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DIGITALISATION FOR OPTIMISATION ON CIVIL CONSTRUCTION – CASE STUDY

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To my Grandfather,

Professor Doutor Carlos Azevedo

RESUMO

Durante a última década, a crescente implementação de tecnologias diversificadas viabilizou a digitalização, automatização e incorporação de processos de construção em todas as fases da cadeia de valor da construção (Oesterreich e Teuteberg, 2016).

Contudo, na realidade, o conceito de Construção 4.0 não consiste somente na utilização de tecnologias novas ou já existentes no sector da construção. O conceito de Construção 4.0 pressupõe igualmente uma transformação abrangente e profunda dos processos de gestão das empresas de construção através da exploração e sucessiva aplicação dos dados recolhidos em tempo real, utilizando tecnologias novas ou já existentes para efeitos de tomada de decisão (Dallasega et al., 2018).

Numa fase inicial da redacao deste documento, foi feita uma analise a conjetura da industria da construcao civil. Quais as tecnologias, os processos, e os conceitos que sao implementados diariamente e quais as metodologias e ferramentes digitais utilizadas.

A tese seguinte visa explorar as potenciais dinâmicas e mudanças aplicadas na indústria da construção, com base num estudo de caso dos trabalhos desenvolvidos pela empresa Regal Homes London, com sede em Londres, através da implementação de ferramentas de gestão que visam optimizar os processos na indústria da construção, a fim de facilitar a análise dos dados e, consequentemente, o processo de tomada de decisão.

PALAVRAS-CHAVE: Construcao 4.0, Digitalização, Otimizacao, Plataformas Colaborativas, Produtividade.

ABSTRACT

During the past decade, the increasing use of a wide range of technologies has enabled the digitalisation, automation and integration of construction processes at all stages of the construction value chain (Oesterreich and Teuteberg, 2016).

However, in practice, Construction 4.0 is not only about using new or existing technologies in the construction sector. The concept of Construction 4.0 also implies a comprehensive and deep transformation of construction companies project management processes through the use and exploration of data collected in real time using new or existing technologies for decision-making purposes (Dallasega et al., 2018).

An overview of the construction industry was made at an early stage of writing this document. Which technologies, processes, and concepts are implemented on a daily basis and which methodologies and digital resources are employed.

The purpose of this thesis is to explore the potential of dynamic changes in the construction industry, through a case study of the work developed within the company Regal Homes London, based in London, through the implementation of management tools that are aimed to optimise processes in the construction industry in order to facilitate data analysis and therefore the decision-making process.

KEYWORDS: Collaborative Platforms, Construction 4.0, Digitalisation, Optimisation, Productivity.

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SYMBOLS, ACRONYMS AND ABBREVIATIONS

A&R – Automation and Robot

AI – Artificial Intelligence

AM – Additive Manufacturing

BD – Big Data

BIM – Building Information Modelling

CC – Cloud Computing

CCS – Considerate Constructors Scheme

CMP – Construction Management Plan

CPPS – Cyber-Physical System

GPRS – General Packet Radio System

GSI – Grid Secure Infrastructure

GSM – Global System for Mobile communication

HCI/HRI – Human - Computer/Robot Interaction

IFC – Industry Foundation Classes

IoT – Internet of Things

ISO:14001 – International Standard that specifies requirements for an effective environmental management system

KPIs – Key Performance Indicators

M&P – Modularisation and Prefabrication

MEP – Mechanical, Electrical and Plumbing

NCR – Non-Conformity Report

NCSC – National Cyber Security Center

OH&S – Occupational Health and Safety

OS – Operating System

L&P – Laser Scanning and Photogrammetry

RHL – Regal Homes London

S&A – Simulation and Algorithm

SWMP – Site Waste Management Plan

VR/AR – Virtual Reality/Augmented Reality

1
INTRODUCTION

1.1. INTRODUCTION

The construction industry sector aims to incorporate innovative technologies that have already generated progressions across multiple industries. However compared to other industries such as business services, manufacturing, finance, transport and utilities, the construction industry is clearly far behind in investment and deployment of 4.0 technologies (Underwood and Isikdag, 2011). The industrialised construction approach, commonly referred to as the factory system, intends to use as a model the technological advances used in optimised industries and recreate these advances in the construction industry from design to construction, implementing smart manufacturing, smart devices and automation.

A framework of the processes and changes that the industrial sector has undergone in the last centuries, giving rise to Industry 4.0 in recent years, can serve as a comparative method for the construction sector. Which tools and ideas have been applied and how they can be successfully transferred to the construction sector is the challenge in the new era of construction.

The use of technology and digital tools, along with the application of consolidated concepts and methodologies already used in other industries, is becoming more and more a reality in the construction industry. The changes are increasingly noticeable, however there is still much to explore, possibly having to adapt from the concept of how to design to build, the materials to be used, the training inherent in the process. All these processes with the purpose of consolidating the implementation and use of digital tools in order to optimize the construction processes.

In this paper this analysis will be done, applied to a specific case study carried out in a corporate context, following the execution of a construction project of a building in London.

The purpose of this thesis is to explore the potential of dynamic changes in the construction industry, through a case study of the work developed within the company Regal Homes London, based in London, through the implementation of management tools that are aimed to optimise processes in the construction industry in order to facilitate data analysis and therefore the decision-making process.

1.2. TARGET ADN MOTIVATION OF THIS WORK

Since the moment I joined the university I considered to do my dissertation in a business environment. In addition to this intention I also intended to pursue another target, the experience of what it is to live and work in another country, with a different culture and different language. Believing thereby that the challenge of doing the dissertation in a business environment would become even more challenging but at the same time more fulfilling.

The pleasure of working in a team has been present in my memory for as long as I can remember, since team games with friends to group work at school. This interest grew even more during my academic

career, mainly due to the participation in associative movements, such as the Students' Association or the Academic Federation. The opportunity to work with the people who are stakeholders in society has made the experience of working in the field, which comes from carrying out and managing activities, extremely impactful in my perception of how to manage a team, the expectations, time and resources.

One of the most challenging issues that companies are facing is how to encourage collaboration between teams. Their challenges have included getting teams to know each other better, eliminating competition and improving communications within departments and between individual workers. As more companies expand to multiple locations or move further away altogether, the scope of these challenges will only continue to grow.

Collaboration has long been a benchmark of high-performing organisations. In industries other than construction, many companies have done away with cubicle walls and implemented measures to have their employees work in a communal space to encourage collaboration. According to the 2017 Workplace Productivity and Communication Technologies Report, over 60% of employee time (more than six hours out of nearly nine working hours) is spent communicating with co-workers, and in addition the same report shows that nearly 15% of employees' total time spent working is wasted on inefficient communications. With so much time devoted to communication, it is clear that it is an essential need for an effective collaboration.

Combining teamwork with good communication, through digitalisation and the implementation of management softwares that overcome existing barriers, was indeed one of the biggest reasons that led me to write this dissertation. Based on the fact that studies show that communication and teamwork are one of the main factors when it comes to positive results in the optimization of processes I tried to research, investigate and deploy some of the technologies and management methods in the work and functions that I came to perform at Regal Homes London.

1.3. THESIS STRUCTURE

The present document is structured in five chapters. As the title of the dissertation "Digitalisation for Optimisation on Civil Construction - Case Study" makes explicit, this work aims to study the management processes currently used in the civil construction industry, the results obtained through them and the repercussions of the deployment, transition and implementation of digital platforms with the aim of optimising the management and decision-making processes in the civil construction industry.

The initial idea of this dissertation was to investigate and explore the present situation of the role of digital platforms in the construction industry. However, undertaking the dissertation in a business environment, due to the possibilities created by the company, enabled me the opportunity to work actually on site. In the company I was assigned to a specific project, having for that reason the possibility, simultaneously with the execution of the thesis, to carry out functions of Site Manager in a development under construction by the company.

The thesis has been organised according to the following framework:

- Chapter 1 contains an introduction to the theme addressed in this document, along with an explanation of how the thesis has been structured.
- Chapter 2 contains a comparative analysis of the construction industry in contrast to other productive industries, such as manufacturing. The intention was to identify the differences between each industry and what adjustments have been or are being made to fit the concept of Industry 4.0 in the construction sector. What technologies, processes and concepts are implemented on a daily basis and what methodologies and digital resources are used.

- Chapter 3 presents a survey and description of the data management that Regal Homes London deploys on a daily basis and the digital tools used. Regarding the data, which RHL generates and implements on a daily basis, which are the methods and analysis tools employed. A survey of their potentialities was undertaken, followed by an personal analysis of the pros and cons in the use of each digital tool.
- Chapter 4 is the actual case study. According to the goals of the case study and the global objectives of the company, a detailed compilation of data was performed through digital tools that subsequently served to simplify decision making on site or management strategies to be adopted by the company.
- Chapter 5, after the conclusion of the case study, a summarised critique of the current landscape of construction 4.0 in the world and in the company is explained. It was observed that, although the quality of the collected data is good and well structured, a collaboration platform that connects all the digital tools used is missing. Also, during my thesis, the company started to analyse the use of a new platform, PROCORE, with the main objective of implementing the use of a single digital tool that allows a standardisation of the company's processes.

2
TECNOLOGIES, PROCESSES AND DATA

2.1. INTRODUCTION

In this chapter a comparative analysis of the construction industry was carried out in contrast to other productive industries such as manufacturing. With the intention, to identify the differences between each industry and what adjustments have been or are being made to fit the concept of Industry 4.0 in the construction sector. What are the challenges in implementing the new processes, the technologies, processes and concepts that are implemented on a daily basis and what methodologies and digital resources are used.

Industrial processes and technologies are constantly evolving along with human civilisation, as working methods are constantly changing to fulfil and respond to the needs that technology creates in people's daily lives. In fact, the development of technology can be associated to each of the past Industrial Revolutions.

The term Industrial Revolution refers to the process of transformation in modern history from an agricultural and craft economy to one dominated by industry and machine manufacturing. The process began in Britain, where the Industrial Revolution was largely confined between the 1760s and 1830s. From Britain, the revolution gradually spread across Europe and into the United States and other parts of the world.

The *1st Industrial Revolution* was characterised by words such as Industrialisation, steam power, steel, main features, with the main impacts taking place in the technological, socio-economic and cultural sectors.

- Technological changes were due to the use of new basic materials, such as iron and steel. The use of new energy sources, as fuels for motive power, such as coal, electricity, oil, and the combustion engine, plus the invention of new machines, such as the spinning loom and the steam engine.
- Socio-economic changes due to the development and implementation of a new working strategy known as the factory system, which envolved a greater division of labour and specialisation of roles, and also a greater application of science to industry. The transition from manual to machine-based work has led to the emergence of new occupations.
- Cultural changes with repercussions in bringing together and bridging different cultures and realities such as developments in transport and communications, including the steam locomotive, steamship, automobile, airplane, telegraph and radio.

These changes made possible significantly greater use of natural resources and the mass production of manufactured goods.

At the end of the 19th century, the *2nd Industrial Revolution* dictated the beginning of mass production through the increasingly widespread use of electricity, the arrival of the internal combustion engine and the increase in the use of oil as a new source of energy. This revolution had an enormous socio-economic impact, as the period between 1870 and 1890 registered the biggest increase in economic growth in such a brief period as ever in previous history.

- The socio-economic impacts had repercussions on living standards, as this increased significantly in the newly industrialised countries, since the prices of goods fell dramatically with the increase in productivity. However, there was a downside, as consequently unemployment rose and major disruptions occurred in trade and industry, with many workers being replaced by machines and many factories, ships and other forms of fixed capital becoming obsolete in a short space of time never experienced before.

The factory system centralised production in separate buildings funded and run by specialists. The division of labour made unskilled and skilled labour more productive and led to rapid population growth in industrial centres (David Grigg et al., 1992).

- Technological advances have contributed strongly to progress in transport and communications alongside the rapid expansion of high-tech industries, requiring the development of multi-level training systems for industry, the standardisation of education and the growing prestige of engineering education as the most talented young workers were sent to colleges.

The Second Industrial Revolution transformed society significantly, with major repercussions on culture and the way people adapted to a new reality. Urbanisation increased rapidly. The population moved into hastily built housing in cities to be closer to the factories.

- The industrial mass production systems were lacking workers and for this reason, the educational system developed educational standards to qualify many standardized specialists with default qualifications, ensuring that the advances brought by this Industrial Revolution were efficient for the productive processes.

The *3rd Industrial Revolution* marks the 20th century as the period when information technology was born with the appearance of the digital era. The creation of the world wide web, was one of the greatest achievements of humankind in the 20th century, allowing a constant and facilitated connectivity that did not exist before. This revolution introduced some structural changes in the industry, with repercussions in the way the human being used technology to date, promoting the transition to the use of telecommunications technologies, the increase of automation in production (using electronic systems) and, consequently, the rapid development of services. Productivity has experienced tremendous growth and as a result the demand for workers directly involved in production has decreased. However, the development of education began to be based on the ideas of integration and globalisation, with a growing awareness of the importance of education through the promotion of academic mobility and the guarantee of international educational standards.

The *4th Industrial Revolution*, also know as Industry 4.0, assumes that each object is equipped with an integrated technology that allows it to connect with other objects. This concept, i.e. the concept of Cyber-Physical Production System (CPPS) is the key to this revolution, as it enables the success of the Internet of Things (IoT), creating an information-filled network for the proper management of industrial processes, with Industria 4.0 based on the two concepts listed before mentioned, as shown in figure 2.1.

The 21st century is presenting society with a new industrial revolution. A dramatic change that the industrial sector is experiencing, so drastic that today the synonym for Industry 4.0 is "smart manufacturing", as shown in figure 2.1, associating therefore the existence of an integrated information management to the use of digital technology. When combined with automation, big data and analytics, and the IoT, digitalisation creates opportunities for substantial gains along the entire industry value chain (Gurdur et al., 2019). Thanks to the digitalisation of businesses, the modern industrial scenario must be

understood as a place in which people and machines coexist in the same environment and guarantee efficient production (Garcia-Muina et al., 2018)

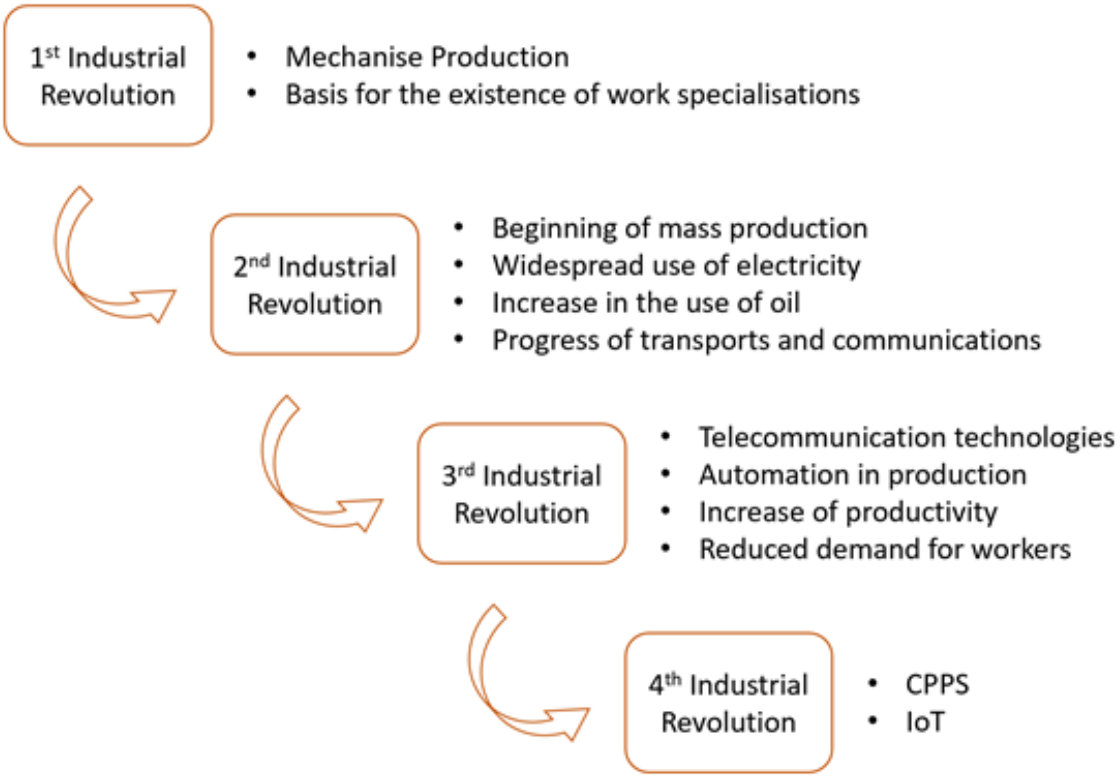

Fig. 2.1 - Progress of Industrial Revolution

Construction Industry is different from other industries. An important feature of this difference is it the "one-off" nature, as each construction project is a "unique" project, very different in nature and type from each other.

During the past decade, the increasing use of a wide range of technologies has enabled the digitalisation, automation and integration of construction processes at all stages of the construction value chain (Oesterreich and Teuteberg, 2016). Considering the similarities with the concept of industry 4.0 and since it is related to the construction industry, this trend has been referenced as "Construction 4.0". As a matter of fact, the fourth industrial revolution, also referred as Industry 4.0, has been continuously changing the construction sector in an increasing way since 2009. The development and adoption of Building Information Modelling (BIM) tools have brought planning functions closer to the actual sequence of construction execution, thereby enabling the visualisation of projected execution over time of a digital model (4D planning) and expected costs (5D planning) (Wang et al., 2014).

Such technologies, related to Industry 4.0, are characterised by systems connected by sensors, intelligent machines, mobile devices, and new software applications (Gerbert et al., 2016). Advanced digital technologies are increasingly including the use of drones to inspect and survey construction sites (Hilfert and König, 2016). New additive manufacturing methods, such as 3D printing, have been implemented in large-scale building components (Gerbert et al., 2016). In addition, 3D scanners could be used to create digital models of complex buildings, while Global Positioning System (GPS) and Radio

Frequency Identification (RFID) could be used to locate materials, equipment and workers (Gerbert et al., 2016).

However, in practice, Construction 4.0 is not only about using new or existing technologies in the construction sector. The concept of Construction 4.0 also implies a comprehensive and deep transformation of construction companies project management processes through the use and exploration of data collected in real time using new or existing technologies for decision-making purposes (Dallasega et al., 2018). These processes need to be studied to favour the valorisation of relevant data captured using 4.0 technologies at all stages of a project's life cycle, with the aim of exploiting this data in real time and afterwards. The main uses of these 4.0 technologies and the applications that can be associated with them also need to be studied in order to highlight all the benefits they can generate in the construction industry.

As far as the implementation of Industry 4.0 in the construction sector is affected, the concept is far from being used to its full potential. When compared to other industries such as business services, manufacturing, finance, transport and utilities, the construction industry is still far behind in terms of investment and adoption of 4.0 technologies (Underwood and Isikdag, 2011).

The main features of Industry 4.0, according to the study by the *Directorate-General for Internal Policies Policy Department A: Economic and Scientific Policy Industry 4.0*, conducted by the European Parliament in 2016, are:

- Interoperability: cyber-physical systems (work-piece carriers, assembly stations and products) allow humans and smart factories to connect and communicate with each other.
- Virtualisation: a virtual copy of the Smart Factory is created by linking sensor data with virtual plant models and simulation models.
- Decentralisation: ability of cyber-physical systems to make decisions of their own and to produce locally thanks to technologies such as 3d printing.
- Real-Time Capability: the capability to collect and analyse data and provide the derived insights immediately.
- Service Orientation.
- Modularity: flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules.

Many of the technologies presented in the previous section regarding Industry 4.0 can be applied to all phases of the life cycle of a construction project. To categorise the different applications of technologies applicable to the construction sector through the implementation of the Construction 4.0 concept, applications can be categorised into the following ten actions, *Construction 4.0: Survey of Research Trends*, In ITcon (2019):

1. Automate
    - The full or partial execution of technical tasks without human intervention.
    - Giving the example of robotic machines that can autonomously and safely read data transmitted to them in code format and transform it into a specific action (Gerbert et al., 2016). Automated and unmanned tasks on construction sites become achievable in this way (Gerbert et al., 2016), as shown in figure 2.3.

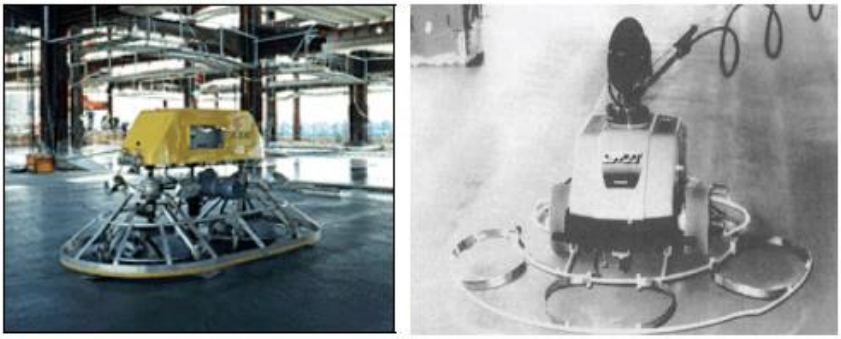

Fig. 2.2 - Concrete compactor robot and Concrete finishing robot – Source: Trends in Robotics and Automation in Construction (2008)

2. Communicate
    - The use of technologies that allow the transmission of data, information, or knowledge to a human being or between human beings.
    - Mobile communication technology applied with the concept of the Internet of Things, as shown in figure 2.3, to the construction sector is used to optimize the sharing and communication of information in real time (Wong et al., 2018)

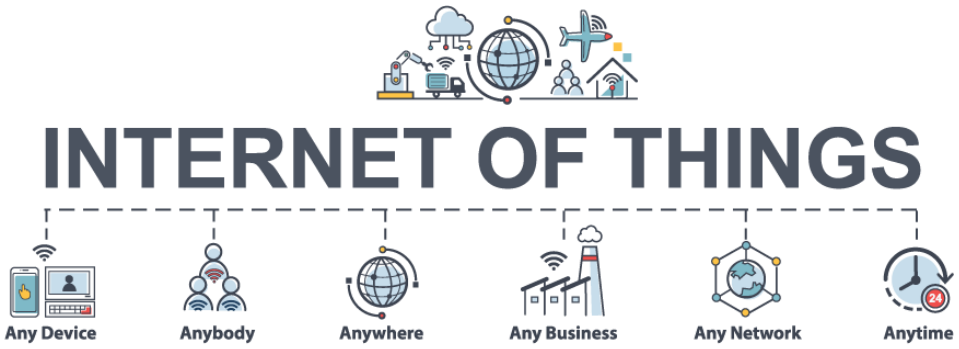

Fig. 2.3 – Internet of Things – Source: www.smartrek.io

3. Distribute
    - Focus on placing human or material space as a function of time.
    - Giving the example of embedded sensors such as Radio Frequency Identification (RFID), enables automatic tracking of equipment and materials can reduce material costs (Dallasega et al., 2018). RFID can be used for access control on construction sites (Oesterreich and Teuteberg, 2016).

4. Locate
    - Tracking the positioning of man and material in space and time.
    - Mobile devices, such as mobile phones and tablets, have evolved exponentially in the last 10 years. The camera of a smartphone can be used to scan barcodes and digital RFID tags that are permanently attached to specific elements of the building, allowing to monitor eventual movements of the building (Laine and Ikonen, 2011). The location of workers, assets and equipment can be tracked in real time using RFID, as shown in figure 2.4, and GPS technology for the purposes of security management, facility management, process management and measuring activity base progress (Tezel and Aziz, 2017).

Fig. 2.4 – Radio-Frequency Identification (RFID) importance of asset tracking and effective inventory management – Source: comparesoft.com

5. Model
    - A proposed project structure converted into a digital model.
    - This solution allows to link the different construction tasks to be performed by the different specialties anticipating possible conflicts before the construction phase (Dallasega et al. 2018). A typical example is the process recognised as the nD modeling, which integrates multiple dimensions of information such as time and cost into a digital construction model (e.g. BIM) from the initial design to the final construction phase, as shown in figure 2.5.

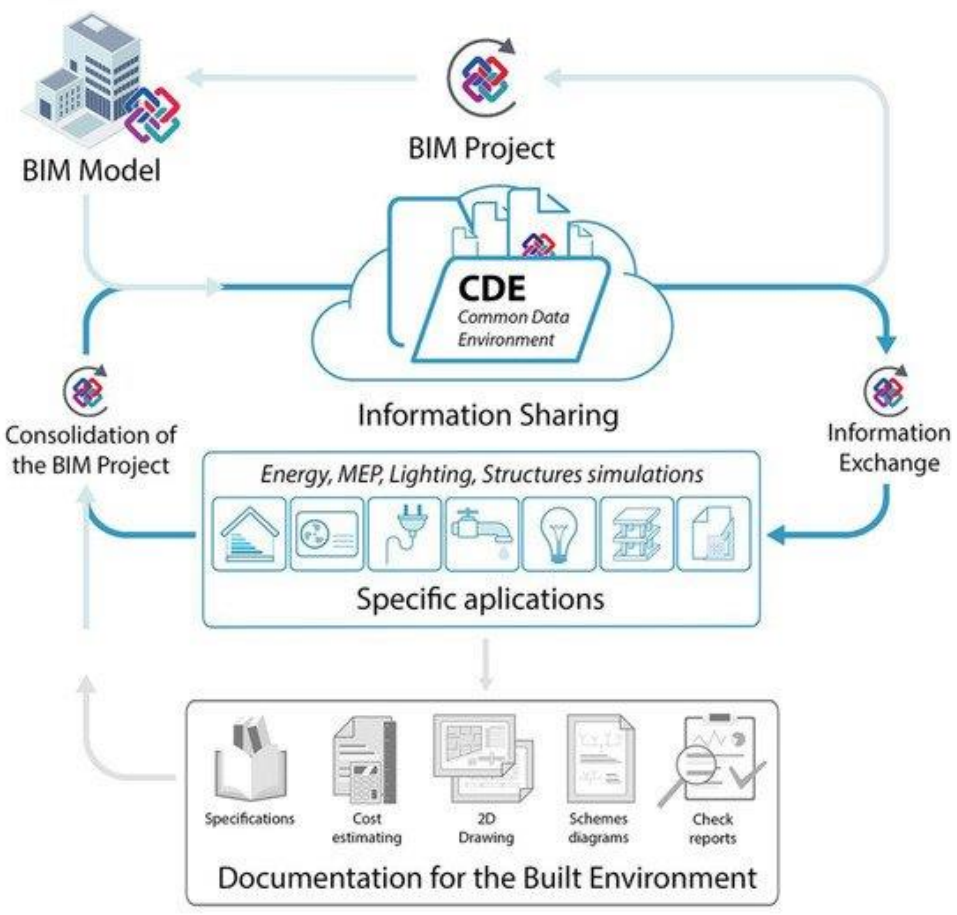

Fig. 2.5 – BIM Workflow – Source: M. Iannantuono (2021)

6. Optimise
    - Making the system operate at its highest capability.
    - For example, neural networks and artificial intelligence are employed to define the location of the crane on site, bearing in mind the optimization of upcoming tasks to be performed (Irizarry and Karan, 2012). Combined with statistical techniques, neural networks are also used to optimize the construction process and improve construction efficiency (Zhao et al., 2017).

7. Reconstruct
    - The conversion of an existing physical system into a digital model.
    - Sensors such as 3D laser scanners, red-green-blue (RGB) camera and thermal camera can be fused to obtain complete and accurate 3D thermal point cloud models of building interiors (Adán et al., 2017). Finally, 3D visualisation can provide important support for urban planning, construction and management (Yeniceli and Ozcelik, 2015).

8. Simulate
    - Software simulation processes for a particular project
    - Simulation and visualisation are methodologies which enable construction designers to detect and prevent accessibility issues and hazardous situations on construction sites earlier in the design and planning stages (Lin et al., 2013). Logistic processes, for example, can be previously simulated in a virtual environment in order to optimise the performance of the construction process

9. Standardise
    - Development of standardised regulations
    - Although not common in the construction industry at a project level, due to the inherent 'one-off' nature of construction, the establishment of standards and norms facilitates process optimisation with the development of a database to be used across the construction industry. As a result, this area has been a focus of the BIM standard, such as the Industry Foundation Classes (IFC), which can be interpreted as a means of information exchange (Hjelseth, 2017).

10. Visualise.
    - Turn processes into more visual outcomes by using a digital model.
    - Nowadays, smartphones are a constant in everyday life, so it is possible to get the best out of it by using smartphones as a tool to identify elements on construction sites to request and view images from BIM software (Laine and Ikonen, 2011).

Nowadays there are conditions to deploy in the Construction 4.0 a considerable amount of the concepts associated with Industry 4.0, converting the construction industry into a more optimised industry and approaching it in terms of productivity with the remaining industries. Concepts such as prefabrication and BIM are already established in the construction sector of some countries, however there are other technologies to be developed that will support the concept of construction 4.0 as a whole. Of the seven chapters associated with the 4.0 construction concept, they are divided into several subchapters of tools and methodologies implemented as described in the numbers in parentheses of each subchapter as shown in figure 2.6.

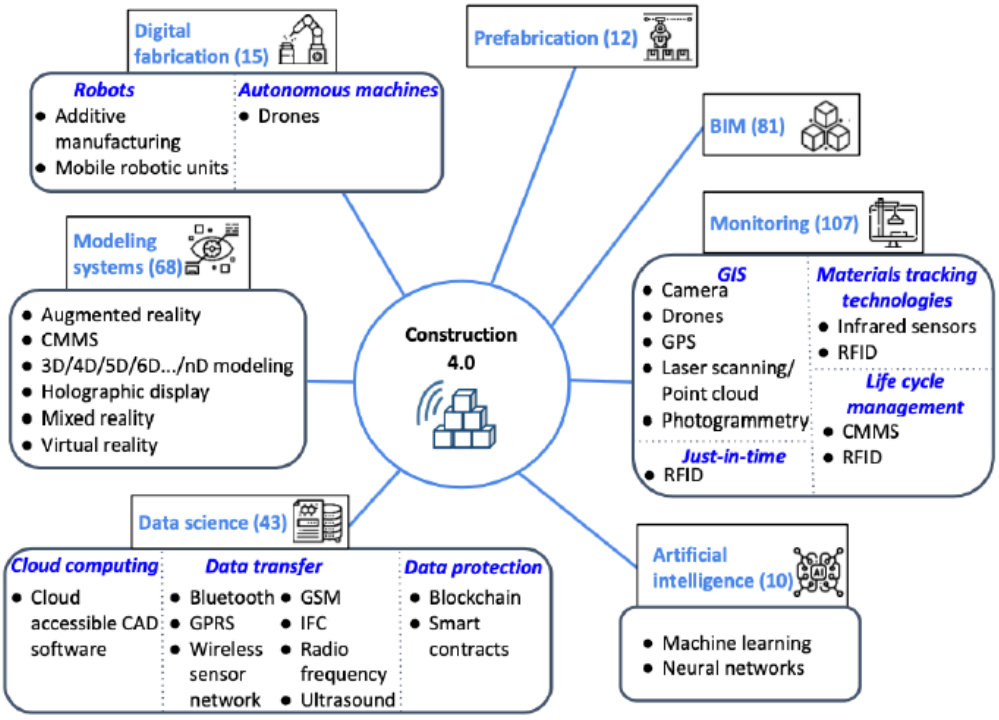

Fig. 2.6 – Seven Technology groups and their supporting technologies – Source: ITCon (2019)

The table 2.1, shows that the same technology can have several different actions. In what follows, each of these actions is briefly discussed.

Actions	Technologies
Automate	Crabots
	3D printing
	Mobile robotic units on site
	Neural networks/Artificial intelligence (AI)
	Unmanned aerial vehicle (UAV)/Drone
Communicate	Mixed reality/Virtual reality (MR/VR)
	Radio frequency identification (RFID)
	Wireless sensor network (WSN)
Distribute	n-dimensional (nD) modeling
	RFID
Locate	Barcode
	Bluetooth/RFID
	Camera
	Geographic information system (GIS)
	Global system for mobile communication (GSM)
	Third/Fourth generation (3G/4G)
	Wireless fidelity (Wi-Fi)
	Global positioning system (GPS)
	Laser scanning/Laser Detection and Ranging (LaDAR)/LIght Detection and RAnging (LIDAR)
	nD modeling
	RFID
	Sensors
	UAV/Drone
	VR
Model	nD modeling
Optimize	Augmented reality
	Bluetooth
	Mobile devices
	Neural networks/AI
	Parametric design (PD)
	RFID
Reconstruct	Camera
	GIS
	Laser scanning/LaDAR/LiDAR
	Point cloud/3D scanner
	Photogrammetry/Stereo-photogrammetry
	UAV/Drone
Simulate	Blockchain
	Digital twin
	GIS
	Industry foundation classes (IFC)
	Machine learning
	Neural networks/AI
	nD modeling
	VR
Standardize	IFC
	Parametric design (PD)
	Prefabrication
Visualize	Augmented reality (AR)
	Smartphone camera
	Holographic display
	nD modeling
	VR

Table 2.1 – Actions associated with applied Construction 4.0 technologies – Source: ITCon (2020)

2.2. CURRENT TECHNOLOGIES

The benefits of industrialised construction have been well explored. The basis of the previous statement is due to concepts that sustain that an industrialised construction will be better than traditional construction due to the reduction of construction cost, reduction of waste produced, reduction of construction time, and reduction of labour.

Technologies and techniques from the manufacturing sector have been progressively adopted in the construction industry. This new concept, called Construction 4.0, has as its principle the implementation of automation methodologies, lean construction, digital technologies, and manufacturing techniques for site construction (Anil Sawhney and Mike Riley et al. 2020). Information and communication technologies that enable smart and connected cities, or even automation systems that enable the optimization of construction processes, as shown in figure 2.7, such as Cyber Physical Production Systems (CPPS) and the Internet of Things (IoT), are also on the rise (Aaron Costin and C. Eastman et al. 2019) Technologies and concepts such as these are beginning to be transmitted from other industries to the construction industry.

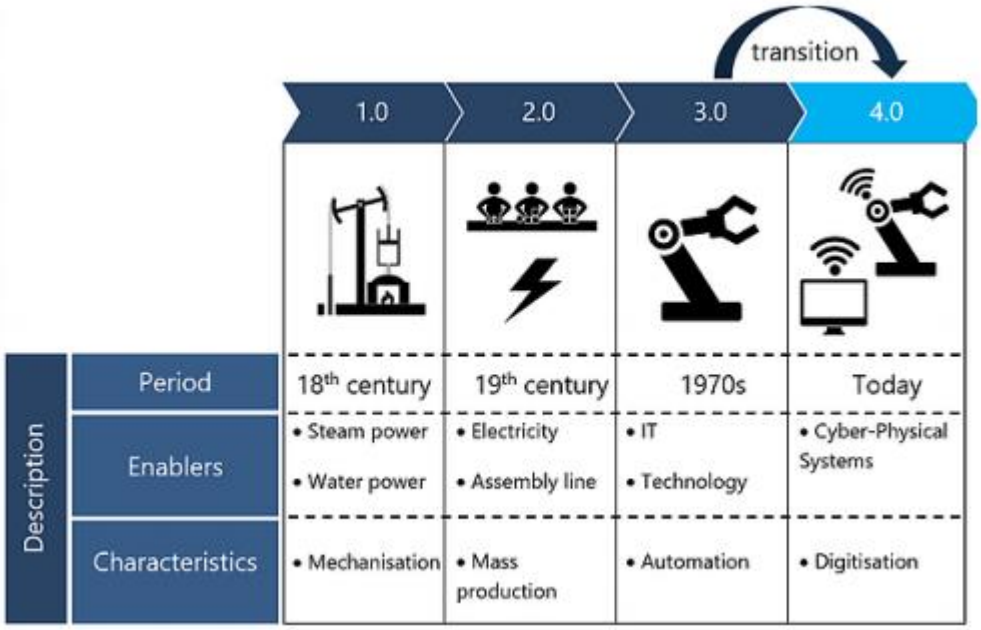

Fig. 2.7 – Information and communication technologies – Source: Industry 4.0 Concept Introduction into Construction SMEs (2017)

2.3. EFFECTS ON PRODUCTIVITY

The construction sector is one of the largest in the world economy, with investments in construction-related goods and services every year totalling around $10 trillion. However in terms of productivity, the construction sector still remains far behind the other major industries, with only 1% annual growth over the last 20 years, the industry's productivity has trailed that of other sectors for decades, and there is a $1.6 trillion opportunity to close the gap.

Globally, over the last 20 years, construction sector productivity growth in manpower has been on average 1%, compared to 2.8% for the total world economy and 3.6% for manufacturing, as illustrated in figure 2.8 . Inherent to everyday human life, the global need for infrastructure and housing will be difficult to satisfy, and difficult to change. It is estimated that an increase in construction productivity in a value-added industry could increase by $1.6 trillion per year in the total economy.

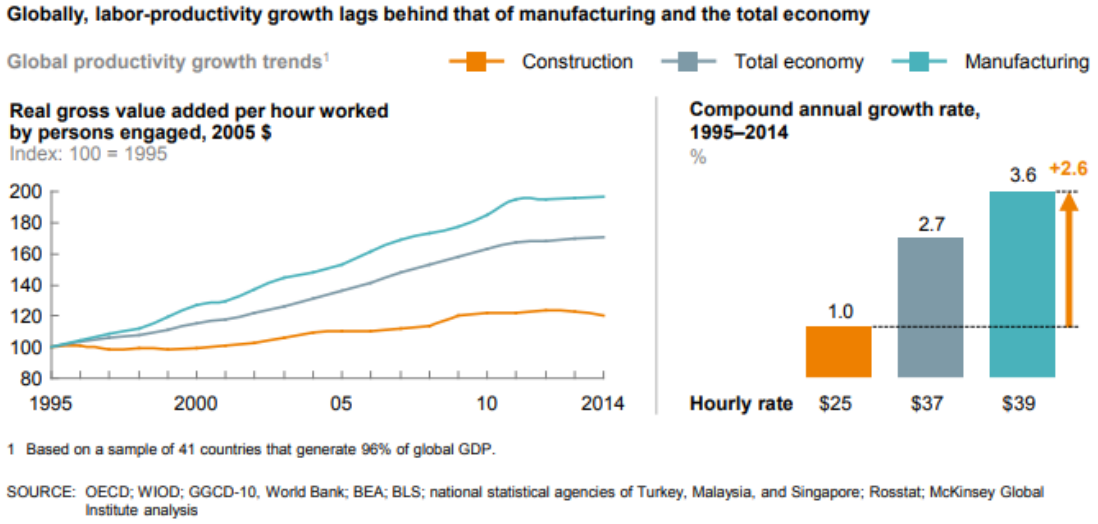

Fig. 2.8 – Global Productivity growth trends - Source: *McKinsey Institute (2017)*

Several studies, such as the '*MGI Construction Productivity Study' (February, 2017)*, confirm several reasons for this poor performance.

- The fact that the industry is largely regulated, highly dependent on public sector demand, and highly cyclical.
- The informality of construction processes and corruption affect the market.
- Highly fragmented, with contracts mismatched in the allocation of risks and rewards, and where owners and buyers are often inexperienced.

Factors like these increase the likelihood of poor project management and execution due to insufficient skills and inadequate design processes. In addition mentioned previously, the construction sector also suffers from under-investment in skills development, R&D, and innovation.

Due to the large differences and variations across the industry, the productivity performance of the global construction industry is not uniform. The sector is divided into two major sub-sectors:

1. Large-scale civil, industrial and housing works, most often referred to as heavy construction
2. Fragmented specialist trades such as mechanical, electrical, and plumbing work that act as subcontractors or work on smaller scale projects

The sub-sector, derived from its magnitude, tends to have 20% to 40% higher productivity, however there are endemics, potentially structural, which raise the issue in meeting costs and schedule commitments on mega-projects, which leads stakeholders to frequently resort to subcontractors from specified trades.

Considering the volume of business and work handled, a subcontractor can generally be expected to be less productive than the larger companies in the other half of the sub-sector, since in the event of a loss, the loss could be considerable. For this reason heavy construction companies spend on expanding their business to increase productivity. This has a major impact on the construction industry, since the productivity of the heavy construction sub-sector is not immune to the lower productivity of the other half. Consequently, any action to increase industry productivity has to be applied to the entire supply chain and to both parts of the market.

The tendency and intention to reduce the gap between the construction industry and the manufacturing industry & the rest of the global economy is notorious. To achieve this goal, the market must adapt accordingly, taking the necessary steps to optimise the construction industry in order to increase productivity and consequently reduce costs. As the study '*MGI Construction Productivity Study'* -

Report *(February, 2017),* as illustrated in the graph of figure 2.9, indicates, this distance can be bridged or, with a combination of cases, even exceeded at best. To achieve this, a seven-pronged approach is suggested to boost the construction industry through process optimisation.

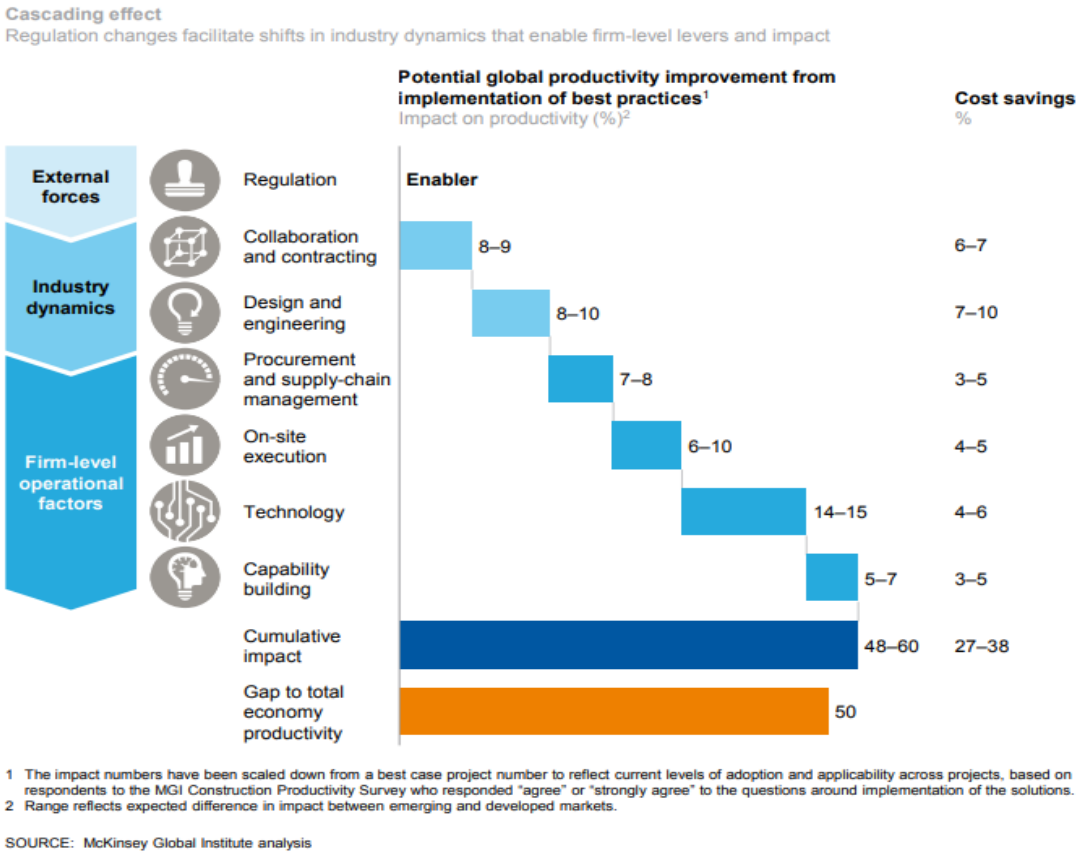

Fig. 2.9. – Potential global productivity improvement from implementation of best practices – Impact on productivity (%) – Source: *McKinsey Institute (2017)*

The proposed dynamics have strong socio-economic, logistical and digital aspects, which argue that only through a disruption of the construction industry will it be possible to achieve the desired objective. Nevertheless, as the report '*MGI Construction Productivity Study' - (February, 2017)* describes, the following proposals will be useless if not implemented in a logical sequence, starting with the regulation imposed by the authorities, followed by the dynamics of the industry such as collaboration, design and engineering. Only then, and only after establishing a strong foundation and pillars, should the pursued objective be consolidated, increasing the cumulative impact and making the most of it.

Concepts to mitigate low productivity in construction:

- *"Reshape regulation and raise transparency"*
    - In this topic the answer must include the government and the existing stakeholder. A mitigation of the bureaucracy inherent in approval processes, reducing informality and corruption, as well as encouraging transparency about costs and performance, establishing the benchmarking capacity of projects and companies.

- *"Rewire the contractual framework"*
    - The framework of how contracts are executed must be based on a collaborative and problem solving system. To achieve this, a standard should be defined to facilitate the decision making process, becoming more substantiated and objective. This criteria should have relevant data such as best value, results from years and projects carried out by the company, and not just focus on cost. All of this will be possible through collaborative platforms with the function of connecting people and facilitating corrective actions to be taken together. Therefore, it is expected that the performance of those involved in the projects improves, by minimizing fluctuations in cost and time estimates.
- *"Rethink design and engineering processes"*
    - The major impact on productivity comes with the idea of thinking of construction as a manufacturing system, using off-site production whenever possible, and minimizing on-site construction through pre-fabrication technologies. This allows not only to reduce the margin of error on site, as the number of tasks to be performed on site is reduced, but also the number of people needed to perform the task. In terms of sustainability, the impacts are even greater since waste is reduced to practically zero, and the environmental impact is consequently lower.
- *"Improve procurement and suplly-chain management"*
    - The number of supply chains and stakeholders in the construction industry often makes pragmatism difficult and less straightforward. Combining best practices implemented and consolidated in other industries through innovative and digitally empowered approaches can produce substantial changes. Also, better planning and greater transparency between contractors and suppliers will have significantly positive repercussions on delays. Therefore it is essential to ensure that methods such as digitalisation of procurement and supply chain workflows lead to more sophisticated logistics management and just-in-time delivery. The use of equipment related to the Internet of Things (such as wearable devices, radiofrequency identification tags, and sensor technology), allow developing a better supply chain of information, improving real time decision making.
- *"Improve on-site execution"*
    - A key approach is the secret to optimisation in any kind of task to be performed, and the construction industry is no exception. First, the introduction of a detailed planning process to ensure that key activities are carried out on time. The second, reshaping the relationship and interactions between owners and contractors, with a view to the tasks to be carried out using key performance indicators. The third is optimising what precedes projects, the procurement of approval and development of project milestones is completed before construction begins on site. Finally, careful planning and coordination across different disciplines on site to reduce waste and variability, a principle commonly referred to as lean construction.

- *"Infuse digital technology, new materials, and advanced automation"*
    - Technological advances associated with Industry 4.0, can be implemented in the construction industry in order to optimise processes by digitisation and automation of some of the processes. Being a one-off industry, not all methods can be replicated from the concept of Industry 4.0. However, companies are increasingly using digital tools such as 3D building information modelling (BIM), as well as collaborative platforms, the use of robotics such as drones, and unmanned aerial vehicles for scanning, monitoring and mapping. One of the ways to consolidate this digital transition within companies and consequently in the construction industry, is to define departments within companies that have people allocated with specific functions to develop the concept.

- *"Reskill the workforce"*
    - Stakeholders in the construction industry, from decision-makers to labourers, must be continuously updated and trained to use the latest digital equipment and tools. To turn this into reality, companies have to allocate funds to be specifically invested in the training of workers and the constant updating of the technology used.

2.4.THE VALUE OF DATA SECURITY

2.4.1.INTRODUCTION

As the construction industry advances, new technologies are implemented almost every day faster than the industry can adapt, which increases the likelihood of risks and exposure to system failure. Nowadays it's not just about making sure offices and construction sites are safe from thieves.

Data security, in a system that is becoming more and more IT-based, is one of the subjects at the forefront of discussion for most companies today. The idea of stealing a company's money, compromising a person's identity or hijacking files used to be reserved for only physical crimes such as burglary, robbery or theft. However, everything comes with a downside and the age of digitalisation, where we are increasingly reliant on technology for every aspect of our day-to-day lives, has meant that data security has become a priority - both in personal life and in the business world.

The digitalisation of the construction industry means vast amounts of highly sensitive data, including construction models, documents, designs and personal data are now being processed, stored and shared around the clock, the majority in the cloud. The industry's processes are increasingly dependent on software systems and the speed with which they can communicate and record auditable data. Precisely for this reason, and because more and more humans are relying on cloud services at all times, service interruptions and data breakdowns can have serious consequences. These include: business disruption and lost revenue; time and productivity; operational stability; and brand equity.

2.4.2.CIBERSECURITY STRATEGY

Cyber security is like any other business approach, there is no one way of doing things that works for all companies and industries. The security strategy needs to be tailored to the size of the business and the potential risks inherent in it.

Cyber attacks can be carried out in a variety of ways, however the vast majority are of a basic nature, most often carried out by relatively unskilled individuals. Scams like the following are increasingly common due to lack of awareness or poor investment by companies in cyber security

- **Phishing:**
  Phishing scams attempt to obtain personal information such as names, addresses, and other personally identifiable information (PII) such as social security number information. Phishing scams may incorporate links to redirect users to websites that appear legitimate but are corrupted. These types of scams create a sense of urgency, are very dangerous because they manipulate users and can affect their good judgment. (Conteh and Schmick et al. 2016)

- **Baiting:**
  Baiting is similar to a phishing attack, but lures a victim through enticement strategies. Hackers use a lure of promised goods for a user to provide their access credentials to a specific website. Bait schemes are not limited to online digital scams and can also be launched through the use of physical means (Conteh and Schmick et al. 2016)

- **Wire transfers:**

Wire transfers are an area where thieves have access to companies, or individuals. Particularly interesting in construction, where multiple invoices and payments are involved in daily work. In these scams, criminals simulate false invoices or phone calls requesting immediate payment for items, in order to avoid default. Once the money is transferred, it is gone forever (Austin et al. 2019) A method to mitigate situations like the one described above would be to make wire transfers prohibited without making a specific phone call to someone to authorize the transfer.

As the construction industry undergoes a digital transformation, similar to the revolution that the manufacturing industry went through, it is expected that the construction industry will also suffer from cyber attacks. The implementation of Cyber-Physical Systems (CPPs) and Internet of Things (IoT) interconnected equipment create security challenges transitioning into the construction industry. The revolution that the construction industry is going through is fundamental to mitigate the current gap to the other developed industries and to increase productivity and sustainability of production. The solution will be to invest in cybersecurity systems, in parallel with the investment in equipment that promotes Building 4.0, in order to be prepared for an eventual attack.

Attackers often use common methods to attack a network. Many of these methods can be mitigated by implementing basic cybersecurity controls. There are several frames that outline what good cyber security controls look like. The National Cyber Security Centre (NCSC) in the UK recommends reviewing how to protect against cyber-attacks, including the NCSC's 10 Steps to Cyber Security, ISO/IEC 27002 and the NIS Cyber Security Framework, as shown in the figure

Fig. 2.10 – Ten Steps to Cyber Security – Source: ncsc.gov.uk

The implementation of the concept of construction 4.0 is still far from being consolidated in the construction industry. Adaptations have been made and tools such as BIM and the use of prefabrication are increasingly used nowadays. Regal Homes London, the company that owns the project on which I carried out this case study has been pushing, as described in the next chapter, to keep up to date and be at the forefront of the transition that is happening in the construction industry.

3
ORGANISATION DATA MANAGEMENT

3.1. TOPIC APPROACH

Following on from the previous chapter's summary of what digital resources are currently in use along with the challenges associated with the transition in the construction sector, this chapter has made a link to the topics previously covered and researched and described what digital methodologies, approaches and tools Regal Homes London implements on a daily basis.

This analysis was done so that the readers can understand which type of digital tool is included, in a simplified explanation of how they work, what their potentials are, as well as a final critical analysis of each of the digital tools discussed.

The use of tools to maintain quality through the creation of summarised and digital reports. The use of collaborative platforms such as Microsoft 365 and Dochosting that allow for greater real-time connectivity. The use of database collection and analysis platforms such as Microsoft Power Bi.

3.2. FINAL CAD

3.2.1. HOW DOES IT WORK?

Finalcad is a construction management application and software. Finalcad helps contractors, architects and owners to act in synchronicity, build quality projects and manage risk through solutions that provide progress reporting, defect management, quality controls and analysis.

The collaborative platform allows all stakeholders to be involved in the day-to-day in a more synchronised way. Share photos, comment, assign tasks in real time. The fact that it is easy and intuitive to use and manage observations allows to be used on a mobile application and the time spent on each task to be reduced.

Being adaptable, it can be implemented in all specialties and during the various phases of the project, from design, construction, reception, handover, operation and maintenance. All these features allow autonomous management from design to KPI analysis.

Also, in the attached documents, *the attachment VI* was included, which shows an example of the reports that are generated through the final cad. In this same document, it is possible to notice that the report of the building under construction is divided by areas, number of observations, status of the tasks, date of creation of the tasks to be carried out, the progress, any comments and to whom the task is assigned.

This allows that in a building under construction, with several tasks to be done simultaneously, it is easier to filter them in order to assign them to the right people in charge more efficiently

3.2.2. POTENTIALITIES

Quality – Key to maintain the standards

Less Defect	Saved Per Day	Executed Controls
25%*	4 hours*	100%

Table 3.1 – FinalCad: Quality – Source: finalcad.com

Improve the overall quality of their projects, as shown in the three parameters of table 3.1. Throughout the project, the software allowed me to complete site inspection sheets, identify and accelerate snags analysis by creating a summary report that was then automatically sent to subcontractors.

- Conduct inspections and audits
  - Access the inspection sheets while on the move. At the end of the day, check that the work is in accordance with the construction procedure.
- Identify defects
  - Each time I have had the need to generate a problem report, I did it in a few steps: highlighting the defect or problem in a few seconds. Subsequently, save the defect with a photo and comment and assign the repair to the appropriate team along with its deadline. This ensures that the project is supervised closely in order to control deadlines and budgets.
- Share information
  - Where necessary, it was possible to communicate with the clients, architects, engineers or teams working on site through working groups.

- Standardise your project
  - Design a future project by harmonizing libraries of the most common defects and their controls, based on the learnings from previous projects. Thereby teams from the same company generate a database based on the same benchmark, even when working on different projects.

Progress – Track the project

Visibility
100%*

Table 3.2 – FinalCad: Progress – Source: finalcad.com

Allows the user to lucidly check the real-time status of the project's progress, as shown in table 3.2.

- Organise your project
  - Organize all tasks and actions to be performed by the responsible teams by assigning them specific tasks. As well as specifying who does what and within which deadlines.
- Monitor teams work progress
  - Check the work progress for each sector and team by consulting the observation statuses. Indicate outstanding tasks and continue to track the progress of the project.
- Guarantee the performance of your tasks
  - Assign the teams responsible for the tasks that will be assigned to them, sending the action to be implemented through groups.
- Anticipate your future projects

- With a crystal clear view on projects, human and financial resources are managed closer to the next project. Challenge the processes and compare the contractors. And, ultimately, improve, continuously.

Safety – Work in a secured environment

Safety checks accessible	Inspection time saved	Safety events recorded
100%*	50%*	100%*

Table 3.3 – FinalCad: Safety – Source: finalcad.com

Boosting proactivity and responsiveness in security matters becomes easier, as shown in the three parameters of table 3.3. Acting in a preventive way instead of acting in a reactive way.

- Make safety everyone's business
  - Risks are present in the construction industry. It is therefore necessary to carry out inspections to ensure that the site complies fully with safety rules. In this way it is possible to identify more quickly any situation that could compromise the safety of your teams and your project thanks to your observations.
- Share information immediately
  - Share hazardous situations with all relevant persons mitigating the consequences of hazards. Dedicated working groups allow accelerated and centralised data sharing.
- Store safety observations
  - Once a safety report is detected and shared, it is stored, forever. That way it is accessible to anyone at any time in the application database.
- Prevent Safety issues
  - Identify risks and adjust your security controls accordingly. It allows you to build the individual inspections and audits using the survey form or by using the Finalcad standards. Each project has its own specificities, and even if there is a standard across the construction industry regarding the safety, it is also necessary to adapt and benefit from its selection of each measure to be implemented and therefore contribute to the safety process of the project.

Collaboration – Adopt a new collaboration

Saved a day	Centralised exchanges	Time to share information
1 hour	50%*	0 seconds

Table 3.4 – FinalCad: Collaboration – Source: finalcad.com

Collaboration and dynamics between various trades is inherent to the construction industry. Organizing collaboration between all stakeholders allows you to organize information and make the respective decisions more informed and jointly, thereby focusing on the most relevant decisions for your project management, as shown in the three parameters of table 3.4.

- Structure exchange into work groups
  - Regardless of the purpose, projects involve multiple activities, teams, and stakeholders. That said, Finalcad makes it easy to create working groups on every issue that seems relevant, making project management easier.
- Communicate with all stakeholders
  - Whenever it is necessary to share information or discuss a specific topic, it is possible to send a message to the dedicated workgroup, which members of the group will be automatically notified of the message and will be able to respond faster.

- Give context to conversations with plans
    - In order to be more accurate, and to get an answer with a smaller margin of error, it provides the ability to add context to all your conversations, locating each element on the relevant plane, through plans, elevations, and details
- Stay in contact with your projects

3.2.3. PROS AND CONS

In my opinion, the final cad has proved to be the digital tool which optimises construction processes the most. It overcomes eventual communication barriers between those involved in the construction process, since it creates succinct and explanatory reports using photos and small phrases. It also allows these same reports to be sent automatically to those responsible for solving the tasks that are addressed to them and, in the future, through a mobile application, to update the actual status of the tasks.

After exploring the software's properties and functionalities, table 3.5 describes general aspects of the software along with personal considerations of its use.

Pros	Cons
• Ease of communication • Good interface • Optimised information flow • Ability to customise	• Expensive licences

Table 3.5 – FinalCad Pros and Cons – Source: finalcad.com

3.3. ASTA POWERPROJECT

3.3.1. HOW DOES IT WORK?

When it comes to managing construction projects, you need software to work with in order to optimize and organize the project program. Planning and management software automatically and practically immediately allows us to analyze the finishing dates and delays of each task in a project program.

By using the wrong software, in a project with a contract where it is necessary to show cause and effect, as well as the impact of progress on the work, will likely generate the wrong answer, leading to increased cost and damage to the project.

Like other management and planning programs such as CS Candy, Microsoft® Projectand Primavera P6, the Asta Powerproject was designed to support the way construction and planners work and improve with its contribution that aims to meet the requirements in the area of planning and management in the construction industry.

Therefore and due to the Asta Powerproject being 100% designed for construction projects, it is expected that will be easy to use, with top quality presentation of project outlines and features a Free Project Viewer that allows to share outlines. Asta Powerproject even allows the user to import/export the projects into Microsoft® Project or Primaver P6.

3.3.2. POTENTIALITIES

As previously outlined the Asta Powerproject was designed to support the way construction planners work and evolved with their input to meet the industry requirements. For this reason, before any experience with the programme, I was expectant about the potential that the programme has to offer. Being a unknown programme to me, yet at the same time the programme used by 90% of main contractors in the UK and many smaller companies, I was provided with a certified course to better understand the processes and how to apply them.

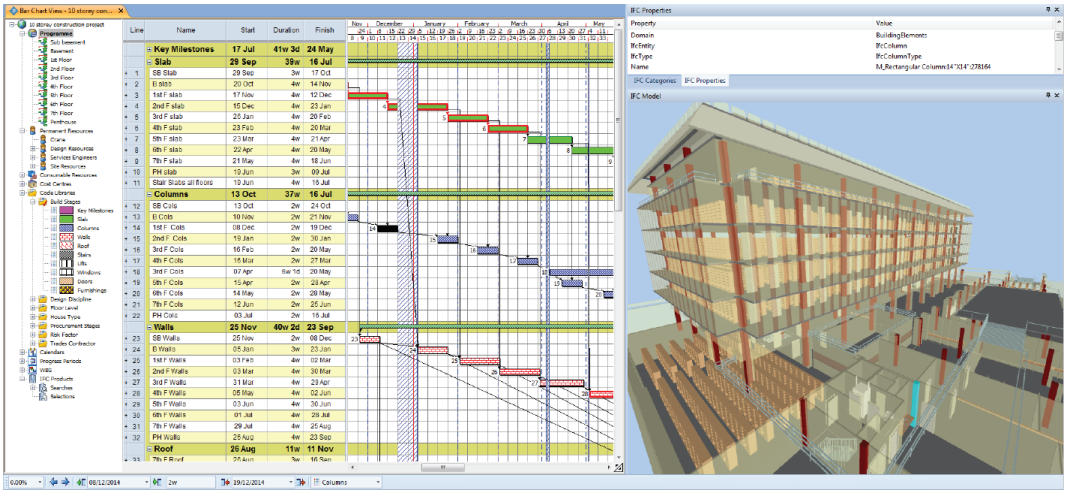

Fig. 3.1 – Display of a dynamic 3D schedule on Asta Powerproject – Source: elecosoft.com

The course, apart from teaching how to use the program in a more complete way, revealed some of the program's potentialities, some of which, for distinct reasons, I didn't use so often. However, as shown in figure 3.1 – "*10 Reasons to Use Asta Powerproject for Managing Construction Projects"*, and being a program specifically for the management of civil construction projects, it has several potentialities that meet the concept of construction 4.0,

- Easier to use
    - On the user's perspective, functions such as drag and drop make the programme more intuitive and easier to use.
- Superior presentation of project plans and simpler printing
    - Control over printouts.
    - Display only the relevant parts of the plan by turning different.
    - Highlight important information by adding annotations.
- More precise scheduling for greater accuracy
    - Create and edit links.
    - Links are clearly displayed between tasks.
    - Produce an accurate Critical Path Analysis every time – with just one click.
- Share plans
- Cost effective licensing
    - Worth it for companies with multiple users.
- Collect and update progress easily on mobile devices
    - Record project progress quickly and easily via mobile devices.
    - Update progress at any time, from any location. No signal needed to record progress values.
    - Take photographs and record notes which can be associated with particular tasks or building stages.

- Plan and manage repeated tasks on one row of the plan
  - Save time and space on the Gantt chart by displaying overlaping repeated tasks.
  - Information is presented in a very compact form.
  - Highly-effective for the finishing stages of fit-out work or multistorey construction.
- Ability and ease of integration with other software
  - Open files from other software systems, such as Microsoft® Project and Oracle Primavera P3 & P6.
  - Save Asta Powerproject files into formats that can be opened in such systems
  - Easy integration with estimating, accounting and BIM tools.
- Link projects plans to 3D models within a single application
  - Asta Powerproject BIM allow to create a 4D planning.
  - The combined IFC file and schedule interact smoothly and effectively, decreasing the risk of human error and speeding up the linking process.
- Filtering for easier managing of sub-contractors
  - Highlight the work of different trade contractors with colour codes.
  - Subcontractors are not required to have the software to read or update tasks.
- Protection against litigation caused by delay
  - Progress in each Progress Period is displayed in a separate colour.
  - Information on how much progress was recorded in a specific Progress Period is kept, even when the task is completed.
  - Create an unlimited number of baselines
- Used by 90% of top UK contractors and many smaller companies
  - 46 of the top 50 UK contractors use Asta PowerProject *1
  - Over 80,000 construction users worlwide

*1*Construction News Top 100 listing 2014*

3.3.3. PROS AND CONS

In an initial phase, the company allocated a series of trainings necessary to develop my project, trainings in which the power project training was inserted. This program ended up being very similar to the planning programs existing in the market, but used in the company due to the company's commercial agreements. The use of this tool ended up not being as much as I expected, since the company hired a responsible person, who is only dedicated to the planning and progress management for all their projects.

Still one of the difficulties of using this digital tool, is related to the fact that the tasks to be performed have a predefined sequence, durations and hierarchical connections between them, something that many times does not happen in a real project situation, either by adjusting dates, anticipating or delaying tasks. This can create conflicts in the program planning and ultimately mislead the user when it comes to critical path analysis.

After exploring the software's properties and functionalities, table 3.6 describes general aspects of the software along with personal considerations of its use.

Pros	Cons
• Scalable for projects of all sizes • Allows users to view repeat tasks in a single row • Includes an integrated BIM module for 4D planning, combining a 3D model and project plan in one application • Free reading application	• Point and click scheduling option can be very difficult if you have a complex schedule. • Not very many trained operators

Table 3.6. – Asta Powerproject Pros and Cons

3.4. MICROSOFT® POWER BI

3.4.1. HOW DOES IT WORK?

Many organisations are embracing a data literacy and using business, sales, operations and other types of data in meetings and decision-making processes. When it comes to data analysis, the faster and simpler it is to analyse data, the easier it is to understand and make logical and well-founded decisions, and consequently optimizing the processes developed by organisations.

More than ever these days, information means power and informed decision-making. However, sometimes the amount of information can be a problem when it is necessary to make decisions based on this information, for lack of clarity due to the difficulty of analysis, especially if the subject is Big Data.

The analysis of data allows, at the same time, to have an overview of the company and depth of information at each point of the business. It is through this analysis that it is possible to manage with real information and strategies. This allows companies to invest time, manpower, money and other resources in a much more accurate and secure way.

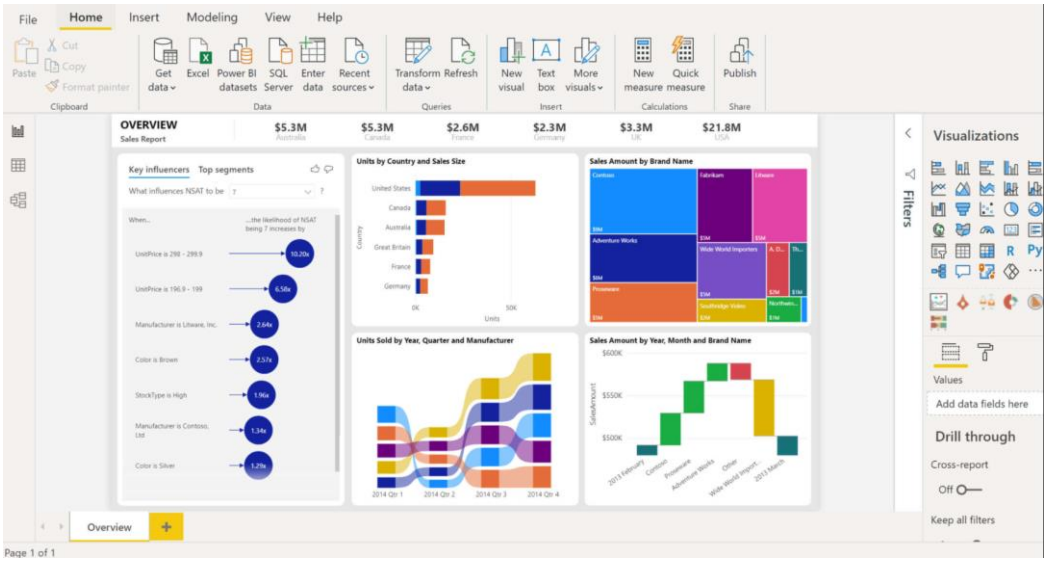

Fig. 3.2 - Display of a dashboard report on Microsfot® Power Bi – Source: powerbi.microsoft.com

Microsoft® Power Bi is one of the tools developed by Microsoft®, which gives analysts and developers a powerful wide field of business intelligence and analytics but which at the same time, and despite its potential, is a surprisingly lightweight application. By using Microsoft® Power BI, information becomes more centralized and therefore easier to analyze and make decisions. The data discovery, data modeling, data visualization and sharing processes are simplified by using only one application. The processes in developing Power Bi solutions tend to follow a pattern, and although it can be difficult to master at an early stage, once the processes and tools have been consolidated, the program becomes intuitive to use, with a wide range of possibilities that are constantly being updated. In addition to dynamic and visual reports that allow the data to be analysed practically instantaneously, the fact that development problems that would previously have required weeks to solve in an office BI solution can be solved in just a few hours

Microsoft® Power Bi offers these possibilities of analysis and data mining, automatically updatable and with the possibility of being connected to collaborative platforms, through the creation of succinct and visual dashboards as the example illustrated in figure 3.2. With Microsoft® Power BI is it possible to

connect, model and visualise data, creating personalised visualisation reports with KPIs that best fit the user's requirements. Then share the data securely, or even incorporate the information into an application or website. Microsoft® Power BI also has the capability to allow users to connect to different data sources in the same application, on-premise or in the cloud. Example of Microsfot® Excel, Salesforce, Google Analytics, Social Media, and even IoT devices to get real-time data and transform all that data into live and interactive dashboards.

Microsoft® Power Bi also allows it to work as a collaborative platform, creating dashboards that provide real-time insights of activity status, control how data is accessed and used, empowering everyone in the organisation to make data-driven decisions that drives strategic actions. Microsoft® Power Bi also has a Mobile feature which enable the data analysis from anywhere, at any time.

3.4.2.POTENTIALITIES

As outlined in the previous sub-chapter, Power Bi's capabilities are quite extensive. The main purpose is to be a program that facilitates the data analysis by optimizing the time and effort spent in the analysis of results and data. Nevertheless, from all the capabilities listed above, after using the program and analysing the reviews made by other users, these are the potentialities that generate more consensus.

- **Ability to revolutionise a business**
  - The program gives users the ability to shape data in a certain way and how to pin it to the source itself.
  - One of Power BI Desktop's most powerful and effective features is the Query Editor, which enables users to transform data types, performing the transformation by adding new columns, splitting and merging, and adding a query. This enables the program to perform a transformation of the inserted data, as desired, resulting in an effective formatting and visualization of reports.

- **Potentiated interactivity:**
  - Multi report interactivity, between different reports, with only some matching data, can be realised once connections between reports are made in advance.
  - By clicking on a bar of a graph, the user can easily modify the display of the information that corresponds to it. Similarly, to see the values of location charts, lists and KPIs, the user only needs to choose a location on the visual map.
  - The Power BI filtering feature allows the user to filter information, without losing information, in order to make graphs more concise and contain only the desired information.
  - These capabilities make Power Bi a tool that executes the report with clarity and improved structure, optimising the amount of time normally spent creating and analysing reports.

- **Advanced Measurement:**
  - Power BI uses a specific Data Analysis Language (or DAX), a formula language. The format similarities to information from Microsoft® Excel are considerable, but it eliminates the complexities of report stacks. So, with DAX, it is possible to produce powerful Power BI metrics easier and with a faster approach.
  - To optimise metric creation a more advanced tool is available in Power BI, called 'Quick Measures', which allows the creation of more complex DAX language expressions such as monthly growth, a percentage difference, etc.

- **Display Hidden Data:**
  - Through the 'Insight' tool in Power BI it is possible to cross-check the information hidden in the report data, through graphs generated inside graphs that, if intended, have the potential to provide more effective and stronger metrics.
  - The visualisation in the Power Bi dashboard of this type of information provides transparency to the data analysis across businesses and projects. By facilitating an easier understanding of income/costs in a particular section/category of the project, the identification of trends and cost savings becomes more tractable.

- **Big Data Storage Capacity:**
  - Big data is a field meant to analyse, extract information systematically, or deal with complex data sets or millions of data sources that makes it impossible to be processed by a traditional data processing application software.
  - A file with millions of lines will not open or run easily on a normal machine, and even if it is possible to open the file, the issues of generating substantial information from that data will be inevitable, since not all programs are designed to process that amount of data. Precisely for these reasons Power BI was designed specifically to process and transform millions of rows, optimizing the time required to perform what could otherwise be a time consuming task, and with the ability to compress the file without compromising quality and performance.
  - An effective tool to transform files that would be expectedly heavy, since they retain a lot of data, into lighter files, making them easier to use and share.

3.4.3. PROS AND CONS

After the requirement of the company, and in the context of the implementation of Power Bi, I faced some obstacles in the implementation at 100%. One of the main factors is the fact, that the wide graphic analysis diversity factor that Power Bi provides no longer makes sense or is not well applied if the quality of the data to be analysed is not adequate.

For example, as two users create a database that is not standardized with the company's methodologies, it may create obstacles at the time of analysis and report generation, becoming therefore counterproductive to use a tool that has the purpose of facilitating decision making.

This sometimes leads to the fact that the data produced or to be analysed must be revised before being inserted in the program, making its use meaningless. However, if companies create standardization processes that guarantee that the connections between parameters to be analyzed are made automatically and without the need for adjustments.

After exploring the software's properties and functionalities, table 3.7 describes general aspects of the software along with personal considerations of its use.

Pros	Cons
• Extremely powerful platform with a wealth of data source connectors • Custom Visualisations • Cost • Constant updates and Innovations	• Refresh cycle is limited • The User Interface • Rigid Formulas

Table 3.7 – Microsoft® Power BI Pros and Cons

3.5. MICROSOFT® 365

3.5.1. HOW DOES IT WORK?

Nowadays it is impossible to talk about technology and not mention Microsoft®. Microsoft® is a computer technology company, founded by Bill Gates and Paul Allen in 1975. It later became the largest software company in the world, according to the Global 100 Software Leaders by Revenue (2016), conducted by the consultancy firm PWC. At the time this document was made, according to Forbes Magazine Microsoft® Windows was the dominant operating system (OS) worldwide, with a market share of around 70%. Its best-known software products are the Microsoft® Windows line of operating systems, the Microsoft® Office suite, and the Internet Explorer and Edge browsers. Nevertheless, Microsoft® has a range of products specifically designed for productivity.

Microsoft® 365 is the productivity cloud designed to make it easier for the users to manage their business. More than just applications like Word, Excel, PowerPoint, Microsoft® 365 brings together productivity applications with powerful cloud services, device management, and advanced security in a single connected experience.

3.5.2.POTENTIALITIES

- **Technologies:**
  - The program has built-in hardware and software savings, along with reduced IT effort.
  - Disaster recovery capabilities, IT security and covers uptime

- **Mobility:**
  - Consider how workers can access data anywhere and at any time, since it is compatible with different devices, it can be accessed through a computer, tablet or smartphone.
  - Applications improve worker efficiency, resulting in faster project completion time.

- **Control and Compliance:**
  - It seeks to reduce costs and compliance effort by using industry standards and embedded best practice to eliminate, with the required features and safety, the need to undertake further projects that would otherwise be required.

- **Business Intelligence:**
  - Opportunity to make better decisions due to time optimisation across multiple repositories. Reduced decision times can result in increased worker productivity.

- **Enterprise Social:**
  - Collaboration in a business environment is facilitated through tools that stimulate social communication. Microsoft® 365 enables you to do this with the software itself, improving communication between co-workers.

3.5.3.PROS AND CONS

Being perhaps one of the most used digital tools in the world, it allows that the know-how regarding its use is quite consolidated. For this reason it makes sense that companies instill its daily use, so that, through tools provided by Microsoft, work methodologies are standardized.

After exploring the software's properties and functionalities, table 3.8 describes general aspects of the software along with personal considerations of its use.

Pros	Cons
• Remote Access • Outworking • Security features • Budget	• Internet reliability

Table 3.8 - Microsoft® 365 Pros and Cons

3.6.DOCHOSTING

3.6.1.HOW DOES IT WORK?

The construction industry works closely with the design field, from architects to designers, as every project, from the smallest to the largest, is subject to design. However design changes are a major concern in the construction industry. Designs that are modified at the client's request, updates that have to be made due to incompatibilities of materials even while the work is under construction, or even due to changes in construction methods.

The construction industry is a typically outdated sector, in which some of the intervening agents have a lack of technological, literary and language knowledge, and the use of drawings aims to facilitate the communication process to explain what is intended as the end result. Due to the constant updating of drawings, this inevitably leads to an excessive use of disposable materials, such as paper. Collaborative platforms will therefore minimise sustainability issues, and simplify communication and approach between stakeholders involved in the construction sector, mitigate the risks of making modifications and, consequently, waste generated will be reduced.

3.6.2.POTENTIALITIES

Dochosting is a collaborative platform with an intelligent management system that allows you to carry out a project maintaining all the data related to a project in an organised way and with a rigorous revision control, in a simple and user-friendly way.

- Make documents, drawings or sets of papers accessible to specific people in just a few clicks, as shown in figure 3.3.

Fig 3.3 - Dochosting system display, number of users with access to the project and total number of files – Source: dochosting.com

- Perform regular updates ensuring that everyone is looking at the latest version of the relevant plans (C, corresponds to the construction phase and 4, to the number of updates made), as shown in figure 3.4

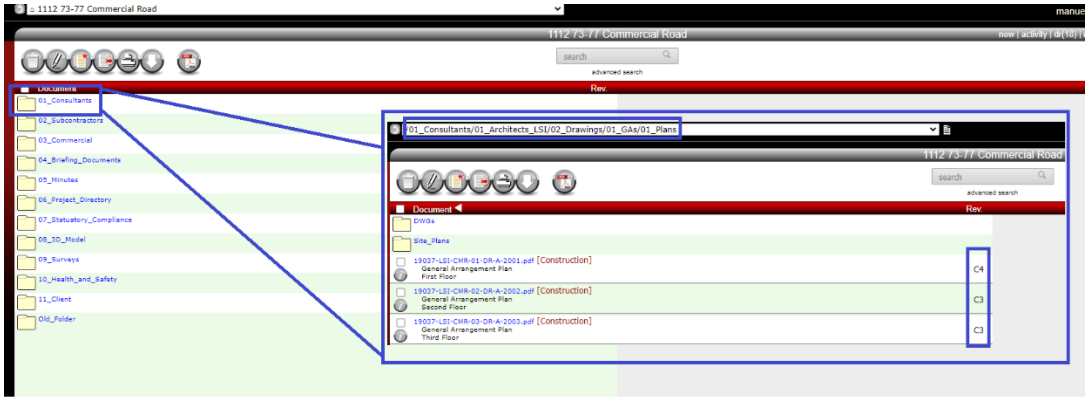

Fig. 3.4 - Example of access to folders with data and number of updates made. – Source: dochosting.com

- Organise the designs into variable sets so that, according to the different requirements and permissions, everyone is able to get the right data with the corresponding updates, as shown in figure 3.5

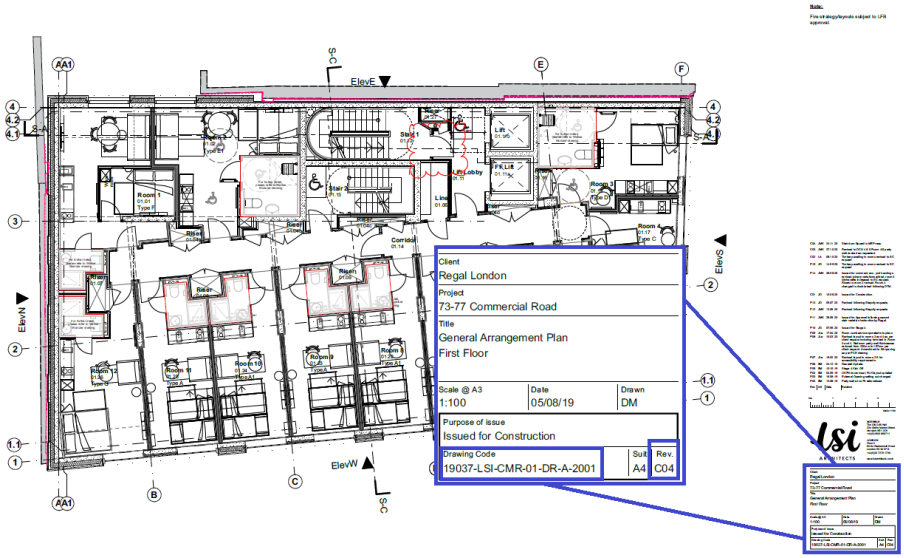

Fig. 3.5 – Drawing of the typical floor plan of the building, with description of the file name and respective construction phase – Source: dochosting.com

- Monitor each design, who saw it, when it was seen, when it was updated, at which stage of design it is (blue square, under construction, means that it is ready for construction or already under construction with changes to be made), all in a fully auditable manner. Generate a comprehensive report, as shown in figure 3.6., based on an extensive register of designs and documents in one click (red squares, at provisional stage, means that it is awaiting comments, design reviews or extra data and therefore is not ready for construction phase yet)

REGAL LONDON

Regal Homes London
1112 73-77 Commercial Road

dochosting data management

Drawing/Document	Title	Status	Rev	Date	T.I.
/01_Consultants/01_Architects_LSI/02_Drawings/01_GAs/01_Plans					
19037-LSI-CMR-01-DR-A-2001	General Arrangement Plan First Floor	Construction	C4	25-Nov-20	
19037-LSI-CMR-02-DR-A-2002	General Arrangement Plan Second Floor	Construction	C3	25-Nov-20	
19037-LSI-CMR-03-DR-A-2003	General Arrangement Plan Third Floor	Construction	C3	25-Nov-20	
19037-LSI-CMR-04-DR-A-2004	General Arrangement Plan Fourth - Thirteenth Typical Floor	Construction	C5	25-Nov-20	
19037-LSI-CMR-08-DR-A-2008	General Arrangement Plan Eighth Floor	Construction	C3	25-Nov-20	
19037-LSI-CMR-09-DR-A-2009	General Arrangement Plan Ninth - Thirteenth Typical Floor	Construction	C3	25-Nov-20	
19037-LSI-CMR-B1-DR-A-1999	General Arrangement Plan Basement Level	Construction	C1	11-Aug-20	
19037-LSI-CMR-GF-DR-A-2000	General Arrangement Plan Ground Floor	Construction	C4	27-Apr-21	
19037-LSI-CMR-R1-DR-A-2015	General Arrangement Plan Roof	Construction	C4	05-Feb-21	
/01_Consultants/01_Architects_LSI/02_Drawings/01_GAs/01_Plans/Site_Plans					
17262-LSI-A1-GF-DR-A-1730	Site Proposed Plan	For-Comment	P2	12-Nov-19	
19037-LSI-CMR-ZZ-DR-A-1700	Site Location Plan	For-Comment	P1	04-Nov-19	
/01_Consultants/01_Architects_LSI/02_Drawings/01_GAs/02_Sections_Elevations					
19037-LSI-CMR-ZZ-DR-A-2050	General Arrangement Elevations West & North	Construction	C2	18-Jan-21	
19037-LSI-CMR-ZZ-DR-A-2051	General Arrangement Elevations South & East	Construction	C2	18-Jan-21	
19037-LSI-CMR-ZZ-DR-A-2070	General Arrangement Sections Sheet 01	Construction	C1	11-Aug-20	
19037-LSI-CMR-ZZ-DR-A-2180	Coursing Sections Whole Building Section	Construction	C1	11-Aug-20	
19037-LSI-CMR-ZZ-DR-A-2181	Coursing Sections CS01 Typical Floor Glazed Facade	Construction	C1	11-Aug-20	
19037-LSI-CMR-ZZ-DR-A-2182	Coursing Sections CS02 Curtain Walling	Construction	C1	11-Aug-20	
19037-LSI-CMR-ZZ-DR-A-2183	Coursing Sections CS03 Blank Facade	Construction	C1	11-Aug-20	
19037-LSI-CMR-ZZ-DR-A-2191	Coursing Sections Party Wall Sections at no. 50	Information	P1	05-Dec-19	
/01_Consultants/01_Architects_LSI/02_Drawings/01_GAs/02_Sections_Elevations/01_Detailed_Elevations					
19037-LSI-CMR-ZZ-DR-A-2170	Detailed Elevations West & North	Construction	C2	18-Jan-21	
19037-LSI-CMR-ZZ-DR-A-2171	Detailed Elevations South & East	Construction	C2	18-Jan-21	
/01_Consultants/01_Architects_LSI/02_Drawings/01_GAs/04_RCPs					

Fig. 3.6 - Report with the different phases of construction – Source: dochosting.com

- By having everything in a collaborative platform, which can also be used via a mobile phone, it saves hours of time in the administration and management of projects.

3.6.3. Pros and Cons

A platform that, in an ideal world, has everything to work perfectly. However, there are still knowledge gaps in the use of digital tools. The use of collaborative platforms, particularly Dochosting, is primarily aimed at design review, ensuring that changes and/or adaptations are constantly updated in the cloud, i.e. accessible to all parties involved in the project.

As well as the clash of services to be built, which by not being connected through a BIM platform, create design conflicts between specialties at the time of construction, since designs are not overlapped to mitigate the existence of conflicts.

After exploring the software's properties and functionalities, table 3.9 describes general aspects of the software along with personal considerations of its use.

Pros	Cons
• Creation of a repository with all the updates • Centralised data • User-friendly and intuitive platform	• Design updates are charged extra • Expensive design update price

Table 3.9 - Dochosting Pros and Cons

4
CASE STUDY

4.1. REGAL HOMES LONDON HISTORY

Regal Homes London is one of London's leading private mixed-use property developers. Desite of the focus on high-specification mixed-use residential developments and a wide number of projects across London, where it is headquartered, over the last 20 years, RHL also has projects in the United Arab Emirates, China and Hong Kong.

The core business area is residential projects for sale and developments for lease. In recent years, RHL has adopted a new approach to expand its business and pursue new market opportunities, undertaking projects such as hotels, flexible workspaces, retail and logistics, always with the aim of optimising production costs and maximising opportunities for the company and its partners.

4.2. REGAL HOMES LONDON METHODS AND ORGANISATION

At the time of my arrival to the company Regal Homes London presented itself as a company with over 100 employees, managing and developing 7 different projects simultaneously in each of the 3 main projects they had an average of 114 workers daily, with a total turnover of the company that exceeds 350 million pounds. The table 4.1, expresses the average number of workers on site, between April and June 2021, and the total budgeted value of the respective.

Code	Project	Average Head Count	Budget Values
1112	Commercial Road	88	£ 20,900,000.00
-	Clapham	84	-
1109	Central & Cecil	155	-
1107	Wenlock Road	30	£ 4,750,000.00
1110	60STJW	99	-
1114	Orchard Wharf	-	£ 239,700,000.00
1118	Clarendon Road	-	£ 71,800,000.00
1125	Warburton Road	-	£ 18,360,000.00
		Total	£ 355,510,000.00

Table 4.1 - Number of workers on site and the total budgeted value of the respective, between April and June 2021 – Source: Regal Homes London

Notes: The missing values in the table have the following reasons:
1- Average Head Count: The three projects are still in planning condition, which means that at the date of this document elaboration they had not yet started the construction works.

2 - Budget Values: It was not possible to obtain the exact budget value for the projects until the date of this document elaboration.
As the UK is one of the countries with huge investment in Health & Safety, Regal Homes London has as one of its essential business foundations the Health & Safety area. Regal Homes London have a specific department with a purpose to review the organization's Management system to ensure its continuing suitability, adequacy and effectiveness. Assess opportunities for improvement and the need for changes to the Management system, including the OH&S/Quality/Environmental policies and OH&S/Quality/Environmental objectives.

It should be noted that Covid-19 made a dramatic impact on the world, in the industry, and in every human life since February 2020. This has resulted in a dramatic effort and changing day to day life for all site teams, subcontractors, and Senior Management, who have been forced to adapt to a new reality to keep sites running at full capacity. However, this was only achieved by implementing the requirements set out by health authorities and government and complying with Covid's company-wide management plans.

4.3. TARGET TO BE ACHIEVED

As the first and only case of a student doing his master thesis in a business environment at Regal London, and being new to the company, it was necessary to make some changes in the organisational processes. As previously mentioned, Regal London, has as main area of activity the construction and sale of developments, with the aim of efficient construction, profitable and focus on the cost benefit ratio.

I was allocated to the "Commercial Road Project" team, as Assistant Site Manager, to study the methods used by the company, and consequently how to improve the collection, organization and analysis of the data obtained in order to facilitate the decision making through the implementation of digital tools. At my arrival, the construction site was already in a very developed phase, with structure and facade concluded, and building fit out and MEP works on going.

The main objective of this case study was to collect data to optimize the processes and construction methods, aiming to achieve higher productivity. After collecting this data another of my tasks was to refine the data through digital platforms, creating more visual and summarised reports in order to support the decision making that the company applies on a daily basis.

4.4. COMMERCIAL ROAD PROJECT– "STAY CITY HOTEL" EXPLAINED

4.4.1. THE PROJECT

The project comprises the complete demolition of the building that occupied the plot, and the development of a new project.

Fig. 4.1 - Design of the aparthotel Wilde - Stay City (Commercial Road Project) – Source: Regal Homes London

The development will be an aparthotel, with a 14-storey building, as shown in figure 4.1, including a single basement level, comprising 156 hotel rooms on the upper floors, a coffee shop and reception area at ground floor level, as shown in figure 4.2, and all service and support areas for the houses at ground floor and basement level. Additionally, there will be a gym in the basement for the use of the aparthotel users and a self-service laundry.

Fig. 4.2 - Common area on the ground floor of the building, coffee shop. Still under construction at the date of this publication – Source: Regal Homes London

The fact that the project was an aparthotel, the client was looking for a commonly referred to as a build-to-suit project, with FFE included. FFE or FF&E is an abbreviation for Furniture, Fixtures and Fittings, which means that when building a new development, furniture and other ancillary items will often be separated and placed in the rooms, ready for use, as shown in figure 4.2.

Fig. 4.3 – Example of a typical aparthotel room, ready to use – Source: Regal Homes London

The £21 million project will offer 5,737 sqm of rental space and is situated on the corner of Commercial Road and Greenfield Road on the eastern edge of the City of London, as shown in the west and north elevation sections of the building in figure 4.4

Fig. 4.4 – General Arrangement Elevations - West & North – Source: Regal Homes London

4.4.2. PURPOSE

As a result of one of the partnership methods described in the subchapter 4.1 the current project has emerged. The intention of the hotel chain company, Stay City, to invest in the construction of the first "*Stay City by Wilde*" tourist development in London has led to the partnership with RHL.

Staycity already operates two Wilde by Staycity hotels in London and has signed a 30-year lease for a third. With London being one of the strongest hotel markets in Europe, and aparthotel concepts proving to be resilient and in demand, the company felt it would be a good bet to realise a third project in the city.

The Commercial Road development is a great example of Regal Homes London's approach to working and delivering successful projects, which consequently transform local areas through innovative mixed-use schemes, providing valuable residential, commercial and retail opportunities across London.

The cooperation between client and developer, as well as with subcontractors, allied to a strong ambition to build a more sustainable, optimised and energy efficient building, has led to the construction of the first building by RHL with a fully prefabricated façade, the use of prefabricated bathroom modules and a heating recovery system for energy efficiency of the entire building.

Committed to ceasing its contribution to climate change, in consistency with the Paris Agreement target to restrain global warming to below 2°C and to pursue its effort to 1.5°C, the UK is engaged in ending its contribution to climate change.
According to the Climate Change Commission, the UK has set the world's most ambitious climate change target to reduce its carbon footprint by 78% by 2035 compared to 1990 levels. This Carbon Budget caps the volume of greenhouse gases emitted over a five-year period between 2033 and 2037, taking the UK more than three quarters of the way to achieving net zero by 2050.

Project delivery methods are ways in which the design and construction of buildings must work together to achieve what is intended. Different project specification attributes often determine which methods are used and where project complexity, knowledge, modification flexibility and risk assessment, among other factors, are taken into consideration by those who must undertake the project.

The methodologies implemented in this project had as main objective the optimisation of the construction processes. The decision to use sustainable and cost-effective construction methods was intending to speed up the construction process by reducing the number of workers needed on site, as well as reducing waste, which is often one of the main problems inherent in the construction industry. Allied to a greener and more efficient construction approach, it also aimed to engage with the local community, minimise environmental, health and safety impacts and complies to workers, Local Authorities achieving their requirements.

The development took place in two distinct phases: the demolition of an old building and the subsequent construction of the new development with different peculiarities, some of which are described in the next sub-chapter.

4.5.PARTICULARITIES

4.5.1.USE OF PRE-CAST CONCRETE PANELS AND BATHROOM PODS

The selection of construction materials and methodologies based on the principle of optimising construction processes was the priority in this project. To accomplish this target, an *OFF-Site* vs. *Insitu* analysis, performed by an independent contractor, was commissioned to determine the most advantageous solution for the construction of the building.

The analysis conducted to the implementation of off-site construction methods, concluded that:

1. Reduced embodied carbon of the Offsite construction vs Traditional construction.
    - A reduction of 32% over traditional construction methodologies, as shown in figure 4.5

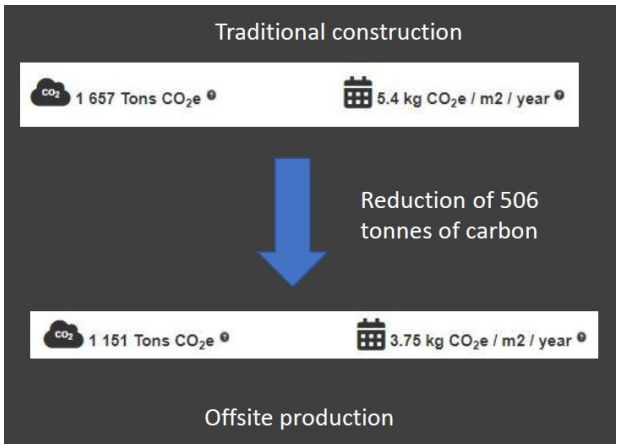

Fig. 4.5 – Traditional vs.Offsite – Carbon reduction - Source: Regal Homes London (2021)

    - Software called **'One-Click LCA'** was used to determine the embodied carbon at all life cycle stages, focusing on the superstructure of the building, as shown in figure 4.6.

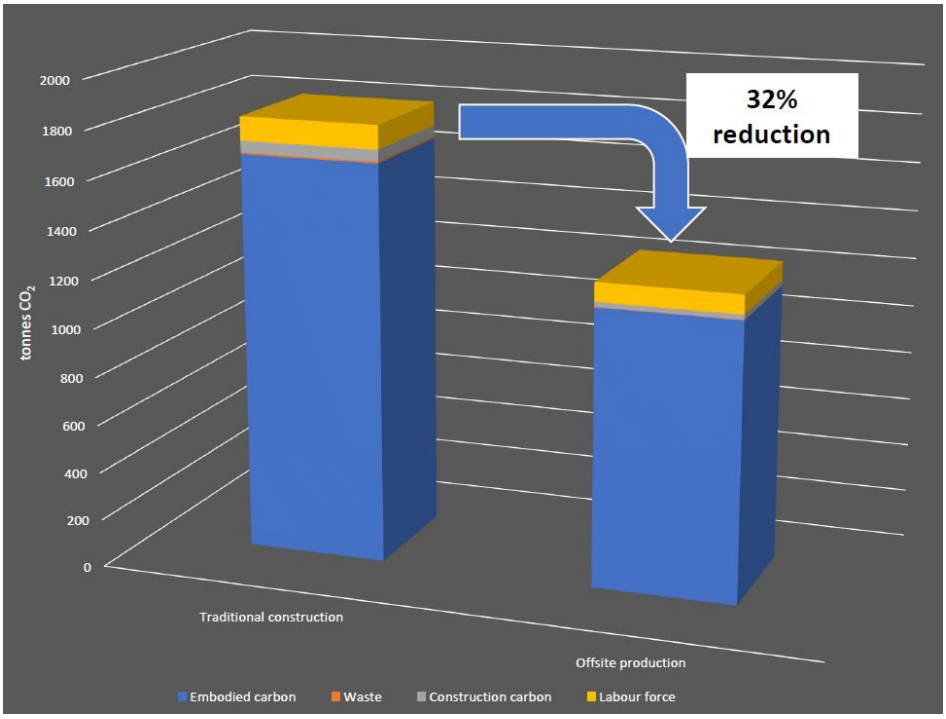

Fig. 4.6 – Carbon percentage reduction achieved through offsite production - Source: Regal Homes London (2021)

2. Reduced waste on site.
    - The use of precast concrete panels is significant in the reduction of on-site waste, as shown in figure 4.7, e.g., by reducing the necessary use of formwork.

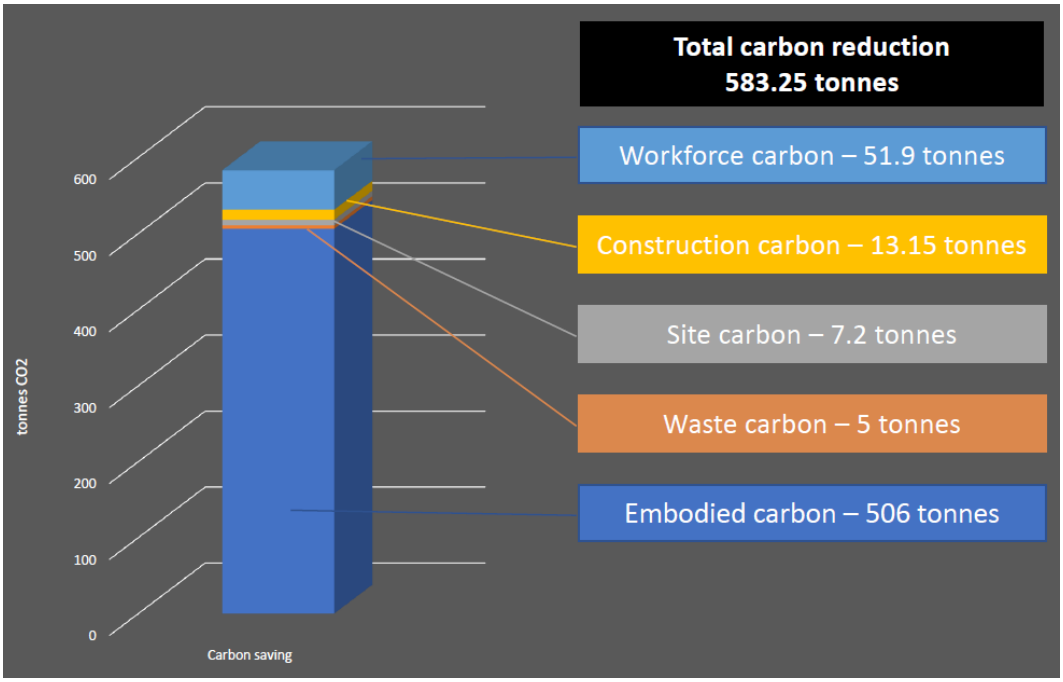

Fig. 4.7 – Total Carbon Reduction from Offsite Production – Source: Regal Homes London (2021)

3. Site efficiency and Improved build programme.
    - Site storage is not necessary, as the prefabricated elements are stored in the factory and delivered just in time to be installed directly from the truck.
    - No additional fire or weather protection is required, eliminating time consuming process and reducing the number of trades on site. Less reliance on weather conditions during installation reduces delays on site and shortens the programme.
    - Due to the fact bricks and windows are part of the precast concrete panels, the need for extra on-site deliveries for these materials has been eliminated. The site on Commercial Road has no storage space for materials, so a traditional build would require weekly deliveries of bricks as the building façade went up.
    - The onsite programme is reduced by around 8 months because of the offsite production, for the superstructure construction.

4. Less labour required on site.
    - This translates to less traveling to the site every day. In London, peak hour trips produce an average of 1.35kgCO 2 /person/day* (*Imperial College London research for EDF Energy), so using off-site production site saves a total of 50,328kg CO 2 over the course of construction.

5. Reduced use on site electricity and water.
    - The onsite water use is reduced, using the Part G calculator it is estimated each person uses around forty-one litres per day within the welfare facilities for WC, hand washing and preparing hot drinks/washing up. This represents a saving of 2,419 *litres* of water per day and almost 3 million *litres* over the construction period.

4.5.2. ASHP – AIR SOURCE HEAT PUMP SYSTEM

Air source heat pumps are one of the renewable heating technologies that allow to generate and optimise the use of energy, leading to a reduction in the operating costs of the services in the future.

4.5.2.1. Advantages

- Low Carbon Footprint
- Save Money on Energy Bills
- Can be Used for both Heating and Cooling
- Can be Used for space Heating and Domestic Water
- Easy Installation Process
- Low Maintenance
- Long Lifespan
- Can work even in Low Temperatures
- High Seasonal Coefficient of Performance (SCOP)
- No fuel storage needed
- Can be powered by wind or solar energy
- Eligible for RHI

4.5.2.2. Disadvantages

- Lower heat supply than boilers
- Electricity is needed to run an ASHP
- ASHPs can be noisy
- Lower efficiency below 0°C
- Extra spending to install underfloor heating

4.5.3. THICK SLAB OPTION IN LIEU OF THE PILLING

London is a particular hotspot of subsidence. Most properties in the Greater London area are built on what is know as London clay, which is one of the most shrinkable soil types of all as it is highly susceptible to volume changes caused by high water content. In areas where settlements are common due to soil liquefaction or water table issues, pile foundations are a better choice. Pile foundations are required in areas where the built structures are large and heavy and the underlying soil is weak.

The scheme started life with a piled foundation design, however due to the configuration of the building, with the core offset to one side, this gave a high density of piles close to the neighbouring building that were extremely congested. The neighbouring building had an old partial basement, which meant that piling from high level was very difficult to do without the risk of damage. In addition piling from a low level, on such a small and congested site, was explored, but studies soon revealed that this was very difficult to achieve when considered in the context of the temporary works required. At the same time, the need for more height in the basement was driving excavation further down into the ground.

The Ground Investigation report was reviewed again and a further study commissioned to gather data to develop a raft foundation. At the same time the foundations of the existing buildings were extensively surveyed. The adoption of a raft allowed a workable solution for the temporary works, excavation, underpinning of the existing buildings and raft construction to be developed in principle and then refined in detail once the basement contractor was procured and appointed.

4.6. RESEARCH METHODS

4.6.1. DATA COLLECTION

Once the targets were defined, my role was to collect data that would allow to verify the weekly productivity of the different trades working on site. Therefore, with different trades with tasks to perform in the same room, it was necessary to verify which program should be executed and which tasks should be performed, bearing in mind that some tasks were directly dependent of others. At the same time, it also allowed me to know which tasks were independent from the others, enabling me to give a progress order and monitor their progress.

Upon considering the most efficient way to carry out this survey, I developed a database that served as a tracking device, and at the end of each week, on Friday, I surveyed the progress of the week, by inputting a "V" if it was finished, the cell automatically turned green, or with an "X" if the task had not been completed and the cell automatically turned red, as shown in figure 4.8. This tracker was done in Microsoft Excel, using tools such as conditional formatting, and the following formula, which allowed me to count the total number.

$$cell = countif(C2{:}C195, \text{"v"})$$

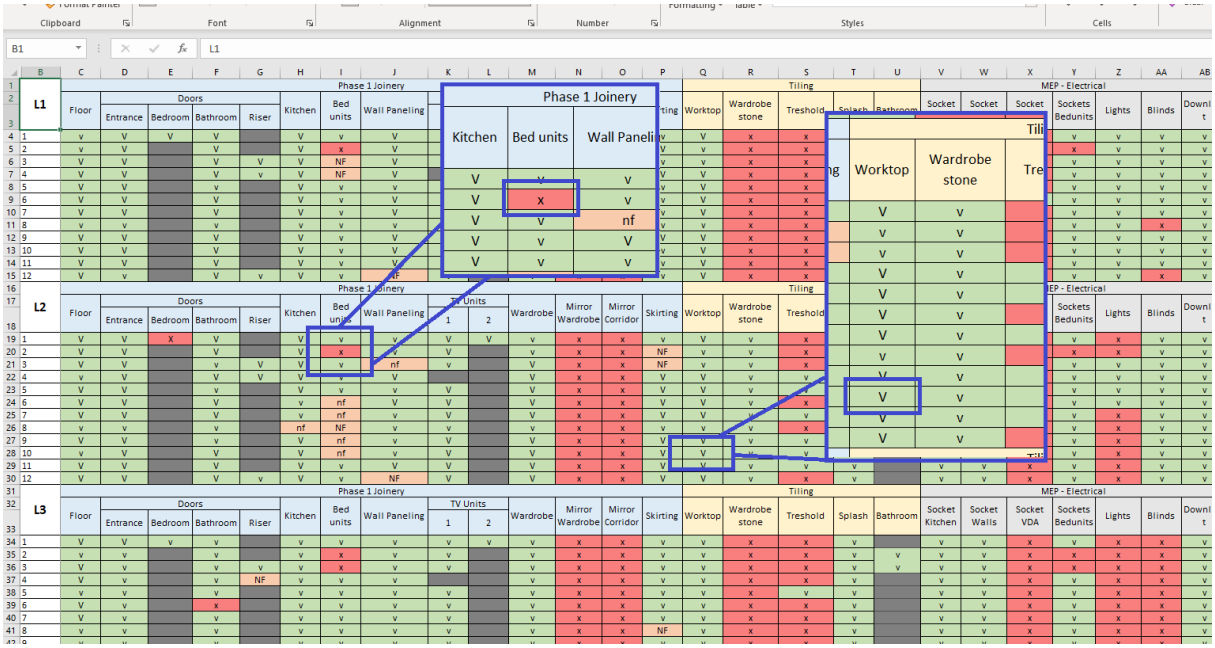

Fig. 4.8 – Tracker of trades to follow up

However during the course of my activity, I was asked by the company to create a standardised data collection system that would allow the collection of data more efficiently, allowing the reports made by the project managers, to be automatically presented in a homogeneous presentation for the company, regardless of the project.

Therefore, I developed a macro program in Visual Basic Application (VBA), as shown in figure 4.9, which allows the project managers to insert the required data, exempt of susceptible errors, once the macro cells have been formatted with the data validation tool, as shown in the figure 4.10, with the data defined in "Pick Site_ID" and "Pick Type" in the figure 4.11, in order to compile a database that would later be analysed by a data analysis program.

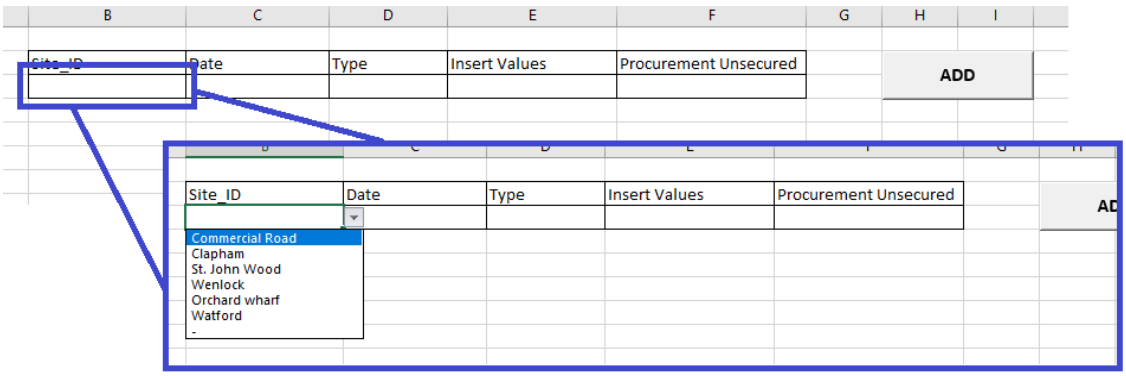

Fig. 4.9 - Macro for data entry. Procurement case

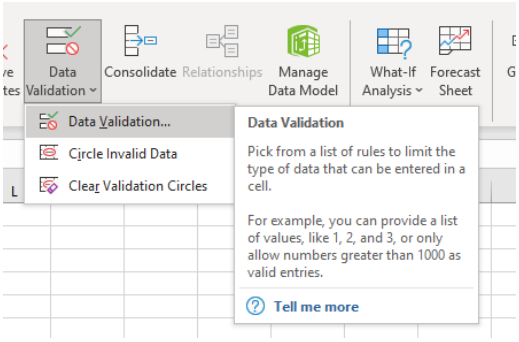

Fig. 4.10 – Data Validation Tool

Fig. 4.11 - Set data in "Pick Site_ID" and "Pick Type"

The creation of the code, full explanned at *Attachement VII*, allows systematising the input of data into the system. The macro, not shown in its entirety in the figure 4.12, thus allows to create a database that will later be analysed in a database automatically. The database was connected through a cloud device to the Microsoft BI program, to keep the data updated at a distance of a click or a mobile application.

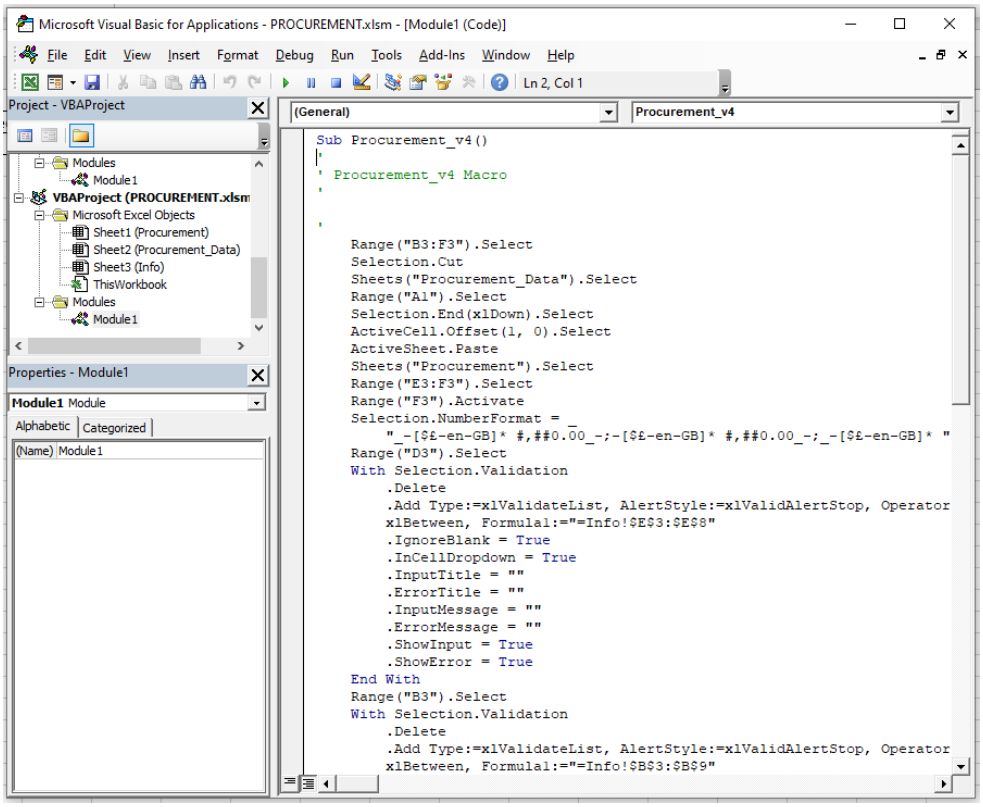

Fig. 4.12 - P Section of the code relating to procurement

However, in this report I only demonstrate the Macro for Acquisitions, however, I have made other macros for Planning, Accident Frequency Rate, SHEQ Inspections, Employer Directives and Turnover, as shown in the figure 4.13, so that the report is renewed automatically according to the choice of filters adopted. The report, although cannot demonstrate it through this document, *attachment VII*, will be interactive, allowing the user, through the selection of different graphs, to analyse new graphs without the need to delete or move data.

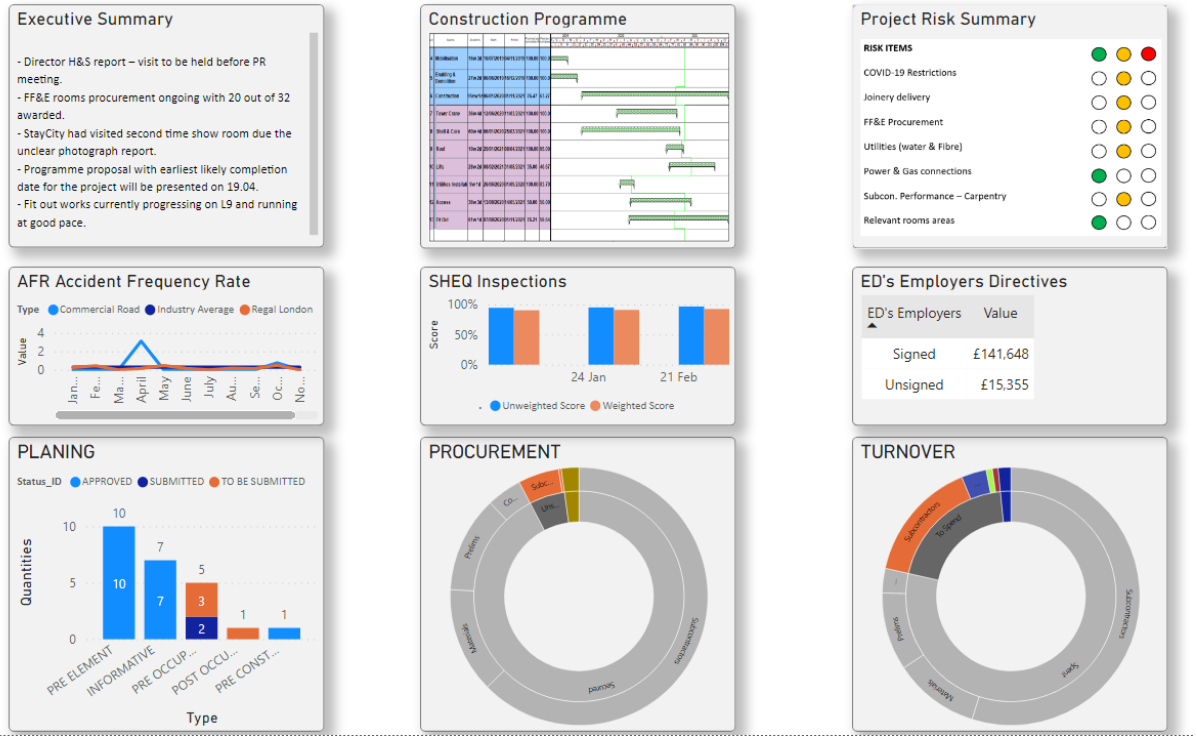

Fig. 4.13 – Dashboard of Monthly Report

4.6.2. Data Analysis

Once I obtained a significant sample (data from two weeks), I generated the productivity graphs by task performed, as shown in figure 4.14, to allow me, during the daily meetings with the subcontractors, to show the collected data and analyse the reason for the decrease or increase in productivity and, if necessary, to make adjustments. In figure 4.15 the specific case of the weekly production of assembling number of beds. The productivity calculation was made through the division of the obtained results by the intended results, being able to deduct that if the productivity was above 100% they would be above the intended productivity and if it was below 100% they would have a negative productivity.

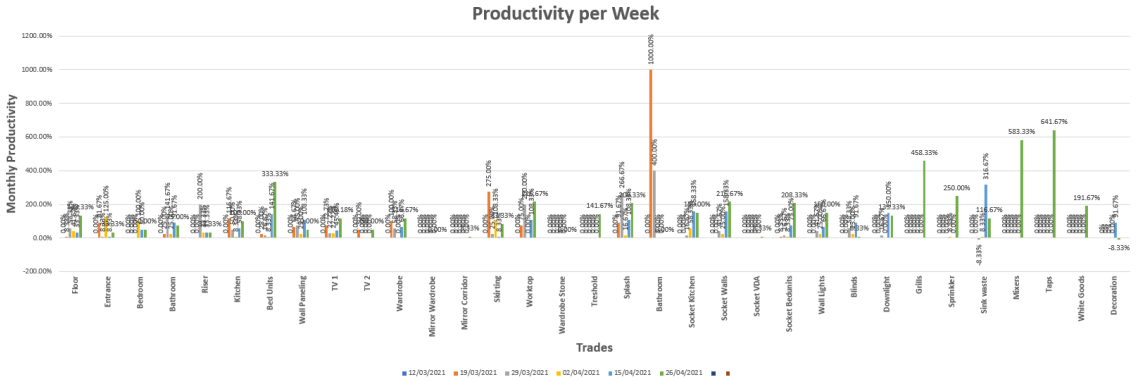

Fig. 4.14 – Productivity per trade, per week

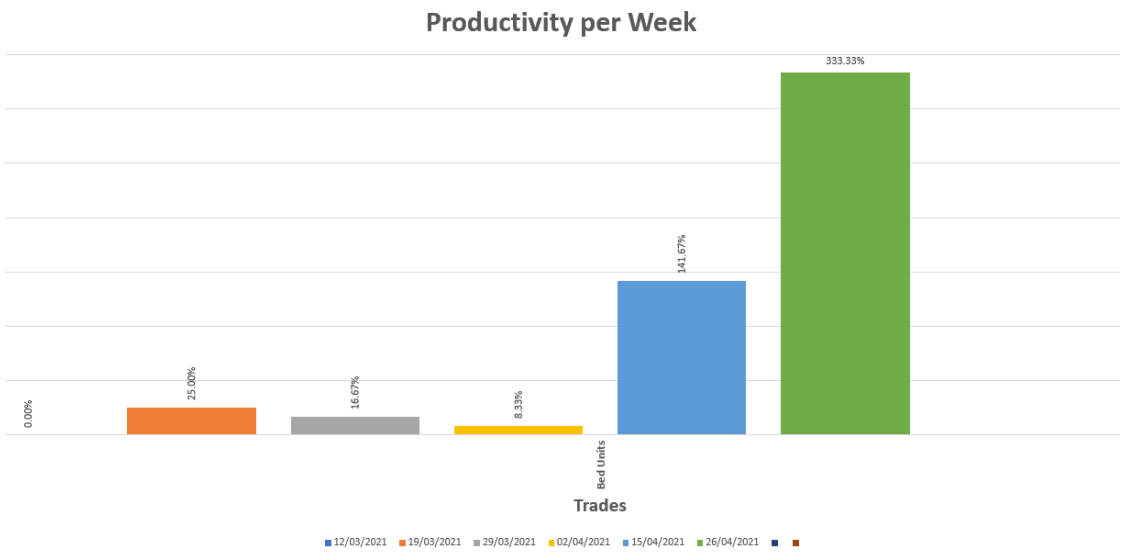

Fig. 4.15 – Productivity of Bed Units Assembled per week

4.6.3. QUALITY

In the construction industry, quality is one of the crucial factors for a successful business growth, maintaining a professional reputation, and keeping it profitable. When it comes to construction quality, it can be divided into two subcategories.

1. **How to ensure quality?**
   Quality monitoring in construction involves establishing the process of identifying, documenting and analysing non-conformances and mitigating their impacts through the implementation of corrective and preventative actions. Regal Homes Construction Ltd is dedicated to the proactive elimination of actual and potential non-conformities and deficiencies. Non-conformities in products, services or the management system are investigated and actions implemented to prevent recurrence.
   Through the use of standard references such as ISO, there is an intention to ensure the safety and quality of products, and to encourage innovation in a global market while maintaining quality standards. At Regal Homes London the following ISOs are used to enforce UK standards:

   - BS EN ISO 9001:2015 Quality Management System Standard 10.2 nonconformity and corrective action
   - BS ISO 45001:2018 Health & Safety Management System 10.2 incident, nonconformity and corrective action
   - ISO 14001:2015 Environmental Management System Standard

2. **How to increase quality?**
   Delivering a high standard of quality is a key issue for the construction industry, and Regal Homes London is committed to those standards. Poor quality on a project is more likely to result in repairs and consequently losses to the company, which explains Regal Homes London's slogan "Getting right at the first time".

   Regal Homes London is associated with initiatives such as BREEAM and CCS which aim to raise standards in the construction industry.

4.6.3.1. Identification of Non-conformances - *(How to ensure quality?)*

It is the responsibility of all employees to bring suspected non-conformances to the attention of their line manager or other nominated representative, these can be non-conformances in relation to quality management, health and safety management and environmentalmanagement.

Non-conformances can be identified through the following activities:

- Internal audit and inspection findings
- Third party audit findings
- Complaints (internal or external)
- Observation
- Incidents
- Housekeeping inspections
- Checklist findings
- Near-misses

Non-conformances will need to be recorded via FinalCad Non-Conformance Report.

4.6.3.2. Control of Non-conformances - *(How to ensure quality?)*

Following the identification of a non-conformance a non-conformance report, will need to be completed and the project non-conformance register referred to for a nonconformance report number and to be updated with the details of the non-conformance.

Once identified the underlying cause(s) of the non-conformance are to be investigated and appropriate corrective action(s) taken according to the nature of the non-conformance. The subsequent investigation and verification activities are undertaken to determine the cause(s) and allow for the implementation of preventive action to avoid reoccurrence.

Any corrective or preventive action taken to address the causes of the non-conformance must be reasonably practicable, i.e. appropriate to the magnitude of problems and commensurate with the impact encountered.

Repeated non-conformances of the same nature or same offender are to be reported to the SHEQ Manager and Construction Director for action and resolution.

4.6.3.3. Closure of Non-conformances - *(How to ensure quality?)*

When the non-conformance report has been completed in full with the completion of corrective and preventative action(s) the report will need to be sent to the Regal Homes London SHEQ Manager for closure and update of the project and construction division non-conformance registers.

In the event of a non-conformance report being issued to a subcontractor a meeting will be required with representatives of their senior management team, Regal Homes Construction Director and SHEQ Manager for closure.

4.6.3.4.BREEAM – *(How to increase quality?)*

BREEAM (Building Research Establishment Environmental Assessment Method) is a sustainability assessment method that is used to masterplan projects, infrastructure and buildings.

Source: https://www.breeam.com/

BREEAM is one of the planning conditions to develop any building construction project in the UK, more specifically in London, being mandatory by several government organizations. The platform aims to standardize the classification of construction processes through the use of benchmarks. BREEAM assigns a general classification of the work, as shown in Figure 4.16, by evaluating the various subsectors, shown in Figure 4.17.

BREEAM Rating	% score
OUTSTANDING	≥ 85
EXCELLENT	≥ 70
VERY GOOD	≥ 55
GOOD	≥ 45
PASS	≥ 30
UNCLASSIFIED	< 30

Fig. 4. 16 – BREEAM Rating – Source: breeam.com (2021)

- Awarding BREEAM credits

Each category is sub-divided into a range of assessment issues, each with its own aim, target and benchmarks. When a target or benchmark is reached, as determined by the BREEAM assessor, the development or asset score points, called credits. The category score is then calculated according to the number of credits achieved and its category weighting. Once the development has been fully assessed, the final performance rating is determined by the sum of the weighted category scores. – Source: breeam.com (2021)

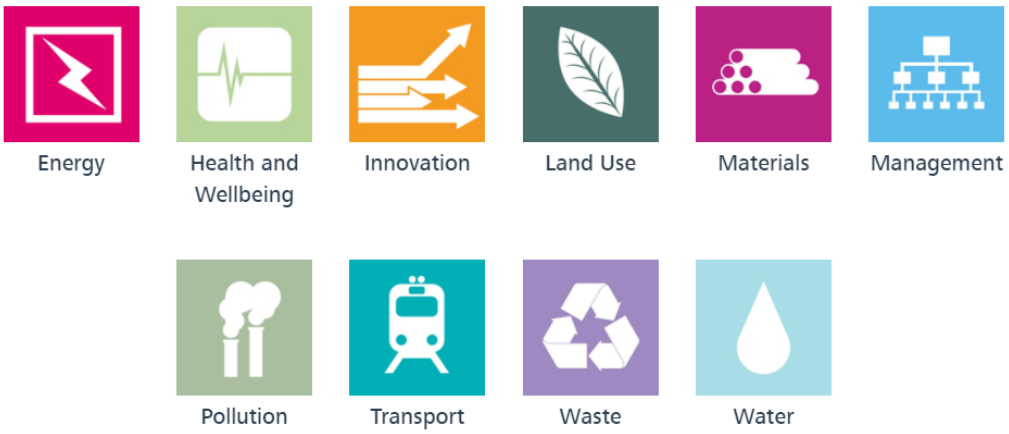

Fig. 4.17 – BREEAM Category Issues – Source: breeam.com (2021)

4.6.3.5.Considerate Constructors Scheme (CCS) – *(How to increase quality?)*

According to Considerate Constructors Scheme CCS, any company, or supplier that registers with the Scheme makes a commitment to meet the minimum requirements of the Scheme's Code of Considerate Practice. To establish compliance, and recognise performance beyond compliance, Scheme Monitors will visit offices, depots and individual projects or work areas, and will use the appropriate Checklist to

confirm a score against each of the five Code headings – appearance, community, environment, safety, and workforce.

Separate Checklists have been developed to recognise the differences between sites, companies, and suppliers but each includes several questions within the five key sections of the Code. The Checklists include the Scheme's minimum compliance requirements, and these are highlighted either as separate bold questions or as bold prompts.

Each section of the Checklist is scored out of nine points, with a score of 5 indicating compliance. All compliance requirements highlighted in bold on the Checklist must be satisfactorily addressed to achieve compliance in that section. However, Monitors are not only assessing compliance with the Scheme's Code and Checklist but also look to identify measures taken which are above and beyond these requirements and addressing the non-bolded questions/prompts on the Checklist may result in a higher score.

An additional 5 points are then available, at the discretion of the Scheme, to reward those sites, companies or suppliers who have developed innovative ways of addressing Scheme expectations. The following will apply:

- Monitors will review all potential innovations presented to them and include any that they deem suitable within the Monitor Report which will be passed to the Scheme's Innovations Team to review, however no more than five can be submitted with the report.
- If a site, company, or supplier feels they have more than five innovations, they must select the five that they feel have the strongest chance of approval. The Monitor may assist in selecting those to be presented but the responsibility sits with the site, company or supplier being visited.
- Each approved innovation will now result in one additional point being added to the overall Monitor's score, up to a maximum of 5 additional points.
- The report will still present a score out of fifty which will be used to establish the star rating and eligibility for awards.

Source: https://www.ccscheme.org.uk/

4.7. METHODOLOGY AND IMPLEMENTATION OF CLOUD AND MOBILE SOLUTIONS

4.7.1. INTRODUTION

Regal Homes London is a construction company that is in constant development, which means that it is often looking for better options with a view to better adapting to the market. Thus, the use of various digital tools, aimed at optimizing processes and monitoring quality parameters in accordance with British standards, allows you to be at the forefront of developers and stakeholders in the city of London

4.7.2. WASTE

When it comes to the construction, demolition or refurbishment industry, it is important to understand where the project can save time and money and where performance can be improved to further reduce its environmental impacts.

As part of RHL's commitment to improve the way construction waste is managed, RHL deployed, in every project, the use a collaborative platform called SMARWASTE, which has features that help users and site managers not only to achieve the above, but also to fulfill the increasing monitoring and reporting requirements of the projects.

SmartWaste enables an data supply chain, with relevant site data uploaded by organisations, in order to be analysed and reported by the client or main contractor, providing the vital data needed to identify trends and areas for improvement, facilitating the decision-making process.

4.7.2.1. Site Waste Management Plan

A Site Waste Management Plan (SWMP) is conceived before any construction work begins and is designed to estimate the amount of waste that will be produced as a result of the project, in order to compile a plan to effectively remove the waste in a timely manner.

Once the project is underway, a record should be kept of the amount and type of waste removed. The purpose is to manage waste in a cost-effective and efficient way, making the most of recycling materials wherever possible. However, even after listing those reasons, the question arises.

- Why should a SWMP be implemented?

Knowing in advance the necessary steps to dispose of waste reduces the amount of indecision during the construction process. People will know exactly what to do with their waste as they produce it, resulting in less time wasted and more time focused on the project, thereby improving efficiency.

In the construction industry disposal costs, especially considering the waste that goes to landfill, can be very expensive. Arranging for the waste to be recycled will lead to greater profitability, meaning that the project will be more cost effective.
Considering the effects that waste has on the environment, and how simple it is to recycle, could encourage people through environmental awareness, to take a more active role in reducing the impact of business on the Earth.

For the reasons listed above, and also because the SWMP has a mandatory component in the execution of a UK construction project, the plan should be executed taking into account what is intended, what should be identified and contemplated, and finally who should perform what tasks.

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bre

Site Waste Management Plan for 73-77 Commercial Road Date:Wed Jul 21 19:14:39 BST 2021

Responsibilities

	Name	Company	Company Type	Contact details
Who is responsible for drafting the SWMP?	Vitor	Mr	Principal contractor	07989999761
Who is responsible for implementing the SWMP?	Manuel	Mr	Principal contractor	07945126784
Who is the waste champion?	Vitor	Mr	Principal contractor	07989999761
Who is the person in charge of the project?	Vitor	Mr	Principal contractor	07989999761
Who is the client?	StayCity	Mr	Hotel company	
Who is the principal contractor?				

Fig 4.18. – SWMP Responsibilities – Source: smartwaste.co.uk (2021)

The Project Manager, with the assistance of Assistant Site Manager, the Quantity Surveyor and the SHEQ Manager, should define and produce the Site Waste Management Plan prior to the

commencement of each project in accordance with the Waste Management Policy, as shown in figure 4.18 of the responsibilities conferred on each member of the team.

The management of each role is not assigned to a specific position, in the case study of the project in particular, they were assigned to me by delegation by the Project Manager. Therefore, the Assistant Site Manager, should also be responsible, during the various phases of the project, for adapting the respective plan according to any setbacks and/or changes.

The Site Waste Management Plan **should identify** the following:

- the waste streams generated in the development
- an estimate of the projected volume/tonnage
- the proposed method of disposal.

The Site Waste Management Plan **should ensure** that:

- Details of each waste delivery
- The name of the waste transporter
- Registered transporter license number and expiration date
- Waste disposal site
- Waste management license number or waste management exemption details
- Details of the waste deliveries that the disposal site is licensed to accept.

Once the SWMP is completed, the data collection and updates must be entered monthly in the SmarWaste platform, obtaining a considerable sample, in order to monitor and analyse the costs and the amount of waste and, if necessary, modify the daily strategies and methodologies in the management of waste on site.

The procedure on how to proceed with this data update should be carried out by performing the following steps:

1. To access the website, enter the username and password provided by the SHEQ Department from the link on the Projects homepage via sharepoint, or via the link https://www.smartwaste.co.uk, as shown in figure 4.19

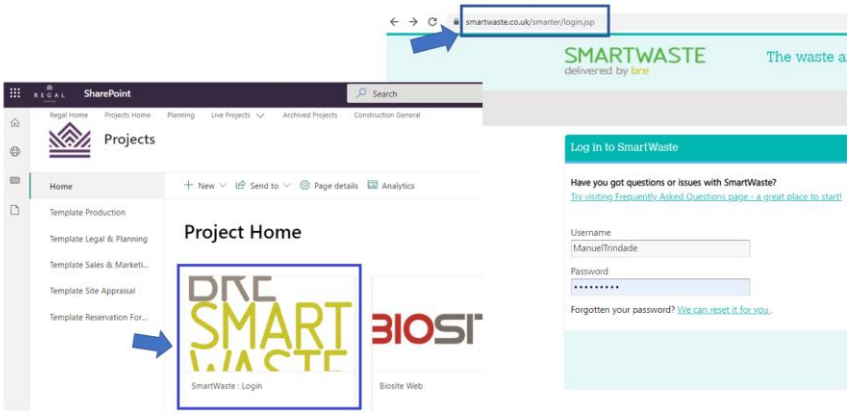

Fig. 4.19 – Access to SmartWaste – Source: smartwaste.co.uk (2021)

2. Once logged in to the Smartwaste portal, as shown in the figure 4.20, select the project where the data is to be inserted.

(Note that, in order to protect the data for each project, the access will be restricted according to the level of permission that each user has.)

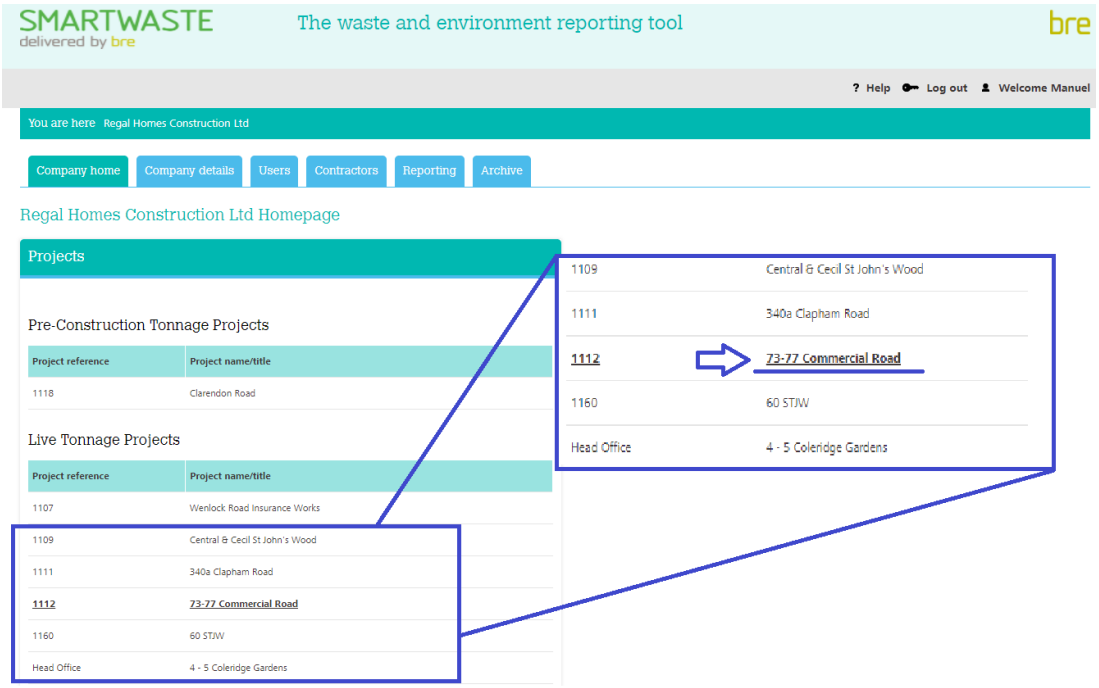

Fig. 4.20 - Selection of the intended project – Source: smartwaste.co.uk (2021)

3. To enter a Waste Transfer Note select 'Add Data' from the 'Project Start' menu and select "Waste", as shown in figure 4.21. This will then bring up the blank waste data entry proforma, as shown in figure 4.22

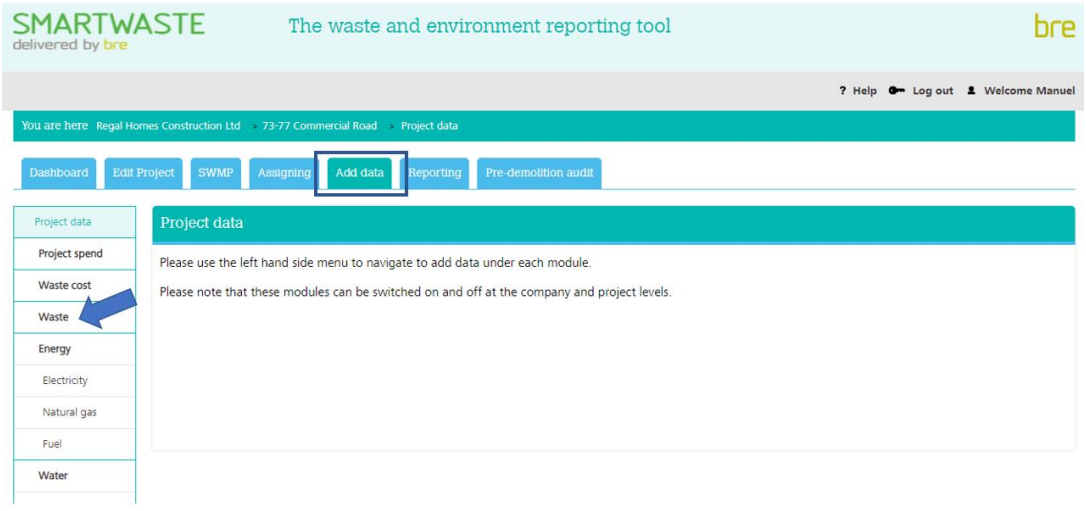

Fig. 4.21 – Input waste data – Source: smartwaste.co.uk (2021)

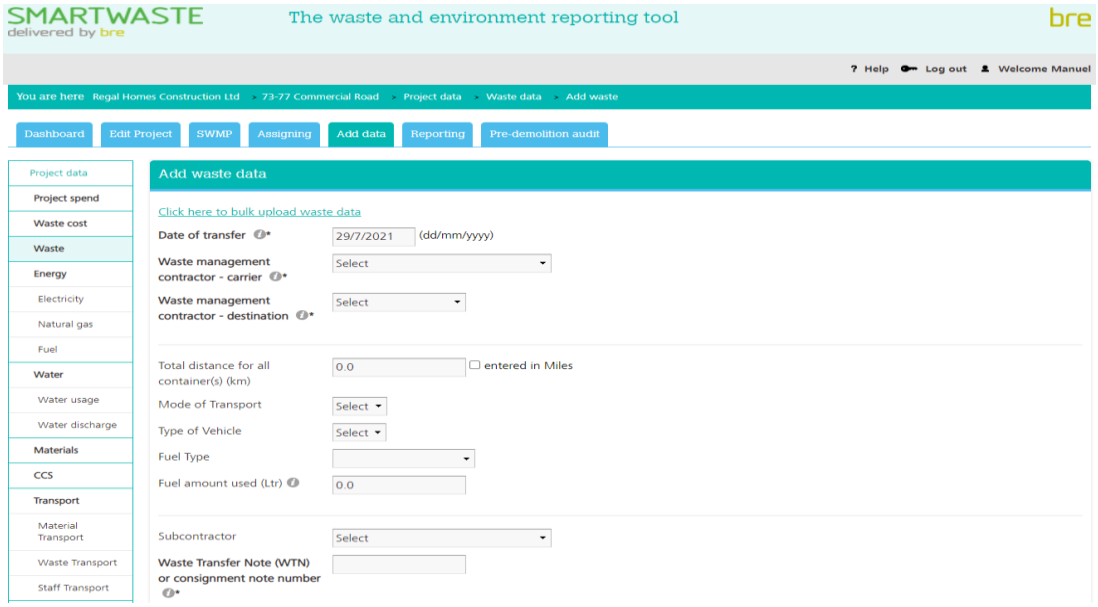

Fig. 4.22 – Waste data entry proforma – Source: smartwaste.co.uk (2021)

4. Date - Enter the date given on the waste transfer note (WTN).
5. Waste carrier - Select the waste carrier from the drop down menu.
6. Waste destination - Select the disposal site from the drop down menu.
7. Subcontractor - Select the Subcontractor responsible for generating the waste.
8. WTN number - Enter the WTN number indicated on the ticket.
9. Container reference - Leave blank.
10. Container type - Select the container/dumpster size from the drop down menu.
11. Number of containers - Leave as default (0), unless bulk loads (i.e. demolition and excavation waste only)
12. Total tonnage - Leave blank unless an exact weight is recorded in WTN.
13. Work package - Select the work package that generated the waste.
14. Project phase - Select the phase of the project that generated the waste (Construction, Demolition or Excavation).
15. Waste Management Route - Refer to your site specific waste stream guide, which will identify the waste management route for each of your waste streams.
16. Re-use on site (e.g. direct re-use of material such as bricks or wood)
17. Direct recycling (e.g. segregated waste streams which are sent directly to a processing facility for recycling, such as PVC windows, pallets and cardboard)
18. Recovery (for example, waste that is taken to a Waste Transfer Station for sorting or waste that is used for energy, this will typically be mixed waste)
19. Landfill (e.g. material going to a landfill site, particularly hazardous waste such as asbestos).
20. Off-site/on-site - You should also select that the waste has been sent off-site.
21. Segregated container - tick if the waste has been kept separate from other waste streams (e.g. all containers, except mixed waste).
22. After entering the previous data in the specified fields, the application will create a database with the data related to each collection, as shown in figure 4.23.

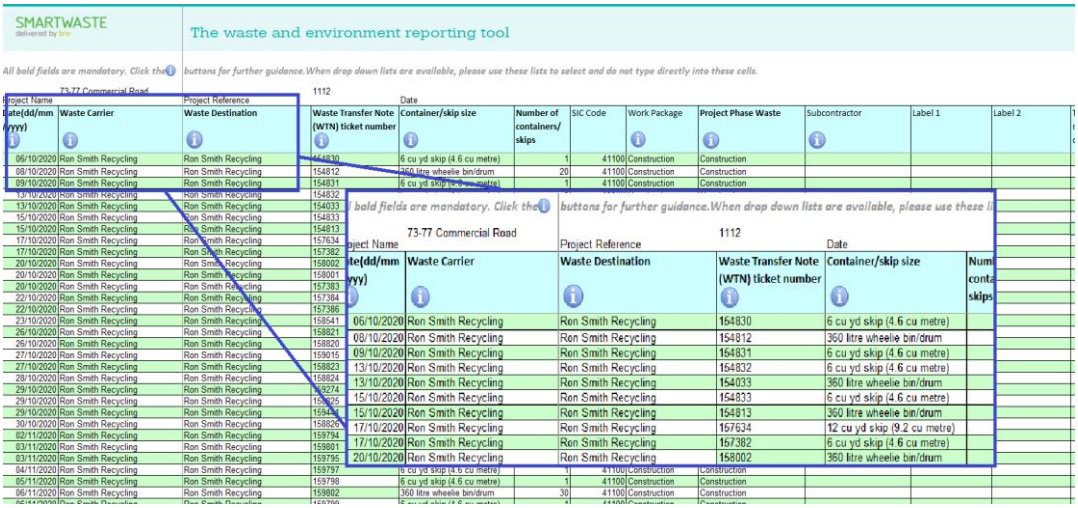

Fig. 4.23 – Waste collection database – Source: smartwaste.co.uk (2021)

23. Upload Waste Transfer Note 'WTN
24. Select the correct waste type, as shown in figure 4.24, from the list using the European Waste Code given in WTN. Click on the box to open the complete menu. (Example of Concrete)

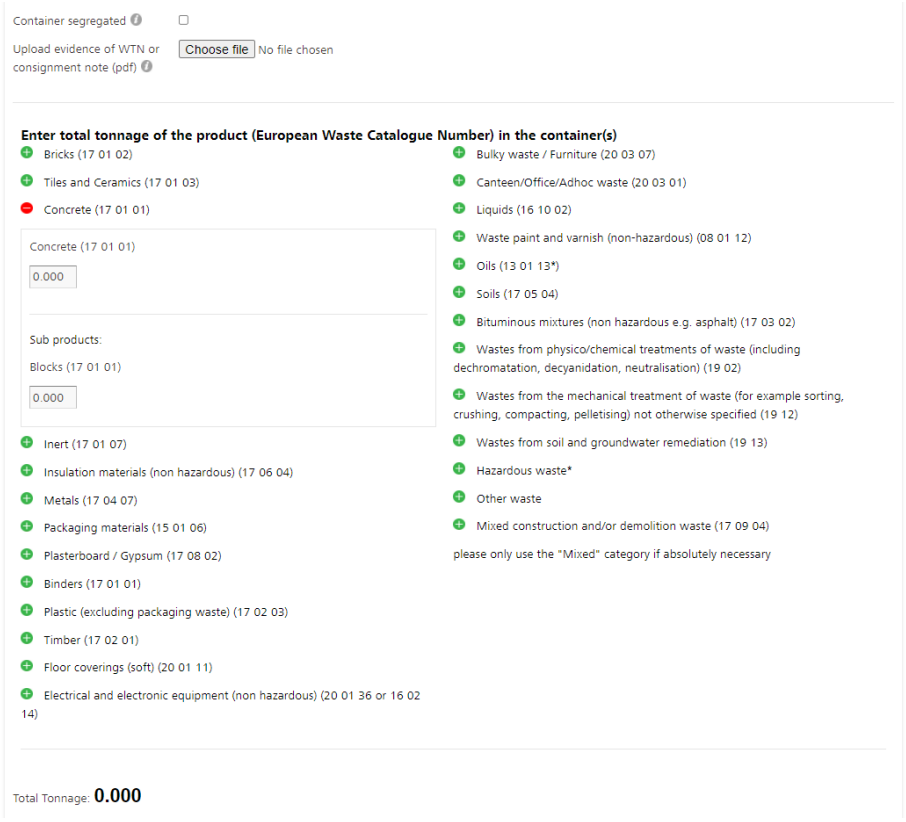

Fig. 4.24 – Waste type per product, according to the European Waste Catalogue number – Source: smartwaste.co.uk (2021)

25. Lastly, click on save, as shown on figure 4.25, and the data will be saved and a report will be generated. The report will already include the new data entered, updating the report to show all the data entered to date, since the beginning of the project.

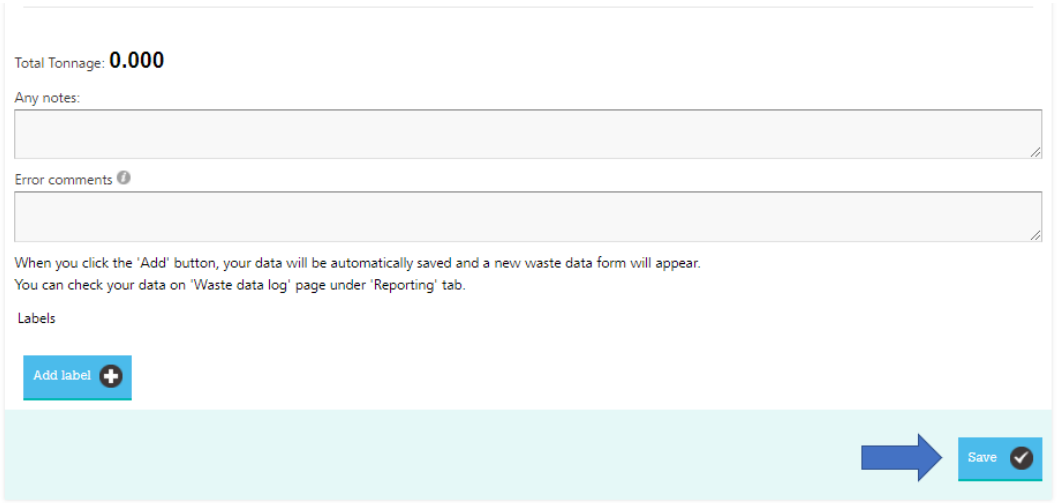

Fig. 4.25 – Save the data and generate the SmartWaste Report – Source: smartwaste.co.uk (2021)

After all data related to the waste generated on site is entered, Smartwaste generates a report with all the data that indicates the overall status of the site through graphs containing summarised data, as shown in figure 4.26.

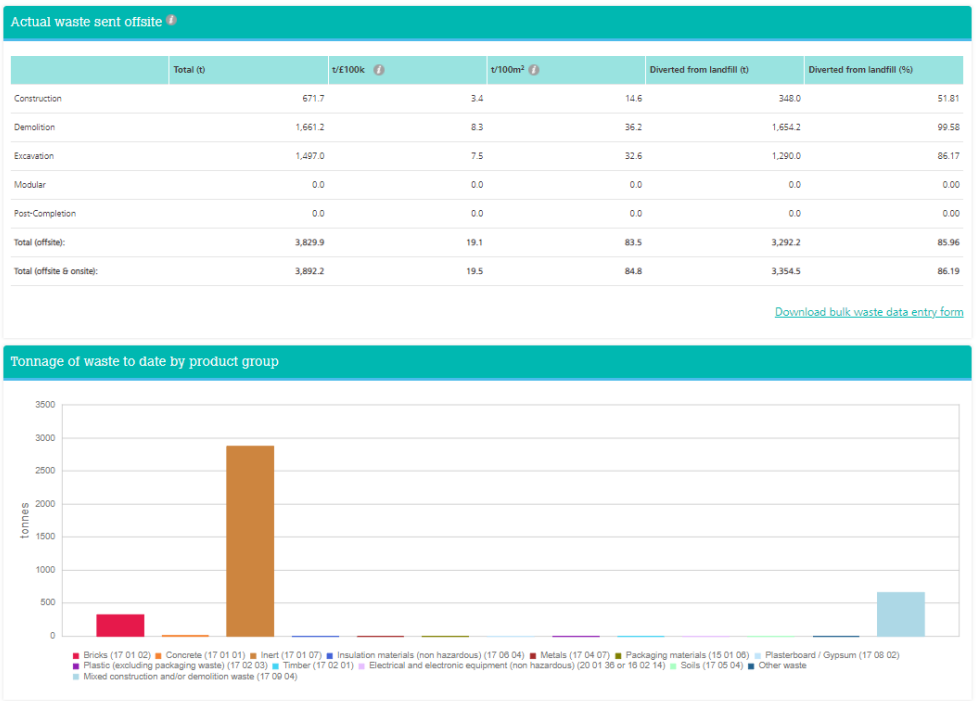

Fig. 4.26 – Smarwaste Dashboard. Example of chart of Waste sent Offsite and Tonnage of waste to date – Source: smartwaste.co.uk (2021)

(Note: Complete report generated by the program, updated on July 29th 2021, can be found in the annexes of this document)

The report presented, only focused on waste management, although Smartwaste has so many other management categories that I used on a daily basis, as shown in figure 4.27, such as water, energy and workers' time management.

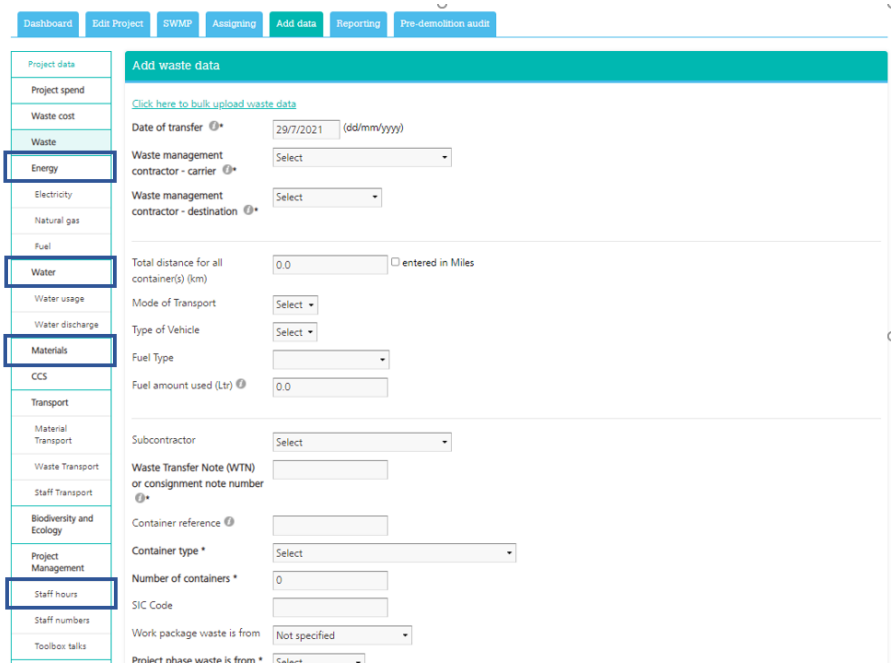

Fig. 4.27 - Example of other management categories of the Smartwaste platform, such as water, energy and worker's time management – Source: smartwaste.co.uk (2021)

Figure 4.28 provides a forecast of the types and quantities of waste, classified by trade, by specificity of waste, respective project phase and quantities used on site up to the date on which the data was collected, 21 July 2021.

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Site Waste Management Plan for 73-77 Commercial Road

Date:Wed Jul 21 19:14:39 BST 2021

Forecast of waste types and amounts

Work Package	Subcontractor	Waste type	Waste Sub Type	Estimate amount (m3)	Estimate amount (tonnes)	Likely cause	Notes
Substructure		Concrete (17 01 01)		0.0	1.3		
First Fix		Plasterboard / Gypsum (17 08 02)		0.0	26.0		
Second Fix		Plasterboard / Gypsum (17 08 02)		0.0	26.0		
First Fix		Metals (17 04 07)		0.0	2.0		
Second Fix		Insulation materials (non hazardous) (17 06 04)		0.0	0.2		
Construction		Packaging materials (15 01 06)		0.0	10.0		
Total				**0.0**	**65.5**		

Fig. 4.28. – SWMP Forescat of waste types and amounts – Source: smartwaste.co.uk (2021)

BRE SMARTWASTE

Project : 73-77 Commercial Road

Considerate Constructors Scheme

Project CCS score	38
Project CCS target	
BREEAM CCS Credits Achieved	2

Fig. 4.29 – BREEAM CCS Credits Achieved – Source: smartwaste.co.uk

4.7.3. ASTA POWERPROJECT

Asta Powerproject was designed to support the way construction and planners work and improve with its contribution that aims to meet the requirements in the area of planning and management in the construction industry.

The attached programme screenshot, allows the visualization of a summarized construction program, as shown in the figure 4.30, allowing the user to verify the general progress of the different construction phases. Every week the droplines were executed, which consists in updating the percentage of tasks completed to date.

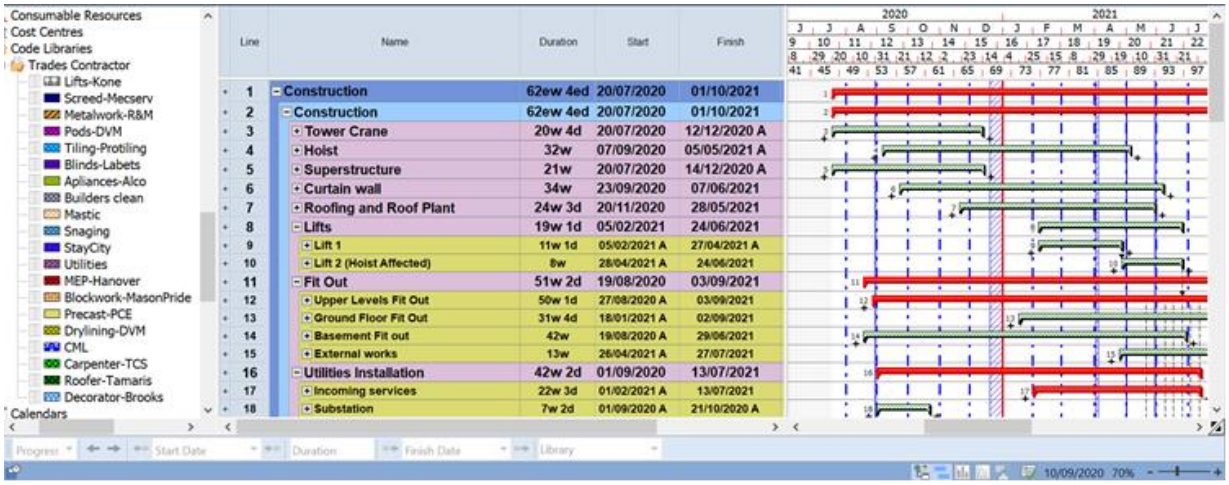

Fig. 4.30 – Dispaly of the Commercial Road Project summarised – Different phases of construction

The figure 4.31, has exactly the same function but with a higher level of detail, allowing us to know through which tasks are left unfinished and consequently at risk of reaching the critical path.

Note: The Critical Path Method (CPM) describes the sequence in a project that will result in the last task to be carried out.

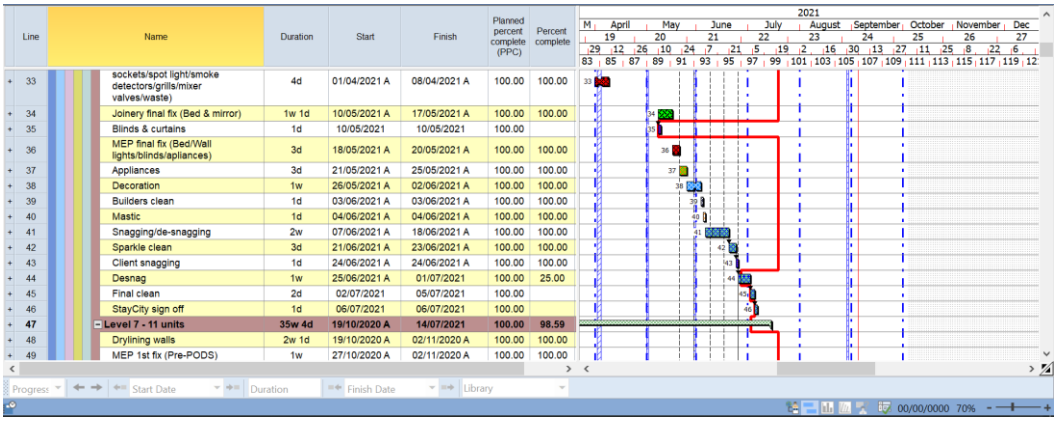

Fig. 4.31 – Display of the Commercial Road Project task to do specified per trade and level

4.7.4.FINAL CAD

Finalcad helps contractors, architects and owners to act in synchronicity, build quality projects and manage risk through solutions that provide progress reporting, defect management, quality controls and analysis. The collaborative platform allows all stakeholders to be involved in the day-to-day in a more synchronised way. Share photos, comment, assign tasks in real time.

Therfore, this subchapter intends to demonstrate the typical features and methodologies used in my daily basis through FinalCad.

4.7.4.1.How to create a new project

FINAL CAD – Create a new project (numbers, plans, areas, trades)

The following procedure allows you to create a project, this being the first step in the process

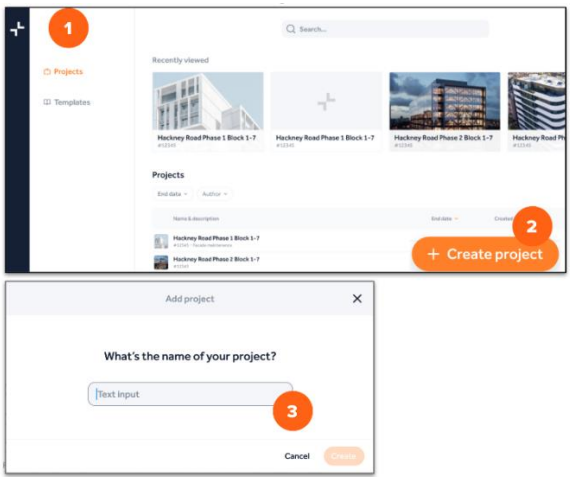

Fig 4.32 – How to create a report on Final Cad

1. Choose Project by click in Projects
2. Click on the button "+ Create Report"
3. Input the Project Name

4.7.4.2.How to add new users to the project

The following methodology allows adding users to a project, specifying their specialty and their company

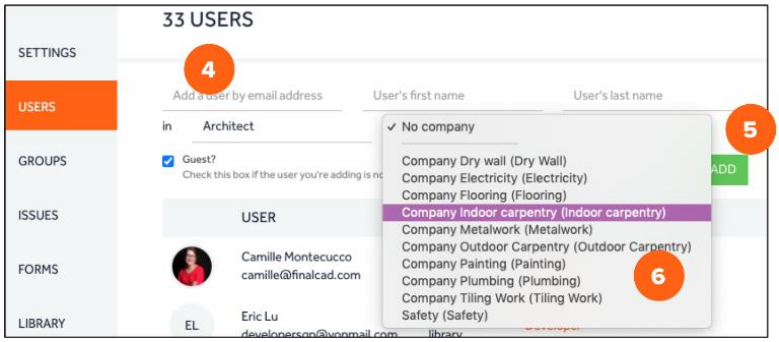

Fig. 4.33 – How to add new user to the project

4. Choose user by clicking on Users
5. Specify the trade and the company
6. Click "Add" button to update users

4.7.4.3.Create a issue report (trade, issue, solution, lead time, finish date, update)

The production of an error or non-compliance report was perhaps one of the tools I used the most during my functions as a construction site manager. The application allows the elaboration of succinct reports, with images and messages that are automatically sent to the intervenient of the respective task or specialty. The reports are created automatically after performing the procedures as shown in the figures, 4.34 and 4.35.

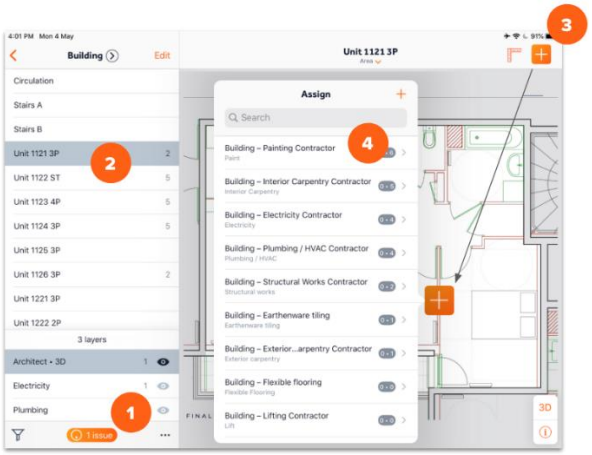

Fig. 4.34 – Create a report issue

1. Choose type of issue
2. Choose room location of the issue
3. Drag the icon to the exact location of the problem
4. Indicate the speciality reponsible

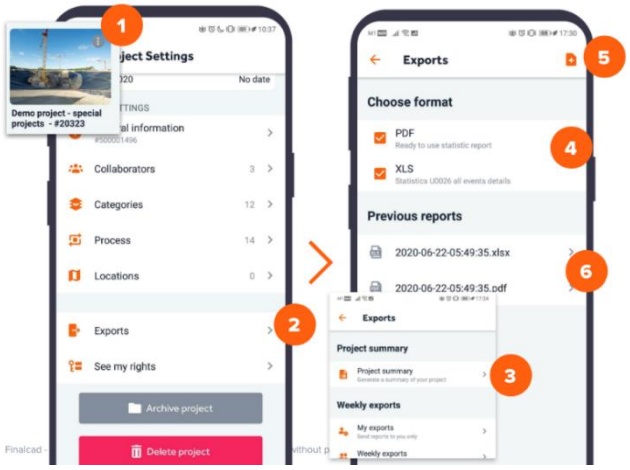

Fig. 4.35 – Generate the project summary report

1. Choose the project
2. Click on exports to create a report
3. Choose Project summary report option
4. Choose file format of the report
5. Click on the icon to generate report
6. See the old reports

4.7.5.MICROSOFT® POWER BI

Power Bi's capabilities are quite extensive. Although cannot demonstrate it through this document, *attachment VII*, will be interactive app, allowing the user, through the selection of different graphs, to analyse new graphs without the need to delete or move data.The main purpose is to be a program that facilitates the data analysis by optimizing the time and effort spent in the analysis of results and data.

4.7.5.1.Importing data

Power BI is best known for the impressive data views and dashboard capabilities it has. However, before starting to build reports, it is first necessary to connect the data sources.

Excel remains the most popular application in the world, and as such, it is hoped that at some point it will be used as a data source, as shown in figure 4.36:

1. To get started, open Microsoft Power Bi.
2. On the start banner, you will find the "Get date" button, as shown in figure
3. Select the data and configure it
4. Upload the date and the Navigator dialog will launch

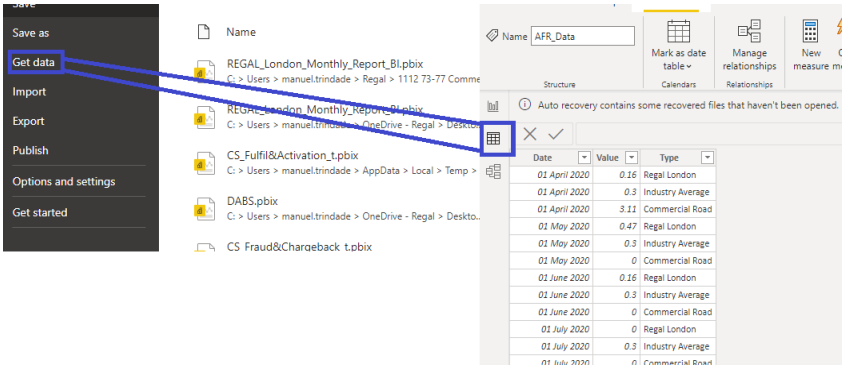

Fig. 4.36 – Importing data

4.7.5.2.Building relationships

The building of relationships is the most important piece of Microsoft® Power BI. It is this process, the building of relationships, that makes everything else work smooth in Microsoft® Power BI.

Often, Microsoft® Power Bi will create the relationships automatically. It is important to verify these auto-detected relationships to ensure accuracy

The user should be aware of the following characteristics of relationships:

- Auto-detected relationship
- Relationships automatically filter from the one side of the relationship to many side

After importing data the user should verify that all auto-detected relationships gave been created correctly. The numbers represented in the following figure represent the possibilities of connections, as shown in figure 4.37:

1. **One Side:** The 1 indicates the "*Project_Name*" as the one side of the relationship.
2. **Direction:** the arrow indicates which direction that filtering will occur.
3. **Relationship:** The line between two tables represents that a relationship
4. **Many side:** The * indicates that the "*Procurement_Data*" table is the many side of the relationship

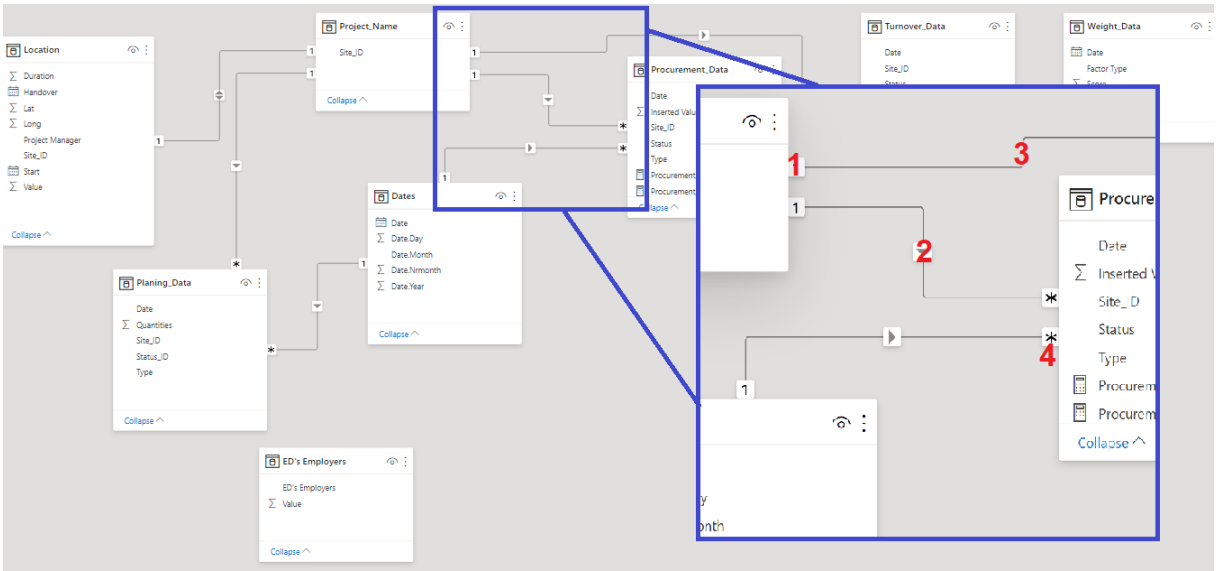

Fig. 4.37 – Building relationships

4.7.5.3.Create a dashboard

After loading the data and consequently analysing, establishing and verifying relationships, power bi allows the user to create interactive reports. The potential to create interactive reports allows data to be analysed, depending on the desired filters, optimising the time spent on report creation and subsequent analysis.
The platform has a wide range of graphs at its disposal, as represented in figure 4.38, along with online repository that is continually updated with data analysis tools.

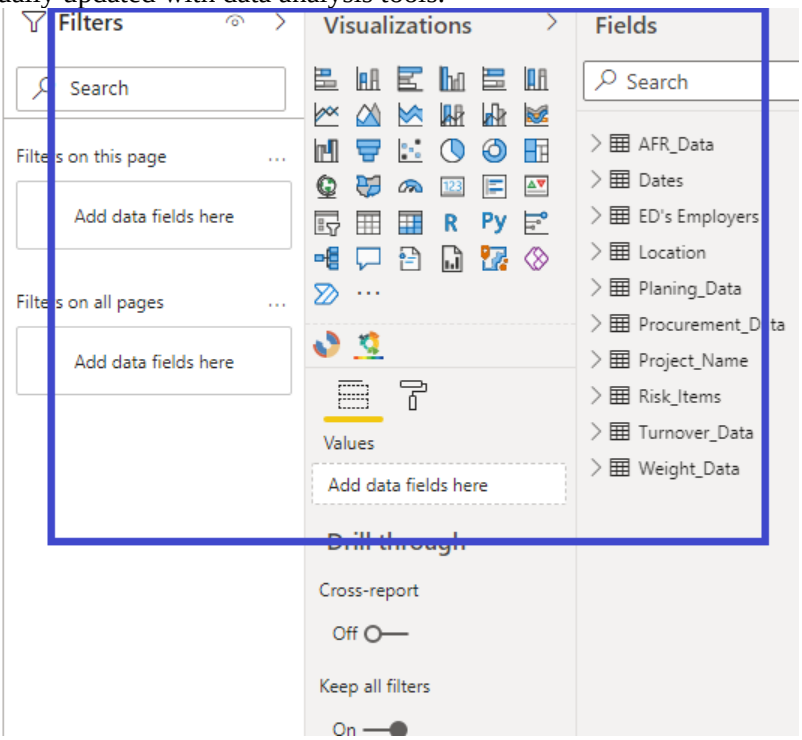

Fig. 4.38 – Type of filters and visualizations

5
CONCLUSION

5.1. CONCLUSIONS

The construction industry has been moving towards digital transformation. Areas such as BIM and prefabrication are increasingly used, and with positive results. Case study shows that a large part of the project was carried out through manufacturing processes, with a considerable success rate. However, a truly digitalised construction industry is only a few years away.

The use of digital tools, such as collaborative platforms and sensor systems with the implementation of the Internet of Things, is and should be the next concept to consolidate in the construction industry. However, the stakeholders must adapt to the new era in order to take full advantage of the new transition, whose main objective is to connect people and optimise the process.

Companies must not only invest in the improvement of the digital tools they use daily, but also in training those who are part of it. Also, the need to standardise the methodologies and work approaches will optimise the construction processes. The decision to focus on the subcontractors that the companies work with through a quality analysis that meets the standards used by the main contractor will also be one of the methods that will most easily ensure the quality and progression of the optimisation processes.

The "one-off" construction factor is still one of the ideas that contrasts with, analogy with Industry 4.0, the concept of factory system and mass production in the construction industry. The next phase will be the use of digital tools to integrate services across the supply chain, along with increased automation and a shift in communications. Choosing more sustainable, more efficient construction methodologies, or even standardising certain construction methods will allow companies to specialise more and reduce research costs in other areas, making the focus more concrete and optimised.

5.2. SUGGESTIONS FOR FUTURE RESEARCH

5.2.1. PROCORE

One of the major challenges in the industry, felt during this case study, was the fact that, regardless of the quality of the data collected, all of it was dispersed. Several times it was found that the intervening parties in a construction project, use different or even obsolete digital tools, with different formats and that consequently are not compatible, or adjustments have to be made. This makes it impossible to optimise the processes.

The importance of the data was even more remarkable, since the dissertation was carried out in a business environment and in a construction management context, with real situations and real decision making. The vast amount of data generated in the course of a project makes it difficult to combine all the data, referring to productivity, waste production or quality reports, without standardising the methodologies and approaches.

To conclude, during my dissertation, the company showed interest in implementing the Procore tool, a tool that, despite never having worked with it, allows to gather the desired data in a single application. Also having the potential to work with Procore software developers to mold the application according to our needs. In order to help with all the items that need to be operated within the Procore tool, a work team from Regal London, in which I had the privilege of being invited to be part of, was responsible for the creation of a document that will be a guide for the standardization of the management process of all future Regal projects.

This document is to be followed and read in conjunction with all training and software guidelines prior to the work being carried out. Ensuring that all those involved in the project, from stakeholders, main contractors, subcontractors, surveyors, etc., follow the procedure.

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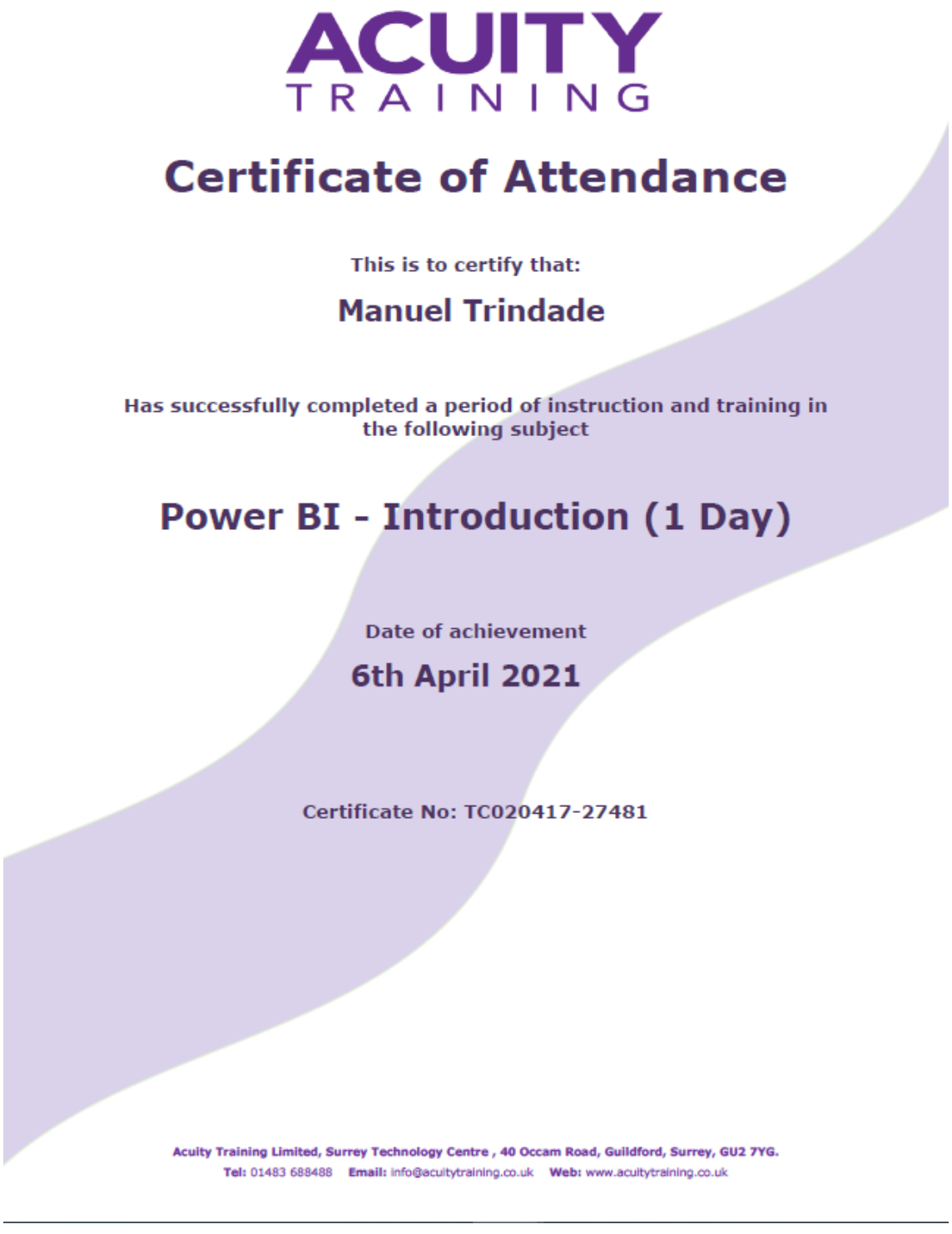
ATTACHMENTS

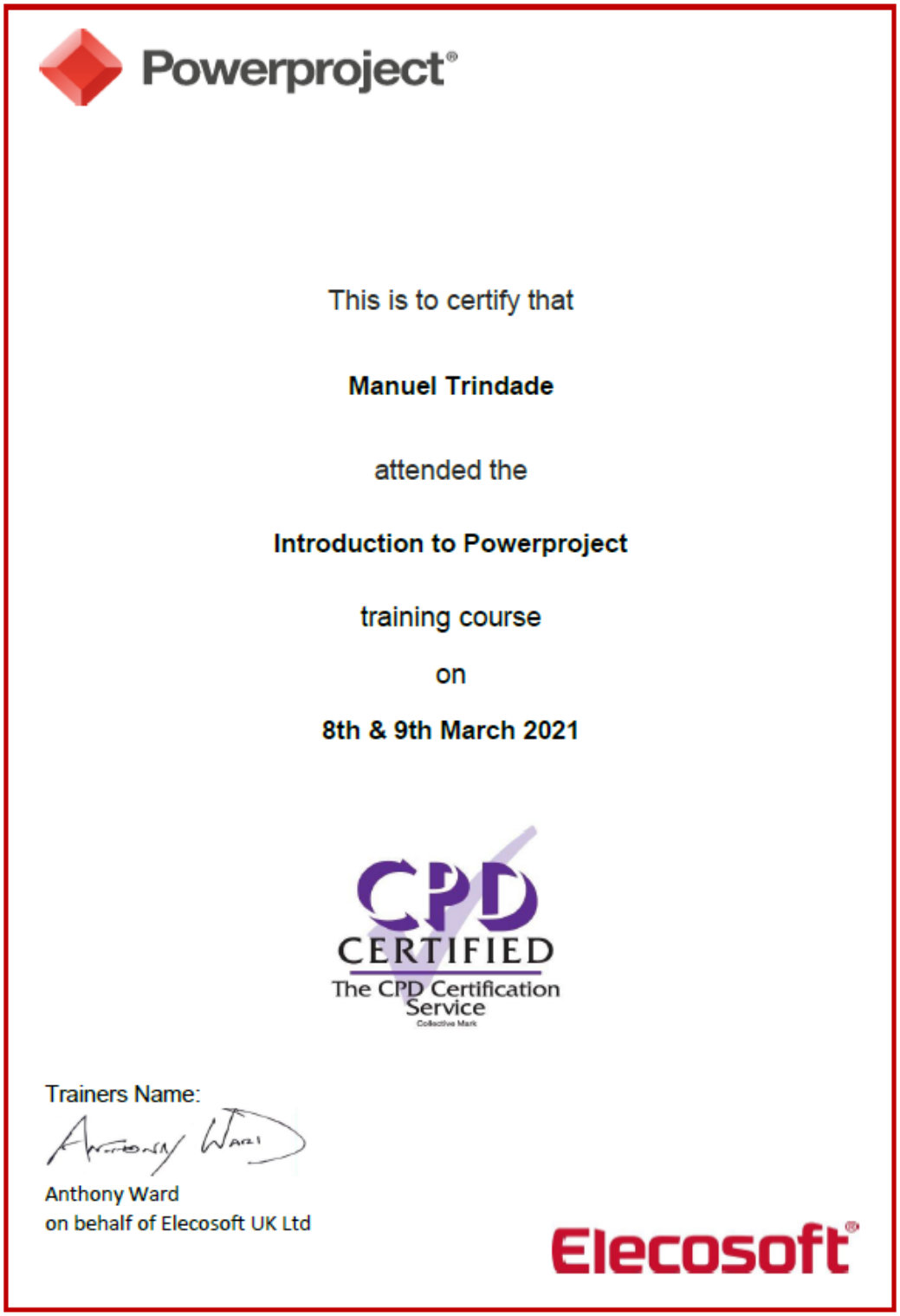
Attchament I

POWER BI CERTIFICATE



Attchament II

ASTA POWERPROJECT CERTIFICATE



Attchament III

CCS CERTIFICATE

BEST PRACTICE CERTIFICATE – PLASTIC AND PACKAGING

Attchament IV

BEST PRACTICE – CARE ABOUT APPEARANCE

Attchament V

SMARTWASTE REPORT

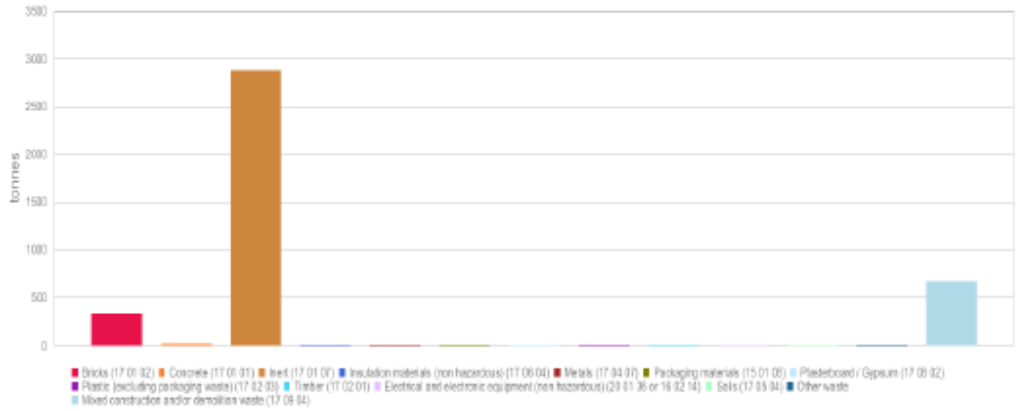
BRE SMARTWASTE

Project : 73-77 Commercial Road **Start Date :** **End Date :**

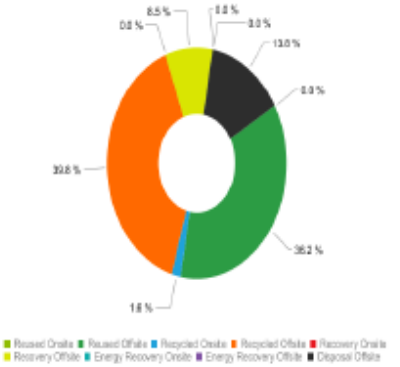
Actual waste sent offsite

	Total (t)	t /£100k	t /100m2	Diverted from landfill (t)	Diverted from landfill (%)
Construction	671.7	3.4	14.6	348.0	51.81
Demolition	1,661.2	8.3	36.2	1,654.2	99.58
Excavation	1,497.0	7.5	32.6	1,290.0	86.17
Modular	0.0	0.0	0.0	0.0	0.00
Post-Completion	0.0	0.0	0.0	0.0	0.00
Total (offsite):	3,829.9	19.1	83.5	3,292.2	85.96
Total (offsite & onsite):	3,892.2	19.5	84.8	3,354.5	86.19

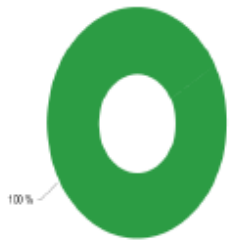
Tonnage of waste to date by product group



Waste management routes (for actual waste)



Actual waste (onsite)



Other waste KPIs

Waste cost KPIs		Number of waste containers to date	763
Total	£0.00		
/£100k	£0.00		
/100m2	£0.00		

BRE SMARTWASTE

Project : 73-77 Commercial Road

BREEAM waste benchmarks

This project is working towards BREEAM New Construction 2014

	Project Target	Achieved Performance
Actual non-hazardous construction waste (tonnes/100m2)		14.6
Non-hazardous construction waste diverted from landfill (% by weight)		51.81
Non-hazardous demolition waste diverted from landfill (% by weight)		99.59
Non-hazardous excavation waste diverted from landfill (% by weight)		86.17
Credits for Construction Resource Efficiency		0
Credits for Diversion of Resources from Landfill		0

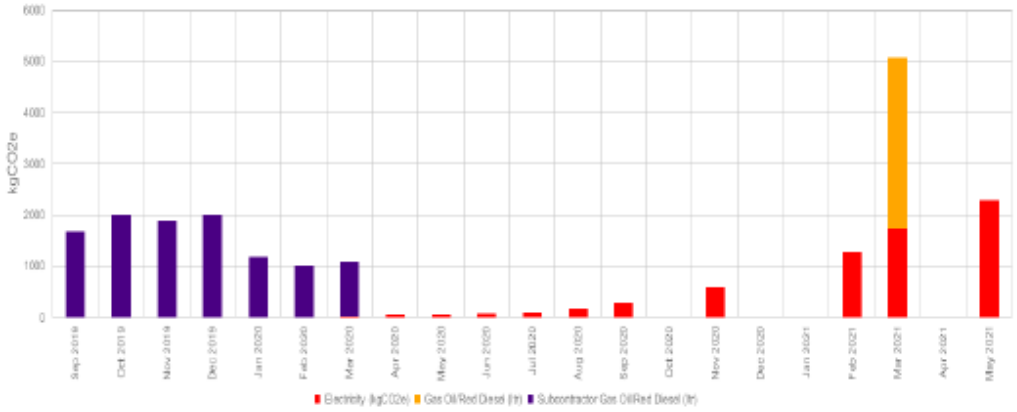
BRE SMARTWASTE

Project : 73-77 Commercial Road

Energy use

Electricity	26,742.0	kW h	6,556.2	kg CO_2e	kg CO_2e /£100k	102.8
Natural Gas	0.0	kW h	0.0	kg CO_2e	kg CO_2e /100m^2	448.2
Fuel Litres	5,080.0	Litres	14,011.2	kg CO_2e		
Fuel KGs	0.0	KGs	0.0	kg CO_2e		
Total CO_2e production			20,567.4	kg CO_2e		

CO_2e by Month and Source



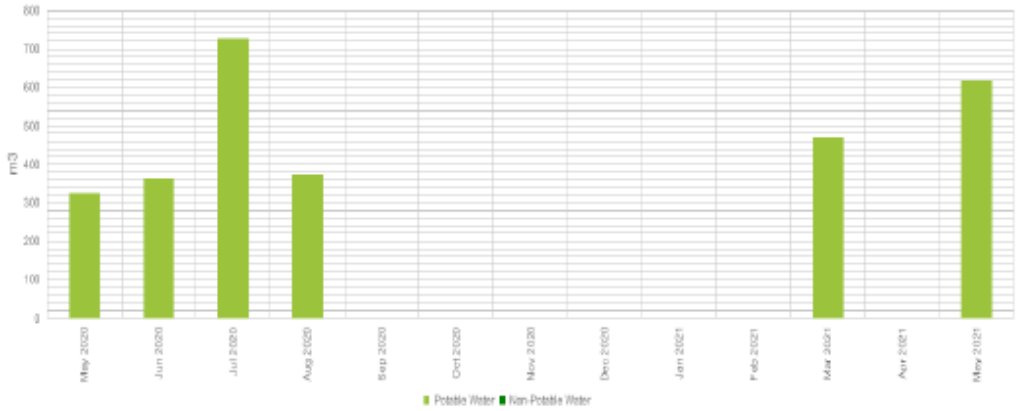
BRE SMARTWASTE

Project : 73-77 Commercial Road

Mains water use

Total usage	2,872.2 m^3
/£100k	14.4
/100m^2	62.6

Monthly water use



Monthly water discharge

No Data Available

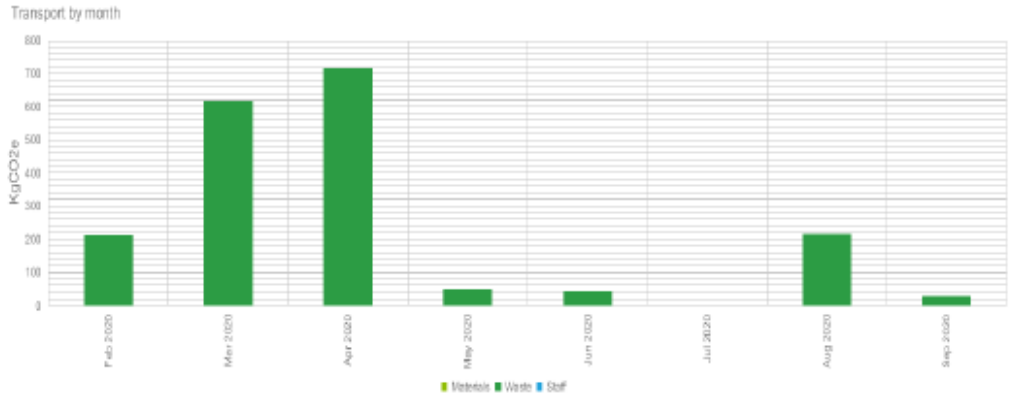
BRE SMARTWASTE

Project : 73-77 Commercial Road

Transport use

	$kgCO_2e$	$kgCO_2e$ /£100k	Distance Travelled (Kms)	Distance Travelled (Miles)	Fuel Consumption (litres)
Materials	0.0	0.0	0.0	0.0	0.0
Staff	0.0	0.0	0.0	0.0	0.0
Waste	1,870.8	9.4	2,160.0	1,342.3	670.8
Total	1,870.8	9.4	2,160.0	1,342.3	670.8

Transport by month



Attchament VI

FINAL CAD REPORT EXAMPLE

Snag/Commercial Rd Stay City
Client Snagging

Finalcad

staycity APARTHOTELS

1 remaining observation	**7** total issues
5 average validation time (days)	**85%** total progress

LEVELS	OBSERVATIONS	OPENED	FIXED	SOLVED	LAST CREATION	PAGES
1 Floor	7	1 (14%)	0 (0%)	6 (85%)	07/19/2021	2
1	7	1 (14%)	0 (0%)	6 (85%)	07/19/2021	11

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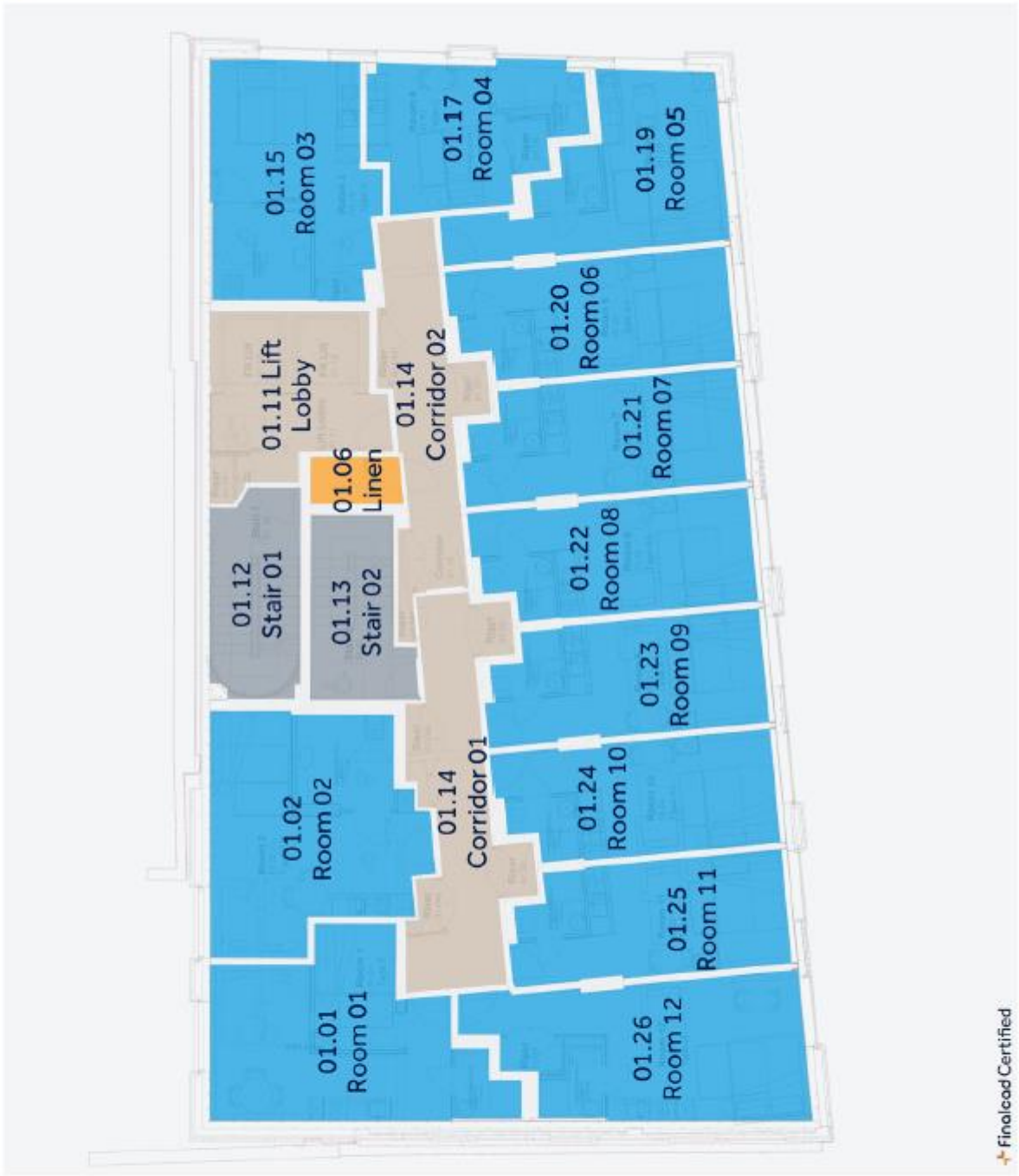
Snag/Commercial Rd Stay City
Client Snagging
1 Floor

Finalcad



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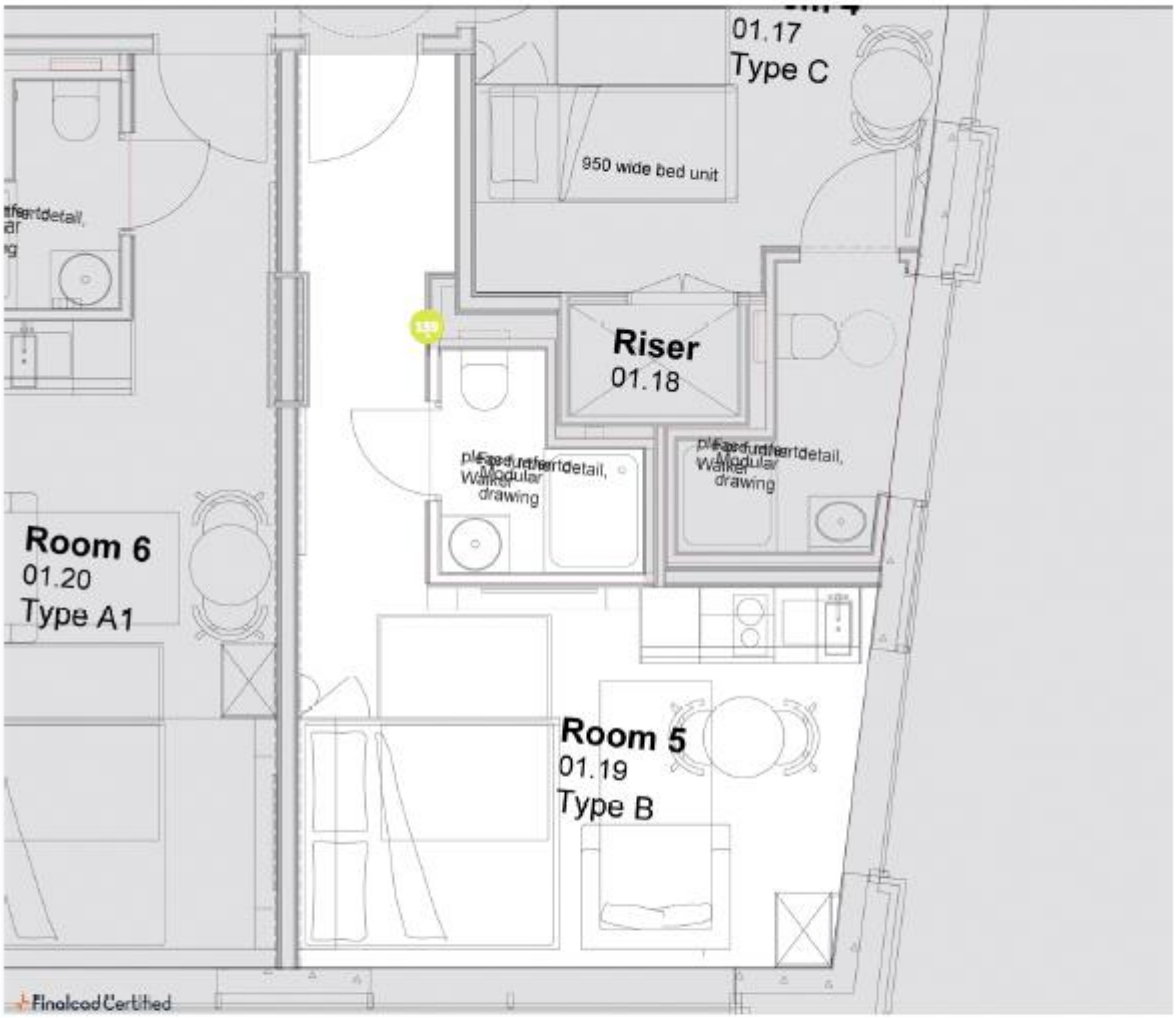
Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.19 Room 05 Architect

Finalcad



	OBSERVATION	ASSIGN TO	CREATION	VALIDATION
139	**Magic man** 06/04/2021 • Manuel Azevedo Trindade • Improve rough edge Phase: **Delivery**	TCS TCS	Manuel Azevedo Trindade 06/04/2021	Diogo Ribeiro 06/08/2021 • Solved

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Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.19 Room 05 Architect

159

Magic man
06/04/2021 Manuel Azevedo Trindade

Finalcad

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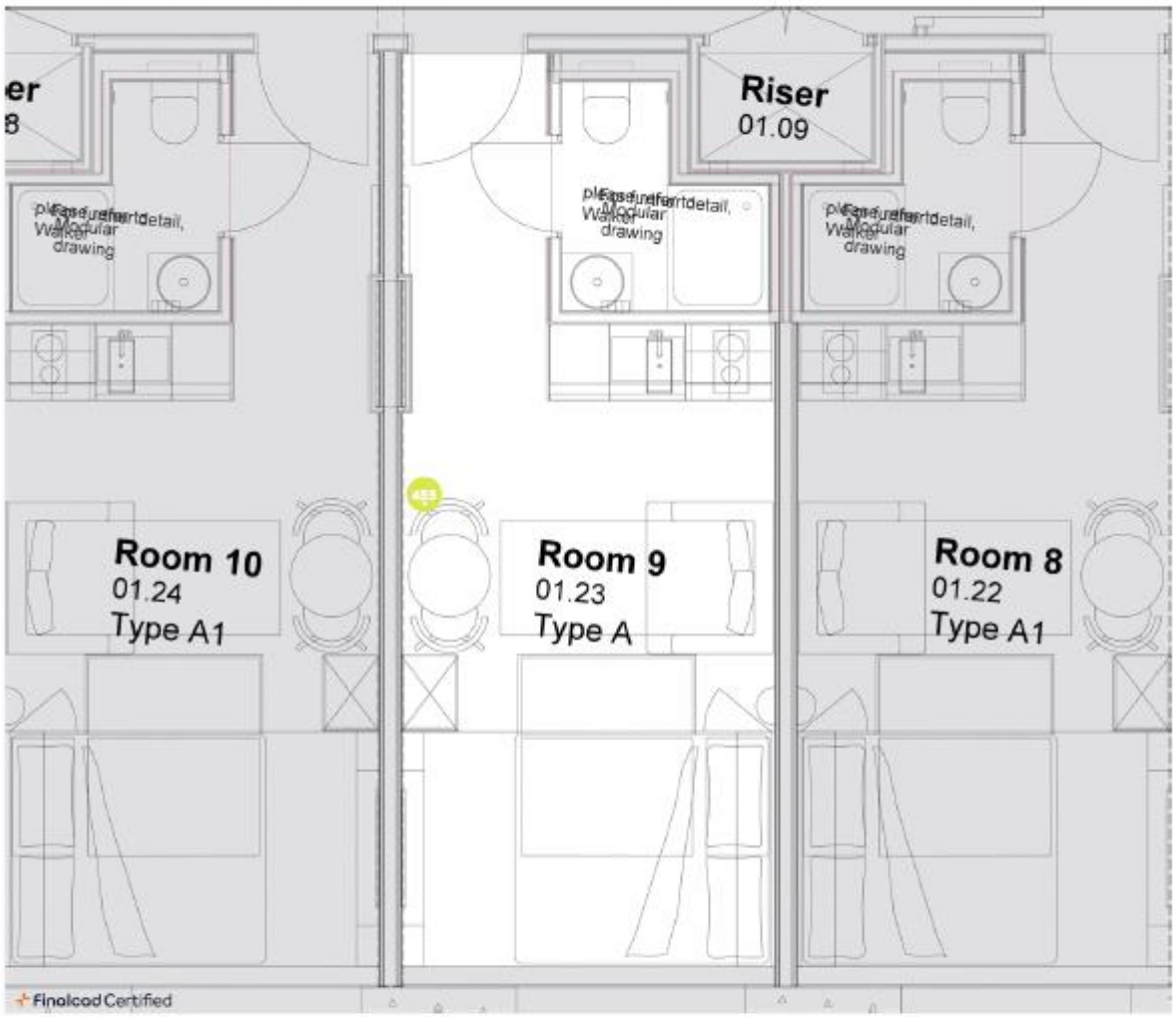
Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.23 Room 09 Architect

Finalcad



	OBSERVATION	ASSIGN TO	CREATION	VALIDATION
455	Snag Phase: Delivery	Brooks Decoration Brooks Decoration	Manuel Azevedo Trindade 06/28/2021	Manuel Azevedo Trindade 07/02/2021 • Solved

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Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.23 Room 09 Architect

Finalcad

Snag
06/28/2021 Manuel Azevedo Trindade

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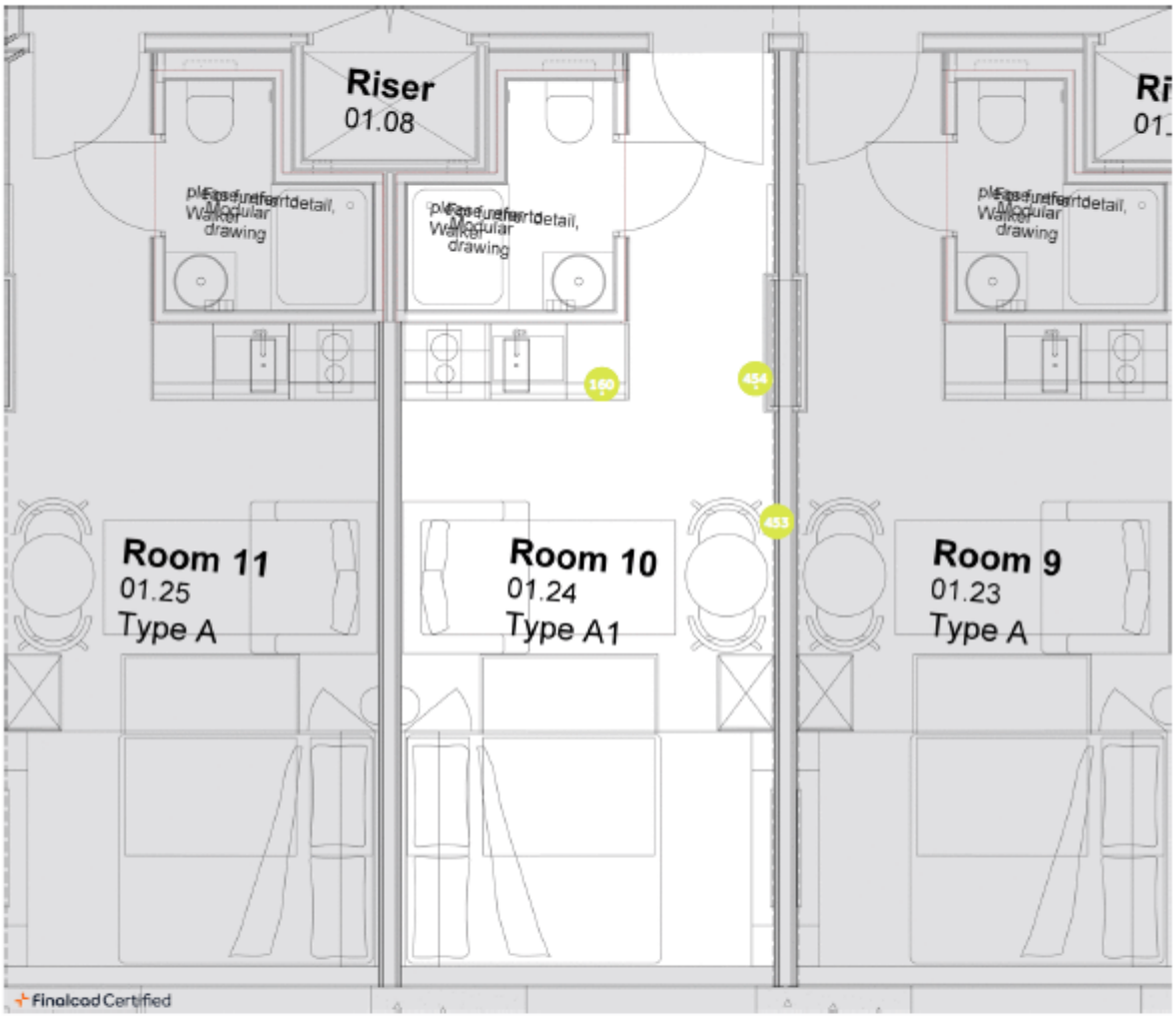
Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.24 Room 10 Architect

Finalcad



		OBSERVATION	ASSIGN TO	CREATION	VALIDATION
160		**Snags** 06/04/2021 • Manuel Azevedo Trindade • fix panel **Phase: Delivery**	TCS Carpentry	Manuel Azevedo Trindade 06/04/2021	Diogo Ribeiro 06/08/2021 • Solved
453		**Snags** **Phase: Delivery**	Cherwell Joinery	Manuel Azevedo Trindade 06/28/2021	Manuel Azevedo Trindade 07/02/2021 • Solved
454		**Snag** **Phase: Delivery**	Brooks Decoration Brooks Decoration	Manuel Azevedo Trindade 06/28/2021	Manuel Azevedo Trindade 07/02/2021 • Solved

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Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.24 Room 10 Architect

Finalcad

Snags
06/04/2021 Manuel Azevedo Trindade

Snag
06/28/2021 Manuel Azevedo Trindade

Snag
06/28/2021 Manuel Azevedo Trindade

Snag
06/28/2021 Manuel Azevedo Trindade

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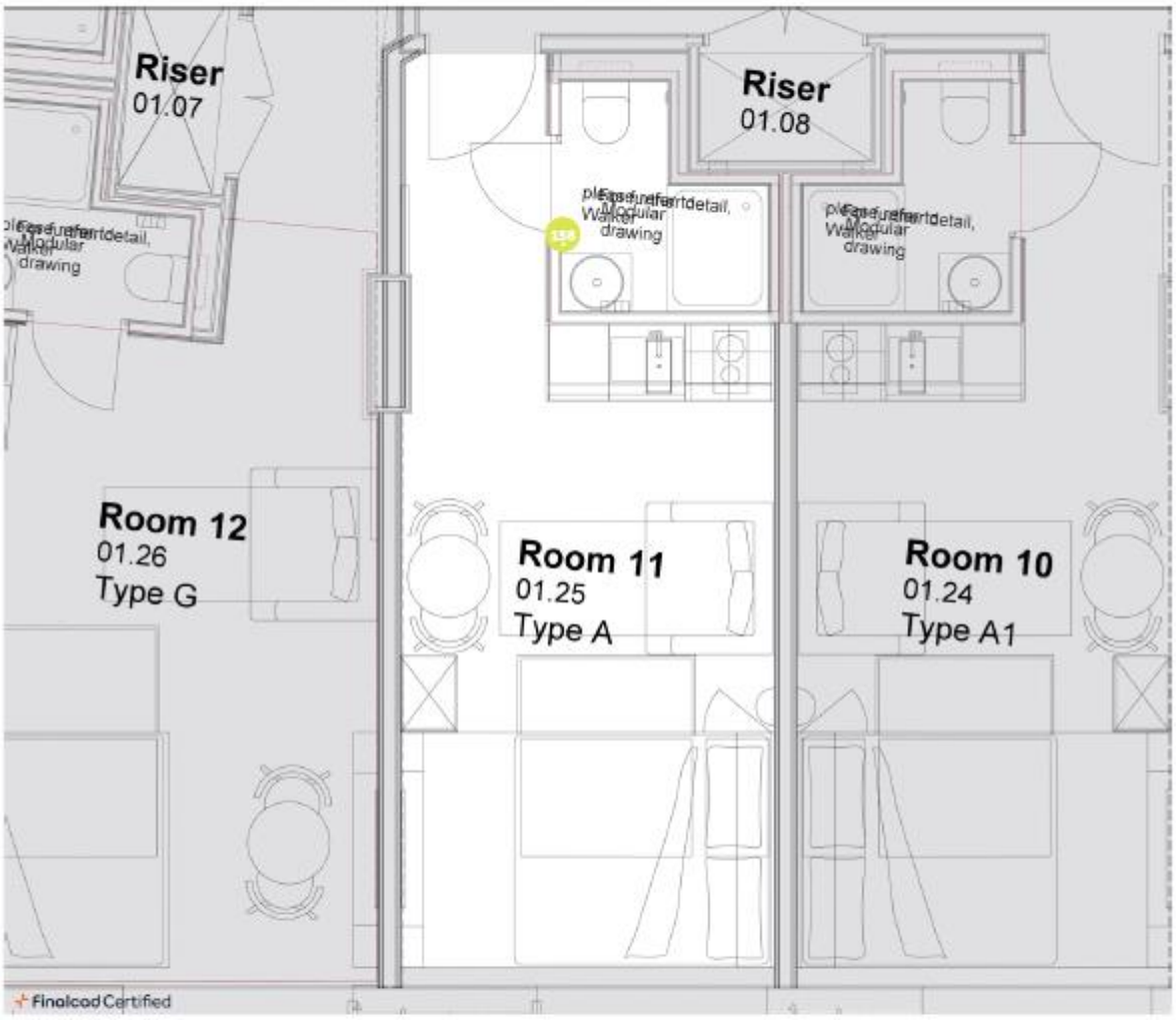
Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.25 Room 11 Architect

Finalcad



	OBSERVATION	ASSIGN TO	CREATION	VALIDATION
158	**Magic man** 06/04/2021 • Manuel Azevedo Trindade • **Infill** **Phase: Delivery**	TCS TCS	Manuel Azevedo Trindade 06/04/2021	Diogo Ribeiro 06/08/2021 • Solved

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Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.25 Room 11 Architect

Finalcad

Magic man
06/04/2021 Manuel Azevedo Trindade

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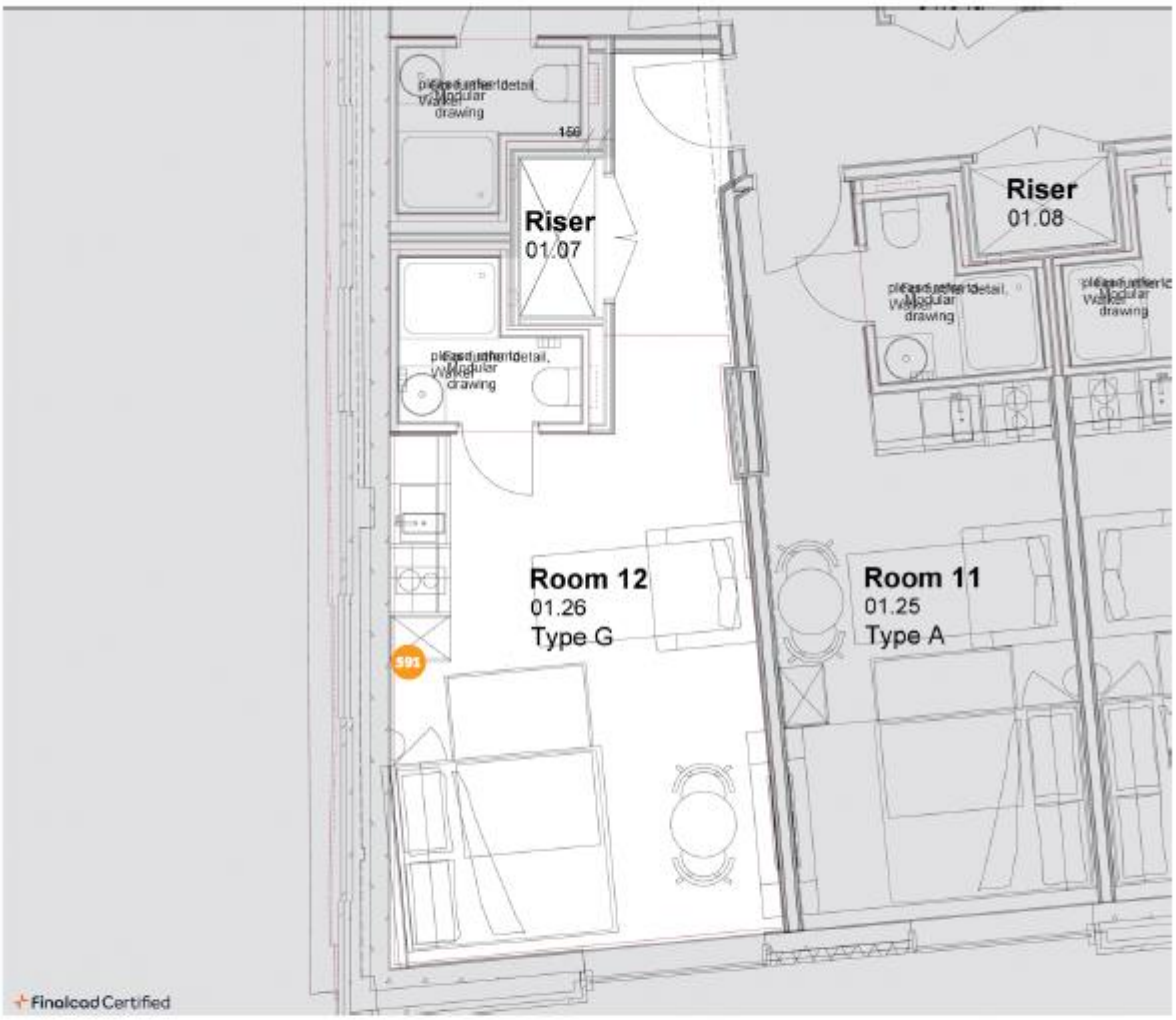
Snag/Commercial Rd Stay City
Client Snagging
1 Floor - 01.26 Room 12 Architect

Finalcad



	OBSERVATION	ASSIGN TO	CREATION	VALIDATION
591	Snag Phase: Delivery	Brooks Decoration Brooks Decoration	Manuel Azevedo Trindade 07/19/2021	

Opened Fixed Solved Outdated
Format A4 • Snag_Commercial_Rd_Stay_City.pdf

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Attchament VII

FULL EXAMPLE OF IMPLEMENTED CODE – PROCUREMENT

```
Sub Procurement_v4()
'
' Procurement_v4 Macro
'

'
    Range("B3:F3").Select
    Selection.Cut
    Sheets("Procurement_Data").Select
    Range("A1").Select
    Selection.End(xlDown).Select
    ActiveCell.Offset(1, 0).Select
    ActiveSheet.Paste
    Sheets("Procurement").Select
    Range("E3:F3").Select
    Range("F3").Activate
    Selection.NumberFormat = _
        "_-[$£-en-GB]* #,##0.00_-;-[$£-en-GB]* #,##0.00_-;_-[$£-en-GB]* ""-""??_-;_-@_-"
    Range("D3").Select
    With Selection.Validation
        .Delete
        .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _
        xlBetween, Formula1:="=Info!$E$3:$E$8"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
    Range("B3").Select
    With Selection.Validation
        .Delete
        .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _
        xlBetween, Formula1:="=Info!$B$3:$B$9"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
    Range("B3:F3").Select
    Range("F3").Activate
    Selection.Borders(xlDiagonalDown).LineStyle = xlNone
    Selection.Borders(xlDiagonalUp).LineStyle = xlNone
    With Selection.Borders(xlEdgeLeft)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
```

```
        .Weight = xlThin
    End With
    With Selection.Borders(xlEdgeTop)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
        .Weight = xlThin
    End With
    With Selection.Borders(xlEdgeBottom)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
        .Weight = xlThin
    End With
    With Selection.Borders(xlEdgeRight)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
        .Weight = xlThin
    End With
    With Selection.Borders(xlInsideVertical)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
        .Weight = xlThin
    End With
    With Selection.Borders(xlInsideHorizontal)
        .LineStyle = xlContinuous
        .ColorIndex = 0
        .TintAndShade = 0
        .Weight = xlThin
    End With
    Range("A1").Select
End Sub
“
```

Attchament VIII

MICROSOFT POWER BI REPORT