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How does Industry 4.0 impact on ETO construction companies?

MASTER OF SCIENCE REPORT IN
MANAGEMENT ENGINEERING

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Abstract

The order fulfillment strategy known as "Engineering-to-order" reimagines new parts or entire products to be able to meet special needs in accordance with the special requirements in the customer's order, on the basis of which a customized product is supplied to the customer. Construction is closely related to people's lives. Building materials, buildings, and equipment have all been significantly impacted by technological advancements brought forth by Industry 4.0 which has resulted in technical advancements that have had a substantial influence on construction materials, structures, and equipment. The development of Industry 4.0 has caused setbacks in the traditional construction industry. On the other hand, a select number of ETO construction companies have made some headway through technological advancements. Additionally, contemporary architecture is beginning to incorporate information theory, systems theory, cybernetics, and ecology. Therefore, the influence that the development of Industry 4.0 has had on ETO construction companies is the focus of our thesis. We discovered that the majority of ETO construction companies analyzed by us have already begun the innovation of technology; however, the amount of technology application ability and coverage is still insufficient. This is the case despite the fact that the application of science and technology to the completion of the ETO process production concept has not only had a positive impact on the building itself, but has also prompted people to become more environmentally conscious.

Key-words: Engineering to order; ETO; Industry 4.0; BIM; Construction

Abstract in lingua italiana

La strategia di evasione degli ordini nota come "Engineering-to-order" reinventa nuove parti o interi prodotti per poter soddisfare esigenze speciali in base alle esigenze speciali dell'ordine del cliente, sulla base della quale viene fornito al cliente un prodotto personalizzato . L'edilizia è strettamente legata alla vita delle persone. Le società di costruzioni ETO e le sue espressioni, quindi, hanno un impatto sulla psicologia, sulle emozioni e sul comportamento delle persone oltre a come vivono, lavorano e interagiscono tra loro. I materiali da costruzione, gli edifici e le attrezzature sono stati tutti significativamente influenzati dai progressi tecnologici portati dall'Industria 4.0 che ha portato a progressi tecnici che hanno avuto un'influenza sostanziale su materiali da costruzione, strutture e attrezzature. Lo sviluppo dell'Industria 4.0 ha causato battute d'arresto nel settore delle costruzioni tradizionale. D'altra parte, un numero selezionato di società di costruzioni ETO ha fatto progressi grazie ai progressi tecnologici. Inoltre, l'architettura contemporanea sta iniziando a incorporare la teoria dell'informazione, la teoria dei sistemi, la cibernetica e l'ecologia. Pertanto, l'influenza che lo sviluppo dell'Industria 4.0 ha avuto sulle imprese di costruzione ETO è al centro della nostra tesi. Abbiamo scoperto che la maggior parte delle imprese edili ETO da noi analizzate hanno già avviato l'innovazione tecnologica; tuttavia, la quantità di capacità e copertura dell'applicazione della tecnologia è ancora insufficiente. Questo è vero nonostante il fatto che l'applicazione della scienza e della tecnologia al completamento del concetto di produzione del processo ETO non solo abbia avuto un impatto positivo sull'edificio stesso, ma abbia anche spinto le persone a diventare più consapevoli dell'ambiente.

Parole chiave: Ingegneria su ordinazione; ETO; Industria 4.0; BIM; Costruzione

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1. Executive Summary

The construction industry is an important pillar of the global economy which encompasses the design, construction, refurbishment, and administration of buildings, as well as the construction industry itself and its associated decorating, rehabilitation, and so on. Buildings, structures, and facilities for different enterprises, mines, railways, bridges, ports, highways, pipelines, houses, and public amenities are among its products. When construction sector goods are transferred to consumers, they comprise a range of productive and non-productive fixed assets. In addition, "ETO" stands for "engineer to order," which refers to a method of production in which a product is only designed and manufactured after an order has been placed for it. If a manufacturer chooses to use the ETO approach, they will be able to fulfill their customer's precise requirements. And because of the high level of uncertainty, there is a need to revisit the new business models and system design of these construction companies which implement ETO order fulfillment approach in the context of the new era. In instance, even while they utilize ETO order fulfillment tactics, the production automation design and engineering management strategies involved in them are inseparable from technology and Industry 4.0. This is because both of these things are always evolving. These are all dependent on technology and the development of Industry 4.0, while lean management in the context of ETO is also being looked at. Compared to other industries, the construction industry is lagging behind in terms of technological content, industrialisation, automation, intelligence and organisational management, and it is only through the use of high technology to transform traditional industries that the industry can develop at a faster pace. The construction industry is a labour-intensive industry, but this does not mean that it is very distant from high technology, on the contrary, the development and application of high technology in the construction industry has huge space and potential. Modern new technology mainly includes information technology, new material science and technology, robotics, marine technology, ecological technology, etc., combined with the characteristics of building construction, the application of high technology is found to the greatest extent.

According to the introduction that was just read, in this research paper, I studied a significant amount of material that was linked to ETO, Industry 4.0, and Industry 4.0 in ETO architecture, among other topics. My first search criteria on Scopus were "architecture AND service," which led to the retrieval of sixty publications that were relevant to my topic, but I did not pursue any of these leads. Because of this, we shifted our tactic and modified the search keywords to include both "architecture" and "engineer-to-order." As a result, we were able to get 94 articles that were pertinent to our inquiry; several of these papers discussed BIM, ETO, lean management, and Serviti*ation, to name a few. As I read through them, I realised that a large part of the construction industry is now operating according to ETO, and that the current situation is not that the overall production is according to ETO, but that there will be a series of design-to-order production in the process production, for example the design of the relevant building components needs to meet the custom requirements of the user, and more specifically, I think that BIM is also in the ETO construction industry to face some business and customer related I think that BIM is also a tool, a way or a concept for the realisation of services in the ETO construction industry when faced with problems related to business and customers. I have therefore defined my research programme and methodology.

After completing the reading and search of the literature, I started the web analysis, that refers to the methodical analysis of online and trending information. It is a method that may be used to gather, measure, report, and evaluate the goals of the project that you need to assess, such as researching the expansion of a business inside a certain sector. As a result, I complete the required information by searching for keywords. To begin, I was looking for the corresponding construction ETO companies on the website. There is not a collection of businesses in the corresponding industry that can be found anywhere on the internet, so what we decided to do was to filter by category while using the websites of stock exchanges in order to find the companies that are listed as being in the construction industry and to find those that are ETOs. During the course of the survey, I chose 65 different firms, with roots in the United States of America, France, and China. After going through the screening process, we were ultimately left with close to 50 different companies to examine in further detail. Based on this, I concluded my study by filtering each company's website and categorizing them using tables based on the technologies now employed by ETO construction businesses, such as production line technology, smart worker technology, and smart technology, among others. This action was taken so that it would be easier to detect whether various ETO building businesses had implemented the technology at varying technical levels. The findings are given in a compound table that gives a clear visual representation of the data necessary for analyzing and comparing them. The results were presented in a double-entry table, which provided a clear visual representation of the results we needed and allowed us to analyse and compare the results.

Through the results we can see that understood from an economic point of view, high technology is one of the most important products under Industry 4.0. In the perspective of ETO architecture, high technology is a cluster of technologies based on the cutting-edge technologies of the era in which they are located. From the point of view of technology intensity, high-tech is a generic term for a knowledge-intensive, technology-intensive category of products or industries. Regardless of the angle of understanding, high-tech has the characteristics of high knowledge, high innovation, high intelligence, high investment, high return, high risk, high strategy, high penetration and high competition. At present, we find that high-tech for ETO construction companies can not only provide new technologies, new techniques, new materials and new equipment for traditional industries, improve the technical structure, labour structure and capital structure of traditional industries, but also be able to breakthrough to improve the demand for customised requirements of users, drive the growth of social economy and greatly promote the upgrading of industrial structure. As ETO construction enterprises enter the era of Industry 4.0, the investment in research and development and the widespread application of high technology is the only and necessary way to achieve industrial upgrading. The construction industry can not only promote the upgrading of the technical structure through the high added value of high technology, but also promote the improvement of the cost and profitability of the entire construction industry through the transformation of traditional technology at different levels. For example, the use of the Internet platform for the construction industry to integrate traditional research and development, procurement, supply and management at a high level can greatly reduce production costs and can achieve higher economic benefits.

2. Introduction

The phenomenal economic expansion seen in emerging nations, along with historically low financing rates in many wealthy nations, is fueling an uptick in the demand for building. In addition, throughout the period of projection, the expansion of the market is anticipated to be driven by investments made by the private sector in the construction industry, the development of new technologies, and growing levels of disposable income. The expansion of the market is also being driven by a rise in the amount of money being spent by governments throughout the world on housing and infrastructure. The market for construction supplies and services is anticipated to reach $7.28 trillion in 2021 (Markets, 2022), and it is forecast to reach $14.41 trillion by 2030, expanding at a compound annual growth rate (CAGR) of 7.3% from 2022 until 2030. The erection, maintenance, and repair of buildings or other real estate, in addition to the construction of roads and other public services, are all included in the broad category of construction. It also include alterations and additions to the structure, including load-bearing walls, beams, and outside walls, among other things. In addition, the planning, finance, design, and construction processes for each distinct kind of building project, in addition to the labor involved in its upkeep, maintenance, and enhancement, are entirely different. The sales income received by entities such as individual operators, companies, and partnerships that construct buildings and engineering projects, such as highway and utility system construction, is included in the construction market.

The functions of the construction industry are mainly to carry out construction and installation activities for various building materials and components, machinery and equipment, etc., and to build productive and non-productive fixed assets for the national economy. The development of the construction industry is very closely related to the scale of investment in fixed assets, promoting and constraining each other. The construction industry enterprises in a country are responsible for providing the most basic material security for the various sectors of the national economy and the people of the country, and are the foundation and core of the physical industry of the entire country, occupying an important position in the core competitiveness of the country.

In a fiercely competitive market environment, the emergence of high-volume construction enterprises can no longer well meet the individual needs of customers, and the ETO (Engineering to Order) strategy, driven by customer demand, presents incomparable advantages.

The ETO strategy which is an adaptive, demand-driven approach to the manufacturing process involves making unique engineering designs for products or making larger product builds for modifications in accordance with the customer's order requirements, with each customer order resulting in a unique set of building builds, a list of building materials and a different process route. Nowadays, large and complex construction companies such as large hydroelectric construction and housing commercial residential use have started to implement a order fulfilment strategy regarding ETO, i.e. receiving a customer order and re-designing a certain building component, then organising procurement and production management according to the build so as to achieve the maximum satisfaction of the market and customer needs. The uniqueness and uniqueness of the building design and manufacturing process make it necessary for such companies to manage the production process through project management, i.e. each order is seen as a project, hence this model is also known as the project-based manufacturing model. Compared to batch, process-oriented building and construction enterprises, the production characteristics of ETO-type complex construction-type enterprises are as follows:

- The variety of building components that can be completed is large, mostly in single or small batch production, and the repetitiveness of production management is low.

- Each order of building components requires a new production technology and tooling preparation, the product design cycle is long and the company has the characteristic of synchronising the design and manufacturing process. The term quantity standard here refers to the standardised data specified for the production object in terms of production time and production quantity, and is an important basis for the preparation of production plans.
- Complex building structures and assembly relationships, each consisting of thousands of different materials and components, with strict process timing constraints and set requirements between individual envelope structures and building components.
- Product design is carried out on a product project basis, while the product project drives the entire production process, thus combining the characteristics of project management and production management.
- Production lead times for some components may be as long as tens of days to months, with obvious constraints on bottleneck resources such as key equipment due to long production lead times.
- On-time delivery in accordance with customer orders is the preferred goal of the enterprise, and therefore requires all levels of production organisation and all links to cooperate with each other to complete production on schedule.

Due to the above production characteristics of ETO-type construction enterprises, there are several major challenges in production planning and management. Firstly, the complexity of the building components, processes and production organisation makes it difficult to use an integrated model and technology to plan the entire production. Due to the large size of the enterprise, the complexity of the production organisation and the many product levels, often multiple construction projects are scheduled for production at the same time, so production planning management has to cover multiple product projects, different levels of the same product and multiple levels of production organisation such as enterprises and sub plants, so it is difficult to use a single model to describe and solve the complex production planning management process in an integrated way. Therefore in order to cope with this situation in ETO construction companies, the addition of technologies related to Industry 4.0 has largely helped the construction industry to be able to better complete the ETO order fulfilment strategy. Industry 4.0 contains a shift from more centralised control to decentralised enhanced control, which is very significant for ETO construction companies. Depending on the process requirements of ETOs, construction companies in the construction industry may be sourcing and transporting large volumes to address the customisation and differentiation requirements of their customers, and this is being disrupted in Industry 4.0, just as the largest taxi companies have no cars, and the largest retailers have no physical shops and no more product inventory. So what about the future of the ETO construction industry? In fact our information and network age is also bringing revolutionary changes. The digitisation of the whole life cycle of products and the whole manufacturing process as well as the integration of ICT-based modularity will result in a highly flexible individual, digital order fulfilment strategy of products and services, in which bim is a core technology platform. Thus seeing the correlation between informatisation and industrialisation, BIM is an important technology and technical platform for promoting the development of new industrialisation and informatisation in the construction industry. BIM technology is driving a disruptive revolution in construction also brings a large degree of innovation to the ETO production process as well as helping the ETO to be implemented into practical solutions rather than just empty talk. This thesis therefore examines the impact and changes that ETO construction companies are experiencing under Industry 4.0, based on the above-mentioned challenges.

3. Literature review

3.1. Defining Engineering to order

Engineer to Order, often known as ETO, is an order fulfilment strategy in which a corporation is required to redesign its goods in accordance with particular criteria in client orders (Cannas and Gosling, 2021). These requirements may include the presence of bespoke requirements for certain components. In this order fulfilment strategy, the company needs to design the product to meet the special requirements of the customer, such as the existence of customization of certain parts, in order to make new parts to meet these special performance and structural requirements, or to make a certain degree of variation of other types of parts so that it can provide customized products to the customer.

It is worth noting that ETO is determined from the final product only after the customer order is received, and only after the order is received does the design begin and the procurement and production are organized.

ETO is a new complex R&D-based order fulfilment strategy for project-based or contract manufacturing companies with highly customised products. More and more companies are adopting this strategy because some products (e.g. low-voltage distribution cabinets) are difficult to standardise due to their characteristics, or because companies seek to maximise the comfort experience of their customers. ETO products require the redesign of product solutions or components to meet these special needs, or the design of variants of other types of components, on the basis of which customised products are offered to customers. The complexity of these products, which are often complex assemblies or functional products with many variants, is reflected in the complexity of the product structure, the complexity of the production process and the complexity of project management. In this production mode, the high degree of uncertainty of customer requirements increases, as do the costs of research and development, the complexity of production management and the extension of production cycles, which make production operations more difficult.

Before discussing the characteristics of ETO, we need to understand other manufacturing strategies such as MTO and ATO. The most confusing one compared to ETO is MTO, which is the manufacturing of the product required by the customer according to the original design of the customer's order, which is finalised and cannot be produced before the customer's needs are determined, because the sub-part of the component is flexible and can be configured according to the customer's needs (Gosling and Naim, 2009). In general terms, this is like the "car-riding option process", where the user determines the configuration, whereas production planning is based on planning the production schedule and purchasing raw materials according to the products specified in the order received, so that the product can be manufactured according to the customer's specific requirements and stock can be kept to a minimum. In this type of production, the customer requests certain configurations of components or products, and the manufacturer provides customised products based on the customer's requirements, organising the production and assembly of the products to meet the customer's needs. The manufacturer must have different components and a number of flexible assembly plants ready to assemble a wide range of products in the shortest possible time. From this diagram we can see the difference between the model design of ETO and other planning processes with different manufacturing strategies, as shown in the diagram.

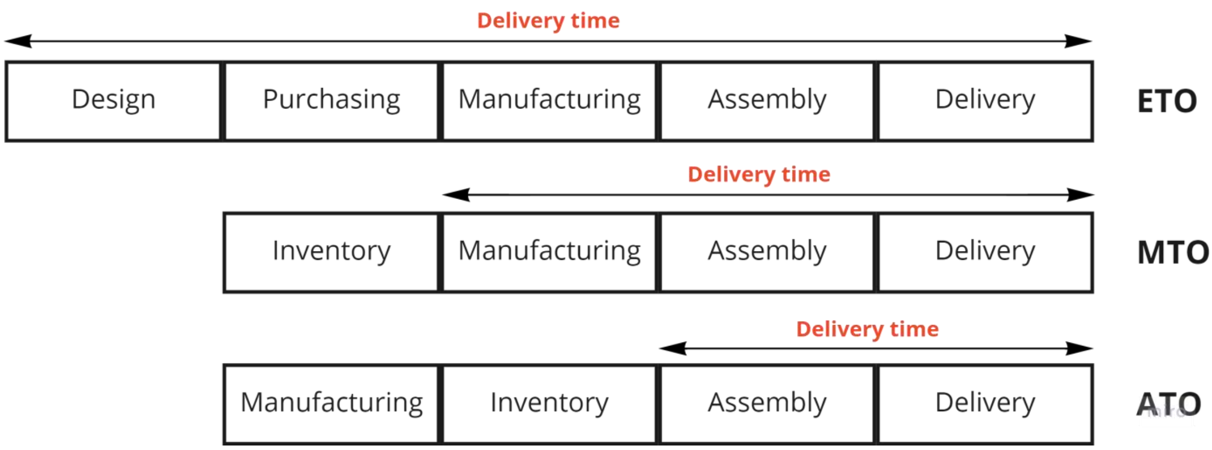

Figure 1.1 Difference between ETO to MTO and ATO

(https://www.jianshu.com/p/3a9c51e55185)

From the above analysis it can be seen that the advantage of the order-oriented assembly ATO model is that the lead time is only the assembly time and the inventory is less stored in the semi-finished goods store before assembly. The order-oriented order fulfilment strategy MTO, which has a longer lead time, but the inventory is stored only in the raw material store. The order-oriented design model ETO is characterised by the longest lead times but minimal inventory.

If we look at the characteristics of ETO from the perspective of the whole product life cycle, then we need to know that at different points in the product life cycle we need to choose different manufacturing strategies, then at this time we usually use the ETO model during the introduction period, the MTO or ATO model during the growth period and the MTO or ATO during the decline period, as shown in the figure below.

We can thus conclude that the main characteristic of ETO is that it is designed and procured at the same time, and goes through a series of processes of production, delivery, operation and maintenance, which in simple terms is more like the agile development model of the software industry. This model requires a higher level of research and development, the higher the requirements for user customisation, the stronger the modularity, componentization and generalisability of the research and development, and the need to take into account the pressure of delivery, manufacturability and total cost of ownership with quality.

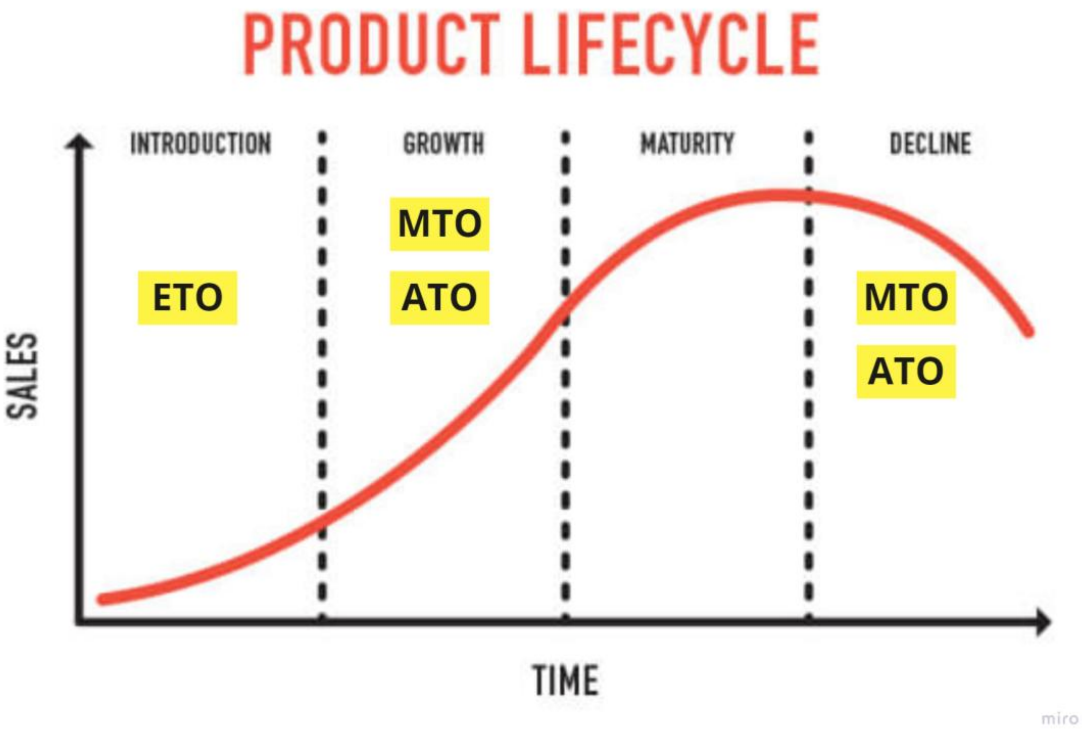

Figure1.2 Product Lifecycle(Arnold et al, 2022)

3.2. Defining Engineering to order in Construction Companies

Many construction businesses are "engineer to order" (ETO), meaning they design, engineer, and finish the product after receiving the order. Product design for each order is customised according to customer specifications, including the development of order-specific content such as bills of materials, drawings and work instructions for production (Cigolini, Gosling, Iyer and Senicheva, 2020). The diversity of the work of ETO companies in the construction industry, the customised and complex products and the potential uncertainty of the market, therefore, suggest that the construction industry is typical of ETO production, with the exception of the existence of property developers who sell their houses based on finishes, of which the home improvement industry is generally organised according to the customised needs of the customer, therefore the construction industry as well as the civil engineering industry, where the production and manufacture of construction is done on an A-side basis, is also

ETO. The most typical examples are construction and civil engineering, but these are not ordinary manufacturing industries.

3.3. Defining Industry 4.0

The so-called Industry 4.0, which actually stands for fourth industrial revolution, was first unveiled in Germany at the Hannover Messe in April 2013 and has since sparked a worldwide race for industrial transformation. Before formally explaining Industry 4.0, we have to start with the mechanisation of Industry 1.0, which started with the steam engine as a symbol of the common industrial changes that were manifested by the replacement of human power with steam engines, from which craftsmanship separated from agriculture and formally evolved into industry.The electrification of Industry 2.0, on the other hand, is marked by the emergence and widespread use of electricity, which replaced the original steam power with motor-driven machines, from which the parts and components needed for the production and assembly of products were divided, and industry entered the era of mass production. Then the automation of Industry 3.0, characterised by the application of the PLC (Programmable Logic Controller) and the PC, from then on, machines not only took the place of most of the manual labour of human beings, but also some of the mental labour, and industrial production capacity has since surpassed human consumption capacity, and human beings have entered the era of overcapacity.Today's entry into the era of Industry 4.0 means that for the first time, global mankind is able to network buildings and services, uniting resources, information and people through union, at a time when the world of industrial production will also feel the enormous impact of this phenomenon. And in the manufacturing sector, this technological evolution can be described as the fourth phase of industrialisation, known as Industry 4.0 (Calabrese, Dora, Levialdi Ghiron and Tiburzi, 2020). (Figure 1.3)

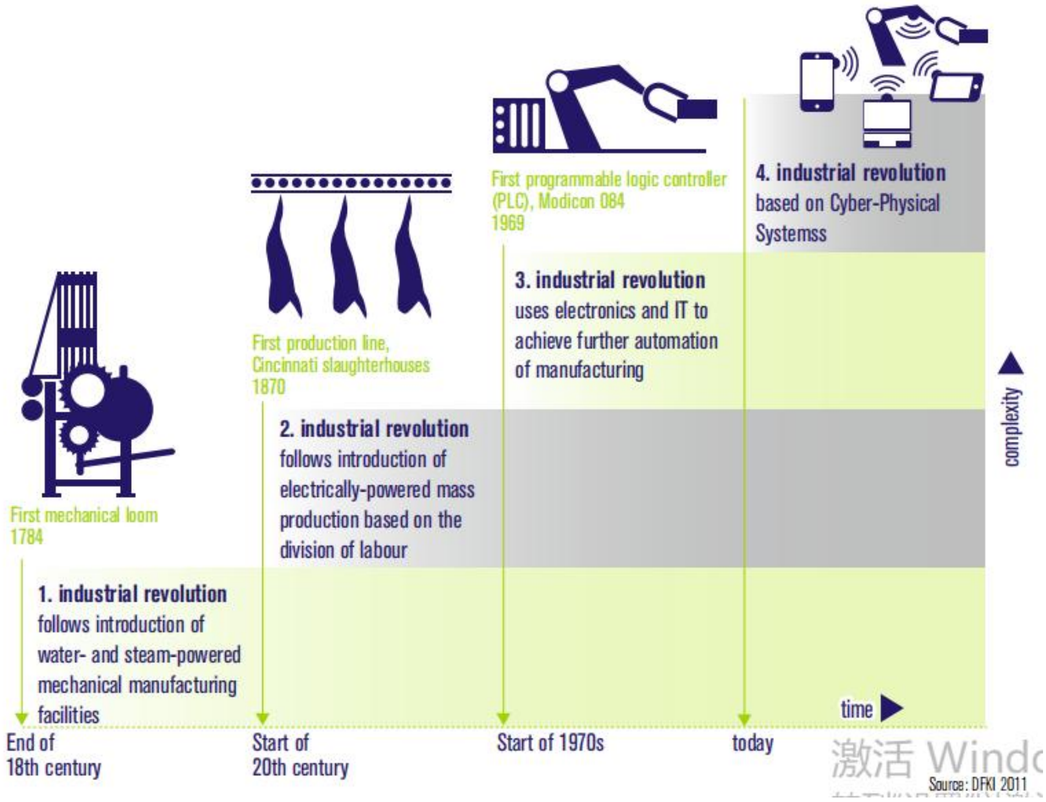

Figure 1.3 Evolution of the Industrial Revolution(Martin, 2017)

As you can see, In fact, Industry 4.0 is a product of the social demands derived from the development of human economic civilisation and the further development of computer science and technology. On the one hand, as economic power increases, people's demand for diversity and individuality in production becomes higher and higher, and people are more aware of what they want. The large-volume, homogeneous products produced by uniform production lines no longer meet people's needs, and the flexibility and customisation of production products have been increasingly valued, resulting in the characteristics of Industry 4.0.

The Industrie 4.0 initiative characteristic is:

✧ Service Orientation

The company can make use of the services that another company can offer. The smart factory is based on a service-oriented building architecture. All physical-information systems can provide specific processing services through the network.

✧ Meeting individual customer requirements

Industry 4.0 enables the incorporation of customer standards and ideas in design, configuration, ordering, planning, production and operation to best meet user needs, and the last step can be changed.

✧ High Flexibility, Interoperability and Virtualization

Interoperability is a very important enabler for Industry 4.0. Interoperability is the ability to enable decentralised control systems to work in harmonisation to achieve a common goal through the digital exchange of relevant information, combined with virtualisation, such as BIM technology, which demonstrates significant advantages in the ETO construction sector and whose high degree of flexibility is the epitome of customisation.

✧ Decentralization and Modularity

As the demand for products continues to grow, production systems are set to become increasingly difficult to control centrally. However, to ensure quality and traceability of the production process, Industry 4.0 technology makes it possible to track and record the operation of the entire system at all times. Modular technology is geared to adapt to changing requirements: modular systems can be flexibly replaced with different modules or the functions of individual modules can be expanded. In this way, modular systems can be easily adapted to seasonal fluctuations or changes in product characteristics. Intelligent factories and industrial production can utilise the 'plug and play' principle to flexibly add new modules.

✧ Real-Time Capability

In the process of working on tasks, it is largely necessary to collect and analyse production data in real time, and the timely access to and analysis of production data that Industry 4.0 can provide offers great potential for optimising production processes. Factories are able to continuously track and analyse production conditions and optimise production processes in time, which can significantly reduce non-productive times.

In summarising, with the upward trend in the level of the industrial value chain and the individualised needs of customers, the value distribution of production has begun to shift from that of manufacturing to that of services, with an increasing share of service oriented activities with regard to, for example, product development, improvement, sales, maintenance and recycling. Simultaneously, driven by new technologies and continued economic stimulation, it is necessary for service-oriented manufacturing capabilities to become the key to determining the competitiveness of companies now and in the future as well as a major source of profit (Calabrese, Levialdi Ghiron and Tiburzi, 2020). Traditional companies are transitioning their business focus from production to service orientation, and global business development is showing a trend towards servicification, i.e. a shift from a predominantly production process to service-oriented manufacturing. The emphasis of Industry 4.0 is on improving systemic service capabilities, as is evident in the construction industry for example in home furnishing and equipment construction. Servitisation is essentially the creation of more and more additional services based on physical products, gradually satisfying the various needs of users, when and where they are, and gradually reconfiguring the business model with a focus on services, ultimately completing the transformation to a service-oriented business and realising the digital transformation in the context of Industry 4.0.

3.4. Influence of Industry 4.0 on ETO Construction Companies

With the creation of the concept of Industry 4.0 and the popularisation of high technology such as Big Data and Artificial Intelligence, the construction industry is showing a trend towards a high degree of informationisation and automation, with production processes and production modes becoming progressively more intelligent and integrated, as well as providing more personalised services for customers. The traditional mode of measuring indicators and making decisions through data obtained from the actual production process is no longer able to meet the current needs of enterprises in the control of multi-unit complex production systems. It has become an emerging research hotspot in the field of intelligent construction. In simple terms, this means that the full cycle of material and construction production, planning and design, construction and transport, operation and maintenance, through to dismantling and disposal (abandonment, recycling and reuse, etc.) has begun to complete the transformation to Industry 4.0, and thanks to the development of Building Information Modelling (BIM) (Fargnoli et al., 2019) and other technologies, there is a growing awareness of the potential and benefits of its implementation. This has enabled ETO Construction to generate and manage building data throughout the life cycle, resulting in improved performance, efficiency and productivity.

In the construction sector, the costs of operating infrastructure or buildings often exceed the costs of the design and construction phases, thus demonstrating that Industry 4.0 transformation should not only be applied to the design and construction phases, but should be considered in the context of the entire construction cycle. A recent report suggests that the United Nations Environment Programme (UNEP) states that the building and construction sector is responsible for "39% of total CO2 emissions" (Launched: 2020 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION | Globalabc, 2022). These alarming figures for the construction sector highlight the urgent need for an Industry 4.0 transformation of traditional construction methods and building asset operations to become more sustainable over time. One of the main solutions to this environmental problem is the implementation of industrial production processes, which use prefabricated modules produced in a controlled environment and then transported to the construction site for assembly, while optimising real-time design, reducing the potential for errors and avoiding rework during the construction phase, and speeding up the construction process according to the client's needs, reducing construction costs for the owner. Refer to Figure 1.4 (*https://www.bim4efm.com/post/bim-based-life-cycle-management*).

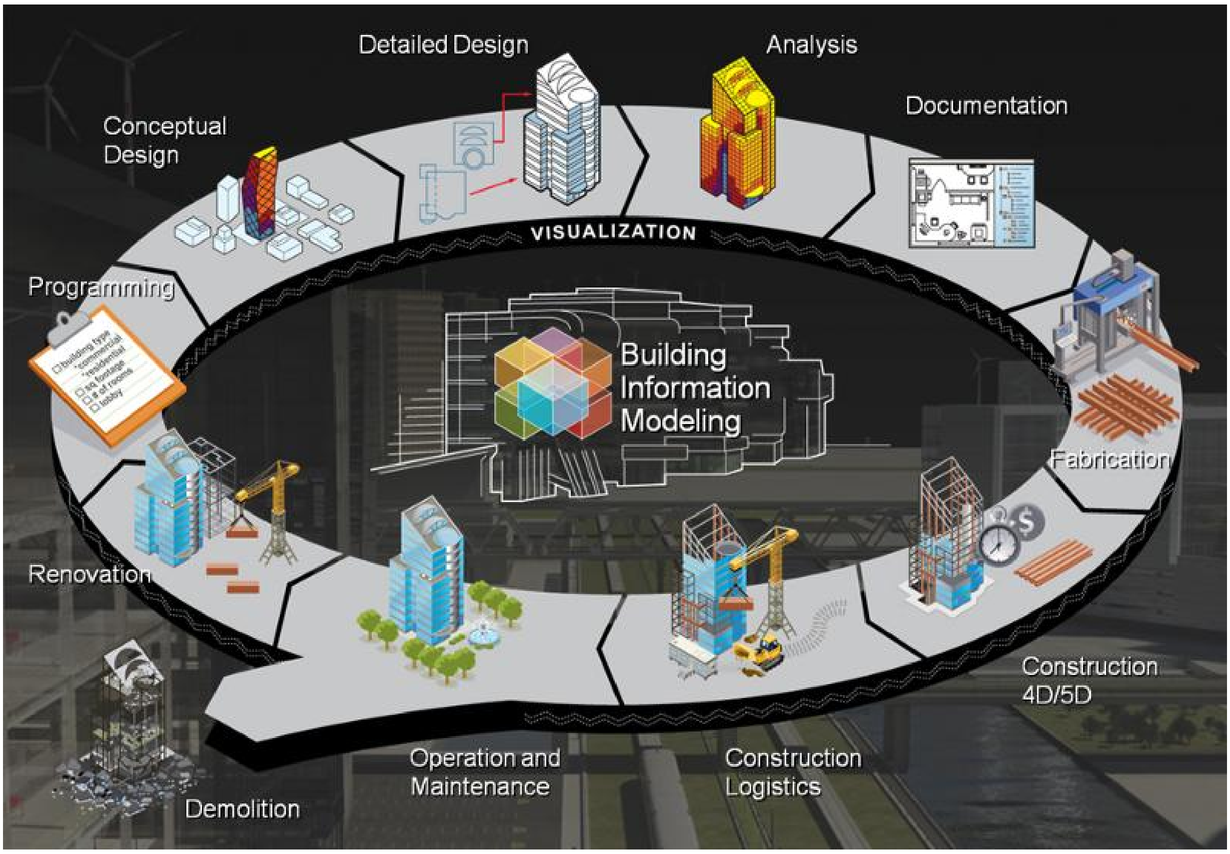

Figure 1.4 BIM Lifecycle Management (Autodesk empowers innovators everywhere to make the new possible, 2022)

The technology of Industry 4.0 enables us to master the entire construction lifecycle in ETO Construction. Due to the specificity of the ETO model, users can change the profile of the product at any stage, so to adapt to such variable needs, BIM technology, as the most advanced and universally applicable technology in the Industry 4.0 era, is profoundly applied to ETO Construction, which is a given management tool, mainly for design, construction and project management. And above all, it plays a role in sharing and transmitting the data, information and project planning generated during the construction data process This is exactly what is needed in the context of Industry 4.0, enabling those involved in construction to be accurately informed of construction information and to respond and fulfil customer requests in a timely manner. This technology has led to increased productivity and cost savings to a certain extent.

According to the above introduction I have investigated and explored through the search of construction companies and the application of technology under Industry 4.0, and have now compiled a summary of the major ETO construction companies currently using and mastering the relevant technology under Industry 4.0, where information statistics from 9 dimensions, the survey companies including Italy, France, the United States, China, a total of more than 60, because China in the process of investigation In the process of the survey, I found that the construction companies were more dependent on the technology standards and guidelines given by the state or the uniform technology provided by the relevant technology companies, and that most of the companies were owned by the state, so the remaining 40 companies were excluded and studied in depth, resulting in the following table 3.1.

Company Name	**Source**	**Type of company**	**Production line technologies**	**Smart worker technologies**	**Smart equipment technologies**	**Computing technologies**	**Sharing technologies**	**Smart products technologies**	**Data analytics technologies**	**Network technologies**	**Cyber-security technologies**
ACCSYS TECHNOLOGIES PLC	London Stock Exchange	fabricate construction materials									
ALUMASC GROUP PLC	London Stock Exchange	fabricate construction materials and Building construction									
AUKETT SWANKE GROUP PLC	London Stock Exchange	Architectural design and development		Virtual reality	Spatial Freedom	BIM modeling	BIM lifecycle 360-Bim Track		BIMcollab		
BALFOUR BEATTY PLC	London Stock Exchange	Constructions	3D Printing-Laser scanning	Virtual reality	Drones-Capturing reality	BIM modeling			BIM Digital Twins		
BILLINGTON HOLDINGS PLC	London Stock Exchange	Structural design	3D Modeling			3D Modeling					

GENUIT GROUP PLC	GALLIFORD TRY HOLDINGS PLC	FOX MARBLE HOLDINGS PLC	FORTERRA PLC	EUROCELL PLC	EPWIN GROUP PLC	ENERAQUA TECHNOLOGIES PLC	CRH PLC	COMPAGNIE DE ST-GOBAIN	BRICKABILITY GROUP PLC	BREEDON GROUP PLC
London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange
Built enviornment	Constructions	fabricate construction materials	manufacturers of housing components	manufacturers of housing components	manufacturers of housing components	Construction equipment design and materials	fabricate construction materials	Lightweight and sustainable building design and construction	Materials and Contracting Services	fabricate construction materials
Prefabricated modular construction								Digital design and 3D printing	Solar energy	
Permavoid flexible drainage system						Ground source heat pumps and air source heat pumps		Modular spaces building		
	Information modelling-BIM-Digitally driven processes					Intelligent control system				
	Information modellin					Cloud system		Virtual Object Library-Virtual model		
Renewable heating systems						Intelligent control system			Solar energy product	
Intelligent control	Digitally driven processes					Cloud system		Virtual Object Library		
	Digitally driven processes							Virtual Object Library		
	VR									

SIT	MAIRE TECNIMONT	LUVE	CEMENTIR HOLDING	CAREL INDUSTRIES	CALTAGIRONE	BUZZI UNICEM	ARISTON HOLDING	IBSTOCK PLC	HERCULES SITE SERVICES PLC	HEATH(SAMUEL)& SONS PLC
Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange	London Stock Exchange	London Stock Exchange	London Stock Exchange
Environmentally sustainable companies	Building energy companies	Built enviornment		Built enviornment	Real Estate	fabricate construction materials	Sustainable Environment Corporation	manufacturers of housing components	Constructions	manufacturers of housing components
	3D printing									
		Kinetic test fan tunnel		Iot-Information Networking						
	digital transforming	CFD-digital anlysis		Remote Cloud System						
				Remote System-Iot						
	3D printing			Iot						
		CFD		Remote System-cloud-Information Networking						
				real time Monitoring						
		CFD								

Countryside Properties PLC (CSPLF)	Consorcio ARA S.A.B. de C.V. (CNRFF)	Century Communities Inc. (CCS)	Berkeley Group Holdings PLC (BKGFF)	Beazer Homes USA Inc. (BZH)	Barratt Developments PLC (BTDPF)	WEBUILD	TREVI FIN INDUSTRIALE	SOMEC
WSJ	WSJ	WSJ	WSJ	WSJ	WSJ	Italy Stock Exchange	Italy Stock Exchange	Italy Stock Exchange
Real Estate	Real Estate	Real Estate	Real Estate	RESIDENTIAL BUILDING CONSTRUCTION COMPANIES	RESIDENTIAL BUILDING CONSTRUCTION COMPANIES	Constructions	Constructions	Constructions
		Modular production		Solar energy-Daylight sensors		Automatic conveyor belts		Flexibility and module production
			VR AR	MMC				Lean management
	Intelligent Systems		VR AR				Digital control system	
		Building Information Modelling - Automated Design - Collaboration Tools				Metaverse		
	Intelligent Systems	Digital Modular Platform				Digital Information Points-Metaverse		
		BIM		Modular pre-construction			Digital control	
		Digital Modular Platform				Digital Information Points		
		Digital Modular Platform				Digital Information Points-Metaverse		

Sekisui House Ltd. ADR (SKHSY)	Nobility Homes Inc. (NOBH)	Persimmon PLC (PSMMF)
WSJ	WSJ	WSJ
RESIDENTIAL BUILDING CONSTRUCTION COMPANIES	RESIDENTIAL BUILDING CONSTRUCTION COMPANIES	RESIDENTIAL BUILDING CONSTRUCTION COMPANIES
Prefabricated modular construction	Wood-derived materials	
Prefabricated modular construction		
	Photovoltaic panels	
	Information transforming Technology	
	Photovoltaic panels	

Table 3.1 Application of existing technologies at ETO Construction Company

4. Methodology

The purpose of this chapter is to provide the reader with an understanding of the methodology and associated research approach used in our study. In this chapter, we will explain the research philosophy, methodology and strategy and why this approach was adopted, as well as discussing the constraints associated with data collection and the methods used for data collection.

The aim of the research in this thesis is to investigate the impact and changes that ETO construction companies are currently experiencing in an Industry 4.0 environment. I t is vital to obtain valid data and information to gain an accurate understanding of the issue under study. Therefore, it is vital to select the appropriate research methodology and conduct the research effectively in order to answer the research questions and meet the research objectives. From this I will explain later.

4.1. Research framework

This dissertation makes use of secondary sources analysis methodology where the research approach implemented has been that of refers to the process by which you gather information for your project from different sources such as websites, books, magazines, blogs, WeChat, databases, etc which is also known as desk research, is a research method that involves compiling existing data sourced from a variety of channels(Heaton, 2008).

Usually when using this method we use it because the information we need is not available directly from the client or the corresponding database. An example of this would be when, for example, one wants to obtain information about trends or developments in relation to a project, as in the case of the topic we are studying in this paper, the impact of Industry 4.0 on ETO Construction, where we need to focus on both the trends in the industry and the current problems faced by ETO Construction, so this method seems more appropriate. Alternatively, a desk study can be chosen when there is already a macro understanding of the problem, for example, we are actually already in the process of Industry 4.0, we are to a large extent familiar with the development of the corresponding technology, and the corresponding ETO construction companies are partly aware of it on a macro level, but we want to go further in relation to this current situation. Desk research helps you to build up a first-hand, complete body of knowledge and prepares you for subsequent research and users.

When using secondary sources analysis, I should first draw up a thought table centred on ETO construction companies and technology under Industry 4.0. Afterwards, I think carefully about the sources of useful information and fill in the table with information corresponding to the companies and technologies we need by means of a summary, a short description of the information and the sources and findings of the information to be used to see the overall picture. Before filling in the information each time, it is necessary to consider the significance of this central topic for the solution of the problem.

Once I had done my desk research, I had a further understanding of the topic, which will be elaborated on later, an initial direction of research having learnt about the antecedents of the topic, the different points of interest and technological advancement and the different perspectives of the companies involved.

The units of analysis in this report are the entities that can be talked about at the end of the study and can be considered the main focus of the study. We have used the units of analysis of organisations and institutions and have analysed close to 65 ETO construction companies, originating from Italy, France, China and the United States. The types of companies engaged in the construction sector were also identified, and nine technologies and techniques that may exist in and accompany construction companies in the Industry 4.0 era were listed and qualitatively analysed. The purpose of this is to clearly demonstrate the strategies and tactics put in place by the major ETO construction companies in response to technological change and innovation in the context of Industry 4.0, as well as the impact on the construction industry as a whole in a true Industry 4.0 process.

4.2. Data selection

If we are trying to find the database of all construction companies out of nowhere is actually very difficult, since few websites will collect the names and related information of companies in a certain industry as a whole, and we thought of a way for investors to buy and sell securities through the Internet by means of a network stock securities trading platform, which, firstly, online securities trading takes the ubiquitous international Internet as a carrier, and through the high-speed and effective The flow of information fundamentally breaks through the geographical limitations and provides a very direct and aggregated search condition for our search. Secondly, online stock trading, through the international internet, overcomes the shortcomings of inadequate information on screening through traditional search engines and helps to improve the efficiency of our search and allocation of the companies we need.

Once again, the online securities trading platform, on an ordinary computer can fully grasp the market situation and the latest developments in trading which is also very important for us to search and screen the ETO construction companies required a standard and threshold. In addition, online trading is inclusive to all aspects of securities activities, so that we can learn about the company's information delivery, trading, clearing and settlement matters without having to leave home, saving a lot of time and money for our research. So we can quickly know which listed companies exist in the relevant fields, such as the construction field we need. There may be a question at this time whether companies that are not listed should be ignored, and our answer is that they can be ignored, because companies with listed capacity usually have a large market and corresponding market capacity in the local area, which can have a certain impact on the local economy, thus Finding companies in this way is not always a good way to help us filter out the leading companies in the industry, either.

After finding these construction companies, I tried to find out if they fell within the ETO category. It is also different from the "continuous batch" model of a manufacturing plant. You may see some construction companies that are still traditional build-to-print on a large scale, but I would classify them as ETO construction companies because they have started to use customisable technologies such as housing information models, customised modular production, etc. This is a series of phenomena that indicate that they are transforming into ETO companies. This is a series of phenomena that indicate a transition to the ETO category and I think it can be classified as an ETO construction company.

Considering the well-known ETO companies in the thesis and literature, my way of considering them is as follows. In the many publications I have read on the subject of ETO, the construction field of ETO is inherently not well known and recognised by most people, and the traditional construction industry as we know it is inherently a complex and traditional existence, which manifests itself in several ways. The second point is that during the production of a product, the construction personnel and tools have to move along the construction object with the different parts of the construction, constantly changing the place of operation. In order to adapt to the frequent changes in construction conditions, our construction machinery is mostly relatively small or easy to move, manual operation is also more, to a certain extent, affect the development of technology in the construction industry, and those such as the need to follow the ETO process of construction, the technology and tools needed to have more technological capabilities.

At the same time, due to the different functional requirements of the building or structure, the natural and socio-economic conditions in which it is located, each project has its own unique engineering design and construction organisation design, and the price of the product must be determined individually and costed separately, which poses the problem that while considering ETO, the overall fluctuation in our price costs will be so great that we usually do not consider the overall adoption of ETO as a whole, but will instead consider individual components. Finally, there is the long production lead time. The duration of larger projects is often measured in years, and construction preparation also takes a long time. As a result, a lot of manpower, resources and money are often tied up in production over a long period of time and it is not possible to provide all the useful products and changes in a short period of time. It is therefore not a valid argument that there is a very well-known ETO company in the construction industry, but rather that we consider the various stages of construction to improve our ETO-related processes and to further the ETO transformation plans of construction companies through relevant technological advances such as Industry 4.0.

4.3. Data gathering

The methodology I used was a web analysis approach, reviewing close to 65 companies to base the full text discussion on their data and content.

This was done firstly through personal review and analysis and secondly through communication with the tutor in order to harmonise interpretation and avoid possible bias and errors. I provided a way to browse queries by category through a web-based classified directory. The classification search engine works by manually discovering, crawling and identifying information on the web, relying on the knowledge of cataloguing and citation staff to create a hierarchical catalogue of subject trees according to book classifications, subject classifications or other classification bases, and classifying the collected and filtered information into categories. Here I can gather a large amount of company information through the major stock sites, using a classification search engine using the site login/inclusion method, based on the main theme, user objects and network resources to build a classification system, the collection of local website pages for manual editing, layer by layer category, the formation of vertical affiliation, horizontal association of the two-station directory database, for example, we need to be the construction company this classification, then In the search process, it needs to be fixed for the category to ensure that all of our search content meets our search requirements and reduce our screening time. From this, we can learn that users search based on the category system and its rules of classification, browsing category by category until they get the resources they need. When users use the classified catalogue, they can gradually search for sub-categories from the top down through the search engine's classified catalogue, and the classification methods used in the web resource catalogue are subject classification, subject classification, geographical classification and faceted grouping classification. This is the first level of the search and the second level is to analyse the potential content of these potential companies through the themes we are looking at. The second level is to examine the potential content and technical framework of the company through web analysis, qualitative analysis of the company and extraction of complex information points from their website. Based on what is already known, a detailed investigation of the listed ETO construction companies was refined, discussed accurately in terms of the different technological classification dimensions, and tables were completed to provide informed clues and evidential support for the subsequent discussions and conclusions.

4.4. Data analysis

The research method in this paper uses a compound statistical table in statistics (http://pages.intnet.mu), which can combine data from two or more statistical elements on a single table, allowing for a clearer and more lucid picture of the data. But unlike the traditional compound statistics table which is usually used to count quantities, this time I used it to count the relevant technologies corresponding to the different ETO construction companies involved in the basis of Industry 4.0, providing nine dimensions on the technology column side and, in the statistics table, specifying the specific technology applications and types under that dimension. The advantages of the compound statistics table are also very obvious. The compound statistics table can represent multiple sets of data, also in a way that allows for a clearer and more lucid representation of the data. For the purpose of our research, we wanted to find out whether the same technical characteristics existed in different companies in order to test our suspicions and to see how the relevant macro developments were progressing. The data skeleton is so easy and convenient to use in the query and inference phase that it is also more user-friendly. In addition to the above points, the advantage of compound statistical tables for comparisons is often overlooked. While we are used to feeling that they can help us to make intuitive inferences, comparisons between companies can also be made from compound statistical tables. For example, at the technology level we sometimes see two companies using the same technology in to the same dimension, as shown on figure 4.1, but in fact you will find that in fact the two construction companies themselves are of a completely different type Through this feature, we can find a lot of commonalities in the technologies used in ETO construction companies, which will be of great help in our later research, especially for the macro trends in the use of Industry 4.0 in contemporary society in ETO construction companies, as well as creating a lot of room for reflection on the future limitations and implications.

Company Name	Source	Link	Type of company	Production line technologies	Smart worker technologies	Smart equipment technologies	Computing technologies
ACCSYS TECHNOLOGIES PLC	London Stock Exchange	https://www.accsysplc.com/	fabricate construction materials				
ALUMASC GROUP PLC	London Stock Exchange	https://www.alumasc.co.uk/	fabricate construction materials and Building construction				
AUKETT SWANKE GROUP PLC	London Stock Exchange	https://www.aukettswanke.com/	Architectural design and development		Virtual reality	Spatial Freedom	BIM modeling
BALFOUR BEATTY PLC	London Stock Exchange	https://www.balfourbeatty.com/	Constructions	3D Printing-Laser scanning	Virtual reality	Drones-Capturing reality	BIM modeling
BILLINGTON HOLDINGS PLC	London Stock Exchange	https://billington-holdings.plc.uk/	Structural design	3D Modeling			3D Modeling

Figure 4.1 Excerpt of compound statistics table

From this we can see that analysing the current situation is the basic purpose of our data analysis. We need to clarify the current market environment, what is the market share of the direction we are studying, what are the sources of technology, what are other companies like, what is the development status of competing products, what are the relative strengths and weaknesses of different companies, etc., all of which are part of the analysis of the current situation. There are two aspects to this: the analysis of the overall macro situation and the analysis of the specific situation of the different companies.

The third purpose of data analysis is to predict the future, so to speak, and it is vital for the researcher to use data analysis to predict future product trends. It is possible to predict future trends based on the strength of the trends and developments based on the data changes in the product in the recent period and use the next period to verify whether the trend is feasible and to achieve critical growth in the overall technology driven by data.

5. Results

The graph below depicts the many technological indicators utilized by various ETO construction firms in the context of Industry 4.0 that I found and collected from the website. The graph illustrates that the most generally used technologies are computer and data analysis technologies, which are used by ten organizations each, while the least frequently used technology is cyber–security, which is used by just three companies. BIM–related technology, which includes BIM modeling, BIM tracking, BIM management, and other particular high–frequency technologies, is one of the most often employed by the majority of ETO construction organizations. I also discovered that over 40% of the businesses utilizing these high frequency technology were largely involved in building construction and design.

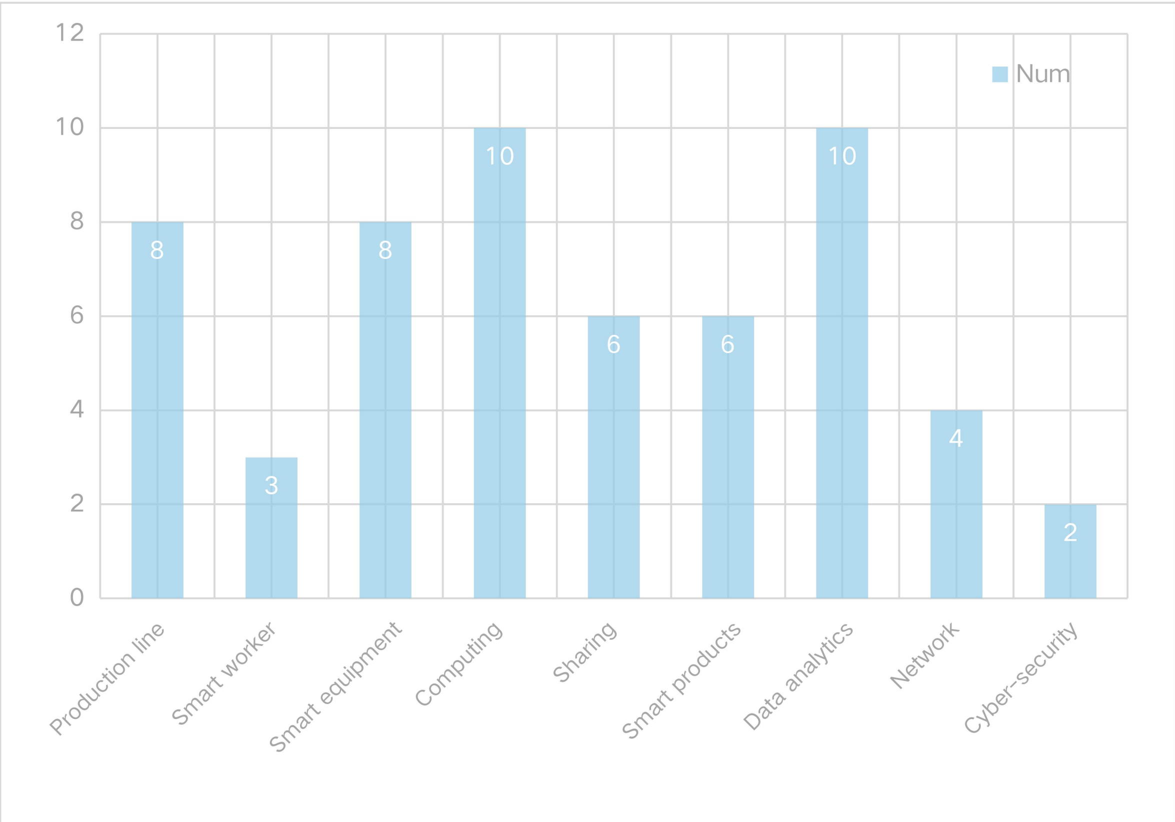

Figure 5.1 Technologies in ETO construction companies

Through my study, I've determined that BIM and digitalization are the most prevalent technologies, while metaverse is the least prevalent. I'd want to explain how these technologies are utilized in the manufacturing process at ETO Construction. Building Information Modeling (BIM) is used by “BALFOUR BEATTY PLC” (Building Information Modelling (BIM), 2022) to create and manage vital information about a building or infrastructure. BIM delivers information throughout each phase of the project lifetime, from design to decommissioning, so that our clients may make educated decisions. This method increases the efficiency of the design, building, operation, and decommissioning processes. Since we began utilizing BIM, we have recognized several advantages for our clients, designers, supply chain partners, as well as our own workers and enterprises.

The advantages for clients include: early design to help speed up the approval process, simple modeling of options and impact assessments for each option, lifecycle modeling to reduce energy use and carbon generation, optimal solutions to reduce design, construction, and operational costs, and the availability of data that can be integrated with facility management programs to ensure a comprehensive set of asset data is readily available at the time of handover. By integrating all contributors, including clients and facility managers, designers and our supply chain partners benefit from increased collaboration, smoother delivery, and enhanced safety, reduced site rework due to better planning and design, and increased resource efficiency. British Standards Institute simultaneously gave BIM Level 2 accreditation to Balfour Beatty (BSI). In addition, “CAREL” has, throughout the years, produced systems and applications for vertical market areas with extremely particular demands and solutions that are highly tailored (What we do, 2022). In particular, CAREL develops, produces, and sells humidification and control systems for the residential, industrial, and commercial HVAC markets. It provides solutions for each application area that can be integrated into individual units, such as heat pumps, room air conditioners (CRAC), chillers, and air handling systems, as well as complex systems, including but not limited to shopping system centers, supermarkets, museums, and data centers. CAREL also provides services associated with its products, such as commissioning or contract work, remote operation and monitoring of HVAC/R systems and components to facilitate interaction between the company's service centers and end users, and subscriptions to dedicated remote systems and machinery utilizing Internet of Things (IoT) attributes to process data for operation and control services. The IoT family was designed to connect HVAC and refrigeration market-specific cloud and local solutions. Included are benchmarking, statistics, warnings, and standard reports to assist users in optimizing their daily operations and achieving their service, energy, quality, and marketing objectives more effectively. The growth of these operations is a strategic initiative for the Group, with an emphasis on the future.

According to the above table, I discovered that out of the 67 construction enterprises that I polled, there were a total of 630 survey subsets, which were surveyed the total of 63 compaies, and were surveyed the total of 10 technology categories but only 73 subsets were engaged in the relevant technology, which resulted in a technology coverage rate of just 12% which found that because construction is more complex than engineering design, traditional construction enterprises in the individual production process, capital consumption is more huge, and the level of computer application is low, so in the context of Industry 4.0, the development of information technology in the construction field is the key link in the development of information technology in the entire construction industry.

The application of information technology in construction is mainly reflected in information technology construction, information technology construction is the overall goal of construction information technology, according to the order to complete the customer's requirements, this is also the most can appreciate the difference between ETO construction enterprises and traditional construction enterprises production process, in the construction process involved in all departments, all stages of the extensive use of information technology, the development of information resources, in order to promote the construction technology and management level The process of continuous improvement and significant increase in construction production efficiency. At present, the application of information technology in ETO construction enterprises with the support of Industry 4.0 is mainly manifested in the following four aspects.

First, in the construction of buildings, through the computer office using computer technology for various calculation operations and auxiliary management work, such as office automation system, bidding system (volume calculation, tender quotation, tender production, construction plan design, cost calculation, preparation of the project progress network), design calculation system (deep foundation pit support design, scaffolding design, template design, construction detail design), project management system (project cost, quality, progress management, daily information management), etc.

Secondly, the automation control technology characterised by information technology has achieved better results in construction. Such as quality control of large volume concrete construction, verticality control of high-rise buildings, automatic control of ready-mixed concrete loading, the use of synchronous lifting technology for the overall installation of large components and equipment and the overall climbing scaffolding lifting, the production and processing of curtain walls, the subsidence of buildings or deep foundation pits support, deformation observation and engineering measurement, construction material testing data collection, etc.

Third, the application of virtual reality technology in building construction, such as the application of virtual reality technology, can be a construction process preview of large and complex construction projects, in the actual construction before the discovery of defects in the design, or the comparison and optimisation of construction solutions. Another example is the underground process virtual reality system, which can simulate the excavation process, calculate and demonstrate the possible collapse of the area and range, providing a reliable basis for the design of soil nail support.

Fourth, the application of multimedia technology and network technology in construction. Such as the construction site image transmission, the manager sitting in the field office can see the site of various situations; construction site using camera surveillance system, used to monitor the site safety, fire, etc.. Remote expert accident consultation; computer-based construction process handover processing and monitoring management of road and bridge projects.

In addition, I advocate that the information management system of the enterprise should gradually join the international Internet to share resources and better serve our users in the cumbersome production process of ETO, to improve the decision-making ability and management level of the enterprise, so as to achieve construction informatization, engineering process and technical management standardization. The significance of informatization in construction is not only to use information equipment to replace manual information processing operations, but more importantly, a highly informatized system has many advantages that cannot be matched by manual operations. This is particularly true in the areas of information retrieval, exchange and processing. The development of informatisation improves the quality of information utilisation by increasing the quantity of information available, and promotes the transformation of information resources into real productivity in construction production, which has the role of "accelerator" and "multiplier" for the development of the construction industry.

6. Discussion

In response to the above discussion, it is easy to see that ETO construction companies in the post-Industry 4.0 process (Construction 4.0 The next revolution in the construction industry, 2022) are routinely upgrading their workflow to a highly collaborative state, whether on a technological level, product level or information level, largely to cope with the pressure and production requirements brought about by design-to-order, as opposed to the traditional construction order fulfilment strategy, where ETOs require a large number of design ETO requires a large number of designers and builders, and our focus in this order fulfilment strategy is different from that of traditional production. We focus more on project management through relevant technology, such as BIM for construction project production management, as shown in figure 6.1, or CFD digital twin information modelling forecasting, because each order is a separate project, from receiving the order, communicating with the customer, to design, procurement, manufacturing, assembly, delivery and so on, a series of actions, all need to be completed by different departments, and need to cooperate with each other. This is why the technical features of the ETO construction company are different from those of the traditional companies and are based on the conversion of technical functionality into high batch and high frequency information transmission, which is very important for the development of the order fulfilment strategy of the ETO construction company in the era of Industry 4.0.

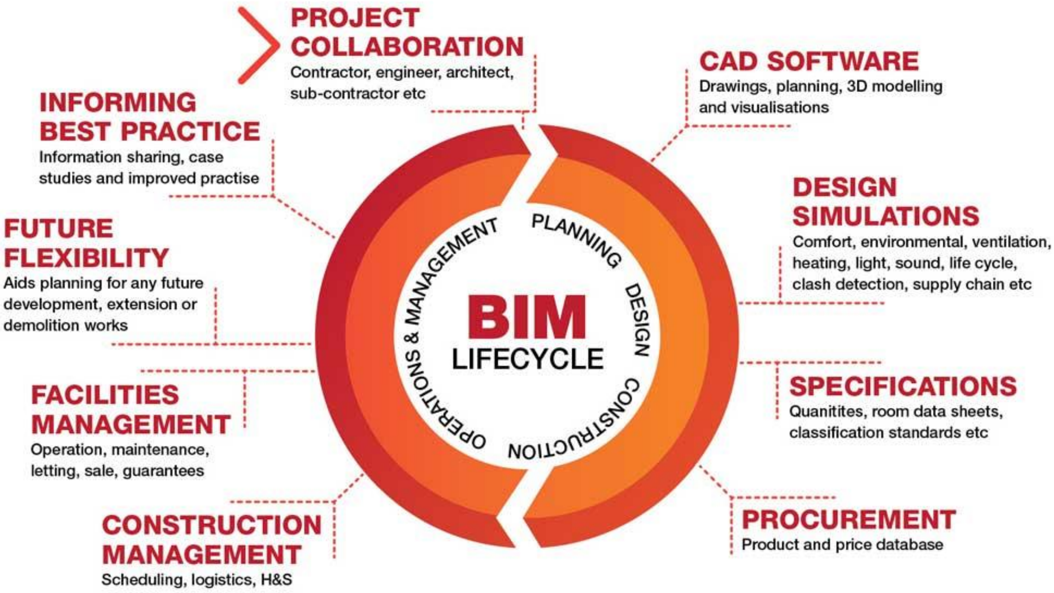

Figure 6.1 BIM for construction project production management

(Alimentation et al., 2022)

Another consideration is that construction firms now have technical resources as a result of the advent of Industry 4.0. You will be extremely glad if your organization is an ETO production and processing model with highly experienced technical design employees. Because there are numerous technical design issues that can be resolved for you. Some ETO enterprises, for example, demand production flexibility for modular construction. We have frequently stated that a production line may manufacture more than one type of product, and that modifications may occur even within a product family. As a result, no order fulfilment strategy necessitates more production flexibility than ETOs.

The current construction ETO firms require more horizontal and vertical synergy through the Industrial Internet's construction. Horizontal synergy refers to the requirement to break down information barriers between the front and rear ends of the industrial chain in order to enable the effective flow of business, data, and capital flows along the industrial chain, ultimately realizing collaborative manufacturing. One requirement is to carry out networked collaborative production among multiple factories within the group, optimize the manufacturing process through efficient use of each factory's resources, and fully exploit the benefits of intensification. Another requirement is to realize business decisions and collaborative manufacturing of production line equipment within a single production, to improve its own agile manufacturing and flexible manufacturing capabilities, and to grasp the operational status of equipment and accurate process in real time. This is also a prerequisite for Industry 4.0. This is also a new project-level change brought about by the Industry 4.0 era to ETO Construction, through intelligent manufacturing, including the development of multi-plant collaborative manufacturing solutions and intelligent solutions for individual building component plants to replace the traditional "construction by drawing" scenario with a service-oriented system architecture, by transforming The intelligent system for the assembly of buildings and concrete, as well as the optimization and upgrading of the procurement cloud platform, the establishment of a city-level quality assurance book management system, an integrated system for intelligent testing of special raw materials and personnel training, and other service platform systems cater to the ETO production process to a greater extent, eventually allowing the establishment of real-time production management, quality control, trading, logistics, and service collaboration on a regional level while producing to order. The installation of demonstration applications should achieve the enhancements necessary for construction production and improvements to user customisation requirements, as well as the synergy impact of point station connectivity and data volume resolution.

After the technology related advances are discussed, then in fact the development of Industry 4.0 has helped many construction companies who want to transform their ETOs to be able to manage multiple own construction and outsourcing factories in a unified manner, so that the projects can be assigned to multiple construction factories to produce alone according to the order requirements, and to be able to implement and supervise the progress, quality, raw materials, yards, delivery and other data of each factory to ensure that the design is designed according to the order at the very beginning. The customisation requirements of the user are completed, avoiding rework and modifications at a later stage of the construction period, leading to unpredictable stoppages and delays, while the technological innovation also realises the informationisation of the whole system in the construction's ETO industry, integrating logistics procurement, production control, management, professional services and marketing. The solution consists of the Building Manufacturing Execution System, which manages the various operations of the plant operations and serves the personnel of the various departments, and the Digital Building Production System, which monitors the building construction production line and serves the upper management system. The solution realises the digitisation, transparency, visualisation, online and traceability of the ETO construction enterprise, making lean production possible and providing the basis for future big data analysis and intelligent decision-making through data precipitation. In the traditional discrete construction business model, the quality of the components is strongly linked to the construction of the building, and well-funded construction teams are able to set up modern assembly line production, which is often more efficient in terms of production and product quality. The post-modern prefabricated building components industry is still a minority of companies that can establish automated lines, and most of them have limited investment in production lines and construction equipment, with human tactics still being the mainstream of the contemporary era. In addition to the increasing demand for assembled ETO buildings at the social level, many orders are completed overtime and the quality of the products fluctuates greatly. And based on the advent of the Industrial Internet and the 4.0 era, the inclusion of manufacturers of components into the collaborative platform, the management and even distribution of orders through big data analysis, the mutual coordination between manufacturers can be achieved, the joint contracting of project works, the practice of unified subcontracting of the relevant accessories involved, the smooth production, it is easier to enhance the production efficiency of each enterprise, while in terms of quality control, it is also easier to operate. Using the industrial internet to build a collaborative platform for the upstream and downstream of the industry chain in the assembly building industry, a secondary rational division of labour is carried out to gradually realise the specialisation of production plants and the assembly line operation of industrial workers, on the premise of enhancing each module to a standardised level. At the same time, the order information is aggregated and analysed through the big data of the collaboration platform, and all products are transported to the construction site on time for assembly according to the needs of the construction schedule, and a quality management system with full process traceability is configured. In addition, the application of the industrial internet collaboration platform enables the production process and supporting equipment and moulds of each production plant to be further specialised, improving management efficiency and reducing costs, and making it easier to improve the technical level and proficiency of workers, which is an effective means of improving product quality.

The gradual servitisation of construction companies means that these ETO construction companies will change from just providing products or products with additional services to providing "product services", including products, services, support, self-service and knowledge, and that services will play a more dominant role in the whole production process than in traditional construction companies It is the main source of adding value to the product. An important prerequisite for servitisation is customer orientation, which is consistent with the concept of design to order, to better understand and meet customer needs through increased service. Servitisation emphasises that value is identified and understood by the customer, which changes not only the traditional notion that value is created by the company, but also the traditional paradigm of value creation. Servitisation is an interactive relationship between supplier and customer, where one party does not act alone to satisfy the needs of the other, but where the customer is often involved as a partner in the production of the servitised product. In the servitisation process, the customer and the supplier share a common goal and work together to deliver value and add value.

In the past, construction companies have often built projects according to customised drawings, which has determined the conditions and foundations for servitisation in the construction industry itself, a very important piece of information that is often overlooked, so that ETO construction companies are more actively affected by Industry 4.0. The "one-off and unique" nature of the project means that no two projects are exactly the same, so all projects should be individual and customer-driven, so the technology associated with Industry 4.0 can be better applied to this scenario, which shows that construction companies are inherently service-oriented. However, the current level of servitisation in construction enterprises is not high, mainly due to the lack of the concept of using services to add value to customers and the lack of a servitised organisational management system, as well as the lack of a mature servitised business model.

The servitisation of construction companies refers to the addition of services throughout the project completion process, so that clients can continue to perceive value and gain benefits during the project realisation process, rather than just at the final delivery of the project. There are two other reasons why the servicification of construction companies is currently a trend, namely the increasing interest of customers in investing in products throughout their life cycle and the increasing complexity of technological innovations. In order to add more services, construction companies have to change and redefine their business models. Servitisation will change the way companies earn their profits and expose construction companies to new challenges of business design and organisational change. As a result of servitisation, construction projects will become more long-term processes and will lead to better relationships with clients.

7. Conclusions

7.1. Summary

Contemporary technological developments in the context of Industry 4.0, including building construction technology, material technology, equipment technology and design media technology, have provided the means to support the revolutionary advances of the ETO architectural enterprise. The consistency of architectural forms with the standardised and homogenised principles that characterised the technology of the machine industry era can be very clearly felt in industrial societies. Innovative research has become an important feature of contemporary social development, and with the continuous emergence of research results, a large number of new technologies, materials and techniques have been applied to the practical activities of building construction, as shown in the following points.

1. Ready-mixed concrete and concrete conveying, using the innovation of technology

Concrete is the main raw material for modern building construction, and the quality of concrete directly determines the quality of building construction. Ready-mixed concrete technology uses advanced technology to mix the concrete before construction, one is to reduce the construction process, greatly reducing the waste of human and material resources, and objectively shorten the construction period; secondly, standardised concrete can avoid the errors in manual proportioning and mixing, to ensure the quality of concrete. In addition, through innovative technology, pumped concrete delivery technology was used to ensure the stable quality of concrete during the delivery process. In the field construction of concrete, the quality of concrete construction is further ensured by adopting measures to prevent alkali aggregate reactions in concrete, for example, by using low alkali cement, sand and gravel materials and low alkali active materials as far as possible. At the same time, through prestressed concrete technology, low relaxation high-strength steel strands and new prestressing anchor jigs are used in combination to effectively reduce the concrete slab thickness and height, thus achieving the effect of reducing the self-weight of the building and enhancing the performance of the building.

2. Innovative application of reinforcement processing technology

Reinforced-concrete structures are the first choice for most buildings, and the quality of reinforcement processing has a crucial impact on the quality of building construction. In the welding of reinforcing bars, electroslag welding is becoming increasingly popular in the processing of reinforcing bars because it is not affected by the chemical composition of the bars, their weldability and the weather, and because it is safe and simple to operate without open flames, especially for the connection of vertical or diagonal (inclination within 4:1) reinforcing bars in cast-in-place reinforced concrete structures, especially for column and wall reinforcing bars in high-rise buildings. In the area of reinforcement connection technology, the rib stripping and rolling technique is used to roll the longitudinal and transverse ribs at the end of the bars to be connected directly into a common thread by means of a thread rolling machine and connect them with a special straight thread sleeve. The use of straight-thread connection technology can greatly enhance the strength of the reinforcement joint and bring into play 100% of the tensile strength of the reinforcement, and is simple and efficient to operate and can be quickly processed on the construction site.

3. Innovations in GPS monitoring

With the construction of high-rise and super high-rise buildings, these tall buildings require construction placement. The old methods of measurement and control of construction are difficult to meet the needs of these high buildings. Because the measurement and control of super-high rise buildings are affected by the temperature difference between above and below, sunlight and wind, some axis control and positioning of the building cannot be carried out well, which affects the development of the construction industry. The use of advanced GPS measurement and control technology is a convenient and reliable way to ensure the quality of construction work through a series of measurement controls. This technology can quickly and accurately carry out the measurement and control work of construction, providing a strong guarantee for the construction work of super tall buildings.

4. Total station coordinates method

Coordinate method is also a very good technology, coordinate method of proofing technology uses the total station of many advantages. The construction measurement work of building construction is also supported by some advanced equipment, and the total station is a very good equipment. The total station is highly accurate and automated, making it easy and fast to use in construction work. Coordinate method of placing using the total station makes direct use of some of the coordinates of the control, which eliminates the need to do the placing work, reduces the time spent on construction surveying and is also more accurate and less likely to make mistakes. Such technology, those complex, not easy to measure the control of the building application is very convenient and fast.

7.2. Limitations

Many construction companies have been able to embrace the idea of adding services to their business models, but most have not yet developed the mechanisms needed to help build a fully service-oriented business model. Some companies have only identified strategic steps to build customer orientation and customer satisfaction and to maintain a stable relationship with their customers. This is because most companies want to maintain ongoing cooperation with their customers, especially in the planning and design phases of a project. The client presents their needs and gives specific instructions on what they want from the project, and the company tries to guide the client to their interests. At this point, the company's main objective is still to satisfy the client and help them to achieve their goals, without giving much thought to how the complete mechanism for creating maximum value for the client through whole-life servitization should be set up. Servicing is not a task for one phase of a project, but must be based on a holistic approach to the whole lifecycle, considering the interconnectedness of the different phases and their realisation mechanisms in order to ensure the best possible outcome.

Some construction companies' business models include value-added services, but these are usually provided only in the pre-delivery phase, especially during the economic and technical feasibility studies. Most companies have not yet focused on how to provide new services to their clients during the project implementation process. Once the project has been delivered to the client, the process of providing services is over, so the post-delivery phase is largely omitted. Only a small number of companies can offer their clients the service of defining project objectives and setting up project committees, from data recording and surveys, to site studies, to testing the implementation or construction of the project in its final stages. This whole project management is the ideal service model for construction companies. The whole process management includes the overall management of the project, from the initial involvement of the client to the post-delivery operational phase when solutions are proposed for the client's problems. Obviously, it is more beneficial to have the same company take on all tasks, including all phases of project completion, as it provides more accurate technical and economic feasibility analysis, better planning, avoids delays, takes responsibility for the quality of the entire project and ensures that the project is implemented as designed. As the company is responsible for the entire project process, it can also streamline the project interface and save time in project completion. Finally, because of the ETO construction concept, we need to focus on the post-delivery feedback process. Construction companies have recognised the advantages of providing a comprehensive range of goods, services and knowledge to their clients, but do not yet see the post-delivery phase as a major part of the overall project process. As a result, most companies continue to forgo providing maintenance services alongside construction, thereby neglecting the post-delivery feedback process and the opportunity to use it to gain a competitive advantage. In fact, the use and maintenance of project equipment in the post-delivery phase provides very useful feedback data that can improve the design of future projects and contribute to their technical and economic improvement. The information gathered through post-project evaluation, operation and maintenance, as well as diagnostic services, is important for the development of an internal feedback process that can help to correct deviations in project implementation and provide the basis for improvements in project design, thus enabling the company to provide more effective and sustainable solutions to its customers.

7.3. Future research directions

From the future development trend of construction technology, housing construction technology innovation has the following distinctive features.

- Energy conservation and environmental protection of buildings will become an important direction for future construction technology innovation. The construction industry has always been regarded as a traditional industry with high energy consumption and high pollution. In the context of building an ecological country, the construction industry also needs to achieve a shift towards energy conservation and environmental protection, attaching importance to the economic benefits as well as the social benefits. Therefore, construction technology must pay sufficient attention to energy saving and environmental protection, and promote the innovative application of energy saving and environmental protection technology on a large scale.
- Achieving low carbon emissions from buildings is an important element of technological innovation in housing construction. By applying zero-carbon energy and new energy in the building construction process, developing low-carbon building power structures, actively using solar energy, wind energy and other clean energy, effectively reducing the energy consumption of

building construction equipment and building equipment, and building intelligent and environmentally friendly communities.

- Actively introduce new material technologies and improve the innovative means of construction technology. With the development and application of new materials, new structures such as films, twisted surfaces and net shells are constantly applied to building construction, which not only beautifies the appearance of buildings, but also strictly guarantees the construction quality of buildings.

Green energy efficiency is a future trend in the construction industry and is the result of a combination of market demand, government policy and corporate strategy. The widespread development of green and energy-efficient buildings will provide new impetus for the transformation of construction companies into service providers. The demand for 'service capability', breakthroughs in construction technology, innovations in 'Internet+' and the widespread promotion of green and energy-efficient buildings will provide strong support for the transformation of ETO construction companies into service providers under Industry 4.0.

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