Productivity of construction project after IR4.0 Norms

by

TEO KHAI SHENG

24498

CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Teo Khai Sheng

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ABSTRACT

Industrial revolution 4.0is a transformation from industrialization to digitalization. Digitalization in construction industry will ease the communication between different industry. Digitization of construction industry had speed up due to the restricted movement of country. Most of the company productivity became low as the construction project is stop due to the movement control order. Thus, most of the company will start to digitalize. This research will determine the technology that can be used in construction industry after IR4.0.

The most significant advantages of digitalization in the construction industry are time savings in project execution, increased performance, increased speed of work, improved document quality, faster response time, and streamlined working methods. Among the technology are big data, Artificial intelligent, Building information modelling and Virtual reality. By utilising current technology, the construction industry will have high productivity and save more construction cost due to the reduction of the failure cost. This report would look into how emerging technology is being used in the construction industry and how it is affecting the industry. Lastly, this research paper will also determine the effect of the IR4.0 to the other area. As we know the contribution of the construction industry to Malaysia is just around 10% to Malaysia GDP. Although the amount of contribution is low, but it will bring a high productivity to the other sector. After IR4.0 in construction industry, it will increase the productivity of the other industry due to the increase of factory construction rate.

Chapter 1

INTRODUCTION

1.1 Background of Study

Because of technological advancements, the Industrial Revolution 4.0 is rapidly changing. Construction 4.0, like Industry 4.0 for the automotive industry, refers to the exploration of new technologies by the design, engineering, construction, and operations industries. By determine the effect of the technology to the construction industry, this may ease the developer, consultant, engineers and contractors to be well prepared to face the industrial revolution. Among the technology that we can used in construction industry are big data, automation, Building information modelling and Virtual reality. These technologies can be used to ease the management of the construction projects. Construction project management starts with the analysis of vast amounts of practical data on requirements that should be changed before designers begin to create solutions based on measurable acceptance criteria.

Artificial intelligence technologies that process and learn from a large amount of data, according to Hamledari 2018, will optimise the transfer of functions to design solutions. The developer and management will make an informed decision by using the data.The virtual reality technique can reduce the miscommunication between architect and client. This will reduce the miscommunication between the stakeholders. In construction Industry there are many informations sharing and communications. By using appropriate technology, we can ease the communication between all the stakeholders. From the research of Pia Schonbeck 2020, the use of operational data will enable functional, information-based consumer decisions. Augmented reality offers an incentive for stakeholders in the design process to assess features. In addition, in the handover process, visualization techniques may transfer information to end users. The design of the product is often checked late in the construction process. Projects that do not have preventative measures to reduce defects. Digital processes that use acceptance values as conditions in construction projects allow for continuous monitoring and control of building outcomes.

1.2 Problem Statement

Construction industry is moving at face pace towards IR 4.0 by improving its processes and productivity. However, not much conclusive studies can be found analyzing IR 4.0 productivity effects in the construction processes, which creates an obstacle towards IR 40 effective implementation by stakeholders. This highlights the need to investigate productivity outcomes by IR 4.0 technologies for better understanding. Moreover, this transformation will replace some trades by the technologies, which might create some challenges to the labors with medium qualification. This will bring some negative effect to the society by creating uncertainty to job security. For effective implementation and acceptance of IR 4.0 among stakeholders, there is a need to access job opportunities under IR 4.0.

1.3 Research Outline

Objective

The objectives of this study are stated as below:

1. To identify the IR 4.0 technologies affecting the construction industry.
2. To investigate the productivity impacts by IR 4.0 technologies to construction processes.
3. To identify the effect of IR4.0 toward the Job opportunity in construction industry.

Scope of Work

This study will cover the IR 4.0 technologies which will be implemented in construction industry to increase the work productivity.

Chapter 2

LITERATURE REVIEW

2.1 IR4.0 Technology

2.1.1 Big Data

Smart cities are a relatively new form of urban growth. The rapid development of a new generation of information technology, the widespread application of computerization in urban management practises, and the promotion of better urban management approaches are all happening at the same time. Cloud computing-based smart service support and the Internet of Things big data cloud platform will provide higher technology for smart city development and make it more compatible with city social attributes. In the management of construction industry, there are many data such as traffic, security, coordinate, government data,education data, material procurement and so on.

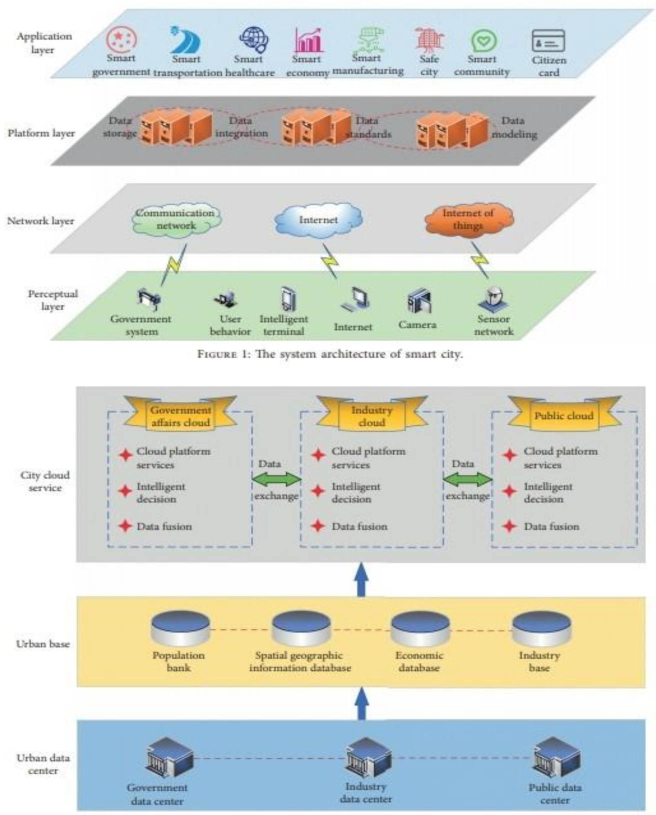

Figure 1: big data in construction industry (source: Zhao2020)

From the figure 1 by Zhao 2020, we can see that the application of big data in future development of smart city. The application layer consists of smart government, transportation, healthcare economy manufacturing, security, community and so on. In a construction industry, a series of data which include management, construction material procurement, quality inspection and nearby existing structure data collection need to be done before starting construction. When a deep interconnection between the industry. Pauleen & Wong 2016 state that the big data Is a set of data which is very large and complex to be processed by traditional software. By using the technology and Building information modelling system platform, we will be easier to communicate, save money, mitigate risk and so on. Based on the identified issues, more empirical validation and case studies for big data use in OSC can be conducted in the future. Big data has a lot of potential for improving supply chain management efficiency, but it can also be used for component design analysis, construction cost analysis, and time analysis in other areas of OSC. (WANG,2020)

2.1.2 Building information modelling

Cloud computing technology is the major transformation force towards industrial revolution 4.0. In the architecture, engineering, and construction industries, cloud-based BIM integration can be used to handle construction projects. According to a recent paper published by McGraw Hill Construction (2014), not only does implementing BIM in a construction project help to increase collaboration among project stakeholders, but it also helps to generate a good return on investment by eliminating errors and omissions. When a client wants to search for contractor, the cloud system will generate the tender document and advertise it to the contractors. Then the contractor can just send the document online for client's evaluation. This may increase the productivity of contractors due to the limited contracts and increased contractor numbers. A blockchain can be used in the cloud system so that the contractor competes in a fair platform. The tender evaluation can be done by the cloud analytic system to ensure the contract is awarded in a fair condition.

Figure 2 below shows that the function of cloud can be used in construction industry. When the building planning stage, we can use the cloud system to analyse the present data of the development area. Survey can be done easily from the data analysis system. Besides, cloud system may ease the developer to contact with local authority to ease the process of building plan approval. According to Wang X., Li H., Wong J. and Li H. there are many researchers had applied the cloud technology in the construction industry. Among the example are LEED compliant cloud to do life cycle of building assessment.

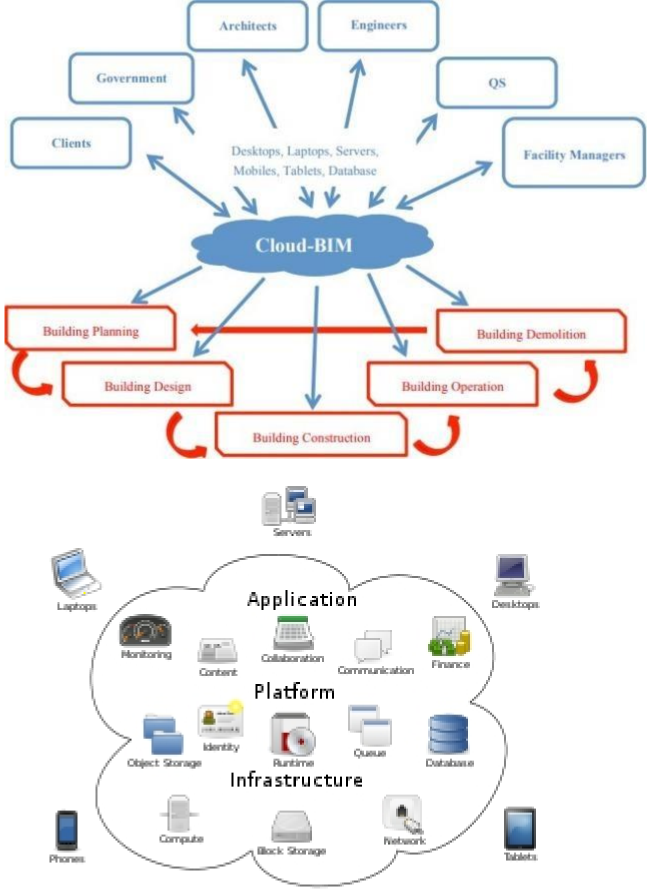

Figure2: Cloud BIM Concept

The use of virtual servers to access records, models, and data related to a project over an internet connection is cloud computing in construction. The rectification work program can be managed well by using a cloud software. The contractors, management and client can know the problem of the project and rectify it easily. Besides, a cloud can also function as a data analytical system to determine the major problems meet in the project. This may help the management to make an accurate decision.BIM and AR technology can be combined and used together as inspection tool, management and training purposed.

2.1.3 Automation and robotics

The construction industry is similar to the manufacturing industry. In fact, for builders, automation is a fantastic way to improve operational efficiency while lowering costs. Automation has a wide range of applications in the building industry, from the initial planning stages to the operation and maintenance of the final structure.

Sheet pile driving automation, according to Melebrink (2019), could reduce costs and improve safety for this critical construction job, as well as increase the scope for interventions. Prototype and design had been discussed in his research paper. The robot is capable of transporting a payload of three sheet piles to a new construction site, locomoting, and installing the piles in order. Piles interlock to create a continuous wall. Romu may theoretically build a wall of any length by travelling between a construction site and a supply cache for reloading. The pile is driven into the soil by Romu's own weight and vibration.

As a result of manual inspection of civil infrastructure, the need for a fully autonomous robotic system for civil infrastructure inspection is increasing. Pham and La (2016); Pham et al. (2016). By using robotic system in inspection, we can reduce the training cost of workers as the robotic system can replace the high skilled task with lower risk of failure. A drone can be used to determine the defects of the building. By utilizing drones in construction industry, we can ease the management and quality control process.

2.1.4 Augmented reality

In different phases and divisions of construction projects, AR is used. Many researchers assume that AR is the most obvious and obvious technology to be introduced in the construction project for introducing automation into construction. In 2018, AR will certainly make a significant contribution to changing the construction industry's culture to a fully automated industry in the near future.

The first function of AR will be shown in Scheduling and project progress tracking. From Zaher et al ' (2018), AR has significantly strengthened the building project's scheduling.; to allow visualization of construction development, It has the ability to show an as-planned vs. as-built shape. In their study, Hui et al. (2017) showed that In a building project, AR may be used to schedule safety tasks effectively. From the previous researchers, we can see that AR had changed the traditional method of construction scheduling.

Besides, AR technology will enhance the communication and data requisition. Effective communication and knowledge collection from the construction site is an essential requirement for successful construction projects. Thus, with the use of Virtual reality, project stakeholder will know the requirement of client accurately.

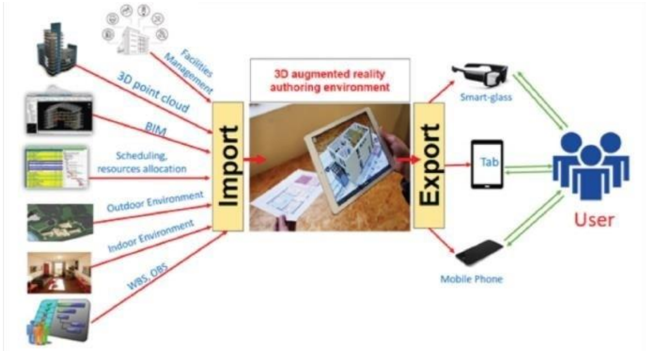

Figure 3 : information acquisition process using AR technology

AR systems provide quick and easy access to information, assisting project managers in determining corrective actions to minimize costs and delays caused by incompatibilities in results. Many researchers believe that augmented reality is one of the most effective ways to gather information from the construction site and that it could be a useful tool for interacting effectively among the project's various stakeholders.

AR technology also can be used in the most important part in construction. Quality control and defect prevention are important aspects of building management, as we all know. AR plays an important role in global construction because it allows for the integration of automation into the system for quality and defect management. Various studies demonstrate the usability of VR in QA/QC in a variety of ways. In a defect rectification process, the defect information will be sent to the site defect manager. The drawing will be change by the design management group or consultant. After the drawing is approved by site inspector, the workers will start to build the building. By using AR technology, the defect area will be reshaped in the 3D BIM model and the model will send to a CAU marker. We can compare the product we created with the 3D model using augmented reality. This approach can help staff make less mistakes.. AR technologies make it easier for construction management to deal with flaws that are likely to be unnoticed and save time in the inspection process. AR technologies improve the existing manual-based fault control to minimize the workloads of site supervisors and proactively eliminate construction job defects through the use of BIM and AR technologies.

2.1.5 3D printing

3D printing is a method of creating three-dimensional products from a digital format. (Ramya & Vanapallis, 2016, pp. 398-408). 3D printing, also known as additive manufacturing (AM), has the potential to revolutionise the construction industry, with anticipated benefits including improved structural performance, reduced material consumption and waste, streamlined and expanded design-build process, increased customization, greater architectural independence, and improved on-site accuracy and safety. Unlike traditional manufacturing methods for construction products, metal 3D printing allows for the rapid development of non-prismatic components, internal stiffening, openings, mechanically graded elements, variable microstructures, and mechanical properties by controlled heating and cooling and thermally induced prestressing. There will be new challenges and demands for the construction industry in additive manufacturing, such as the need for more technologically savvy engineers, a greater use of advanced computer analysis, and a new way of thinking for structure design and verification, with a greater focus on inspection and load testing. AM is intended to complement rather than replace conventional manufacturing processes, with a strong potential for hybrid solutions, structural strengthening, and repair.

Industry 4.0 necessitates the use of 3D printers. Today, 3D printing technology has reached a point where companies are recognising significant, tangible new value for themselves and their clients who use it. Leading companies and consultants around the world are investing heavily in 3D printing knowledge and skills so that they can advise and enter their customers in the surge of Industry 4.0, revolutionising supply chains, product portfolios, and business models in the process. This is excellent news for the 3D printing industry and the leading manufacturers. The cost of 3D printer will become lower when it started to globalize.

2.1.6 Data analytics and Artificiant intelligence

Risk management and evaluation can be improved with real-time data analytic, both on-site and off-site. It has the potential to offer smart wearables new capabilities in terms of accident prediction and sending early warnings and alarms to employees. It can also be used to assist machine learning systems that can deal with threats in real time. (Turner,2020). By managing the data produced from the construction industry, we can mitigate failure which induce management cost.

On the other hand, Yu 2016 state that For the estimation and prediction of concrete compressive force, Artificial Neural Networks were used to mine past experience. This has been useful in evaluating how the five key components of concrete, namely water, cement, metakaolin, fine aggregate, and coarse aggregate, affect concrete consistency and, as a result, building quality. These data are collected by placing sensors in an obtrusive manner on the structure being built. On the other hand, non-intrusive methods such as the use of RGB cameras could be a viable choice for recording the progress of construction projects. To manipulate data streams from RGB cameras, image processing techniques are being pioneered to extract useful information from captured digital images and videos.

The following are suggested potential directions for AI use in OSC based on the defined issues:

1. Configuration, segmentation, and optimization of prefabricated elements using AI-based design;
2 logistics data processing by complex data analysis.
3 Determine the distances between the plant and the construction site.
4 Optimize supply chain management to minimize costs.
5 Using historical and real-time data, predict various future project risks.

2.1.7 Internet of things (IoT)

New possibilities for directly linking wireless sensors to the Internet have emerged with the introduction of the Internet of Things (IoT) concept and the most recent development of the next generation of networking. The Internet of Things (IoT) is a network of connected objects (such as sensors) that can capture and exchange data in real time over the Internet. (MENG & ZHU ,2020). Abdelgawad (2017) mention that Since the Internet of Things allows for real-time data access from a remote location, a physical central station on a control site can be eliminated. Maintenance costs are reduced, and productivity is increased. The development of an IoT-based sensing system can provide a low-cost, dependable, and fast monitoring solution. In recent years, researchers have demonstrated the feasibility of integrating wireless sensor systems into the Internet of Things for structural monitoring. Current studies at the University of Olsztyn's Institute of Geodesy and Civil Engineering influenced the selection of criteria for controlling building structural protection (Poland).(ZABIELSKI, 2020).

IoT applications in construction have extensively used various integrated technologies such as RFID, sensors, and BIM. This section focuses primarily on IoT system architecture and current implementation barriers. WANG(2020) had mention about the future direction of IOT technology in construction industry. The following are some suggestions for IoT use in OSC in the future.:

1. Information sharing and transmission: network signals must be improved with greater stability; For real OSC standard service specifications, data consistency and delivery speed should be tested.
2. Data sharing and storage for logistics management in projects must be discussed in terms of security and privacy.
3. The IoT process should provide a quality audit of prefabricated parts in manufacturing, transportation and assembly systems, construction safety management, and environmental protection issues.
4. BIM, GPS, RFID, and other technologies should be built into industrial standards that are more applicable to OSC projects.
5. Rather than simulation by virtual models, more realistic experiments should be performed for implementation in real-life, off-site projects.

2.1.8 Blockchain

WANG,2020 mention that based on the identified problems, the usage of blockchain in smart contract management, addressing security concerns, and achieving a faster approval process are the immediate future directions for blockchain use in OSC. By using a blockchain, we can ensure the transparency as the tender will be send to different construction tender evaluation unit.In its implementations, blockchain technology demonstrates a range of advantages, including reliability, accountability, traceability, knowledge sharing, and monitoring. (Wang 2020). Smart contract management, resolving security concerns, and achieving a faster approval process are the immediate future directions for blockchain use in OSC, based on the defined issues.

2.1.9 GPS

Construction companies benefit greatly from GPS because it helps them handle costly machinery such as towers and mobile cranes, as well as earth moving equipment, support vehicles, and heavy trucks. In reality, it's widely used to monitor all kinds of properties, including generators and compressors. Zhong (2017) state that GPS can be used for load and unloading detail. It can help to determine the coordinates of precast components.

2.1.10 RFID

Radio Frequency Identification Devices (RFID) are devices that use radio waves to identify themselves (RFID) RFID systems are divided into two categories. The first is a powerless computer, while the second is an active machine with a battery in its name. The majority of RFID papers in OSC address the passive RFID process. A passive RFID system typically includes an antenna, RFID reader, and tag. The tags are often applied to vehicles, devices, and objects, allowing the status and numbers of the targeted items to be quickly identified and recorded in digital data. Wang 2017 mention that RFID can be used to identify the real time object information to ease the asset assessment. By introducing RFID in the management of resources, manpower, and equipment, CPM goals such as time, efficiency, cost, protection, and the environment can all be improved.

2.1.11 VR

Virtual reality in construction is advantageous to all parties involved. Virtual reality makes it much easier to clearly showcase and present a construction project, which reduces miscommunication between contractors, designers, and their clients. According to Zhang2019, VR technology can guide the production process.Training can be given to the construction labour using VR technology. This technology will solve the communication issues in construction industry.Besides, it enables stakeholders, especially those with limited experience and knowledge, to gain a first-hand understanding of the project.(Alaloul,2020). By using VR technology we can visualize the client expectation on the building and save more cost.

Chapter 3

Methodology

3.1 Description of Methodology

To achieve the project's objectives, the methodology is divided into four phases: data collection and interpretation in the first, second, and third stages, and research production in the fourth stage. The following sections go into the specifics of each stage:

Stage 1: Detailed literature review

Stage 2: Determine factor affecting construction industry

Stage 3: Questionnaire Development

Stage 4: Quantitative Survey

Stage 5: Sampling of data

Stage 6 Statistical analysis

Stage 7: Data Collection & Analysis as illustrated in Figure 4.

3.2 Detailed Literature Review

A thorough analysis of the literature on automated progress tracking in the construction industry will be done, resulting in a deeper understanding of the studies. In the past, exploratory research was conducted in the literature. A total of 148 related studies were discovered in the "Web of Science" research database.Following a thorough review, the number of relevant studies was reduced to 55 publications and a total of 11 developments that will impact the construction industry in the future, each with three factors. The appendix contains more information on each aspect.

3.3 Analytical Hierarchy Process (AHP)

Despite the fact that the AHP is one of the most sophisticated methods available in the field of management science and organizational research, it is difficult to incorporate due to its complexity. Fortunately, software tools have been developed to automate the mathematics-intensive part. To get the results, the user must follow a simple data collection methodology, which is then fed into the tool.

Procedure

Step 1: Define Alternatives

The AHP approach begins by defining the choices that must be considered. Alternatives may include the different criteria that must be used to determine solutions. They may also be distinct characteristics of a product that need to be weighted in order to better comprehend customer comprehension. At the conclusion of step 1, a complete list of all possible options must be prepared.

Step 2: Define the Problem and Criteria

The following step is to model the problem. According to the AHP methodology, a problem is a related set of subproblems. As a result, the AHP approach divides the problem into a hierarchy of smaller problems. In the course of breaking down the sub-problem, criteria for testing the solutions emerge. However, a person may move on to deeper levels of the issue, including root cause analysis. A subjective decision is when to avoid splitting the problem into smaller sub problems.

Example: To determine the best alternative that affect the work productivity. If the AHP method is used, the problem of best technology affected the productivity will be broken down into smaller problems like augmented reality, automation and robotics, cloud computing and so on. Each of these sub problems can then be broken into smaller problems till the appropriate criteria has been reached.

Step 3: Establish Priority among Criteria Using Pairwise Comparison

To construct a matrix, the AHP method uses pairwise comparison. For instance, the company would be asked to consider the relative value of technology versus job opportunities. So there will be a pairwise distinction between cloud computing and AR in the next matrix, and so on.The managers will be asked to fill this data according to the end user's or people who will use the process's expectations.

Step 4: Check Consistency

Most software tools that assist with AHP problems provide this move. For example, if I say that efficiency is twice as important as technology and that technology is half as important as economy in the next matrix, the following situation arises:

productivity = 2 (technology)

technology = 1/2 (job opportunity)

Therefore, productivity must equal job opportunity
However, If I gave a weight of more or less than 1 in the pairwise comparison of liquidity and likelihood of appreciation, then my information is inconsistent. Inconsistent evidence produces inconsistent outcomes, but avoidance is better than care.

Step 5: Get the Relative Weights

The programme tool can use the data to perform a statistical calculation and assign relative weights to the parameters. Once the equation is complete with weighted parameters, the alternatives can be evaluated to find the best match.

3.4 Quantitative Survey

Based on the results of the content review, a questionnaire survey was built based on previous efforts. The questionnaire was broken down into six parts, which are listed in the table below.

Section A	Demographic Profile
Section B	AHP Survey
Section C	Important Factors affecting construction productivity

The questionnaire used a Likert scale of 1 to 5 to gauge respondents' opinions on the technologies that could be used after IR4.0. All stakeholders in the construction industry who serve as contractors, consultants, developers, government agencies, non-government agencies, and institutions are eligible to participate in the survey.

3.4.1 Sampling

Contractors and staff registered with the Construction Industry Development Board (CIDB) were the study's target respondents. According to the CIDB's annual report for 2018, a total of 95997 contractors were recorded. With a population of 95997 and precision levels of 10%, the sample size was calculated using equation (1) below (Israel, 2003):

$$N=N/(1+N(e)^2$$

Where:

“N” represents population size,

“e” represents precision level

“n” represents sample size.

From the output of the equation, the minimum sample size was 99 and this study has obtained a total sample size of 100 which meet the minimum criteria of sample size.

3.4.2 Statistical Analysis

The data from the quantitative questionnaire was analysed using IBM SPSS 26. The collected data was then subjected to statistical analysis, descriptive analysis, and the computation of the Relative Importance Index (RII) for each factor. The following equation (2) was used to determine the value index (El-Sawalhi & Hammad, 2015)

$$\textbf{Relative Importance Index (RII)} = \sum W/AN = (5n_1+4n_2+3n_3+2n_4+1n_5)/5N$$

where w is the weighting given to each factor by the respondent, ranging from 1 to 5, The sample size is N, and n1 represents the number of respondents for "strongly disagree," n2 represents the number of respondents for "disagree," n3 represents the number of respondents for "neutral," n4 represents the number of respondents for "agree," n5 represents the number of respondents for "strongly agree," and N represents the number of respondents for "strongly agree."

3.5 Project Research Flowchart

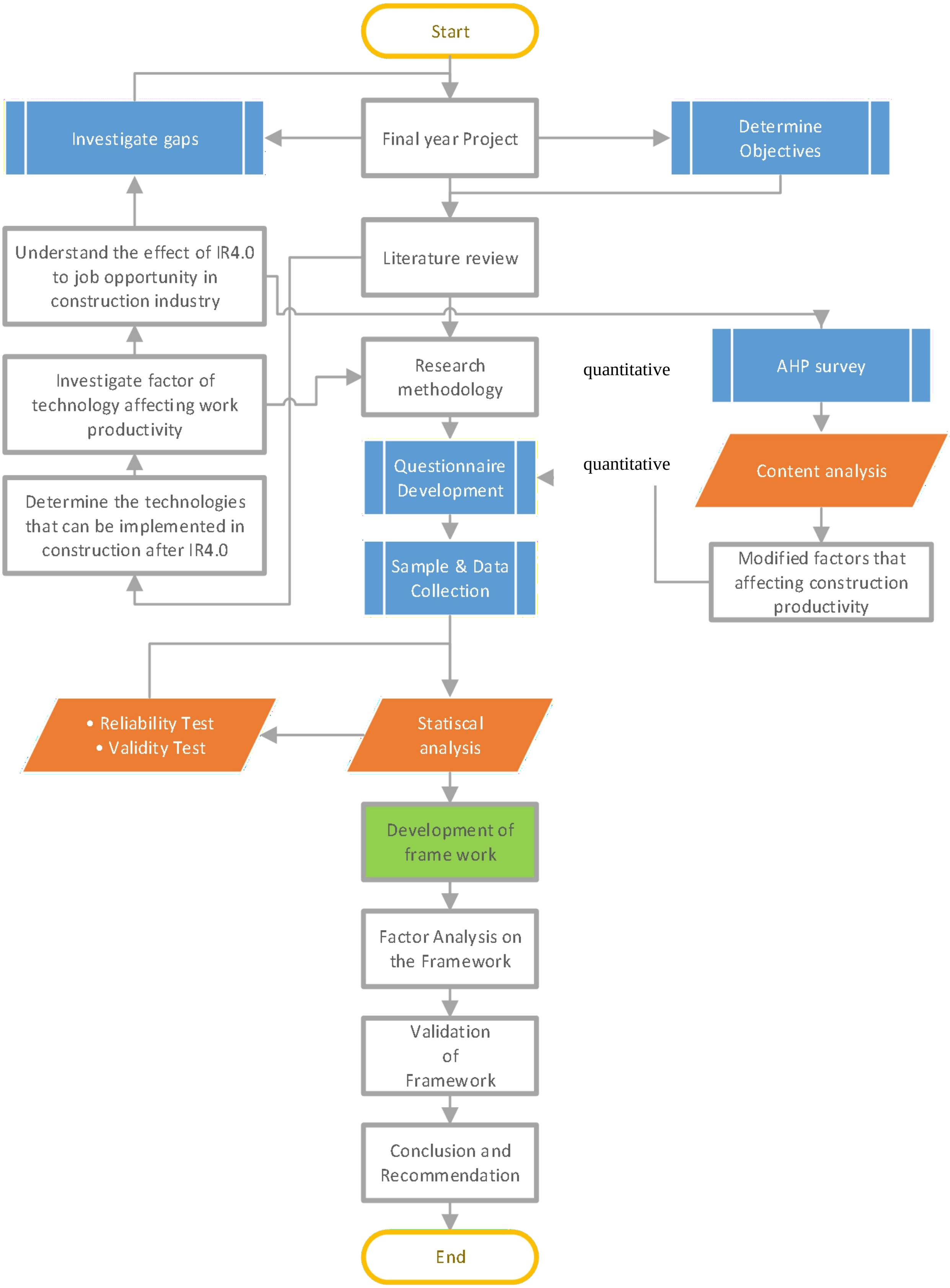

Figure 4 Flowchart of the FYP research

3.6 Gantt Chart

No.	PROJECT BREAKDOWN	project timeline																											
		2020														2021													
		SEPTEMBER		OCTOBER				NOVEMBER				DECEMBER				JANUARY				FEBRUARY				MARCH				APRIL	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project topic selection																												
2	Preminary research work																												
3	Submission of proposal																												
4	Research work & survey preparation																												
5	Proposal defence																												
6	Submission of draft interim report																												
7	Submission of draft interim report																												
8	Research & Survey																												
9	Conclude data																												
10	preparation of final draft report																												
11	Submission of Final report																												

Table1: Project Gantt chart

3.7 PROJECT RESEARCH KEY MILESTONE

No.	Details	Week
1	Project Topic Selection	1, 2
2	Preliminary Research Work	2, 3, 4, 5
3	Extended Proposal Submission	6
4	Project Work Continues	7
5	Proposal Defence	8, 9
6	Project Work Continues	10, 11, 12
7	Interim Draft Report Submission	13
8	Interim Report Submission	14
9	Project Work Continues	1, 2, 3, 4, 5, 6, 7
10	Progress Report Submission	7
11	Project Work Continues	8, 9, 10, 11, 12
12	Pre-Sedex	10
13	Draft Final Report Submission	11
14	Dissertation Submission (Soft Bound)	12
15	Technical Paper Submission	12
16	Viva	13
17	Project Dissertation Submission	15

Table2: Project milesto

Chapter 4

Result and Discussion

This chapter covered the data collection, analysis, and discussion for each of the stages mentioned in Chapter 3. (research methodology).The content analysis, which is the product of the quaantitative survey, will be introduced and discussed first in this chapter. Second, the statistical interpretation of the quantitative survey results will be analysed and presented. Finally, the factor analysis of the core factors that contributed to the conceptual structure's creation will be discussed and presented.

4.1 Descriptive analysis

Data was collected from construction stakeholders in Peninsular Malaysia through a questionnaire survey. A total of 305 emails were sent to the Construction Industry Development Board's registered members (CIDB). Just 101 people out of 580 responded, yielding a response rate of 17.4 percent. The collected data for the variables was analysed using IBM SPSS 26 software for the descriptive analysis. The graphs below depict the demographic profile of the respondents.

Table 3: Respondents educational level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1. HIGHEST EDUCATION LEVEL	1	1.0	1.0	1.0
	Bachelor's Degree	81	80.2	80.2	81.2
	Diploma	1	1.0	1.0	82.2
	Doctorate, Phd	1	1.0	1.0	83.2
	foundation	1	1.0	1.0	84.2
	Master's Degree	9	8.9	8.9	93.1
	secondary	1	1.0	1.0	94.1
	SPM	6	5.9	5.9	100.0
	Total	101	100.0	100.0	

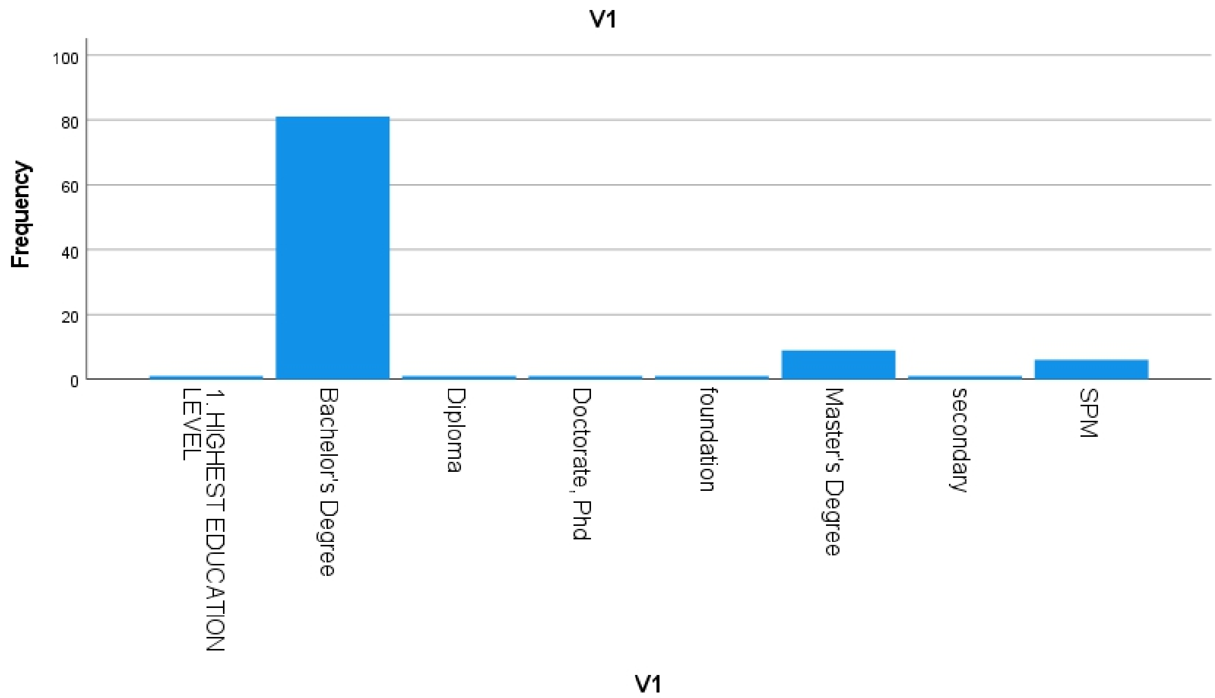

Figure 5: Highest Education Level of the respondents

From the figure above 80.2 percent (81out of 101) of the 101 total respondents had earned a bachelor's degree, 9 percent (8.9 out of 101) had earned a master's degree, and 5.9 percent (6 out of 101) had earned their highest education, SPM. It was important to know the respondents' educational levels in order to ensure that their responses were accurate.

Table 4: Organization main business

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	8	7.9	7.9	7.9
	Construction Contract Management System Provider	1	1.0	1.0	8.9
	Construction material supplier	7	6.9	6.9	15.8
	Construction Project Management	6	5.9	5.9	21.8
	Consultant	7	6.9	6.9	28.7
	Contractor	26	25.7	25.7	54.5
	Developer	30	29.7	29.7	84.2
	education	1	1.0	1.0	85.1
	Education	3	3.0	3.0	88.1

	Government agency	1	1.0	1.0	89.1
	Manufacturing	3	3.0	3.0	92.1
	MANUFACTURING	1	1.0	1.0	93.1
	mechanical	1	1.0	1.0	94.1
	NGO agency	1	1.0	1.0	95.0
	Quantity Surveyors	1	1.0	1.0	96.0
	Researchers	2	2.0	2.0	98.0
	Students	1	1.0	1.0	99.0
	WORKER	1	1.0	1.0	100.0
	Total	101	100.0	100.0	

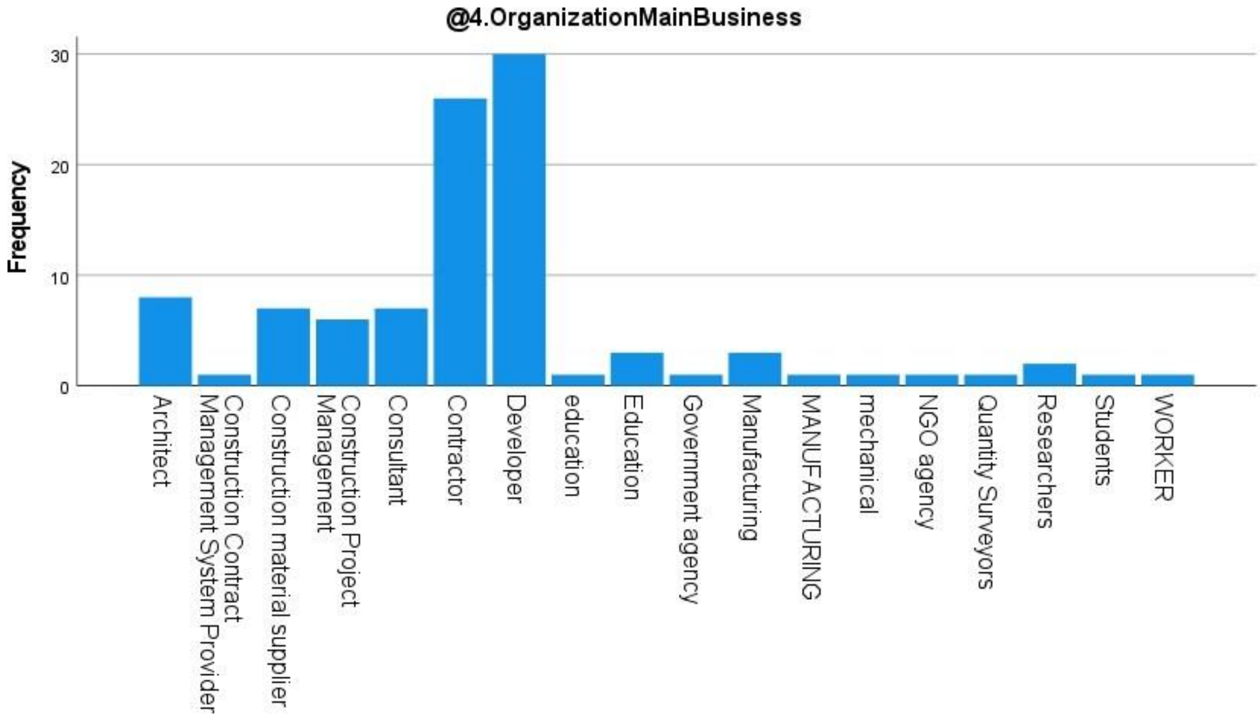

Figure 6: Organization Main Business of the respondents

To the data from a different perspective, he variety of organization main business is open for the survey. 29.7 percent (30/101) of the respondents work as developer, 25.7 percent (26/101) is contractor, 6.9 percent (7/101)work as consultant and 7.9 percent (8/101architect each. For construction material supplier and construction project management, an percentage of 7.4% (5/68) each involved in this survey. The other 13 respondents are from manufacturing and educational area.

Table 5: Year of experiences

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 to 3 years	30	29.7	29.7	29.7
	3 to 5 years	33	32.7	32.7	62.4
	5 to 10 years	15	14.9	14.9	77.2
	Less than 1 year	19	18.8	18.8	96.0
	More than 10 years	4	4.0	4.0	100.0
	Total	101	100.0	100.0	

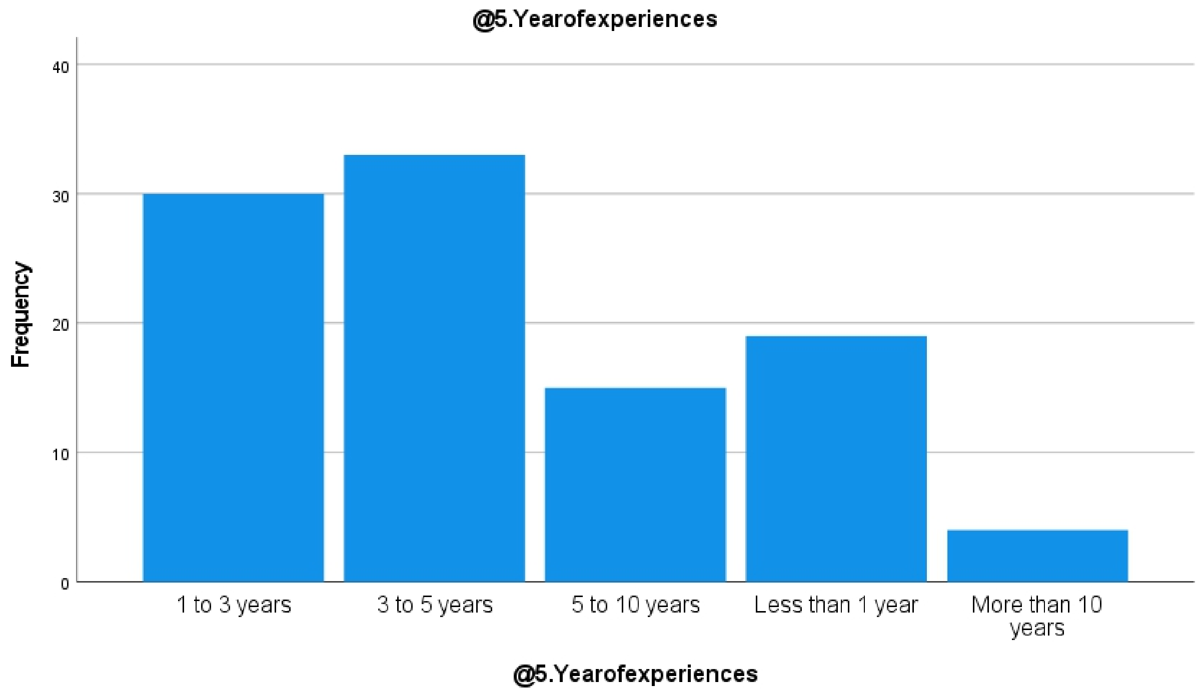

Figure 7: Years of Working Experience

Regarding the work experience, 32.7% (33 out of 101) of respondents have worked for 3-5 years,29.7% (30 out of 101) of respondents have worked for 1-3 years and 14.9% (15 out of 101) of respondents have worked for 5-10 years which shows that the respondents have sufficient experience and knowledge in the research industry.

4.2 Analytical Hierarchy Process

4.3.1 AHP analysis for main criteria

	Technology	work productivity	Job opportunity
Technology	1.00	5.00	5.00
work productivity	0.20	1.00	6.00
Job opportunity	0.20	0.17	1.00
total	1.40	6.17	12.00

	Technology	work productivity	Job opportunity	Weightage	Ranking
Technology	0.71	0.81	0.42	**1.942**	**1**
work productivity	0.14	0.16	0.50	**0.805**	**2**
Job opportunity	0.14	0.03	0.08	**0.253**	**3**
total	1.00	1.00	1.00		

Table 6: AHP analysis for one of the respondents

From the response of the respondent, technology will affect a lot to that construction industry after IR4.0 Norms. When the construction technologies came into the industry, it will affect work productivity and followed by job opportunity. As compare the responses from construction industry workers, we found out that 87.1% (88 out of 101respondents) had the same responses.

4.2.1 AHP analysis of alternative in worker productivity

	VR	GPS	RFID	BLOCKCHAIN	BIM	IOT	Data analytic and AI	3D printing	AR	Automation & Robotic	Big data
VR	1	6.00	3.00	0.33	0.33	1.00	5	0.33	2	3	0.166666667
GPS	0.17	1	6.00	2	7	1	2	2	3	2	0.166666667
RFID	0.33	0.17	1	6	4	1.00	5	5	1	0.5	0.166666667
BLOCKCHAIN	3.00	0.5	0.17	1	6	1	1	1	2	8	1
BIM	3.03	0.142857143	0.25	0.166666667	1	6	1	4	3	1	2
IOT	1.00	1	1.00	1	0.17	1	6	1	2	0.5	9
Data analytic and AI	0.20	0.5	0.2	1	1	0.166666667	1	6	1	1	1
3D printing	3.03	0.5	0.2	1	0.25	1	0.166666667	1	6	1	4
AR	0.50	0.333333333	1	0.5	0.333333333	0.5	1	0.166666667	1	6	1
Automation & Robotic	0.33	0.5	2	0.125	1	2	1	1	0.166666667	1	6
Big data	6.00	6	6	1	0.5	0.111111111	1	0.25	1	0.166666667	1
total	18.59393939	16.64285714	20.81666667	14.125	21.58	14.77777778	24.16666667	21.74666667	22.16666667	24.16666667	25.5

Table 7: Responses from a respondent

	VR	GPS	RFID	BLOCKCHAIN	BIM	IOT	Data analytic and AI	3D printing	AR	Automation & Robotic	Big data	total	ranking	Avg	Consistency
VR	0.05	0.36	0.14	0.02	0.02	0.07	0.21	0.02	0.09	0.12	0.01	1.11	6	0.10	19.23
GPS	0.01	0.06	0.29	0.14	0.32	0.07	0.08	0.09	0.14	0.08	0.01	1.29	1	0.12	20.64
RFID	0.02	0.01	0.05	0.42	0.19	0.07	0.21	0.23	0.05	0.02	0.01	1.26	2	0.11	18.22
BLOCKCHAIN	0.16	0.03	0.01	0.07	0.28	0.07	0.04	0.05	0.09	0.33	0.04	1.16	4	0.11	19.47
BIM	0.16	0.01	0.01	0.01	0.05	0.41	0.04	0.18	0.14	0.04	0.08	1.13	5	0.10	18.19
IOT	0.05	0.06	0.05	0.07	0.01	0.07	0.25	0.05	0.09	0.02	0.35	1.07	7	0.10	21.68
Data analytic and AI	0.01	0.03	0.01	0.07	0.05	0.01	0.04	0.28	0.05	0.04	0.04	0.62	10	0.06	19.21
3D printing	0.16	0.03	0.01	0.07	0.01	0.07	0.01	0.05	0.27	0.04	0.16	0.87	8	0.08	19.08
AR	0.03	0.02	0.05	0.04	0.02	0.03	0.04	0.01	0.05	0.25	0.04	0.56	11	0.05	18.74
Automation & Robotic	0.02	0.03	0.10	0.01	0.05	0.14	0.04	0.05	0.01	0.04	0.24	0.71	9	0.06	23.43
Big data	0.32	0.36	0.29	0.07	0.02	0.01	0.04	0.01	0.05	0.01	0.04	1.22	3	0.11	21.82
total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00		CI=	3.743
														RI=	1.12
														CR=	3.342

Table 8: AHP analysis of one of the respondents

From the analysis of the respondent response, we had ranked out the weightage of the technology in affecting the construction technology. The respondent had mentioned that GPS is the most important technology in the construction industry. The technology is then followed by RFID, big data, Blockchain, BIM, VR, IOT, 3D printing, automation& robotic, data analytic and AI and lastly AR.

After summarized the 101 responses from survey, a ranking of technologies that will affect the construction productivity is shown in the table below:

Rank	Technology
1	Virtual Reality
2	GPS
3	Internet of Things (IOT)
4	RFID
5	Building Information System
6	Blockchain
7	Data analytical and AI
8	3D printing
9	Augmented Reality
10	Automation and Robotics
11	Big Data

Table 9: ranking of technologies that will affecting the construction productivity

4.3 Relative Importance Index (RII)

The ranking results for the important factors are shown in Table 10 below. As indicated by, the significance level of each factor can be classified as follows: (Akadiri, 2011), High, H (0.8 RII 1), High to Medium, H-M (0.6 RII 0.8), Medium, M (0.4 RII 0.6), Medium to Low, M-L (0.2 RII 0.4), and Low, L (0 RII 0.2).

Technology	Solution	Relative Index	Ranking by category	Importance Level
VR	project members use VR to mitigate uncertainty.	0.83960396	4	H
	helps stakeholders to understand the project from a first-person perspective, especially those with of lack experience and expertise	0.855445545	2	
	Project designing	0.84950495	3	H
	VR-based techniques have been utilized in the construction sector training sessions.	0.885148515	1	H
GPS	detect coordinates of precast components for load and unloading information.	0.863366337	1	H
	asset tracking	0.857425743	2	H
	Construction Progress Monitoring	0.851485149	3	H
RFID	To automatically identify near-real-time object information	0.831683168	2	H
	To detect the status of elements for asset management	0.845544554	1	H
	To collect the near-real-time status of components.	0.831683168	2	H
BLOCKCHAIN	Reduction of supply chain cost with improved efficientcy	0.881188119	1	H
BIM	Construction Logistics.	0.851485149	1	H
	Clash Detection.	0.847524752	4	H
	Site Monitoring.	0.845544554	6	H
	Quality Control.	0.861386139	3	H
	Safety Management.	0.862745098	2	H
	Cost Estimation.	0.84660194	5	H

		2		
IOT	timely information sharing	0.865346535	1	H
	To realize automatic data collection and item-level management.	0.861386139	2	H
	To collect and visualize emissions	0.855445545	3	H
	To achieve near-real-time visibility and traceability in OSC.	0.833663366	4	H
Data analytics and Artificiant intelligence	To estimate transportation cost.	0.84950495	4	H
	To optimize or predict the construction tasks.	0.855445545	3	H
	To optimize supply chain management and assist selecting factory locations	0.871287129	1	H
	To assist optimizing the design of prefabricated components.	0.861386139	2	H
3D printing	low skill worker needed less architect, engineer and contractors	0.857425743	3	H
	Utilization of regulated technologies over manual operations will minimize the human errors,	0.865346535	2	H
	Wastage Control	0.835643564	6	H
	Enhances Working Efficiency	0.855445545	4	H
	Construction Safety	0.871287129	1	H
	Less Site Machinery and Equipment	0.84950495	5	H
	Freedom of Design and Flexibility	0.831683168	7	H
Augmented REALITY	Improving performance in Construction processes	0.857425743	1	H
	Mobile AR provides visual diagrams, instructions, and technical information to maintenance workers overlaid on actual control panels	0.851485149	2	H
Automation and robotic	The aim of this study was to look into the factors that influence robotics adoption in precast concrete production.	0.877227723	2	H
	Use of robotics for construction progress monitoring	0.867326733	3	H
	To build a robotic system or manufacturing automation strategies	0.881188119	1	H
Big Data	improve the supply chain management	0.906930693	1	H

	BIM integrated construction processes for life cycle assesment	0.867326733	3	H
	extracting knowledge to facilitate decision making processes	0.899009901	2	H
	Retrieving data from sensors intregated across IoT environment and systems	0.845544554	4	H

Table 10: Relative Importance Index for each Technologies

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The current study showed how technology would help construction workers be more productive. Regardless the organization accept or not, technologies will replace the traditional construction industry. In order to achieve the study's goals, a quantitative approach was used. TThe research starts with a thorough analysis of the literature, which uncovered the key factors thought to affect construction efficiency. As a result, the results from previous research were used to conduct an observational hierarchy process survey, which was followed by content review.The result showed that there are 11 technologies which will be used in the construction industry with 41 factors that affecting the construction productivity we had used AHP method to determine the weightage of technology that will affect the construction productivity. A quantitative questionnaire survey was also performed, which included all 46 important factors in order to use the Relative Importance Index to assess the most important factor in each technique. The questionnaire's findings indicate that the data is trustworthy, and that all of the variables are of "High" significance.As a result, factor analysis was used to create a conceptual framework for construction productivity after IR4.0 Norms. To minimize the number of variables, exploratory factor analysis was used first, and nine latent constructs were identified. Among the latent construct are VR, GPS, RFID, BIM, IOT, Data analytics & AI, 3D printing, Automation & robotics and Big Data.

To summarise, the study's objectives were met, but there were some flaws despite the study's best efforts. As a consequence, it is suggested that further work be done to develop and refine the constructs. First, the sample data size was insufficient for factor analysis; however, a larger sample size is expected to improve the model's fitness significantly.Second, the number of construction industry experts interviewed was insufficient; at least five construction industry experts with at least ten years of experience should be interviewed. As a result, it is anticipated that the findings of this study would be helpful to the construction project in terms of transforming the construction business to achieve higher construction productivity.

References

Abdelgawad, A.; Yelamarthi, K. Internet of things (IoT) platform for structure health monitoring. Wirel. Commun. Mob. Comput. 2017, 2017, 6560797. [CrossRef]

Adams, W. C. (2015). Conducting Semi-Structured Interviews. Handbook of Practical Program Evaluation: Fourth Edition, August, 492–505. https://doi.org/10.1002/9781119171386.ch19

Adeleke, A. Q. (2020). Industrial Revolution 4.0 can help boost construction industry. *New Straits Time*. Retrieved from: https://www.msn.com/en-my/news/national/industrial-revolution-40-can-help-boost-construction-industry/ar-BB19RYCB

Ahn, S.; Han, S.; Al-Hussein, M. Improvement of transportation cost estimation for prefabricated construction using geo-fence-based large-scale GPS data feature extraction and support vector regression. Adv. Eng. Inform. 2020, 43.

Akadiri, O. P. (2011). Development of a multi-criteria approach for the selection of sustainable materials for building projects. PhD Thesis - University of Wolverhampton, 1–437. http://wlv.openrepository.com/wlv/bitstream/2436/129918/1/Akadiri_PhD thesis.pdf

Akinade, O.O. *Bim-Based Software for Construction Waste Analytics Using Artificial Intelligence Hybrid Models*; University of the West of England: Bristol, UK, 2017.

Alaloul.W.S, Saad.S, Qureshi.A.H. Construction Sector: IR 4.0 Applications.

Ali, S.; Al Balushi, T.; Nadir, Z.; Hussain, O.K. *ICS/SCADA System Security for CPS*; Studies in Computational Intelleigence; Springer-Verlag: Cham, Switzerland, 2018; Volume 768, pp. 89–113.

Anderer, J (2020) Work productivity improves after 30 minutes of fresh air outdoors, research shows. *Study Find*. Retrieved from: https://www.studyfinds.org/work-productivity-30-minutes-fresh-air/

A. Rashidi, M.H. Sigari, M. Maghiar, and D. Citrin, 2016. An analogy between various machine-learning techniques for detecting construction materials in digital images. KSCE Journal of Civil Engineering, 20(4), pp.1178-1188. 2016

Arashpour, M.; Heidarpour, A.; Akbar Nezhad, A.; Hosseinifard, Z.; Chileshe, N.; Hosseini, R. Performance-based control of variability and tolerance in off-site manufacture and assembly: Optimization of penalty on poor production quality. Constr. Manag. Econ. 2020, 38, 502–514.

Baldini, G.; Desruelle, P.; Bono, F.; Delipetrev, B.; Gkoumas, K.; Sanchez, I.; Pagano, A.; Nepelski, D.; Prettico, G.; Urzi Brancati, C.; et al. Digital Transformation in Transport, Construction, Energy, Government and Public Administration; Publications Office of the European Union: Luxembourg, 2019

Benzama, S. (2020) , answer on question "How would you describe the year of 2020 in one word/ picture," *Quora*,(6 May 2020), https://www.quora.com/How-would-you-describe-the-year-2020-in-one-word-picture-not-just-from-your-perspective

Boeing (2018) Boeing Tests Augmented Reality in the Factory, Boeing Innovation and Technology. Available at: https://www.boeing.com/features/2018/01/augmented-reality-01-18.page

Buchanan, J., Kelley, B. and Hatch, A. (2016) Digital workplace and culture: How digital technologies are changing the workforce and how enterprises can adapt and evolve.

Carneiro, J.; Rossetti, R.J.F.; Silva, D.C.; Oliveira, C. BIM, GIS, IoT, and AR/VR Integration for Smart Maintenance and Management of Road Networks: A Review. In Proceedings of the 2018 IEEE International Smart Cities Conference, ISC2, Kansas City, MO, USA, 16–19 September 2018.

Ding, K.; Shi, H.; Hui, J.; Liu, Y.; Zhu, B.; Zhang, F.; Cao, W. Smart steel bridge construction enabled by BIM and Internet of Things in industry 4.0: A framework. In Proceedings of the 2018 IEEE 15th International Conference on Networking, Sensing and Control (ICNSC), Zhuhai, China, 27–29 March 2018; pp. 1–5.

Doanne, D. P., & Seward, L. E. (2011). Measuring Skewness. Journal of Statistics, 19(2), 1–18

EC (2018). Capitalising on the benefits of the 4th Industrial Revolution. Brussels: European Commission.

Frankenfield, J (2020). Cloud Computing. *INVESTOPEDIA.* . Retrieved from: https://www.investopedia.com/terms/c/cloud-computing.asp#:~:text=Types%20of%20Cloud%20Computing%20Cloud%20computing%20is%20not,services%3A%20software-as-a-service%20%28SaaS%29%2C%20infrastructure-as-a-service%20%28IaaS%29%2C%20and%20platform-as-a-service%20%28PaaS%29.

Gbadamosi, A.Q.; Mahamadu, A.M.; Oyedele, L.O.; Akinade, O.O.; Manu, P.; Mahdjoubi, L.; Aigbavboa, C. Offsite construction: Developing a BIM-Based optimizer for assembly. J. Clean. Prod. 2019, 215, 1180–1190.

Gie Yong An, P. S. (2013). A Beginner's Guide to Factor Analysis: Focusing on Explotary Factor Analysis. Journal of Financial Services Marketing, 9(2), 79–94. https://doi.org/10.1057/fsm.2014.17

Garg, A.; Kamat, V.R. Virtual Prototyping for Robotic Fabrication of Rebar Cages in Manufactured Concrete Construction. J. Archit. Eng. 2014, 20, 06013002.

Hamledari, H.; Azar, E.R.; McCabe, B. IFC-Based Development of As-Built and As-Is BIMs Using Construction and Facility Inspection Data: Site-to-BIM Data Transfer Automation. J. Comput. Civ. Eng. 2018, 32, 04017075

Han, C.; Ye, H. A novel IoT-Cloud-BIM based intelligent information management system in building industrialization. In Proceedings of the 2018 International Conference on Construction and Real Estate Management: Innovative Technology and Intelligent Construction (ICCREM 2018), Charleston, SC, USA, 9–10 August 2018; pp. 72–77.

Han, D.; Yin, H.; Qu, M.; Zhu, J.; Wickes, A. Technical Analysis and Comparison of Formwork-Making Methods for Customized Prefabricated Buildings: 3D Printing and Conventional Methods. J. Archit. Eng. 2020, 26

Han KK, Golparvar-Fard M (2017) Potential of big visual data and building information modeling for construction performance analytics: An exploratory study. Autom Constr 73:184–198 . https://doi.org/10.1016/j.autcon.2016.11.004

Han, Z.; Wang, Y. The applied exploration of big data technology in prefabricated construction project management. In Proceedings of the 2017 International Conference on Construction and Real Estate Management: Prefabricated Buildings, Industrialized Construction, and Public-Private Partnerships (ICCREM 2017), Guangzhou, China, 10–12 November 2017; pp. 71–78.

HOSSAIN et.al.(2020). A Review of 3D Printing in Construction and its Impact on the Labor Market

Huda, S.; Miah, S.; Hassan, M.M.; Islam, R.; Yearwood, J.; Alrubaian, M.; Almogren, A. Defending unknown attacks on cyber-physical systems by semi-supervised approach and available unlabeled data. *Inf. Sci.* **2017**, *379*, 211–228.

Hui, P., Wei, J., & Peylo, C. (2017). System and method for mobile augmented reality task scheduling: Google Patents.

Hwang, B.-G.; Shan, M.; Looi, K.-Y. Knowledge-based decision support system for prefabricated prefinished volumetric construction. Autom. Constr. 2018, 94, 168–178.

J.B. Yu, Y. Yu, L.N. Wang, Z. Yuan, and X. Ji, The knowledge modeling system of ready-mixed concrete enterprise and artificial intelligence with ANN-GA for manufacturing production. Journal of Intelligent Manufacturing, 27(4), 2016. pp.905-914. 2016.

Krieg, O.D.; Lang, O. Adaptive automation strategies for robotic prefabrication of parametrized mass timber building components. In Proceedings of the 36th International Symposium on Automation and Robotics in Construction (ISARC 2019), Banff, AB, Canada, 21–24 May 2019; pp. 521–528.

Li, C.Z.; Xue, F.; Li, X.; Hong, J.; Shen, G.Q. An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction. Autom. Constr. 2018, 89, 146–161.

Lorenz, M., Rüßmann, M., Strack, R., Lueth K., & Bolle M. Man and Machine in Industry 4.0. Boston: Boston Consulting Group.

Mao, C.; Tao, X.; Yang, H.; Chen, R.; Liu, G. Real-time carbon emissions monitoring tool for prefabricated construction: An IoT-based system framework. In Proceedings of the 2018 International Conference on Construction and Real Estate Management: Sustainable Construction and Prefabrication (ICCREM 2018), Charleston, SC, USA, 9–10 August 2018; pp. 121–127.

McIntosh, M. J., & Morse, J. M. (2015). Situating and constructing diversity in semistructured interviews. Global Qualitative Nursing Research, 2. https://doi.org/10.1177/2333393615597674

Melenbrink, Nathan, and Justin Werfel. (2019) Autonomous Sheet Pile Driving Robots for Soil Stabilization. In proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Montreal, Canada, May 20-24.

MENG & ZHU ,(2020). Developing IOT Sensing System For Construction-Induced Vibration Monitoring and Impact-assesmentPan, M.;

Pan, M.; Pan, W. Determinants of Adoption of Robotics in Precast Concrete Production for Buildings. J. Manag. Eng. 2019, 35

Pan, W. Determinants of Adoption of Robotics in Precast Concrete Production for Buildings. J. Manag. Eng. 2019, 35.

Pauleen, D.J., & Wang, W.Y.C. (2016). Does big data mean big knowledge? KM perspectives on big data and analytics. Journal of Knowledge Management, 21(1). https://doi.org/10.1108/JKM-08- 2016-0339 b

Pham, N. H., & La, H. M. (2016). Design and implementation of an autonomous robot for steel bridge inspection. In 2016 54th annual allerton conference on communication, control, and computing (Allerton) (p. 556-562). doi: 10.1109/ALLERTON.2016.7852280

Prescott, C. (2018) ‘Dataset: Business enterprise research and development (2006-2017)’. Office for National 977 Statistics. Available at: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/datasets/ukb usinessenterpriseresearchanddevelopment.

Ramya, A., & Vanapalli, S. (2016). 3D printing technologies in various applications. International Journal of Mechanical Engineering and Technology, 7(3) 116-127.

Rymarczyk,J. (2020). Technologies, Opportunities and Challenges of the Industrial Revolution 4.0: Theoretical Considerations 8(1)

Schwab, K. (2016b). The Fourth Industrial Revolution: What it means. New York: Crown Publishing Group.

Smith, C. 3-D Printing Reshaping Construction Industry. Available online: https://www.dcd.com/articles/3-d-printing-reshaping-construction-industry (accessed on 1 July 2020).

Turner.C.J, Oyekan.J et.al (2020) Utilizing Industry 4.0 on the Construction Site:Challenges and opportunities.IEEE Transactions on Industrial Informatics

WANG, M. WANG, C., C. et.al. (2020). A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction towards Industry 4.0.

Wang, Z.; Wang, T.; Hu, H.; Gong, J.; Ren, X.; Xiao, Q. Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. Autom. Constr. 2020, 111, 103063

Xu, G.; Li, M.; Chen, C.H.; Wei, Y. Cloud asset-enabled integrated IoT platform for lean prefabricated construction. Autom. Constr. 2018, 93, 123–134

ZABIELSKI.j (2020). Monitoring of structural safety of building using wireless network of MEMS sensors.Faculty of Geo i=engineering,University of Warmia and Mazury in Olszltyn,10-719

Zaher, M., Greenwood, D., & Marzouk, M. (2018). Mobile augmented reality apications for construction projects. *Construction Innovation, 18*(2), pp. 152–166.

Zhang,RX, Tang YY et.al (2020). Factor Incluencing BIM Adoption for Construction Enterprises in China

Zhang, Z.; Pan, W. Virtual reality (Vr) supported lift planning for modular integrated construction (mic) of high-rise buildings. Hong Kong Inst. Eng. Trans. 2019, 26, 136–143.

Zhao,Zhang (2020). Impact of Smart City Planning and Construction on Economic and Social Benefits Based on Big Data Analysis. *Hindawi*.

Zhong, R.Y.; Peng, Y.; Xue, F.; Fang, J.; Zou, W.; Luo, H.; Thomas Ng, S.; Lu, W.; Shen, G.Q.P.; Huang, G.Q. Prefabricated construction enabled by the Internet-of-Things. Autom. Constr. 2017,