# Abstract

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, it can solve the long lasting problem such as ….. and provide a remote working platform by enhancing the collaboration between different stakeholders, managing the data effectively and provides insight to managers to set-up strategies and policy to enhance the construction safety during different stages of a construction project.

With the emerging technology IoT (Internet-of-Things), the sensory data of the environment and the human action 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 a innovative ways.

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 sensor data to……….

The choice of sensory data will also be discussed to make these visualisation techniques more useful. It is found that ……….

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

# Introduction

-Overview

-> How big and its importance to economy?

Construction industry is one of the largest sectors in the world economy. According to (McKinsey & Company, 2017), there is about $10 trillion annually spent on construction-related globally, which is equivalent to 13 percent of GDP. Besides, there is about 7 percent of the world’s working population working for the construction industry. It shows that the construction industry plays a fundamental role in the global economy. However, 98% of infrastructure projects are over budget or delayed around the world, with an average of 80% over budget and at least 20 months late. Construction’s productivity is also lagging global productivity by over 30%. If constructions productivity is improved to average global productivity, it would pay for 50% of the total demand of infrastructure (Changali et al., 2015).

-> Collaboration

Construction industry is complex and dynamic in nature (Mohd Nawi et al., 2014), it entails many stakeholders at various stages such as planning, design, construction, and operation. The stakeholders are mainly client, designer, contractor, and manufacturer who are involved from the start till completion of the project. As a result, it revealed that traditional construction project delivery practice among these parties generated many problems associated with fragmentation likes isolation of professionals, lack of co-ordination during design and construction stages. As it is carried out in a sequential manner, it would significantly affect the quality and the progress of the works.

Information Management

Apart from poor collaboration, information management is very poor in construction industry. According to a research in China (Xu & Luo, 2014), it has identified and discussed many consequence due to poor communication and information transfer among different stakeholders, 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% time wasted due to inconsistent information, dislocation, and ambiguity respectively on a typical construction project.

Safety

Safety is also one of the main concerns as compared to other sectors. The construction industry has long been recorded with the highest number of fatalities and accident rate among all industry sectors around the globe. For instance, according to (HSE, 2019), around 79,000 construction workers have suffered from work-related ill health (new or long-standing) and 30 fatal injuries in 2018/19. There is also around 2.1% of workers in the sector reported suffering from a musculoskeletal disorder they believed was work-related (new or long-standing cases). This rate is statistically significantly higher than the rate for workers across all industries (1.2%) [ibid]

Lead to Delay, low productivity, high cost,

It shows that the communication, document management between different parties and safety management is very important, otherwise it is detrimental to a project quality and can lead to delays, budget overruns and many abortive works.

-Objectives

Smart City Context, Digital Transformation

Many papers and reports referring the smart city concept arisen from the population growth, urbanisation, and an opportunity to capitalise on the economic return through the growth of using technology. According to (Cosgrave, 2017), optimisation, efﬁciency and control are the core elements of smart city. The main point is that **the smart city framework can integrate** all these systems effectively with linking the interrelationships between multiple city systems, the output can be efﬁciency multiplied. As (Hollands, 2008) suggested, a city just focusing on the development of technology is not adequate to regard as a ‘smart city’. Instead, a smart city can emerge only in relation to people, processes, and systems.

To minimise abovementioned consequence, an initiative called Project 13 under the smart city paradigm has risen to develop a new business model for the infrastructural projects. It is an industry-led response to delivery models that fail not just the stakeholders as mentioned before, but also the operators and the citizens of economic infrastructure. It aims to develop a new business model to boost certainty and productivity, improve whole-life outcomes. Digital transformation is a key enabler of this new business model. (Radford, Jamie; Macdonald, 2020)

NASA Control Room

A NASA control room is definitely a solution under the digital transformation to manage the construction data and improve the project delivery effectively. In the past, people using the NASA control room to rapidly account for changes to the space vehicle exposed to the extreme conditions in space, and with lives on the line. 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. By using the NASA control room concept in construction, we can improve the collaboration, information management and monitor the working environment in construction site in real time.

Scope of Research

The scope of research of this dissertation is as follows:

* How to implement a control room in construction industry to solve the long-lasting problems of a construction project in different stages?
* What types of visualisation technique should be used to give insight and improve project delivery?
* What types of sensor data should be captured and what data standard should be formulated?

This dissertation frames the setting of the control room that contribute in different stages of construction project and use a case study to visualise the data from sensors and mock anonymous data. It provides an overview of the core visualisation technique of a control room that can be used in the construction industry. It focuses on three visualisation techniques with the data: Online model viewer, Dashboard, AR/VR

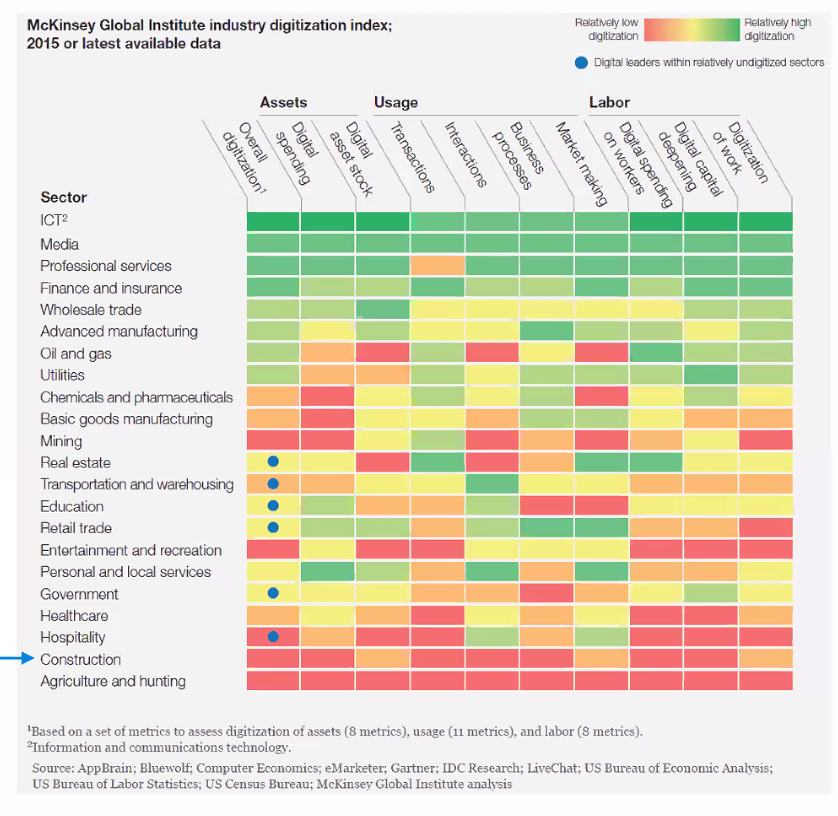
It also illustrates what data standard should be formulated to improve the data management, which makes a sustainable development of a construction project. This can act as a reference in the construction industry.

# Literature Review

(Technology gap in construction, why everyone know this problem, but less to implement)

(Gap of Construction Industry to technology)

Regarding the population growth, urbanisation and climate change further increase the pressure for productivity and quality improvements and the global pandemics also raise questions about how affected businesses and world economies can continue to deliver efficiently. However, construction is slow in development compared with other industry. According to McKinsey Global report, the digitalisation index of construction is very low, (lack of technological expertise)



Although the industry has recognised the need for change and adopted many technological solutions such as ……… , they are fragmented point solution and disorganised (Woodhead et al., 2018),. Instead, a key step for construction companies to have a long-term advantage is to recognize a “planned IoT ecosystem” rather than combining many “point solutions”. Ecosystem means an integrated “layer” of hardware, software, connectivity, and information ﬂows linked to key decision-making activities.

Besides, construction industry lack of real-time application, according to McKinsey and Company, if everyone in the project submits updates on a simple and timely manner, then it becomes easier for all teams involved to work as one and remain on the same page as the project proceeds, so it would not make the progress go back in terms of scheduling and budget due to rework and hence lead to the project delay and over budget.

(What and why we need control room)

In response to such implications,….. Control room concept is an integrated solution and a single platform to fulfil this gap.

The control room concept was first applied in the 1970s during the Apollo 13 program by NASA, where engineers on the ground needed to be able to rapidly account for changes to their vehicle while exposed to the extreme conditions in space, and with lives on the line. When life support failed, NASA found they could no longer base corrective decisions on the original model because the actual module had undergone significant changes as the result of exposure to an extremely hostile environment. The original model needed to be updated to more closely mirror the current state of the module.

<https://info.expeditors.com/horizon/rise-of-the-digital-twin>)

how control room works in other Industry e.g. Banking

There is another example in the financial services industry using the control room concept. <https://www.youtube.com/watch?v=oYzqpfinyvc>

According to (StarCompliance, 2019),

the Head Of The Compliance Control Room at one of Africa's leading banks suggested that there's a growing awareness in the financial services industry have a need for a control room function as part of the larger compliance function due to the increased regulation as well as increased complexity in the day-to-day operations of the institutions"

Control rooms can act as a firm's nerve centre to monitoring the deals data such as mergers and acquisitions, equity offerings, debt offerings, …etc. The deals themselves are very complex and generate a deluge of data that must be rigorously monitored, and the deal data must be organized, recorded, and analysed. The volume of this deal data is immense and there is a need to keep track of who's involved in what and who said what to whom can be overwhelming, there is very little room for error and a premium placed on clearing deals quickly.

Some control room members said that one of the importance of control-room is to use automated software to keep them working effectively in the fast-paced environment and there is a lot to keep track of data. Software can automate much of what previously could only be done manually but it also keeps data organized and up to date.

if they aren't cleared and response quickly enough, and lost reputation, if conflicts result in regulatory action. Again, our veteran compliance officer: "Control room is a compliance function, the purpose of which is to manage the flow of sensitive corporate information in a multi-service financial institution, like ours. The more services you offer the greater chance for conflicts, and the more the need for a control room. You need to manage the flow of information in every respect."

Cost / Safety in construction is also very important, a similar control room concept should be adopted in construction.

(Components of control room)

Digital Twin

In order to build the control room, we must need the digital twin concept as the basis,

In the past, NASA used a combination of physical and mathematical models to monitor the activities in outer space, today’s information technology allows for pure virtual renderings with amazing precision. The same dynamics can also apply to construction.

A Digital Twin creates a digital representation of a physical building asset. It exists in the plan and design phase of a project as a method for better planning, design and construction of a project. It also plays a role at later phases of the lifecycle, especially after commissioning and provide long-term benefits for asset performance, optimisation, and reliability opportunities. Alternatively, Digital Twins can also be created after a physical version of it already exists, during its use phase. Physical assets can, therefore, be digitised when in operation.

In this approach, simulation and analytics from the digital representation can be tightly coupled with execution, which enable a cycle of continuous improvement and innovation. Measure performance, design based on current, data-driven observations, execute to design, and then measure execution to design; continuously adjusting and course-correcting to adapt to changing market conditions and to exploit emergent, potentially fleeting opportunities.

According to <https://www.intellias.com/digital-twin-technology-a-guide-for-2019/>, the three key factors that have made digital twin technology possible are:

**Velocity:** IoT devices can relatively easily collect massive volumes of data and transfer it to a digital twin in almost real time.

**Resolution:** Digital information helps us get a close look at the finest details of physical assets.

**Learning:**

Machine learning algorithms can analyze gathered data and make predictions, refining the digital twin based on gathered information and calibrating the general model and its details.

Although there are so many report/marketing to describe the advantage of digital twin concept, it is a lack of clear and entire manual to describe how to use it. This paper is to research how to utilise this concept to build a control room and investigate its essential components and possible function: With the development of technology become more mature, it is more easy for use to build the digital twin, this paper serve as a guildline to discuss what essential components are required.

There are some fundamental components of the digital twins:

Collaboration Platform

A cloud-based common data environment should be used as a centralised collaboration platform, project data can be exchanged between different parties and software.

Cloud

CDE 19650 defintion

Visualisation Techniques

To aid in visualisation of the data and the building model, the following will be investigated:

* Web viewer

The viewer enables users to visualise 3D (and 2D) models in a browser or smartphone app. The digital twin of the building model created can be probably displayed it using this technology.

* Dashboard

The companies use key performance indicators (KPIs) to gauge and compare performance in terms of meeting both strategic and operational goals in a dashboard. Construction industry can also make use of the objective benchmarks and find a way to measure excellence across the industry. KPIs of different size companies can also make use of this technology to digitize the information and integrate them in a centralised platform. The analysis result of the data across the industry can help to improve processes and lead to better performance and project delivery. It is the number one priority for Project Managers, Project Directors or any other person in charge of project planning to implement a planning process which will subsequently allow them to gain a clear view of each project’s status.

* VR/AR

Augmented Reality (AR) can help field operatives fix equipment they have no experience of by using their mobile phones to overlay real-time diagnostics and instructions to open machinery and replace defective parts. We also have experience of solutions that use Virtual Reality (VR) to help operatives understand hazards in a physical location they have not yet visited.

(what has been assummed in the result, how reliable is the analysis, why choose the methodoloy you chosen??)

🡪 We need a hub to work tgt and visualisation, to connect the things tgt

Lack of data standard, so this dissertation to investigate

Apart from that, the reality is that challenges such as common data exchange standards, inconsistent metadata, Application Program Interfaces (API) not working as well as they could, and asynchronous performance issues are already being grappled with through National BIM Standards (NBIMS), Construction and Operations Building Information Exchange (COBie) and National CAD Standard (NCS) to name a few. It shows that there is a missing data strategy that links to a ‘bigger picture’ such as a smart city. (Woodhead et al., 2018)

# Methodology

(Main point 🡪 demonstrate how to build a practical case study)

-System Architecture of NASA Control Room in Construction **(virtual)**

-> How the ecosystem works

How your works related to ISO 19650 workflow

-Sensor Data

-> how the sensor to collect the data

-> How the microcontroller works

-Web Server

-> How the Azure database build

->How the endpoint to be build

-Infrastructure for visualisation

-> How BIM360 + Forge: Viewer

-> How PowerBI Dashboard to be built

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

->Site Description

->how sensor set up and collect data in the factory

->Revit Model Specification

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