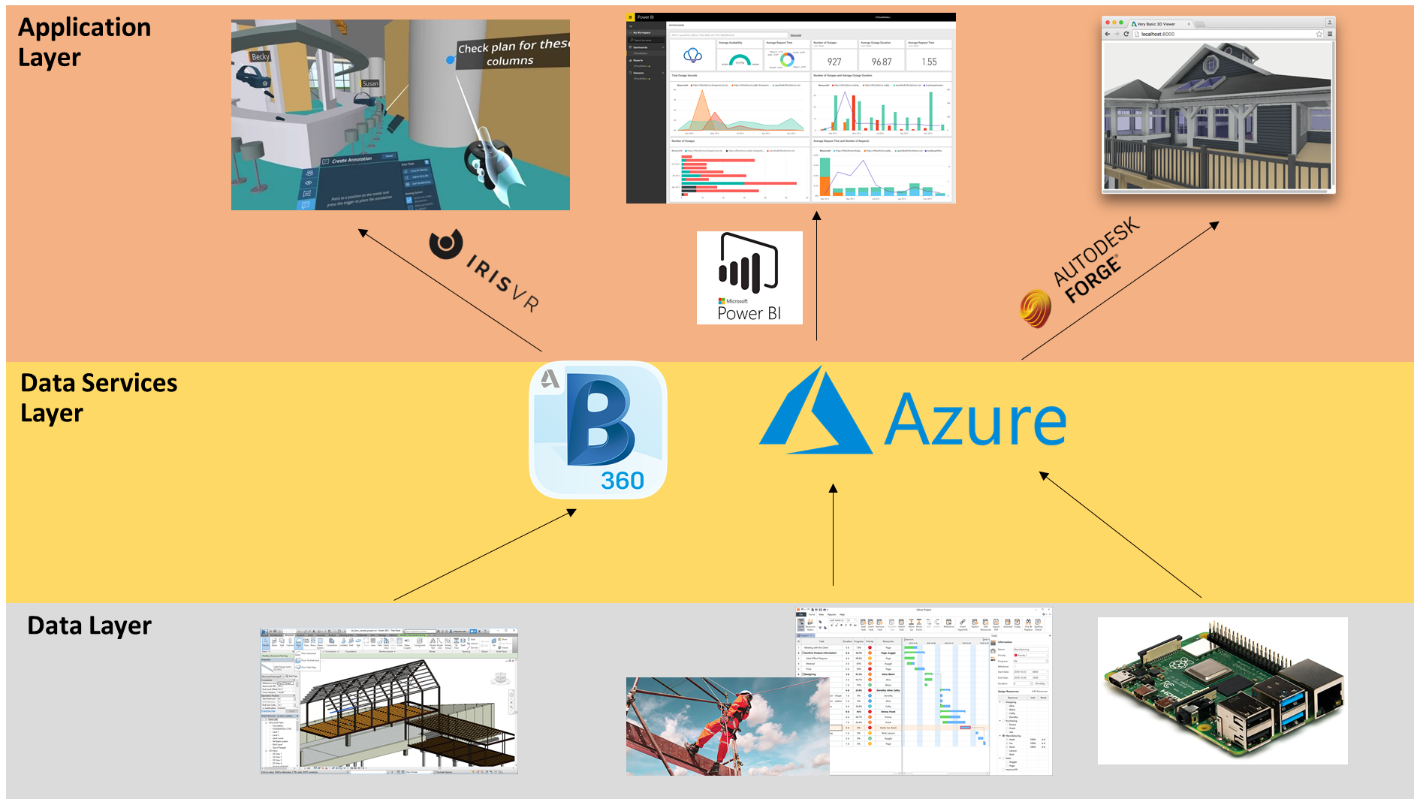
Apart from that, the data strategy of Control Room should consist of a common data exchange standards and Application Program Interfaces (API) for third-party developers to develop external applications so that many solution can be connected together and links to form an entire system such as a connected smart city (Woodhead et al., 2018).

# Methodology

To understand how the control room works and uncover the possibilities of using control room in construction, this study will make use of services and software available on the market to build the prototype of a Control Room system. The functionality and visualisation techniques of them will be evaluated to investigate what functionality of a control room should be provided and how it can be improved.

# Integration framework of Control Room in Construction

The hierarchy of the framework are the Data Layer, Data Services and Application layer and the entire ecosystem is shown as the below figure:



# Data Layer

Each of the component (from left to right) in the data layer represents an aspect of the construction site to reflect the performance.

1. Model Data: the virtual model of the physical configuration of the considered location
2. Project Performance Data: Safety and Progress Data
3. Sensory data: Working condition of the construction site

# Data Services Layer

The model data will then be published in a standardised format to BIM360 platform for collaboration and analysis. While the project performance data and sensory data will use using Microsoft Azure Services for data storage, processing and the data can be retrieved by API to feed into elements in application layer for visualisation

# Application Layer

The Application layer is for data visualisation. Model data in BIM360 will be visualised in VR environment with IrisVR, the project performance data will be visualised as dashboard by Microsoft PowerBI. The sensory data will be visualised with the model data on BIM360 by Autodesk Forge API.

# Source of Data

# Model Data

The models data is a digital prototype of a residential house, which is a template file provided by Autodesk Revit 2020 and in format of “ .rvt”. The 3D model can be visualised as the below figure:

The model contains objects data relating to the architectural and structural elements. All objects in the model contained information such as object name, type ID, furniture name, material information and major dimensions in object property.

The model data will then be published to BIM360 to simulate the collaboration between the structural and architectural team. Details will be discussed on session 4.3.1.

# Project Performance Data

Two datasets of project performance data used for this study is taken from the ‘Project Hack’ hackathon organised by Project Data Analytics Community. The consent of using the dataset for this study is granted and the data is anonymous. The data has been modified for visualisation purpose only.

The first contains all incident record of a construction site, it includes detailed information with 1023 rows and 26 columns, such as date of accident, accident category, nature of injury and damage classification and type of contact.

The second contains the handover record for different rooms and area of a construction site, it includes information with 193 rows and 16 columns, such as code for the room/area, handover date for stages 1-5 and handover status.

# Sensor Data

Low cost sensors Raspberry Pi (RPi) has been selected as the prototype of IoT devices to capture the construction environment data. RPi is a Linux-based platform. It is a credit card-sized computer and even can be as an alternative of a desktop computer. As it is low cost and different operating systems are supported, it is suitable for ranges of projects such as acting as IoT device. The version used in this study is the Raspberry Pi 4 Model B which is newly released on the end of May 2020. The RPi can connect with local area networks with WIFI and transfer the data received from the sensors to Microsoft Azure IoTHub services, which will be explained in Section 4.4.1. The technical details are given in the below Table:

Table: Technical specification of Raspberry Pi and sensors

|  |  |  |  |
| --- | --- | --- | --- |
| **Sensor** | **Data to capture** | **Image** | **Technical Data** |
| SHT20 | Temperature,  Humidity | SHT20 溫濕度傳感器模組I2C 通訊- 台灣物聯科技TaiwanIOT Studio | Cost  Operating Voltage  Working Current |
| PMS3003 | PM2.5 | Laser Particle Concentration Dust Sensor Pm2.5 Plantower Pms3003 ... | Cost  Operating Voltage  Working Current |
| MH-Z19 | CO2 | 100% New&original MH Z19 MHZ19| | - AliExpress | Cost  Operating Voltage  Working Current |

Figure to show final configuration of the Raspberry Pi with sensor installed.

# Field Info

To simulate a working condition of a construction site and the ability of the sensor to collect the empirical data, the sensory system was installed on a local factory in Hong Kong. The following sections describe the approach to install the system and how the working condition can be reflected from the data.

-Field Test and Data Collection of sensors **(physical)**

->Site Description

->how sensor set up and collect data in the factory, install location plan

-> level chart

# Statement of Ethics

All the data used in this dissertation do not contain any personal information and Project hack has granted consent to me for using their data for dissertation purpose. Therefore, no ethics approval was required. (Github link here???)

# BIM360

# BIM360 Collaboration

BIM360 will be used to simulate real-time collaboration, the modules of this cloud platform such as Document Management, Design Collaboration and Project Management modules will be used for exploring the functionality on multi-disciplinary coordination on all project information. Drawings, model data and relevant files uploaded on BIM360 support version control with the help of module Document Management. Design Collaboration module can show the different drawing packages at different time created by different parties and will allow them to decide whether to consume that package for their further amendment. The data also supports requests for information (RFIs), submittals, inspections and more will the module Project Management. The platform also features a powerful insight and analytics layer that includes interactive dashboards and reporting, for making decision and predictive analysis. (ISO19650 workflow)

# Forge API

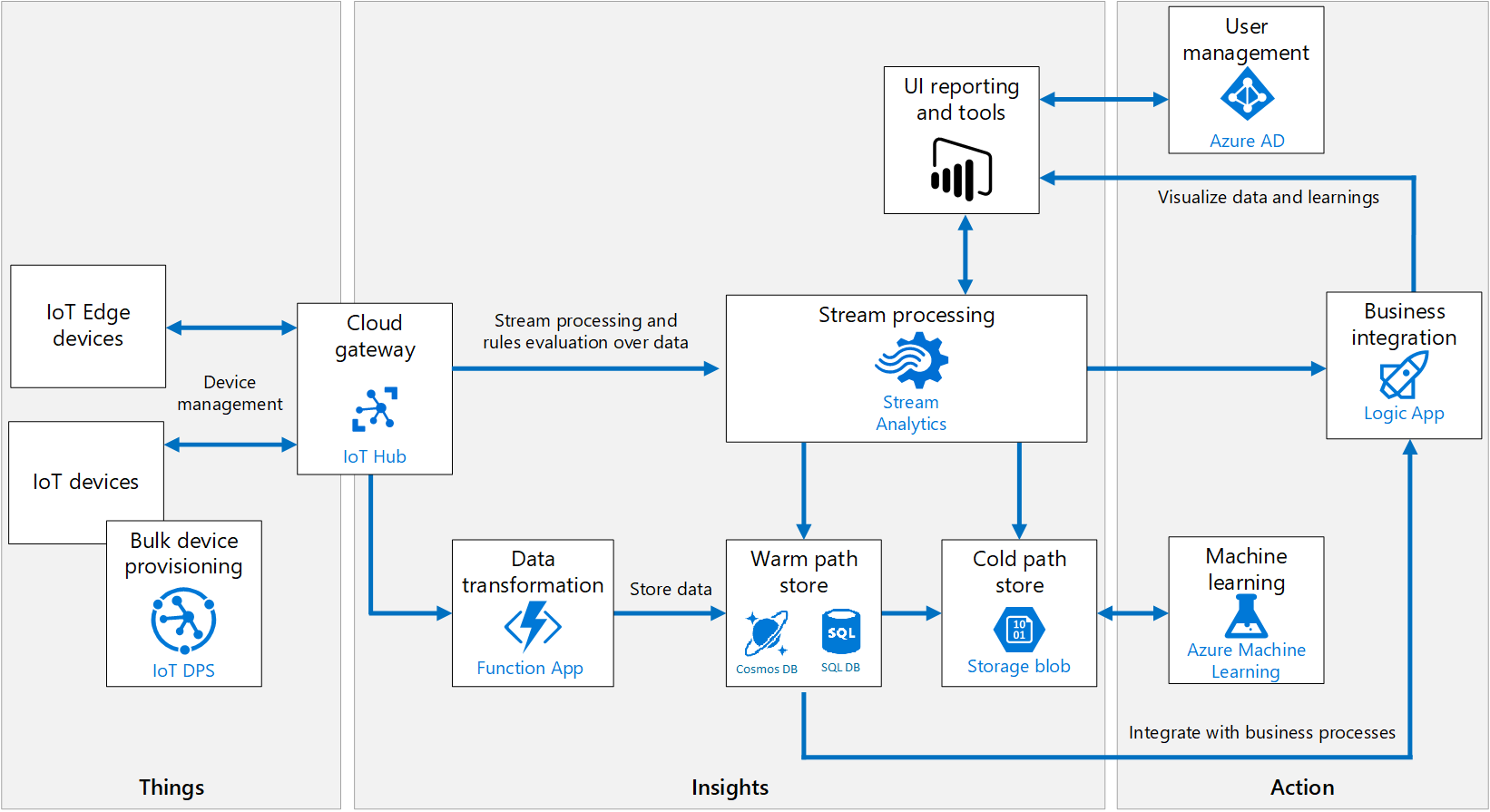
To retrieve the data from BIM 360, the Autodesk Forge API has been used. It comprised of multiple API’s, each one dedicated to a specific group of tasks related to the Autodesk cloud ecosystem. The data in BIM360 such as model data, checklist, issues and so on can be further developed for automated processes, workflows and data visualisation. All the available API can be explored on [forge.autodesk.com](file:///C:\Users\vmone\AppData\Roaming\Microsoft\Word\forge.autodesk.com).

# Microsoft Azure

Microsoft Azure offers cloud service in three main categories: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). PaaS will be focused on this study. Platform as a service (PaaS) is a cloud-based development and deployment environment, with resources to deliver our own applications. PaaS not only includes the elements of IaaS such as servers, storage, and networking, it also provides middleware, development tools, business intelligence (BI) services, database management systems, and more. It is designed to support the full development of the lifecycle of a web application like building, testing, deploying, managing, and updating. PaaS enable me to simply managing the underlying application infrastructure and middleware or the development tools and other resources. Azure cloud services offer a free tier one-year subscription to their services for students. The services can also be purchased as pay-as-you-go basis.

# Data Capture and Storage

Data has been sent over to Azure for interception and storage in a database for management, analysis and visualisation. For the sensory data, the sensor with the microcontroller Raspberry Pi (RPi) act as a node and registered as an ‘IoT devices’ in Azure. By using the IoTHubs services as the gateway, the data can be further processed as below figure.



# Database Management

Azure SQL Database is a fully managed PaaS database engine that handles most of the database management functions such as upgrading, patching, backups, and monitoring without user involvement. With Azure SQL Database, a highly available and high-performance data storage layer for the applications and solutions can be created. It also allows to process both relational data and non-relational structures, such as graphs, JSON, spatial, and XML. Data in file format like .csv can be moved to an Azure SQL Database using a Bulk Insert SQL Query.

A python script (Appendix XX) was used to insert the performance dataset which is in .csv format. It established a connection to the SQL Server with the required credentials and perform inserting to the database. Python Libraries such as panda and pyodbc will be used for data processing and building connection with the SQL Server.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table Name** | **Field** | **Type** | **Description** |
| SAFETY |  |  |  |
| PROGRESS |  |  |  |

# Streaming of Sensory Data

Besides, Azure Stream Analytics is a real-time analytics engine that is designed to analyse and process high volumes of fast streaming data from multiple sources simultaneously.

Relationships has been formed between input sources RPi in IoTHubs and output sources such as SQL Database to trigger the streaming of real-time sensory data from IoT device to SQL Database. The Python script (Appendix xx) has executed on the RPi to connect with the IoTHubs. RPi is set to send data every 10 seconds. The parameters obtained are the microcontroller device id, timestamp, temperature, humidity, CO2\_level and PM2.5\_level. These parameters are added as a new row in the Azure SQL Server database.

In summary, there are 3 tables which are the safety data, progress data and sensory data of the data layer for the control room.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table Name** | **Field** | **Type** | **Description** |
| SENSORY |  |  |  |
|  |  |  |
|  |  |  |

# API Endpoint

Azure App Service is an HTTP-based service for hosting web applications, REST APIs, and mobile back ends. Node.JS application has been developed to retrieve the data from the SQL Server Database. The script is on Appendix XX. It defines an URL endpoint for triggering GET request from the tables in SQL database and returned as a JSON object for live data visualisation and analytics. these API endpoints can also be used for the development of the visualisation applications. The API documentation can be found on the studies GitHub page.

# Visualisation Techniques

# VR

The Prospect plug-in developed by IrisVR, the model data in BIM360 can be converted for VR visualisation. The 3D Views of the model can be imported directly into VR and automatically become viewpoints. It can create a narrative for the VR experience which is in 1:1 scale. The immersive VR headset Oculus Quest will be used for this study. It is a completely wire-free, PC free and with all the sensors built in. The specification is as follows:

|  |  |
| --- | --- |
| Display panel | OLED |
| Display resolution | 1440 x 1600 per eye |
| Refresh rate | 72Hz |
| CPU | Qualcomm Snapdragon 835 processor |
| RAM | 4GB RAM |
| Battery | Lithium-ion battery with 2-3 hours playtime, depending on what you are playing |
| Degree of Freedom | 6 degrees of freedom head and hand tracking |
| controllers | Two touch |
| Weight | 571g |

# Dashboard

A dashboard application was built on top of Azure SQL Server Database to provide data visualisation and analytics. Microsoft Power BI will be used to visualise the construction performance data as a dashboard. As Power BI can get data from different source, data can be retrieved from Azure SQL database after the connection has been set up. Whenever the data has been sliced or another field has been created for visualization, Power BI will make a query to the database.

# Web Viewer

The Web-Application was to provide a plug-n-play tool for user from any background to understand the working environment of the construction site with the visualisation of sensory data. The BIM 360 APIs of forge API will be used to develop a viewer application to visualise the model data in BIM360. The viewer Application is a WebGL-based, client-side JavaScript library for 2D and 3D model rendering. The model data will be first translated to SVF using the [Model Derivative API](https://forge.autodesk.com/en/docs/model-derivative/v2/) of BIM360 APIs. Once the process has completed, the viewer will be able to visualise these translated files.

# Besides, the real-time sensory data will be visualised with JavaScript library D3/Chart.js on the page with the model. New data streams can be added dynamically (as they are discovered by the caller over time), simply by calling the **yDomain** method with the new array of data series names. The chart will automatically update the new data series into the available space in the SVG.

Then, the website will be deployed to Azure.

# Result & Discussion

The performance of the Control Room system will be explained by looking at the usages of the data by different applications as mentioned on Section 4.

(Put video and the link of the Control Room)

(focus on how the visualization technique and control room give some surprise things)

(COVID-19 , so only can test by myself)

# BIM360: (how to collaborate with the BIM model)

The study try to investigate how the cloud collaboration tool BIM 360 can enhance the collaboration between different project team members. The author has used the module “Document Management” and “Design Collaboration” for demonstration. The BIM model data first opened in the local desktop software Autodesk Revit for modifying the design such as add additional structural elements like beams, columns and walls. The model can then upload to the Document Management module of BIM 360 by a one-click button in the Revit. The document management module provides a version control for model data, what have been updated in each version and tracking who have modified the model. The model in the cloud platform can also be compared together and the difference can be highlighted. It provides a good way for the managers to easily identify how the design has been changed due to construction constraints, which raise the awareness to the update of information.

Besides, the following case study illustrates how to make use of the “Design Collaboration Loop” concept to enhance the collaboration of team members and the information management. The structural team member can make use of the ‘Link Revit’ function in the local desktop software Revit to consume the finalised model from other team members such as the architectural team. After that, the structural team can design the structural elements such as beam, columns and walls based on that model. After that, the structural team can synchronize and published the finalised model to the BIM 360. Later, the structural team can create a package in the timeline as shown on below figure so that the packages can be shared to other team members to consume this model and keep on modify it. This is the concept of the design collaboration loop, which provides a continuous and smooth handover of the model data between different team members, which enhance the collaboration and information management. (figure)

# Management of Issue

Besides, different team members can raise RFI, issue to the model….

# Drawbacks

The design collaboration workflow is effective for the collaboration of team members. However, it is a bit complicated and create different model data files which may lead to confusion. Since after the publish of the data file by one team member to the BIM 360, the model saved in the folder of “WIP (Work in Progress) folder”, which is created automatically under the work breakdown structure of the design collaboration module. Besides, after the packages is created in the design collaboration module, the model data will be saved in “Shared” folder for sharing to other team members for consume. And finally, after the model has been consumed, the model will be saved in the folder named “Consume”. As a result ,multiple model data files has been created by using this design collaboration loop concept and it may make confusion to the beginners which model is the latest one and which model they should be used if he does not familiar with that design collaboration concept.

Besides, separate to different software and file format (rvt, nwc, nwa), easy to confuse

# VR

# Visualisation in VR

Originally this study intends to invite different construction professionals to use the VR headset and identify its benefit in construction environment to make this study have different view of using the VR visualisation to BIM model data.

However, under the current COVID-19 pandemic, it is hard to invite so much people as we need to keep our social distancing. As a result, the author gets the result by using the VR headset Oculus Quest by himself.

# Case Study: Project Coordination & Training

By using this VR visualisation to the model data, the author can fully immerse in complete 3D models. The author find that this kind of VR visualisation gives a great perception for the project team members for understanding the construction environment than traditional drawings. Different team members can carry out regular remote VR meeting to collaborate each other and understand the need other team members.

(charts)

After they all have agreed how they would modify their design or the construction sequence, team members can use the design collaboration module of the BIM360 to modify their BIM model file based on the design collaboration loop. As a result, different team members can modify the model effectively and avoid crash of elements or design error. It greatly increases the productivity. Combining the VR visualisation method can greatly unleash the potential of the collaboration tools of a Control Room.

Besides, as many literatures suggested that VR has a great use in education and training purpose, it is a good tool for using in safety training purpose. As I can visualise the model from it very beginning to the final completion stage. I can identify all the safety hazards during the construction and the find out the exact locations which with the high risk to safety deficiency. For example, some location such as the outer stair from the model which is above ground for xx meters and at the edge location, which is highly susceptible to the hazard of falling from height. As a result, the managers can arrange special training and pay more attention during the construction of that stairs. (charts)

# Drawbacks

VR can provide a great perception to the users in an immersive environment. However, it often exists as a separated plug-in or services rather than integrated with the collaborate tool such as BIM 360. It made the construction need to pay extra cost to buy this service to use, which lower the motivation for the construction professionals to adopt this technology. According to two services providers like “IrisVR” and “the Wild” which can function as a plug-in with Autodesk BIM360 and Revit. Their monthly subscription is about $225 USD and $295 USD, which is not an affordable price for some company especially some small size company to adopt this solution.

Besides, taking the VR plug-in by “IrisVR” as an example, the author need to open the local desktop software Autodesk Revit to load the model data from the cloud BIM 360, and use the VR plug-in to transfer the BIM model data its external VR software “Prospect” to parse the data become VR format so that we can use the VR function on that external software which shown on the below figure. It is quite not user-friendly and not “plug-n-play” enough. (charts of that software)

To make it more user-friendly, it should be integrated in the cloud platform of Control Room (such as the BIM360), so that when all the project team members access to the cloud platform, they can open the model file and then press one button to access the immersive VR environment for walkthrough and remote meeting immediately rather than installing so much software for the VR function.

# Dashboard

# Case Study: Safety Data to identify critical safety record

A dashboard has been developed based on the modified data sourced from HSE. It is an interactive dashboard to visualise the details of the safety accident record across 2012 to 2017.

In the first dashboard, we can identify the trend that the number of accidents is decreasing across the years and Area B with the highest number of accidents. One can choose whatever categories under different indicators such as “severity”, “age band”, “main activity”, “Risk Category” and “Injury Type” so that the total number of fatalities, incidences and the number of accidents across different years will be changed. It is easy to identify most of the accidents belongs to the activity of M&E installation , category of risk with slip or trip on the same level, workers suffering from body parts such as lower limb and the age band susceptible to accident belongs to 25-34. According to these messages provided by the data via the dashboard, the project managers can make decision like paying more attention to the activity of M&E installation and putting more training to the workers aged with 25-34.

Besides, the second dashboard use a tree level diagram to visualise the number of accidents. The tree diagram separated into different levels, the first one is severity, second is injury type, third is location and the last one is main activity. For example, when we selected one of category under the first level ‘severity’, then the number of accidents will be separated into different groups under the second level ‘injury type’. And then it will separate into different groups under the third level ‘Location’, when we click one of the group, the number of accidents will be separated in different groups again under the forth level ‘main activity’, so that we can identify the number of accidents based on different level.

(charts)

# Drawbacks

The PowerBI is a great platform to present the data to give insight, patterns or abnormality. However, as construction sector is a complicated and complex industry, it is quite difficult to standardize a database schema format for data visualization. Since different construction company will have their own standard and indicators to report their project safety, progress related issue and workflow for quality assurance process. As a result, the dashboard function of the control room platform should be highly customizable so that the user can manually edit the schema so that they can keep track on the indicator they want.

Besides, some users may still want to use the PowerBI dashboard for data visualization rather than developed a new one themselves for the control room platform. However, its integration capabilities with other applications must be improved upon for a better experience. Originally the PowerBI dashboard can be integrated with the BIM 360 cloud platform, so that the construction professional can understand the condition of the BIM model and the project data at the same time. However, Microsoft have changed their data security policy so that they don’t allow the user to publish the PowerBI dashboard to the websites and other external software unless some complicated network setting has been set. It makes the integration between the PowerBI and other platform not in a convenient way. One of the solutions which is good for a Control Room platform which can utilize the PowerBI dashboard visualization, it should be at least able to open and interpret the PowerBI “.pbix” file to avoid the network policy setting by Microsoft.

# Web Viewer

# Description of sensory data

Overall, xxx data points were collected from [date]. The range of different parameters is tabulated as below:

|  |  |
| --- | --- |
| **Parameters** | **Range** |
| Temperature |  |
| Humidity |  |
| CO2 |  |
| PM2.5 |  |

# Visualisation of sensory data

As the forge api is not very user friendly and not so many documentations available on the internet, the web viewer is not a completely ﬁnished product, but it shows the ability and the function it could have.

The web viewer is as shown on the below figure. There is a toolbar below the 3D model for the users to navigate the model such as rotating the model or dragging for translation of model data. Besides, there is a property panel so that the user can find out the information for each of the elements inside the model.

(chart)

Besides, the sensor data such as humidity /temperature/Concentration of CO2, PM2.5 of indoor element is visualised with the JavaScript library Chart.js/d3 on a separated div. It can dynamically display sensor readings with the changing frequency of 10 seconds.

(chart)

# Functionality for Construction Professionals

To test whether the working condition is safe for the workers.

We produced the BIM with details of the room/wall/window/door elements and sensors within the building which are sufficient for monitoring the building energy performance.

# Drawbacks

The forge API is not for easy for the beginners to use. Although Autodesk can already provide different documentation on the internet, it is highly fragmented and not easy to start with. Also, some of the coding practice suggested from documentation which is only for the old version of the viewer application. For example, the author wants to customise the property panel of the viewer application to add customised content such as the sensory data but it is not successful.

Regarding to this issue, a visual programming interface is suggested so that the user can make use of this API to link the data or get data from other external application easily. The Author originally want to integrate the sensory data into the digital model for visualisation, however, it is very difficult to carry out this task and very less documentation to explain how to do it. As a result, the author use external library to visualise the sensory data. As capturing data by IoT device is becoming much popular, the Control Room platform should provide an easier way to integrate both the sensory data with the model data for visualisation.

# Limitation (500)

Although this study shows the ability of how the overall Control Room system to improve the project delivery, there was some limitation for this study.

The most important one was due to the social distancing practice by COVID-19, which makes the author can only test its ability by himself instead of inviting other construction profession to give some feedback and comments on the system especially for the VR one.

# Recommendation (500 words)

-Talk more about how the integrity can be improved

=> forge is difficult to use, less documentation

=> PowerBI cannot insert as card on the BIM360 platform

=> BIM360 shd with plug-in to display the sensory data /SQL data

weak in support external data such as sensory data

# Future can do

->expansion of sensory data (capture by camera)

->Natural Language Processing from data

->Mobile apps function

# Conclusion

A good building process to build a connected city.

19650 standard shd extend to smart city

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# Research Log

# Appendix

Coding, github

1. https://www.youtube.com/watch?v=oYzqpfinyvc [↑](#footnote-ref-1)