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IN PRAGUE

FACULTY OF
CIVIL ENGINEERING

DIPLOMA THESIS

2020

JAKUB
SMOLEŇ

ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Smoleň** Jméno: **Jakub** Osobní číslo: **439186**

Fakulta/ústav: **Fakulta stavební**

Zadávající katedra/ústav: **Katedra ekonomiky a řízení ve stavebnictví**

Studijní program: **Stavební inženýrství**

Studijní obor: **Projektový management a inženýring**

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce:

Datový standard objednatele pro plánování staveb

Název diplomové práce anglicky:

Empolyer's information requirements for construction planning

Pokyny pro vypracování:

V současné době je velmi aktuální téma EIR (Employer's information requirements), někdy také uváděno jako datový standard, nebo požadavky objednatele na data. Téma zasahuje do popisu datových požadavků na projekty u nás i ve světě. Student provede rešerši těchto standardů. Praktická část bude zaměřena na požadavky na data související s plánováním s využitím informačních modelů staveb.

Seznam doporučené literatury:

Metodiky Státního fondu dopravní infrastruktury.
Metodiky České agentury pro standardizaci.
Lukas Klee et. al., 2018, International Construction Contract Law 2nd Edition, Willey.

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Jméno a pracoviště druhé(ho) vedoucí(ho) nebo konzultanta(ky) diplomové práce:

Datum zadání diplomové práce: **26.09.2019** Termín odevzdání diplomové práce: **05.01.2020**

Platnost zadání diplomové práce: ______________

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III. PŘEVZETÍ ZADÁNÍ

Diplomant bere na vědomí, že je povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací.
Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

.

Datum převzetí zadání — Podpis studenta

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF CIVIL ENGINEERING

EMOLOYER´S INFORMATION REQUIREMENTS FOR CONSTRUCTION PLANNING

DATOVÝ POŽADAVEK OBJEDNATELE PRO PLÁNOVÁNÍ STAVEB

Statutory declaration

I hereby declare that the diploma thesis titled “Employer´s information requirements for construction planning” submitted to Czech Technical University in Prague was written by myself under the guidance of Ing. Josef Žák, Ph.D. I have stated all the resources used to elaborate this thesis in conformity with the Methodical guide for ethical development of university final thesis.

Prague, 5th January 2020 Jakub Smoleň

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Abstract

This diploma thesis focuses on the Employer's Information Requirements (EIR). It defines what they are, how they are being used and their implementation in selected countries around the world. The practical part will describe a selected project, which will be thoroughly examined in whether it used any elements of Employer's Information Requirements, what is the use of these elements in the project, and whether there still is a room for improvement.

Key words

Employer's Information Requirements, Building Information Modeling, Data, Planning, Visualization, Sequencing, Management, Investor, Contractor, Development

Abstrakt

Táto diplomová práca sa zameriava na datové požiadavky objednávateľov pre plánovanie stavieb. Definuje čo sú, ako sa používajú a ako sa implementujú vo vybraných krajinách po svete. V praktickej časti bude opísaný vybraný projekt, ktorý sa dôkladne preskúma v tom, aké využitie majú tieto požiadavky v stavebnom projekte a či stále existuje priestor na zlepšenie.

Kľúčové slová

Dátový požiadavok objednávateľa, Informačné modelovanie stavieb, Dáta, Plánovanie, Vizualizácia, Postupnosť, Manažment, Investor, Dodávateľ, Development

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1. Introduction

When people working in the construction industry are asked about Building Information Modeling, they usually arrive at an image of a building drawn in three dimensions, consisting of all the different elements from the concrete slab in the foundation to smallest pipes and cables of mechanical, electrical or plumbing units. A model from which we could collect valuable data during not only the phase of planning and construction, but also from the phase of building´s operation. Although these people would not be entirely wrong, they seem to simplify the matter at hand into an ideal solution everyone hopes Building Information Modeling would one day be. With that being said, there are still many steps and decisions to be made in order to arrive to this point. The building stones for a successfully executed project using Building Information Modeling are the data we feed into the project in order to get the results which would not only find their use in the project itself but could be measured and evaluated for projects in future. In order to fill data into a model all of the addressed parties need to create a guide on what amount of data is necessary in order to execute the project successfully. The document for creating, evaluating and improving the process of data assembly is called Employer´s Information Requirements. This document, if done right, could be a massive push forward into a deeper assimilation of BIM into the everyday building practice. Moreover, if the project investor is not an expert in the Building Information Modeling, this document could be a safe haven for the him/her, in case some of the paid professionals decided to execute their work in the "paper-based" traditional way they were used to from the past.

The aim of this work is to give a thorough description of the Employer's Information Requirements topic. This work will be divided into two parts. The first part of the thesis is going to research the EIR, their purpose, their creation and maintenance system, their connection to other BIM attributes (such as IFC) and present a short overview of how they are being used in selected countries. It will evaluate legislature, standards and practice in elected countries in order to give an overview of where this topic is today and how it could be developed in the future. Moreover, it will take a look at some of the more problematic projects in the Czech Republic and surrounding countries and discuss whether there could be a solution found using the EIR. The second part of the thesis will concentrate on an existing project, which will be evaluated based on the use of EIR. The work will discuss whether the project has reached its potential from the EIR standpoint and give commentary on the matters which could be improved. A conclusion at the end of the thesis will offer an insight to the outcomes of this thesis and provide a glimpse into the future of EIR.

In no way should this work serve as an advertisement to companies and software used in the thesis. Furthermore, this work should not present any of the studied objects in a negative nor positive manner. This work is meant to be an informative guide on the current situation in Employer's Information Requirements.

2. Employer's information requirements

This chapter of the thesis introduces employer's information requirements (EIR) in depth. At the beginning, it presents BIM and its overall benefits to the construction industry. It explains how EIR connects to BIM, and how it enhances the whole process.

2.1. Purpose of EIR in BIM

In the rapidly changing world, where new groundbreaking technology can be an outdated glyph few months after its release, there is an ever-growing demand for the construction industry to use the conveniences of today's world. When looking at the collected data, we find that construction industry, specifically its productivity, has stagnated if not decreased in the last two decades. The productivity in the manufacturing industry, on the other hand has nearly doubled (McKinsey&Company, 2015).

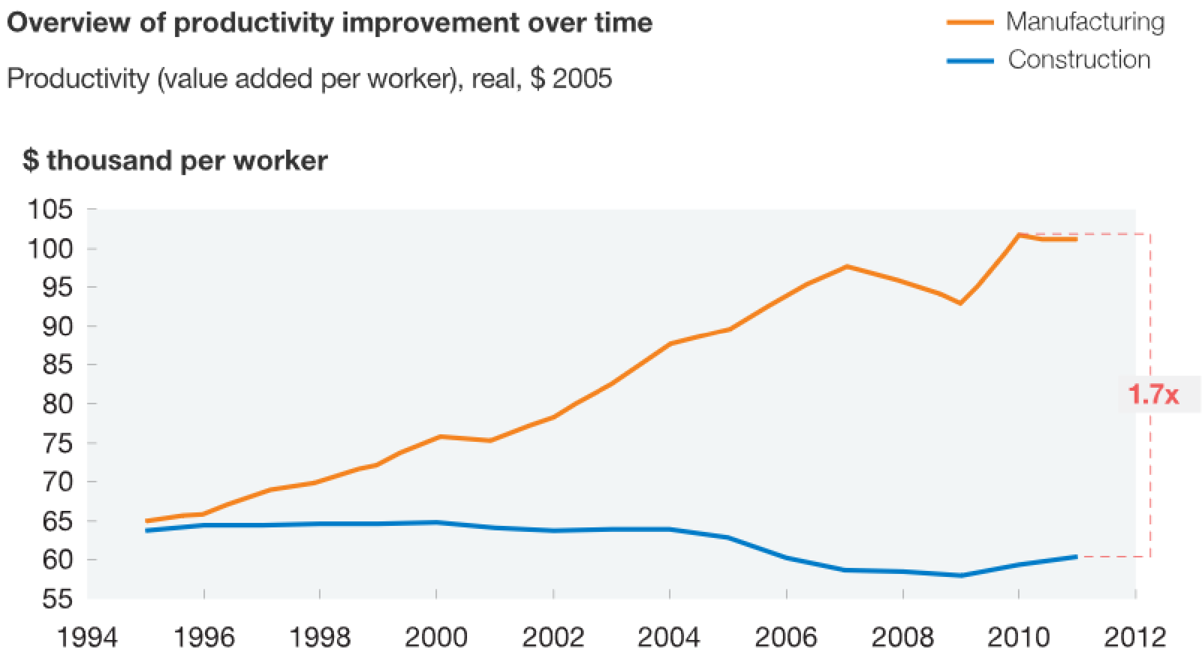


Figure 1. Productivity of manufacturing doubled compared to construction (McKinsey&Company, 2015)

One may argue, that the comparison of these industries is not a fair one, since the product of a construction industry is an original piece, whereas the manufacturing industry has the advantage of creating large portions of similar products on a regular basis. The given properties of manufacturing industry have made it easier to be standardized, therefore cancelling out or outsourcing possible errors. Construction still however is in the field of industry, and the more productive and profitable one will always be the more lucrative in the eyes of investors, future talent and the general population. The assumption progressive civil engineers would and should make is to go one level deeper and concentrate on tasks which are needed to construct a building. These tasks are repeated regularly at every construction project therefore, they have the potential to be standardized, and this is the point where BIM enters the formula.

Implementation of BIM has had and will continue to have enormous influence on the state of the construction market. A study has shown that contractors rate BIM benefits among top three in their companies. The companies surveyed experienced a 19% growth in marketing new businesses and reducing overall project duration. A growth of over 20% was observed in better cost control predictability and reducing construction cost. Reduction of rework and company image enhancement have experienced an improvement of over 30%. Finally, owner/designer collaboration has been improved by 35%, while reduction of errors and omissions has been enhanced by 41%. The study also measured the correlation of BIM engagement of companies to its benefits. The results are showing that half of the contractors with the highest level of BIM engagement report very positive return on investment. The return of investment for the most engaging companies is measured at over 25%. Companies with the lowest BIM engagement report an ROI of 11% while a third of those companies reports numbers which are negative or barely breaking even (McGraw Hill, 2014).

Companies trying to adapt to the new trends in construction will also have to manage the creation of new jobs facilitating for a smooth adaptation of BIM in their construction field. The responsibilities and skillset of a delivery team of a project will have to adapt to the changes BIM brings. People in project teams will have to get used to their new or “pivoted” role. For example, estimators will have to transform their skillset to fulfill more of a cost engineer role. However, roles such as planning, management, and quality control/validation are not expected to undergo any significant changes. Early BIM adaptation puts an emphasis on experienced project management, design and architects, however there is a belief that graduates will find newly created fields appealing and could resolve the overall skill gap (Gathercole).

The data centricity of companies in construction business will have to follow suit of companies in other fields of industry. In these data centric industries, validating and verifying information exchanged between collaborating parties are key in their contractual relationships. The construction industry has for centuries been able to understand the demand for newest information management aids and translate them into design. These aids are in the range of physical models to computer aided design and were always adapted into the industry in order to make the industry more efficient. However last 40 years have shown, that litigation for incorrect or late exchange of information has driven parties affected to regard information exchange as a burden. In addition, they started incorporating information exchange into their risk management procedures. The point has been reached, where if the industry does not develop mechanisms of formalizing the data exchange between parties before they happen and does not check, whether they are acceptable when they happen, BIM and the predicted efficiencies it could bring will not move forward. The spectrum of data verification is broad and has many levels. Starting with the easiest data exchange fit to be checked by a computer, to the hardest ones requiring expertise and considerable judgement by construction professionals deciding upon them. The irony of current situation is that the industry is starting off from the highest level of the spectrum, trying to validate through clash detection, rather than concentrating on much more straightforward activities such as robust data sharing re-use. For a shared success of clash detection, each party must submit their BIM content in form that can be federated consistently and therefore allow for the clashes to be identified. Causes of failure are usually tracked to the lack of contracts considering clear data and how it can be shared and re-used. The contracts should define items such as grids, co-ordinate systems, object names, locations, classification etc. (Lockley, 2015).

The EIR should eliminate bad decision making, which could be made even by an experienced professional, but is not backed by proportionate data. All of the required data should be decided upon and written down at the beginning stage of each project and should be presented to all parties having stakes in the project.

2.2. Definition of Employer's information requirements

Even though the (ISO, 2018) has renamed the Employer's Information Requirements into Exchange Information Requirements, the main idea stays the same for both interpretations of EIR. The EIR encompass managerial, commercial and technical features of creating project information. Both managerial and commercial aspects should incorporate the production standard, methods and procedures to be implemented by the delivery team. Technical aspect of an EIR document should determine the detailed pieces of information, which are essential in answering the project information requirements. These conditions are to be expressed in a way, in which they can be integrated into project related instructions. The EIR document should align with milestones of a given project, which change the status of the project during its lifecycle (could mean completion of some or all project stages), resulting in information exchange. (ISO, 2018)

EIR should be considered whenever information exchange takes place. Particularly, EIR collected by an appointed contractor should be sub-divided according to needs and passed on during any of the appointments set by a contractor with his sub-contractors along the supply chain. In a perfect scenario, parties which are being given the EIR should compare it with their own EIR and augment or at least comment the original document in order to evaluate whether this task is manageable by a sub-contractor. Sub-contractor information exchange does not have to be shown to the investor if it stays in the boundaries of the original EIR. Number of different information exchanges are needed across a project, the EIR from all these appointments should form united and harmonized information sets sufficient to address all of the project information requirements. (ISO, 2018)

2.2.1. **Establishing employer's information requirements**

The investor shall establish the EIR, which should be met by the contractor during appointments scheduled by the investor. The investor should establish the level of information needed to satisfy each information requirement. The owner can also use other metrics such as level of accuracy if he/she considers this criterion appropriate. Establishing clear rules for acceptance of each information requirement is crucial in order for investor to have functional leverage on all of the contractors during the whole duration of the project. The acceptance criteria should consider the project's information standard, if there is one, and optimal project information production methods. The owner should also produce additional supporting information for the main contractor in order to fully understand what information is required from them. Supporting information should incorporate:

- existing information on assets
  - either from within investors organization or from external providers or public sources (mapping and imagery)
- shared resources
  - output templates (BIM execution plan), object libraries (3D elements), style libraries (lines, texts hatch), information containers (BIM execution plan)
- references to national or international standards
- examples of similar information deliveries from the past

One of the most crucial data contained in the EIR are the delivery dates, which should be connected to project milestones and key decision points as well as the time needed by the investor for review and acceptance of given information. (ISO, 2018)

Together with asset information requirements (AIR), project information requirements (PIR), and organizational information requirements (OIR), the EIR create a unified and standardized approach with which an investor can optimize his/her business in accordance to building information modeling. The crucial point in delivering the information into a project are the information delivery cycles. Principles introduced by these cycles are:

- Information is needed for decision making in all parts of the life cycle, including when there are intentions of developing new, enhancing existing, or decommissioning old information in a project.
- Information is stated through sets of requirements defined by the investor, and delivery of said information is scheduled and delivered by the contractors

- In a case of a supply chain, information should travel through a supply chain to a most relevant sub-contractor
- exchange of information should involve sharing and coordination of said information through a Common Data Environment, clearly stating procedures enabling a consistent approach by all organizations involved

Revision of acquired information is necessary in order for the whole process to work. Information which is delivered and approved has to undergo a feedback loop to decide whether this information was handled accordingly. The feedback loop shown in figure 2 is a good tool for iteration and further improvement of information exchange between two exchanging parties. Information verification and validation as well as its documentation is a must before any information exchange takes place. If there has been a change in the contractor or sub-contractor between one stage of the project and the next, another check should be executed if there is a delay on a project before the next project stage starts. Second information check may not be needed if the contractor does not change and the project runs smoothly without any delays. (ISO, 2018)

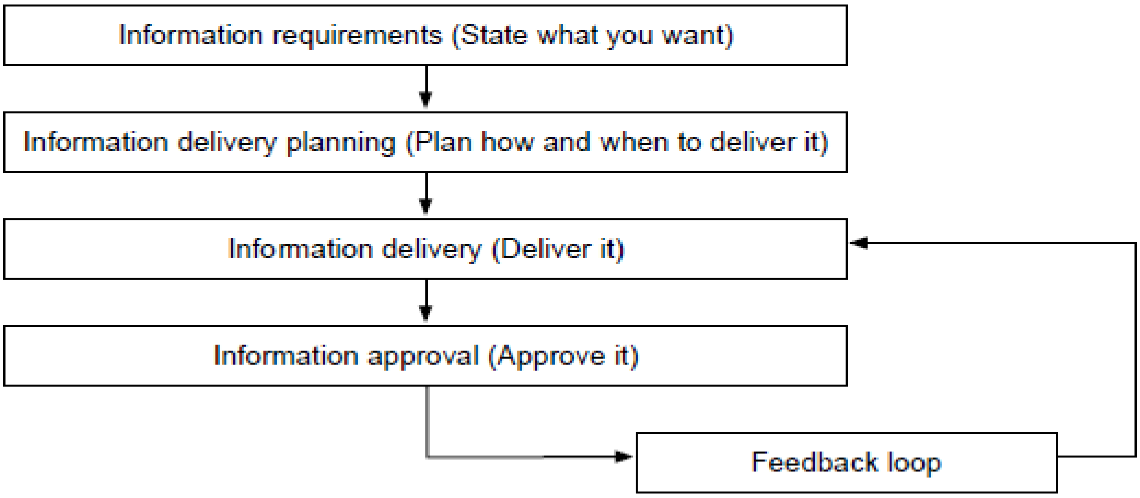


Figure 2. Information iteration and adjustment with the help of a feedback loop (ISO, 2018)

Put in a more practical sense, what the EIR are providing us are tools, by which we can control the project and execute key decisions based on hard evidence incorporated in data, which the investor collects from the contractors. The investor therefore has an opportunity to make a key decision based on hard evidence and data, rather than on an educated guess or many times chance. The data collected by a mere document stated at the beginning of a project could be worth millions of euros saved at the successful construction and operation of a building. Considering the ability to learn from project to project, an investor in a perfect scenario, could even build his/her own library of benchmarks according to which he or she could decide which actions to execute/not execute to ensure smooth running of a project. In continuation of a practical analogy, assumptions can be made, that by setting a mere start construction and end construction date for each element in a federated model, investor could concretely address problems with penalties on a delayed project. Investor could furthermore recognize bottleneck activities according to data collected on more projects in order to accommodate for the expected delay in the contracts. The whole process should help in creating better and more transparent contracts between an investor and a contractor.

Timing of information delivery should be following a delivery plan, which should be defined for the whole project or for the medium or short-term periods according to the density of appointments between parties. The timing of every information delivery should be incorporated in each information delivery plan, with reference to project management schedule when it is known. A responsibility matrix should be created in one or more levels of detail, the axes of the responsibility matrix should classify:

- information management functions
- information management tasks

R = responsible for undertaking activity A = accountable for activity completion C = consulted during activity I = Informed following activity completion	Employer/Investor	Third party	Contractor	Sub-contractor
Appointing individuals to undertake the information management function	A	I	R	R
Establishing project's information requirements	A	C	A	A
Establishing project information delivery milestones	R	I	A	A

Establishing tender response requirements and evaluation criteria	A	I	I	I
Compiling information to tender invitation	A	I	I	I
Contractors tender response	I	I	A	I
Confirmation of contractors BIM execution plan	A	I	R	C
Test project's information production methods and procedures	R	I	A	A
Information model review	A	I	A	R
Capture lessons learned for future projects	A	I	R	R
…				

Table 1. Responsibility matrix (ISO, 2018)

Information managed in the common data environment should be recognizable by all of the stakeholders. To support this, following needs to be agreed upon:

- format of information
- format of delivery
- how an information model should be structured
- means of data structure and classification
- names of attributes for metadata (properties of objects)

(ISO, 2018) states, that classification of objects should be in accordance with ISO 12006-2, while object information should be in accordance with ISO 12006-3 in order to support object exchange.

2.2.2. **Managing collaborative production of information**

Information should be at any time available to people who are expected to execute their function with the use of information. A common data environment (CDE) enables to solve this issue with a development of a federated information model. This model is created out of several information models created by a sub-contractor (MEP, HVAC, facade etc.) put together to create an overall model. Coordination issues are to be addressed at the production of information rather than detected after the delivery of information. Issues could range from spatial ones, such as installations being in collision with concrete walls, to functional, such as the amount of air flow through an HVAC unit being too low to supply the whole indoor space. (ISO, 2018) identifies more instances of spatial issues and categorizes them into "hard" issues, "soft" issues, and "time" issues. Hard issues would mean an element occupying a place of another element, while a soft issue could mean that an element is occupying space of maintenance of another element. Time issue would mean two objects existing at the same place at the same time. Selecting a generic model element and applying it onto an overall model to pinpoint the space that is needed for installing, connecting or maintaining an object.

Establishment of information containers should also be specified in the EIR. After completing the constructional phase of the project and shifting the project into its operational phase, latest information containers should be kept as support documents for facility management. Archived information containers should be marked as a read only, as a reference to the latest ones. The timescale for holding the information containers should also be set up in the EIR. Current revision of information containers can only be in one of these three states: work in progress, shared, published, and archived as seen in the figure 3.

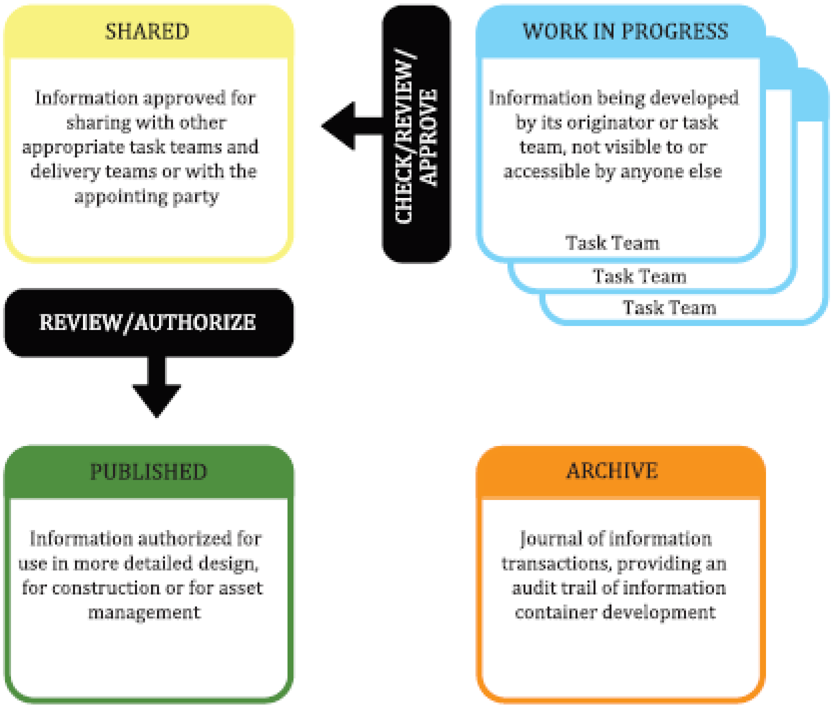


Figure 3. Three states of information containers (ISO, 2018)

The work in progress state should be the most crucial state for each designer and person contributing to the construction project. During this stage the information container should not be accessible by any other task team working on the project. The check and review process then compares submitted information against information required by the EIR. The shared state offers space for collaborative development of the information model. All of the information containers shall be consulted by appropriate consulting teams in order to compare and coordinate with their own produced information. All parties should have access to these containers but no party should have the right to edit any of the containers at this stage. In a case where a container needs to be edited, it should be brought back to the work in progress state and should be edited by its author for second resubmission. In the review/ authorization

process, the containers should be checked against requirements for coordination and accuracy stated in the EIR. If a container does not fulfill the expectations (accuracy, scope, completeness, etc.) it travels back to the work in progress state and should be edited for resubmission. This authorization should filter information which is crucial in project delivery, including more detailed design or time scheduling, from information which is not crucial and could be further edited without any influence on the project schedule. The published state is for information, which has been authorized for final use of the project. The archive state is utilized as a journal of published information during the whole project life cycle. It serves as a trail of the overall project development and collects all information, which was already used in the project. (ISO, 2018)

2.2.3. **Costs and benefits of creating an EIR document**

As with all the newly applied practices in business, there is an expectancy of hardship in successful application of using employer's information requirements as a steering document for all the data in a project. There is a possibility of a steeper learning curve, however. The more people, which are interested in the topic of digitalization of construction and have some construction background are brought to companies with the desire to apply new BIM practices, the steeper the aforementioned learning curve could get. However, the difficulty of creating a 4D model raises exponentially with the ‘correctness’ of the 3D model. 4D model creation requires a simple linking process in order to facilitate for the added dimension of time into the project. Therefore, the presence of a scheduler during the 3D design phase is highly recommended (Jacobi, 2010). Another hardship would be to apply this method onto pilot projects and to convince people working on the project of the benefits of having clear information sources and routes to get to these sources. There are going to be mistakes made during the process and one of the key aspects of bringing functional EIR into construction practice is to monitor these mistakes and to learn from them on projects in the future. New or at least slightly changed versions of jobs will be necessary to manage these changes in the application of EIR and in construction industry in general. Many professions will be required to get involved with a project in the very early stages. “What if” scenarios could be implemented for testing and improvement of different schemes. EIR should also clarify which professions and at which time are to enter the project in order to make the whole process effective. With that being said, cost of changes during the actual construction of a building are unquestionably higher than all of the costs mentioned above. In a broader term however, costs at the beginning of a construction project, whether it be even before tendering for a contractor or at the start of the project can be costly. According to (Stephen P.R. Charles) the difference between a proactive change to the project at the start and the reactive change during the project is not high in terms of financial costs. The document argues that reactive changes can be at times less expensive than proactive changes. Reactive changes place a construction project to performance levels which were initially expected at the start of the project, while proactive changes are put in place to better the overall performance of project above the targets set initially. From the perspective of two researched construction refurbishment projects done by (Stephen P.R. Charles), the research found that a significant contribution to project cost overrun is in relation to proactive changes, nevertheless these have the biggest potential to bring down the whole life cycle cost of the whole project.

Even though Figure 4. shows a graph of impact of changes made in the design process, one could assume that a document setting up clear rules on how to use data and how to interpret created data for the designing process of a project could have the same if not higher benefit compared to starting early with the design of a project. Therefore, it can be argued that employer's information requirements could not only bring clear set of rules by which data should be handled, but also creating an environment in which many optimizations could be performed, therefore lowering the overall life cycle cost of the whole construction project.

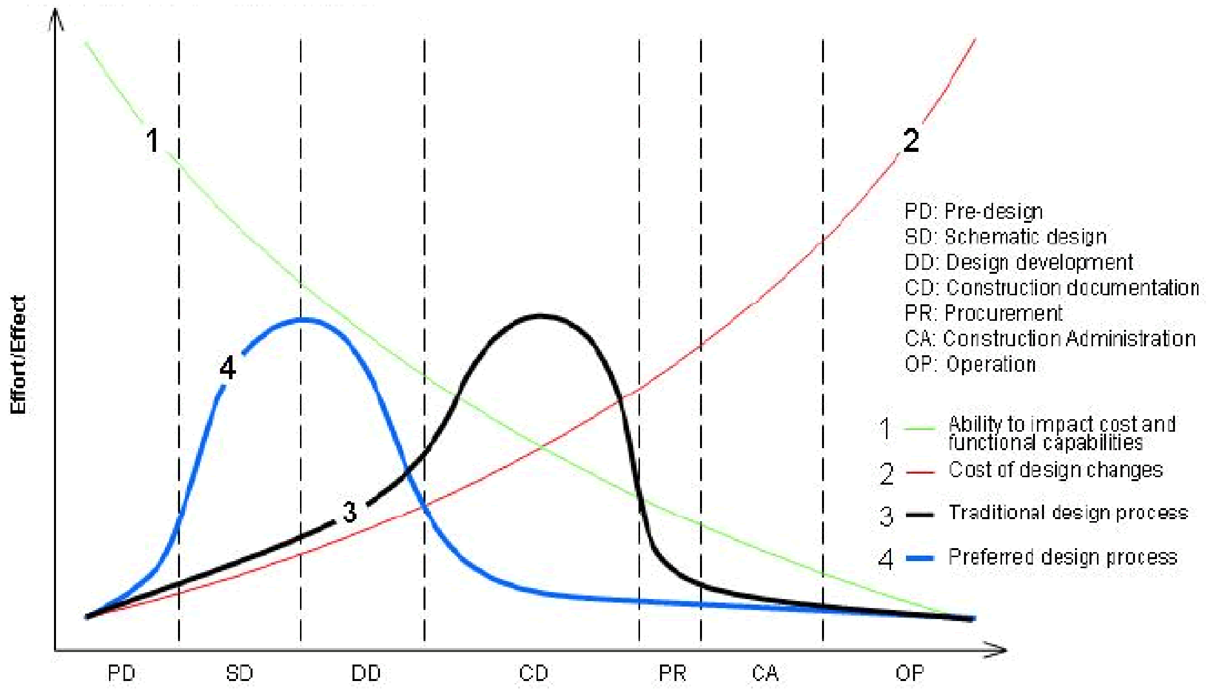


Figure 4. Effort and reward of design decisions (Adapt4ee, 2012)

2.3. Construction sequencing in EIR

Construction sequencing could be described as the process of incorporating an additional extra layer of scheduling data onto a project information model. Additional dimension can be used on different project components in order to build them as the construction project develops. Therefore, step by step project visualization is achievable. To put it in practical terms, construction sequencing allows to create a visualization of each project step through connection of a 3D model with the project schedule. Thus, stakeholders can acquire an exact project overview and stay on top of everything that happens on site, while also pushing for a safer and more straightforward planning process. Visual project scheduling can be immensely beneficial for both people management and material management on site. Moreover, based on the addition of data scheduling in the project information model, project owners can have an overall image of the project from design to completion at a very early stage. Detailed visualization of each step should be able to help the management team in the prevention of mistakes, detection of clashes and re-adjustment according to information added to a project. The result of implementing construction scheduling could also mean that every project worker could be at least one step ahead of what is happening on site. Being one step ahead of what is happening on site also means the trust and confidence in the materials needed in order to perform the future task, which would have been seen on the visualization. Another positive could be seen in the minimization of on-site construction meetings in order to keep all of the professions up to date on current project advances, while all of the workers could already be on the same page by following the visualization of time advancements on the project. Project monitoring could also advance with the addition of time into the information model, while current project advances could be compared to the initial design in order to find any deviations from the agreed plan. Finally, use of construction animation could have an immense potential in providing better safety on the project both in terms of breaching data and site accidents hazards.

EIR can play a pivotal role in providing crucial data in order to create a construction sequencing model. People may think of the EIR as a root from which the whole tree grows, and as a saying goes: ‘A tree stands strong not by its fruits or branches, but by the depth of its roots.’ It is especially true when accessing construction sequencing problematics. Firstly, EIR should point out whether a project needs construction sequencing and whether it is feasible. For some projects, which could be similar to previous projects, construction sequencing may not be the most groundbreaking tool, since most of the workers would already have done a similar project in the past and therefore would not need an additional simulation to navigate them through the project. Secondly, if the decision went in favor of utilizing construction sequencing on a construction project, it is crucial to access additional data needed in order to create such sequence. One may start with simply putting a start and end date for all construction parts in order to put them onto an imaginary timeline. This practice however combines many coordination tasks between schedulers and designers. It is crucial to create a contract in which there would be minimal room for cutting any corners and therefore making the job easier. Only a working sequencing model will bring the expected benefits, thus there has to be a safeguard in the EIR against any false information or lack of any in form of penalties. Coordination between professions is also crucial in order to create comparable file formats. The EIR should clarify which software is to be used on the project and how to correctly name and sort each element so there will not be any clashes between the software. Close cooperation between schedulers and designers could help push this process forward and bring the expected benefits, for example if the floor plates are being created sequentially and not one at a time, schedulers could cooperate with designers in creating a model with divided floor plate in order to accurately model the whole situation in the time sequencing model. From the standpoint of health and safety, the EIR could require a health and safety professional to be a part of the designing process in order to pinpoint any unsafe construction sequences and to identify and mitigate possible risks. Interdisciplinary cooperation could be a standalone chapter in the EIR in order to select correct contractors in order to finish the construction project in a collaborative manner.

2.3.1. **Software for construction sequencing**

One of the vital decisions for an investor is to decide whether they want to limit their contractors with a concrete software or platform. As it usually is, there are two sides to both coins. If an investor decides not to directly specify a software or the overall platform, the result could be a wider range of contractors bidding to become the main contractor, since the market, if not dominated by one software company, should provide a wide spectrum of software for construction sequencing. Moreover, having more contractors proposing different software in their BIM execution plans, should also work as a valuable data resource not only for the companies creating the software but also for the investors, who can get a better scope of what each software manufacturer brings to the table. The perceived natural leaning for an investor demanding a working construction sequencing simulation can be to start with an open approach to the solutions at the start of his/her EIR journey, and could stick to a preferred software manufacturer after more buildings built and iterations to the EIR created. The path of setting a firm software platform and it’s anchoring into the EIR offers the ability of an accelerated contractor tendering process, while the number of contractors bidding should logically be lower. Furthermore, it could encourage higher communication quality and respect among bidders, while it could be a sign of maturity in building information modeling from investor. Nevertheless, project owner will lose valuable options with sticking to one manufacturer and could miss out on new developments in the field of construction sequencing. Motivating employees to stay flexible and search the market for the right solution could be one of the challenges an investor could face in the wake of higher-level building information modeling.

In the next few paragraphs, most notable BIM software solutions are going to be introduced with their functions and capabilities. The companies and their software are presented based on knowledge gained from talking to construction professionals in the field of civil engineering and BIM.

Navisworks + MS Project (Autodesk)

Autodesk has enabled for construction sequencing through its Navisworks software and its interconnectedness with the MS Project, a scheduling solution from Microsoft. Unity of these two programs allows for many construction sequencing tools. Navisworks with its functions enables to animate the 3D model and to add time specific information onto identified sets of objects. Moreover, there is a capability of creating a surface model in Infraworks, yet another software from Autodesk, which can be linked to the model at hand in Navisworks, to create a simulation of not only the building, but also its surroundings. Another positive can be seen in the integration of MS Project, a software known very well to construction schedulers. Some of the negatives are that the multiplatform interconnectedness works only with a very careful preparation of both of the programs and their merge. MS Project has to have the right element codes for each element from the start, even before the 3D Revit model is transferred into Navisworks, otherwise the solution may not work properly. As shown in the practical part of the thesis, if the construction sequencing approach is not counted with from the start of the project, the abilities with both programs shrink to minimum. Construction sequencing then gets more of a marketing purpose, where there is a possibility of creating eye pleasing simulations before the project start. Project monitoring and project timing are not in the scope and therefore cannot be fully utilized in the project.

VicoOffice(Trimble)

Trimble has acquired Vico Office in 2014. The software offers three modules in order to satisfy most of the needs not only in construction sequencing but also for construction budgeting and visualizations. Compared to the solution from Autodesk it

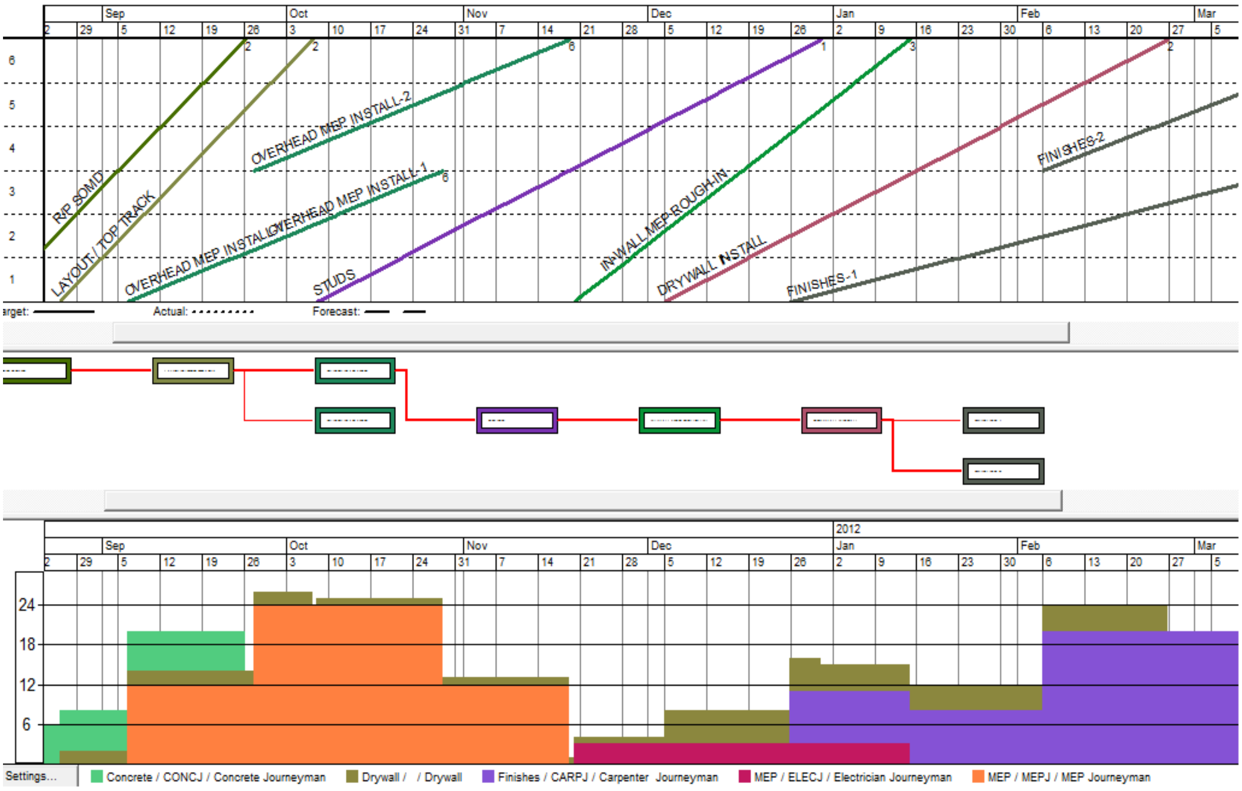


Figure 5. Vico Office look ahead graph with metered workforce (Trimble, n.d.)

does not require a tedious element naming procedure with MS Project, since the software itself has a native scheduling program incorporated in itself. However, the software is not yet tailored to every country's needs and requires tedious amounts of work defining object classes.

Synchro (Bentley)

Bentley has bought Synchro only recently in 2018. Synchro has been deployed to support construction planning, scheduling, and project management across a wide variety of projects. It incorporates other construction variables (human, materials, equipment, falseworks and space) for reliable and safe project delivery (Wilkinson, 2018). Bentley now plans to incorporate Synchro into its new "ProjectWise" platform. Synchro offers a top-notch construction sequencing visualization with honorable mentions of recent accomplishment with the Camp Nou, FC Barcelona football stadium in Spain (AEC, 2019).

All of the software named can, either natively or through add-ons, export the work into an IFC file format. Information foundation classes (IFC) have been developed by the buildingSMART initiation, in order to bring a common ground and language to all the existing BIM models. It converts the model into a text readable by almost all other software on the market and therefore allows interoperability across all of the major platforms. The functionality does not stop there as it is able to be read by several desktop clients, therefore eliminating the need to own a dedicated software from a dedicated platform in order to merely view the project, which at some cases is the only thing needed (Lifewire, 2019). It can be argued that IFC plays a pivotal role in construction sequencing while it is able to express a demand for a functional time related modeling into a cross-platform readable language. This offers a solution for most of the investors, who then technically would not have to buy an expensive construction sequencing software, but rather could go for one of the less expensive viewing alternatives online.

2.3.2. **Industry foundation classes and construction sequencing**

This part will introduce IFC concepts and rules needed to implement working construction sequencing into practice. At the beginning there is a need to stress out the importance of clear rules and practices set by the EIR at the beginning of the project onto the involved parties, in order for a working model enhanced by the ability to create and adapt schedules into the model.

All of the information in this part of the thesis is overtaken from (buildingSMART, 2019), as buildingSMART is the administrator and editor of industry foundation classes. The web page describes the steps needed to procure a working model with construction sequencing enabled. It does so with the use of diagrams which will be described in depth in this thesis for a better understanding of IFC.

At first, there is a need to specify how the time is measured in IFC through time quantity. Time quantity is the tool used by IFC to describe object’s link with time. The sub-parts of this quantity are:

- Name
  - Described by an IFCLabel - It is a string which is human-interpretable representation of a name of object and shall have a meaning in natural language, in contrast to purely machine readable identifiers.

- Description
  - Comprised of IFCText, which is an alphanumeric string intended to further develop an object. It should be readable by humans and is for information purposes only.
- Unit
  - Measurable unit depending on the object's material and its use in the building.
- Time Value
  - IFC Time Measure is used as a value of duration periods. It can be set to seconds (s) or days (d) or other units of time.
- Formula
  - String value defined by IFCLabel.

Once the time quantity is set up transparently, IFCDateTimeResource needs to be set up. While time quantity was the pure measurement of time, time resource interconnects the time quantity with the construction project at hand. The term IFCDateTimeResource incorporates many sub-terms and ideas in order to utilize the whole potential of the data procured. First off there is a classification into time series. Time series include all the same attributes as time quantity, therefore it would be safe to say that time quantity is a subset of time series. However, time series differ from time quantity in having also start times and end times of tasks stated as well as data type. Therefore, it is safe to say that time series allocate a spot for a time quantity of elected object on a timeline. The time series are further divided into regular and irregular time series. The difference between irregular and regular time series is that the regular time series has the opportunity to utilize time step as a subset. That allows for a standardization of regular time series, while it is assumed that same objects would have same time steps on the timeline therefore making them easier in allocation. (buildingSMART, 2019)

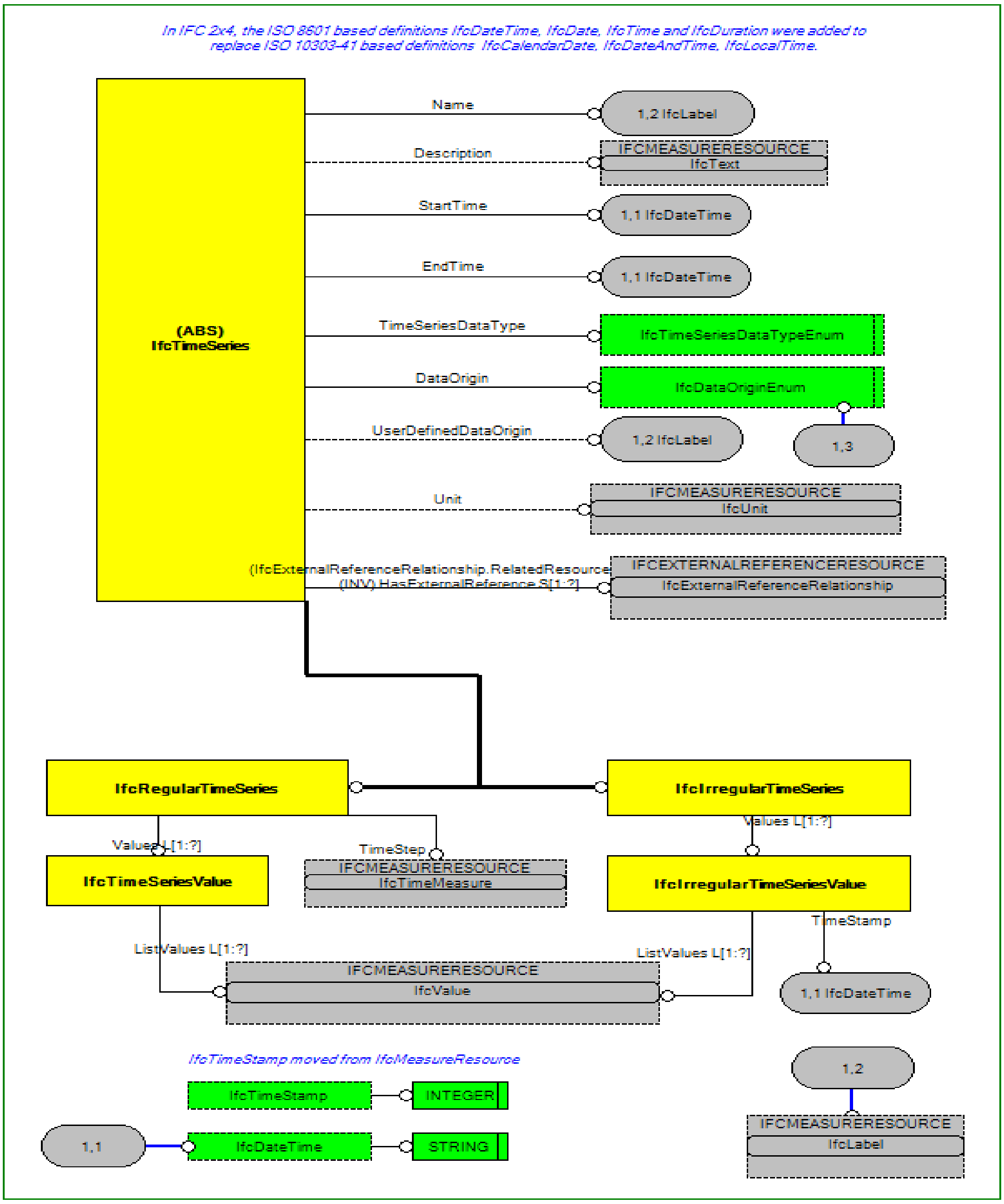


Figure 6. IFC time series (buildingSMART, 2019)

Last IFC part of construction sequencing would be to generate IFC Scheduling time. The scheduling time consists of lag time, resource time, event time, task time, and work time. Even though all these subsets may sound similar at start, they have some differences better described in Figure 7. The main differences between these times is when these subsets are being used, while not all of these subsets have to be used all at once. An example could be the comparison of task time against a resource time. The two actions have very similar attributes such as scheduled start and scheduled finish, but differ in the actual values these attributes represent. While task time is concerned for the task at the site, the resource time would also include procurement of a given resource even before it enters a construction site. (buildingSMART, 2019)

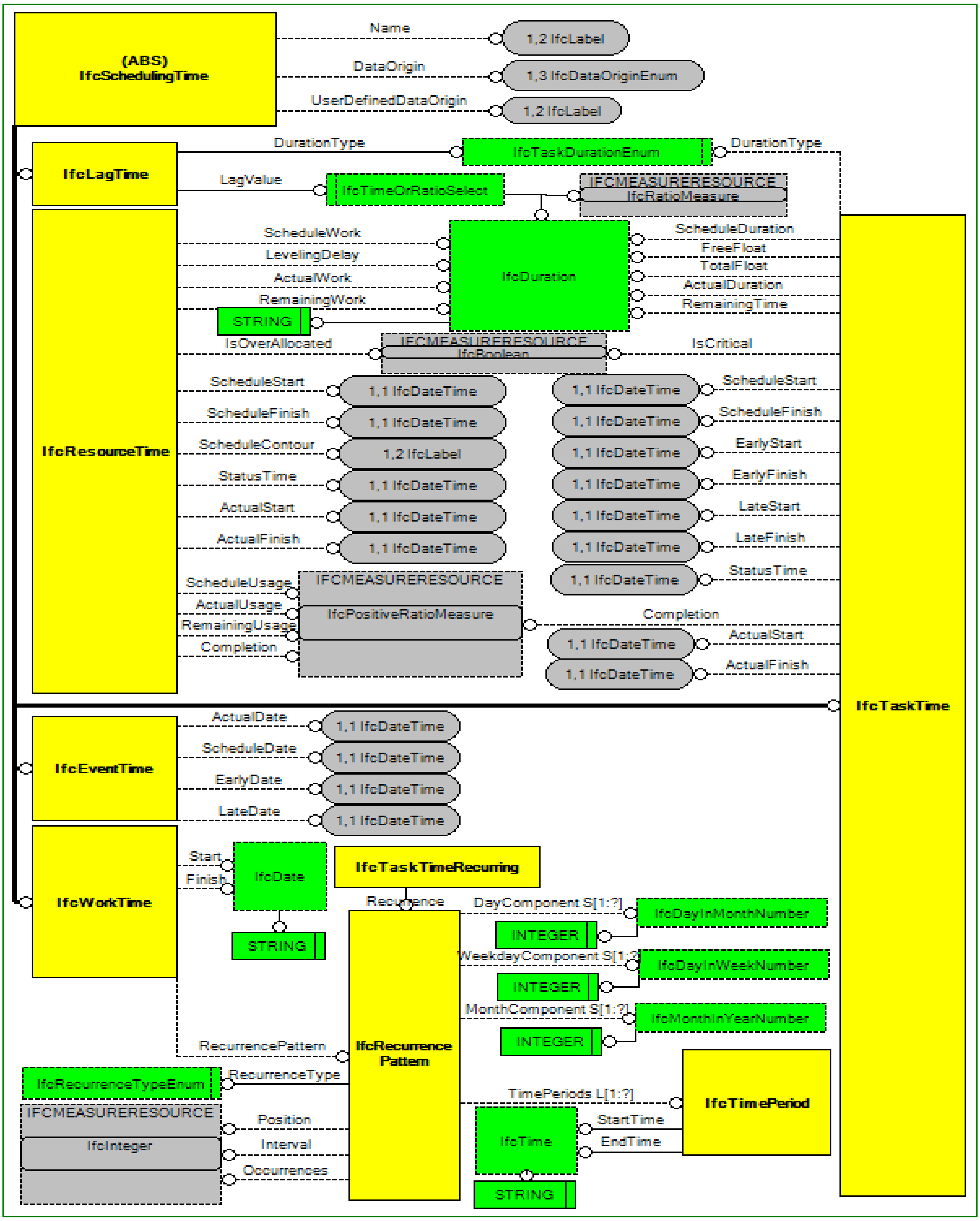


Figure 7. IFC Scheduling time (buildingSMART, 2019)

3. Employer‘s Information Requirements in selected countries

This chapter focuses in application of EIR in different countries. It evaluates the countries overall approach to building information modeling and derives this information in order to present their singular approach to the EIR. The selected countries are Czech Republic, United Kingdom and Sweden. The countries were selected on the basis of data available and on their different levels of BIM immersion. Some information in this chapter comes from an interview with a BIM professional in a Swedish company and their documents presented.

3.1. United Kingdom

United Kingdom has been a pioneer of building information modeling with their standardized way of achieving it. The standards the country has presented have been many times used in order to create ISO 19650 as an international standard. (SFC) states that ISO 19650 will be identifiable to those which are already using BS 1192 and PAS 1192. ISO 19650 is fundamentally just an internationalized version of UK's BIM L2 model and contains all the principles and high-level requirements. The UK's intention to move from BIM L2 as a UK Standard to international standards roots back to 2011. In 2011 a "Report for the Government Construction Client Group – BIM Strategy Paper" was released. The document identifies BIM as a disruptive and "game changing" way which would have an immense impact on global construction market. It further argues that BIM technologies and processes have transcended national or geographic borders. There was also a growing consensus between construction professionals that BIM being more globalized would inevitably put pressure on creating international norms and standards. In order to support of new international standards, the British Standard Institution published a National Annex to ISO 19650 in order to aid execution and ensure BIM L2 can be delivered in accordance to the ISO framework. The National Annex clarifies all regional or country specific terms. The term Employer's Information Requirements has also originated from British norms, ISO 19650 calls them Exchange Information Requirements as mentioned in the chapter 2 of this diploma thesis.

The (Employer's information requirements EIR, 2019) recognizes a basic structure for a contract in which EIR take place. In the part of investors documents it clearly states the clear division of documents and their interconnectedness. The relationship between EIR and other contractual documentation is clearly stated by putting the contract at the top of a top-down tree structure. The contract will inevitably have to include BIM Protocol. The protocol states that in the event of a conflict or inconsistency between the terms a of the protocol and any other documents contained in the agreement, except where the protocol states otherwise, the terms of the protocol should prevail. This gives immense contractual power to people setting up the protocol. EIR should be an inseparable part of the BIM protocol, having the main say in how the project should create and treat its data. On the other side, the Employers Information Requirements should have a strong link to Employers Requirements, which does not have to be a BIM document. Employers Requirements could take on the role and encircle the vision and long-term plan for the company. They could also serve as a boundary for valuable data for the company, such as KPIs. EIR should reflect the Employers Requirements and translate the tasks set up by the document into the language more understandable for a BIM process. Example of this could be modeling with time or scheduling related information. The Employer’s Requirements could just set up a need of thorough following of time during the construction by means of visualizations and processes connected with a marketing division of a company. The EIR document could take this information and translate it to the contractor in a form of added time sensitive attributes to elements. These attributes could also contain additional information about their weight on a critical part in order to see their impact on the overall construction. EIR should also be a counterpart document to the BIM Execution Plan put forward by the main contractor. In fact, the BIM Execution Plan should be a direct response, which is put into the pre-construction process by the contractor and it should clearly set out contractor’s proposed approach, capability and capacity and competence to meet the EIR. Large or complex projects could also include a Project Implementation Plan, which is a statement which could also contain software versions, exchange formats, methods and procedures if they are not clearly defined in the EIR. (ISO, 2018)

According to (PAS 1192-2:2013, 2013): *“The employer's information requirements is a pre-tender document setting out the information to be delivered, and the standards and processes to be adopted by the supplier as part of the project delivery process”*. In addition the (Employer's information requirements EIR, 2019) defines the EIR as the information that will be needed by the employer from their own internal team as well as from their suppliers for the development of the project and for the operation and maintenance of the completed built asset. Relevant extracts from the employer's information requirements are included in procurement documents for the appointment of each supplier appointed directly by the employer, which may include: advisors, consultants, contractors etc.

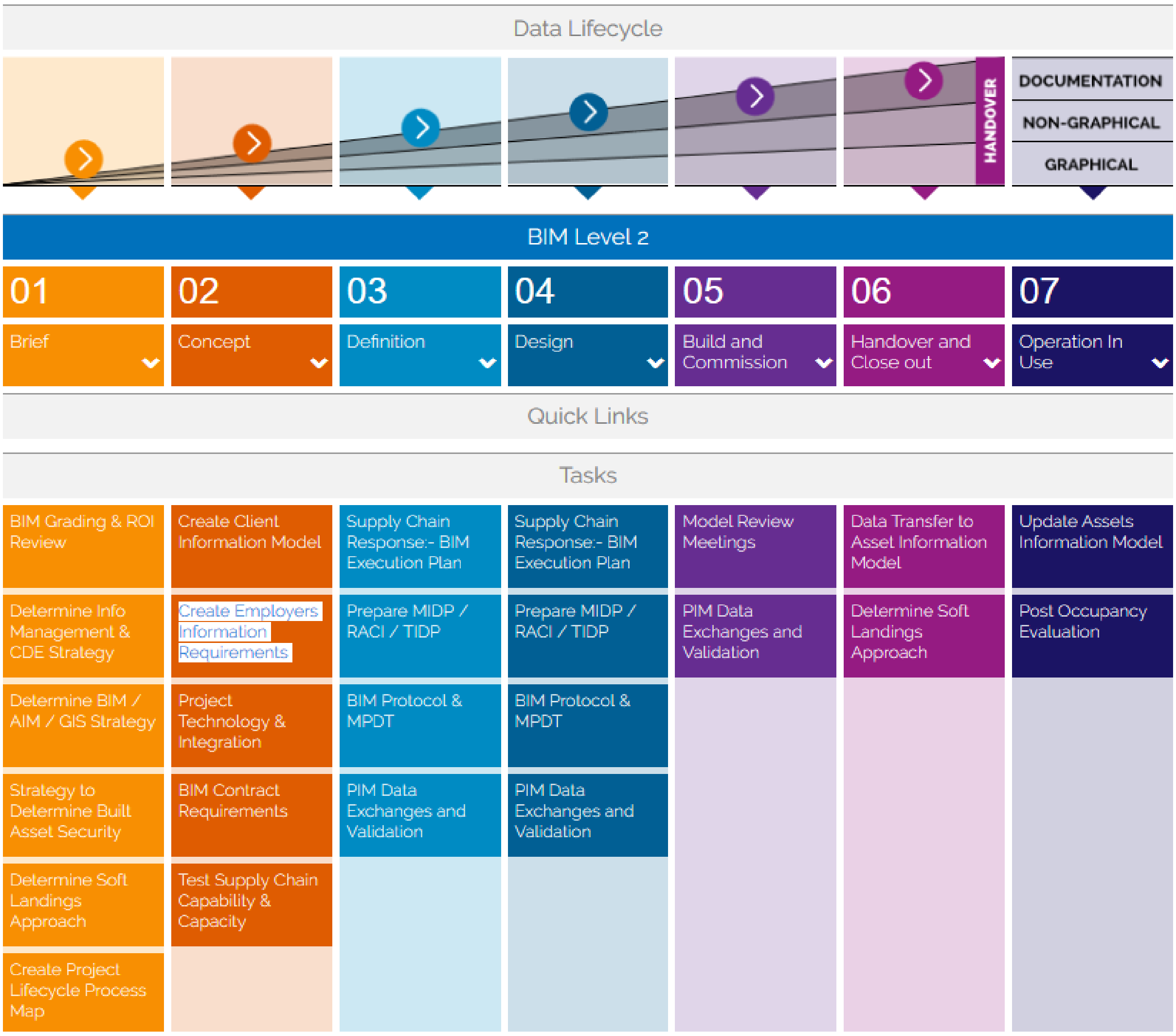


Figure 8. Placement of EIRs in the scope of a whole project (SFC)

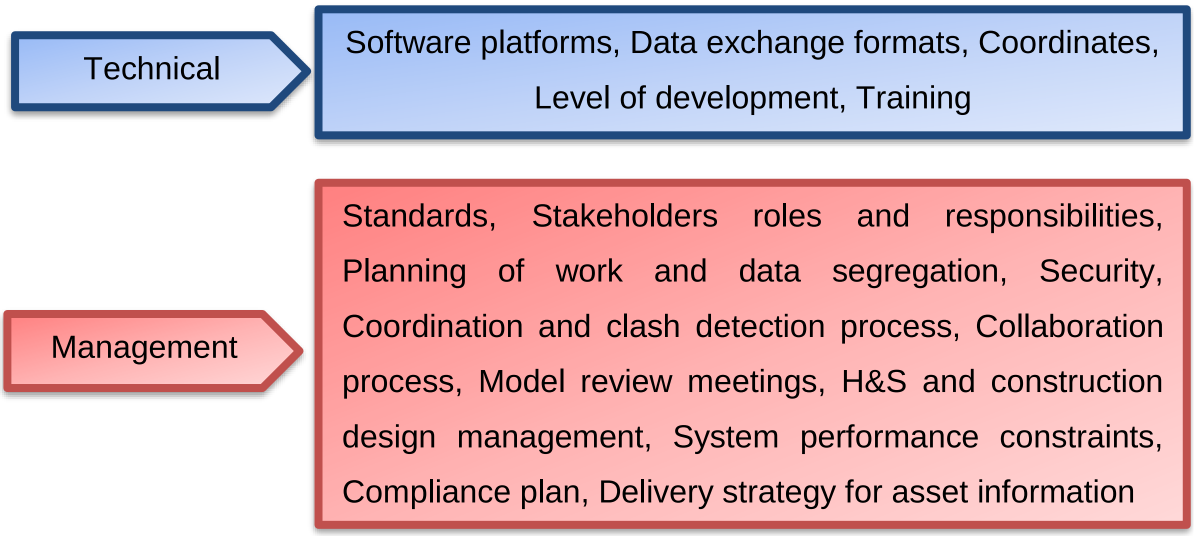
The Scottish Futures Trust (SFC) identifies four major questions when it comes to EIR:

- By whom is the information shared?
- What information is needed?
- When is the information needed?
- Why is the information needed?

These four questions, even though they may sound simple, are the core for a successful EIR document according to the practice in United Kingdom. Next to answers to these questions a successful EIR usually includes:

- Standard methods and procedures clarifying information formats naming conventions and advice on how to supply this information
- Prescription for standards and processes that are needed from the supplier to be adopted as part of their contract
- Information related roles and responsibilities giving clear definition of the roles and what is expected of them
- Information delivery plan or information schedule identifying which information deliverables should be delivered by whom and when

The content of a complete EIR should cover three main areas:



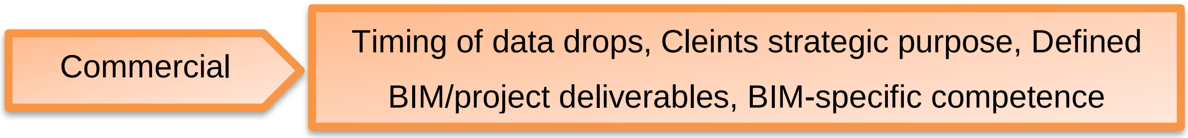


Figure 9. Areas of a complete Employer's Information Requirements document (SFC)

Building Information Modeling at level 2 has become mandatory for use on all public sector buildings in 2016. However, surveys show that the central government seems to be failing in enforcement of the BIM level 2 compliance requirement according to the NBS. The survey on 1000 construction professionals has shown that 51% of people agreed that the government is not living up to target. Only 9% of people asked have responded by saying they believe that the government does not seem to be failing at enforcing BIM level 2. The mandate required all public contracts procured by the government department to be BIM level 2 compliant by April 2016. Only 19% of the respondents concluded that construction industry has taken up the challenge versus 50% saying it had not. Nevertheless, the survey has shown increased awareness and use of BIM in the industry, indicating that the government policy indeed boosted BIM adoption. More than 62% of people asked were using BIM in 2017, an increase from 545 the previous year. The 8% difference between years 2016 and 2017 is the biggest recorded in survey in three years. Construction professionals who use BIM are convinced of the benefits with 70% saying BIM will reduce cost while 60% saying BIM will save time and increase efficiency. "Clearly, the supply chain and clients are on a common learning curve and everyone is learning together," Mark Bew from Digital Built Britain said. According to him, the progress shown by the survey is good and should be celebrated. (Cherkaoui, 2017)

3.2. Czech Republic

Czech Republic has to the contrary of UK not been an early adopter of BIM requirements in public construction tenders. The flexibility of construction companies and new institutions set up by the Czech Republic with joint efforts from the Ministry of Transport, Ministry of Industry and Trade, the state fund for transport infrastructure and CzBIM Council professionals, gives Czech Republic a healthy environment in which BIM practices will be able to thrive. BIM began to be discussed in the Czech Republic on a wider scale in 2011. The impulse was the activities of innovative design companies that saw their development in 3D, but in the meantime without further overlap towards the use of data throughout the construction life cycle. The transmission of BIM data and its importance has not been discussed so far. In addition, since standards are not defined at national level, participants in each project must agree on their own conditions, which in many cases exceeds their professional and time possibilities. This creates data units that have different content and structure of data and whose use in other phases of the project is problematic. Since 2012, the technical standards of ISO and CEN concerning the BIM method have been gradually adopted, but for their application it is necessary to develop examples of use and to elaborate their relation to current practice. Much more progressive are manufacturers of building materials. Manufacturers have started to create individual element libraries. Some manufacturers already include such libraries and catalogs on their pages, but mostly these are only partial data and often intended only for selected SW tools. A prerequisite for the real use of the BIM method in practice is the definition of the requirements for the properties of construction products and elements for the creation of the BIM model. Given the fragmentation of the market for individual types of SW and the constantly evolving IFC standard, it is appropriate to set requirements for the characteristics of individual construction products universally, so that they can be processed in any SW, both construction product manufacturers, BIM libraries and designers. The properties of the products can then be interconnected with the IFC format according to ISO 16739 in the database. The aim is to standardize the output, not the workflow. The basis is the performance of construction products, which are declared by the manufacturers in the declaration of performance of the product, in the declaration of conformity, resp. in the technical documentation. The declared properties of construction products must be based on the applicable regulations. (MPO, 2017)

The key term mentioned in the material is the beginning of 2022, when it is planned to impose the use of BIM for over-limit public works contracts financed from public budgets (including preparation and project documentation), taking into account the conclusions of the pilot projects evaluation and considering the specifics of individual types of constructions. The MPO will have a managerial, methodological and control role over the whole complex of preparation, implementation and use of BIM, both in interdepartmental discussions (Interdepartmental Expert Group for BIM) and with foreign countries (EU BIM TG). As of 31 October 2018, the Ministry of Industry and Trade will regularly inform the Government of the Czech Republic on the state of fulfillment of the concept. (Kratochvílová, 2017). Moreover, descriptive, non-graphical part of information captures data from basic elements of 3D model and translates them to be usable for design, simulation, realization, operation and other applications in the construction life cycle. When preparing data libraries, it is necessary to use a data standard, which avoids conflict with the provision of the Public Procurement Act No. 134/2016 Coll. (§89, par. 5), therefore, only provides basic data and does not favor certain suppliers or products. (Synek, 2018)

When it comes to the EIR and their use in the Czech Republic, there are documents created by The State Fund for Transport Infrastructure (SFDI). These documents are guides on creating a data standard for the infrastructure projects around Czech Republic. Other construction fields have yet to wait for such a document and are mostly reliant on the commercial sector and progressive investors, which are willing to invest in creating an Employer's Information Requirements document. The purpose of this document is to provide data creators with adequate background to information modeling of infrastructure buildings. The document specifies basic requirements for the preparation of information models of buildings. Moreover, the document defines level of development of models, building objects, and individual elements, including their properties according to project phases. Furthermore, the document specifies formats, units, levels of detail, marking of each file properties, color standards, and more. The document serves as a prescription for information modeling of infrastructure buildings and should be referred to in the contract for works. This document compares itself directly with the Employer's Information Requirements documents used outside of Czech Republic. The document specifies the BIM data creation rules for use by the builder, designers, contractors, manufacturers of building components, BIM libraries, etc. in all phases of preparation, implementation and operation of infrastructure buildings. The data standard is based on the open IFC data format, allowing exchange information between software platforms while allowing data expansion for additional data according to user needs. It is a document specifying basic rules and approaches. It advises investors to test the information contained in this document on pilot projects. Furthermore, it should be a document which is dynamic and should still have room to grow in order to fulfill the 2022 BIM goal. This document and all other published documents with 2022 in aim are coordinated by Czech Standardization Agency (ČAS). Czech Standardization Agency serves as an administrator to these documents and as a whole creates the concept for information modeling. (SFDI, 2019)

Relevant data utilization chart was created in order to identify data which is vital to the project and data which could be in the case of the project neglected. The data is aggregated into relevant groups based on their usage. The groups are then evaluated and the final data groups with the biggest relevance could be used in a project. The data standard specifies all standardized information in the model with which it will be loaded with selected uses of BIM. The data standard cannot fully cover all conceivable uses of the BIM model. The principle implies that information models processed on the basis of the data standard will be able to be used beyond the currently defined framework of the data standard within the construction life cycle. Thanks to the unique architecture of the data standard and the fact that it is based on an IFC file format, the data standard itself can be replicable for further projects.

Attribute groups/ BIM utility		Path/Levelling	Concept creation in 3D	Element specification, attributes, manufacturers	3D as built model	Common data environment an its integration with owner's software	Creation of plans from the model
Number of data utilized		1	11	32	2	3	19
Significance in the process		10	10	10	9	9	9
Group attribute index	Group attribute name						
I	Identification	1	1	1	1		1
C	Construction part			1			1
P	Period						1
V	View	1	1	1	1		1
A	Amount						
P	Construction phase						

Table 2. Data usage on a reference project (SFDI, 2019)

When it comes to classification with real elements and construction tasks classification systems come to play in order to create a well set up system. In cooperation with the Czech Agency for Standardization (CAS), CoClass classification system was chosen for pilot testing. The system introduces properties corresponding to the individual levels of classification: Building entity, Built space, Functional system, Construction system, Component. For these properties a group was created within the data standard. In case of classification system, the individual elements and objects are complemented with this group of properties.

Skupina elementů / objektů	Typ elementu / objektu	Šablona vlastností složená z následujících skupin vlasností						
		I	S	E	Z	M	F	Označení šablony PDPS
trasa	osa	4		1			1	I4+E1+F1
	niveleta	2		1			1	I2+E1+F1
zemní práce	výkop/odkop	1	3	1	1	3	1	I1+S3+E1+Z1+M3+F1
	násyp/aktivní zóna	1	1	1	1	3	1	I1+S1+E1+Z1+M3+F1
	sanace	1	1	1	1	3	1	I1+S1+E1+Z1+M3+F1
	sejmutí ornice	1	3	1	1	3	1	I1+S3+E1+Z1+M3+F1
	rozprostření ornice (ohumusovani)	1	1	1	1	3	1	I1+S1+E1+Z1+M3+F1
	založení trávníku	1	1	1	1	3	1	I1+S1+E1+Z1+M3+F1
	úpravy svahů [dlažby z lom. kam., ve	1	1	1	1	2;3	1	I1+S1+E1+Z1+M2;3+F1
	zemní krajnice a dosypávky	1	1	1	1	3	1	I1+S1+E1+Z1+M3+F1
	pláň	1	1	1	1	2	1	I1+S1+E1+Z1+M2+F1
odvodnění	příkopy	1	1	1	1	2	1	I1+S1+E1+Z1+M2+F1
	příkopová tvárnice	1	2	1	1	1;2	1	I1+S2+E1+Z1+M1;2+F1
	štěrbinové žlaby	1	2	1	1	1	1	I1+S2+E1+Z1+M1+F1
	žlaby curbking	1	1	1	1	1	1	I1+S1+E1+Z1+M1+F1
	podkladní beton	1	1	1	1	2	1	I1+S1+E1+Z1+M2+F1
	podsyp	1	1	1	1	2	1	I1+S1+E1+Z1+M2+F1
	trativod	1	2	1	1	1	1	I1+S2+E1+Z1+M1+F1
	drenážní šachty	1	2	1	1	4	1	I1+S2+E1+Z1+M4+F1
vozovka/chodník	CBK	1	1	1	1	3&6	1	I1+S1+E1+Z1+M3&6+F1
	posyp	1	1	1	1	2	1	I1+S1+E1+Z1+M2+F1
	obrusná vrstva	1	1	1	1	3&6	1	I1+S1+E1+Z1+M3&6+F1
	ložná vrstva	1	1	1	1	3&6	1	I1+S1+E1+Z1+M3&6+F1

Table 3. Chosen groups and their data usage (SFDI, 2019)

The data standard distinguishes between construction elements and structures. The most prominent difference is to be seen in the sets of properties, which for construction elements are based on the Declaration of Properties (DoP) according to the act of construction elements and their use in buildings and the technical policy of the Ministry of Transport. To specify the properties, it is necessary to carry out a Declaration of performance given by the Act on Construction products. (SFDI, 2019)

3.2.1. **Construction sequencing in Czech Republic**

Construction sequencing and its interconnectedness with the Czech infrastructure EIR is well documented in exhibits of the data standards from (SFDI, 2019). When it comes to actual implementation of time into the construction model, the Czech guide offers a simple solution of how to track time in the project. Under the column called Period (Etapizace), one can see five attributes closely connected with the sequencing process. Obviously, the two main attributes would be start and finish of given task. Start and finish are qualified in the IFC file format with IFCTaskTime Scheduled start and scheduled finish. Another attribute is the length of a task, defined by the

IFCTaskTime Schedule duration. The fourth attribute is called method of determination, which describes how the investor or contractor comes up with the scheduled time. Method of determination could be planned, calcualated, firmly set etc. The last attribute describes the method of construction and a period, which the construction undergoes at a given moment. The period could be a strictly given time (days, months etc.) or a flexibly given time given accordingly to changes in scheduled starts and finishes.

Název skupiny vlastností	Označení vlastnosti	Datový typ	Jednotka	Příklady hodnot	Ozančení dle IFC	v IFC4
ETAPIZACE						
E1	Zahájení	Date	[-]	DDMMRRRR, MMRRRR, RRRR	IfcTaskTime, A:ScheduleStart	1
	Ukončení	Date	[-]	DDMMRRRR, MMRRRR, RRRR	IfcTaskTime, A:ScheduleFinish	1
	Doba trvání	String	[-]	DD, MM, RR	IfcTaskTime, A:ScheduleDuration	1
	Způsob stanovení	Enum	[-]	Plánovaný, vypočtený,...	IfcDataOriginEnum	1
	Stavební postup / etapa výstavby	String	[-]	S1, S22	IfcTimePeriod	1

Table 4. Groups and attributes (SFDI, 2019)

3.3. Sweden

The information collected in this part is from a BIM professional from Sweden, and is based on the correspondence and documents acquired by the author from the contact person. The documents acquired are part of data requirements from Skanska in Sweden.

The current situation regarding BIM in Sweden could be described as more or less dependent on commercial projects being done by companies, which are interested in implementing BIM and developing it mostly on their own. Research has shown that all investigated groups of actors in civil engineering industry have established their own BIM policies, BIM units, BIM training and BIM methodology in different ways. Technical engineering companies and contractors have however been early adopters in the use and adaptation of BIM in Sweden, while architects and project owners have been more of a late coming party. Generally speaking, the use of BIM has required the allocation of large financial resources in establishing BIM competence and knowledge along with large investments in new software solutions (Linné, 2016).

Architectural firms and client organizations have come to a problem in internally establishing and developing its BIM competences due to the difficulty among the organizations to see the benefits of BIM. Nevertheless, it seems like several individual projects involving all stakeholder groups have used and adopted a very advanced level of BIM. Still these ‘extraordinary’ projects are limited in numbers, therefore still many projects do not use BIM with an intention to use it throughout the whole construction process. Only few projects are directed by the view of BIM as a management tool stretching the whole life cycle of the building project. Instead BIM is mostly used as a tool for visualizations and coordination in design and planning. Nevertheless, some companies have already started to implement an integrated project design methodology where many project actors cooperate together, sometimes even in the same office in order to make the whole implementation process run more precise and smoother. The facility management activities have not yet been affected to a large extend, while the immaturity of the client organizations along with the lack of resources in developing a sufficient information system prohibited the affected parties further handling of BIM operated facility management. However, the empirical illustration is showing that client organizations can play an important role in demanding BIM when initiating new projects. Public project owners have just started (2016) to identify and determine specific BIM requirement and it is obvious that the client organizations are dependent on interaction with contractors and technical consultant t further develop its BIM competence and BIM requirements. (Linné, 2016)

In the sense of traditional EIR, it can be argued that Sweden does not have any concrete template or standard of how to create and edit such a document. However, companies such as Skanska have developed their own data requirements when participating on a project. They have created a document called Requirements specification, model and information management. In the appendices of this document one can find versions of information requirements required by the company. First appendix is a sort of a checklist highlighting the basis for information needed in order to participate on a project. Information such as right X, Y and Z axis coordinates, correct rotation to the common zero point, all objects are named in accordance with BIP codes etc. Each checklist bracket has its own signature and comments box in order to make the process more interactive. The second appendix further deals with project’s height system and describes coordinates. Appendix nr. 3. contains a table with interchange formats and software requirements as well as the use of model delivery. In the use of model delivery, the investor clearly states which functionalities are expected to be derived from a functioning model. Information such as collision check, information fall of, work preparation in production, quantity removal and 4D simulations can also be a part of this table as shown in table 4. (Hakestam, 2019)

Application	Minimum requirement	Comments
3D apd	Yes	This is possible if model and information management requirements specification is followed
Coordination	Yes	This is possible if model and information management requirements specification is followed
Collision check	Yes	This is possible if model and information management requirements specification is followed
Inspection	Yes	This is possible if model and information management requirements specification is followed
Information fall off	Yes	This is possible if model and information management requirements specification is followed
Work preparation in production	Yes	This is possible if model and information management requirements specification is followed
Quantity removal, Building	Yes	This is possible if model and information management requirements specification is followed
4D Simulation	Yes	This is possible if model and information management requirements specification is followed
Visualisations easier for project understanding	Yes	This is possible if model and information management requirements specification is followed
Survey model is used for setting out according to project requirements and deliveries.	Yes	This is possible if model and information management requirements specification is followed
Quantity withdrawal, Installation	No	
Installation in production	No	
Higher quality visualisations for e.g. sales materials	No	
Visualisations of different classifications of object	No	
Energy calculations	No	
Miscellaneous project-specific (Calculations, simulations, etc.)	No	

Table 5. Use of model delivery (Hakestam, 2019)

Appendix nr. 4. talks about a concrete model stamp (which is meant for a Revit file) which should appear on all models throughout the entire project. Fifth appendix discusses naming of drawings and files in accordance to Swedish norms and standards and conventions as seen in the table below.

A	-	40	-	1	-	1	10	2	.	PDF	Position
A											Responsible party
	-										Dash
		40									Drawing/File contents see SS 03 22 71, edition 2
			-								Dash
				1							Reporting method see BH90 and SS 03 22 71, edition 2
					-						Dash
						1					Building
							10				Floor
								2			Part of plan (0 if not applicable)
									.		Point
										PDF	File type

Table 6. Naming of drawings (Hakestam, 2019)

The 6th appendix discusses parameters/ attributes a project should contain in order for it to be a fully BIM immersed project. The parameters are taken over from Autodesk's Revit and concretely are named as such. One could find TypeID, TypeDescription, FireRating, SpaceName, SystemName, SystemID, Height, Diameter, Length, Width, TopElevation, BottomElevation, SystemCode etc. Skanska has however added some of its own values in order to further develop the project and therefore one can find attributes such as frame depth, frame type, safety net, break in protection, threshold type, fittings etc.

Bet.	Disciplin	Company	Name	BIM/CAD Responsible
B	Developer			
PrL	Design Leader			
Ap	Responsible project network			
PBK	BIM-Coordinator			
A	Architect			
K	Designer			
KP	Prefab designer			
E	Electricity consultant			
V	Ventilation			
HWS	Heating, water and sanitation			
SP	Sprinkler			
L	Landscape architect			
M	Ground			
TE	Totalentreprenör			

Table 7. Organization (Hakestam, 2019)

Seventh appendix introduces a drawing stamp, which should be present on every drawing and should not change its design for the whole duration of the project. The last appendix discusses organization and role appointment throughout the project as can be seen on Table 7. (Hakestam, 2019)

4. Employer's Information Requirements and problematic projects

This part of the thesis will introduce two construction projects which were executed in the not so distant past. The projects will be thoroughly evaluated from all possible angles and at the end a conclusion will be drawn in order to decide whether a straightforward Employer's Information Requirements document would be of assistance to these projects. Moreover, construction sequencing as a subset of EIR will also be evaluated. Projects which were picked are Višňové tunnel between Lietavská Lúčka and Dubná Skala in Slovakia and the D1 highway between Humpolec and Větrný Jeníkov in the Czech Republic. Projects were chosen due to their complexity and controversy, where both of the project received countrywide attention for reasons not connected with a sound construction progress.

4.1. Višňové tunnel

The Višňové tunnel is a 7,455 meter long highway tunnel located on the D1 motorway on the Lietavská Lúčka – Dubná skala section and will after its completion become the longest traffic tunnel in Slovakia. The exploratory tunnel was officially bored along the southern tunnel tube axis in May 1998 by tapping on the foundation stone by then prime minister Vladimír Mečiar. The so called 'Alžbeta' exploration tunnel was being bored by Doprastav one of the biggest construction companies in Slovakia, from both portals simultaneously. Length of 573 meters was bored upwards by 0,50% followed by a downward slope of 2,27% with a length of 2545 meters. From the Dubná Skala portal the tunnel was bored upwards in the slope of 2,27m in the length of 4362 meters. (Bratislava, 2013)

There was an unexpected number of geological complications during the excavation, the most serious problem being the large inflow of water. In February 2001, the workers bored through 2970 meters from the Vrútky side and reached 1970 meters from Višnové (SME, 2001). The whole exploration tunnel was bored through on the 24th of August 2002. Consequently, the construction of both tube tunnels was postponed to 2003 and later to 2007. On October 16th 2009, with the participation of then Prime Minister Robert Fico, the foundation stone of the building at the eastern portal was ceremoniously tapped, officially commencing the construction of the tunnel. The tunnel was supposed to be a part of the so-called first package of PPP projects, but it was not finally implemented (SITA, Dnes začali stavať ďalších päť úsekov diaľnice D1, 2009).

After the change of the government the whole process stopped and had to be competed again. It was to be paid from the EU funds and the state budget. At the end of 2011, the competition for the contractor was announced by the so called FIDIC yellow book (design and build). Tender envelopes were opened on 26th June 2012. The offer from the consortium of Skanska and Strabag to build the entire highway section with a 338 million Euros turned out to be surprisingly low, as this represented only 37.7% of the originally estimated cost of 895 million Euros. (SITA, Skanska a Strabag sa pre tunel Višňové obrátili na ÚVO , 2013). Consortium Salini Impregilo S.p.A. and Dúha a.s. has won the tender for tunnel Višňové with a price of 409 mil. Euros. The tunnel was being made until the year of 2018, when the national highway agency came to a realization, that works are far behind the schedule or that works are not being done at all.

The contract for the construction of tunnel Višňové was temrinated by a different interpretation of the contract between the National Highway Agency and the Salini Impregilo – Dúha consortium. In particular, the claims for additional payment for differences that arose between the project submitted in the competition and the project that was to be implemented according to the current standards and the National Highway Agency requirements were in dispute. Agreement on the completion of said tunnel by a consortium was withdrawn by the Ministry of Transport of the Slovak Republic. According to the approved material, National Highway Company did not waive contractual claims against the contractor. These are contractual penalties. If confirmed by the International Dispute Settlement Commission, it could be able to recover them from the contractor. In the opinion of the consortium, the conditions and documents specified in the competition differed from the actual situation. This was also affected by legislative changes, and the contractor was not interested in re-designing the original project and providing additional building permits to the extend required by new circumstances. According to the consortium, in addition to legislative changes, it was also the technical level of documents, which was insufficient due to more than a decade since they were prepared. According to Duha, the amount that the National Highway Agency and the consortium disputed over was more than 100 million Euros. However, these proposals were not accepted by the National Highway Agency, while there was no consenus as to whether this price was part of the original offer or were extra work. Thus, according to Duha, there are no technical, professional or capacity reasons which would prevent the consortium from completing the work under the contract. The only reasons for termination of the contract is a divergent view of the claims submitted, namely the recognition of the reimbursement of costs and the decision whether or not they belong to the original contract price.

4.1.1. **Višňové with EIR**

This is a prime example of faulty contracting, and not setting things up straight from the beginning. If we look at the project, everything that happened prior to the tender and contract is a prime example of not creating boundaries and rules for both contractual parties in case of a conflict. Employer's Information Requirements could and should be used as a safeguard in events of contractual disputes. When the contractor agrees to EIR and prepares a good quality BIM execution plan, all of the rules should be at that point set in place in order for the contract to work. Safeguards such as penalties for not following the accepted time schedule, not feeding enough information to the project or on the other hand not evaluating all of the information a project becomes, could be implemented and their violation could be penalized. The main purpose of EIR however should be to utilize a smooth and sound progress during the duration of the whole construction project, and if a problem occurs EIR together with the BIM execution plan should be used as a concretely set boundaries, which safeguard both parties from any wrong doing from their counterpart.

4.2. Větrník – Jeníkov highway

Větrník – Jeníkov highway is a part of a highway in between 90th and 104th kilometer which interconnects two biggest cities in the Czech Republic. The highway was meant to be reconstructed with a contract of 1,75 billion Czech Crowns. The tender was won by a consortium of Geosan (Czech company), Toto Construzioni Generali (Italy) and SP Sine Midas Stroy (Kazakhstan). The whole contract started in march of 2018. The complications were apparent when Road and Motorway Directorate found out that the repairs of the section of the D1 were delayed and were not completed as expected before the winter. Traffic on the highway, particularly in the Vysočina region collapsed due to heavy snowfall. The traffic jams were spread over 10 kilometers. The Vysočina Region said that the collapse of the D1 traffic was caused by the modernized section which was unprepared for winter conditions. Road and Motorway Directorate had also sent a binding investor order to the consortium to repair spilled caverns under the left lane of D1 lane near Humpolec. According to Road and Motorway Directorate the detailed schedule of construction was the best evidence of the contractor's approach to modernization at Humpolec. The schedule read that six people were to work on the construction during the week and zero during the weekend (ČTK, 2018). Thus, one can assume that the adequate number of workers on a highway reconstruction should be higher. The Road and Motorway Directorate has later on made the decision to end the contract with the consortium and will enforce penalties, as the consortium has caused great damage. (Šindelář, 2018)

4.2.1. **Větrník – Jeníkov Highway with EIR**

A similar case as was with the tunnel in Slovakia. A consortium wins a lucrative contract, which the consortium is not able to finish and therefore the contract has to be cancelled and there are losses on both sides. Employer's Information Requirements could have been here used to filter out companies not being able to finish the construction. Requirement for construction planning could serve as another managerial tool to supervise companies during the fulfilment of their contract. EIRs could be a great indicator when there is a contractor who bids with a lowest price, since the contractor would then have to accept all of the terms stated in the EIR and would have much less space to maneuver with any speculation.

5. Construction planning – Parkview project

This chapter of the thesis will be focusing on the Parkview project located in Pankrác district of Prague. At the beginning there will be a through introduction to the project and its specific attributes. Then a case of construction planning will be introduced, where a construction sequencing visualization was created with the help of Navisworks and MS Project software. This approach to construction planning will be compared to another construction planning approach, which can be created with the help of a clear set of rules stated in the Employer's Information Requirements and the help of Industry Foundation Classes. The two approaches will be evaluated with the aim to find a preferred option, which could be used in the future to fully embrace the possibilities Building Information Modeling offers.

5.1. Overview of the project

As mentioned above, Parkview is an office development project located in the Pankrác district on Prague 4. Neighboring City Tower, V-Tower and City Green Court, Parkview covers the last piece of plot for office buildings in the close vicinity of Centralní Park Pankrác. The building has been designed by Richard Meier, a worldwide renowned architect stationed in New York. Cuboid a local architectural studio is co-working with Richard Meier in the design of the building. Parkview was developed by Skanska Property Czech Republic, a development branch of a Swedish construction company with operations around the world. Main contractor for the building is Skanska a.s. a construction company and a sister to Skanska Property Czech Republic. The construction started in April 2018 and is planned to finish in the second quarter of 2020. Parkview has three underground floors and nine floors above the ground with a usable terrace. Gross leasable area of the project is 15 818 square meters and a mix of tenants is supposed to be occupying the area. Parkview is an innovative and energy-efficient building that uses significantly less energy and water than conventional office buildings. It includes a number of energy-saving solutions to minimize environmental footprint and significantly reduce operating costs. (Skanska, 2019)

Some of the energy efficient solutions utilized in the project are:

- High quality and efficient LED lighting with occupancy and motion sensors to minimize power consumption.
- A significant amount of drinking water (approx. 30%) is saved through efficient fittings.
- The high-performance facade, sophisticated ventilation and air-conditioning system, cooling beams and energy recovery lifts reduce building energy consumption by 36%
- The building collects rainwater and is used to irrigate the garden and green roof.

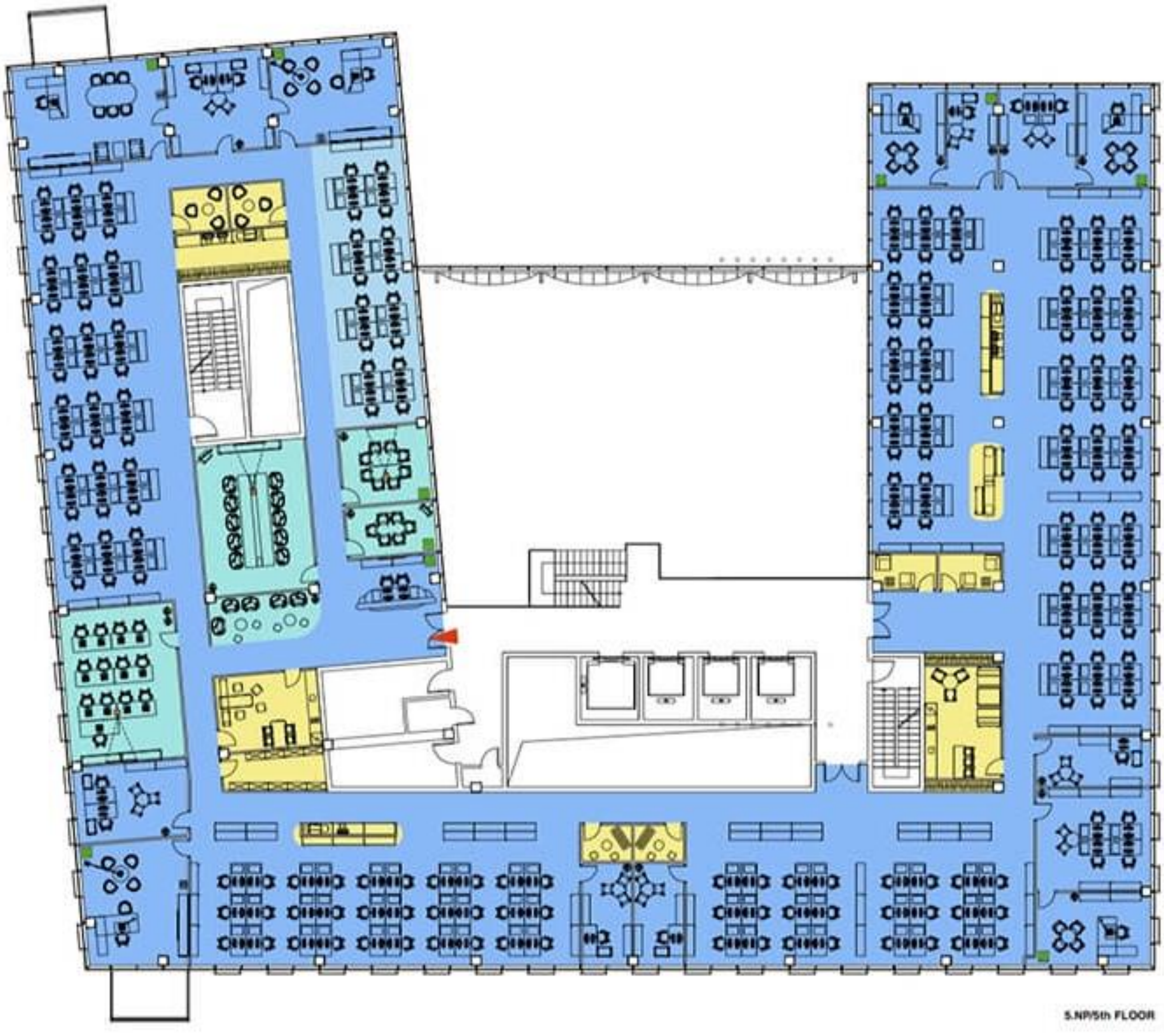


Figure 10. Typical floor plan of the building (Skanska, 2019)

Parkview has is shaped like the letter U and has a modular facade mostly made out of glass. A regular floor can be observed on figure number 11. (Skanska, 2019)

5.2. Construction planning of the Parkview project

As written above, this chapter evaluates two options of construction planning on the given project. It covers positive and negative aspects of both solutions as well as the amount of work needed to execute these solutions. The end of the chapter will reintroduce industry foundation classes and apply them onto the Parkview project.

5.2.1. **BIM aided construction planning not covered by the EIR**

At the beginning, it is needed to say that the investor did not plan for the integration of a BIM assisted construction planning to take place on the Parkview project. The project however, does have an Employer's Information Requirements document created. Parkview's construction planning was, and at this day still is based on the regular construction planning practices used in the Czech Republic and around the world. The classical approach consists of creating a construction schedule, which is to be followed by the construction company executing the project. The schedule is made in one of the construction scheduling software available on the market. The construction planner works with observations from older construction projects as well as norms and standards in order to generate data which is in turn fed to the scheduling software in order to create a schedule. The schedule is usually a part of the contract signed by the investor and the contractor in order to monitor and preserve construction milestones of the building. The role of building information modeling plays a very little role in this process, if any. Still there is an option of how to create a construction planning simulation out of the project. The resource a construction planner, with the intention of creating a visualization, is a working 3D model of the building and the most up to date schedule the building has.

In the case of the Parkview project, all the software used in order to apply BIM solutions onto the project is connected to the Autodesk platform. 3D modeling was all done in the Revit software, which was after its completion converted into a Navisworks file format. First task in creating a construction visualization was to acquire a cumulative 3D model. The cumulative model consists of many different construction fields put together. These fields are ranging from the monolithic construction of the whole structure, through the building facade with all of its elements ending with MEP models of the building thoroughly showing all of the building's connections and functions. This cumulative model presented in Navisworks software can be seen in figure number 11.

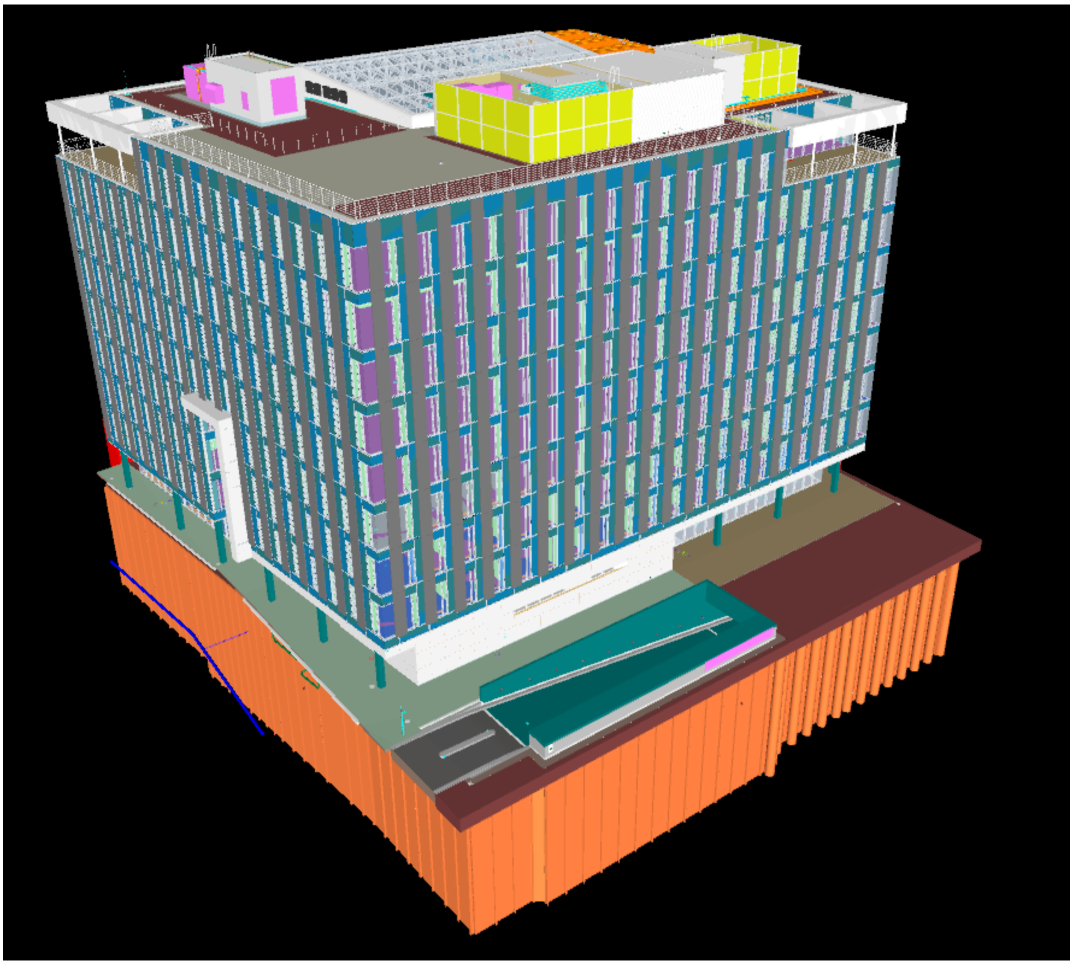


Figure 11. 3D model of Parkview in Navisworks software (Author)

Another task, after acquiring a representative 3D model of the building, was to acquire a construction schedule of the whole length of construction in order to accurately simulate the construction process. For that purpose, a schedule made in MS Project was acquired. The schedule covered most of the building's monolithic structure and the whole facade, some of the internal fit-outs of the object were also included in the schedule, but were not described in a detail. All of the processes, which were to be included in the construction sequencing visualizations had to have a certain level detail to them in order for them to be connected to construction elements from the 3D model. Both construction schedule and the 3D model had to be merged together in order to create a construction sequencing visualization. Navisworks has a function of merging MS Project's schedule into the Navis file. This allows for coupling of Navisworks sets of objects together with construction processes interpreted by the construction schedule. As it was not planned to create a construction sequencing visualization from the start of the project, the sets from the 3D model did not match the sets described by the schedule. The work on coupling the sets with the time from the schedule was done manually in the Navisworks software. Some of the objects had to be merged with other objects in order for them to fit into one time period described by the schedule, and on the other hand some of the time periods from the schedule had to be taken with a bit of an abstraction in order to fit some of the object sets together. The coupling had to remove some of the notions which were set up by the time schedule. Concretely the floor plates of each floor were done mostly in four takes, that meant that the whole floor was not filled by concrete at once. However, this could not be done in the 3D model, while that would mean the model would have to be converted back into a Revit format and the floors would have had to be divided manually into four parts. The same principle was used with the modular facade, which had to be simplified into larger modules in order to fit into the schedule and to keep the logic of the construction as well. The technological part of the construction (MEP) was not sequenced according to the schedule, while the provided schedule did not contain detailed information for it. All of the simplifications done in order for creating the visualization meant, that the model cannot be used during the construction process as a reference for the people working at the construction site. Together with the use of Infraworks software however, one is able to design the surroundings of the building. The timeliner and animator functions in Navisworks can create a video of a construction sequence from every angle imaginable, therefore allowing for a thorough view of all the angles and even the interior of the building. This brings an option for the building to be better marketed, while people are able to place the building into perspective of the real world. The simulation can be then added into the model placed in real world in order to create a visualization set at a defined place with the progressing time as shown on figure number 12.

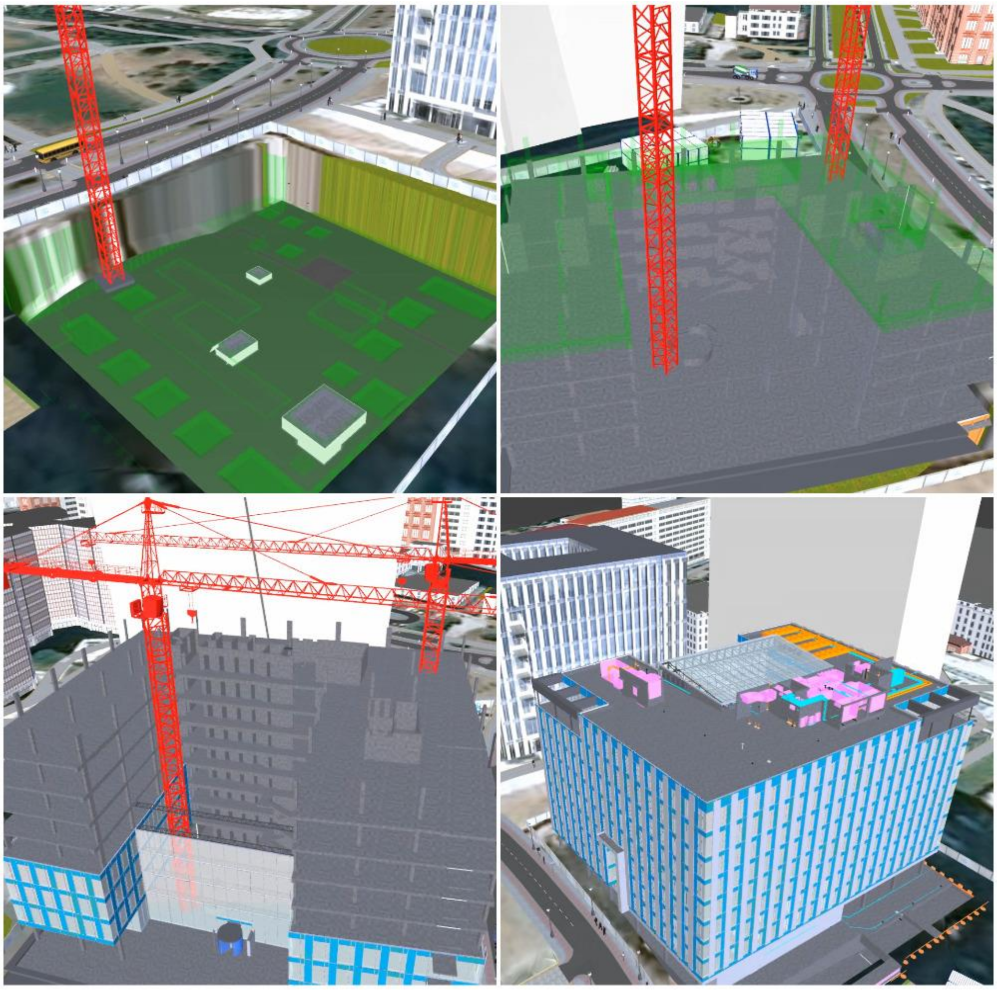


Figure 12. Construction sequencing visualization done in Navisworks (Author)

The undoubted positive of this method is that every employee, whether it be construction planners or BIM specialists, are most likely very experienced with software such as MS Project or Navisworks. The time needed to create such a simulation can be fairly shortened once the worker acquires enough experience through a number of projects. The notion of BIM assisted construction planning is however completely different to the executed method. The biggest benefit of having a BIM assisted construction planning is that it would be directly interconnected with the model. If something at a construction site changes, or the design of the model itself changes there are hardly any tools to incorporate these changes into the construction planning model. The only way to incorporate such changes would be to manually change all the elements and their time, which would be extremely time consuming and most of time probably very counterproductive. Moreover, the construction scheduler, a person who create the schedule for the construction is not an active contributor to the Building Information Modeling process, which by itself is an unwanted situation, while BIM specialists only acquire a document by which they can make such construction visualization happen, rather than actually communicating with the employee and gathering knowledge.

Construction planning visualization created by this method can be found in the attachments together with the source Navisworks program. The schedule and the model were provided by Skanska Property Czech Republic. The surrounding area was created with the help of Infraworks software by Autodesk. Animation of the project was done by merging the schedule with the 3D model in Navisworks and then using timeliner and animator feature to 'bring the construction to life'. Some of the objects had to be simplified in order to fit the model into the schedule, therefore some degree of simplification can be observed in the visualizations.

5.2.2. BIM aided construction planning covered by the EIR

The second option of construction planning, which will be discussed in this thesis is an early adaptation of construction planning into an Employer's Information Modeling document created by the investor at the beginning or even before the project start. The investor should evaluate to what degree and on which project construction planning should be adopted. The choice of the right project could mean the defying line between a successful adaptation of construction planning or the failure to do so. At first, there should be an evaluation of the current state of matters and the ambition whether to go forward with BIM aided construction planning. Prior to the decision an investor should thoroughly analyze whether he/she has the information and manpower needed in order to develop such document. Moreover, the investor should evaluate running projects and projects in the pipeline and choose one which would suit the role of a pilot project. The people working on the project, especially the designers and construction planners should acquire clear and meaningful explanation of their changed roles and responsibilities on the project. The EIR document could require regular meetings between the designers and the planners in order to define a common ground. Moreover, the document should set milestones which would mark the development of the project and their impact on the construction itself. Requested functionality of the construction planning should be clear from the start. In other word the investor should specify why he/she wants to couple the 3D model with the schedule and what benefits it should bring to the construction. Regular visualization emissions should be presented to all of the stakeholders on the project in order to give them a better sense of what is currently happening on the project and what is about to happen in the future. This could lead to beneficial feedback from all the stakeholders, since the visualization could give them a better overview on the whole construction. Groups of construction workers could have their parts of the construction project visualized in order to bring better clarity in between construction teams, therefore also bettering the health and safety aspect of the site. 'A picture paints a thousand words' situation should become a regular occurrence amid not only the designers and planners but also for all of the construction workers, who could themselves develop ideas of how to do the work differently and even with better efficiency once they see where they are supposed to work, on what, and at what time. Therefore, the document should specify the degree of detail of the visualizations in order to procure meaningful data to the workforce. Moreover, the EIR document should specify the concrete software solutions tied to the construction planning, whether it would be a platform or a cross-platform solution. One of the most important aspect of the EIR document would be the implementation of Industry Foundation classes, which may seem trivial at first but could get tricky with the choice of suitable software. The bare minimum of information, which every 3D modeled object should have, could be taken from the Czech infrastructure standards described in the third chapter of this thesis. The setting of the attributed could look like this:

Attribute Name	**Data Type**	**Unit**	**Value examples**	**IFC codes**
Start	Date	-	DDMMYY,MMYY, YYYY	IFCTaskTime, A:ScheduleStart
Finish	Date	-	DDMMYY,MMYY, YYYY	IFCTaskTime A:ScheduleFinish
Process length	String	-	DD,MM,YY	IFCTaskTime A:ScheduleDuration

Construction stage	String	-	S1, S22, etc.	IFCTimePeriod

Table 8. Simplified IFC table for data needed in the EIR (SFDI, 2019)

As with every new process established to an industry, mistakes are expected to happen. The negatives, such as lack of experienced workers on the market could make the application of BIM aided construction planning extremely difficult. It is however very vital to know how to motivate workers and create a feeling of trust in the process in order for the process itself to work. Some pilot projects could see negatives overweighting the positives, but the expected positives described in this thesis have the ability to revolutionize the field of construction engineering. Together with the cost management solutions offered by the quantity outtakes from the 3D model, BIM aided construction planning could transform the whole construction industry and make the production levels higher and more competitive against all the other industries.

5.2.3. **Industry foundation classes applied on the Parkview Project**

As mentioned above, IFC is a common language, which is understood and interpreted by all of the BIM platforms and their software. With its help a ‘network of bridges’ interlinks all of the manufacturers and their platforms. The main benefit of having a common language between all of the software is the enormous flexibility it offers to its users. Some professions do not require a software, which is enormously rich in its function and therefore comes with a fitting price tag. Some stakeholders have the need to view the project as it is without the urge to edit any part of it, that is when IFC comes into use. Being a universal file format, serving a vast spectrum of stakeholders, from designers to construction workers, it is a useful leveling tool in order to keep the market open to new coming software and its developers. It is safe to say, that without the existence of industry foundation classes, the market could have been dominated by a few large corporate companies without any need for accepting newcomers.

The Parkview project is based entirely on the Autodesk platform. This is mainly due to the designing company being a big enough to afford this solution. Having a one platform BIM solution for the whole project is an ideal state which is not and will not be the case for every construction project. Even though there may not be a need to convert the project into an IFC file format as of yet, the process will be presented in this diploma thesis in order to showcase what is possible at this stage of development of the project. The complete Navisworks file with the whole construction planning integrated within was taken and tested whether it could be transformed into an IFC file format. For this purpose, Navisworks has a native solution in order to export the work done in the Autodesk platform into an ifc. file. The add-in is called Codemill IFC Exporter and serves as a handy tool for everyone wishing to make their project more accessible for as many people as possible. The Codemill IFC exporter can convert the model at hand into two possible ifc. versions. The versions are 2x3 and 4, with IFC4 being the latest version of the common language. The exporter offers more options of export, from a pure construction parts-oriented export, to an export oriented in greater depth for their attributes.

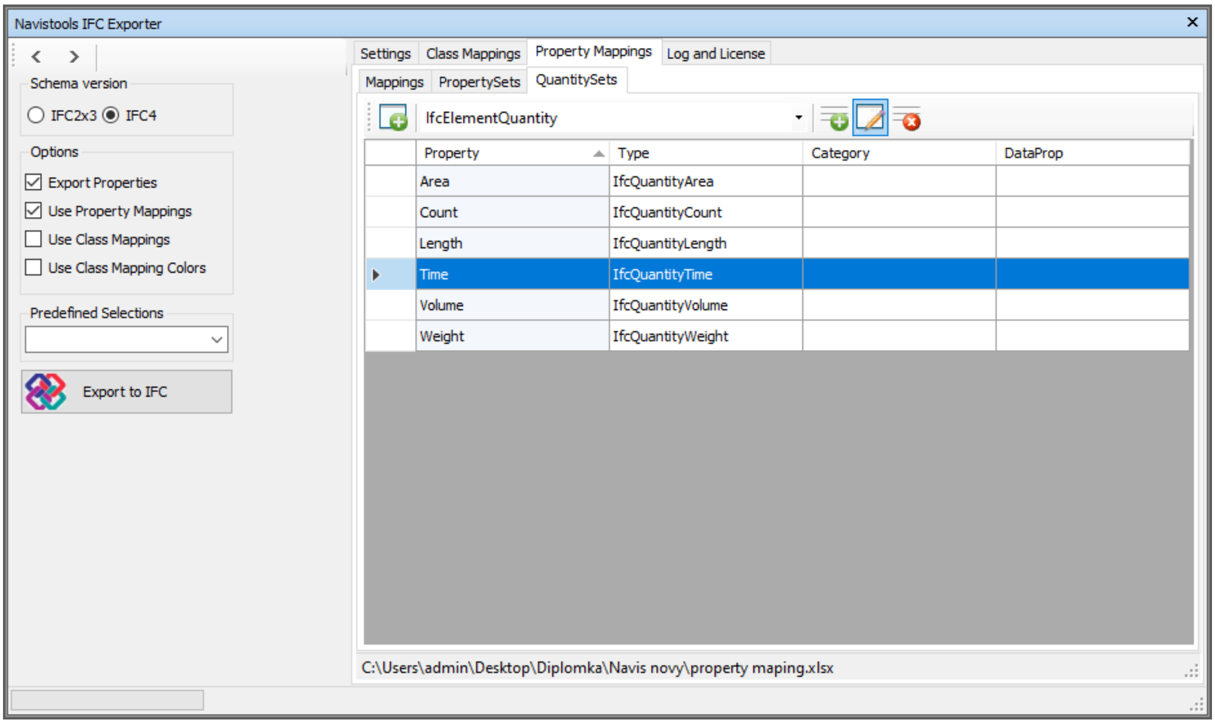


Figure 13. IFC file exporter for Navisworks (Author)

The preferred solution for the Parkview project would have been to export the whole building with all of its elements and to also integrate the dimension of time into those elements. Exporting the building itself did not take too much effort, the exporter creates a large file which can then be compressed into a much smaller one, due to the document consisting mainly of text. The more challenging part was the addition of time into the ifc. document. The exporter shows a solution of exporting all the information needed from the TimeLiner function from Navisworks, nevertheless the program froze at every instance of such exportation attempt. The possible solution, which unfortunately cannot be supported fully by the thesis can be seen on Figure 14.

The time attribute exporting solution was based on the knowledge of IFC formatting gathered from (buildingSMART, 2019). At the end it is needed to say, that even though time attributes of elements were not converted into an ifc. file format, a lot can be

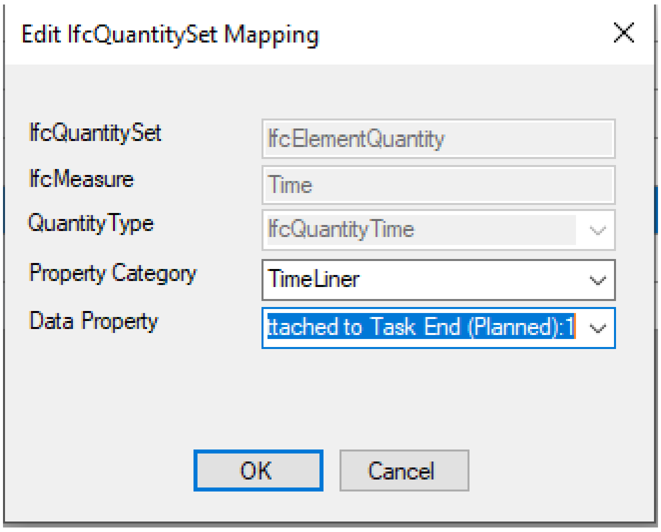


Figure 14. Time attribute exportation into an IFC file format (Author)

observed from the 3D building model itself which was exported successfully. The reasons for an unsuccessful time export could be plenty. The IFC exporter was offered just as a trial version and therefore possibly lack some functionality. The schedule in MS Project could have been formatted differently from the beginning, therefore not allowing for a smooth exportation.

In conclusion, more research would be needed in order to offer a working exporting solution for the given model. As mentioned above, the difficult process of exporting a a timeliner schedule into ifc. file could have been averted if the project was set up with construction scheduling in consideration from the beginning.

6. Conclusion

This thesis deals with Employer's Information Requirements, a document which should introduce the demands for the data, which should be provided as an input at the start of the construction project but also as an output, which should be harvested during and at the end of a construction project. More concretely, the thesis deals with the application of a more digitalized version of construction planning with the help of Building Information Modeling and utilizing the EIR.

The first part of the thesis introduces Employer's Information Requirements and places them on the map of Building Information Modeling. It names the benefits this approach to construction planning could bring and provides statistics, which explain why such a change is necessary. Furthermore, the thesis explains which data/information is vital for BIM aided construction planning and why.

The second part of the thesis focuses on the Employer's Information Requirements in depth. The ISO19650 international standard is being utilized in order to explain basic notions of EIR and their further development. The chapter explains how one should establish the EIR document and introduces all the steps needed in creation of such document. Information flow and revision approach is described, in order for creation and filtration of data. Moreover, the chapter explains what a responsibility matrix is and how such matrix can be used to further develop the EIR document. Costs and benefits of creating such document are explored to clarify for whom such document could be helpful. Next in the chapter, construction sequencing problematic is presented. The notion of visualizations during the construction is discussed together with the software creating these visualizations. At the end of the second chapter, Industry Foundation Classes are introduced as a common language and a solution for all of the construction planning and visualizing intentions.

The third chapter discusses the use of EIR in three selected countries around Europe. The approaches are thoroughly evaluated from all available sources in order to give an overview of similarities and differences between these countries. The UK is presented as a benchmark from whose standards the ISO borrowed in order to create an international standard ISO19650. Later, Czech Republic introduces its take on the

EIR and construction planning with their norms for the infrastructure. At the end of the chapter, Sweden and its documents which could be compared to an official Employers Information Requirements document are introduced.

Fourth chapter of the thesis deals with two problematic construction projects both in Czech Republic and Slovakia. It introduces the two projects and offers an alternative to how matters could have been handled with the help of EIR.

Fifth chapter of the thesis deals with the practical execution of construction planning on a selected project in Prague. At the beginning the project is described in detail. Later on, an approach of creating a construction planning visualization, created for the purpose of this thesis, is executed and described. All of the positive and negative aspect of such construction sequencing are taken into consideration. In the middle of the chapter, an alternative approach, with the help of Employer’s Information Requirements from the start of the construction project, is presented. As is the case with the first approach all of the positives and negatives are described. At the end of the chapter, industry foundation classes and their possible role on the Parkview project were discussed.

To conclude the thesis, Employer’s Information Requirements are a great tool for all construction industry professionals. However, the investor is the actor to whom such document can bring the biggest benefit. Functioning construction planning can be set up at the start of the project by these requirements and therefore bring more clarity to every stakeholder of aforementioned construction project. The feedback from these stakeholders could be helpful during the whole duration of the project. With the addition of attributes offered by the Industry Foundation Classes (such as ScheduleStart or ScheduleFinish) a working cross-platform 3D model interconnected with time can be created. All of these notions are worthy of further development in order to make the construction industry more efficient and competitive with respect to other industries.

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8. List of Figures

9. List of Tables

10. List of Abbreviations

AIR	Asset Information Requirements
BEP	BIM Execution Plan
BEP	BIM Execution Plan
BIM	Building Information Modelling
EIR	Employer’s Information Requirements
CAD	Computer Aided Design
CAS	Czech Standardization Agency
CDE	Common Data Environment
COBie	Construction Operations Building information exchange
IFC	Industry Foundation Class
ISO	International Organization for Standardization
LOD	Level of Development
OIR	Organizational Information Requirements
PIM	Project Information Requirements
RIBA	Royal Institute of British Architects
SFTI	State Fund for Transport Infrastructure
UK	United Kingdom
2D	Two-dimensional
3D	Three-dimensional

11. List of Attachments

Attachment A: Parkview – sequence of construction visualization

Attachment B: Parkview – atrium entrance visualization

Attachment C: PDF file of the Diploma Thesis.