POLITECNICO DI MILANO

Master in

Building Information Modelling

BIM A+ European Master in Building Information Modelling

Guidelines for preparation of OIR (Organizational Information Requirements) document for Miastoprojekt Wrocław following ISO 19650

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of illegal use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of ethics and conduct of Politecnico di Milano.

SOMMARIO

Il successo di business e la sua redditività rappresentano l'obiettivo primario di qualsiasi organizzazione nel settore costruzioni, che esso sia raggiunto tramite un ritorno sull'investimento, reputazione, incremento degli affari o soddisfazione del cliente. Per ottenere questo risultato, una organizzazione deve possedere un business plan ben sviluppato e obiettivi definiti da implementare.

Il futuro del Building Information Modelling (BIM) in Polonia è sia emozionante che sfidante. La speranza è che il crescente uso del BIM migliori l'integrazione dei diversi ruoli nell'industria delle costruzioni e ne aumenti le prestazioni. Esistono diverse analisi nella letteratura che esplorano le problematiche tecniche di strumenti e standard BIM, che si interrogano sull'effettiva utilità del BIM, che valutano la sua integrazione nella gestione e manutenzione degli edifici, etc. È importante porre l'attenzione anche sulle problematiche manageriali nell'adizione del BIM e negli aspetti collaborativi per capirne la complessità e la natura interdisciplinare.

La mission di Miastoprojekt Wroclaw è quella di promuovere una efficace implementazione di progetti su misura in riferimento ai rapidi cambiamenti del contesto e degli standard. Considerando che l'azienda vuole proseguire lo sviluppo delle proprie competenze nel campo del BIM, come il suo sviluppo e la sua implementazione, la definizione dei requisiti informativi dell'organizzazione (OIR) rappresenta parte integrante della strategia aziendale in questa area.

L'obiettivo del lavoro di tesi è definire un framework per l'implementazione del BIM nell'azienda tramite lo sviluppo di prospettive per i requisiti informativi dell'organizzazione. Questi ultimi dovranno essere coerenti alla norma ISO 19650 e agli altri standard ad essa complementari e dovranno integrare metodi, procedure e requisiti tecnici per lo sviluppo di processi BIM. Lo scopo di questo lavoro è dunque di proporre un piano di implementazione specifica per i requisiti informativi dell'organizzazione Miastoprojekt Wroclaw, all'interno della metodologia BIM, per garantire la raccolta delle informazioni utili a supportare le attività di gestione dei beni immobiliari e le altre funzioni organizzative dell'azienda.

La natura dell'industria delle costruzioni è differente rispetto alle altre, come ad esempio la manifattura. La natura temporanea e l'unicità dei progetti di costruzione si riflettono nella scelta della localizzazione, nella definizione delle soluzioni costruttive e nella definizione del gruppo di progetto. Naturalmente, ogni progetto ha uno sviluppo diverso, a causa di svariati fattori come, ad esempio, diversi requisiti per la progettazione, lo sviluppo delle tecnologie, la differenza nella normativa locale e differenti condizioni geografiche e geotecniche.

Nell'industria delle costruzioni, nuove strutture sono create ad ogni intervento e la sfida principale è di controllare il processo di progettazione e le relative scadenze. Inoltre, in ogni progetto ci sia aspetta di avere informazioni di alta qualità disponibili e pronte all'uso nel momento del bisogno durante l'intero processo di costruzione. Sfortunatamente, nella realtà ci sono spesso troppe informazioni per ottenere una visione d'insieme e non abbastanza per ottenere prestazioni eccellenti. Inoltre, la qualità dei dati è spesso bassa e frammentaria, con diverse parti di informazione sparse nell'intera documentazione. È quindi necessario promuovere un flusso informative integrato, accessibile a trasparente per tutti gli attori coinvolti.

Parole chiave: BIM, cespite immobiliare, costruzione, gestione, requisiti informativi dell'organizzazione (OIR)

ABSTRACT

The success of the business and its profitability is the ultimate goal for any organization in the construction industry, whether that is achieved through return on investment, reputation, repeat business or client satisfaction. To accomplish that, an organization must have a well-defined business plan and objectives to implement.

The future of Building Information Modelling (BIM) in Poland is both exciting and challenging. Hopefully, the increase in the use of BIM enhances the integration of the roles in the AEC industry and eventually improve performance. There are many literature reviews which exploring the technical issues encountered with BIM tools and standards, interrogating the usefulness of BIM, evaluating the maintenance of buildings and etcetera. It is important to focus as well on managerial issues in BIM adoption and collaboration, to understand the complexity and the interdisciplinary nature of BIM

The mission of Miastoprojekt Wroclaw is the effective implementation of projects tailored to the rapidly changing realities and standards. Because the company wants to continue the development competence in the field of BIM, such as development and implementation, the creation of Organizational Information Requirements (OIR) is part of the company's strategy in this area.

The objective of the thesis is the definition of a framework for the implementation of BIM in the company through the development of expectations for the OIR. The document should follow standard ISO 19650 and any relevant documentation; describing methods, procedures and technical requirements for performing BIM workflow. The purpose of this dissertation is to propose a specific OIR implementation strategy for Miastoprojekt Wroclaw, within a BIM methodology, for capturing information which help inform asset management and other organizational function.

The nature of the construction industry is different from other industries, such as the manufacturing, the temporary nature, and uniqueness of construction projects is reflected in locations, construction solutions and project teams. Naturally, each project would be designed each time differently, because of many factors such as different demands for design, development of technologies, different local building codes, local geographical and geotechnical conditions.

In the AEC industry, new facilities are created every time, and the primary challenge is to control the design process and the corresponding deadlines. Besides, in each project is expected to have essential high-quality information available and ready just-in-time and through the entire construction process. Unfortunately, in reality, there is either too much information to maintain an overview or not enough to achieve excellent performance. Moreover, the quality of the data is often low and difficult to locate, with various pieces of information within the complete documentation. The proper information flow should be integrated, accessible and transparent for all parties.

Keywords: assets, BIM, construction, management, OIR

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1. INTRODUCTION

1.1. Overview

For over a decade, we have witnessed the second digital revolution in construction, directly affecting the methodology of the investment process: the development of building information modelling (BIM) technology. According to the British standard, BIM is a process of design, implementation and use of buildings using objects with electronic information. The first revolution, the introduction of computer-aided design process (CAD), concerned almost exclusively the design services sector, and the next BIM changes the functioning of the entire construction industry. The consequence of the above is entirely new requirements, both in terms of the scope of work and quality of services rendered to architects and subcontractors by awarding entities.

The simple comparison of buildings from different periods reveals the fundamental problem of contemporary architecture. It shows that construction is one of the last branches of the economy with such manual production methods, despite the use of very advanced technologies. At the design stage, more and more special computer software is used to eliminate many errors and deficiencies in the documentation. Whereas during the implementation, the bricks are still glued with mortar, concrete is poured into the formwork and such, elements are cut, paint and so on. In conclusion, there are still some craftsman's methods of implementation, which are not much different from those used in the 19th century. This situation is unthinkable, e.g. in the automotive industry, where the human element has been reduced to the necessary minimum in favour of automation. Commercial investments are gradually moving towards prototyping to improve the final product and departure from the current methods of implementation. Currently largely supported only at the design stage with the use of BIM.

There is a process in construction that the other industries have been behind for many years – change investment design and implementation technologies. Nowadays, at least in Europe, the progressive commercialization of all areas of life, including architecture, can be observed. This trend, which started in the 1980s, is only interrupted by financial crises on the real estate market. The primary paradigm of its implementation is to be quick and profitable. For instance, in machine design much earlier than in construction, three-dimensional work, reliable design tools and product life cycle management were commonly used. Testing systems have long been used in machine design collisions and simulations, enabling complex analyses. It arose open format for the exchange and several standards to facilitate design and production, as well as many innovative solutions that have increased productivity in the engineering industry. No wonder that in the search for effective methods to support the investment process in construction, some of proven standards from industry were used. Likewise, the manufacturing industry has shown a dramatic improvement by shifting their process to lean production. Lean principles applied for the construction industry may also improve workflows of the construction processes as a mutual contribution with BIM (Koksela et al., 2010).

Many of the items commonly used today were first developed for the space industry. Probably in future within construction, some of the solutions would be used as a factor in the current laboratory research on space technologies. The engineers and scientists working on future bases on the Moon and Mars are

looking for entirely new concepts for their construction, taking into account the inability to transport hollow bricks, concrete or reinforcing steel. Construction technologies are being improved with the use of 3D printers or quasi-pneumatic structures, which help to create a self-realizing construction process. Moreover, in more technologically advanced branches of the economy, such as the automotive and aviation industries, anonymous research and design teams have been operating for a long time. Insomuch as the product is not responsible for a single designer, but a real concern. It is part of the globalization processes and the links between corporations and global capital.

The changes within other industries have started broader questioning the outdated tools and technologies used within construction investments, together with economic challenges, allowed to start a technological renaissance in the construction community. Because of the recession, many firms were forced to rechange the way of delivering construction product to customers under new margin and overhead constraints. The early stage of BIM gave many organizations a starting point to focus not only on the technology, but the underlying processes that were built around these tools. That was a significant push for innovation in construction and design environment. New technology and processes required proper and structured introduction of information for improvement in both the design and implementation of the investment. That is why standardization occurs to be so important not only the project but also at the organizational level of companies.

1.2. Research motivations

Research motivation can be summarized as searching for solving some of the problems facing the architectural, engineering and construction (AEC) industry in Poland through proposing a framework for the implementation of BIM in the company Miastoprojekt Wroclaw. Personal motivation is exploiting the new methodology with all necessary methods, procedures and technical requirements and to develop my skills and keep up with the latest technology.

1.3. The problem statements

BIM is slowly being introduced in Poland, more and more companies base their work to a greater or lesser extent on this methodology or partly using its technology. Nevertheless, the construction market is very chaotic with its use in practice. Virtually every design, contractor or Investor creates their work standards, not quite knowing how the projects supposed to be organized. Usually, it is the construction companies that impose the way of generating projects or possible improvements. Investors, in turn, do not quite know what BIM is and do not realize that the main benefits of using the full methodology are on their side. Besides, most design offices do not use the potential of their BIM tools and only use them to create models based on 2D drawings to perform visualizations.

There are some challenges connected with BIM adoption in Poland. For example, from a structural and functional point of view is a database and information management issue. BIM will not include all of the information that is needed because it is hard to predict everything in advance. Although BIM will integrate building processes, it will fragment the workload into specializations, and that is one of the main fears of the employees. People tend to fear of losing professional jobs due to more efficient technology or simply they do not trust unknown. Some might claim that creativity is reduced because

of the use of BIM. However, it seems that the area of the creativity is moved into another field of making proper tools, software and languages which will be capable of computing faster the shapes we want.

Responding proactively to all of concerns and worries is a vital part of onboarding BIM. People need to be reassured that BIM is most useful for saving money by cutting out time inefficiencies, not labour expenses. Investing in BIM implementations is misunderstood as investing in workforce reduction, but that is the wrong conclusion (Mortice, 2018). Most of repetitive, boring jobs would be replaced into another one, more specific with higher creativity and productivity. These specializations are a key for further development and broader general knowledge.

However, improving the internal organizational processes does not add value to the client. It is determined by many other benefits resulting from the use of BIM technology, such as the almost unlimited possibility of the second generation of additional studies and drawings from the model, multidimensional visualization of the investment that facilitates its imagination and understanding by both the Investor, work manager and the future facility manager. Besides it gives more straightforward and partly automated process of project correctness verification, the possibility of more efficient performance of variant analyses taking into account both functional and aesthetic as well as economic factors, speed of introducing changes and development of replacement documentation with new design guidelines and many others.

1.4. Research objectives

This dissertation aims to propose a specific BIM implementation strategy for Miastoprojekt Wroclaw, to solve the issues of the current project to improve the performance of the entire organization and reap the benefits from BIM. In order to achieve the above aim, the following objectives are identified:

1. Explore the structure of the company and the level of awareness about BIM in the company.
2. Investigate the existing information flow within on-going projects and the company's platforms.
3. Propose solutions to overcome the issues that diminishing performance and workflows.
4. Perform the organization projects and team assessment.
5. Investigate the company readiness and the organization's capabilities to implement BIM.
6. Identify the main internal goals influencing BIM implementation.
7. Present BIM implementation paths.
8. Determine the barriers deterring BIM implementation.
9. Explore the main driving forces and information requirements for pushing the company towards BIM implementation.
10. Propose a framework of the scope of strategy for the company to enable the mandate of BIM.

The main goal for each organization is the success of the well-defined business tailored to rapidly changing realities and standards. The objective of the thesis is the definition of a framework for the specific OIR implementation strategy for Miastoprojekt Wroclaw within BIM methodology. The OIR document should help to capture information for asset management and other organizational function.

1.5. The scope of research

The scope of this research is limited to exploring and investigating the structure of the Miastoprojekt Wroclaw and their awareness about BIM, the main factors expediting the BIM implementation and the readiness of the company to implement BIM. Moreover, the ability of BIM adoption in the company to manage projects was checked from a theoretical and a practical standpoint. The review of management processes, standards and platforms circulations was researched aside to the research on BIM Maturity and BIM adoption strategies with how these should have been approached in practice. Therefore, the scope of this research is the guidelines for the organizational requirements of the company regarding the quality of information and also the access and use of data. In the broader context, an industry is moving towards a more integrated practice, supported by information systems such as BIM. Research methodology

The research methodology consists of three phases:

1. ***First phase***: a literature review to build a broad understanding of covering the scope of the research presented.
2. ***Second phase***: questionnaire survey, semi-structured interviews to collect the employees and experts' perceptions about the existing procedures and process in on-going projects or the platforms in the company.
3. ***Third phase****:* validation and analysis of the collected data, execution of team and organization assessment in order to provide guidelines for organizational requirements accordingly with proposed BIM adoption strategy for the company.

1.6. Key findings and Contributions

This study is the research to contribute to investigate the key factors influencing and expediting the organizational requirements in BIM adoption for the substitute investor and provide a suggested path for implementing BIM in Miastoprojekt Wroclaw.

1.7. Structure of the research

The study was divided into six chapters, followed by appendices. Chapter one includes an overview, the problem statement, research motivation, research objectives, the scope of research, research methodology, key findings and contributions and structure of research. While, chapter two encompasses literature review of BIM methodology, standards and necessary documents in Chapter Three, the research methodology, data collection and includes the results and its analysis are described. Chapter four describes proposed guidelines for organization requirements and strategy for BIM implementation in Miastoprojekt Wroclaw. Finally, chapter five provides a conclusion, summarising results and main findings, research limitations, and recommendations for further researches.

2. STATE OF THE ART

The information flow within the AEC industry is involved, although the traditional medium is a document. The design information is employed to show the form, function and behaviour of a product among the design team, such as architects, engineers and design consultants. However, manufacturers and subcontractors also generate it (Elhendawi, 2018). The subset of data consists of various drawings from different parties, specifications and schedules. During the design process, some changes occur, which are covered by addenda, answers to requests for information (RFI) and change orders. Professionals and managers spend a significant amount of time managing information, like addressing information flows. Furthermore, inadequate design information commonly leads to unintended outcomes, as building defects, schedule delays and cost overruns. That is why the AEC industry require integrated, relevant and accurate information for more effective performance.

For decades the AEC industry has been suffering from its inefficiency, poor productivity and low performance. There is a significant change in the AEC industry towards a genuine worldview move to increase the efficiency, and productivity improve quality (Baiden & Price, 2011; Baiden et al., 2006). The solution might be BIM which supplement, and eventually replace the traditional documentation with digital and integrated information for buildings design and execution.

2.1. Building Information Modelling

The abbreviation BIM can refer to a building information model as a digital artefact, building information modelling as the process of creating and using a digital model, or sometimes even building information management (buildingSMART, 2012). Currently, BIM influences AEC industry performance and enhance the coordination and collaboration between various project parties as well as interior designers, producers of building materials and Facility Managers(Rahman *et al.*, 2013). BIM is considered a revolutionary technology and process management, proposed as the potential solution for the current issues and in the construction industry(Elhendawi *et al.*, 2019). There are various levels of advancement in the implementation of BIM technology within different industries due to their challenges and specificity of using various software to design or manage a model.

BIM concept is related to virtual design and construction (VDC) in meaning and scope. Therefore The Centre for Integrated Facilities Engineering (CIFE) at Stanford University described VDC as:

> *'The use of multi-disciplinary performance models of design-construction projects, including the product (that is, facilities), Work Processes and Organization of the design–construction–operation team to support business objectives.'*

Equation 1(CIFE, 2012)

Thus, VDC uses the repository for business purposes. BuildingSMART have incorporated the inventive method for describing the building model in their definition:

'Building Information Modelling: Is a BUSINESS PROCESS for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.'

Equation 2(buildingSMART 2012)

BIM is the process of creating and maintaining an object-oriented, parametric, rule-based building model as an information repository for the AEC industry to support various applications in designing, planning, and executing construction work (Eastman, 2009)

BIM is still very often mistakenly simplified to the digital 3D model results from a misunderstanding of the meaning of the advantages of technology. Although a virtual mock-up of a building is an inseparable element of its digital representation, modelling spatial information gives a lot of additional options. The essence of BIM is based on the development of the most comprehensive possible database about the object and the relationship with the elements of the critical information model, which can be used in the further stages of the investment process, and purposefully throughout the life cycle of the building. Additionally, there is many other non-geometric information, such as type of object, material characteristics, key physical parameters or fire resistance class.

2.2. BIM adoption in the world

The BIM awareness is spreading universally, while adoption across the world remains uneven. In the AEC industry, the technological improvement is not only a matter, but as well as triangulation between its social, environmental and economic relationships (European Commission, 2019). The scenario of the construction industry is not the same all over the world, and so is the adoption of technological aspects of BIM. Lack of readiness, initial higher cost, and education are the common barriers for worldwide BIM augmentation(Hu *et al.*, 2018). Technological advancement in all BIM fields such as technology, process and policy is evolving from the developed nations.

Business initiatives play a crucial role in facilitating BIM implementation among the industry, according to European Construction Sector Observatory (2019). First, they help understand what BIM is about and what it means in practice. Second, they are creating a network of BIM practitioners, who can influence BIM implementation domestically but also internationally. Third, they give construction companies more substantial leverage to influencing national construction policy development (European Commission, 2019). Therefore, the authorities cannot freely interfere in the activities of the private sector, which has the possibility of freely (within the law) shaping contracts except the public tenders – mostly influenced by additional factors and regulations - imposed by the legislator.

USA and the UK are the leading BIM, early implementation countries in the world, from which other developed countries are learning so much and fast in the digital shift (Hamma-Adama and Kouider, 2019a). Australia is one of the rapid adopter countries which have established BIM guide, Standards, National Specification and corporated research centre (Hamma-Adama and Kouider, 2019b). In the

other countries where the BIM methodology occurs on a larger scale and is treated as a building information management process, not just as a modelling tool, various strategies for implementing normative principles, relationships between process participants and their course can be observed. A standard method is to develop an official document - a set of acceptable practices or guidelines for a given investment. Another way is to standardize and coordinate activities related to the implementation of the BIM methodology at the state level by imposed norms and legal provisions, as in, for example, Great Britain.

The implementation of BIM in the United Kingdom was almost entirely a top-down initiative, so all activities are coordinated and aimed at achieving clearly defined purposes (Shimonti, 2018). They are linked to the next stages and results to be achieved on the path to full implementation by cooperation between sectors. Consequently, the significant successes of adaptation in the UK is positively related to best practices from earlier USA BIM implementation strategies (Hamma-adama and Kouider, 2019a). The adopted model assumed synchronization of top-down and bottom-up activities, known as Push-Pull Strategy. The compromise between taking actions from one side on fuelling planned changes (bottom-up actions - push), from the second to creating conditions, which simplifies their implementation as most (top-down actions - pull).

Efforts like BIM advocacy programme by BIM Africa Initiative is one of leaps to developing special BIM publications to African countries (BIM Africa, 2019). Moreover, the Middle East, Africa and South America are at the early stage of adoption, mostly in design with a low level of maturity and general knowledge (Shimonti, 2018). The path of adoption varies, some of these countries have just embarked on Macro-BIM adoption study while some have already finished developing their national policy (Kassem and Succar, 2017). In the Middle East, there has been an increase in real estate investments, such as skyscrapers and infrastructure projects, for which there is a need to use BIM (BIMMDA, 2020). At the same time, Hong Kong set a limit on government projects of 30 million Hong Kong dollars.

BIM implementation in Europe is making good progress because of the involvement of companies, academics, professionals and governmental institutions. There are several targets, mandates and national strategies that supports digitalization and a shared vision of BIM in the industry. Europe understands that collaboration across borders and standardizing standard practices is the key to success in BIM adoption. In 2016, the EU BIM Task Group was established to bring together national efforts into a common aligned European approach of the use of Building Information Modelling in public work. Different countries are moving at a different pace. BIM maturity across European countries is spread not surprisingly in the way that western/northern countries appear to be BIM developed, while the southern and eastern countries are adopting BIM at a slower rate (BIMMDA, 2020). The obligation to use BIM are determined by the scope of application or expressed in the form of the size or cost of the investment.

In 2010, Germany conducted a research called BIM - Potentials and Barriers, then issued an order for mandatory use of BIM in projects exceeding 100 million euros and foe all transport projects from 2017 (BIMMDA, 2020). Whereas, in Denmark for all public investments exceeding 5,000 m2 and in the Czech Republic for public projects whose value at the design stage will exceed 6 million Czech crowns and the

value of works - 150 million Czech crowns. As well, France and Spain have rapidly evolving programmes. For example, in France in 2017, BIM was officially mandated, together with standardization roadmap as part of the digitizing strategy for the construction industry, that includes improving the quality of exchanged data, deadlines, data sharing processes and reducing errors, conflicts and overall project costs (BIMMDA, 2020).

Since then, the BIM is metamorphosing the construction industry. Countries around the world have started paying more attention to its adoption, as in the following figure.

Figure 2.2.1 Global BIM Regulation Evolution (Shimonti, 2018)

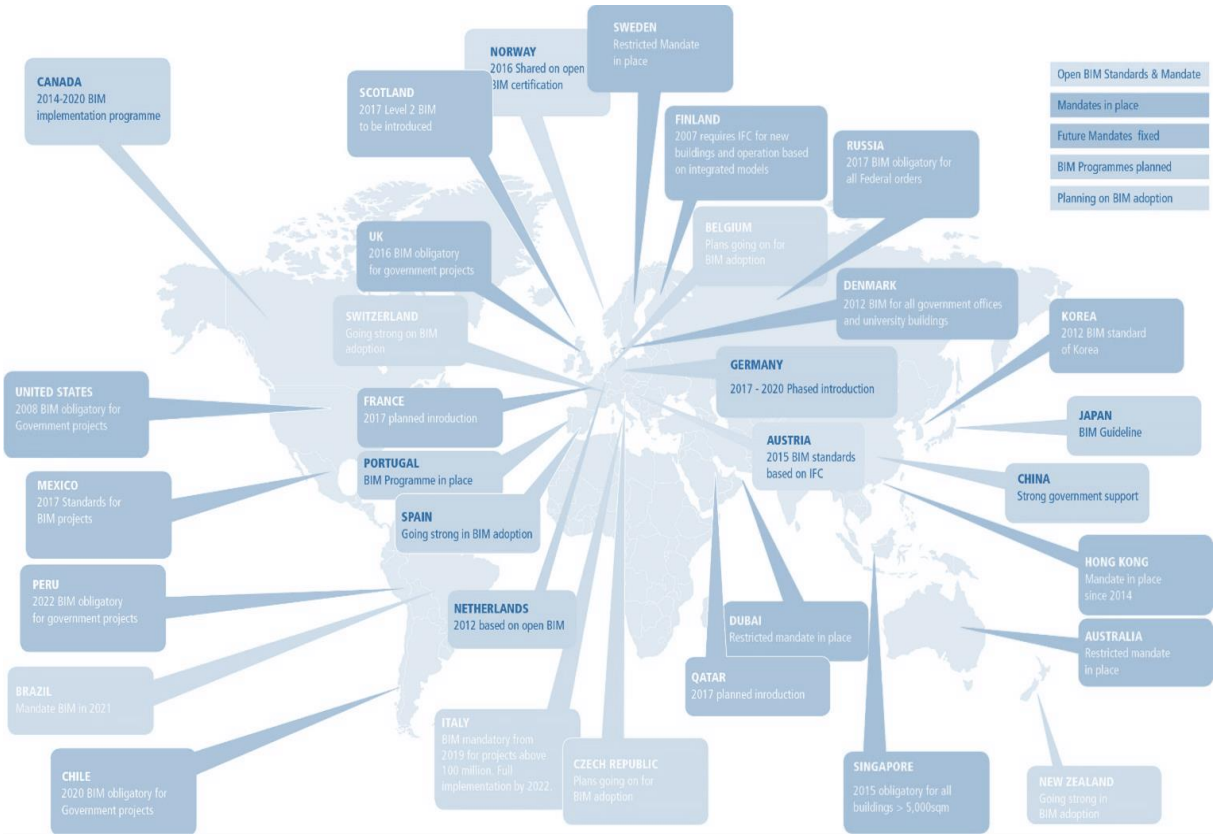
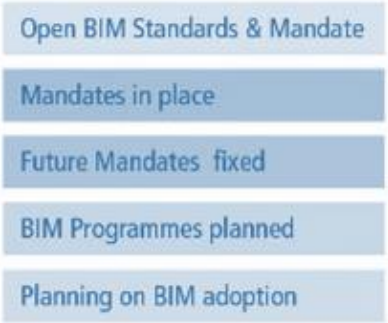


Figure 2.2.2 Legend of Global BIM Regulation Evolution (Shimonti, 2018)



2.2.1. Situation in Poland

However, Poland has recently introduced policies supporting BIM adoption in the construction industry, is still at an early stage of BIM implementation with a relatively low rate (European Commission, 2019). According to this report, only 12% of construction companies use BIM, though mainly for visualization or 3D models rather than for collision detection and use of schedules or optimization. The lack of professional knowledge and BIM requirements in public procurement law, the high cost of BIM initial adoption are the reasons for such low rate, on the other hand, the BIM awareness is slowly rising among the specialists in the construction industry.

Moreover, BIM implementation in Poland has a strong potential mostly among large companies of the construction industry, as a result of national labour shortage, increasing-price of materials and external competition (European Commission, 2019). Nonetheless, the industry and the public sector seems to have small interaction on each other, beyond general BIM workshops and seminars. Moreover, the education process should change in Poland, especially public officials need to formulate how BIM should be effectively taught to educate BIM skilled and knowledgeable professionals among old and new generations (European Commission, 2019). Some renowned polish universities, such as Warsaw University of Technology, have introduced courses concerning BIM, however minimal institutions have full BIM packages (European Commission, 2019).

According to the EU Commission, Poland follow flexible binding approach to BIM implementation. Despite the recently introduced BIM instruments in the construction industry, is not active in BIM standardization field (European Commission, 2019). An amendment to the public procurement law was published in 2016, stating, that "in the case of construction contracts, the contracting authority may require the use of electronic data modelling tools or similar tools. In this case, the project's owner needs to make access to such tools available until such a tool becomes publicly available" (European Commission, 2019). The Polish government started with the transport industry (roads and rails) to experiment BIM pilot projects. Two tenders were including BIM aspects were published in 2017:

- Pilot project for the development of the Zatory bypass on national roads DK28 and DK44 by the Generalna Dyrekcja Dróg Krajowych i Autostrad (GDDKiA) – the National Agency for Motorways
- consultation with industry for the use of BIM on national rail infrastructure works by the Polskie Koleje Państwowe (PKP) - Polish State Railways

Currently, more and more public procurement requires the use of BIM technology. As a result, job offers related to BIM management and implementation are starting to appear on the labour market, mainly in larger companies in the biggest cities in Poland such as Krakow, Wroclaw and Warsaw.

2.2.1.1. The biggest obstacles for BIM in Poland:

For several years now, there has been a lively discussion in Poland about the advantages and threats of BIM implementation. The undoubted positives are integration of the design process and information about the building, optimization and cost control of its implementation and operation. The main problems, apart from financial outlays and the need to raise qualifications, indicated loss of the position

of chief designer to a person or a management team, blurring of responsibility, problems with copyright. Moreover, the optimal procedure for using BIM seems to be criticized in our environment – 'Design and build'. The following lists of obstacles may strengthen these fears of the BIM implementation:

- the absence of (systematic) BIM requirements in public procurement law
- lack of common operational standards and norms
- limited exchange between the industry and the public sector
- outdated educational curriculum at public universities
- high cost of BIM initial implementation
- low awareness of benefits among investors
- low awareness what is BIM among design parties
- low project prices

2.3. BIM Standards in the world

Nowadays, there are standards in many industries in order to enhance the quality of various items, such as food, electricity, construction materials and components. Accordingly, the development of standards in BIM can contribute to for building projects in regards of cooperative processes and deliverables. In the UK, national BIM standards have been developed due to the current legislation, which defines procedures, roles, deliverables, BIM levels (Panagiotidou, 2020). Other countries of North Europe and Singapore also have adopted national BIM standards, and most countries worldwide are following the lead. Wherever the BIM is not institutionalized, public and private organizations are developing their standards for the adoption of BIM.

In Europe, the AEC industry has been confronting strict alter in order to extend efficiency, quality and productivity of construction as well as diminishing costs and duplication of work. Moreover, there is a significant increase in international collaborations due to globalisation. Processes in the construction industry require a standardized way of describing building realisations and related procedures (Panagiotidou, 2020). Around the world, the rules and regulations vary in each country, prevents an agreement on global BIM standards. However, in Europe, European Directive 2014/24 / EU (of the European Parliament and of the Council of 26 February 2014 on public procurement) requires European public administrations to use advanced digital framework in their processes (BIMMDA, 2020).

In general, the first classifications were developed to systematize technical specifications and perform measurements. These classifications were sufficient to some extent, but the situation has changed significantly after an application of CAD followed by BIM (Edirisinghe and London, 2015). The new systems had to take into account the relationship between individual elements, not just between types of objects. Many classification systems have arisen in response to this need, such as British Uniclass, American OmniClass, Swedish CoClass (Zuber, 2020). The essential feature of building classifications is a hierarchy, also called taxonomy. This term means that a given fragment can be described in a very general way, but also detail - they will be the lowest classes. There is a relationship between them: each subclass inherits features of the superclass and has at least one characteristic that distinguishes it.

Historically, the first classification was CAWS (Common Arrangement of Work Sections) listed on the British road map. Instead, the Uniclass is used today, which is based on the ISO standard and characterized by a full content unification by interconnection between tables (BIM A+, 2019). Besides, to include classification of all types of elements, objects, each of the tables is divided into groups, subgroups and sections, and objects. The information can be easily found, and there is no limit to the amount of data that can be included in the classification (with a possibility of extension). The taxonomy is easy to understand and use.

Early standards for CAD include, for example, Initial Graphics Exchange Specification (IGES) in the USA, VDA-FS in Germany or 3D CAD ISO Standard for the Exchange of Product model data (STEP) 10303 (Edirisinghe and London, 2015). Another international standard ISO 13567 is used to standardize the CAD layers, whereas part 2 of ISO 12006 object-orientated modelling models. In 1994 the organisation buildingSMART, formerly International Alliance for Interoperability (IAI), was established to improve the exchange of information between BIM software applications used in the construction industry (Bazjanac, 2008). As a result, Industry Foundation Classes (IFCs) standards were developed as an open data format for open BIM, registered with ISO as ISO 16739 (Edirisinghe and London, 2015). Also, BuildingSMART defines two other corresponding standards ISO 12006 part 3 for International Framework for Dictionaries (IFD) and ISO 29481 Process Definition Standard - Information Delivery Manual (IDM) (Edirisinghe and London, 2015). The other popular BIM standards are ISO 19650, PAS 1192-2, NBS National BIM Object Standard, COBie and BCF.

Although the UK nowadays seems to be a leader in BIM with its globally influential programme, the Scandinavian countries as well as China, Hong Kong, Singapore, and Dubai have regulated BIM for almost a decade. Each country has its local requirements or thresholds concerning BIM, although UK based organisations based on the adoption of the PAS 1192 suite of Standards to demonstrate their BIM capability to their Clients and Employers. BIM adoption accelerated in the UK in April 2016 due to the policy that mandated BIM Level 2 for all centrally procured building projects. As part of its strategy, any government project in the UK must have BIM level 2 (Lorek, 2018). Some companies had to develop the habit of quickly adhering to the standards. Thus, in the coming years, the UK could become a leader in BIM (BIMMDA, 2020).

There are public standards in Scandinavian countries. Finland mandated that any design software required to pass IFC Certification. In Sweden, best practice guides have been published, and whereas Denmark, at universities, BIM is taught as the process to students (Lorek, 2018). Since 2010 Norway has used IFC file formats and BIM with its projects. The IFC specification is the Danish standard file model, which is used for BIM data sharing internationally. Moreover, Denmark has entered an international partnership to facilitate the circulation of IFC through customer expectations and all software that supports BIM applications (BIMMDA, 2020).

Due to its creative design and construction, North America is one of the most critical regions for the BIM industry with a large number of BIM experts. Although BIM is not mandated across all US states, some of them have already put mandates in place. For instance, Wisconsin has mandated BIM since 2010 on all procurement projects with a total budget over $5 million and for all new construction over of $2.5

million (Lorek, 2018). In Canada, the AECO community has developed the BIM standard for buildingSMART Canada to improve its performance, environmental and economic development.

Despite the present financial crisis, BIM is expanding remarkably in Latin America. Chile and Brazil are the countries with the most active diffusion of the methodology through numerous activities. In 2015, the organization responsible for developing BIM standards, Chile BIM, was created. Other countries adopt a bottom-up approach through many activities, such as workshops and seminars organized by trade unions, chambers of commerce and technology companies (BIMMDA, 2020).

In early 2016, South Korea mandated the use of BIM for public projects above $50 million. Already in 2010, the BIM National Architecture Guide was released to govern the use of BIM in public administration, as well as BIM framework standards. Though China does not explicitly require the use of BIM for its organizations, they have established their first series of BIM National Guidelines. The key priorities of the government are to reduce the environmental costs and energy production in the industrial and construction sectors (BIMMDA, 2020).

Australia is leading on projects since 2016 In South Pacific due to national government initiative for BIM requirements. For instance, particular NATSPEC portal was created with BIM tools for the construction industry (Lorek, 2018). From 2015, the government of Singapore started to require electronic submissions from BIM projects of over 5,000 square metres. The implementation of BIM in Singapore exceeds all guidelines and provides a global example (BIMMDA, 2020).

Uniform national guidelines reduce the time and effort spent on planning in building projects, facilitate collaboration and adaption amongst different disciplines and organisations. BIM is the future of the construction industry, and the faster the industry introduces the BIM and its related requirements, the greater the benefits of BIM in terms of the cost and timing of project implementation will be realized (Al-Ashmori *et al.*, 2020). In countries where there are no guidelines, companies need to establish their regulations on how to function with BIM in order to unleash their potential more efficiently. The creation and adoption of BIM specifications and protocols can lead to a consistent and effective method of data exchange with great benefits for construction projects. There several national standards, best practices developed by countries around the world, relevant ones are listed in table (2.3.1)

Table 2.3.1 BIM standardization initiatives by country (buildingSMART)

Australia	NATSPEC National BIM Guide
Belgium	Building Information Modelling –Belgian Guide for the Construction Industry
USA	NBIMS-US (National Building Information Modelling Standard - United States)
Canada	CANBIM Protocol
New Zealand	New Zealand BIM Handbook
Norway	Statsbygg BIM Manual 1.2
Singapore	Singapore BIM Guide - Version 2.0
Hong Kong	HKIBIM - BIM Project Specification
Finland	Common BIM Requirement (COBIM)
UK	LEVEL 2 - PAS 1192.2 2013 / ISO 19650

2.3.1. ISO 19650

The ISO is an institution that develops international standards for multiple different sectors (Pollock, 2019). To form a joint international standard base for the implementation of BIM, in 2018, the new ISO 19650 was published in Parts 1 and 2. Currently, in 2020, on June Part 3 was published and on July Part 5. In 2019, the British Standards Institution (BSI) announced that its British-specific standards were being phased out in favour of international ones.

- **part 1 - EN ISO 19650-1: 2018** Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - information management using building information modelling. Concepts and principles. (ISO, 2018)

- **part 2 - EN ISO 19650-2: 2018** Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Delivery phase of the assets. (ISO, 2018)

- **part 3 – EN ISO 19650-3: 2020** Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Operational phase of assets. (ISO, 2020)

- **part 4** - Information exchange

- **part 5 – EN ISO 19650-5: 2020** Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Security-minded approach to information management. (ISO, 2020)

The ISO-based the new standards from 2018 on two existing British standards: BS 1192 and PAS 1192-2. Both BS (British Standard) and PAS (Publicly Available Specification) are not legislative nor obligatory (except where regulatory instruments or third parties impose the obligation for example by properly formulated contracts). BS 1192 is a general best practice for managing construction information, while PAS 1192-2 is a specification about information management during the delivery phase (Pollock, 2019). The PAS standards were developed to assist the market and constitute sets of recommendations or ethical practices. Mostly the development of PAS scope is proposed and financed by private entities, publicly consulted with stakeholders and then verified by BSI in terms of the legitimacy of further work or detection of a possible conflict with other standardization. UK made both standards public by the to help construction companies achieve BIM Level 2 mandate (Pollock, 2019). However, the Standard's evolution can be traced much further back than publications PAS 1192-2 in 2013 or BS 1192 in 2007 (Shillcock, 2019). In 2002, Avanti Project was established by the UK Department of Trade and Industry to formulate a practical approach for collaborative working.

2.3.1.1. Processes based on ISO 19650

<u>Outcomes from adopting the processes in BIM according to the ISO 19650(UK BIM Alliance, 2019):</u>

- Precise definitions for the information needed, the methods, processes, deadlines and protocols (figure 2.3.1)
- Sufficient quantity and quality of information
- Efficient and effective transfers of information between the stakeholders
- Reduction of waste/rework in the design, construction and asset management

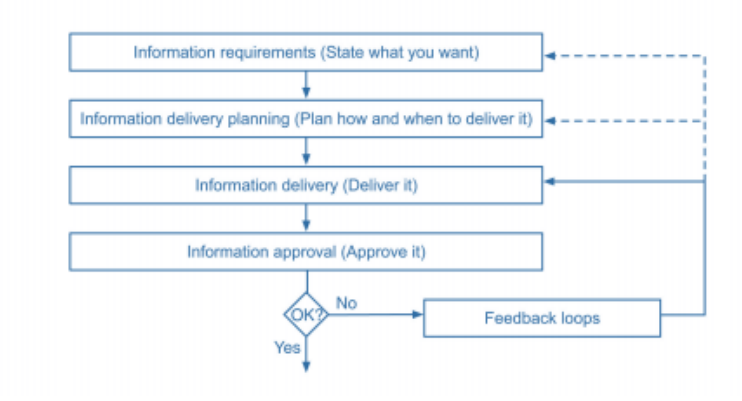


Figure 2.3.1 High-level information delivery flow-chart, ISO 19650-1 Figure 4 (ISO, 2018)

The ISO 19650 series defines information management across the whole life cycle of an asset, which requires linking the asset, project and organisational management in global construction industry that used to work without any unifying framework for information management requirements. The standard is not one solution to fit all projects, however it provides an internationally recognized framework to adopt to projects of any scale and complexity, tailored to the organisational needs (BRIS, 2019). The rules in standard also specify standardization of procedures and documents:

OIR (Organizational Information Requirements) - clarifying what information, when and for whom will be produced and provided. Represents key decision and help in prioritising information improvements.

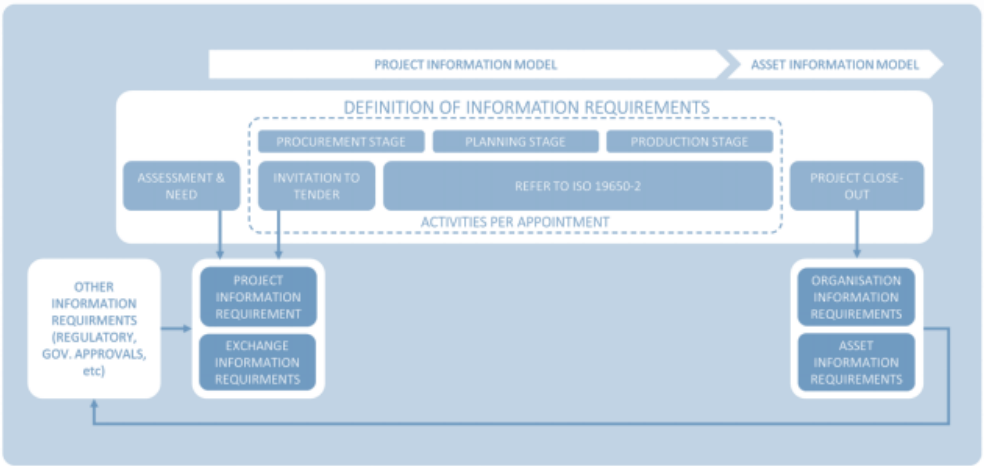
AIR (Asset Information Requirements) - defining information required for all assets operation and maintenance (Asset Information Products) in line with an organisation's management strategy.

EIR (Exchange Information Requirements) - specifying the contracting authority's requirements from all project participants.

BEP (BIM Execution Plan) - a plan that details the awarding entity's requests contained in EIR

PIR (Project Information Requirements) - specifying what information should be produced and delivered for each particular project in line with an organisation's management strategy

Figure 2.3.2 Information requirements informing the PIM and AIM (BRIS, 2019)



Each company should start with the end in mind, by creating the organisational and asset information management requirements, considering the intended uses of data. It is critical that these information requirements form part of the appointment documentation when appointing external parties (figure 2.3.2). Consequentially, improve each appointed party's understanding of their responsibility for leveraging and creating information within a delivery team.

More information about the ISO 19650 series is provided within this paper in further chapter, such as chapter 2.3.3.2 which compare new standard to the replaced PAS 1992:2013 and in chapter 2.7 regarding Organisational Information Requirements, Common Data Environment and Project Delivery. Some of the data about the appointing and appointed parties were moved to the chapter 3.8 with the broader explanation about their function and skills within the project delivery.

2.3.2. BIM L0 and BIM L1 Documents

2.3.2.1. BS 1192: 2007 + A2: 2016

The set of best practices describes the approach to production, quality and exchange of information based on CAD and BIM systems (BSI, 2007). It contains the recommendations for indexing, searching, filtering, sorting, qualitative verification and comparison of documents and their content. Which gives the introduction of SMP (Standard Method and Procedure) that includes:

- agreed roles of individual team members in the investment process - from the client, through designers of various industries, contractors and subcontractors, to facility manager. The standard does not describe the responsibility of individual roles in the project.
- central assumption for a set naming convention that applies to both files and the information they contain
- use of the data storage and exchange environment - Common Data Environment (CDE) and its following structure of folders:
    - Work in Progress (WIP) – storage of unverified data created during the project implementation, used only for team members' needs
    - SHARED - for data is verification to receive another revision and suitability code
      e.g. qualifying a given material for a milestone goal, coordination, cost analysis
    - PUBLISHED – for final data verification and approval with the requirements project
    - ARCHIVE – storage of outdated, replaced or used data, e.g. construction archive or transferred to Asset Information Model (AIM).

BS 1192 supports PAS 1192-2:2013 and PAS 1192-3:2014, and the use of both PAS depends on BS 1192. Currently, the standard has been withdrawn and replaced by BS EN ISO 19650-1: 2018 and BS EN ISO 19650-2: 2018, which are less abundant in recommendations focusing on the CDE.

2.3.2.2. BS 7000-4:2013

This standard is a guide for design management systems in construction (BSI, 2013). In 2013 has been updated due to progress in the industry from CAD to next levels of BIM. Changes that in the field of project management have resulted in the systematization of accompanying processes:

- provides guidelines for managing the design process at all stages for all organizations and all types of projects construction,
- indicates principles for greater efficiency of the project management process, i.e. project team management, members' responsibilities, development of the project's program, project planning, process, project communication and costs,
- guides on resource and value management, technical information and equipment, document management, intellectual property and copyright
- provides policies and standard references for company and project protocols

2.3.2.3. BS 8541 series

Most of the documents in the British Standard series number 8541 can be considered as acceptable practices which present recommendations and guidelines used by competent and diligent practitioners in a given field. Their use is not obligatory, and it is allowed to use other practices that give similar effects. The series consists of 6 documents with guidelines and recommendations:

- BS 8541-1: 2012 Library objects for architecture, engineering and construction. Identification and classification. Code of practice (BSI, 2012) - for identification and classification of library facilities
- BS 8541-2: 2011 Library objects for architecture, engineering and construction. Recommended 2D symbols of building elements for use in building information modelling (BSI, 2011) - for symbols and graphic conventions used by people who prepare drawings
- BS 8541-3: 2012 Library objects for architecture, engineering and construction. Shape and measurement. Code of practice (BSI, 2012) - for the dimensioning the building objects
- BS 8541-4: 2012 Library objects for architecture, engineering and construction. Attributes for specification and assessment. Code of practice (BSI, 2012) - for determination and evaluation of the object attributes
- BS 8541-5: 2015 Library objects for architecture, engineering and construction - Assemblies. Code of practice (BSI, 2015) - for the sharing of structural assemblies at all stages of project life cycle mainly in terms of ready-made elements with proper classification and naming to improve communication
- BS 8541-6: 2015 Library objects for architecture, engineering and construction - Product and facility declarations. Code of practice (BSI, 2015 - for sharing data from product declarations, name conventions or other information from tables within the whole project and asset life cycle

According to the BIM maturity model, the rules to reach level one is described in BS 8541-2: 2011. Others are related to the second and third level of maturity. Currently, in Poland, the scope of the BS 8541 series of standards is hard to implement due to the lack of adequate standards describing documentation. There is a need to change the regulations on the scope and form of a construction project and technical drawing.

2.3.2.4. RIBA Plan of Work (PoW)

The purpose of the document is to organise the investment process at its critical stages, from adopting strategies, through design, construction and use. It is a framework for design and construction that consists of the most important goals and tasks undertaken in a given phase and exchanging information (Sinclair, 2019).

In 2020 a new template was launched, developed from feedback collected since the initial 2013 version. The new plan was made as a response to climate and biodiversity emergency, in line with the UN sustainable development goals to target net-zero carbon for all new and retrofitted buildings by 2050 (Davies and Davies, 2020). The updated version consists of the changes that respond to the digitisation of the industry, modern methods of construction, ethics of work, sustainability and as well the value of aftercare. The new PoW offers both a process map and a management tool with improved approaches to the planning process, procurement procedures and information requirements at each stage. It consists of detailed stage descriptions and new guidance on core project strategies and a number of the titles in structure.

Table 2.3.2 Nomenclature comparison of stages in the RIBA Plan of Work 2013 vs 2020

RIBA PoW	STAGE 0	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6	STAGE 7
2013	Strategic Definition	Preparation and Brief	Concept Design	Developed Design	Technical Design	Construction	Handover and closeout	In Use
2020	Strategic Definition	Preparation and Briefing	Concept Design	Spatial coordination	Technical Design	Manufacturing and Construction	Handover	Use

Although most of the changes to the titles are minor, the most significant difference is Stage 3. This title changes from Developed Design in the 2013 version to Spatial Coordination in the 2020 version. This change was made to describe the purpose of this stage better. Stage 3 is about managing information until the building is adequately coordinated and ready to obtain planning permission and sent to begin Stage 4 (Sinclair, 2019).

In the new version, the green and BIM overlays, which were separate additions to the 2013 edition, are included (Davies and Davies, 2020). The most significant addition is the sustainability strategy, which focuses on sustainable outcomes from the beginning of a project, throughout design and revision into operation. Precise descriptions are included in the RIBA Sustainable Outcomes Guide (Sinclair, 2019). As a result of increasing the complexity of information, the BIM Overlay is replaced. These will require more reliance on models, use of embedded data to drive evidence-based design processes for asset and facilities management purposes (Sinclair, 2019). A glossary of current BIM terms is also included.

To sum up, the PoW poster is a kind of a signpost with brief prompts for each stage. It should be used as an illustrative aid alongside with the more comprehensive document in order to plan and manage the team properly. At the bottom of the framework, nowadays, there are lists of the recommended and expected outputs at the close of each stage.

Table 2.3.3 Tasks related to the next stages in the RIBA Plan of Work (RIBA, 2020)

RIBA Stages	Core Tasks during the stages	Information Exchanges
0. Strategic Definition	• Prepare Client Requirements • Develop Business Case for feasible options including review of Project Risks and Project Budget • Ratify option that best delivers Client Requirements • Review Feedback from previous projects • Undertake Site Appraisals	• Client Requirements • Business Case
1. Preparation and Briefing	• Prepare Project Brief including Project Outcomes and Sustainability Outcomes, Quality Aspirations and Spatial Requirements • Undertake Feasibility Studies • Agree Project Budget • Source Site Information including Site Surveys • Prepare Project Programme • Prepare Project Execution Plan *There is no design team required for Stages 0 and 1. Client advisers may be appointed to the client team to provide strategic advice and design thinking before Stage 2 commences.*	• Project Brief • Feasibility Studies • Site Information • Project Budget • Project Programme • Procurement Strategy • Responsibility Matrix • Information Requirements
2. Concept Design	• Prepare Architectural Concept incorporating Strategic Engineering requirements and aligned to Cost Plan, Project Strategies and Outline Specification • Agree Project Brief Derogations • Undertake Design Reviews with client and Project Stakeholders • Prepare stage Design Programme	• Project Brief Derogations • Signed off Stage Report • Project Strategies • Outline Specification • Cost Plan
3. Spatial Coordination	• Undertake Design Studies, Engineering Analysis and Cost Exercises to test Architectural Concept resulting in Spatially Coordinated design aligned to updated Cost Plan, Project Strategies and Outline Specification • Initiate Change Control Procedures • Prepare stage Design Programme	• Signed off Stage Report • Project Strategies • Updated Outline Specification • Updated Cost Plan • Planning Application
4. Technical Design	• Develop architectural and engineering technical design • Prepare and coordinate design team Building Systems information • Prepare and integrate specialist subcontractor Building Systems information • Prepare stage Design Programme *Specialist subcontractor designs are prepared and reviewed during Stage 4*	• Manufacturing Information • Construction Information • Final Specifications • Residual Project Strategies • Building Regulations Application
5. Manufacturing	• Finalise Site Logistics • Manufacture Building Systems and construct building • Monitor progress against Construction Programme	• Building Manual including Health and

and Construction	• Inspect Construction Quality • Resolve Site Queries as required • Undertake Commissioning of building • Prepare Building Manual	Safety File and Fire Safety Information • Practical Completion certificate with Defects List • Asset Information *If Verified Construction Information is required, verification tasks must be defined*
6. Handover	• Hand overbuilding in line with Plan for Use Strategy • Undertake a review of Project Performance • Undertake seasonal Commissioning • Rectify defects • Complete initial Aftercare tasks including light touch Post Occupancy Evaluation *Building handover tasks bridge Stages 5 and 6 as set out in the Plan for Use Strategy*	• Feedback on Project Performance • Final Certificate • Feedback from light touch Post Occupancy Evaluation
7. Use	• Implement Facilities Management and Asset Management • Undertake Post Occupancy Evaluation of building performance in use • Verify Project Outcomes including Sustainability Outcomes *Adaptation of a building (at the end of its useful life) triggers a new Stage 0*	• Feedback from Post Occupancy Evaluation • Updated Building Manual including Health and Safety File and Fire Safety Information

2.3.2.5. NRM, CESSM

NRM (New Rules of Measurement) consists of three volumes with a set of rules for measuring and making cost estimations. It also contains the necessary guidelines for managing construction costs and maintenance (RICS, 2020).

CESMM (Civil Engineering Standard Method of Measurement) defines the procedure for bill of quantities of engineering works, which enables preparation of offers and can be used for construction settlements (DBW, 2020). The work classification system included in CESMM4 (the fourth version of the document, issued in 2012) covers significant classes of work in civil engineering projects. It identifies the way of division into positions or units and measurement method.

2.3.2.6. LOD/ LOI

A model as a representation of the real object, is supposed to include only the essential information required to generate or update a model without unreasonable effort (Sacks *et al.*, 2018). Time for developing project increases as the amount of information and objects within a model increase, hence, determining the appropriate level of detail of models is critical for project management. However, the term level of detail was replaced by the level of development (LOD) to highlight that the level of detail might not increase with project progression (Sacks *et al.*, 2018). A BIM capability provides a guideline

for the proper levels of development of BIM models for different BIM uses according to details and contents of information.

Table 2.3.4 Model Requirements (BSI, 2013)

PAS	PoW	Geometry Requirements (LOD)	Information Requirements (LOI)
Brief	1	The model may not exist. If there is a model in case of reconstruction or renovation, it may have geometry from existing AIM	No requirements. If there is a model in case of reconstruction or renovation, it may have data from existing AIM
Concept	2	A model can be simplified to a solid form or two-dimensional symbol	No requirements
Design	3	The object's geometry reflects its overall shape	The information allows to choose the manufacturer when it was specified (or in the existing model is inside data)
Definition	4	Objects should be presented as three-dimensional models with access spaces for use, maintenance and replacement	Accurate information with the product's specification
Build and commission	5	Any object with general geometry should be specified based on embedded products	Essential data for further use of model should be retained or provided
Handover and close-out	6	Representation with accuracy as required by as-built documentation	Essential product information, data on commissioning, maintenance and operation, related to health and safety, COBie data (included in the native model with all documentation)
Operation and in-use	7	No requirements	Information about the object is updated with data from users such as maintenance or replacement, including update of changed items

The British standard (BSI, 2013) states that the accuracy of models (in terms of geometry and quantity of information (including COBie and the classification used) should be described in BEP for each project's phase with the arrangements in EIR. It is essential to not overload the models by using minimum LOD, which allows implantation all related objectives. In PAS 1192 (BSI, 2013), there is as well a description of the requirements for geometry and data used to refer to the project. Assigning accuracy levels to project stages is somewhat indicative, in general compliance with the recommendations should allow the achievement of the characteristic objectives for a given stage. For individual model elements, there is no need to use the same LOD, and LOI levels (including those assigned to the stage), e.g. the element at the detailed design stage (stage 5) may represent LOD 3 and LOI 4.

2.3.3. BIM L2 Documents

2.3.3.1. PAS 1192-2:2013

PAS 1192-2: Specification for information management for the capital/delivery phase of construction projects using building information modelling, contains recommendations for the implementation of investments during the period of ordering (BSI, 2013), design and construction of objects following BIM L2. Currently, the standard has been withdrawn and replaced by BS EN ISO 19650-1: 2018 and BS EN ISO 19650-2: 2018, which are less abundant in recommendations focusing on the CDE. Although it was replaced by BS ISO 19650, the information contained in the standards has not become obsolete. On the contrary, ISO duplicates the requirements included in PAS with minor adjustments.

The document focuses on the product delivery phase, which starts with confirmation of the need to take an investment task and ends to pass a ready object to use. The main advantage of PAS (BSI, 2013) is universality for the whole range of projects: large and small, cubature and linear. Standard is created to support the industry in pursuit of BIM maturity level 2 through:

- indicating the standards and processes that should be implemented to enable consistent, structured, efficient and accurate information exchange
- establishing a cooperation framework for projects supporting BIM regarding the architectural, engineering and construction information's production within the individual models shared with the CDE platform,
- providing specific guidance on information management requirements related to BIM projects

<u>Employer requirements</u>

Each project should begin with its purpose "end in mind" by determining the appropriate quality requirements for a project included in Employer's Information Requirements (EIR), as listed in the table (2.3.5). These requirements should be part of the tender documents to enable potential contractors' preparation of a preliminary investment plan with compliance to outlines of contracting authority. Requirements for specific project stages and goals for exchange of information should be measurable, achievable, time-limited and precise. The contracting authority must ensure that the requirements contained in the EIR are consistent with other documents prepared for investments adapted to specific decision points of project life cycle stages, contracts and other industry standards adopted during the implementation of the investment. The BSI's Plain Language Questions (PLQ) was created to help the contracting authority

developing requirements. The list of questions mainly concerns the implementation of PAS 1192-5 (BSI, 2015) assumptions, and the effect of using PLQ is Project Information Manual (PIM).

Table 2.3.5 Three groups of requirements in EIR (BSI, 2013)

Information management	Organizational requirements	Competency assessment
•levels of detail and data segregation, data included or excluded from models •training requirements • work planning, coordination and clash detection •safety and hygiene of work requirements •sustainable construction, project integrity, •compliance plan, process management •technical restrictions, assumptions for IT configurations, software (including version numbers) •other project-specific requirements	•adjustment of information exchange, work stages, purpose and required formats, •strategic objectives of the contracting authority •initial responsibility matrix defining all obligations regarding model or information production according to certain stages of project •standards and guidelines defining BIM processes and protocols to be used in the project •list of any changes, roles and responsibilities, BIM competences specified in the contract	•requirements for competences from bidders •linked with tender documentation such as product/procurement quantities (**PPQ**), project execution plan (PEP), tender questionnaires, offer evaluation plan • detailed offer evaluation

Building Information Modelling Execution Plan

In response to EIR, the contractors shall submit with the offer Pre-Contract Building information Modeling Execution Plan (Pre-Contract BEP) - preliminary BIM implementation plan. That gives the contracting authority possibility to verify contractors' abilities and their interpretation method of the set of requirements. PAS also provides for the option of negotiations with contractors to clarify their approach to investment implementation.

The content of the Pre-Contract BEP should cover all issues contained in the EIR (BSI, 2013) (ISO, 2018) and as well:

- Project Implementation Plan (PIP) - a plan for information modelling as the contractor's statement regarding the ability and competence of providing information required in EIR document. It consists of the appropriate forms, communication solutions and data formats compliance. PIP requires reconciliation but identifies the requirements for training and support, which prepare the whole team for the task. Forms within the document should include:
    - building information management assessment within BIM ability of the contractor or contractors jointly applying for the contract
    - information technology assessment form within IT ability of the contractor or contractors jointly applying for the contract
    - resource assessment form within resource ability of the contractor or contractors jointly applying for the contract
- project objectives for collaboration and information modelling
- significant milestones in line with the project schedule
- Project Information Model Deliverable Strategy (PIM), which after the start of work, is gradually implemented. Strategy for providing PIM models according to BIM L2 assumes delivery of individual studies (together with the corresponding non-graphical data and documentation, that ultimately assembly the federated model. Information on the transmitted data should be supplemented in the Master Information Delivery Plan (MIDP)

After choosing the contractor, he is obliged to create Post-Contract Building Information Modelling Execution Plan (Post-Contract BEP or BEP) - implementable plan, of which content is compliant with arrangements of contracting authority. It is vital that the information is accurate, correct and delivery of certain products is real.

In addition to the information contained in the offer document and approved in the negotiation process BEP (BSI, 2013) (ISO, 2018) includes:

- Task Information Delivery Plan (TIDP), which defines lists of deliverable packages of data broken down by task. It should include information such as format, date of submission and entity responsible for delivery. All task team managers prepare this plan for each industry

  Master Information Delivery Plan (MIDP), which is a compilation of TIDPs provided by task teams managers. The primary purpose of developing MIDP is to support delivery management of project information, including version control. The summary covers the entire project life cycle broken down by stages. It may include a wide range of data provided, such as models, drawings, specifications, schedules and the procedures used.

- The strategy for workspaces (design corridors), which is based on planning and updating parts of the project in case of design changes. The division may result from functions due to the type of system, such as HVAC, MEP or strategic elements like external cladding. Compliance with agreed, dedicated to developing space boundaries enables simultaneous work on models and reduces risk of collision occurrence

BEP records should be continuously monitored, updated and corrected as necessary. Clarification and adhering to established rules reduce the number of unknowns or prepares for necessity searching for solutions. By reducing the overall risk level of the project, the entire team may achieve benefits such as:

- all parties understand the strategic goals of using BIM and their roles and responsibilities
- implementation is adapted to the needs of each team member and the information gaps for new members is removed
- the resources necessary for the proper implementation and the project levels required to achieve the main goals of the project have been identified
  clears specification allows to fulfil project participants obligations

<u>Roles and responsibilities</u>

Responsibilities of individual roles in the project result not only from PAS (and EIR), but also from other project documents such as contract documentation. Recommendations from PAS (BSI, 2013) indicates that the vital role in the team is played by the information manager appointed by the contracting authority, which is not an independent function. Thus, duties are transferred from the design team to contractor. Many obligations related to the use of BIM, including responsibility for the production and quality of information usually is assigned to already existing positions without the need to appoint additional people within the team. The most important when dividing roles is matching the best-prepared person, entity that to perform a specific task. Of course, in smaller companies, many of roles can be performed by the same person. The division of roles within each of the project stages can be done using the RACI Matrix. Including the tasks set and an appropriate definition of responsibilities for individual team members guarantee the effectiveness of the implementation of planned processes.

2.3.3.2. ISO 19650 vs PAS 1192-2

When examining the contents of the ISO 19650 standards against the requirements of the PAS 1192-2, some similarities and difference can be made (Table 2.3.2). The content of ISO 19650 is more flexible and based on the PAS 1192, so the processes are still relevant and reflect best practice of BIM adoption. Core BS/PAS 1192 principles remain. The changes are for clarifications, improvements to make the requirements international by removing any UK-specific references such as Uniclass 2015 and COBie-UK. Standard as well consist the National Annex which role is to clarify implementation within country, help application of ISO to an established system working with naming convention following processes defined within PAS 1192.

Table 2.3.6 ISO 19650 (ISO, 2018) and PAS 1192-2 (BSI, 2013) comparison

	ISO 19650 standards	PAS 1192-2
CDE	• increases the importance • outlines its principles and core working processes (WIP, Shared, Published, Archive) • each "container" must have the attributes (meta-data) such as status, revision and classification • requirements in national annexe define naming convention	• typical focus on standards CDE • CDE area
EIR -principal rules remains	• exchange information requirements • specifies the outset of information management • clarifies information exchange through project stages	• employer's information requirements
Changed terminology and concepts	• PIR (projects information requirements) • Delivery team Mobilization Plan – a more flexible means of ensuring competency and capability of the project delivery team	• PLQs (plain language questions) • PIP (project implementation plan) • Contract
Familiar terminology and concepts	• BEP • MIDP, TIDP • PIM, AIM • OIR, AIR, EIR • files with unique ID based on the naming convention (U.K. Nation Annex)	
New definitions	• Project Information Protocol – defines the terms of appointment in the exchange of information between appointing and appointed parties • Integrated Design Process (IDP)	• New and re-defined terminology used widely within the sector, new concepts with BIM principles
LOI/LOD	• collectively referred to as level of information need	• level of information/detail
Roles	• division into two groups: management of information and production of information • Appointing Party, Lead Appointed Party, Appointed Party • Project Team, Delivery Team, Task Team	• names of appointed roles: • Client, Lead Supplier, Supplier

	• specific tasks are given within an informative (non-mandated) Annexe	
New Requirements	• Project's Information standard • Project's Information production method & procedure • Information delivery risk assessment • Responsibility matrix	

2.3.3.3. PAS 1192-3:2014

Standard PAS 1192-3: Specification for information management for the operational phase of assets using building information modelling (BSI, 2014) relates to information management for support information modelling in the operational phase that begins when assets are transferred. It can be used independently with already existing objects, but mostly affects the scope of data required in the project results delivery phase.

Asset Information Model (AIM) supposed to be the single, approved source of information about data and geometry describing resources and related spaces and objects, data related to efficiency and supplementary information (specifications, manuals, maintenance, health and safety information). The main format for exchanging data with AIM is the Construction Operation Building information exchange (COBie) mostly in the form of a spreadsheet (also PDF documents or BIM models) containing structured information about assets for the commissioning, operation and maintenance. It is essential to retain compatibility in the exchange of data between applications of the management system.

The essential duties of the team include (Office of Projects Victoria, 2019):

- creation and maintenance of an Information Management Process (IMP), covering the entire life cycle of resources such as design and construction delivery, day-to-day operation of the asset, scheduled and reactive maintenance, minor works, major works, decommissioning and dismantlement or demolition
- determination of Organizational Information Requirements (OIR) based on activities of asset management defined in the management strategy and organization requirements enabling the fulfilment of IMP;
- defining Asset Information Requirements (AIR) which define the content of the information model - Asset Information Model (AIM)
- defining systems for data exchange with AIM, such as:
    - Enterprise Reporting System
    - IT Management Systems
    - Asset Utilization Systems
    - Supervisory Control and Data Acquisition Systems
    - Financial System
- defining mechanisms for creating, receiving, verifying, storing, sharing, archiving, analysing and exchanging information to be stored in AIM
- defining AIM maintenance and quality monitoring mechanisms, including data reference integrity using CDE

To correctly determine the operational phase requirements, the cooperation between the contracting authority and the facility manager is necessary. Currently, in Poland, ordering party usually settle commitments on contractors in EIR to provide the model for management purposes without providing technical details.

2.3.3.4. BS 1192-4: 2014

According to BS 1192-4: Collaborative production of information - Part 4: Fulfilling employers information exchange requirements using COBie - Code of practice (BSI, 2014), the contracting authority should require COBie data at least a moment of placing object into service. Depends on the needs, the ordering party may increase the amount of information. The data should be stored in management applications to support tender procedures for facility service and future projects.
Regardless of the level of BIM maturity, COBie data follows specific rules of:

- naming conventions, units used (data in sheets is dimensionless)
- parameters (volume, area, levels)
- break-down scope of infrastructural and cubature investments

2.3.3.5. PAS 1192-5: 2015

Standard PAS 1192-5: Specification for security-minded building information modelling, digital built environments and smart asset management (BSI, 2015) does not describe how to deal with security issues, but only pays attention to the most critical aspects and suggests steps to minimize them. It is particularly important in the era of digital information sharing and digitization. However, this scope may not be justified economically because of disproportionately increase of implementation cost to the additional value from its use. Typical methods of data security used during implemented investments associated with the used CDE platforms should be sufficient for the pilot project.

Standard (BSI, 2015) consists of the clarification of the most critical problems related to the security vulnerability of embedded digital resources in the life cycle:

- safety - preventing the data injury, loss or damage within the environment
- authenticity - data is not left modified in an uncontrolled manner
- availability (including reliability) - the required information is available at the specified time
- confidentiality - access control and prevention of unauthorized access to information or data
- integrity - the accuracy of the data and configuration, avoiding unauthorized changes
- possession - preventing unauthorized access, manipulation or interaction with the data collected
- resilience - upgrading, renewing and restoring ability
- utility – collected data is used

The standard (BSI, 2015) also lists the most important types of risks of storing and sharing digital data:

- hostile reconnaissance or malicious acts
- loss or exposure of intellectual property (including company information and confidentiality)
- disclosure of personal data
- data aggregation

Beyond digital security, the standard (BSI, 2015) also pays attention to physical security. The main recommendation is to implement more stringent procedures and security documents for embedded assets such as:

- Built Asset Security Strategy (BASS)
- Built Asset Security Management Plan (BASMP)
- Built Asset Security Information Requirements (BASIR)

2.3.3.6. PAS 1192-6: 2018

The British construction sector is obliged to apply health and safety rules. The PAS 1192-6 standard: Specification for collaborative sharing and use of structured Health and Safety information using BIM (BSI, 2018) does not introduce additional requirements, but indicates new methods to improve analysis, collecting and reusing safety information.

It is possible to use various applications that facilitate the interpretation of Envorinment and Health Safety (EHS) issues enabling accurate location and realistic presentation. It helps with controlling the risk management and the integration of health and safety systems with BIM data for documenting and sharing during the implementation of the investment. For risk identification, there are used appropriate parameters, additional objects in models, analysis of sequences of construction works, visualization, other analyses based on BIM models.

The standard (BSI, 2018) indicates that the contracting authority should include in the EIR requirements related to health and safety in order to ensure safer work environment, threats and risks reduction, improvement of EHS performance in construction, delivery of required data to the right people at the right time and reduction of construction and operating costs. However, this scope may not be justified economically because of disproportionately increase of implementation cost to the additional value from its use.

2.4. BIM Standards in Poland

There are various classification systems used in construction in Poland, but most common are:

- Polish Classification of Construction Objects (PKOB, 2002)

describes statistics of construction activities, construction reports, lists of buildings and flats, statistics of building prices and national accounts. Also, the classification is used to classify construction works, but is not included for example in small architecture objects, temporary objects or forestry production buildings

- Catalogues of Material Expenditure (KNR)

describes building in a more detailed way by referring to particular elements, not entire building objects, however, has several other disadvantages. Firstly, it has long lost its relevance because it does not cover many new technologies and building materials or entire systems. Secondly, it is preferably used due to the lack of any other instrument for the preparation of bills of quantities (ORGBUD, 2020)

Currently, no classification system would be suitable for use in Polish conditions for BIM implementation. Without agreed, comprehensive system of organizing construction information, it is impossible to ensure interoperability between different design and facility management tools.

However, the Polish construction industry has set up two main initiatives to integrate BIM in the sector. First, the buildingSMART Polska in 2017 established by Hochtief Polska, WARBUD, Mostostal Warszawa, Electra M&E Polska, MOTA-ENGIL and ENGIE Technika Instalacyjna, that contributes via events and workshops to raise public awareness about BIM (European Commission, 2019). In February 2018, the Polish Construction Association, along with the Polish Association of Construction Engineers and Technicians, initiated the BIM Standard PL project to establish BIM standards and promote the collaboration between the industry. This initiative involves as well the Polish Association of Construction Employers (representing 92 construction stakeholders across six associations), and the Polish Association of Civil Engineers and Technicians. At the same time, international events were arranged to encourage the relationship between British, Finnish and Polish construction companies to facilitate the transfer of BIM knowledge and expertise (European Commission, 2019).

According to the EU report, Poland is less active in the field of BIM standardization. However, the is part of the EU BIM Task Group, which incorporates national efforts into a shared and integrated European approach developing a common digital construction industry (European Commission, 2019). It focuses on four pillars: developing infrastructure and industry, creating a shared collaborative framework and basis for public leadership, communicating the vision and promoting communities. Likewise, recently released manual on the European Public Sector's implementation of BIM (EUBIM Task Group, 2017).

In Poland, at the beginning of 2019, the PN-EN ISO 19650 standard came into force, which to some extent meets the needs of standardization. It is somewhat superior to British standards BS 1192 and will ultimately consist of the following parts:

- part 1 – PN-EN ISO 19650-1: 2019 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - information management using building information modelling. Concepts and principles (PKN, 2019)

- part 2 – PN-EN ISO 19650-2: 2019 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Delivery phase of the assets (PKN, 2019)

- part 3 – Operational phase of assets

- part 4- Information exchange

- part 5 – Security-minded approach to information management

The first two parts were adopted by the Polish Committee for Standardization (PKN) in its entirety in English. Applicable parts in Poland recommend using BIM tools throughout the entire life cycle of the facility in the construction sector. The construction process, according to the standard (PKN, 2019), should be based on the smooth exchange of information between all project participants (contractor, contracting authority and designer). The rules in standard (PKN, 2019) also specify equally standardization of procedures and documents as in international version in chapter 2.3.1.

The rules of cooperation and tasks of the participants are quite clearly defined; however, not containing guidelines for the standardization of designers' work using BIM software. Currently, with the

participation of experts and based on the ISO 19650 standard, a Polish document - **BIM Standard PL** is under public discussion, which is planned for 2020.

BIM Standard PL is designed to normalize the course of the investment process, a design approach that is currently imposed most often according to the concepts of contractors (PZPB et al., 2020). Design offices usually have internally accepted standards based on output file templates with settings for graphics, naming, and information resources at a given stage of the project. The standards adopted in Poland lack these coding and nomenclature guidelines, as in the Uniclass system, what hinders cooperation between industry professionals by exchanging files (most often created in various software), as well as using components of external companies (Zuber, 2019). BIM Standard PL is the first stage of standardizing BIM processes in Poland, referring to the designer-contractor-investor relationship and create a common language for investment participants, giving the client clear information about what he can expect from designers and contractors at the each stage of design, implementation and operation of the building (PZPB et al., 2020). Specifying the needs of the investor would allow BEP to be created virtually, which is not only the basis for communication with the designer before the start of the design process but also for creating the appropriate offer.

2.5. BIM Maturity Level

Maturity is determined as a degree in which a particular process (a set of following successful changes) is defined, controlled, coherent and practical concerning the expected effects of its implementation. For an organization, person or project, maturity is seen as the ability to maintain quality and repeatability in services rendered related to BIM, including models and their products (Dakhil, Underwood and Al Shawi, 2019).

Maturity assessment methods found in British publications can be divided into two groups:

- OAM (Organization Assessment Model), which describe the level of process implementation in the organization, such as Succar BIM Maturity Matrix, CIC Research Program's Owner Matrix or Owner's BIMCAT
- PAM (Project Assessment Model) assessing maturity in terms of application of abilities in the process of project

The last method is the most commonly known, as well in Poland, because of the appearance in British Standards, which describes the implementation of BIM in terms of construction design, modelling and data exchange. The core graphic (figure 2.5.1), which was developed in 2008 by Mark Bew and Mervyn Richards, represents the development of levels of maturity during the Building Lifecycle Management (BLM)(Lin, Roithmayr and Chiu, 2015). Even though the documents were corrected and updated with extra description within the years, the main idea remains unchanged. The 0 to 3 levels are used to evaluate how the construction supply chain can function and share information with varying degrees of modelling, collaboration and, finally, fully integrated, interoperable data (The B1M, 2020).

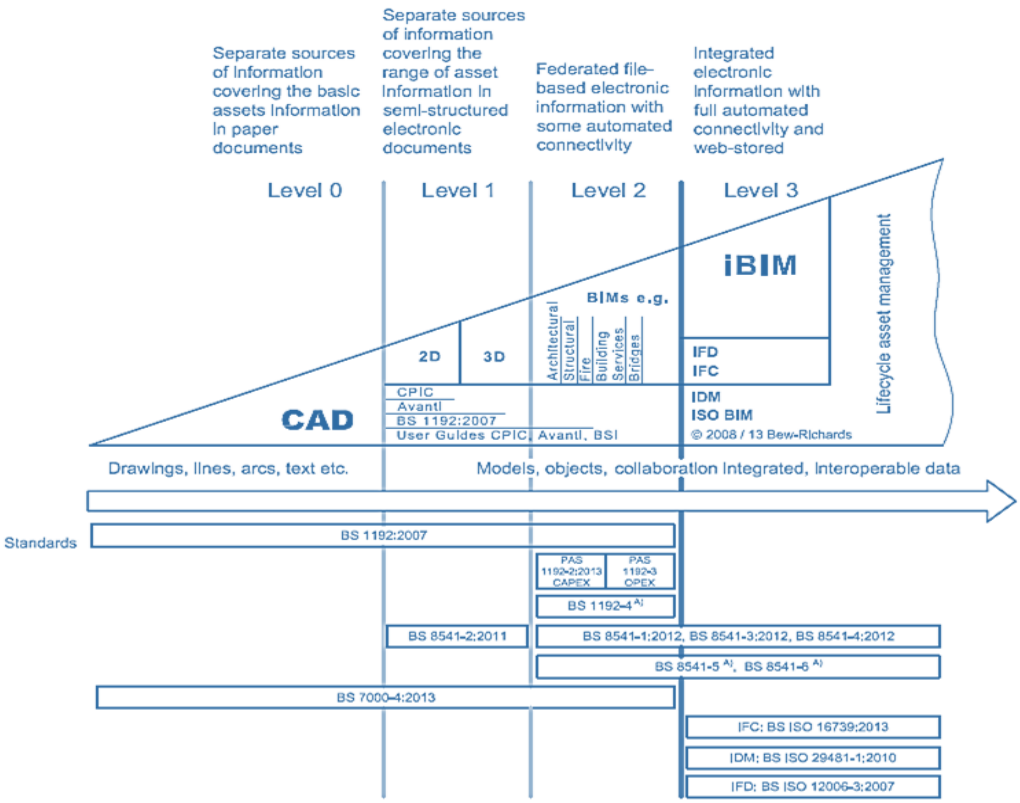


Figure 2.5.1 UK BIM maturity levels extended to asset information management (PAS 1192:2013)

2.5.1. Level 0 (BIM L0)

Level 0 refers to processes characterized by the lack of central management of data exchange, which are mostly based on 2D (flat) CAD drawings distributed in paper or electronic form, or a mixture of both. It is the first step up from generating information by hand. However, it might include the standardization of specific processes by BS 1192 (BSI, 2007), but this process does not have to be comprehensive. Most of the construction industry in the UK represents a level higher than 0.

2.5.2. Level 1 (BIM L1)

Level 1 introduces management and cooperation mechanisms, which are defined in BS 1192 (BSI, 2007), as a set of acceptable practices related to the use of a common data-based environment such as SMP and the CDE. Even though, data source can have a flat form mostly for the drafting of statutory approval documentation, production information or three-dimensional form such non-federated 3D models, mostly used for concept work and visualizations. Information, especially those related to costs, are not integrated or linked to the representation in the drawing/model.

The following things should be achieved and adopted for Level 1 BIM:

- roles and responsibilities
- naming conventions
- the projects' specific codes and projects' spatial coordination
- CDE or electronic document management system (EDMS) for sharing information between all members of the project team

- information hierarchy should support and follow the CDE and the document repository

2.5.3. Level 2 (BIM L2)

Level 2 is defined as a file-based collaboration with repository management by using one of the standard file formats such as IFC (Industry Foundation Class) (BSI, 2013). Its key factor is model with information and drawing data attached or COBie (Construction Operations Building Information Exchange) at project points specified by the contracting authority. In Level 2 BIM the collaborative working is compulsory, the information exchange process is defined to project and coordinated between various systems and project participants. In conjunction with the BIM Task Group the Government set the mandate for Level 2 BIM to incorporate 8 pillars (figure 2.5.2).

The basic principles of information modelling within BIM L2 according to the British standard PAS 1192-2 (BSI, 2013)indicate:

- provision of CDE
- compliance with the documents and standards listed in Pillars of BIM, which are the guide on how specific processes should be carried to function efficiently in BIM teams
- application of the other standards and ethical practices such as project management, creation of documentation and BIM models for the use of library objects, required attributes and classification (BS 8541 series)
- exact EIR)which includes key decision points
- supplier and supply chain capability assessment
- Building Information Modeling Execution Plan (BEP) which contains a description of the required procedures, standards, roles and Master Information Delivery Plan (MIDP) aligned with the project programme
- development of information models for specific industries using dedicated software and linking them into individual databases or using a software platform (shared online area) with one common database
- data acquisition from other industries is made by reference, federation (submission) or direct exchange
- data exchange via models, including native files, COBie sheets and PDF files

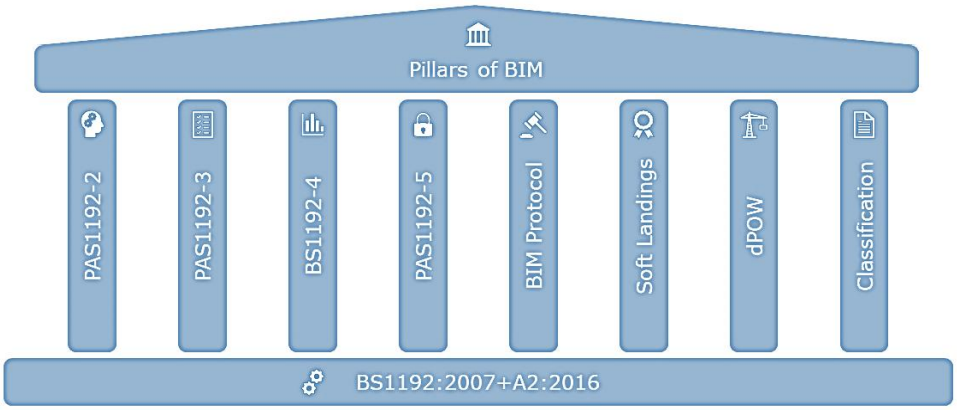


Figure 2.5.2 Pillars of BIM (DGuerrilla, 2017)

2.5.4. Level 3 (BIM L3)

Level 3 is characterized by full integration of processes and data hosted and sufficiently developed in a common data environment enabling parallel operation by all members of the project team in real-time thanks to IFC and IFD. It is as well called iBIM (integrated Building Information Modeling).

Level 3 has not yet been fully defined; however, the vision for this is outlined in the U.K. Government's Level 3 Strategic Plan (H.M. Government, 2015).

- development of an Open Data standard to promote the exchange of project data within the industry
- creation of new contractual frameworks for BIM-based projects to promote cooperation and ensure continuity
- preparing public sector clients to apply BIM techniques
- division of the delivery phases within the level (The B1M, 2020):
    - Level 3 A - enabling Improvements in the Level 2 Model
    - Level 3 B - enabling new technologies and systems
    - Level 3 C - enabling the development of new business models
    - Level 3 D - capitalizing on world leadership

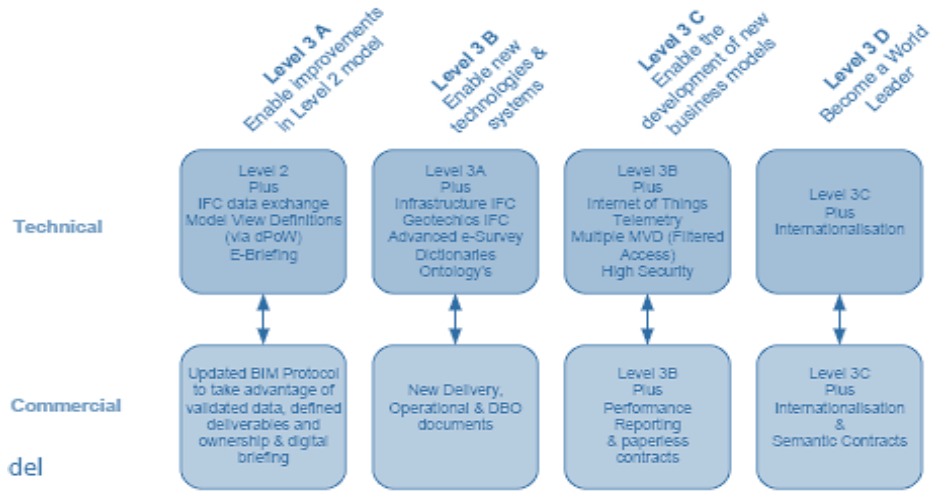


Figure 2.5.3 The key technical and commercial activities for Level 3 (H.M. Government, 2015)

2.6. Dimension of BIM

The almost complete spectrum of additional non-geometrical information that can be implemented in the BIM model gives the possibility of greater use of such documentation. Due to the specificity of issues and particular usefulness, this information has gained the name of additional BIM dimensions. In addition to 3D, we are dealing with the following: 4D, 5D, 6D and 7D and 8D(Josseaux, 2018), as presented in the figure (2.6.1)

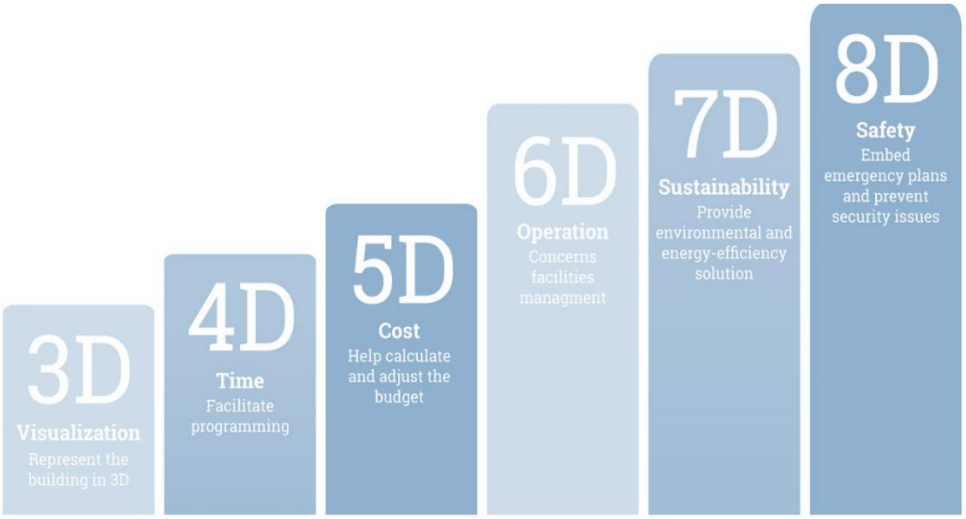


Figure 2.6.1 BIM Dimensions applications (Josseaux, 2018)

Correct development and coordination of the BIM 3D model is one of the most critical elements for significantly automating the process of preparing the necessary documentation. Two- and three-dimensional drawings, lists of elements, as well as more advanced studies, such as work schedules, take-offs and variant analyses, can be generated directly from the model (Sacks *et al.*, 2018). Moreover, the use of BIM technology, through possible data integration of all industry teams related to this tracking of possible collisions. It improves in a revolutionary way the project coordination in many specialities, provided that the appropriate discipline and standards of its preparation are maintained (Williams *et al.*, 2014).

BIM 4D model is an extension of time assigning to each spatial element an additional attribute of the order and period of its implementation on the construction site can generate, using appropriate software, a schedule of construction works and an accessible animation of the subsequent stages of constructing the facility (BIMDictionary, 2020). This information is also useful when monitoring the actual progress of work by comparing the status of completed elements with the assumptions set out in the model for a given point on the time axis. The use of the model to prepare a bill of quantities or construction works schedule should be one of the primary BIM goals that can be used as part of a pilot project (McPartland, 2017).

The use of object-oriented BIM design environment, with a system of classification and identification of individual elements with a correctly prepared model, gives the possibility to make various types of numerical combinations. BIM 5D is an economic dimension in which adding a price attribute allows to generate the bill of quantities and cost estimates from the model and to analyse costs. What allows estimating costs and developing variant analyses at an early stage of the project, and enables general contractors in the building phase to optimize and analyse the use of products from various suppliers (Stanley and Thurnell, 2014).

BIM 6D relates to the model prepared for the needs of the management of the constructed facility and its operation. It may contain necessary data, including for servicing and replacing the right devices at the right time, controlling elements of the Building Management System (BMS) with their spatial visualization and general asset control by the property manager (McPartland, 2017). Additional

information useful during demolition (order of works, recoverable materials) can also be implemented in the model, thanks to which - following its intended use - the BIM model can be effectively used in the entire investment process.

BIM 7D is associated with the development of a model for checking the object's impact on the environment and humans, i.e. energy analyses, carbon footprint calculations. It is particularly useful when designing a purpose covered by an international certification system because it allows more natural optimization of energy consumption and the use of renewable energy systems. The last of the dimensions described for today is 8D - an effective means of preventing hazards in the construction industry. BIM helps to eliminate hazards at the source by preventing design errors in the early stage of projects (Josseaux, 2018).

The critical feature of properly used BIM technology is to minimize the loss of previously collected information between successive stages of the investment process (design, construction, commissioning of the facility), but also between critical stages of documentation development (conceptual, construction, tender, executive design). It is necessary to make a 3D BIM model of a building object at the earliest possible stage of design work. Then it is consistent detailing, both in terms of accuracy and fidelity of the geometrical representation of elements and adequate saturation with their information. An adequately prepared and coordinated model is the basis for creating a precise cost estimate and schedule, improving the process of erecting the object, organization of the construction site so that at the stage of the investment no additional works and downtime occur, causing unplanned expenses (Wang, 2012). After, the model and the data it contains should be developed by the general contractor, and then forwarded to the facility manager.

Therefore, it is the Investor who will save the most on the implementation and operation of the building. Building information management is an innovative way to design and manage projects, mostly focused on shared ownership of information. By adopting BIM, predictability of building performance and operation is improved. Similarly, collaboration within the project increases, which should lead to increased profitability, less costs, better time management (McPartland, 2017). BIM tools allow designers and architects to apply in-depth analysis to the building before any work is even started to determine complex interactions. Also, on-site BIM savings are expressed in making construction more efficient and more controlled. BIM makes more data available and helps to reduce resource waste and time-consuming errors.

2.7. Information Requirements – organizational procedure

In this chapter, the main stages of a typical information process for building investment would be discussed, assuming the implementation of this project from the moment of a demand for its construction, until commissioning. The information requirements taken into account from the very beginning provide consistent, cost-effective and adequately informative BIM model useful for facility management.

Each project should be considered within an overall approach, recommendations with appropriate modifications, corrected and supplemented for a specific investment task. The variety of project might

consist of such topics as reconstruction, revitalization or changing the function/way of using existing facilities, cubature with infrastructure. The information process and its definition in the project is as well affected by its scale and type of contract. The information in its life-cycle can be in different states: created, stored, accessed, used, organised, integrated, maintained, retrieved, disposed, as shown in figure (2.7.1). It is clear that, in case of large projects and high value of contracts, expenditure on IT equipment, software or human resources will be probably more extensive than in a project with a significantly lower budget. The additional cost would be reimbursed in models with richer and higher quality information. Whereas in projects on a smaller scale, the use of the BIM methodology would be limited, hence some roles/functions would be combined, and the scope of the order more inadequate with information model.

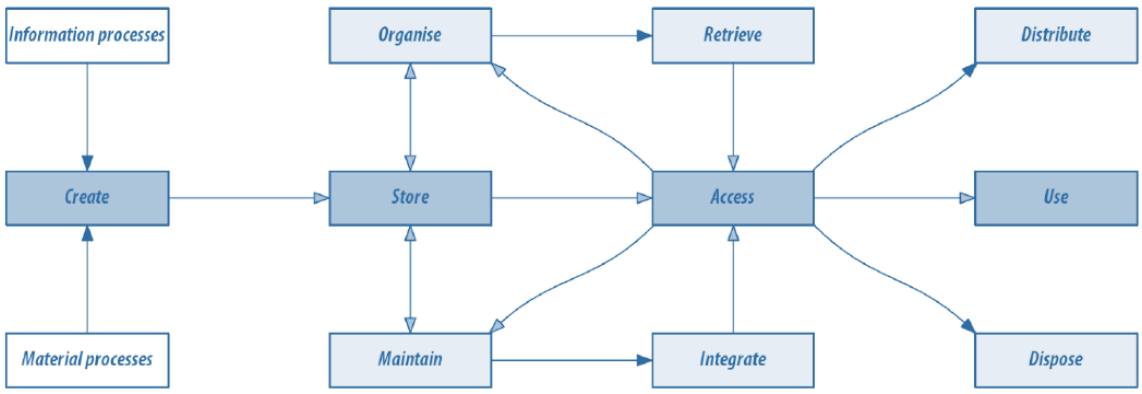


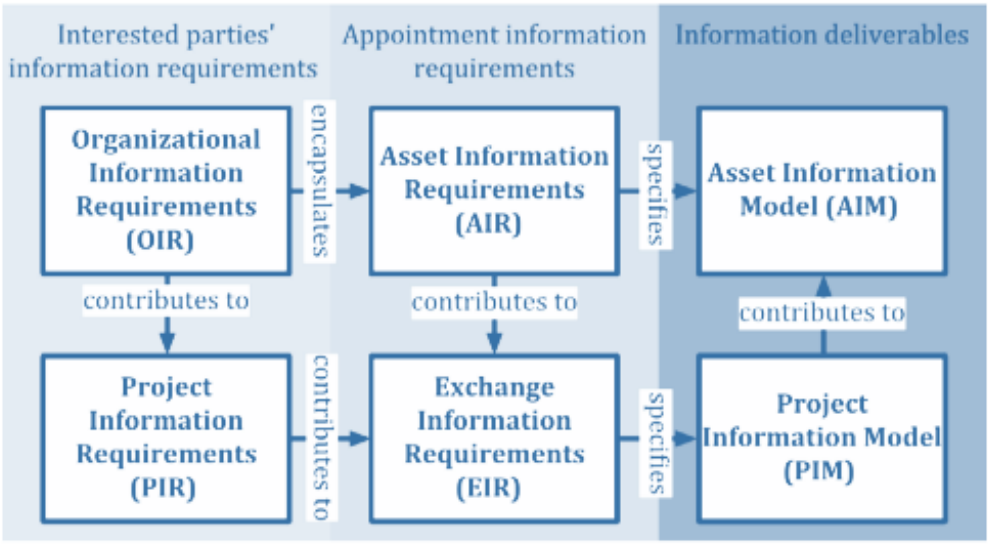
Figure 2.7.1 Project information management principles (Cerovsek, 2019)

Similarly, the scope of the specification of information requirements and investment preparation in the BIM methodology is affected by the type of contract. For investments carried out traditionally, with separate project order and separate construction order, the contracting party should carefully and in more detail define information requirements, interfaces and information exchange procedures for transferring the information model between phases. For investments implemented in the 'Design and build' formula, some specific issues regarding the exchange of information and model information would be solved internally, between the designers and the contractors, appearing externally as one entity or consortium - releasing the contracting party from precise definitions.

2.7.1. Organisation Information Requirements - definition

The more critical the investment becomes during the project; the more information is provided. The typical model of information gathering and exchanging files such as e-mails, PDFs or CAD drawings, contributes to information chaos. Likewise, the lack and duplication of incorrect details (BSI, 2013). The purpose of a project is to create an asset of value. In particular, it is essential to understand the information to support the value creation.

Figure 2.7.2 Different types of information requirements and models according to ISO 19650



As presented on the figure (2.7.2) the purpose of an Organisation Information Requirements document is established what information is required to effectively and efficiently run the company, and with the support of Asset Information Requirement (AIR) as well to give a consistent data flow for asset management or reporting purposes. Information requirements must support the organisational business key decision points in step with project stages and align to operational uses of asset information at critical events. The aim of the BIM process in Project Information Requirements (PIR) is to deliver the models, data and information in order to add real value to support the ongoing management of the assets in the operational phase, and in turn support the organization's broader vision, mission and strategic objectives(UK BIM Alliance, 2019).

The OIR document can provide useful inputs for project and asset management for both the pre-works of new investments and the operational phase of a constructed asset. The OIR may be amended during its life to cope with changes in operational requirements, or to deal with regulatory changes that need informational inputs (BSI, 2018). Across the asset lifecycle several factors need be considered to enable organisational success. First, the nature and purpose of the organisation with its the operating context. Second, the financial constraints and regulatory requirements should be established. Third, the company's needs and expectations and its actors through the processes.

During the regular operation of an asset, the information will be generated by operations and maintenance functions to inform the user and owner of the asset is functioning correctly. The OIR should act as a prompt and filter to the AIR to collect the data that will help to create the Asset Information Model (AIM) and the overall organizational information systems. The flow of information from the AIM, through an AIR during routine maintenance work, and back into the AIM (BSI, 2013). This information will support asset selection, operational performance, risk management and the broader vision of the organisation.

The OIR document, in the case of asset creation or significant works, will inform the AIR document, which will then ensure that the organization is receiving consistent information for all assets under their

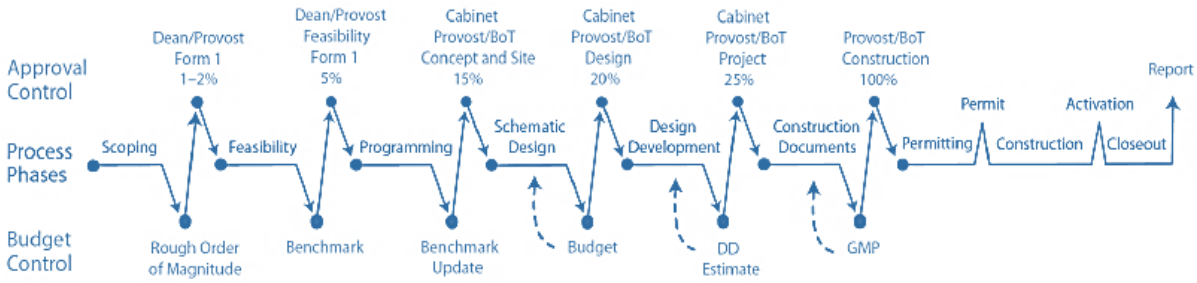
control (BSI, 2018). The chain of information flow is longer because of additional information requirements such as information relating to the specific asset, the Employer's Information Requirements (EIR) for that project and the methods by which the design team will deliver the information (PZPB et al., 2020).

The next step is the creation of the AIR, where the asset owner is checking the OIR with the organizational assets to determine the knowledge requirements for processes based on BIM. There are criteria for asset-level success of AM activities within owner-operator organizations (Greenstreet, 2017).

2.7.2. The Project Delivery in AEC industry

Project delivery has been historically defined as a phase-gate process within the AEC industry. The method is divided into phases (such as schematic design, design development) with a gate at the end of each point, where a decision is made whether to continue based on the available information (Stanford, 2010). The Stanford Project Heartbeat is an example of how the majority of AEC industry in Poland applies phases and informational deliveries.

Figure 2.7.3 The Stanford Project Heartbeat for project delivery (Stanford, 2010).

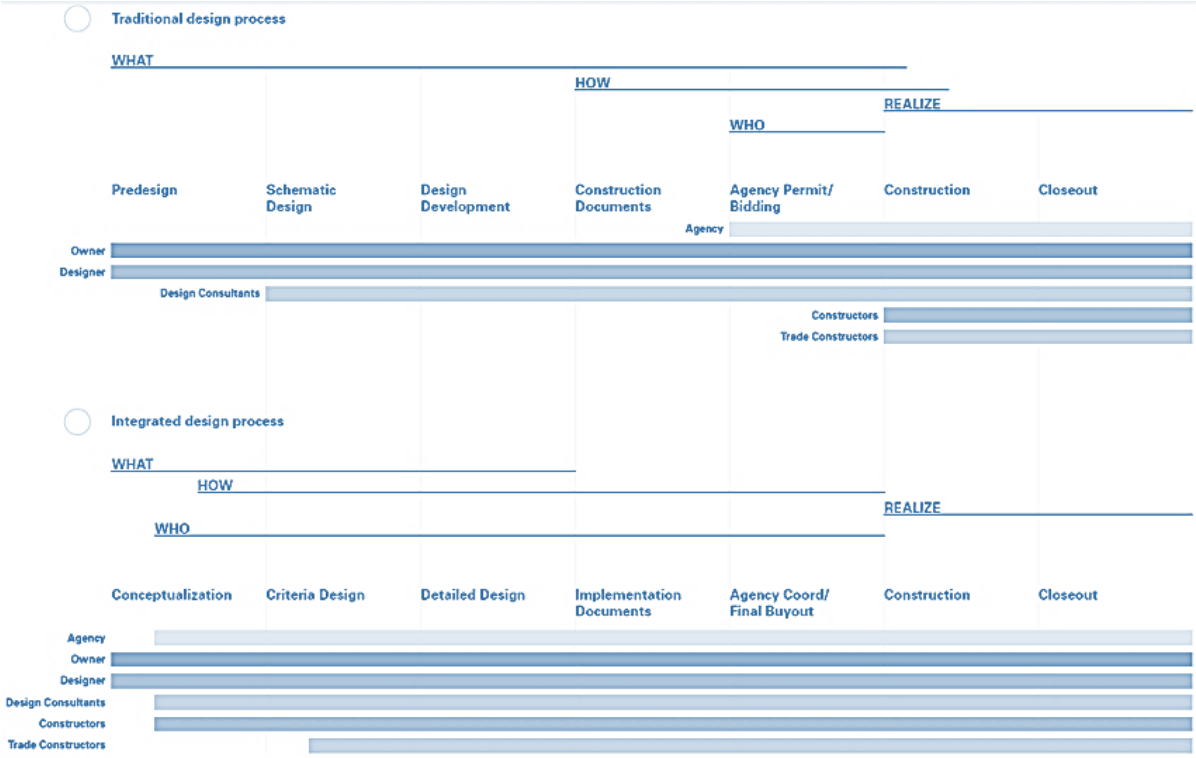


This phase-gate model (Figure 2.7.3) is widely accepted as a project delivery model in the AEC industry, as well as in Miastoprojekt Wroclaw, where the procedure was accommodated with a more or less comprehensive implementation of the intended deliverables. The phase-gate model is a sequential waterfall process, where the subsequent step output is the input for the next stage. Therefore, information can only flow downstream from the stakeholders involved in the earlier phases to the subsequent participants (Bengt, 2019).

2.7.2.1. The Integrated Project Delivery

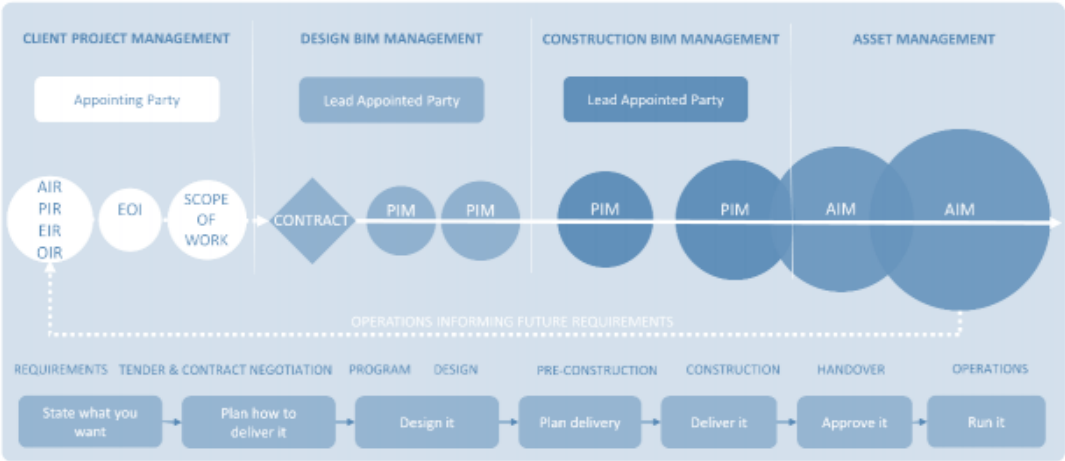
The information needs to flow upstream and downstream in the integrated project delivery process so that the stakeholders can influence on decisions in early phases with each other's knowledge (figure 2.7.4). Constructors and subcontractors are thus active from an early stage, and tasks typically undertaken later in realisation such as procurement, work scheduling and estimation become concurrent tasks with the design (Alves and Lichtig, 2020). The main aim is to collaboratively integrate people, systems, business structures, practices into and insights of all project participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design and realization (AIA, 2007).

Figure 2.7.4 Traditional Design Process vs Integrated Design Process (AIA, 2007)



It appears that the implementation of IPD demands the project participants to adopt new creative protocols and interaction sequences that result from the system and its embedded compensation, process, risk, teamwork and contractual parameters. IPD needs unique features among owners, engineers and design professionals. Thus, IPD envisages reconfiguring the design phase, moving design decisions to earlier times and redefining the market (Azhar, Khalfan and Maqsood, 2012).

Figure 2.7.5 The development of the PIM into the AIM using the ISO 19650 approach (BRIS, 2019)



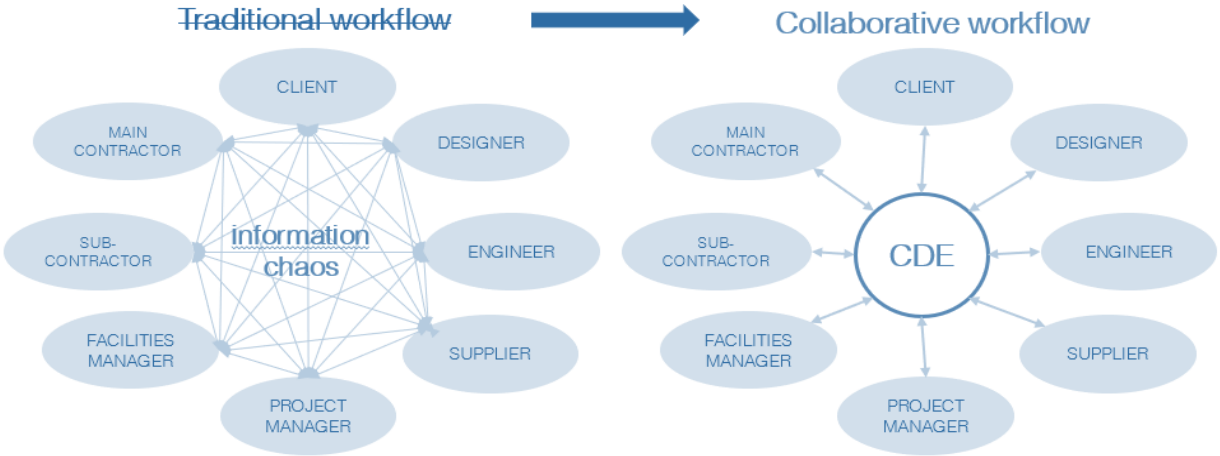
There are key principles for the specification and delivery of project and asset information using the ISO 19650 approach. Namely, information throughout all stages of the life cycle needs to be used to help decision making. All the data should be specified, produced and delivered progressively as presented in the figure (2.7.5). Moreover, the relevant party should be responsible for creating and managing the

information related to scope and information requirements. Finally, appropriate collaboration systems and processes have to established to exchange and deliver data in open formats through the use of a Common Data Environment (BRIS, 2019).

2.7.3. Modelling Information Flow

The information is transmitted continuously in the integrated project delivery process, instead of at the end of the phases (UK BIM Alliance, 2019). Similarly, the building model is regarded as an integral part of the BIM process. The project delivery process or relevant stakeholders stand in a circle around it (ISO, 2016). As presented in the figure (2.7.6) the basic concept is that the stakeholders gather information from a central repository of information required for their responsibilities and enter the information they have produced, instead of sending data to each other (Elhendawi *et al.*, 2019). Preferably, the information needs to be put in the building model before other project members can use it to create a collaborative, continuous workflow. BIM encourages greater cooperation, and processes such as design-build and IPD support. Moreover, BIM promotes the coherence of processes and information sharing (Hergunsel, 2011).

Figure 2.7.6 Traditional and collaborative workflows comparison



2.7.4. Common Data Environment

The ISO 19650-1 (ISO, 2018) explains the CDE as a combination of technical solutions and process workflows. The CDE is supposed to be a single source of information for any project or asset which collects, manages and disseminates relevant, approved project documents in a controlled process for multidisciplinary teams (BIM Dictionary, 2020). A CDE solution could be software or another form of tool like electronic document management systems (EDMS). According to ISO 19650-2 (ISO, 2018), a CDE is provided and managed by the appointing party or a third party acting on behalf of the client. However, each delivery teams may implement their CDEs, but not instead of the project CDE. Many different technologies can be used within a single workflow and different types of project information. For example, the tools may vary for management of documents, contracts or emails. Each solution may have multiple and different workflows and should be selected to facilitate them. Workflows must be developed first to plan, share, store, manage and retrieve timely, correct, complete, and consistent information.

BIM is a collaborative method facilitated by technology and supported by people to communicate effectively, reuse and exchange without loss, modification or misinterpretation(CIOB, 2015). A CDE is a fundamental part to deliver a collaborative way of working (Mordue, 2018), (ISO, 2018):

- enabling access to up-to-date, accurate information about a built asset in a standardized and easily accessible format
- support managing, developing, assuring, exchanging, disseminating and organizing the information created during significant works, minor works and maintenance activities
- allowing access and use of data while maintaining information ownership according to pre-established rules
- coordinating the creation of information, traceability and historical succession of revisions
- the support of a wide range of types and formats
- the ability to create an unlimited number of views using any combination of files
- the ability to use stored and retrieve data created at the design stage to plan construction, costs, facility management
- guarantee of confidentiality and security

BIM methodology involves the exchange of information within a CDE along with an appropriate information hierarchy, as shown below in the figure (2.7.7). Because of is an ideal environment for collaborative working culture, CDE should be a priority for any organisation.

The ISO 19650 series applies the CDE concept over the entire lifecycle of a project or asset, directing both appointing and appointed parties. Teams must be cautious in generating information that satisfies the information criteria to ensure that it is relevant to coherent to all parties. Containers of information include Building Information Models, documentation, reports, cost plans, specifications and other project/asset-related information (BRIS, 2019); should be manufactured using standard geometry specifications and exchange formats, such as IFC. The information needs to be frequently audited by the appointed lead party and the appointing party to ensure the accuracy of information. As an information container develops, it exists in various states within the process, and it can go through different workflows, potentially using multiple solutions (BRIS, 2019). According to ISO 19650-1 (ISO, 2018), information throughout its development should be controlled by the metadata assignment of revision and status code in order to communicate what version the information container is at and its purpose. Additionally, ISO 19650-2 (ISO, 2018), requires that the CDE enables assignment a classification code. The scope of the metadata assignment may be expanded beyond the recommendations and requirements of the ISO 19650 series.

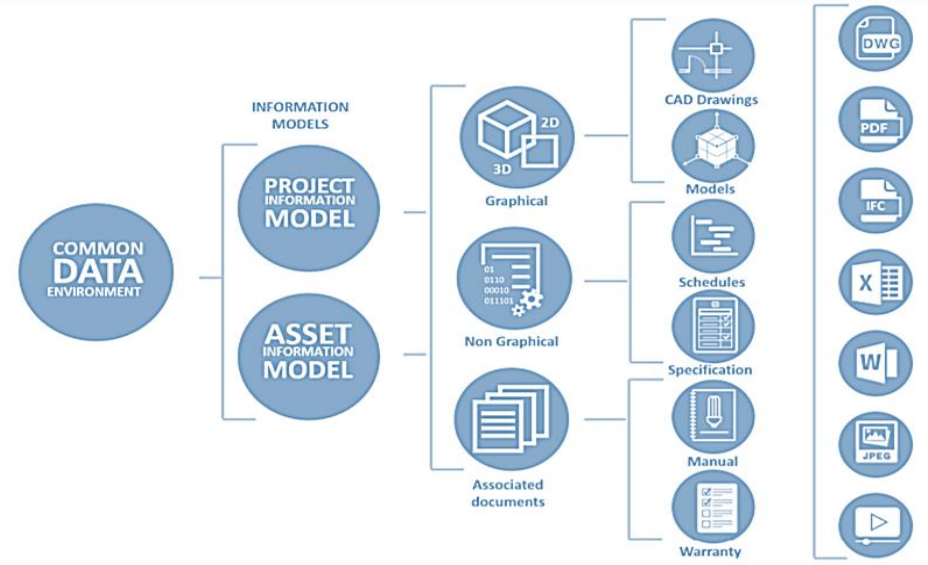


Figure 2.7.7 Information hierarchy (Mordue, 2018)

Information can have a wide range of progressive status levels within the CDE. However, there are four main areas of information (ISO, 2018), as shown in the figure (2.7.8), with recognisable milestones in process allowing information to be transferred from one phase to the next (ISO, 2018):

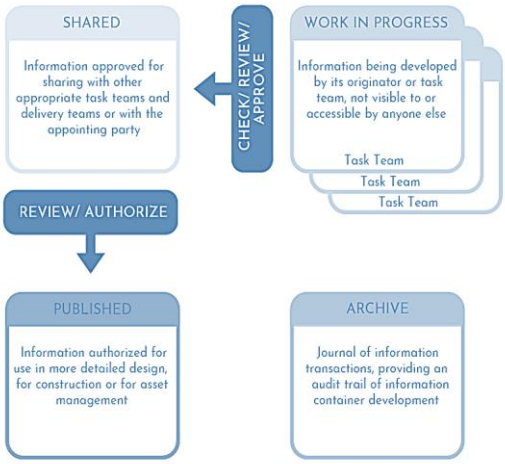


Figure 2.7.8 Graphical information flow (ISO 19650-1)

1. **Work in progress (WIP):** this area is used for keeping unapproved processing information for each particular development team and is therefore not yet accessible to other stakeholders
2. **Shared (or client shared)**: this information has been verified, reviewed and approved for exchange with other teams, including sometimes the client, although it might be subject to change and modification
3. **Published:** this information has been authorized or approved by the client or their representative, and the contents are definitive for daily use by all relevant stakeholders
4. **Archive:** this location is used to create a continuous record of project life cycle progress as well as all transaction and change orders. It can be classified further as being archived and yet valid or archived, but exceeded

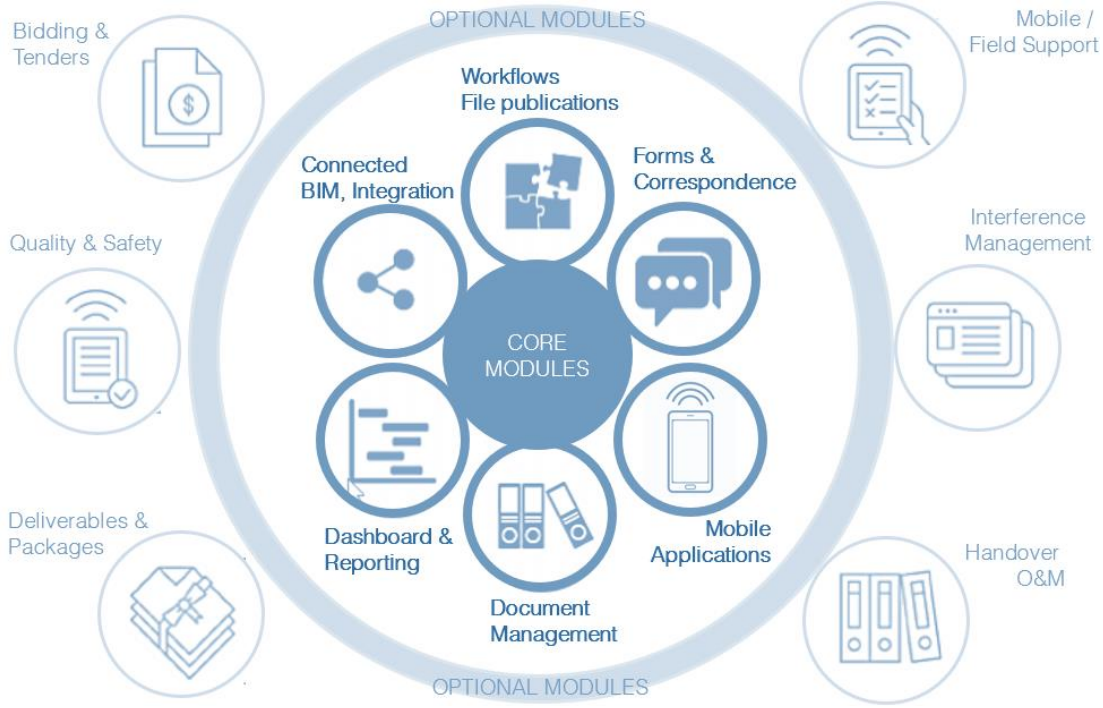
2.7.4.1. Benefits of Common Data Environment

From the analysis of the different papers, some of the following benefits of CDE are listed in the table (2.7.1) and as well graphically represented in the figure (2.7.9).

Table 2.7.1 Benefits of CDE

Control of different versions of the project
Time reduced in checking files, reduction in time for search
Easy access to relevant and reliable information, efficient searching
Save time to transfer accurate information
Workflow: Controlling document Distribution, consistency of documentation
Improve turnaround time, faster document approval
Simplified communication, ubiquity, enable collaborative works
Efficient processes of creation and management of information
Automatic audits, improved analysis
Savings in producing coordinated information, cut control document cost, print savings
Improved estate planning, procurement and maintenance

Figure 2.7.9 Graphical representation of CDE benefits



3. CASE STUDY

3.1. Methodology

The literature review helps to develop an insightful understanding of raising awareness about BIM, BIM standards and processes, BIM documents and requirements, and barriers hinder the implementation, key factors influencing the adaption and the internal organizational readiness.

Due to the quantitative research methods limitations and weakness, a small representation of the target responders, limited outcomes, the qualitative research such as questionnaire survey, semi-structured interviews were conducted via telephone or Skype. The interviews lasted from one to two hours, and their aim was a complete, detailed description of the processes in the company.

3.1.1. The research methodology

The literature review proposed in chapter 2: State of the Art provides the fundamental to proceed with the next phases of the research methodology integrated in the proposed case study as following described

3.1.1.1. Second phase:

Questionnaire survey, semi-structured interviews via telephone or Skype in order to collect the employees and experts' perceptions about the existing procedures and process in on-going projects. The other of the activity of the case study was to make detailed observations of the current practices of employees within the company when using and to archive information in the developed by company platforms. The main problems were identified using perspectives from the interviews as well as document and circulation analysis on the company's platforms. Based on conclusions from the observations, the assessment of Information Management Maturity was performed. Consequently, the proposals for improvements of both platforms were presented.

For the analysis of documents and circulation on platforms, the company has granted authorized access to selected projects. However, permissions have been limited to viewing data and information without editing possibility. Miastoprojekt Wroclaw proposed the selection of personnel for the interviews. Recommendations were extended from the initial sample of three employees with a maximum three interviewees present at each interview. That stands for more than half the number of all permanent employees. The company hires as well as additional specialists per contract as needed, such as BIM experts, who were interviewed on the findings to substantiate them in semi-structured discussions. The BIM professionals responded to all sections, except the responses related to the company processes and procedures. The employees without BIM experience within the project gave their opinions about the key factors leverage the implementation.

3.1.1.2. Third phase:

In order to provide guidelines for organizational requirements accordingly with proposed BIM adoption strategy for the company, the validation and analysis of the collected data, execution of team and organization assessment should be conducted.

As the first step for the third phase, the collection of the responses approach to understanding the organization readiness of implementation of BIM and as well its BIM Maturity level. The qualitative analysis of interview data as reading the transcripts, labelling relevant answers were concluded. Then deciding which information are the most important, creation of categories, deciding which are the most relevant and how they are connected. Finally writing up the results and presenting them as pie or bar charts.

Therefore, the talent management for the employees and the recommendation of BIM Uses were presented. As the second step for the third phase, strategic goals for the company were developed together with the identification of BIM adoption barriers and paths. Consequently, organization information requirements were recognised and validated for changing the business practise to define the scope of the strategy for BIM implementation for Miastoprojekt Wroclaw.

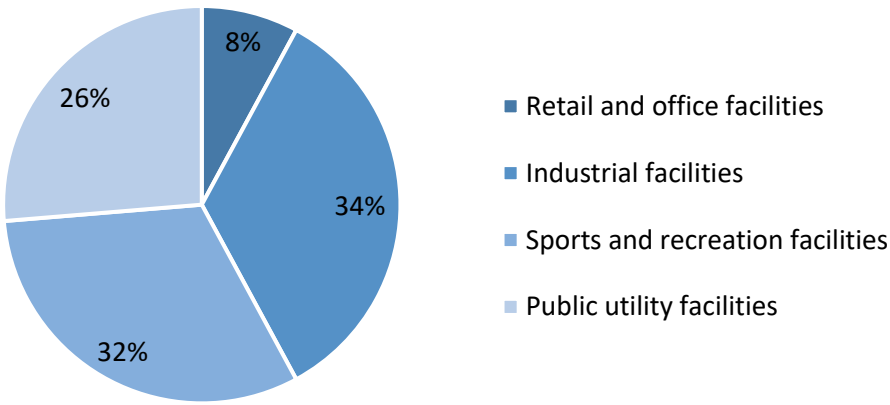
3.2. Company characteristic

In this section, the general company information about types of projects and services, respondents' general characteristics are presented in order to understand the profile of the organisation.

3.2.1. Type of projects in the company

Miastoprojekt Wroclaw as substitute investor mostly provides project management service for private Investors of construction investments (74%), which mainly includes industrial, sports and recreation facilities as shown in the figure (3.2.1). The little over than a quarter of their realisations stand the public procurement. They provide management assistance in the range from the early stage of planning and design through to the project realisation and final settlement of the investment.

Figure 3.2.1 Pie chart. Type of project realisations in the company.



Currently Miastoprojekt Wroclaw is taking care of two on-going public investments with the obligatory introduction of BIM:

- design documentation for the demolition and construction of a railway viaduct for PKP (Polish Railway Lines)
- construction of the Cross-country Skiing and Biathlon Centre in Jakuszyce

Apart from a comprehensive investment project management within the offer of company are services widely connected with construction investment, as indicated in the figure (3.2.2).

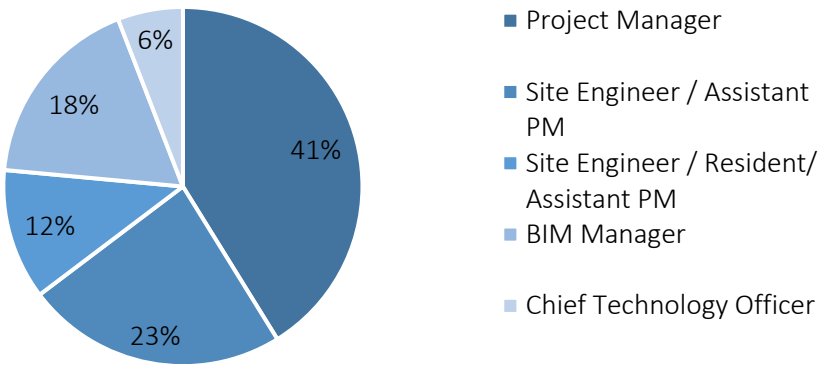
Figure 3.2.2 Bar list. The company's services

Feasibility studies	Technical evaluations	Functional-utility programmes	Design: Concepts, Construction, Tender, Final
Cost estimations	Supervision over the design works	Contract administration	Procuring tenders
Investor's supervision	Cost control and cost optimisation	Risk management	Occupational safety and health supervision
Quality supervision	Technical handovers and start ups	Banking supervision	Investment settlement
Settlement of EU grants	Warranty service	Maintenance	BREEAM and LEED certificates

3.2.2. Respondents general information

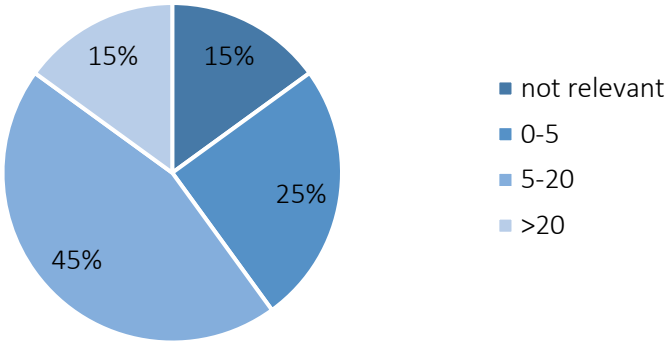
A total of 17 people contributed, from managerial level within the same company on different projects, such as Project Managers, Site Engineers and additional specialists, to provide different viewpoints on the research and to identify a consensus within an organisation. The largest percentage of the respondents (41%) are project manager (figure 3.2.3). Moreover, three BIM Managers (from design and execution stage) were recommended by the Project Manager from the on-going project in BIM – a construction of the Cross-country Skiing and Biathlon Centre in Jakuszyce in Poland.

Figure 3.2.3 Pie chart. Roles of interviewers in the company.



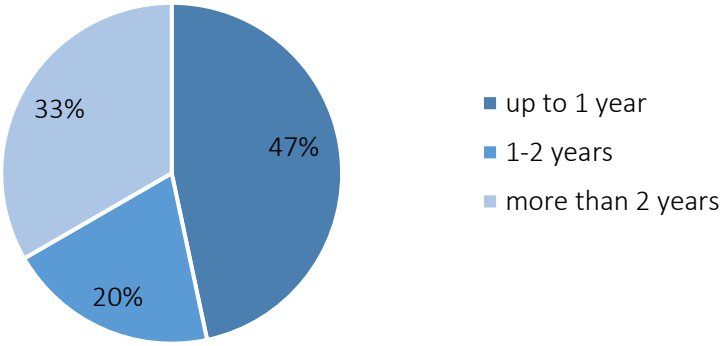
Interviews were mostly focused on the experience based on the latest employee's projects. The number of projects in which employees participated is more or less comparable to the seniority of employees. The largest percentage reported in figure (3.2.4) is 45% of participation from five to twenty projects for Miastoprojekt Wroclaw. However, in this analysis, the specifications of the projects are secondary and not so relevant due to their size.

Figure 3.2.4 Pie chart. The number of projects participated in by employee.



The relatively small seniority, it can be concluded that, in addition to the development of the company by hiring new employees, can give the conclusion that there is a high staff turnover. The most of respondent's years of seniority is up to 1 year (47%) as shown in figure (3.2.5). That might explain knowledge transfer issues or variable readiness for changes and improvements among employees, which are shown further in the results of interviews. Therefore, it might be referred to as a barrier to BIM implementation.

Figure 3.2.5 Pie chart. Employees seniorities.



3.3. Implementation approach for the CDE

The implementation of CDE in the company should start from mapping existing processes and overall assessment of the information management in used platforms, as is presented in figure (3.3.1) Then the requirements or improvements should be listed for considered systems to define proper approach for Miastoprojekt Wroclaw. Finally, in order to provide BIM standards and maintain security of data in CDE, the analyse of cost and resources should be conducted, which is beyond the scope of the dissertation.

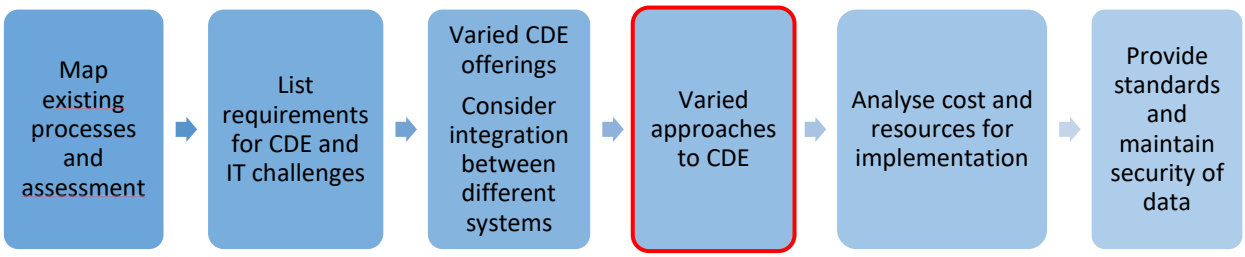


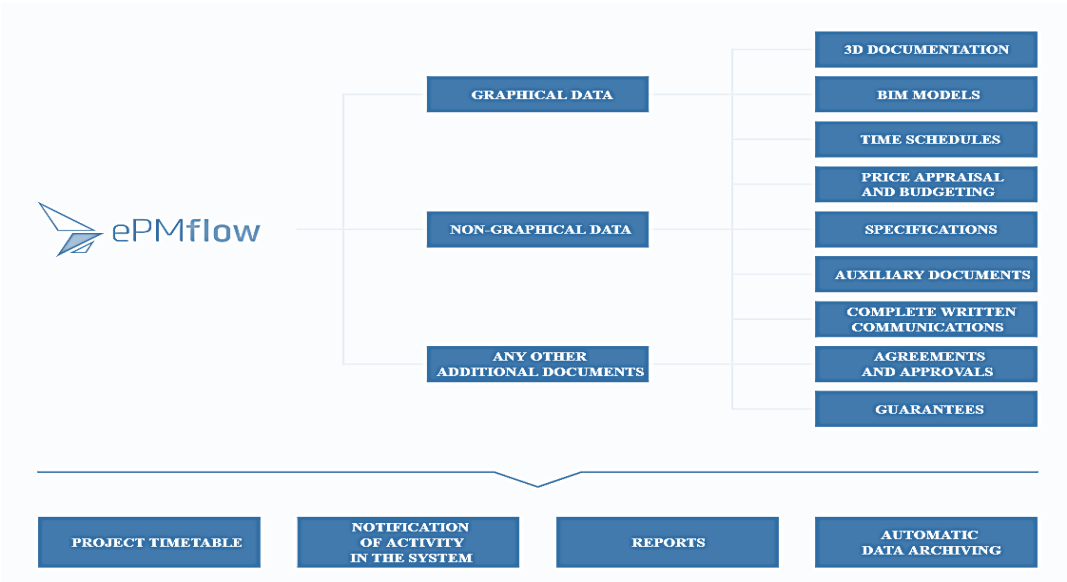
Figure 3.3.1 Recommendation for CDE implantation

3.3.1. The DMS and DCS platforms analysis

During the internship at Miastoprojekt Wrocław, the servers of the existing platforms were modernized, optimised and changed to larger capacities. The whole system is currently transferred and built on polish ePMflow's CDE platform solutions adjusted with the previous requirements of the procedures in the company. The Document Management System (DMS) and Document Circulation System (DCS) are the core, although separated, modules of the platform. The proposed structure of ePMflow's CDE is shown in figure (3.3.2).

The DMS allows arranging the library of the documents in electronic formats, specific to each project accordingly to the desired folder structure. Furthermore, in theory, it enables edition of a document via the system and view of the preceding versions. However, no automatic document change updating was observed in reality. Except that, the DMS has the user's panel with notifications of activities, project timetables and lists of tasks. The DCS provides electronic document circulation along the agreed pathways that allows automatic information flow and accelerate the decision-making process. Additionally, it allows to attach any files to the circulation at each stage by dedicated participants excluding unauthorised changes. Moreover, the DCS provides real-time monitoring of circulation status and time detection reports on development of individual participant.

Figure 3.3.2 The ePMflow's CDE structure (ePMflow,2020)



The whole platform solution facilitates users' communication by allowing real-time access to the documentation from any location via the Internet browsers. Moreover, it allows the automatic e-mail notifications of events such as, e.g., file posting, review. Besides, the levels of access to data saved to the platform are possible to define for individual users or user groups. The ePMflow system theoretically refers to the CDE principles set out in the ISO 19650 series. However, Miasto Projekt Wrocław does not fully use the platform's potential to handle projects accordingly to the standards. For instance, the information flow does not show the evolution of the processing and approval status of or the moments relating to verifications and coordination. Moreover, information throughout its development is not necessarily assigned with the metadata of revision, status and classification codes.

3.3.1.1. Perspectives from the DMS and DCS platforms analysis

The thorough analysis of types of documents, folder structures, various types of documents circulation (e.g. material acceptance requests, requests for information or change, monthly reports, approval protocols) and procedures on platforms was studied within the granted access to selected projects before the employees' interviews. On the DMS platform, the access was provided to a total of 16 projects (5 of them in progress) as Consumer member from 4 possibilities available, in addition to the designated one, there are Author, Manager and Collaborator. Whereas, on the DCS platform, one archived and five ongoing projects were permitted to preview their various circulations. The observations from the study are presented in the following table (3.3.1).

Table 3.3.1 Perspectives from the DMS and DCS platforms analysis

observations of the DMS platform	observations of the DCS platform
• Lack of consistency in the division and naming of subfolders (mainly in the design folders) • Sometimes to know the internal division, folders (in .zip, .rar) have to be downloaded completely • Repetition of information, subfolders in different places of main folders (mainly risks, financing, project materials) • Folders naming for reports or collisions is not unified (with or without the dates) • File naming is not unified (with either the dates or the revisions) • No clear division into descriptive and drawing documentation, editable and non-editable • No folder division into: WIP, Shared, Published, Archived	• The archive shows a maximum of 100 circulations (unable to view the older ones) • Total time in the archive shows the time from which the circulation was established, not the actual time that the circulation lasted • The time of circulations rejected or suspended is not stopped but continuously runs which gives the gain of the days (more than 60) • Even though the circulations are electronic, their opinion time is usually very long.

3.4. Survey

There were three parts of the interviews. First, a semi-structured segment was performed to analyse the current use of BIM, or VDC approaches, and standard procedures and concerns with information management in projects and used platforms. Second, a summary of the outcomes of the interviews to better explain the analysis to confirm the conclusions. And third, a confirmation of the preceding. And third, a review of the previous results and an in-depth discussion of significant issues with the Chief Technology Officer. The interviews were recorded with notes taken during and after the discussions; these notes included interviewees' observations, responses and documents. Most of the questions asked were open-ended, allowing the respondents to answer freely, without directing them first. There was no limit to the length or quantity of responses because the goal was to thoroughly understand the problems and aspects of the company's processes through different points of view. Then all the answers provided were collected, synthesized and appropriately grouped to create visual charts.

3.4.1. The results of the surveys – advantages and disadvantages of used platforms

3.4.1.1. Advantages and disadvantages of the DMS platform

Respondents frequently reported the technical and functional disadvantages of DMS platform, such as tedious searching for documents, uploading and online work issues, slow system operation, manual authorisation and registering, time-consuming archiving. Furthermore, one respondent reported that from the user perspective is very necessary to create a connection between DCS and DMS platforms. In the figure (3.4.1), all of the grouped responses are presented along with the occurrence's frequency.

Figure 3.4.1 Bar chart. Answers to: 'What problems do you see while using the DMS platform?'

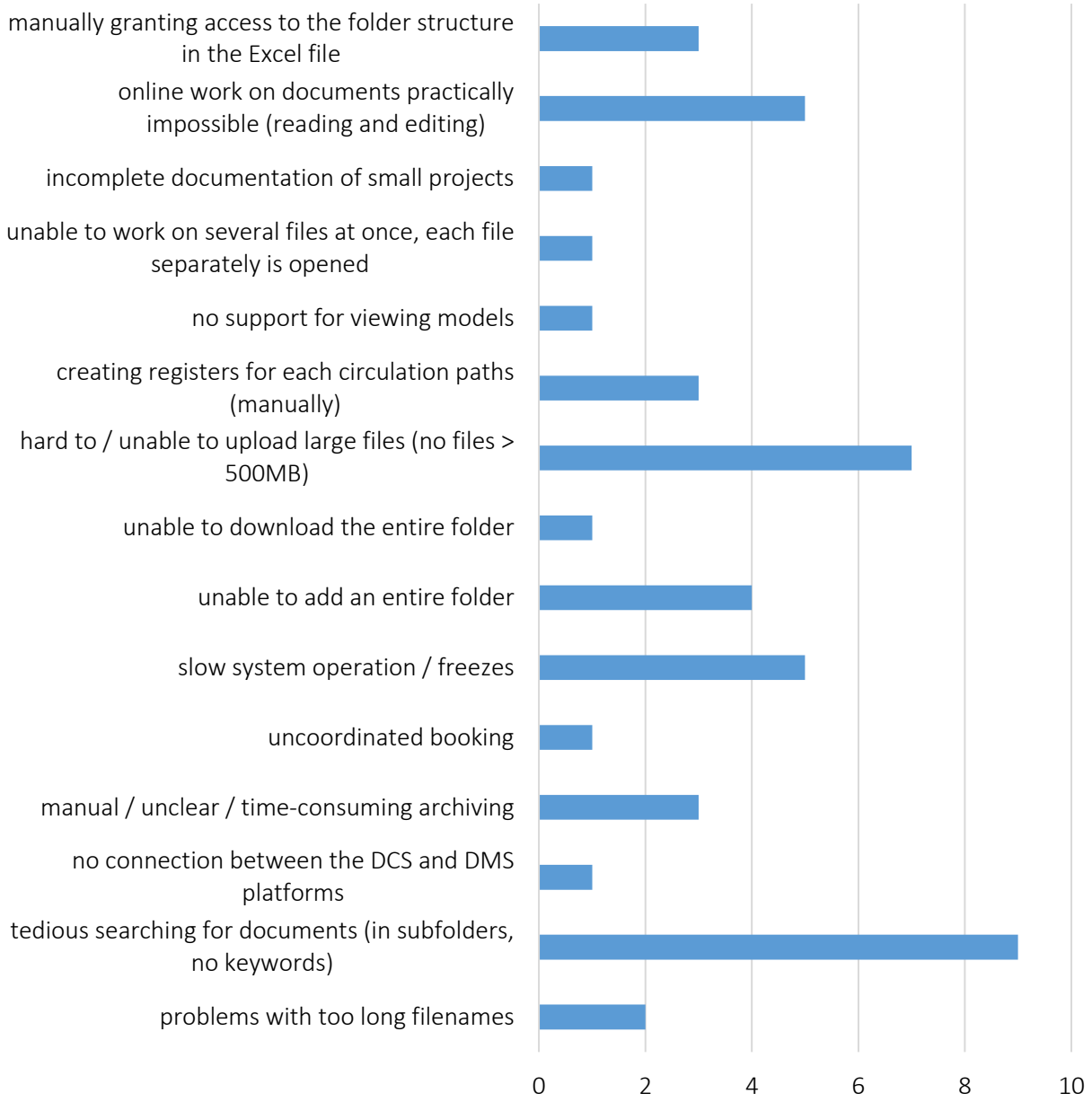
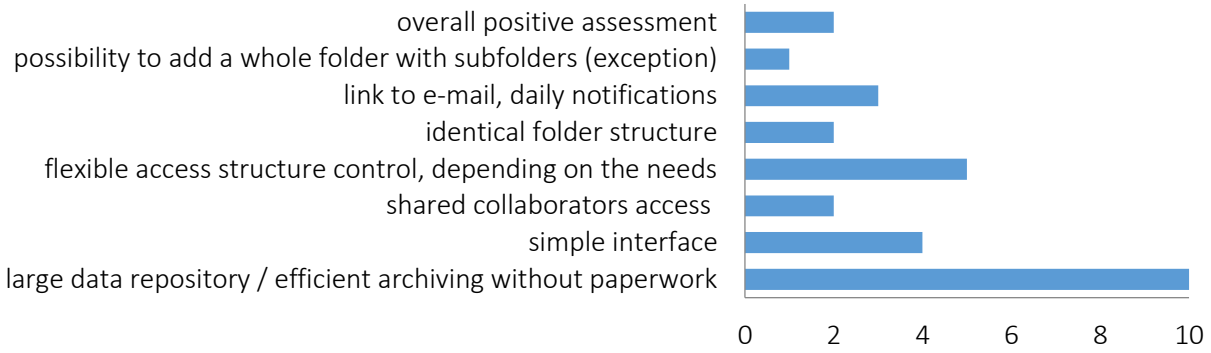


Figure (3.4.2), concludes the main benefits of the DMS platform from the users' perspectives: large data repository with efficient archiving without redundant paperwork. Furthermore, the platform has a simple interface and flexible, although manual, access structure control depending on the needs.

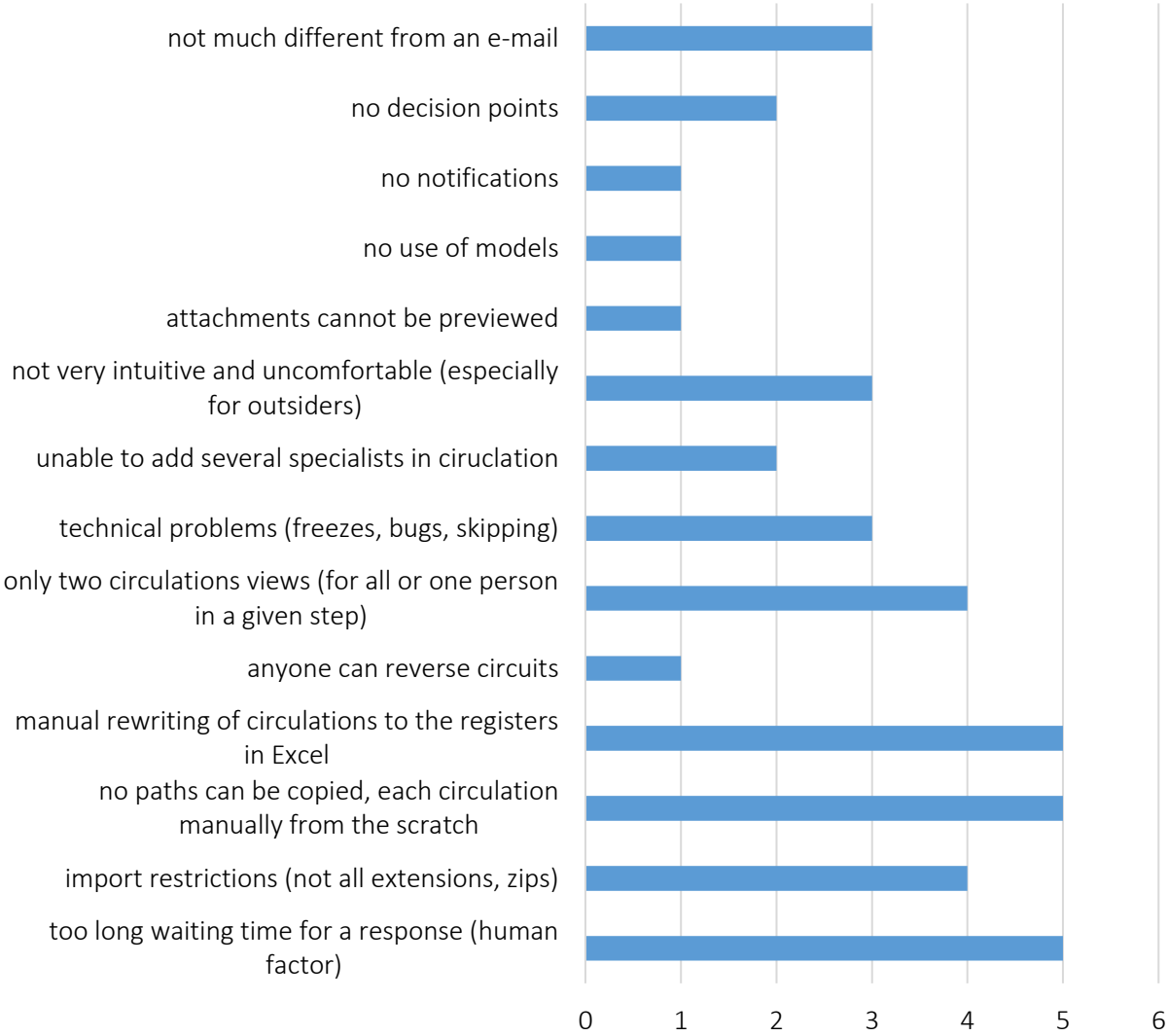
Figure 3.4.2 Bar chart. Answers to: 'What are the advantages of the DMS platform?'



3.4.1.2. Advantages and disadvantages of the DCS platform

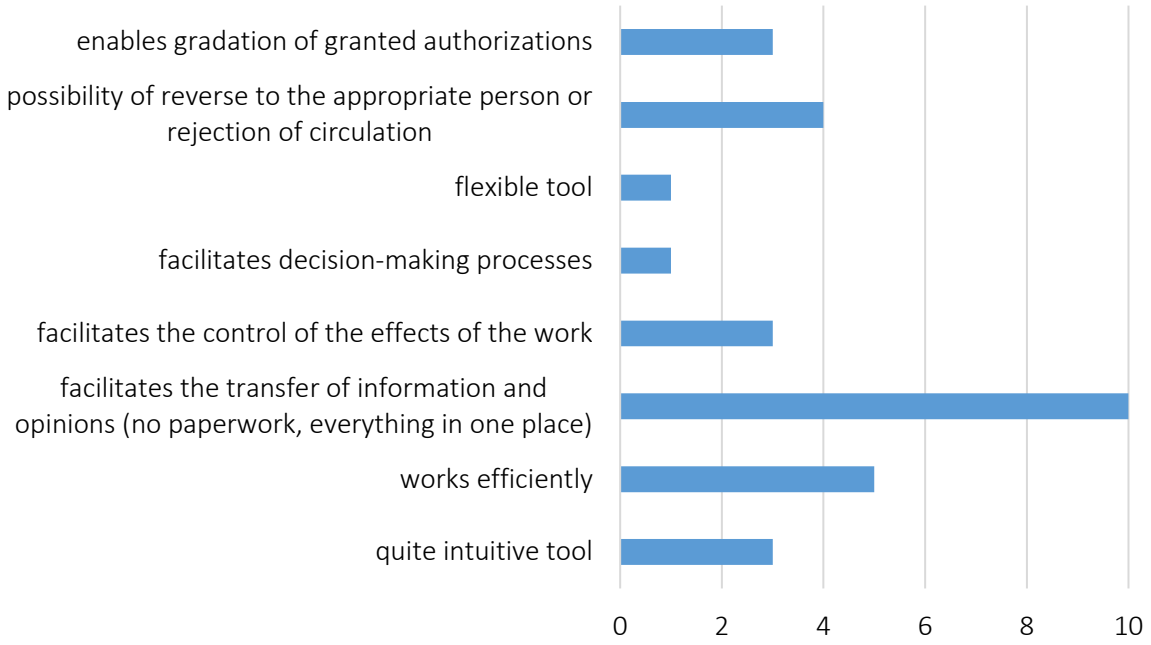
As shown in figure (3.4.3), most of the respondents reported automation and technical problems within the DCS platform, such waiting time issues, manual (re)construction and registering of circulations, slow and not intuitive system operation with similarities to an e-mail.

Figure 3.4.3 Bar chart. Answers to: 'What problems do you see while using the DCS platform?'



The figure (3.4.4) presents the different advantages of the DCS platform. The most common answer is facilitating the transfer of information and opinions through different types of created circulations without the redundant paperwork, all located in the one accessible and authorized place.

Figure 3.4.4 Bar chart. Answers to: 'What are the advantages of the DCS platform?'



3.5. Observed Problems

In this section, the findings and results of the interviews are discussed and presented as bars or pie charts. First, the general problems with the platforms are listed. Second, the observations about the information management in platforms are described accordingly to categorised issues. Then the conclusions from observations contributed with Information Management Maturity assessment and proposals for platforms improvements. Finally, further research is suggested.

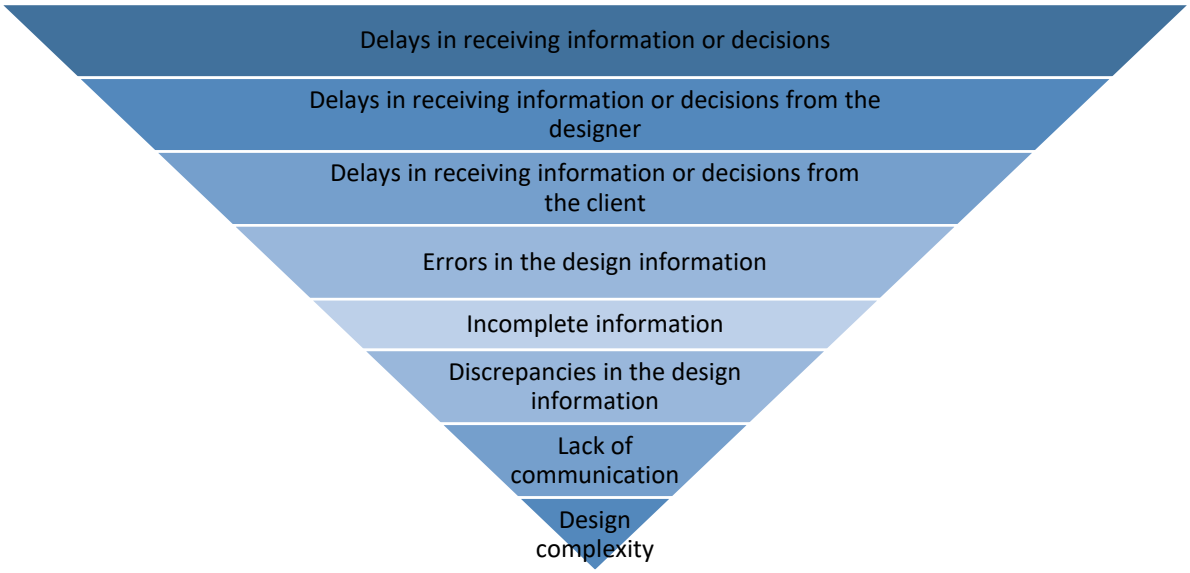


Figure 3.5.1 Inverted pyramid list. The most significant issue within the project.

Project Managers and their assistants mostly identified the schedule delays as the most significant issue within the project. The issue is measurable because it provides long lists of causes for schedule delays, as shown in the figure (3.5.1).

3.5.1. Observation of the information flow -interviews

Workflow observations and interviews showed several problems that employees had experienced with the design information. For instance, time spent on identifying relevant information and distribution of data. Moreover, the structure information found in company's platforms can be implicit, ambiguous, missing, outdated over many documents. Information issues have many aspects which need to be considered to resolve them. The quality of information should, therefore, be understood from the information user's viewpoint (Strong, Lee and Wang, 1997). There are nine types of design information issues faced by professionals during the planning and implementation, such as access, coordination, correctness, distribution, format, handling, precision, relevance and volume (Fischer, 2006). The quality and management of information depend mainly on chosen technologies, organizational processes and procedures which produced better information.

Similarly, information management issues from the Substitute Investor has been grouped as presented in the figure (3.5.2). Later the practical problems within each category were elaborated accordingly.

Access	•Effort required to access design information
Coordination	•Consistency of the coordination procedures among all of the disciplines
Correctness	•Extent of missing, incorrect, or outdated design information
Distribution	•Distribution of the design information to relevant receivers
Format	•Flexibility of the design information medium
Handling	•Effort to transform or update information regarding work tasks
Precision	•Representation of actual and accurate working
Relevance	•Timing of information flow on the project
Volume	•Qantity of documents, files, and other media

Figure 3.5.2 List of the categories of design information problems. (Fischer, 2006)

3.5.1.1. Access

Access to the design information is quasi problematic, regardless of whether the drawings are digital, physical or found in BIM models (only at two projects). The most up-to-date set of physical drawings for a construction project is traditionally located at the site office. Therefore, it can be challenging to identify the current version and to retrieve the complete and updated information. The digital documents are available within the DMS platform for the intended stakeholders. It is an innovative solution which helps to gather required information for the project in one dedicated repository. However, figure (3.5.3) shows that information access is problematic within CAD files or minor issues. Moreover, for information requests, there are specially created circulations on the DCS platform, which

is the project-specific web site often accessible to the General Contractor and the designers but not always available to the subcontractors.

Figure 3.5.3 Pie chart. Answers to: 'Is the information accessible by the intended users?'

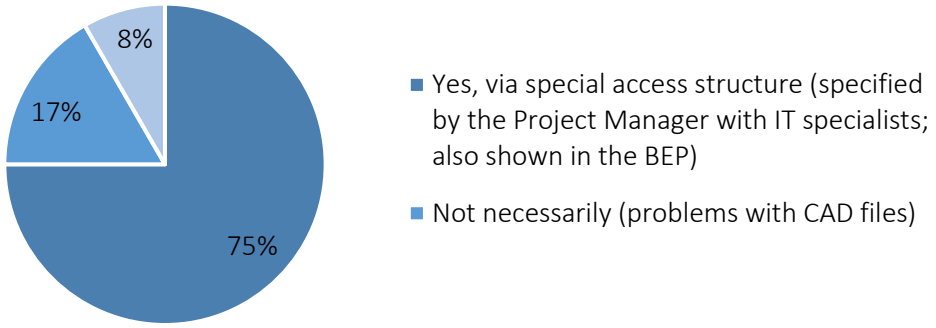


Figure 3.5.4 Pie chart. Answers to: 'Is the authorised access to the content identified?'

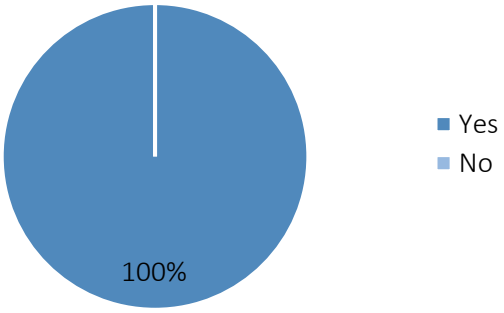
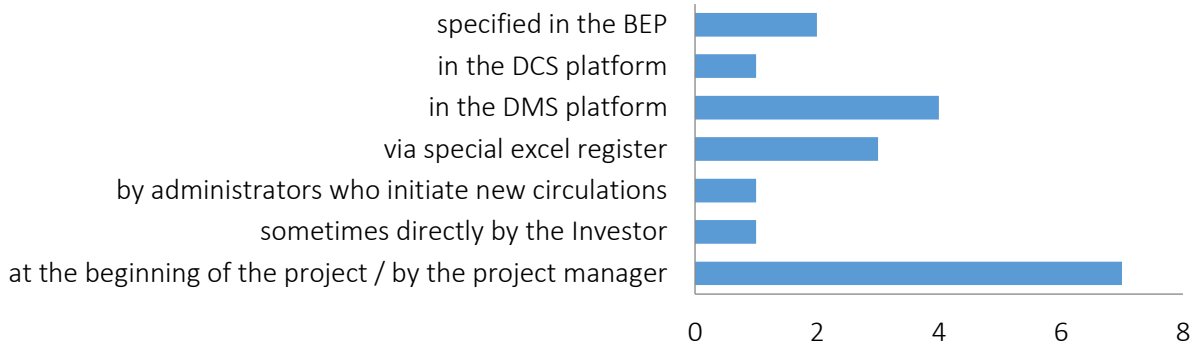
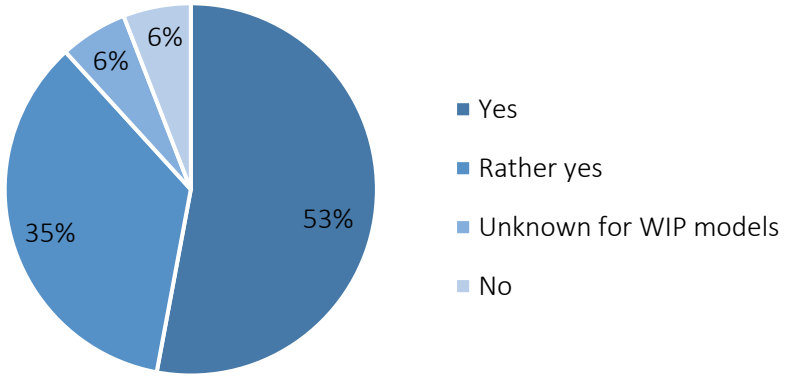


Figure 3.5.5 Bar chart. Answers to: 'How or where the authorised access is specified?'



According to all interviewees, the authorised access to the content is identified as presented in the figure (3.5.4). Figure (3.5.5) highlights that the authorisation to platforms is given at the beginning of the project with the particular graphical access structure (register in Excel) manually created and decided by the Project Manager. Then is sent to the IT Administrator for performance and completion. Through the project, the access structure might need some manual updates due to the expansion of documentation or changes among stakeholders. This process is time-consuming and can cause some delays on the project site, especially when the access to information is invalid or incorrect. However, as shown in figure (3.5.6), most respondents claim that protection from unauthorized activities within processes on platforms is sufficient or preferably sufficient.

Figure 3.5.6 Pie chart. Answers to: 'Is protection from unauthorized access, distribution, and deletion sufficient?'

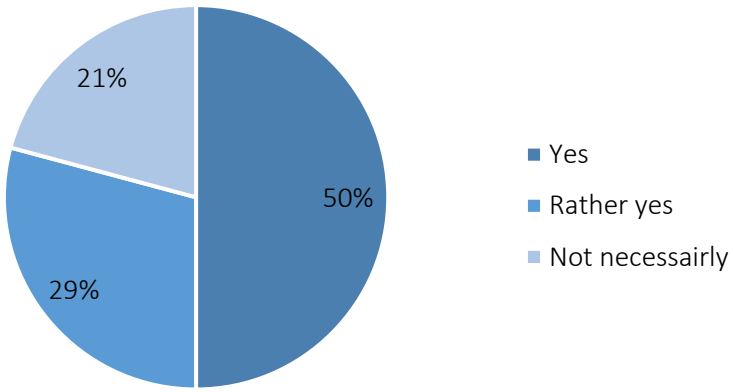


3.5.1.2. Coordination

Coordination is the primary criterion for determining information quality and requirements to execute a specific task in a given context (Fischer, 2006). To avoid collisions among building components, system coordination, conflict detection or constructability review is carried out. Uncoordinated design documents and collisions in buildings are issues usually found in practice based on 2D drawings. The fundamental BIM and VDC methods for coordination through clash detection and coordination meetings are limited to two projects in the company. Coordination issues are often caused by various design disciplines, which do not coordinate their designs with each other.

The information in its life-cycle can be in states: created, stored, accessed, used, organised, integrated, maintained, retrieved, disposed. Miastoprojekt Wrocław developed some basic processes and activities for information management according to interviewees in figure (3.5.7) and (3.5.9). However, 41% of respondents (figure 3.5.9) reveal that some of the procedures should be shortened, because of the lack of proper division or specification following the scale and needs of various projects.

Figure 3.5.7 Pie chart. Answers to: 'Are there all activities where information is created or captured?'



Figures (3.5.8) and (3.5.10) demonstrate where and how the information is created or organised in the company's processes according to employees. Contextual description and required controls of the information need are specified in the Project Book or BEP and its attachments. As illustrated in figure (3.5.8), the main activities are correlated with regular and daily document preparation. However, in BIM realisation the simple information integration occurs with use of WIP, federated and ultimately AIM models. Besides, more types and schemas of the circulations path in DCS platform should be developed according to figure (3.5.10). However, some of the interviewees accented lack of rigid rules for information management or technical problems which may be caused by different documentation standards within the projects. Moreover, the technical problems within the platforms might persist in the organization and maintenance of information.

Figure 3.5.8 Bar chart. Answers to: 'What are the activities where information is created or captured?'

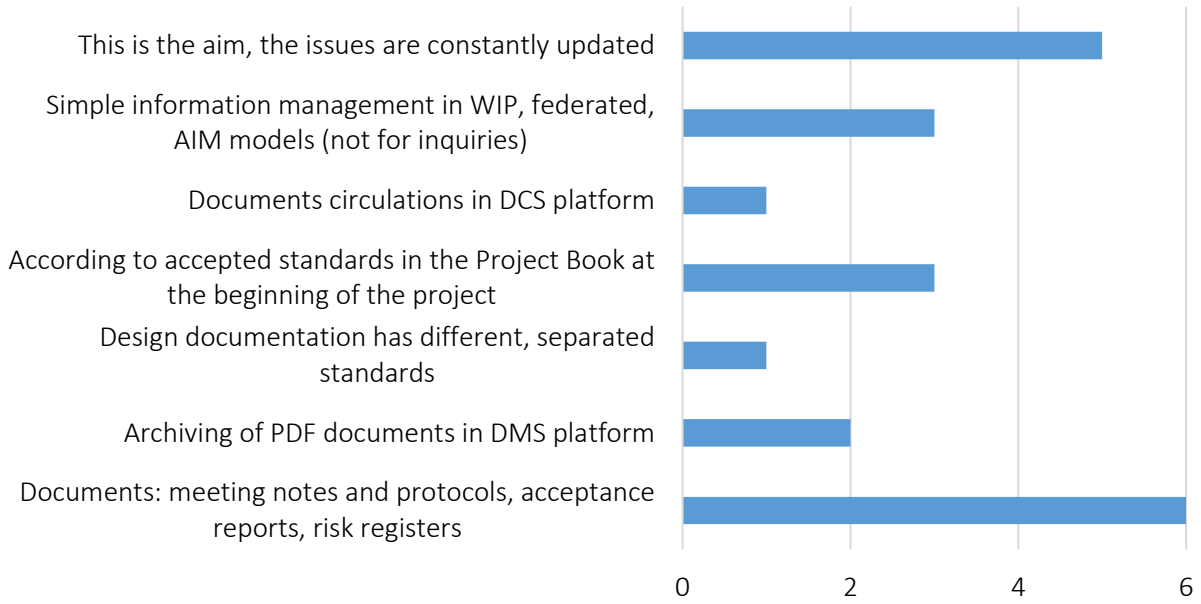


Figure 3.5.9 Pie chart. Answers to: 'Are the activities broken-down only if they are not repeated?'

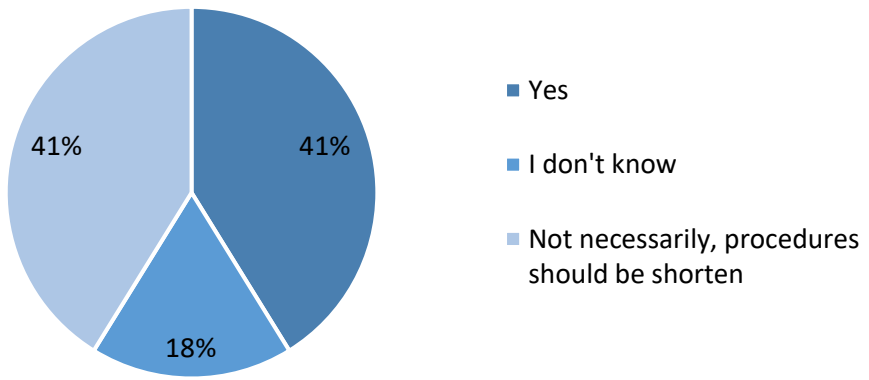
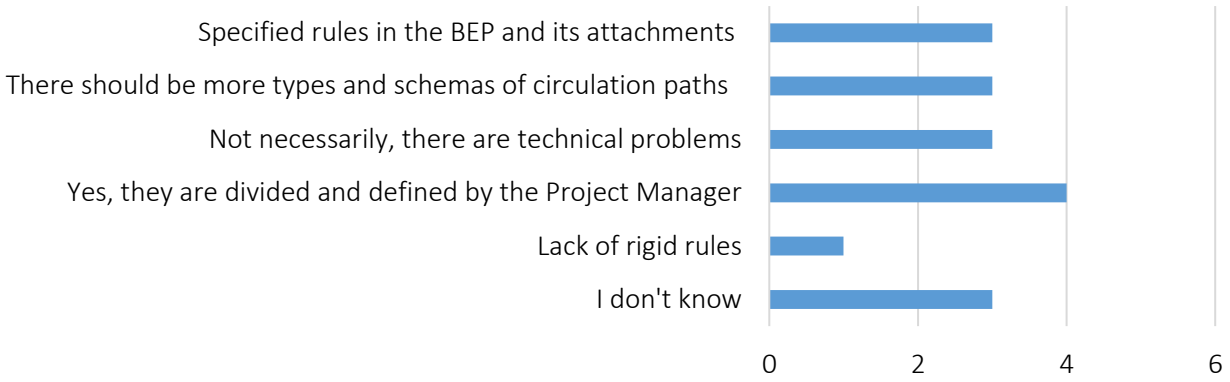


Figure 3.5.10 Bar chart. Answers to: 'Where are the activities broken-down only if not repeated?'



3.5.1.3. Correctness

Request for information procedure is instead followed within the circulation in the DMS platform to achieve fast- track process for correct information accordingly. However, the average time for each circulation is around 10-14 days. As shown in figure (3.5.11), most of the respondents (76%) state that crucial information lifecycle steps are identified. However, in BIM models, documents, specifications or drawings the issues with the accuracy of the design details are expressed as incomplete, obsolete or profoundly incorrect information. Often the data is not approved by regulations or best practice and change quicker than updating the correct file. Another reason why the information is redundant is 'copy-paste' style, in which pieces of older projects are reused. The state of content, originator and creation time of information should be authentic through the procedures. Figure (3.5.12) highlights that the essential roles for the information lifecycle are defined by manually at the beginning of each with different types of access and as well via updates in the Project Book.

Figure 3.5.11 Pie chart. Answers to: 'Are all the essential steps for the information lifecycle identified?'

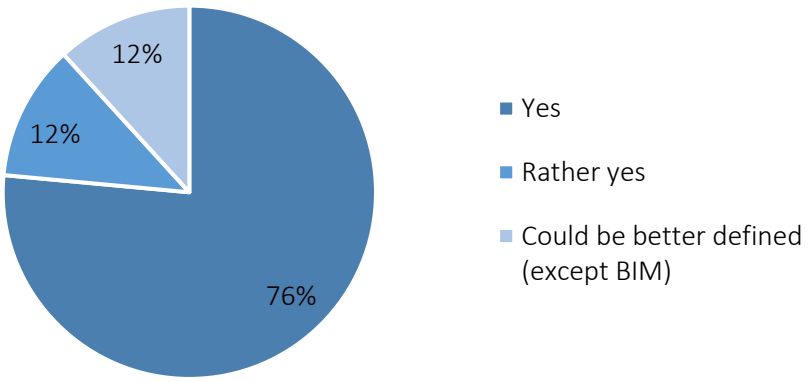
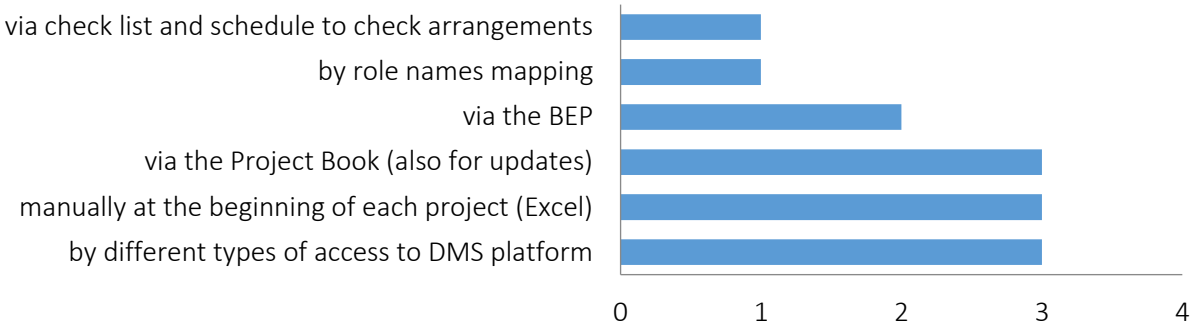


Figure 3.5.12 Bar chart. Answers to: 'How the essential roles are defined?'



3.5.1.4. Distribution

The distribution and the content are specified by Project Manager in the Project Book and within the circulation schemas as shown in the figure (3.5.13). Moreover, within the BIM projects, the British Standards are referenced in BEP for graphical and non-graphical documentation specifications. Over 70% interviewers claim that standards can describe input and output information according to the figure (3.5.14). However, half of the respondents claim that procedures and rules are not necessarily clearly described or written down, and they need to be each time adapted to project (figure 3.5.15). It seems quite applicable to required documents in on-going BIM projects, which were defined from scratch by external experts. Furthermore, the organizational rules are more less adjusted within the folder and file structures or authorised circulations for specific projects. Distribution problems are time-consuming.

Figure 3.5.13 Bar chart. Answers to: 'Where standards clearly define the content that represents input or output?'

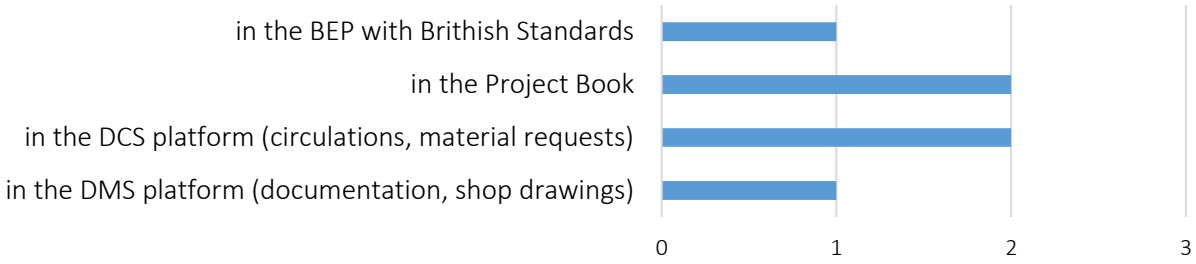


Figure 3.5.14 Pie chart. Standards describe answers to: 'Can the input and output information?'

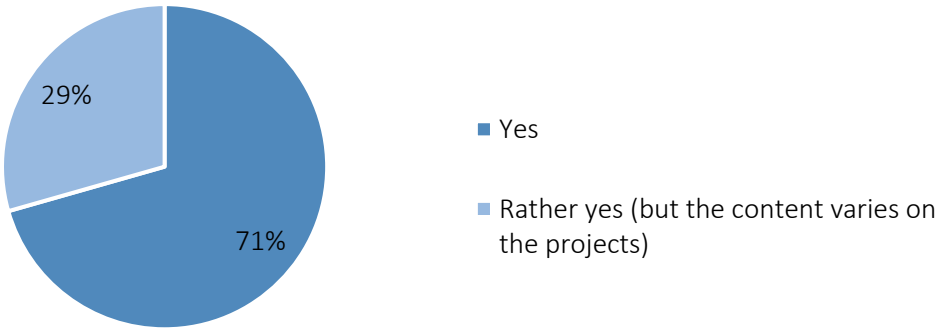


Figure 3.5.15 Pie chart. Answers to: 'Have procedures and business rules been clearly defined?'

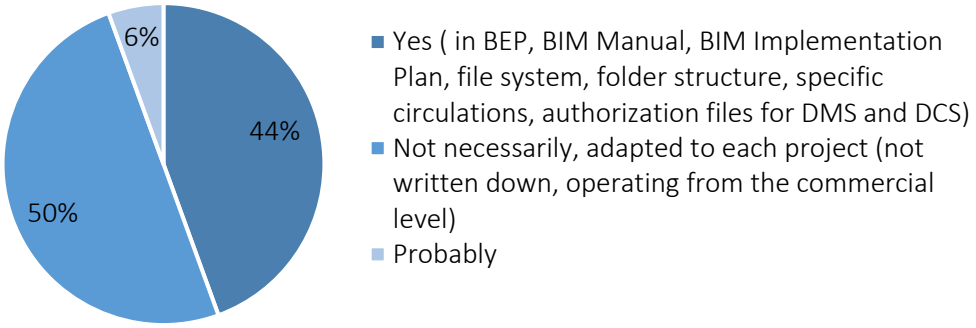
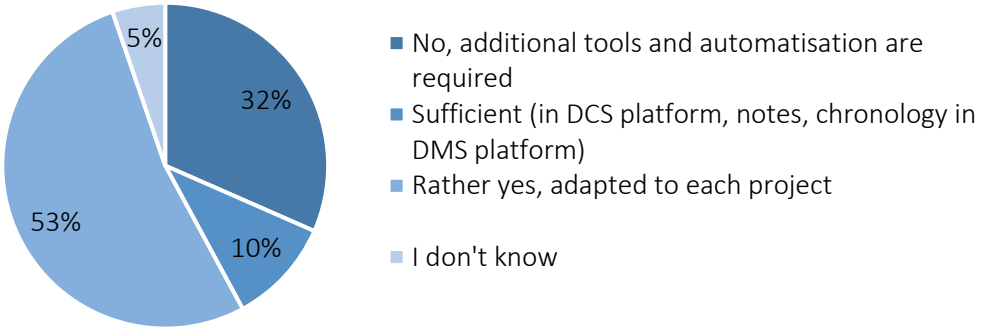


Figure 3.5.16 Pie chart. Answers to: 'Do the outputs describe the process purpose?'



Even though most of the respondents answered that outputs are sufficient for process purpose, a large percentage of interviewees (32%) reported that automatization and additional tools are required (figure 3.5.16). For instance, receivers in the circulations are chosen mainly manually or by the role in the process. First, for relevant information, the routing of drawings, RFIs, RFI responses, addendums, submissions and many emails needs to be screened. Stakeholders and employees devote considerable time on that work. Second, there is no interoperability and quick data sharing between the company's DMS and DCS systems. The information must be re-entered or adjusted manually. The interoperability challenge is also linked to the transfer of data between software and later to facility management systems. Figures (3.5.17) present that Microsoft software is mostly used in projects, specifically Excel, as shown in figure (3.5.18). The high score among 3D modelling and BIM software is not so relevant as it only applies to two BIM-oriented projects, among many others in the company.

Figure 3.5.17 Pie chart. Types of software used in projects.

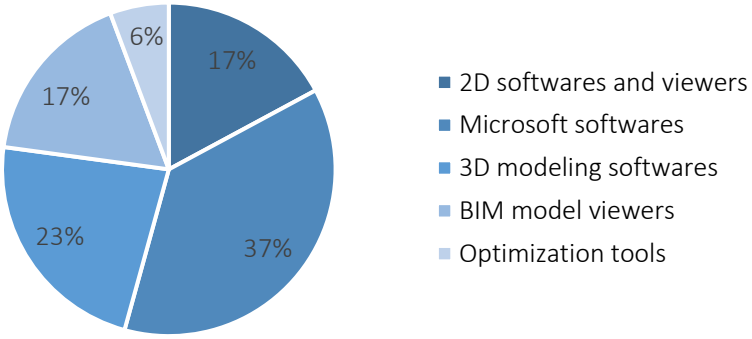
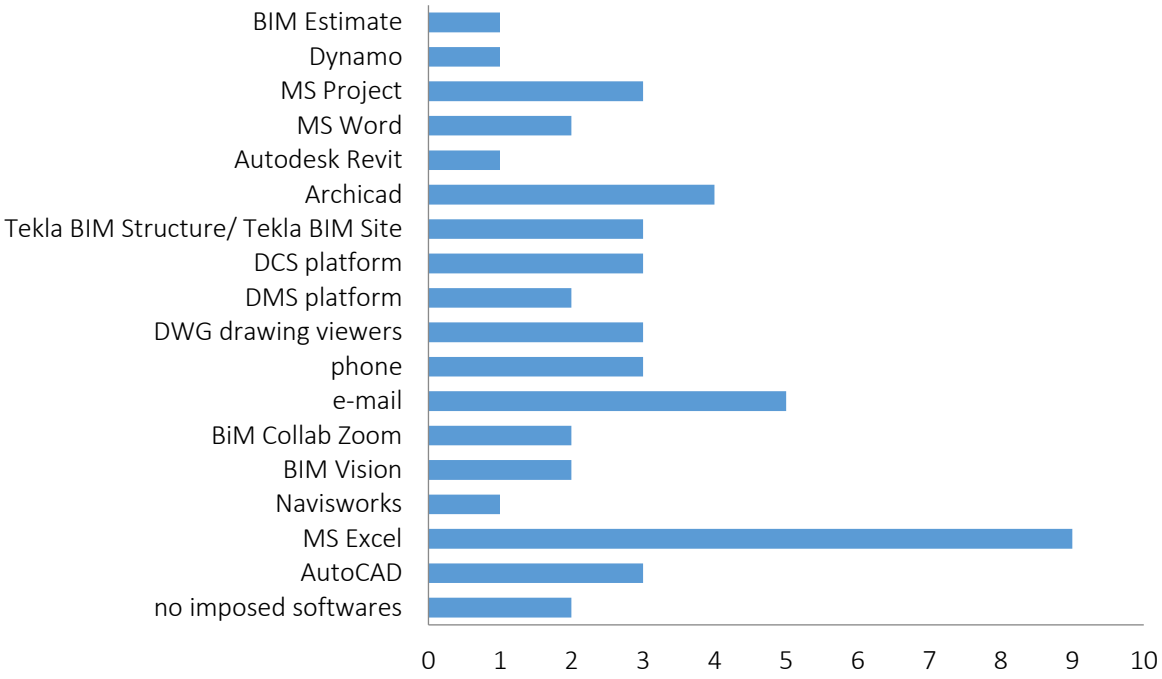


Figure 3.5.18 Bar chart. Answers to: 'Software used during the project.'



3.5.1.5. Format

The format of paper and digital documents varies in each project, and information in databases is distributed among one pre-defined structure, which is not always coherent with the size or type of investment. According to respondents, most of file names and information in the model are unique (figure 3.5.19); however, some while uploaded on DMS do not have appropriate nomenclature. Also, many tasks at the construction site are based on drawings, even though some of the information is generated mainly as 2D documentation when BIM or VDC models exist. The information is distributed, not enhanced with shop drawings or any of the data needed for field installation. Figure (3.5.20) shows that PDF, DWG and editable DOC files are mostly used or created during the projects in the company. Information format is essential: a digital 3D model is more transformable than paper, but digital models are not necessarily superior in terms of ease of locating, transforming and upgrading for employees. Besides, the BIM models in native or open formats are only used on two on-going projects.

Figure 3.5.19 Pie chart. Answers to: 'Are the names of all activities unique in the process?'

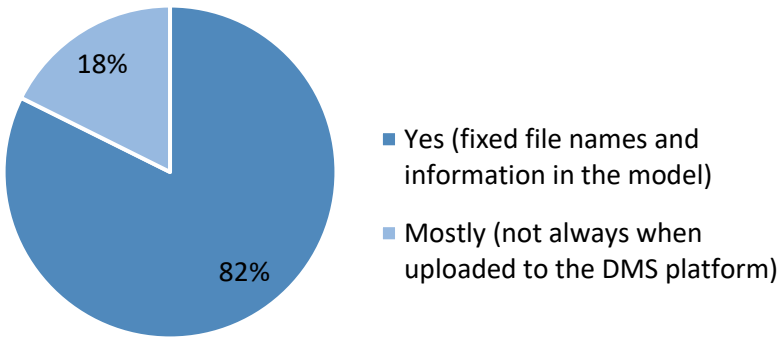
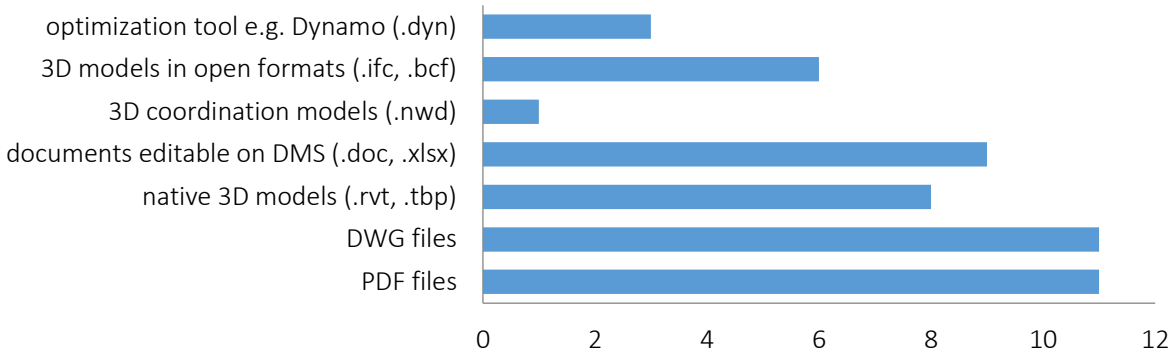


Figure 3.5.20 Pie chart. Answers to: 'Type of documentation used/created during the project.'



3.5.1.6. Handling

Handling is closely related to format, which describes problems with the information medium (Fischer, 2006). In contrast, handling addresses the transformation process, compiling information or changes in the design. Most of the respondents (83%), as shown in figure (3.5.21) claim that the break-down is consistent throughout the process hierarchy; however, do not apply changes in the project. In comparison, the figure (3.5.22) reveals that the break-down is not depth according to the agreed level (33%) or depends on the procedures and employees in the projects (40%). The break-down process is established in the project book or the building project (figure 3.5.23).

Figure 3.5.21 Pie chart. Answers to: ' Is the break-down consistent throughout the process hierarchy?'

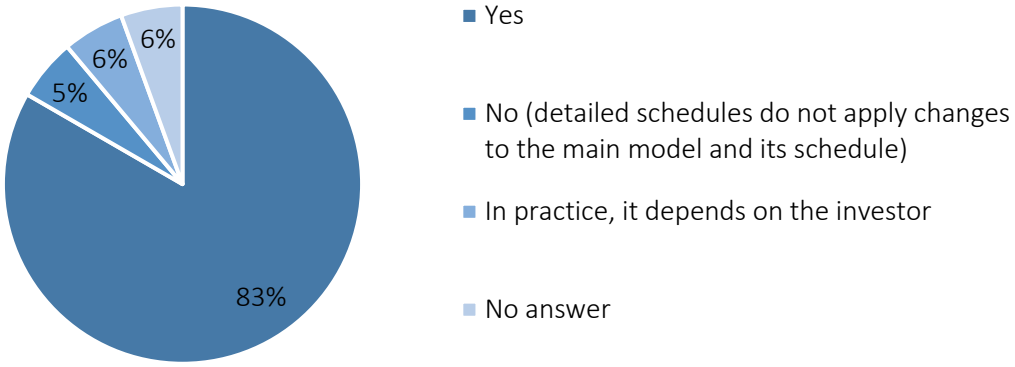


Figure 3.5.22 Pie chart. Answers to: 'Is the depth of break-down according to the agreed level? '

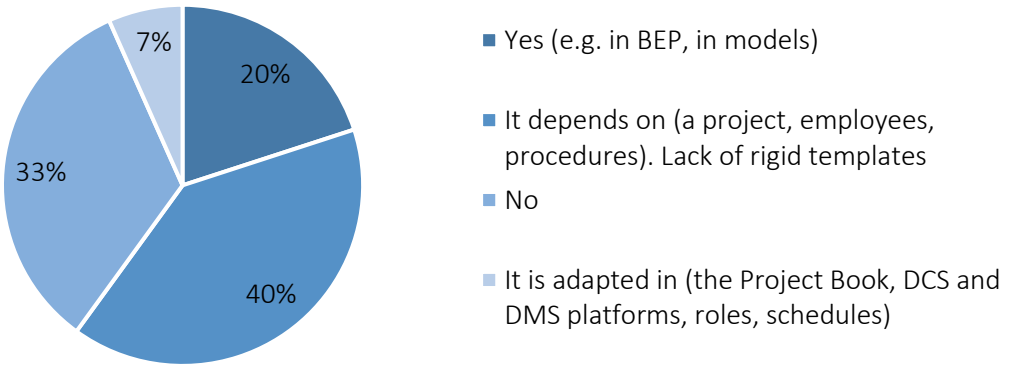
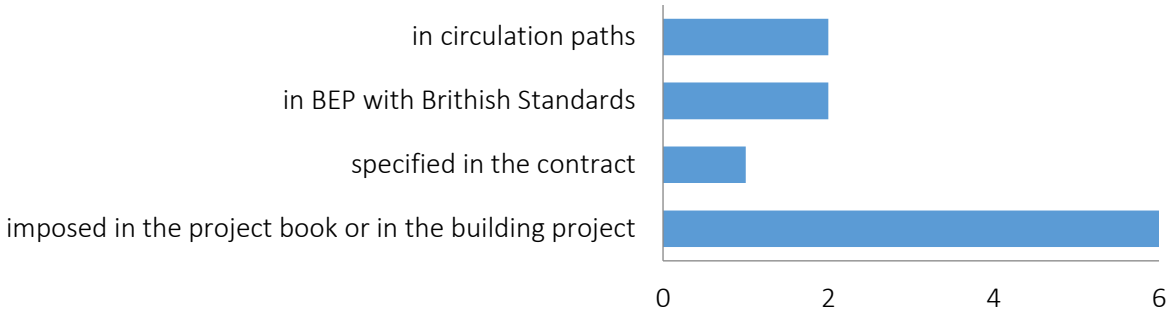
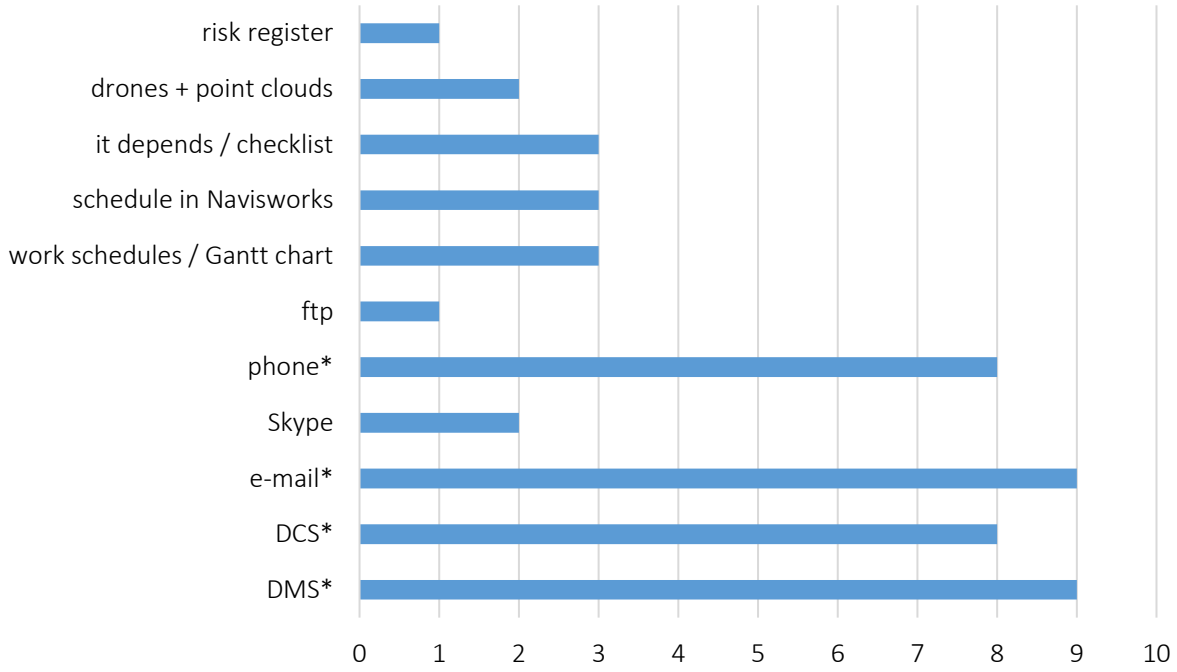


Figure 3.5.23 Bar chart. Answers to: 'Where or how is the break-down of processes established?'



During the interviews, design changes were frequently mentioned as a problem, the difficulty of finding, transforming and updating design data influence on coordination and projects delays. The problem is exacerbated when changes do not include updated drawings and specifications. However, such updates are instead published in addenda and the requests for information answers within the circulations. The respondents listed tools used during the project to handle the information as: DMS and DCS platforms, e-mail and phone (figure 3.5.24). On the company's platforms, there are registers of all of the circulations; hence they are prepared manually. It helps to trace changes to extract the information from RFI answers and add it to the paper drawings manually. However, this technique makes collaboration difficult at later stages. Even with the use of the BIM model, these issues are not addressed directly, especially by using the circulation within the DCS platforms for changes or material requests instead of dedicated built-in tool in 3D software. Furthermore, some of the employees, as shown in figure (3.5.24), claim to use specially created checklists, work schedules or risk registers for tracking milestones and information delivery in project management.

Figure 3.5.24 Bar chart. Tools used during the project.



3.5.1.7. Precision

Precision means detailed and correct data representing real conditions. Documentation, BIM models, and drawings do not always represent correlated data, even though the BIM and VDC methods are used. However, the level of detail and information in most of cases is appropriate for the scope of the project. Problems occur when design remains generic, rather than defining correct and actual measurements, particular products and existing conditions. If a lack of precision is detected too late on the construction site, serious consequences increasing pursue. Precise information requires clear, complete verification procedures, which, according to interviewers, are vaguely defined in the company's processes (figures 3.5.25). According to figure (3.5.26) the validation procedures, nomenclature and structures are adapted to each project and described from the one general template of the Project Book.

Figure 3.5.25 Pie chart. Answers to: 'Are the quality and completeness of the verification procedures identified? '

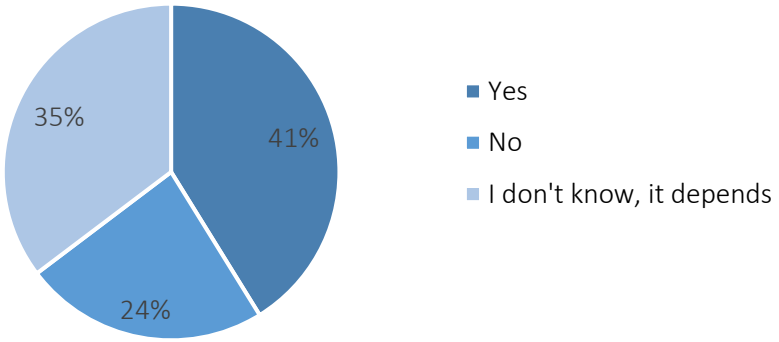
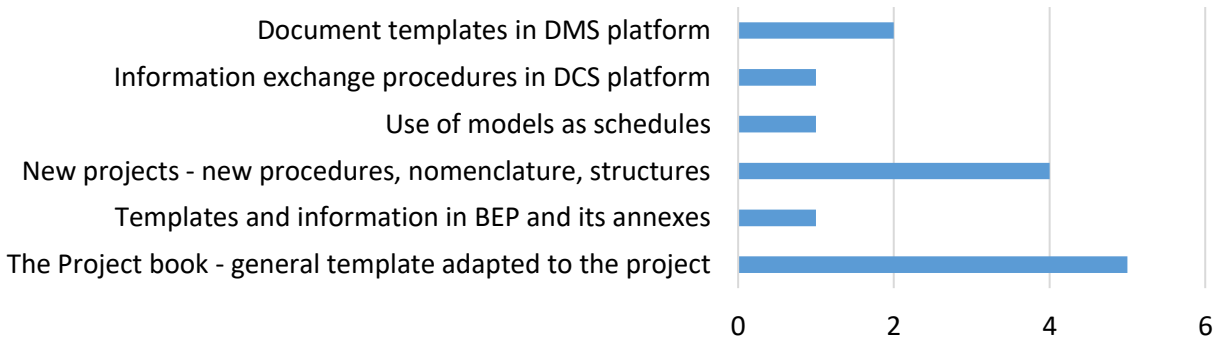


Figure 3.5.26 Pie chart. Answers to: 'Where are the quality and completeness of the verification procedures identified? '



3.5.1.8. Relevance

The relevance of information needs awareness from all stakeholders about the scope and timing of the information delivery. The scope is the subset of design information necessary to accomplish a task, while the timing is the time sequence of delivery of information needed to avoid delays (Fischer, 2006. According to the interviewees (figure 3.5.27), some information is not well-managed throughout the project, and only final files are uploaded on the DMS platform. There are various procedures which depend on the scale and type of project. Figure (3.5.8) reveals that the integrity is crucial for business

purposes (59%); however, some respondents highlight that integrity is instead identified at project level than the company's.

Furthermore, a contractor's informational needs are not always identified at the beginning of the project. The coherence of essential documentation for the company is mainly ensured via the Project Book and document templates with specified fonts or file naming, as shown in the figure (3.5.29 Design information is submitted at the end of each step, though it does not generally serve unique information needs either for general contractor or customer. Where the design information needs clarification, the timing of responses from the client, designer, or manufacturer interferes with and delays the project's workflow. Moreover, the use of the circulation in the DCS platform does not remove the latency issues entirely because of the success response sequences of each participant.

Figure 3.5.27 Pie chart. Answers to: 'Is relevant information managed throughout the project cycle?'

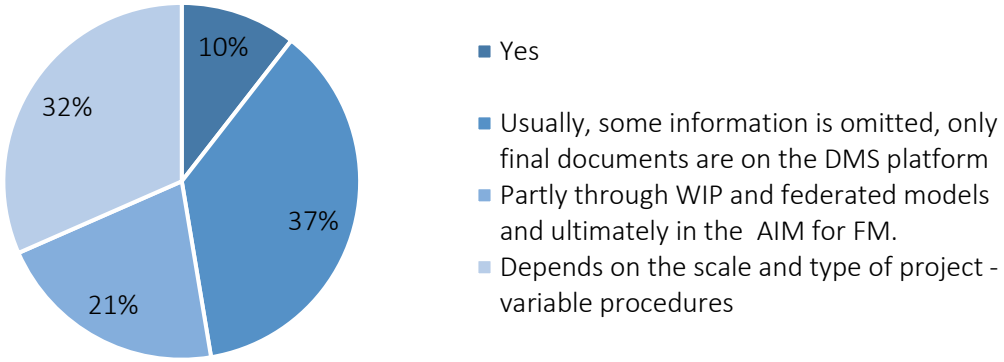


Figure 3.5.28 Pie chart. Answers to: 'Is the record integrity identified if crucial for the business?'

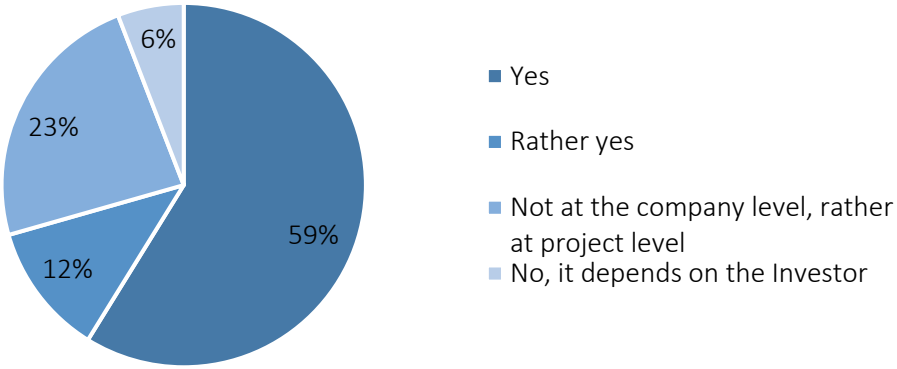
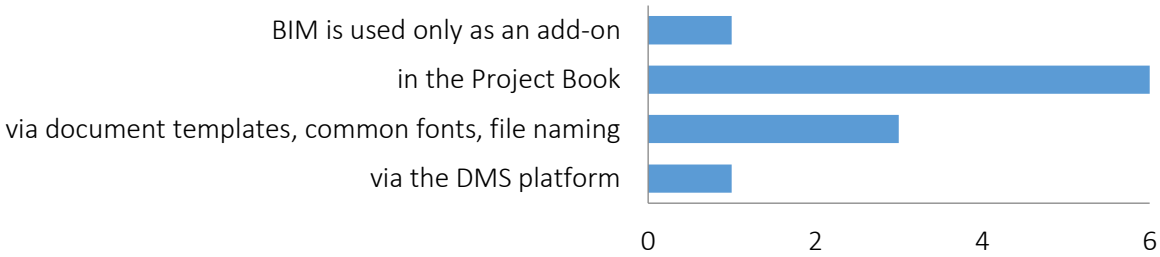


Figure 3.5.29 Bar chart. Answers to: 'How is the integrity of crucial documentation for the company ensured?'



3.5.1.9. Volume

The process of finding the desired information from another project within the DMS platform is time-consuming because most of the cases you need to know precisely where to look for inside the structure. Majority of documents (59%) uploaded do not have entered and defined metadata with keywords or other parameters useful when searching, according to figure (3.5.30). Even though the searching tool is used, the amount of possible results is extensive. Therefore, a general tab for important files is in use, however, rarely. The metadata in models such as parameters and references within BIM projects are the exception (figure 3.5.31).

Figure 3.5.30 Pie chart. Answers to: 'Is the content of the metadata defined and managed accordingly?'

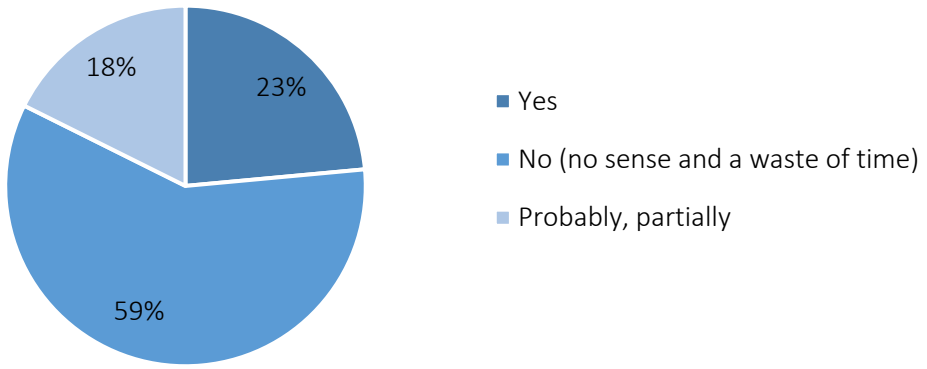


Figure 3.5.31 Pie chart. Answers to: 'What kind of metadata is defined?'

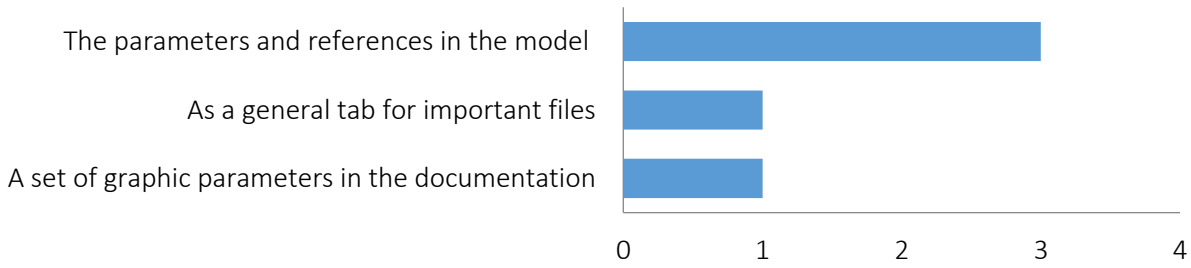
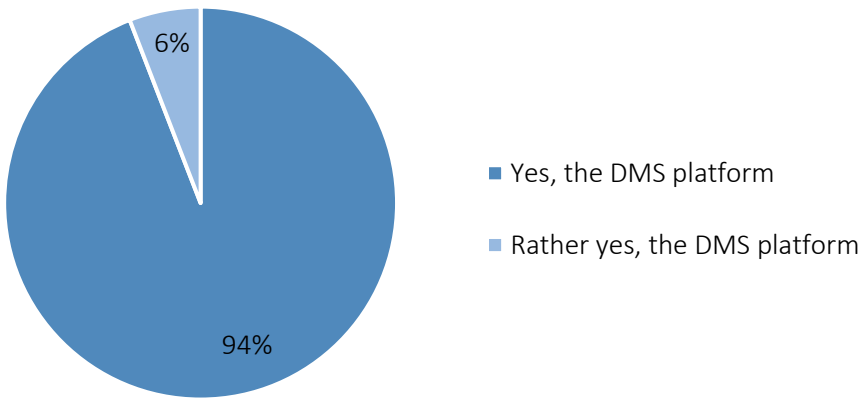


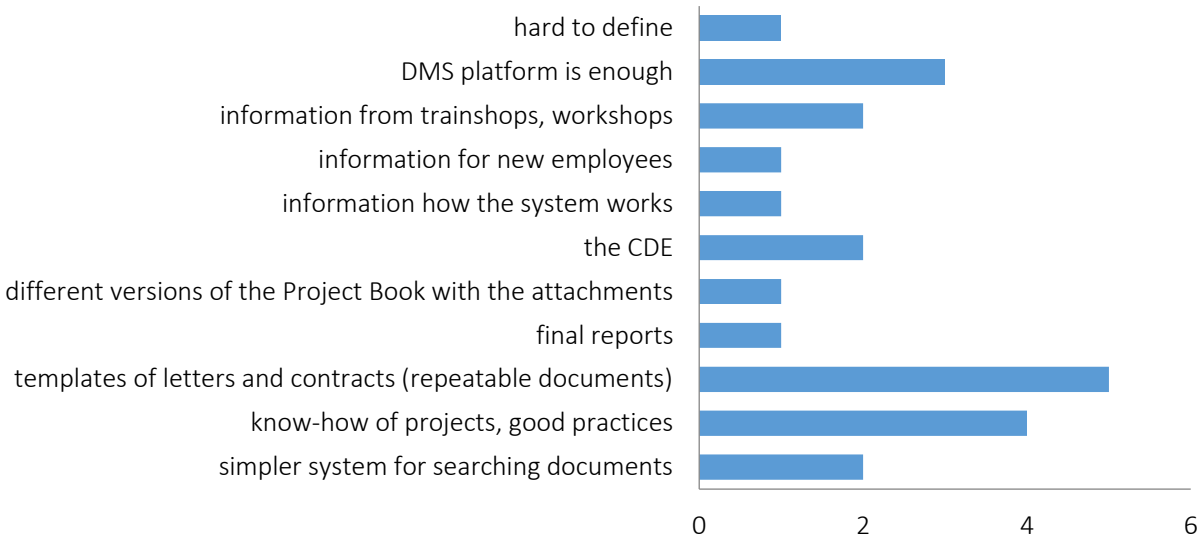
Figure 3.5.32 Pie chart. Answers to: 'Is there a data migration plan for records with long-term value?'



Design information is distributed across a spectrum of media, including documents, drawings, specifications, RFI circulations, addendums. Simply because of the physical or digital volume of information, it is difficult to conceive a clear overview of the project. Therefore, the vital records with long-term value are migrated and stored on the DMS platform in the company, according to 94% of respondents (figure 3.5.32). Nonetheless, the comprehensive view of documentation may be lost as well in BIM practices. The volume of the specifications and number of documentations of the studied projects are enormous, difficult to handle by stakeholders.

Furthermore, the volume of information may cause discrepancies among the subcontractors and a lack of understanding of the scope of work. Consequently, this might lead to assumptions which might be avoided with a properly managed repository. Interviewees stated in figure (3.5.33) that in the current system, there is requirement of more documents template and generally accepted practices with general knowledge transfer of projects, company's processes, trainings or lessons learnt.

Figure 3.5.33 Bar chart. Answers to:' What would you like to have in the repository?'



3.5.2. Conclusion of the observation

The complexity and amount of information determines the scale of the organisation and hierarchies of stakeholders. Advancement in digitalisation means more structured data and ensures connectivity, comparability and creativity(Strong, Lee and Wang, 1997). In the AEC industry, the most common problems with design information are connected with its deficiency and uncoordinated drawings. However, the employees in the Miastoprojekt Wroclaw company stated the information latency and delays in receiving decisions as the significant issues.

The identified categories of information management problems represent guidelines for areas that need improvement within the company's processes and procedures (Fischer, 2006). The interviewees agreed that access, authorisation and availability for intended stakeholders are generally satisfactory. However, distribution, handling and coordination are areas for further improvement. Although, the employees agree on the level of break-down structure of activities in the processes, each time the

procedures are adapted to each project. Project Manager specifies the distribution of the content due to different contractor's informational needs.

Moreover, the significant impact on coordination have as well the effort involved to extract the relevant information. Majority of digital documents uploaded do not have entered and defined useful while searching metadata. Furthermore, the pre-defined structure in databases are not always coherent with the size or type of investment. Therefore, with an enormous amount of documentation, identifying the latest version and obtaining the complete and updated version can be demanding. In order to make data more available and searchable, Miastoprojekt Wroclaw should primarily introduce classification with proper descriptive metadata and information retrieval policies. Then, to exclude underperformance and overload of information, minimal requirements for relevancy and capacity should be specified.

Even though Miastoprojekt Wroclaw developed some basic processes and organizational rules for information management, there is a lack of described rigid rules within the company. The coherence of essential documentation for the company and its validation procedures are mainly ensured via the Project Book and document templates. However, the integrity of information is instead identified at project level than the company's. Although outputs are sufficient for process purpose, some further precise verification procedures are required. Furthermore, some of the procedures should be shortened and automatised in order to reduce information latency. The usability of information is an area for subsequent improvement with both data collection and as well output presentation or long-term storage. Corrective action might define policies and introduce standards for exchange. There is a discrepancy between the quality and completeness of information perceived by employees and externally hired BIM experts. This inconsistency not only suggests different interpretations of the information, but also demonstrates a substantial risk of inadequacy of the information supplied. Which suggests BIM's potential is not being reached. Then it is directly applicable; although the evaluation is based on an existing project procedure, the answers are not in consensus, indicating that verification and accuracy are necessary. Furthermore, precision and correctness need better clarification and audit trail procedure.

3.5.2.1. Information Management Maturity

Quality information is a crucial aspect of asset management in each organization. Moreover, information itself can be considered as one of the most critical assets. The Software Engineering Institute (SEI) created the Capability Maturity Model (CMM) to assess an organization's software and information process. The CMM is similar to ISO 9001 standards (BSI, 2015) which require a minimum level of quality for software processes, however the CMM provides a framework for continuous process improvement.

Figure 3.5.34 Maturity Levels of Information Management CMM (SEI, 2006)

The model represents a five-level evolutionary path (figure 3.6.1) of increasingly structures and systematically more mature processes: Level 1 (Initial) through Level 5 (Optimizing), and evaluates the efficacy of the actions at each level based on assessment of specific areas (Wagenstein, 2006), described in figure (3.6.2). The chosen principles were obtained during the first module - Management of information and collaboration in BIM of BIM A+ is the European Master in Building Information Modelling.

Figure 3.5.35 Chosen principles of Information Management Maturity

Accountability	•documented company policies and procedures
Transparency	•documented policies and business process activities
Integrity	•reasonable completeness, accuracy, consistency, reliability
Protection	•of confidential, classified, essential, sensitive information
Compliance	•applicable laws and authorities regarding information handling
Availability	•criteria for timely delivery of readily available accurate information
Retention - archival	•regulatory and business requirements for information archiving
Disposition - deletion	•laws and policies for disposition of records that are no longer needed

3.5.2.2. Output

The observations in the case study pointed to significant problem areas within the information mismanagement that helps to assess the Information Management Maturity for Miastoprojekt Wroclaw. The Maturity Score is the average of total points subdivided by eight. The overall profile of the Information Management Maturity is summarized in table (3.6.1) and briefly described below.

Table 3.5.1 Information Management Maturity – Miastoprojekt Wroclaw

Information Management Maturity					
Criterion	Initial	Repeatable	Defined	Managed	Optimizing
Points	10 points	20 points	30 points	40 points	50 points
Accountability	10				
Transparency		20			
Integrity		20			
Protection				40	
Compliance		20			
Availability			30		
Retention - archival			30		
Disposition - deletion	10				
Subtotal points	20	60	60	40	0
Total points	**180**				
Maturity Score	**22,50**				

At the **repeatable level**, policies are formed for managing a project to the stage where similar procedures are repeated from successful practices learned on previous projects. Effective project management processes are institutionalized, although the particular processes implemented by the

projects may differ (Smith, 2009). However, there is no formal training or communication of standard procedures. Intuitively defined existing practices are followed, but the responsibility is left to the individual's knowledge, and therefore, errors are likely. Organizations on this maturity level perform essential asset and resource management such as job scheduling, monitoring and reporting. To sum up, Miastoprojekt Wroclaw use repeatable processes, with possibly consistent results, though information management is unlikely rigorous.

3.5.2.3. Proposals for platform improvements

The adoption of current solutions of platform as a Service (Paas) for organization-wide CDE is the best implementation approach for Miastoprojekt Wroclaw. There is no need to change the current offering (ePMflow) into another one, however the integration between the DMS and DCS platforms with the help of provider is worth considering an introduction. After interviews, detailed observations and analysis of the current practices of employees, assessment of information management in the company, the proposals for improvements of DMS platform (table 3.6.2) and DCS platform (table 3.6.3) in accordance of previous conclusions are presented below.

Table 3.5.2 Proposals for the DMS platform improvements

Automation of processes and activities
• Automatic archiving of circulations from the DCS to the DMS (approved and not approved) as registers in the form of a separate file with consecutive names. • The DMS structure should be generated automatically in a graphical form (granting the proper access by the Project Manager or Engineer, from the list of people in the project). • Report automation. Creation of editable reports in only one version and their automatic pdf generation (new date, next revision) to the adequate folders. • A newer version of an uploaded file is automatically saved, and creates and archiving history.
Improving technical functionality
• Different versions of folders structure and their divisions depending on the project type and size. • Improvement of the smoothness and ease of viewing files. • Allowing to upload and download entire folders of files and large files> 500MB.
Integration of platforms and tools
• Linking the DCS and DMS platforms. • Connecting the platform with the phone – introducing an application for a company car booking for hours of use, not days. • Insertion the DMS on the computer's desktop in the form of a folder (like FTP, Google Drive) with the possibility of limiting access to folders to not update everything at once, but only essential and declared information.
Additions
• Introducing the intermediate permission functions. • Creation of a folder with the database of employee experiences and qualifications, documents concerning warranty periods and similar. • Creation of a Lesson Learnt folder with essential documents, final reports, acceptable practices, KNOW HOW materials. • If the DMS is used as the CDE, then the folders should be established as follows: Work in Progress, Shared, Published, Archive. • Decision which types of documents will have metadata entered for better retrieval in the future.

Table 3.5.3 Proposals for the DCS platform improvements

Automation of processes and activities
• Automatic archiving of circulations from the DCS to the DMS (approved and not approved) as registers in the form of a separate file with consecutive names (available from different places) • Automatic naming of subsequent documents. • Automation of paths in circulations by the possibility of repair of the circulation without reversing it and the ability to copy parts of repeating paths • Generating circulations progress reports. Creation of a task – 'to do' lists for documents. • Option to skip someone's step or fill on his behalf information in circulation. • Creation of the own definition of groups of appropriate paths, without the need of change each time with the help of the IT Administrator. Giving more control to the user responsible for creating circulations.
Improving technical functionality
• Proposals for creating additional circulation options as exceptions with filtering options/people • Accelerate the DCS platform charging. • Facilitation of the user's leap between circulations, attaching files from the previous revision. • Shortening the overall response time to 3 days. • Access control within the circulation similar to the DMS platform one, allowing to suspect the entire circulation path with the possibility of partial exclusion of specific materials such as price agreements with changes related to costs, e.g. for subcontractors.
Integration of platforms and tools
• Linking the DCS and DMS platforms for dragging relevant files already existing in the DMS and dropping them inside the user queries. • Automatic reminder about delayed circulation send by e-mail and as well the SMS (with information about someone's delayed time). • Connection with the calendar for the people involved in order to see at what stage is the given circulation. • The e-mail connected with the DCS to automatically pull people's responses to queries in circulations (as a specific button).

3.5.3. Further research

The results of the analysis of interviews in chapter (3.5.1) are presented in charts that provides a quick overview of the company processes and procedures. The graphical representation enables the identification of requirements for design information issues and metrics with divergent responses which require further investigation. Although the charts are a tool that can be used and relevant, further analysis is required to explore the graphic or empirical representation of outcomes. Consequently, the respondents' answers point to potential problems, which are up to the executive department to evaluate their severity and the potential risk.

Further research might help to design information quality for the company in defining how to transfer processes based on 2D documentation into ones based on the model. It can be achieved by evaluating project progress and by defining the discrepancy between the design information needed and the design information provided. This assessment involved user design information, such as contractors, subcontractors and designers, to determine the information criteria about entities and properties and the sequence of deliveries of information. If these conditions could be specified and reported, then

conditions such as importance, quality, performance, performance, and distribution could be automatically assessed. Besides, data from a project information management system may be monitored to quantify access, delivery, and volume of information.

A comprehensive understanding of the causes of delays in schedules and latency in information may contribute to new perspectives on how to avoid them. Standardisation of standard procedures is the way forward for digitisation. Applying corrective actions to project information management to avoid information mismanagement. Miastoprojekt Wroclaw should develop specification of information requirements as contextual description of the information need, function, required controls of the information and impact on business process. Then defining standard controlled vocabularies, methods and procedures before the start.

3.6. Project Delivery in the company

With the current traditional methodology of work in Miastoprojekt Wroclaw, hence digitalised, the most significant commitment and resources are used to prepare the enormous number of various documentation for project's scope, enabling the investment process. In the polish construction industry, new facilities are designed and built every time differently. Most of the company's construction projects are unique because of demand for different design, use of technologies, local building regulations, geographical and geotechnical conditions. Introduction of BIM workflows requires shifting to the development of a digital model of information about a building as a complete source of knowledge about the planned investment for all stakeholders involved in the process.

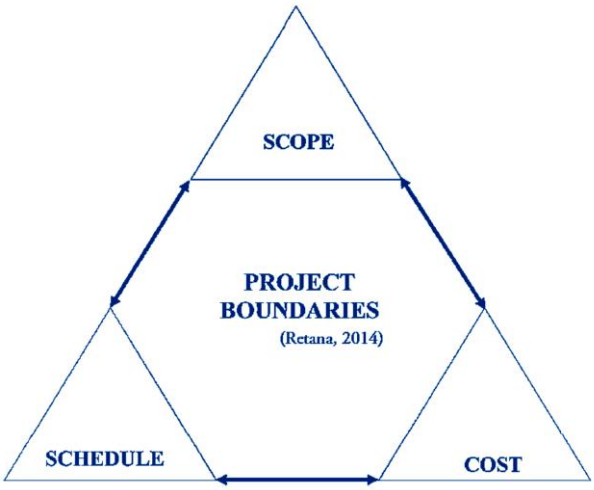


Figure 3.6.1 Project Boundaries (Retana, 2014)

The project management recognizes three project boundary elements such as scope, cost and schedule (figure 3.6.1), which act in tandem with each other (Wagner, 2013 As one boundary element is increased or decreased, the other two elements must behave with increment/decrease unfavourably in order to restore project equilibrium. Scope creep the extension of the scope of the project, for example, by additional work requested by the design problems and modifications frequencies not included within the project schedule (Retana, 2014).

Within this section, the collection of the responses about various investment management approach to understanding the organization readiness of implementation of BIM and as well its BIM Maturity level. The significance of the information due to project management and knowledge are shown within the pie and bar charts in the following chapters (3.6.1) and (3.6.2.). Then the actual use of BIM technology and methods in the company's projects are described in the chapter (3.6.3).

3.6.1. The results of the surveys – management of the project

Each project varies because it presents long lists of issues faced on its site. Figure (3.6.2) shows the main problems mentioned by employees; all of them might cause the schedule delays to vary in length. The answers are based on interviews and help to prioritize lists of issues and focus on the underlying reasons for the identified causes. The critical problems are primarily due to mistakes, incomplete or inconsistent information due to the faulty design information.

According to the respondents, the design errors and the accuracy of the design documents are generally significantly linked and affect the project efficiency and quality. Moreover, the design changes are mostly caused by improper documentation or incorrect decisions. The reworks and the scope creep are the result of error detection, awaiting approval of shop drawings, and delays in procurement due to the documentation's low quality. Furthermore, the design complexity and distribution of information is related to an inappropriate medium for communication. Employees spend an inordinate amount of time for locating, verifying or manually entering specific, updated project information from previous activities. The other of issues faced on the projects are listed in the figure (3.6.2).

Figure 3.6.2 Bar chart. Answers to: 'What are the problems/issues faced on the site of the project?'

Most of the problems are realised during the construction investment directly by employees, during the project meetings or through e-mail, phone notification, as respondents state in figure (3.6.3). These

issues are typically identified by or attributed to an actor who is mostly the general contractor, as shown in figures (3.6.4) and (3.6.5). After noticing the problem, despite information inquiries or digital documentation available on platforms, most of the employees prefer direct contact with stakeholders on coordination meetings or if urgent by phone, e-mail (figure 3.6.5). However, in the project with BIM models, the reports are created.

Figure 3.6.3 Bar chart. Answers to: 'How did you or the project team realize the issue?'

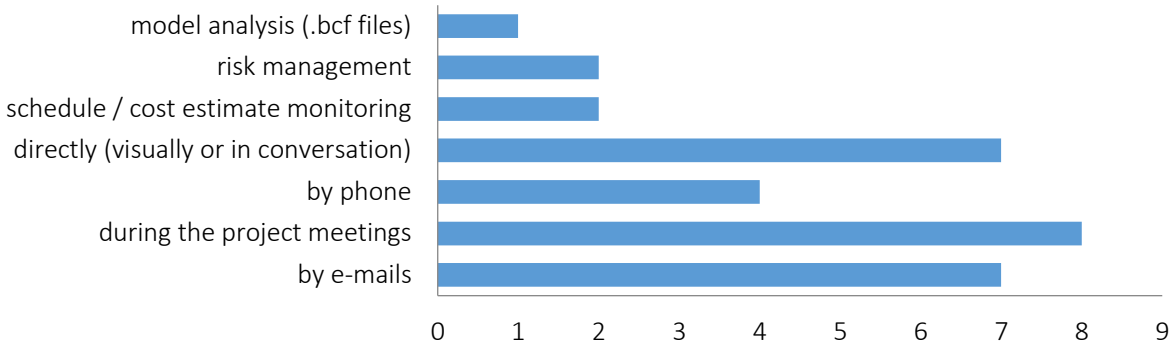


Figure 3.6.4 Bar chart. Answers to: 'From whom did you or the project team come across this issue?'

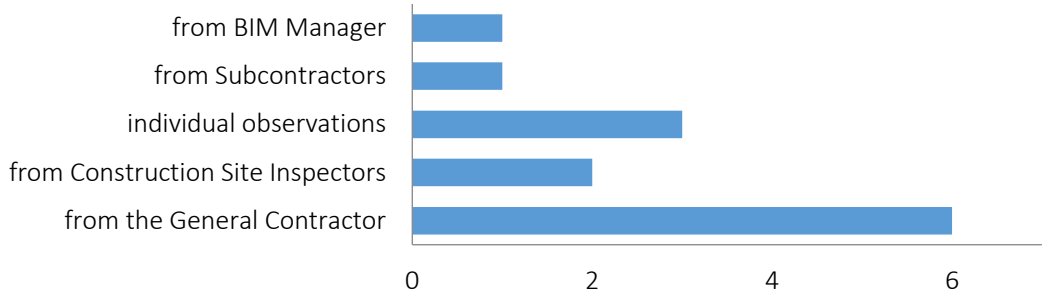
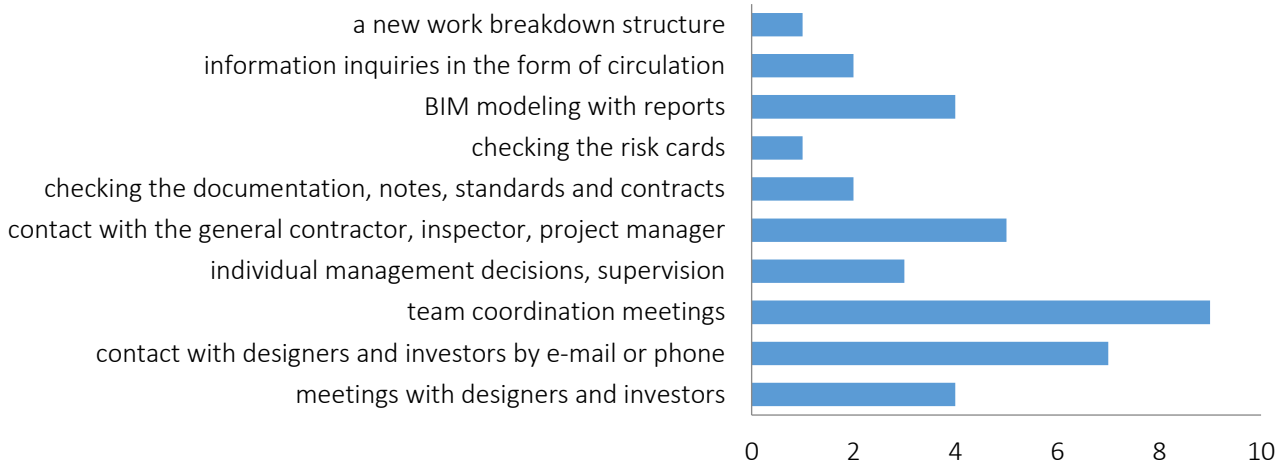


Figure 3.6.5 Bar chart. Answers to: 'What was the first thing that you did to manage this issue?'

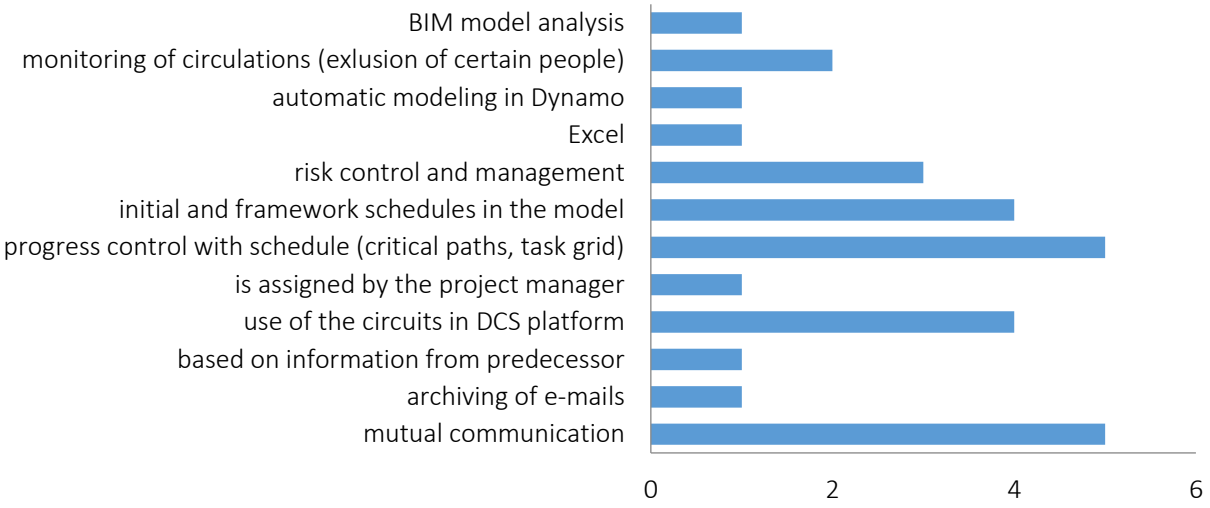


Employees mostly identified the schedule delays as the most significant time-rated issue within the projects. As the solution, the control of milestones in schedule, traditional design and coordination meetings with ongoing conflict or BIM model check, are listed among the other techniques in figure

(3.6.6). Therefore, the main strategies of Project Managers include, as shown in figure (3.6.7) progress control with schedule, mutual communication and framework in the model (within BIM projects). However, some respondents claim that constant monitoring of the progress of circulations in DCS platform helps to select the appropriate remedial actions to prevent latency.

Figure 3.6.6 Bar chart. Answers to: 'What approach do you use to manage the time-related issue?'

Figure 3.6.7 Bar chart. Answers to: 'What is the strategy to manage time-related issues?'



Depending on the severity of the problems, various stakeholders are involved in solving the situation, however the decision-maker and the most responsible person for the investment success is the project manager, who represents investor/client (figure 3.6.8). Among the reported tools to manage problem

are the DMS and DCS platforms, BIM viewers and programs (only in BIM related projects) and schedule analysis, as shown in figure (3.6.9). Correspondingly, the visual evaluation is mentioned.

Figure 3.6.8 Bar chart. Answers to: 'Who is involved in the problem-solving /decision-making?'

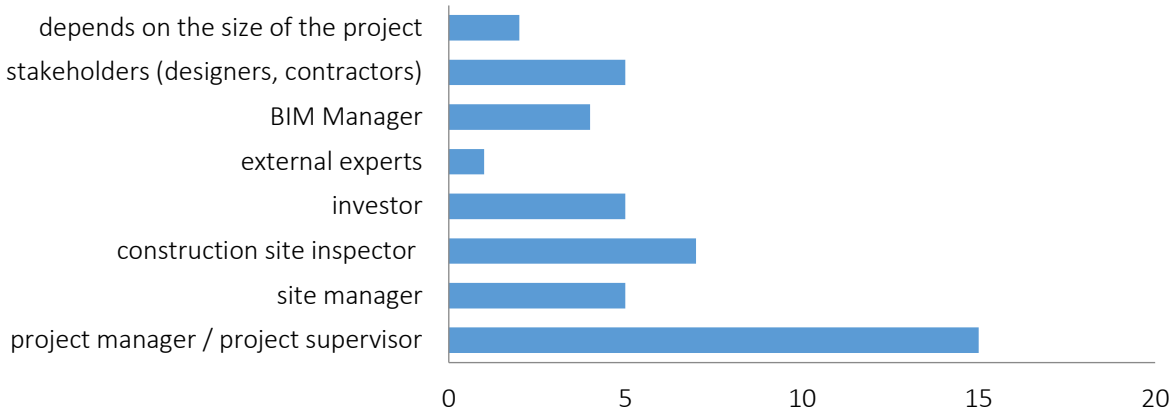
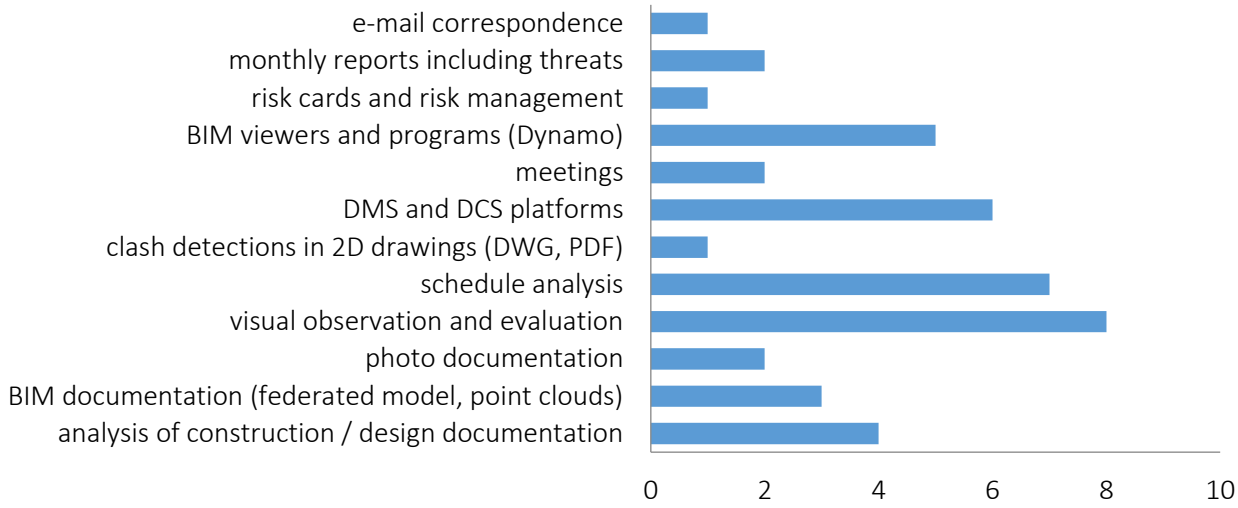


Figure 3.6.9 Bar chart. Answers to: 'Are there any tools you use when managing the problem?'



3.6.2. The results of the surveys – knowledge information

Successful knowledge management ensures that the specialized knowledge of employees is stored in the company for further beneficial use by others. The main goal for Miastoprojekt Wroclaw is to enable organizational learning and sharing knowledge about best practices, lessons learned for an overall organizational improvement. Although, 53% of employees responded (figure 3.6.10) that refer to external experts when the problems occur, still own experience and information from project stakeholders and collaborators are indicated as the primary source. According to the figure (3.6.11), respondents mostly base their knowledge about the project on their own experience together with outputs from the company's investments found on the DMS platform and the current Project Book.

Figure 3.6.10 Pie chart. Answers to: 'Did you refer to any expert from outside of the project?'

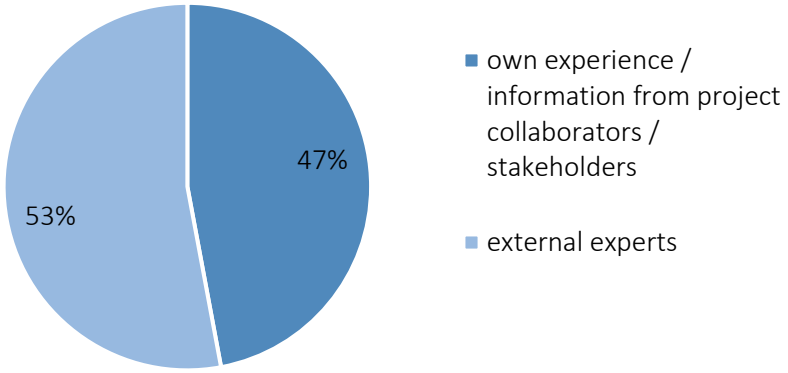


Figure 3.6.11 Bar chart. Answers to: 'Did you refer to an existing best practice or lessons-learnt repository (resp. document) for a solution?'

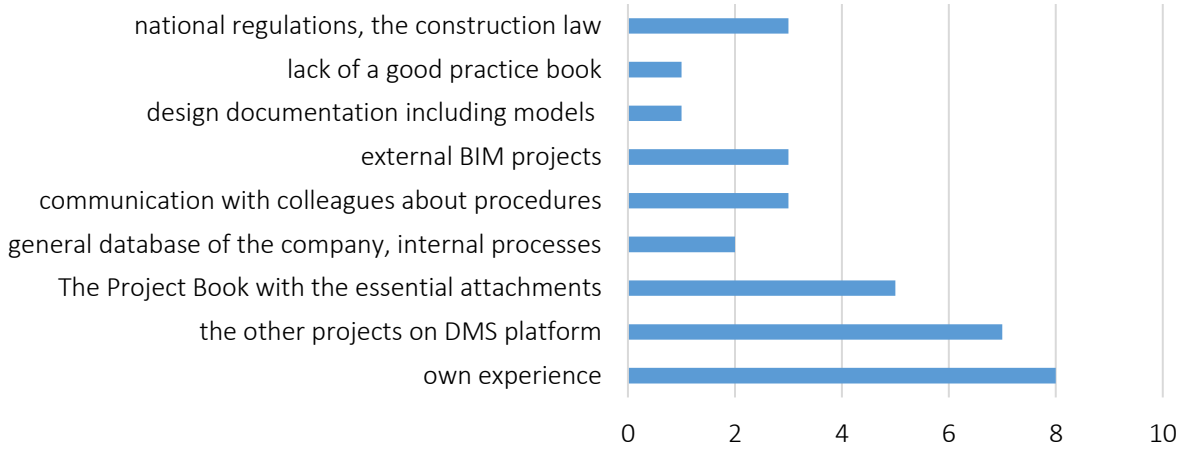
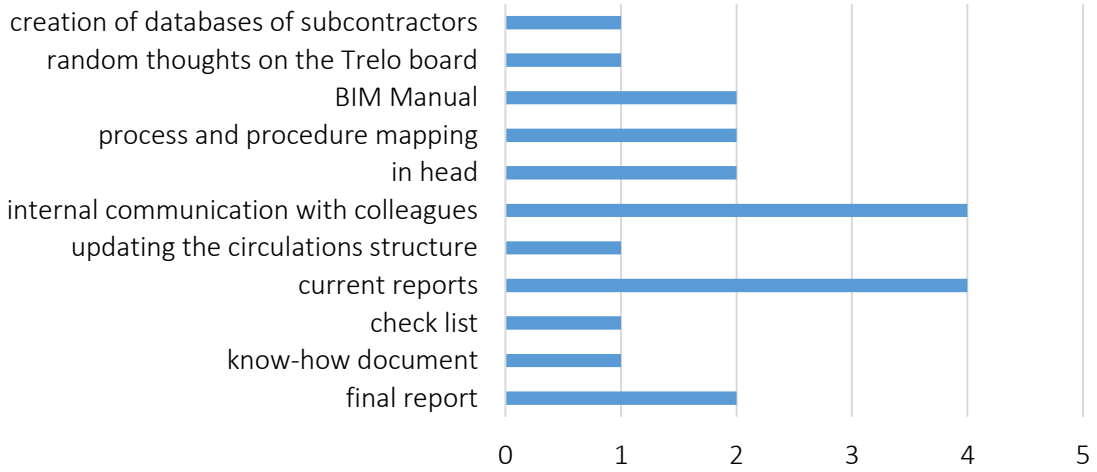


Figure 3.6.12 Bar chart. Answers to: 'How did you record your best practices/lessons learned?'



Thus, effective knowledge management reduces operational costs by making company knowledge more available, accessible, and accurate. Especially in the construction industry, an effective system of distributing knowledge is essential to spend less time recreating existing knowledge. Instead, in

Miastoprojekt Wroclaw, there is no policy for sharing or storing best practices. Most employees reported that some lesson learnt are communicated with colleagues or through current reports; however, without further documented storage process (figure 3.6.12). Furthermore, one respondent outlined the creation of know-how document in the form of a checklist about the main milestones in the construction investment. Single interviewers, mainly external BIM experts drawn BIM Manual and Trello board as mean for sharing best practices. According to figures (3.6.13) and (3.6.14) the knowledge in the project is gained primarily from interproject learning via analysis of documentation and meetings, via social network and individual learning supported with experienced gain in professional life.

Figure 3.6.13 Bar chart. Answers to: 'From where do you gain knowledge about this project?'

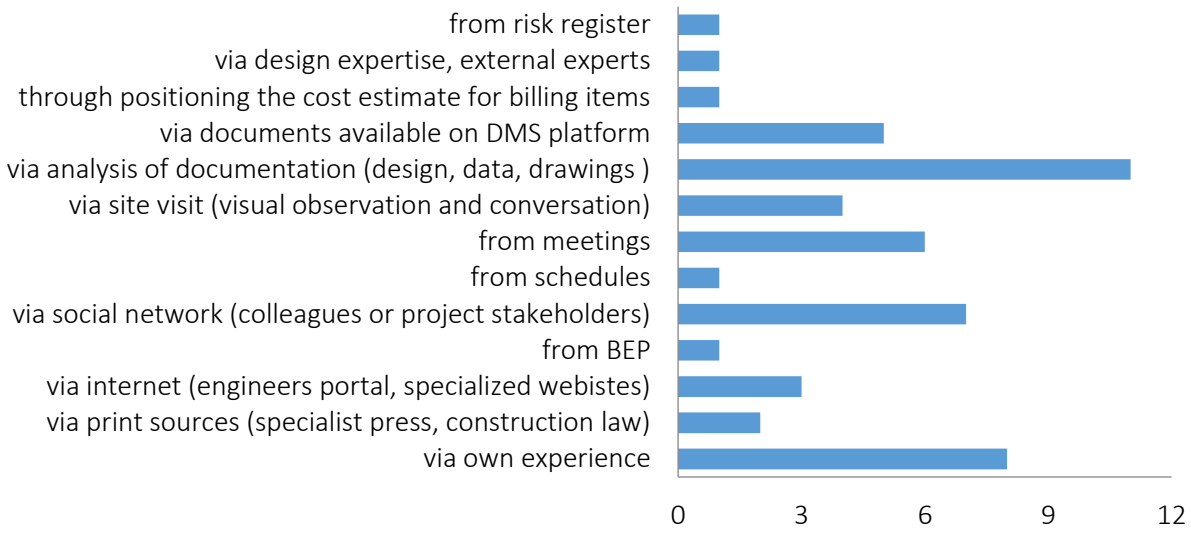
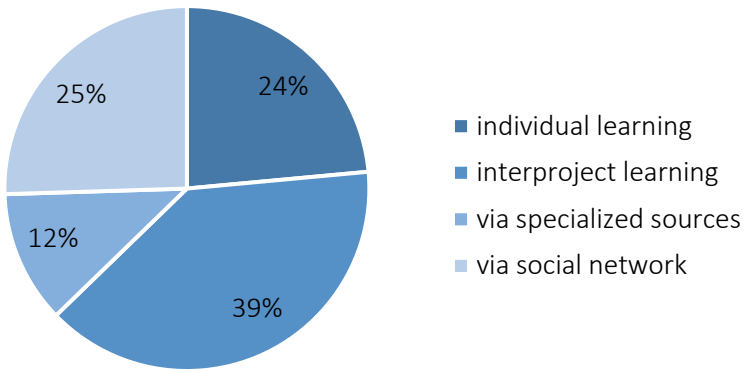


Figure 3.6.14 Bar chart. Knowledge in the project is gained primarily from.



When employees do not share information, the same mistakes tend to be repeated. However, this is avoidable when the lessons-learned are easily accessible to everyone. Consequently, it reduces the need for co-workers to interrupt each other with unnecessary emails or chats.

3.6.3. Use of BIM on projects

Currently Miastoprojekt Wroclaw is taking care of two ongoing projects with the introduction of BIM:

- design documentation for the demolition and construction of a railway viaduct for PKP (Polish Railway Lines)
- construction of the Cross-country Skiing and Biathlon Center in Szklarska Poręba - Jakuszyca

Due to the lack of sufficient competencies on the part of Miastoprojekt Wroclaw, for proceeding with the realisation of these projects, the external specialists from MAD Engineers company were hired as the BIM Managers. Their competencies were mostly used to develop the application of BIM technology focused on technical issues such as model objectives and parameters, information flow, criteria for graphic and descriptive documentation. The BEP document was created separately for design and project execution with the arrangements for files, LOD, LOI for individual elements, 3D modelling guidelines. According to external BIM Managers relation in the interview, BIM function in these projects is at the level of about 10-20%. Mostly because the BIM is viewed as a technological add-on, extra input to the reports rather than a useful process management methodology. Even though some of the employees were trained twice a couple of years ago, their gained knowledge was not used practically. Currently, there is no transfer of knowledge among colleagues, information to other people about BIM and its proper further use. Moreover, there is hardly no BIM coordination between the project manager and work execution.

At the very beginning of the design process, there was a conceptual architecture model which was used as a reference for coordination with industrial designers. Each trade created their model, giving 12 models in total. Then after verification interference checks, they were integrated and federated in BIM Zoom. The whole verification process with clash detection among models' elements took around two months. For further collaboration and analysis, the final integrated model is stored in the .ifc file on the DMS platform. There are no comments or notes shown in the model, and it is not used for reports or design and material queries but rather for viewing. Quantity take-offs are made from the model instead of internal needs on the construction site. Cost estimates are not linked directly to the model, and the measurements are read and then used separately. The BIM is useful for differential cost estimation for general contractor. The Miastoprojekt Wroclaw has notable failure and change record system operated on tablets – Sitework, but within these projects, investors decided to use their more traditional way of error management. Execution works are improved thanks to parameter mapping, creating optimization in Dynamo in WIP models on the construction site. Within the final documentation, there will be no COBie files, but a tailor-made package of necessary parameters adapted to the needs of the investor.

Partially the 4D was introduced at the construction stage in the contractor's information models in the form of scheduling data. Data is applied to the components to obtain correct software information and visualizations showing how the project would evolve sequentially. The information is therefore neither entered to nor linked into the primary model, because the schedules are created as a partial model for around two or three weeks in advance. For a particular component, time-related information includes details on the lead time, how long it takes to build, the order in which parts should be mounted. With the data associated with the graphic and colourful presentation of elements, it is simple to illustrate just how construction progresses through planned works, showing stakeholders how a structure appears visually at each stage.

3.7. BIM Maturity Assessment

A maturity level is a systematic approach that formalises new capabilities to develop in the organization's processes (SEI, 2008). Additionally, it allows for a fundamental distinction between immature and mature entities in terms of (Sarshar et al., 2000). It is wise to take advantage of existing maturity models with already developed maturity terms, performance goals and quality assurance measures.

3.7.1. Organizational BIM Assessment I-CMM

The assessment of organizational BIM Maturity level was conducted with two different tools. As first I used Interactive Capability Maturity Model (I-CMM) in Excel spreadsheet obtained during the first module - Management of information and collaboration in BIM of BIM A+ is the European Master in Building Information Modelling. It has 6 Maturity Levels, shown below.

Figure 3.7.1 Maturity Levels of Organizational BIM Assessment I-CMM (BIM A+,2019)

The current and target levels were measured with the six main categories called as the planning elements (The CIC Research Group, 2010):

- Strategy Elements in Organizational Mission and Goals, BIM Vision and Objectives, Management Support, BIM Champion, BIM Planning Committee
- BIM Uses Elements in Project Uses, Operational Uses
- Process Elements in Project Processes, Organizational Processes
- Information Elements in Model Element Breakdown (MEB), Level of Development (LOD), Facility Data
- Infrastructure Elements in Software, Hardware, Physical Spaces
- Personnel Elements in Roles and Responsibilities, Organizational Hierarchy, Education, Training, Change Readiness

3.7.1.1. Output – current and target level

In this section, the output about current and target levels of BIM Maturity are presented and precisely described. Firstly, the results are shown separately for each main category as radar charts figures (3.7.2-3.7.7). Then, the overall profile of the Organizational BIM Assessment is presented in figure (3.7.8) and summarised in table (3.7.1).

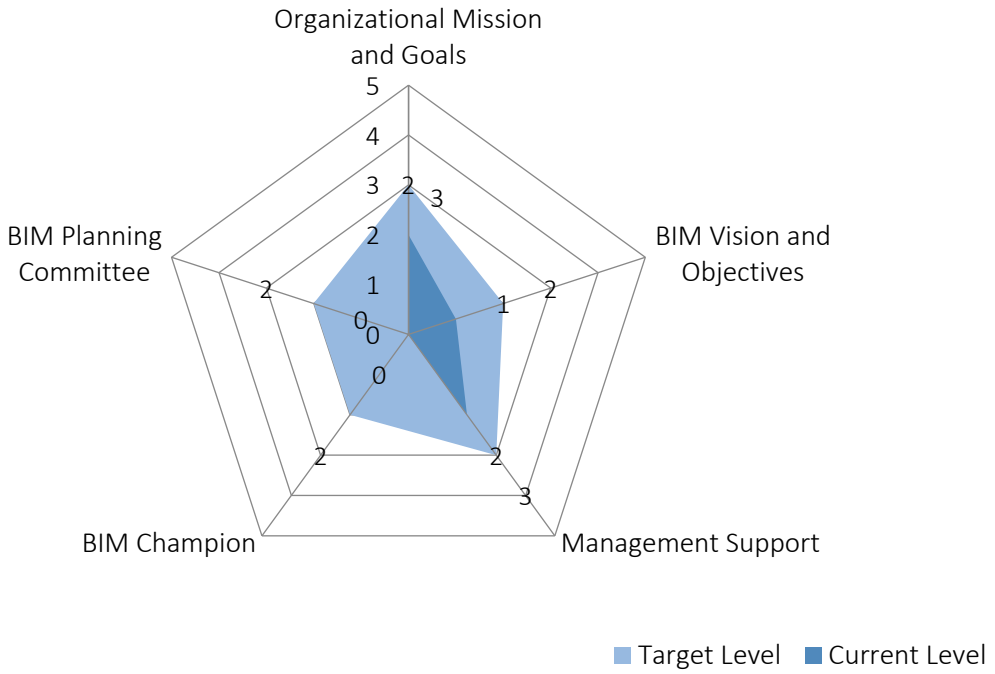
3.7.1.2. Output - Strategy elements

Current level: The basic, managed organizational mission with objectives and essential, initial BIM vision are determined. There is a full and manged support for BIM implementation with some resources within the management. However, no employee is technically qualified and motivated to lead the company by pushing for implementation, overcoming reluctance to change and ensuring BIM adoption. The BIM

Planning Committee, with responsibility for developing the BIM strategy for the firm, is not established (The CIC Research Group, 2010).

Target level: There is an organizational mission that addressed purpose, services, at least defined values, but objectives are still not managed quantitatively. Basic BIM goals are set, and basic tasks and measures are managed towards BIM adoption. BIM implementation is supported in a comprehensive and defined form with sufficient resource commitment. The Managed BIM Committee is formalized but not included in all operations and BIM Champion with adequate time commitment is chosen among the employees (The CIC Research Group, 2010).

Figure 3.7.2 Organizational BIM Assessment – Strategy.

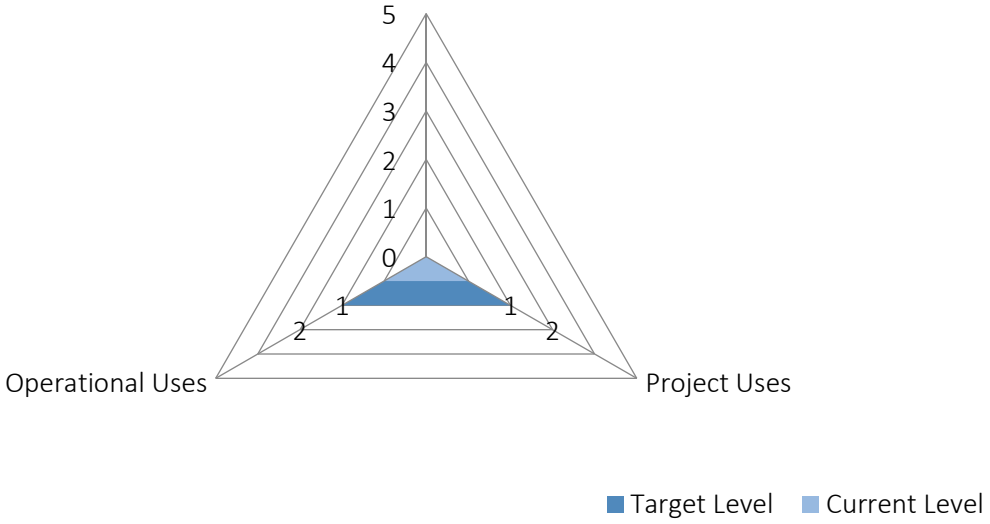


3.7.1.3. Output - BIM Uses elements

Current level: The usual methods for BIM adoption in projects and within the organization are initially developed through the on-going pilot BIM projects. Within the Project Uses, there are minimal owner requirements established. The record (As-Built) BIM model is going to be received by operations on the construction site (The CIC Research Group, 2010).

Target level: The Project and Operational Uses are developed on a managed level with minimal BIM Uses required. Imported or referenced BIM data for operational uses are recorded (The CIC Research Group, 2010).

Figure 3.7.3 Organizational BIM Assessment – BIM Uses.

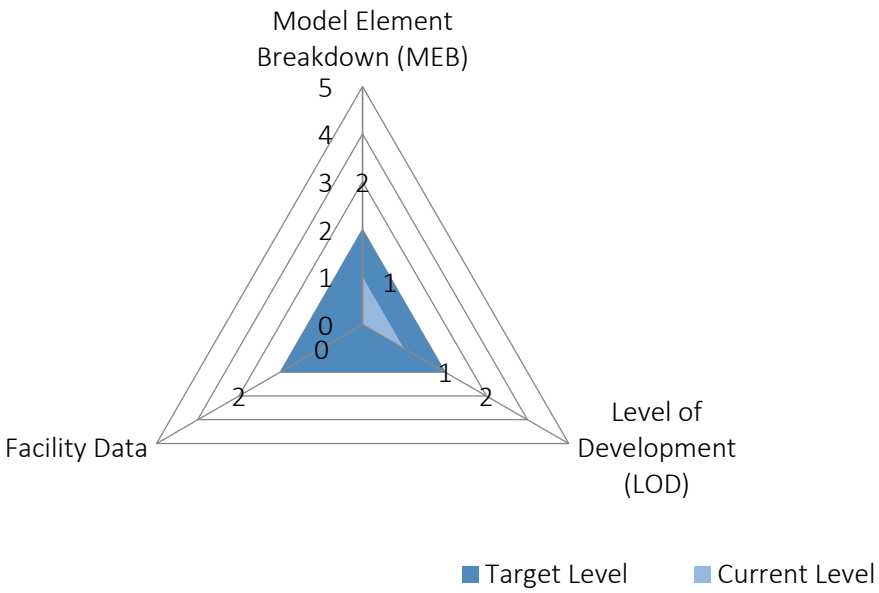


3.7.1.4. Output - Information elements

Current level: Organizational Model Element Breakdown (MEB) is defined initially with identifiers linked to each physical or functional element, but it is not uniform within the entire organization. LOD is initially defined on two on-going projects with the use of BIM, but not standardized within the entire organization. There are no clear criteria of non-graphical information. Therefore metadata is not attached to objects defining various extra features for facility management (The CIC Research Group, 2010).

Target level: Organizational Model Element Breakdown is unified and managed within the organisation. LOD and facility data are standardized and managed within the organization (The CIC Research Group, 2010).

Figure 3.7.4 Organizational BIM Assessment – Information.

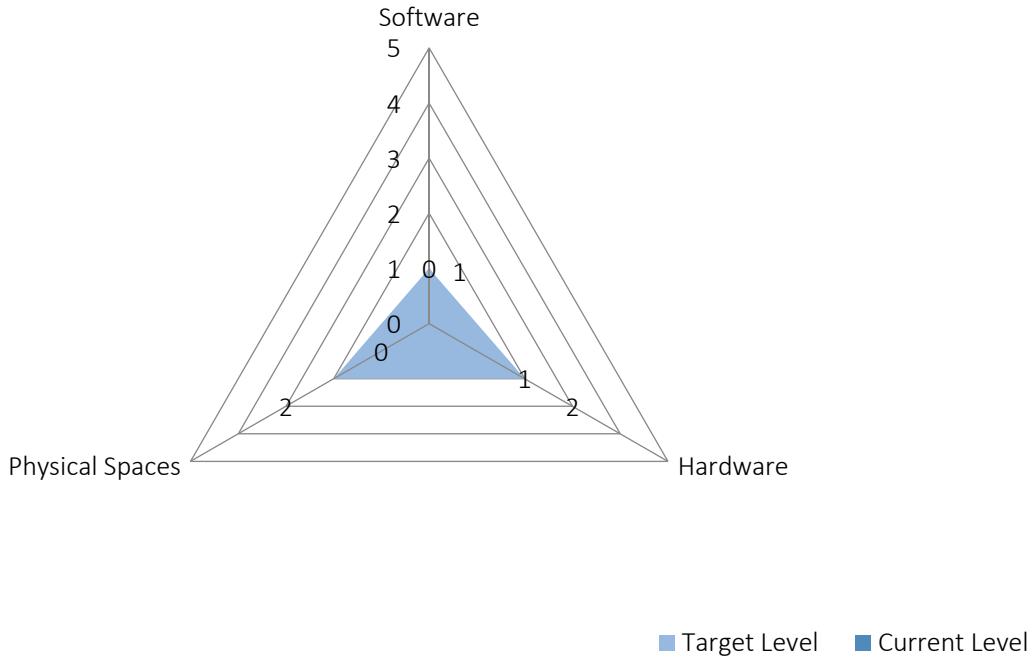


3.7.1.5. Output – Infrastructure elements

Current level: Some of the existing hardware is capable of running essential BIM software. However, the company does not owe any licensed BIM software. There are no specific BIM functional areas within a facility to incorporate BIM in organization properly (The CIC Research Group, 2010).

Target level: Some managed hardware systems within the organization are capable of accepting BIM data (created and obtained). There are several managed workstations for viewing BIM data (The CIC Research Group, 2010).

Figure 3.7.5 Organizational BIM Assessment – Infrastructure.

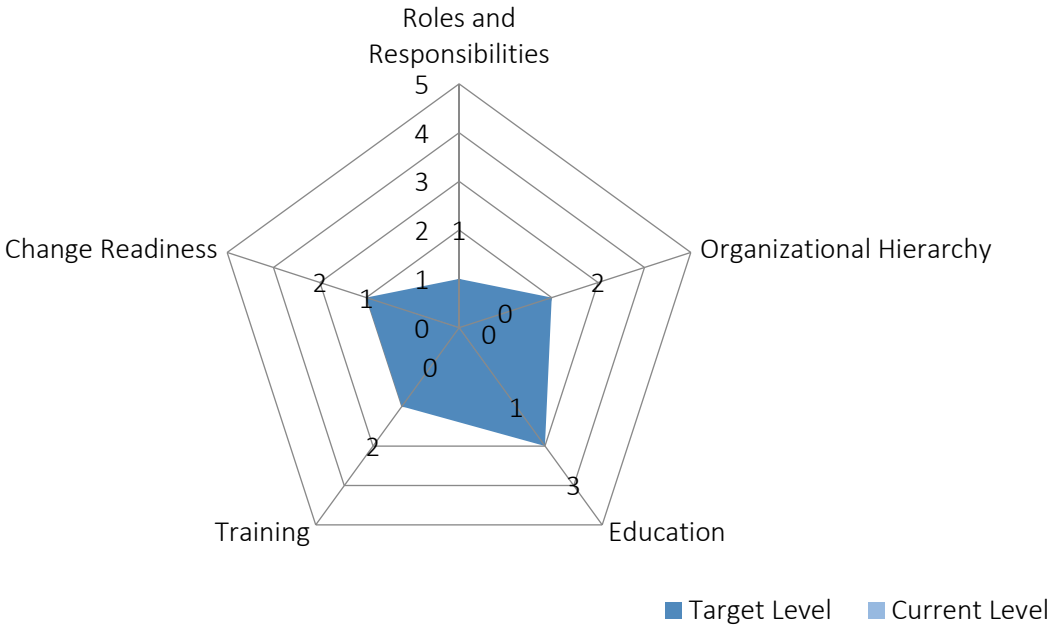


3.7.1.6. Output – Personnel elements

Current level: There are no recorded BIM roles and responsibilities, and the organizational hierarchy does not approach BIM. The ad hoc education is initially conducted as needed, and the training program for employees does not exist. The company established an initial willingness for implementing BIM (The CIC Research Group, 2010).

Target level: The BIM Implementation Team is managed externally of the organization hierarchy. However BIM Champion responsible for adoption is initially chosen. Defined employee education sessions are regularly conducted. The internal training program is managed for all employees that might interact with BIM. The upper management is buy-in preparedness of organization to integrate BIM (The CIC Research Group, 2010).

Figure 3.7.6 Organizational BIM Assessment – Personnel.



3.7.1.7. Output - overall profile of Organizational BIM Assessment

The overall profile of the Organizational BIM Assessment is presented in figure (3.7.8). The current and target level of each subcategory are summarized in table (3.7.1).

Figure 3.7.7 Organizational BIM Assessment Profile – Miastoprojekt Wroclaw.

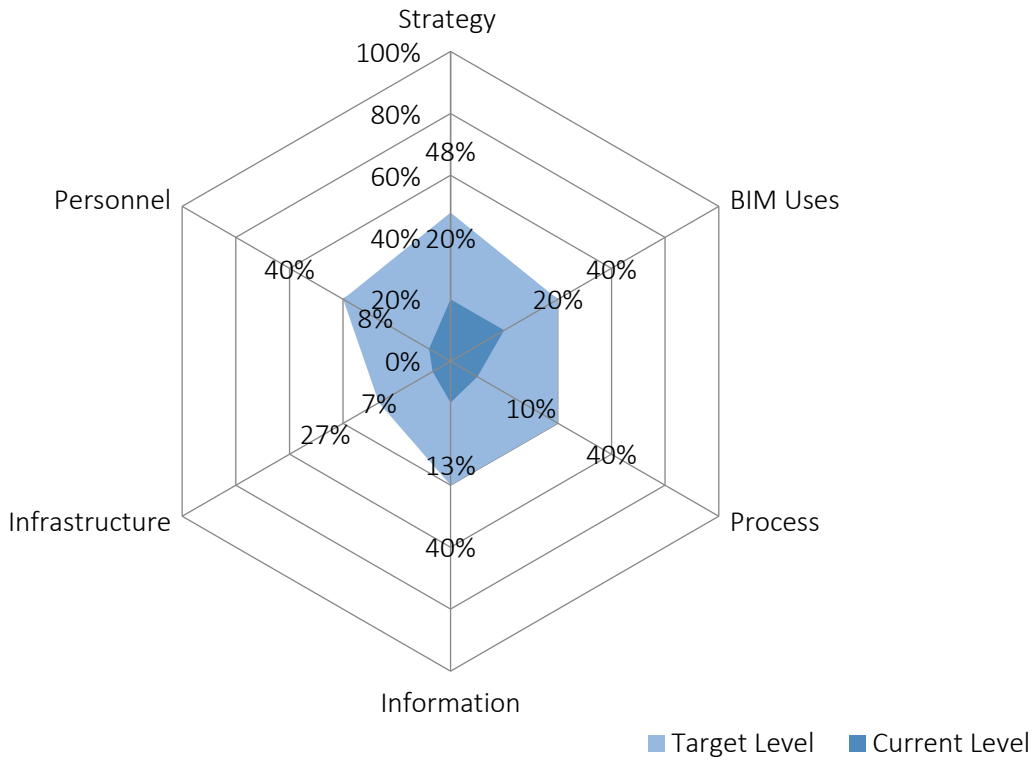


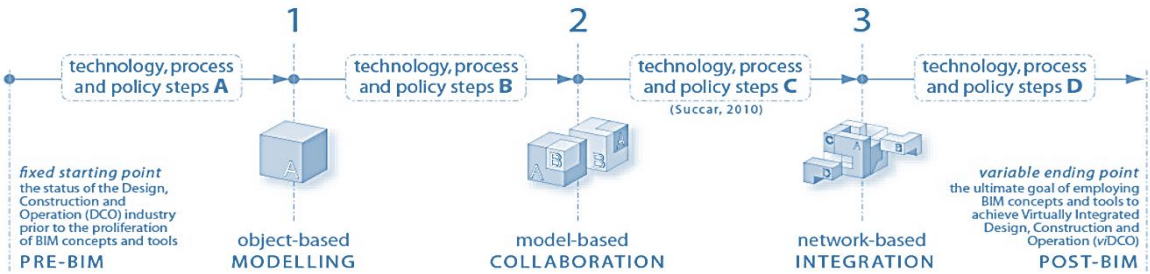
Table 3.7.1 Organizational BIM Assessment Profile – Miastoprojekt Wroclaw

Organizational BIM Assesment Profile									
Level of Maturity		0 Non-Exsistent	1 Initial	2 Managed	3 Defined	4 Quantitatively Managed	5 Optimizing	Current Level	Target Level
Strategy	Organizational Mission and Goals			2	3			5	12
	BIM Vision and Objectives		1	2					
	Management Support			2	3				
	BIM Champion	0		2					
	BIM Planning Committee	0		2					
BIM Uses	Project Uses		1	2				2	4
	Operational Uses		1	2					
Process	Project Processes		1	2				1	4
	Organizational Processes	0		2					
Information	Model Element Breakdown (MEB)		1	2				2	6
	Level of Development (LOD)		1	2					
	Facility Data	0		2					
Infrustacture	Software	0	1					1	5
	Hardware		1	2					
	Physical Spaces	0		2					
Personnel	Roles and Responsibilities	0	1					2	10
	Organizational Hierarchy	0		2					
	Education		1		3				
	Training	0		2					
	Change Readiness		1	2					
							Total points	13	41

3.7.2. BIM Maturity Matrix from BIMe Initiative

The other used tool was The BIM Maturity Matrix from BIMe Initiative, which consists of two axes BIM Capability Sets and BIM Maturity Index. BIM Capability refers to the minimum abilities of an organization to deliver measurable outcomes and is measured through BIM Stages separated by BIM Steps, as is shown below.

Figure 3.7.8 BIM Stages (BIMe Initiative, 2015)



A BIM Competency Set is a hierarchical list of competencies identified for BIM adoption and evaluation. BIM Competency Sets are categorized according to BIM Fields and are discussed in three groups (Succar, 2010):

- Technology Sets in software, hardware and networks
- Process Sets in Leadership, Infrastructure, Human Resources

- Policy Sets in contracts, regulations and research/education.

Not all BIM Competencies are of the same importance and can be divided into Key and non-Key Competencies depending on the needs of the organization (Succar, 2010). The BIM Maturity refers to the gradual and continual improvement within available BIM Capability and is measured through the BIM Maturity Index with five levels, shown as below.

Figure 3.7.9 BIM Maturity Levels (BIMe Initiative, 2015)

In general, the progression from low to higher maturity levels helps to monitor differences between goals and actual results, improves competency, performance and cost predictability and increases efficiency in achieving specified goals (Lockamy III and McCormack, 2003)

3.7.2.1. Maturity Discovery Score

For primary and semi-formal discovery of BIM Capability and Maturity of Miastoprojekt Wrocław, the discovery low detail assessment was conducted. The Maturity Discovery Score reflects the sum of total points subdivided by twelve.

Table 3.7.2 Maturity Discovery Score– Miastoprojekt Wroclaw

Maturity Discovery Score							
BIM Maturity Matrix			a	b	c	d	e
Assessment at Granulity Level 1		Shortcuts	10 points	20 points	30 points	40 points	50 points
Technology	Software	SO		20			
	Hardware	HA	10				
	Network	NT			30		
Process	Leadership	LD		20			
	Human Resources	HR	10				
	Infrastructure	IN	10				
	Products and Services	PS		20			
Policy	Contractual	CN	10				
	Regulatory	RG		20			
	Preparatory	PP	10				
Stage	Stage 1/2	-		20			
Scale	Organization (9)	-	10				
Subtotal		-	**60**	**100**	**30**		
Total points		**190**					
Maturity Score		**15,83**					
	partially achieved						
	fully achieved						

Assessment report for Miastoprojekt Wrocław (organisational scale 9) discovered to be at Capability Stage 1 within the step A (from pre-BIM to object-based modelling) with two on-going projects at initial step B towards Capability Stage 2 within the software and project deliverables. The overall Maturity Level Score is **15,83** between a and b – initial(ad-hoc) and defined.

3.7.2.2. Output according to BIM Maturity Matrix (BIMe Initiative, 2016)

Summary: Implementation of BIM is described by the lack of a general strategy with some defined processes and policies, mostly among non-BIM projects. Moreover, BIM software tools are not deployed within the company, but are used by appointed parties during the design and construction phase. Therefore, BIM adoption in Miastoprojekt Wroclaw is only partially achieved through the efforts of external specialists on two on-going pilot projects but not within the whole organization (BIMe Initiative, 2016).

Technology: Software usage/introduction is not unified in the company, but managed and controlled within appointed parties on two projects, where 3D Models are used to generate specified 2D as well as 3D files. Therefore, data use, storage, and sharing within organizations and project teams are well established. Similarly, interoperable exchange of data is specified and given priority. Hardware requirements are non-uniform and inconsistent between the employees' skills and expected BIM deliverables. Equipment replacement and upgrades are regarded as products of expense, deferred wherever necessary, and committed only when inevitable. Nevertheless, the network solutions through their platforms such as DCS and DMS. Tools for managing content are deployed to monitor structured, and unstructured data exchanged through routine bandwidth connections (BIMe Initiative, 2016).

Process: Senior leaders/managers in the company may have adopted a shared vision about BIM. Similarly, BIM and its implementation perform without the overall strategy and lack actionable details. Therefore, BIM is viewed as a source of technology without much regard for its mechanism and policy consequences. Business opportunities that emerge from BIM are therefore found but not utilized. The working environment is not considered as a factor in employee satisfaction/motivation and is unproductivity-friendly. Accordingly, expertise and best practices are not recognized as an organizational asset and are communicated primarily informally among staff – through tips, strategies and eventually learned lessons.

Moreover, BIM objects (components, parts or families) are defined and in BEP in two projects. Thus, 3D models deliverables (as BIM products) are adequately described into levels of details. In most projects, the visual consistency of the 2D representations is given more importance than the accuracy of the 3D model (if the model exists). The organization's services and products reflect a fraction of the capacities inherent in the free software resources available for modelling quality controls or formal audit procedures (BIMe Initiative, 2016).

Furthermore, BIM Projects are planned independently and supposed to be conducted with practices described in BEP, but within the organization, BIM processes are absent. As a result, management is unaware of staff competency levels, responsibilities are unclear, and team structures pre-date BIM. Correspondingly, employees regarding technological and operational workflows are neither structurally qualified nor introduced into BIM systems. Although, the employees have consistent knowledge about existing policies and circulations within the company. Performance is inconsistent, and success relies on the efforts of external BIM experts within design and construction teams. Also, inside one's initiatives, a mindset of "working outside the system" affectations. Finally, performance is inconsistent, especially

among the workload and latency with circulations, is kind of monitored through the platform activity and eventually manually reported (BIMe Initiative, 2016).

Policy: Basic BIM guidelines are defined in BEP such as documentation protocols, modelling and BIM delivery standards. They are introduced to specifications which are approved by the industry. Though, for 3D models and 2D representation, quality standards and performance benchmarks are set in a minor way. There are no training policies and educational material, and when available, are not suitable or accessible to staff. So far, within four years there were conducted two short BIM trainings for some of the employees. Contractually, the company mostly relies on pre-BIM arrangements with little BIM-specific risk detection and mitigation strategy. However, some BIM requirements are recognised with a definition of responsibility regarding the information management (BIMe Initiative, 2016).

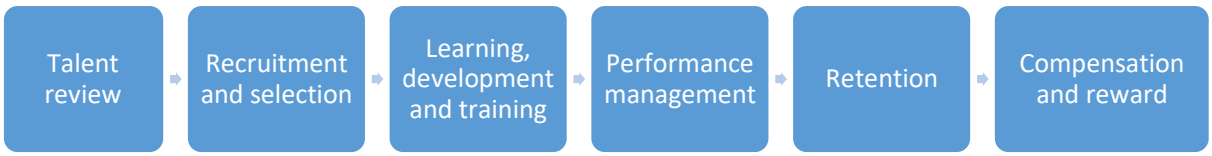
Process areas to focus: Workforce Planning, Competencies Analysis and Development, Training and Development, Performance Management, Communication and Coordination, Staffing, Work Environment (BIMe Initiative, 2016).

3.8. Talent management

Talent management is one of the proposed solutions for improving high business performance by optimizing employee's performance. It should be developed parallelly with the identification of the organizational goals and strategic priorities for Miastoprojekt Wroclaw. It is essential to translate these primacies into talent management practices of attracting, securing and retaining highly skilled employees.

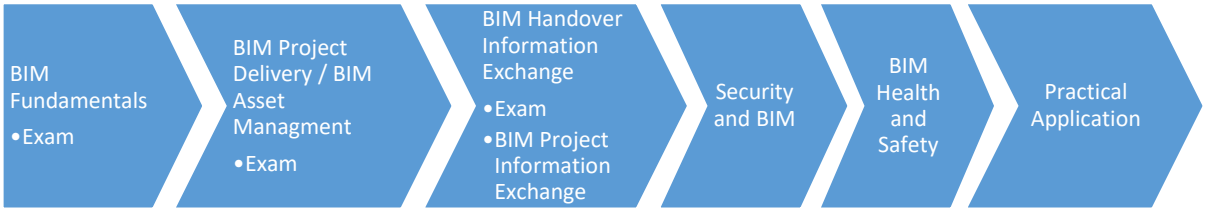
The company strategy is not going to be executed immediately, although it requires addressing and filling the talent gaps to increase organizational productivity and employee's efficiency. Typically, it takes couple of years to execute a strategy fully. For this reason, it is crucial to establish and define the consecutive steps of talent management strategy, as the ones shown in figure (3.8.1).

Figure 3.8.1 Talent management strategy steps



Miastoprojekt Wroclaw requires clear career progression, structured experience and comprehensive skills development in order to shift towards fully integrated BIM. That demands considerable investment in knowledge, training of employees and technology necessaries for the process. The creation of a new workflow, the methodology involves the restructuration. Especially structured training in BIM skills with examination is crucial, as presented in figure (3.8.2). Therefore, the educated people with adequate skills are needed to make an impact within the organization. To achieve all of that, the company should as well define its criteria to enable tracking progress, such as leading and lagging key performance indicators (KPIs). Leading KPIs are less accurate but help to predict effectiveness. Whereas lagging KPIs are descriptive and accurate, because they relate to the past (Badawy *et al.*, 2016).

Figure 3.8.2 BIM skills development roadmap (BSI Global Marketing, 2020)



3.8.1. Function and skills according to ISO 19650

Miastoprojekt Wrocław as the substitutive investor is managing information on behalf of a clients, hence, fulfilling the role of the Appointing Party – Project Team, centrally located circle with letter A, as presented on the following figure (3.8.3).

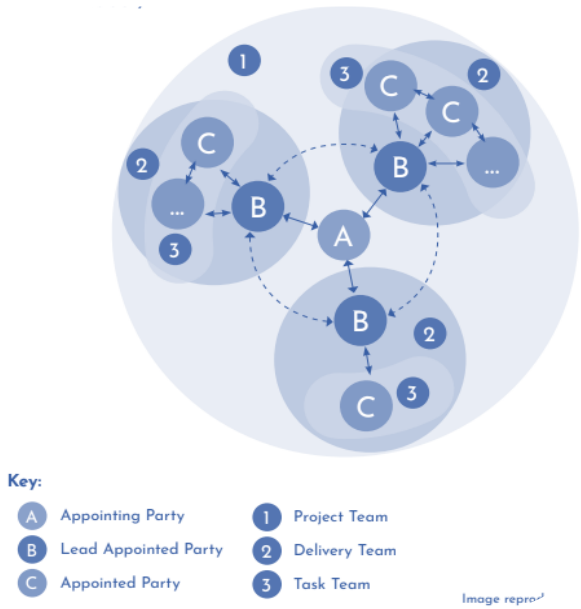


Figure 3.8.3 Interfaces between parties and teams (Bolpagni *et al.*, 2020)

In the context of the ISO 19650 in BIM process, company would be the owning the appointment/project to assure that client's information management functions (figure 3.8.4) is fulfilled by employees or people acting on company's behalf or a combination of both. The main tasks include helping the client-specific information requirements to realise maximum benefit of BIM and supporting the entire project team. First, Miastoprojekt Wroclaw should focus on compiling the functions of Appointing Party (figure 3.8.4) by developing individual skills of information requirements and delivery management presented in table (3.8.1) based on thorough study of ISO 19650-2 standard.

The development of BIM within company leads into new work processes, new definitions and terminology for a common understanding needs to be established. It is essential to educate the whole organisation to ensure that all employees about BIM. The training should relate to the function or role each employee has, both in the company and in projects. Key issues include:

- calculation of a tender and delivery of a bid, for legal and economic implications of requirements and deliverables

- management of a BIM project, for interaction and deliverables for each stakeholder,
- use of BIM technology for time, quality, cost and risk management
- preparation of BEP appointed to future BIM manager

Once a national knowledge is established, BIM certification should be a priority for dedicated BIM personnel and any individuals with direct control over the BIM implementation process.

Figure 3.8.4 Appointing Party functions according to ISO 19650-2.

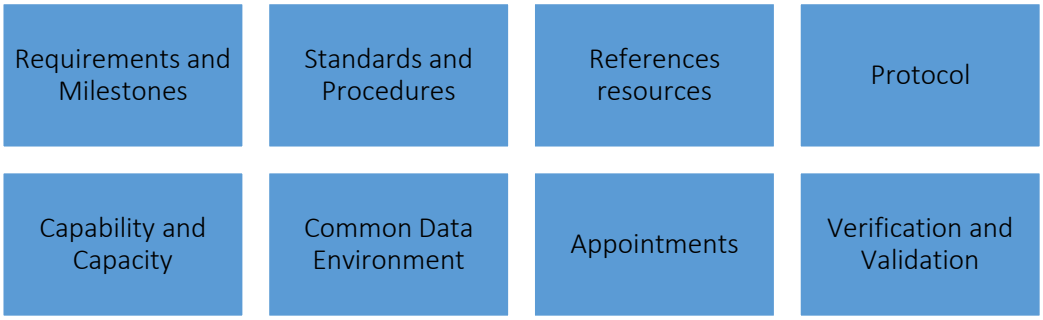


Table 3.8.1 Appointing Party skills according to ISO 19650-2.

Appointing Party skills		
Information management	Information requirements management	Information delivery management
• Understanding the business • Consulting with stakeholders • Understanding the procurement process and gateways • Representing the information management function in project discussion	• Capturing the stakeholders needs • Translating needs into contractual requirements • Reviewing plans to check consistency with requirements	• Detailed knowledge of the procurement process • Assessing the capacity of suppliers during their appointment • Information verification and validation

Miastoprojekt Wroclaw shortly wants to develop the design department. Hence, the main functions for both Lead Appointed Party and Appointed Party (figures 3.8.5 and 3.8.6) should be provided in the investment process. Consequently, the adequate skills are required to be developed for (task) information, coordination, interface, management and information generation, as presented in tables (3.8.2 and 3.8.3). The main tasks for Lead Appointed Party include coordinating information between the delivery team and the appointing party, as well as ensuring that the entire delivery team understands and can meet the project's BIM requirements. Whereas for Appointed Party is creation of a consistent approach amongst the entire task teams to fulfil BIM appointment requirements. Furthermore, designers need to learn how to implement the information into the model and to use the model throughout the process as a primary deliverable.

Figure 3.8.5 Lead Appointed Party functions according to ISO 19650.

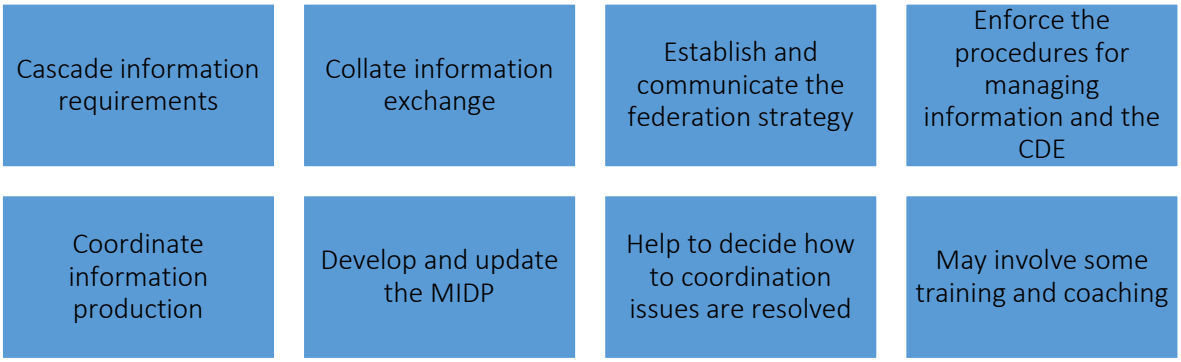


Table 3.8.2 Lead Appointed Party skills according to ISO 19650.

Appointing Party skills		
Coordination management	**Information management**	**Interface management**
• Technical project knowledge • Lead meetings • Resolve disputes	• CDE processes • Project understanding • Team structures and dynamics	• Understand technical issues • Understand federation strategy • Problem-solving
Information Generation		**Task Information Management**
• Technical knowledge • Produce info deliverables as agreed		• Check WIP info • Enforce team procedures • Agree team standards

Figure 3.8.6 Appointed Party functions according to ISO 19650.

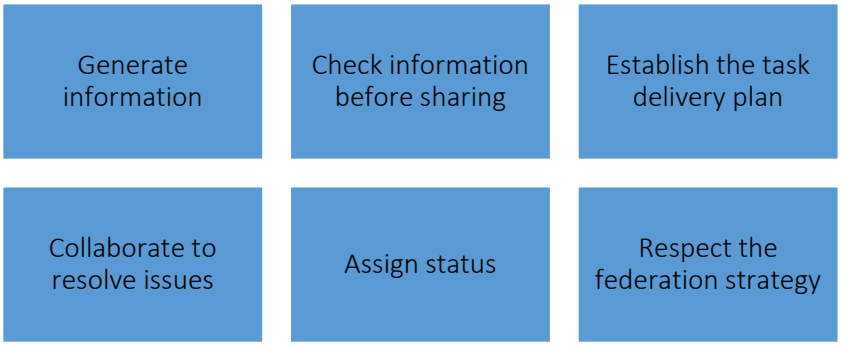


Table 3.8.3 Appointed Party skills according to ISO 19650.

Appointing Party skills		
Interface management	**Information Generation**	**Task Information Management**
• Understand technical issues • Understand federation strategy • Problem-solving	• Technical knowledge • Produce info deliverables as agreed	• Check WIP info • Enforce team procedures • Agree team standards

3.9. BIM Uses

Penn State BIM Uses (table 3.9.1) includes the scope of work and the step of the project within the lifecycle and the level of development of the model (PSU, 2020). Moreover, they give data to create the BIM Objective and Responsibility Matrix according to the use of BIM in a particular stage of the project, and relate the BIM deliverables to the current 2D practices.

Concerning BIM Excellence (BIMe), there are Model Uses (one type of Information Uses) which identify the Information Requirements within 3D digital models without specifying the project's phase. Model Uses are grouped into three categories: general, domain and custom. They simplify the identification of information requirements in the project thanks to division into different disciplines for specific and option to particular group uses for a specific and individual type of coordination process. However, they do not relate the BIM deliverables to the current 2D practices.

In the below table (3.9.1) to the original primary Penn State BIM Uses, some additional BIMe Model Uses (with * before the name) were added to the adequate phase within the lifecycle. Few of the specific BIMe Model Uses' descriptions coincide with the general Penn State ones. These model uses an alternative to defining BIM uses, illustrating the primary purpose that they fulfil on a project, along with additional attributes worth developing within the further BIM adoption stage in company. For instance, it would be useful to put more attention on Quantity Take-Off, Clash Detection, Constructability Analysis and eventually Field BIM, Handover and Commissioning, BIM/FM Integration (BIMFMI).

According to Miastoprojekt Wrocław company profile, which is the substitutive investor, they are mostly responsible for whole supervision of the execution of a project, acting on behalf of the client. However, the firm provides as well services widely connected with construction such as cost estimation, investment settlement and quality coordination. Even though, there is a plan for running the design department in the future, and the company should first focus on developing primary BIM Uses that matching their profile, thus, connected with reviewing, coordinating and managing. The general recommendation is first to invest in Cost Estimation, Phase Planning, Design Reviews and 3D coordination. In the following part of the thesis, there are the short descriptions of the selected BIM Uses for the primary implementation, together with resources and competencies requirements. Once the BIM adoption is at a more advanced stage, it is suggested to introduce slowly other primary BIM Uses for modelling and design that go along with the company's desired development. It follows that Design Authoring, Spatial Programming, Energy Analysis, and eventually Record Modelling with 3D Control and Planning should be adopted.

Table 3.9.1 Penn State BIM Uses with additional BIMe Model Uses (*)

PLAN	DESIGN	CONSTRUCT	OPERATE
Existing Conditions Modelling	Existing Conditions Modelling	Existing Conditions Modelling	Existing Conditions Modelling
Cost Estimation	Cost Estimation	Cost Estimation	Cost Estimation
Phase Planning	Phase Planning	Phase Planning	
Spatial Programming	Spatial Programming		
Site Analysis	Site Analysis		
Design Reviews	Design Reviews	Design Reviews	
	Design Authoring	Design Authoring	
	*Quantity take-off	*Quantity take-off	
	* Constructability Analysis		
	Energy Analysis		
	Structural Analysis		
	Lighting Analysis		
	Mechanical Analysis		
	Other Eng. Analysis		
	Sustainability (LEED) Evaluation		
	Code Validation		
	3D Coordination	3D Coordination	
	*Clash Detection	*Clash Detection	
		Site Utilization Planning	
		Construction System Design	
		Digital Fabrication	
		3D Control and Planning	
		*Field BIM	
		Record Modelling	Record Modelling
			*Handover and Commissioning
			* BIM/FM Integration (BIMFMI)
			Building Maintenance Scheduling
			Building System Analysis
			Asset Management
			Space Management / Tracking
			Disaster Planning

	Primary BIM Uses
	Secondary BIM Uses
	Primary BIM Uses highly recommended to develop as first in the company

3.9.1. Cost Estimation (5D cost estimation) (PSU, 2020).

3.9.1.1. Description

It is a process for which BIM can be used in the company to assist the generation of accurate quantity take-offs and cost estimates throughout the life cycle of a project, typically undertaken by a quantity surveyor or pre-contract estimator.

3.9.1.2. Potential value for the company

- Precisely quantify modelled materials
- Generate more cost estimates at a faster rate
- Better visual representation of project and construction elements that must be estimated
- Provide cost information to the owner during the early decision-making phase of design and throughout the project lifecycle, including changes during construction
- Added to a construction schedule (such as a 4D BIM model) a BIM developed cost estimate can help track budgets throughout construction
- Quickly determine costs of specific objects

3.9.1.3. Resources Required

- Model-based estimating software
- Design authoring software.
- Accurately built design model with quantity surveyor needs in mind.
- Cost data (Including Masterformat and Uniformat data)

3.9.1.4. Team competencies required

- Ability to define specific design modelling procedures to accurate quantity take-off information
- Ability to identify quantities and their suitability for the appropriate design and estimate phase
- Ability to adjust a cost plan to suit data available in the model throughout the design phase

3.9.1.5. Potential output information

- Quantity take-off information in defined structure
- Cost estimate

3.9.1.6. Procurement considerations

- Define cost estimation requirements in the design BIM brief
- Communicate that the Quantity Surveyor or precontract Estimator is responsible for the cost estimate, and the model is to be used as a support tool. It does not replace the traditional responsibilities of the Quantity Surveyor such validity of the source data and source materials, ensuring the coverage of the take-off, proposing alternative solutions and analysing the results.

3.9.2. Phase planning (4D modelling) (PSU, 2020)

3.9.2.1. Description

It is a process in which a 4D model (3D models with the added dimension of time) is used to effectively plan the phased occupancy in a renovation, retrofit or addition, or to show the construction sequence and space requirements on a building site.

3.9.2.2. Potential value for the company

- Better understanding of the phasing sequence by the owner and project participants, showing the critical path of the project
- Monitor actual progress on site against the programme and critical path activities
- Identify programme, sequencing, or phasing issues
- Integrate planning of human, equipment and material resources with the BIM model and estimate the cost of the project
- Space and workspace conflicts identified and resolved ahead of the construction process
- More readily constructible, operable and maintainable project

3.9.2.3. Resources required

- Design authoring software
- Scheduling software
- 4D modelling software

3.9.2.4. Team competencies required

- Knowledge of construction programming and general construction process (a 4D model is connected to a programme and is therefore only as good as the programme to which it is linked)
- Knowledge of 4D software: import geometry, manage links to programmes, produce and control animations, ability to manipulate, navigate, and review a 3D model.

3.9.2.5. Procurement considerations

- If the contractor expects to use design models for 4D modelling, define it in the design BIM brief

3.9.3. Design review (PSU, 2020)

3.9.3.1. Description

A process in which stakeholders view a 3D model and provide their feedback to validate multiple design aspects. These aspects include evaluating the meeting programme, previewing space aesthetics and layout in a virtual environment, and setting criteria, such as layout, sightlines, lighting, security, ergonomics, acoustics, textures and colours.

3.9.3.2. Potential value

- Easily communicate the design to the owner, construction team, and end-users
- Significantly increase coordination and communication between different parties, which is more likely to generate better decisions for design
- Eliminate costly and timely traditional construction mock-ups
- Different design options and alternatives may be easily modelled and changed in real-time during design review, based on end-user or owner feedback
- Create a shorter and more efficient design and design review process with instant feedback
- Evaluate the effectiveness of design in meeting building programme criteria and owner needs

3.9.3.3. Resources required

- Design review software
- Hardware which is capable of processing potential large model files

3.9.3.4. Team competencies required

- Ability to manipulate, navigate, and review a 3D model
- Ability to model photos realistically including textures, colours, and finishes
- Strong sense of coordination, including understanding the roles and responsibilities of team
- Strong understanding of how building/facility systems integrate

3.9.3.5. Procurement considerations for the company

- Define in the BIM brief the expected minimum number of design reviews required

3.9.4. 3D coordination (PSU, 2020)

3.9.4.1. Description

It is a process used throughout the coordination process to determine conflicts of geometry within the BIM model that would result in problems on site.

3.9.4.2. Potential value

- Coordinate building project through a model
- Reduce and eliminate on-site conflicts, which reduce RFIs significantly, compared to other methods
- Increase productivity and decrease construction time due to More accurate As-Built drawings
- Reduce rework on-site and construction cost through potentially fewer variations

3.9.4.3. Resources required

- Design authoring software
- Model review application
- Clash detection software

3.9.4.4. Team competencies required

- Ability to deal with people and project challenges
- Ability to manipulate, navigate, and review a 3D model, to run clash detection software
- Knowledge of BIM model applications for facility updates and building systems

3.9.4.5. Procurement considerations for the company

- Define in the BIM brief the minimum number of formal 3D coordination reviews, the responsible party (the lead the architect, a third-party) and expected workflows or processes (if applicable)

3.10. BIM Implementation

The key to the success of using BIM in an organization is its appropriate implementation plan, adapted to the scale of the projects and type of the company. Correct development and coordination of the BIM play a crucial role in integrating the processes involved within the life cycle of the project by improved building efficiencies. The general concept is presented in the figure Successful implementation of BIM requires a careful and structured approach that takes into account many integrated aspects of the company's operations, from vision and leadership, to the people who will use BIM in their daily project execution. In the following table (3.10.1), the main BIM implementation plans at the organizational level and with a pilot project were described. The guidelines are the own perspectives of literature studies

on relevant case studies of BIM implementation listed within the references and outputs from BIMA + European Master and other similar BIM courses.

Figure 3.10.1 BIM Implementation general plan

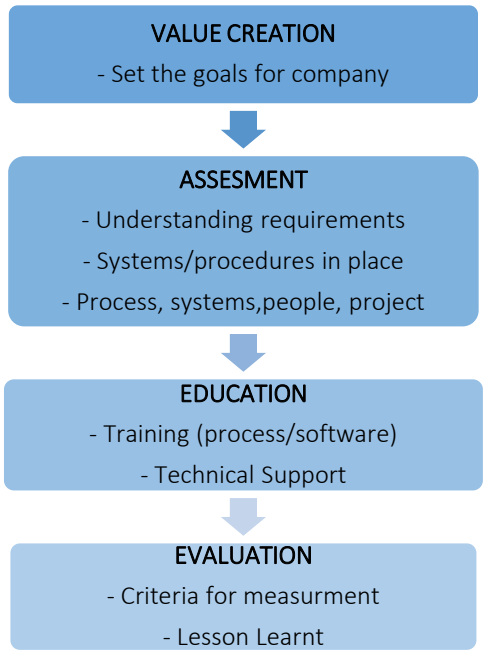


Table 3.10.1 BIM implementation plan at organizational level vs in a pilot project

BIM Implementation	
Why? What? What do you want to achieve?	
Organizational implementation plan Implementation of the BIM methodology at the organizational level	BIM implementation plan Implementation of the BIM methodology in a pilot project
• Understand the BIM concepts and definitions, standards and specifications. • Define the organization type to specify BIM areas for development and the strategic documents. • Set the organization goals which depend on the projects. The benefits usually vary for each project and the beneficiary. • Specify the type of construction projects. • Identify the current processes and their problems. • Choose the space for innovation depending on processes. Become familiar with the other BIM use cases. • Determine the team and continuously motivating, raising their qualifications. • Define the criteria for assessing the BIM implementation.	• Transform strategy into the action steps. • Select the individual activators for the beginning implementation. • Choose a team and a leader. • Lesson Learnt- learning from own mistakes and successes, drawing conclusions. • Learn from your own experience. • Practical implementation with the application of the BIM Uses Cases: - The goal can be achieved with several different BIM Uses. - One of the BIM Uses can produce more than one benefit for the project. - Each of BIM Uses generates a cost for the company.

3.10.1. BIM Implementation paths

A common mistake at the beginning of implementation is to think of BIM only as a computer program, instead of a new method of work, a way of intelligent data flow between all stakeholders and project management. In line with this perspective, the implementation paths in the table (3.10.2) present their main assumptions. This study recommends applying moderated, gradual path to implement the BIM methodology effectively. Therefore, all members and departments in the company must collaborate and combine the efforts. The vision needs to be clearly articulated to towards a common goal. Accordingly, the structure and strategy need to be re-organized for better information exchange.

Table 3.10.2 BIM Implementation paths

Strategy and analysis A controlled path, conscious decisions - often slows down	'Throw at the deep end.' Fast path, requires the help of BIM external specialists	Graduation Moderated, gradual and difficult path to implement
• Analysis and evaluation of the company profile • Defines the strategy and the vision to know more or less what to achieve at the end • Sets the BIM Use Cases and priorities • Requires investment in tools, trainings and development • Inefficient, often remains at a standstill, lowering motivation. • Mostly introduced as a whole implementation which is hard to plan	• Mostly introduced as the BIM pilot project • Rapid transformation from 2D drawings to BIM modelling • Often there is neither previous experience nor training • Lack of appropriate facilities such as tools, competencies, team • Lack of broader strategy, vision or standards introduced • Ad-hoc problem solving to cope with the endeavour	• The scope of implementation adapted to the company and the expectations of the market (Investors) • Tools, the BIM Uses, competences introduced in stages, gradually when the basics are achieved • Continuous use of analyses, concluding the BIM projects • Trainings are spread over the time • Plan B - having collateral for unforeseen situations such as external support of specialists

BIM should be considered as a strategic process that involves organizational change and innovation beyond technical aspects. Therefore, the biggest challenges of all implementation processes are related to the human resources. It is necessary to invest deeply in employees because they affect organizational procedures directly. Especially, there are several things to consider when implementing any BIM Project from the management point of view. However, the most important is time. It is necessary for training team members, adopting the new processes, software's, creating a collaborative way of working for faster data exchange within the members. Moreover, the company should develop clear communication protocols and use the most effective tools for communication. Finally, new procedures for regular reporting of the project's progress and status are required within the existing processes.

3.10.2. Barriers to BIM implementation

Interviewees identified some personal barriers such as lack of understanding of BIM and its benefits, lack of sufficient training and knowledge in applying current technologies. Among process barriers, legal issues (ownership of data- traditional procurement) with insufficient collaboration among stakeholders and time-consuming design were listed in table (3.01.3). For Miastoprojekt Wroclaw business barriers and problems conclude time and cost of training, lack of contractual arrangements, high cost of implementation. In contrast, the in technical level there are absence of BIM technical experts, standards and clear guidelines, sufficient technology infrastructure. Main organization problems identify the reluctance of the managerial staff, various BIM visions, staff turnover, roles and responsibilities issues, disrupted workflows, lack of experience and lesson learnt (Know-how), as presented in table (3.10.4)

Table 3.10.3 Barriers to BIM implementation for the company

Low level of knowledge about BIM among Designers
Low awareness of BIM benefits among Investors and Designers
Too low project prices on the polish market
Time-consuming design in the BIM development
Lack of common standards of operation, legislative regulations conducive to BIM
A small number of specialists with design/execution skills based on the BIM
Fear of the risk of change
Reluctance to change the design/construction methodology
Insufficient cooperation between various market entities
The structure of architectural and construction investments

Table 3.10.4 Main problems with BIM implementation for Miastoprojekt Wroclaw

Various visions and definitions to what extent implement BIM
Implementation of the entire BIM at once (large financial outlays)
The reluctance of the managerial staff
No leader, wrong team with lack of knowledge rotation, wrong roles and responsibilities
1 to 1 experiences translation from other 2D design projects and environments
Lack of standards (maintainer, news, implementation is a long process)
Disrupted workflows by focusing on advanced BIM elements like level of detail
Lack of conclusions drawing, lesson learnt
Legal issues (ownership of data- traditional procurement)

3.10.3. BIM Implementation benefits

Some external factors are influencing the BIM implementations in polish companies such as recently introduced policies for public procurement and documents like BIM Standard PL guiding using BIM data exchange standards, rules and regulations. However, the main internal push factors for Miastoprojekt Wroclaw are desire for innovation with competitive advantages and differentiation in the market. Together with top management support for the development of the design department, the following benefits improving built output quality with BIM can be perceived, as shown in the figure (3.10.2).

Namely, respondents reported the following benefits of BIM from Appointing Party perspective: time-saving, minimizing coordination problems, improving quality and company's processes, earlier involvement of the client in the design stage, reducing cost.

Figure 3.10.2 Identification of the potential benefits of creating a digital information model

3.10.4. Strategic goals

The primary management strategy of Miastoprojekt Wroclaw is the resource management plan. This strategy aims to encourage innovation and advancement in asset management to enable informed decision-making, including the use of digital data management workflows, the development of structured data sets and BIM standards.

Using digital data management and BIM workflows supports the overall asset management objective, including the creation of information models for resources being planned, rebuilt, or existing to transmit more accurate information through the construction process.

The strategic goals of Miastoprojekt Wroclaw are presented as following:

1. Strategic business activities to provide more comprehensive benefits and opportunities: conducting construction, risk management, identifying areas of new activity (with particular focus on the design), cost automation, supporting own decisions and recommendations
2. Managing the delivery of real estate construction services to ensure continuous improvement of efficiency.
3. Raising awareness of asset management and ensuring a transparent decision-making process for facility asset management and its use.

3.11. Achieving Information Flow

The problem observed in practice indicates that employees have several issues with the information management with digitised traditional processes. There is a need to introduced more integrated forms of project delivery with a joint agreement about the exchange and flow of information. To provide a

continuous and effective data flow, the requirements and quality of information have to become explicit. Only when the requirements within the projects are known can they be assured of being fulfilled. The need for a defined organizational purpose increases the need for precise information requirements.

3.11.1. The OIR Framework

For successful implementation of BIM regarding the ISO 19650 series, the Miastoprojekt Wroclaw should start with the statement of need, the precise definition of the information requirements, principles of information management and expected benefits. Different types of information need to be clarified to provide the structure and exchange requirements. Likewise, the processes should be determined.

An organization should develop digital data management workflows and structured strategy integrated into the organization framework. Miastoprojekt Wroclaw mission and goals should be consolidated in OIR document that includes the establishment and categorization of information requirements to meet the needs of the asset management system. Identification of the OIR's will require input from different departments within the company. Data will be needed in particular from the employees involved in the strategic decision making. Therefore, it is essential to understand what the decision-making process is. In the case of the audited firm, entity that makes investment decisions is based on the owner, directors, partly project sponsors and project managers within the specific project.

The OIR template will provide an opportunity to collaborate and integrate information requirements at an organization level. While creating the final OIR, proper consideration should be given to the security implications of access to each piece of data. The OIR will be based on high team requirements, to complete the OIR template, information on these requirements must be provided and will be further developed and extended in the AIR (BSI, 2014). Along with the conventional instruction on building function, form, economy and timing factors, the final OIR will support decisions that generate information out of the model at each information exchange point (Bolpagni *et al.*, 2020). The BIM generates the best value when project starts with purpose and focuses on gathering useful, targeted information throughout the whole asset lifecycle (CIBSE, 2017). The proposed framework of OIR will help the team to aim on clients' information goals while avoiding the technical details of their collection and compilation (this is described in the AIR. The OIR would be used to capture the information required by the Miastoprojekt Wroclaw, which ultimately will help in defining an asset management strategy and project information capture requirements.

The OIR can be created in many ways, such as a simple document, spreadsheet, or a series of fields in a database. The actual mechanism of how the requirements are stored and distributed depends on the organization (CIBSE, 2017). As this is a requirements document, it should establish rules and standards by asking questions. The responses to these questions could be of a form that can be used to fulfil each requirement from the regular operation or design activities associated with the organization's assets, preferably in a digital way. Each requirement should be phrased in a structured, or expected form of response may be given as closed question with a 'Yes' or 'No'.

In reality, this system is rarely automated, and OIRs are usually in document form. Information requested should cover areas including financial, environmental, performance and satisfaction ratings (CIBSE, 2017). It will give a good view of the quality of the assets at the organization level to assist in decision making concerning the assets. It should help in finding what is essential to understand when running the organization. The OIR must be adhered to and followed by all employees in the company.

Identification of questions that the company should answer in order to develop a strategy for the OIR:

- how much time and money will be required to create a data and file store
- how much time and money must be spent for identifying the required information
- how much time and money will be required to collect this data
- what type of people and how many will be needed to run the job and provide management
- what software tools will be used to extract data from the information model and generate reports.

3.11.2. Information requirements

To achieve the strategic goals of the organization, Miastoprojekt Wroclaw defines the scope of activities and defines how the collected and processed information should be used. It was developed based on PAS1192-3: 2014, Annex A (BSI, 2014) and own activities in the field of asset management of Miastoprojekt Wroclaw.

Specific asset management activities (BSI, 2014):

1. Optimizing the asset management strategy and optimizing its asset management plan(s).
    a. Asset accounting, activity costing, forecasting.
    b. Provide a visual/graphical data summary of assets.
    c. Planning and budgeting.
    d. Maintenance, inspection, condition and performance monitoring;
2. Assess its overall financial performance.
    a. Assess the financial benefits of planned improvement activities.
    b. Make life cycle cost comparisons of alternative capital investments.
    c. Determine the cost of specific activities.
    d. Undertake financial analysis of planned income and expenditure.
    e. Obtaining/calculating asset replacement values
3. Model the asset to support operational decision making.
    a. Assess priorities for the future planning of design, construction, repair and maintenance.
    b. Support in making informed decisions regarding activities related to the process.
    c. Asset modifications, refurbishment, replacement, reuse, disposal, recycling.
    d. Support energy efficiency and safety, health and environmental management.
4. Undertake the on-going identification, assessment and control of asset-related risks.
    a. Risk assessment and management.
    b. Contingency planning and emergencies.
    c. Innovation and change management
5. Support the activities related to quality assurance and performance management.

   a. Reduction of work duplication and overproduced information, making information available to a broader audience, promoting collaboration and improving efficiency.
   b. Facilitation of creating data-driven reports for a range of applications/stakeholders.
   c. Improvement of performance while compiling/submitting applications.
   d. Facilitation of careful data management at the component level.
6. Data, information and knowledge management;
   a. Human resources, skills development and competencies.
   b. Establishment of the organization information resource.
   c. Verifying legacy data and knowledge lacks.
   d. Data creation where there are gaps, such as survey data.
   e. Development of CDE where all departments and stakeholders can access asset information.
7. Promotion of consistent national and international standards
   a. Compliance with statutory and regulatory obligations.

3.11.3. Strategic objectives

Miastoprojekt Wroclaw BIM strategy is based on asset management strategy and takes into account both organisational and asset information requirements (Ashworth, Tucker and Druhmann, 2017). A major strategic priority is to ensure that appropriate and high-quality information generated during the BIM process can be combined with information and organization management systems of the company. BIM models and other data created by the project team to assist the improvement of the management, operation and maintenance of the buildings, assets and infrastructure.

The strategic objectives for asset management (Ashworth, Tucker and Druhmann, 2017):

1. To deliver the project following the standards of a design project consistent with BIM Level 2 to reduce costs and optimise construction.
2. To develop an integrated and collaborative workflow to improve teamwork and collaboration and enhance design coordination.
3. To ensure an entire asset management lifecycle process and introduce the transition of appropriate and reliable project data through the client's framework and management resources.

3.11.4. The change of business practices

The adoption of BIM technology requires the integration of the organization's internal environment. At the very beginning, Miastoprojekt Wroclaw should focus on changing and improving its business practices in order to increase work efficiency and surpass workflows. In the following table (3.11.1), some of the proposals are presented.

Accreditation programs based on ISO 19650 gives company a consistent means of assessing the capabilities for better staff trainings, and less time required to familiarise with processes and induction of procedures. Clearly, investment in office system based on ISO 19650 gives more reliable results and raise in productivity.

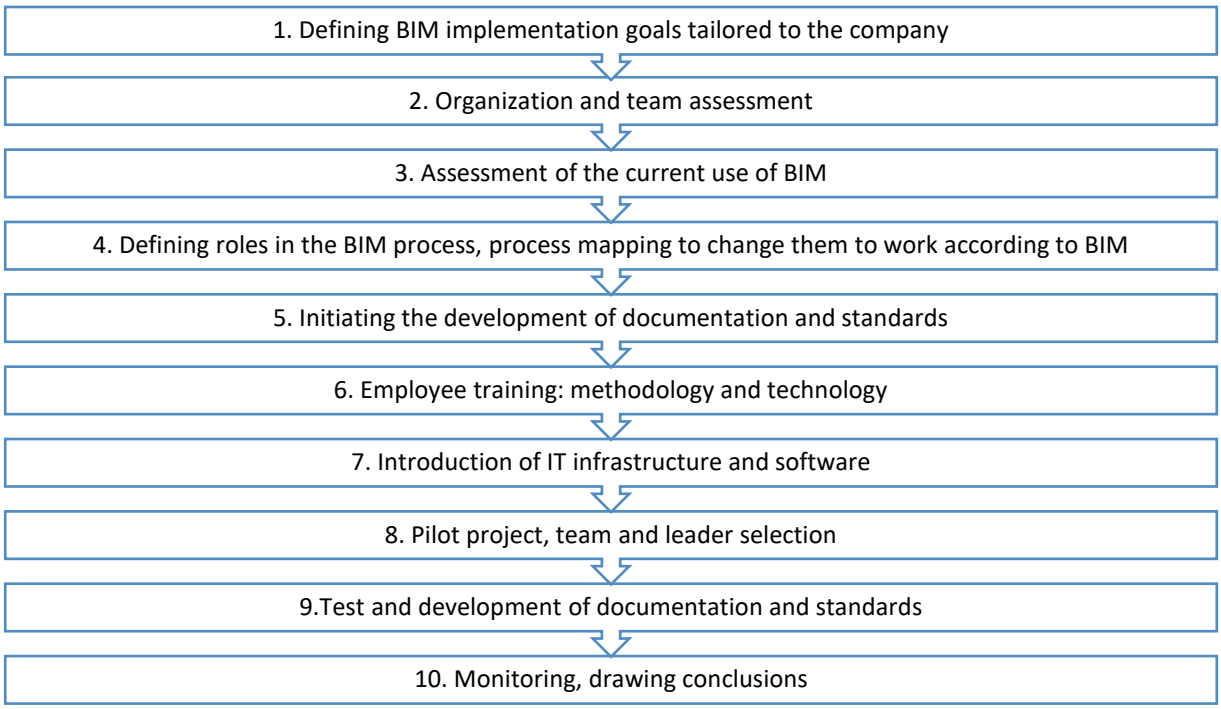
Table 3.11.1 Proposals for business practices improvements

Improved electronic information exchange with a reduction of the maximum amount of manual data entry. Automatization of reports, elimination of manual reports.
Time reduction or elimination of tasks with little or no value.
Reduction of time devoted to 'defence' documentation. Automatizing the creation of reports, registers, protocols.
Integration of the construction cost estimate with building information by using dedicated plugins in chosen programs for modelling.
Reorganize the business processes by performing tasks simultaneously (parallel) instead of sequentially, especially in circulation in the DCS platform.
Automate the real-time monitoring and analyse the operating systems and hardware used in the company.
Analyse the information flow and its accuracy, consistency, completeness and reliability. All information should be entered only once, verified, and if relevant and classified, should have introduced accurate metadata.

3.11.5. Defining guidelines on the scope of the strategy

Information management is a key function of project delivery, according to ISO 19650, requires the appointing party – Miastoprojekt Wroclaw to carry out specific functions mentioned in chapter 3.8.3. (clear set of information requirements, capability and capacity assessment, verification, validation). BIM adoption is an organizational change at the business level. Currently, there is a need to increase the level of comprehension of the BIM principles, rules and terminology among employees through enhanced training (Ashworth, Tucker and Druhmann, 2017). The outlined concepts provide practical advice for Miastoprojekt Wroclaw regarding how they can develop a BIM strategy and OIR document at the start of the BIM adoption and remain engaged through the whole implementation process. Equally with the use of the existing suite of BIM standards and guidelines. The general scope is presented below in figure (3.11.1).

Figure 3.11.1 Guidelines on the scope of the strategy



3.11.6. Defining framework of the scope of the strategy

Based on the analysis of the current status of BIM Maturity level and its implementation of the project model and information, human resources status and other aspects of the analysis, the company should establish comprehensive BIM Implementation team, with initially chosen BIM Champion, unified the BIM technology application and training program for the whole organization. The strategy framework focuses on general action to follow, further assessments and trainings requirements, guidance of project practice and organisation workflows. The whole concept tailored accordingly to the needs of Miastoprojekt Wroclaw is summarised in the following table (3.12.2).

It is essential to think about the change on five levels; why, what, how, when and who. Below there are some key points to consider:

- Get familiar with the correct terminology and incorporate the terms in approach.
- Define information management objectives for projects and organization.
- Assess current and desired resources (people, procedures, training/skills, IT software/hardware)
- Consider how ISO 19650 can complement current practices.
- Define a plan for acquiring the additional resources. Define the new processes and procedures.
- Use structured CDE which allows automation of processes.
- Define the essential measurements.
- Monitor the progress. Check that milestones and objectives are being achieved.
- Continual Improvement Process.

Table 3.11.2 Framework of the scope of the strategy for Miastoprojekt Wroclaw

1.	The purpose of introducing BIM in Miastoprojekt Wroclaw is BIM Stage 2, when information management is carried out according to standards and projects are made as models for separate areas. BIM must be implemented gradually; it is a several years process.
2.	Create a survey about the organization and a list organizing employees' knowledge with their predispositions (how to transfer them into BIM Uses). Case study of the entire organization on a small hypothetical project in a weekend trip.
3.	Defining how to transfer processes based on 2D documentation into ones based on the model. Creating project cards with the most important information about to show the essence of the project without additional searching within the documentation.
4.	Set the organizational structures and processes to standardize them towards BIM methodology such as transfer of competences, improvement of the repository and circulations.
5.	Information management, according to ISO specifications, with adequately defined database documents. Procedural improvements, templates of documents and circulations paths for various types and sizes of projects. Creation of decision gates and reminders for users.
6.	Short about half an hour weekly training for all co-workers to be update with the BIM knowledge. Assurance of constant access to sources and data. Ceding duties to colleagues. Realization of proper BIM Manager training for one or more person. Allow someone to gain the knowledge by working as an assistant.
7.	Purchase of a license for the necessary browsers, such as BIM Collab. At the very beginning of implementation, the free version should be enough. Using openBIM tools like .ifc files.
8.	Performing more pilot BIM topics for competence development. Informing at weekly meetings what exactly is happening in BIM projects within tools and processes. Ensuring knowledge transfer for all employees.
9.	Test and development of documentation and standards. Creation of full BIM schedule with proper BIM Asset Management to check the most critical issues for Miastoprojekt Wroclaw.
10.	Ad hoc support from external specialists in implementing BIM might be essential.

4. CONCLUSION

The very slow but still on-going digital transformation in Poland environment sector requires new standards and methods of project delivery. There is a movement within both public institutions and private companies to develop innovative practices that improve the performance within the construction environment. The justification for Miastoprojekt Wroclaw for implementing the ISO 19650 series as the standard for information management using BIM comes from the need to improve its processes and productivity and move towards digital transformation.

Based on the specific characteristics of BIM application and ISO 19650 and PAS standards, combined with the analysis and assessment of status quo of the company, the general scope for the BIM implementation strategy was defined for Miastoprojekt Wroclaw. The strategy focuses on strategic objectives and organization information requirements, to promote the significant adoption of the BIM processes and workflows, guide project practice and enhance the competitiveness for the company. Having standardised good quality information means it can be exchanged, integrated for different purposes across a range of projects. The plan starts from the research company readiness to BIM adoption and perform organization assessment management processes, standards and platforms circulations, and obtains the capability level of the company of BIM implementation. Then includes analyses the status of the application of BIM with application proposals, and then based on the current situation and industry development trend to develop the strategic objectives for pushing the company towards BIM implementation. Consequently, the guidelines and for organizational requirements regarding the quality of information and also accessing and working with the data.

Through the implementation of BIM and associated software, hardware and resources upgrades, BIM technology will be integrated with project management and organizational information systems such as DMS and DCS platforms. This integration will ultimately support the development of project lifecycle management services. At the same time, Miastoprojekt Wroclaw should pay attention to construction industry development and business innovation, and continuously improve the service quality and company value. The company should aim to dominate the skills and functions of the appointing party accordingly to ISO 19650 and then strive to fulfil some competencies of designers as the appointed party standard represents. To achieve this requires more than new technologies, it needs new operating models that move from traditional ways of working to collaboration across involved parties, plus new standards, policies and capabilities. Developing new integrated business models and exploring information framework across the organization will enable Miastoprojekt Wroclaw to capitalise on the digital transformation agenda.

4.1. Results of organisation research and assessment

The company readiness and capability to BIM adoption is an organizational decision related to the recognized benefits of BIM, managerial support towards the implementation of BIM, organizational level of flexibility towards the change, initial funding issues and strategic objectives. Within the Miastoprojekt Wroclaw, BIM implementation is characterised by the absence of an overall strategy with some defined processes and policies, mostly among non-BIM projects. BIM software tools are not deployed within the company, but are used by appointed parties during the design and construction

phase. BIM adoption is only partially achieved through the efforts of external specialists on two on-going pilot projects but not within the whole organization.

Assessment report for Miastoprojekt Wrocław (organisational scale 9) discovered to be at Capability Stage 1 within the step A (from pre-BIM to object-based modelling) with two on-going projects at initial step B towards Capability Stage 2 within the software and project deliverables. The overall Maturity Level Score is between a and b – initial(ad-hoc) and defined.

Miastoprojekt Wrocław, as the substitutive investor, acting on behalf of the client, is mostly responsible for whole supervision of the execution of a project. The general recommendation for the company is to invest on developing primary BIM Uses (Cost Estimation, Phase Planning, Design Reviews and 3D coordination) connected with reviewing, coordinating and managing among their current employees. Once the BIM adoption is at a more advanced stage, it is suggested to introduce slowly other competencies for modelling and design.

4.2. Framework for OIR implementation

The OIR template has been structured to offer Miastoprojekt Wroclaw a starting point to create an OIR. However, the company needs to tailor the OIR to their own strategic goals on the managerial level. The guidance suggests to start by understanding the management of their assets before establishing the aims for OIR. The information requirements were developed from the perspective of the appointing party and to meet the company needs. The earlier studied BS and PAS BIM standards were used throughout the development of the OIR document. The template includes a guidance section at the front to be later removed after the draft has been developed and is ready for use in the company.

4.3. Framework of the scope of implantation strategy

The primary management strategy of Miastoprojekt Wrocław is the asset management plan. The goal of this strategy is to encourage creativity and innovation in the management of assets, such as the use of digital data management workflows, the development of structured data sets and BIM standards to enable rational decision making. Using digital data management and BIM workflows supports the overall asset management aim, including developing information models for assets being designed, renovated, or existing to transmit more accurate information throughout the construction process.

Some practical implications for company substitute investor profile can be draw. The implementation should have an appropriate financial buffer for expensive software, better hardware and proper employees' trainings to obtain adequate skills and BIM Uses. However, the costs of implementing BIM can be offset by the long-term potential cost savings. Moreover, the company should have a BIM champion with the proper energy and enthusiasm for the changes. This person should support the team daily in terms of technical knowledge and also improves their morale. The first BIM design topic should be simple in order not to face both BIM and design difficulties while working, which could quickly revert to the old, 2D-orientated tools. Also, employees should use standard BIM protocols and follow the requirements from ISO 19650 and PAS standards.

These results help the company to be highly aware of BIM and understand its benefits, barriers and the main push factors to implement BIM. Together with the recognition of the desirable level of practice and the corresponding measurable phenomenon, which can then be introduced. Applying the developed strategy from the defined scope ensures the success of the BIM implementation which in turn improve the company performance and effectiveness, solving the project's issues and enhance the competitiveness in the AEC industry in Poland.

4.4. Limitation and assumptions of research

There is a difficulty to provide a proper image for any substitute investor for construction industry in Poland, due to the small sample size as a limitation of this study. BIM adoption in Poland is still at its early stage. Thus there are not many BIM professionals or enthusiasts. Even though, the Polish government has recently introduced policies and instruments supporting BIM implementation; there is a considerable gap in building law, hence, no consistent demand in the construction industry. However, analysis of interviews is valid as the sample size satisfied the specific company requirements and needs to obtain a representative result. Moreover, the respondents were mostly all permanent employees from Miastoprojekt Wroclaw, such as project managers and site engineers. The respondents, as the participants of construction investment, interact with other project stakeholders, although no responses were directly received from contractors or designers, except three external BIM Managers. Lastly, the findings of this study should be interpreted in the context of Poland, and it may be challenging to generalize
the research findings to other company's profile than substitute investor.

The research is limited to:

- The presented scope of this research (chapter 1.5).
- The influence of governmental impact is not altogether estimated.
- Duration of the dissertation is a few months.

4.5. Further research

Further research might help to demonstrate the embedded processes and procedures in the company that require adjustments to achieve the capability to deliver a BIM project. It can be achieved by evaluating project progress and by defining the discrepancy between the design information needed and the design information provided. This assessment involved user design information, such as contractors, subcontractors and designers, to determine the information criteria about entities and properties and the sequence of deliveries of information.

Moreover, the focus should be put on the criteria to measure BIM implementation systematically in the company. Continual improvement process means that after each business workflow change or employees knowledge gain, the basic organizational assessment should be conducted. Consequently, regular audits give the recognition of BIM adoption for Miastoprojekt Wroclaw. Finally, it is recommended for further research to consider looking at contractually issued AIR with their respective EIR and BEPs to see how they align with OIR and to consider further reviews with practice to help improve the current framework and template.

LIST OF ACRONYMS

2D	2-dimensional
3D	3-dimensional
4D	4-dimensional (time)
5D	5-dimensional (cost)
6D	6-dimensional (operation)
7D	7-dimensional (sustainability)
8D	8-dimensional (safety)
AEC	Architecture, engineering, and construction
AECO	Architecture, engineering, construction and operation
AIA	American Institute of Architects
AIM	Asset Information Model
AIR	Asset information requirements
AM	Asset management
BASIR	Built Asset Security Information Requirements
BASMP	Built Asset Security Management Plan
BASS	Built Asset Security Strategy
BCF	BIM collaboration format
BEP	BIM execution plan
BIM	Building Information Model(ing)
BIMA+	European Master in Building Information Modelling
BIMFMI	BIM/FM Integration
BLM	Building Lifecycle Management
BMS	Building Management System
BS	British Standard
bsDD	buildingSMART Data Dictionary
bSI	buildingSMART International
BSI	British Standards Institute
CAD	Computer-aided design
CANBIM	Canada BIM
CAWS	Common Arrangement of Work Sections
CDE	Common data environment
CESMM	Civil Engineering Standard Method of Measurement
CIBSE	Chartered Institution of Building Services Engineers
CIC	Computer Integrated Construction Research Group at Penn State
CIFE	Centre for Integrated Facilities Engineering
CMM	Capability Maturity Model
CMMS	Computerized Maintenance and Management System
COBie	Construction Operations Building information exchange
COBIM	Common BIM Requirement
CoClass	Swedish classification system
DCS	Document Circulation System
DMS	Document management system
DOC	Document file format
DWG	Drawing file format
EDMS	Electronic data management system
EHS	Environment and Health Safety

EIR	Employer's information requirements
EN	European Norm
ENGIE	ENGIE multinational electric utility company
EU	European Union
EUROFM	European Facility Management Network
FM	Facilities management
GDDKiA	Generalna Dyrekcja Dróg Krajowych i Autostrad
HKIBIM	Hong Kong BIM
HVAC	Heating, ventilation, and air conditioning
IAI	International Alliance for Interoperability
IDM	Information Delivery Manual
IDP	Integrated Design Process
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IGES	Initial Graphics Exchange Specification
IMP	Information Management Process
IPD	Integrated project delivery
IR	Information requirements
ISO	International Organization for Standardization
IT	Information technology
KNR	Catalogues of Material Expenditure (KNR)
KPI	Key performance indicator
LEED	Leadership in Energy and Environmental Design, building rating system
LOD	Level of definition (UK) or level of model detail (USA)
LOI	Levels of model information
MAD	MAD Engineers Company
MEB	Model Element Breakdown
MEP	Mechanical, electrical, and plumbing
MIDP	Master information delivery plan
MOTA-ENGIL	MOTA-ENGIL Construction Company
NATSPEC	National BIM Guide in Australia
NBIMS	National Building Information Modelling Standard
NBS	National Building Specification
NRM	New Rules of Measurement
OAM	Organization Assessment Model
OIR	Organizational information requirements
OmniClass	American Construction Specifications Institute
PAM	Project Assessment Model
PAS	Publicly available specification
PDF	Portable Document Format file
PIM	Project information model
PIP	Project implementation plan
PIR	Project Information Requirements
PKN	Polish Committee for Standardization
PKOB	Polska Klasyfikacja Obiektów Budowlanych
PKP	Polskie Koleje Państwowe
PLQ	Plain Language Questions

PN	Polish Norm
RACI	Responsibility assignment matrix,
RFI	Request for information
RIBA	Royal Institute of British Architects
SEI	Software Engineering Institute
SMP	Standard Method and Procedure
STEP	Standard for the Exchange of Product model data
SMS	Short Message Service
TIDP	Task information delivery plan
UK	United Kingdom
UN	United Nations
Uniclass	British unified classification system
US	United States
USA	United States of America
VDA-FS	CAD data exchange format
VDC	Virtual design and construction
WARBUD	WARBUD Construction engineering company
WBS	Work Breakdown Structure
WIP	Work in progress

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