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Good practice guide

Project

Organization of the Manager's School for adult education and training

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INTRODUCTION

The main objective of the project was to meet common needs and priorities in the field of adult vocational education and training. The project was implemented in partnership by clusters: the Construction Cluster in Poland and the Construction Cluster in Slovenia. The priority of the project Organization of a Manager's School for vocational education and training of adults was to improve the quality of work and practices of the involved organizations, building the organization's capacity in the field of international and cross-sectoral work, which in turn is to enable transformation and change leading to the improvement of each organization.

Both organizations associate companies from the construction industry, currently the main challenge in this industry is the design and implementation of zero-energy buildings and an additional challenge is the optimization of the consumption of raw materials and energy, both at the stage of building construction and operation. Constructing such buildings is a challenge in terms of design and implementation. First of all, it requires companies to be able to efficiently control the production process at every stage - from design, through production, to commissioning. Companies reported the need to streamline production, improve and introduce changes.

In view of the above, a series of workshops under the name of the Manager's School was organized in the project, aimed at training in Lean Management, exchange of experience in the improvement of production processes that take place in the construction industry (especially zero-energy buildings). An important area was the exchange of experiences of Polish and Slovenian participants.

This Good Practices Guide was published as part of the dissemination of the project's effects and it is a collection of publications containing both substantive content presented as part of project activities and the effects achieved thanks to the project.

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PART ONE

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To a man with only a hammer, every problem starts to look like a nail.

H. Maslow

What is bim and why all the fuss?

The construction industry is an important branch of the economy. It may seem strange that, despite the digitisation that is sweeping our surroundings and the general increase in productivity in almost all areas, construction has continued at almost the same level for decades. The way we build has not particularly changed since the Middle Ages. Yes, we are using more modern materials with greater strength, we can build higher and lift more. We can communicate faster and transport materials over greater distances. This allows us to build more and faster. Buildings are better protected from the elements. However, building itself involves the manual performance of certain operations by manual workers. These operations are generally carried out by specialised teams in a specific order, at the same location, which requires good planning and coordination. The process itself has been based for decades, indeed hundreds of years, on flat documentation, a representation of the designer's vision, better or worse fulfilling the expectations of the investor and, in the Middle Ages, the founder.

The investment process at the beginning of the 21st century is still plagued by many inefficiencies, resulting in excessive costs and wasted materials and energy. Despite the increasing digitalisation of everyday life, the investment process, or rather its participants, are bravely resisting digitalisation, which has repeatedly proven to increase efficiency and reduce costs.

Whether the change in the investment process should emulate other industries or rather be a response to the specific ills of the construction industry, the authors leave it to the reader to decide. Nonetheless, the book on digitalisation in construction, which can be a catalyst for the postulated change, starts by pointing out the specific problems that the industry is facing on the organisational and information level.

There is no doubt that implementing change in organisations and processes that rely primarily on people is a challenge that is met with resistance. However, we should be brave in pursuing changes that result in building better, more sustainable, less impactful facilities. Not for ourselves, but for our children - they will have to live in the environment we leave them.

The traditional investment process – what doesn't work?

The investment process, that is: "You will be satisfied..."

What is an investment process? A review of the literature indicates that even the authors of the subject are not consistent on this issue when they present their definitions of. In turn, the diversity of definitions allows for differing interpretations in terms of identifying the starting point, the scope of activities or a clear definition of the stakeholder group[1]. The lack of conceptual standards poses a challenge on the management side significantly affecting the efficiency of the process and the quality of the final product (however defined). Poland is a unique case in this respect, as there is a lack of strong professional institutions related to related to investment project management. This results in a lack of industry standards in the field of investment project management, which would allow for standardisation of the vocabulary of terms, concepts, nomenclature of phases, etc.

One rather general definition states that the investment process is "a sequence of coordinated activities of a technical, legal, technological, organisational, financial, etc. nature, leading to the realisation and operation of a planned construction project within a specified period of time and with limited financial resources". The characteristics of the investment process are the immovability of the product, the individual character of each object, the frequent and profound interference with the natural environment, the need for constant cooperation of the main participants, the long preparation period, the staged implementation of the project documentation, the longevity and capital-intensive.

In contrast, the UK's RIBA (Royal Institute of British Architects) has standardised the naming of stages in the life of a development, setting a benchmark for the construction industry in the UK. In Polish conditions, each investor introduces his own nomenclature and adapts it to his needs and practices. The situation of the lack of nationwide standards in this area generates many inefficiencies, which translate into additional costs for the implementation of investment processes. In order to enable efficient communication during project implementation, the investor himself must plan its course and means of communication. The

[1] In a general sense, *stakeholders* are persons or organisations that are affected by the planned investment or that themselves are affected by the investment in question.

stage of preparation for the efficient management of the investment process is often overlooked as an unnecessary burden on the investment budget - after all, everyone knows what to do, how to do it and when to do it anyway, we have always done it that way and it was good. Such an assumption results in additional costs for rectifying errors resulting from misunderstandings, miscommunication, mistakes and omissions. This approach perfectly illustrates a characteristic of the industry highlighted in the reports, namely slow adaptation to change and low innovation, which hampers the sector's efficiency gains relative to other industries. At Fig. 1 shows the results of a multi-year study of efficiency gains in various sectors of the US economy. The performance of construction is the worst compared to the other industries studied. This is, among other things, the result of the industry's conservative approach.

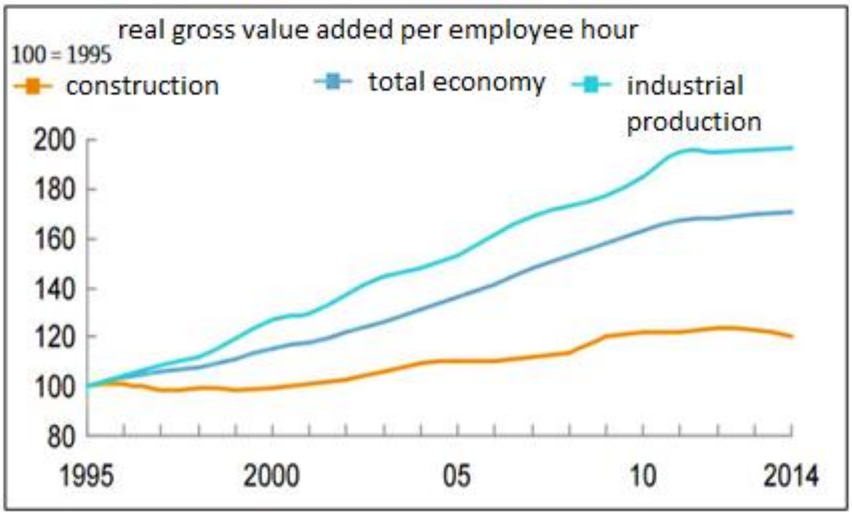

Fig. 1 Productivity growth in construction against the economy 1995-2014

Since the performance of the construction industry in terms of efficiency gains over the long term lags so significantly behind the rest of the economy, and the industry resists innovation, the investment process must be extremely complex, multi-faceted, with numerous variants and options. To some extent this is the case, but - to paraphrase Henry Ford - no venture is particularly difficult if it is broken down into smaller tasks. At Fig. 2 shows the phases of the object life cycle, which are described below.

Investment delivery phase [2]

- **Investment preparation stage** - consists of needs and cost-effectiveness analysis, formulation and development of guidelines for carrying out the investment process resulting in a change in the environment. Compilations are made at a high level of

[2] *Delivery Phase* according to ISO 19650-1:2019

generality and decision-makers use indicator analyses to decide whether to proceed or to abandon the intention. In this phase, for the decision to proceed, analyses of options for carrying out the investment are also conducted. One of the products of this phase is a set of design guidelines.

Fig. 2 Building life cycle diagram

- **Design phase** - design is a complex process nested within the investment process, which is customarily divided into stages resulting from successive studies, which are successive approximations of the description of the planned facility. It is the phase in which key decisions are made for the final outcome of the investment process[3].
- **Construction phase** - the physical construction of a building or structure on the basis of previously prepared and approved documentation. The project delivery phase ends with the handover of the building for use.

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[3]Even if design overlaps with construction, any construction work is preceded by the preparation of documentation, which is the basis for its execution. It is in the design, therefore, that the parameters of the object to be realised are ultimately decided..

Management and operation phase of the investment[4]

It lasts for decades until the demolition or complete reconstruction of the building facility. During this phase, the facility is in use, ongoing maintenance and repairs and upgrades are carried out.

The process is cascaded, meaning that the stages progress in succession. The outputs of one stage form the input to the next. The process is also repeatable, familiar, and led by experienced managers who gain experience by going through the same stages each time. So what is the problem? The challenge is not the stages, but the number of stakeholders, their connections and often conflicting objectives. Business entities of different sizes and specialisations, authorities at different levels, financing institutions, social organisations exert or try to exert influence on the course of the investment process, which, combined with imprecise laws and their interpretations, often turns the conduct of the investment process into a walk through a minefield. This is why investors tend to follow the beaten path and use previously tried and tested solutions. They are often forced to do so by regulations.

The completion of the construction works and the handover of the facility for use completes the investment process, but from the point of view of the life cycle of a building, calculated over decades, it is only a dynamic introduction to the more predictable, but also much longer stage of use and maintenance. In cost terms, depending on the author, the calculation methodology and the type of facility, the costs of the investment process are only 20-40% of the facility's life cycle costs. However, decisions made during the investment process are crucial to the efficiency of spending the remainder of the facility's life-cycle costs.

In addition to financial costs, construction facilities generate environmental and social costs. The industry seems to be more and more aware of and ready to take into account the entire impact of buildings on the environment, but construction projects still result in buildings that do not live up to expectations, which are criticised on various levels. This applies to almost all categories of buildings, from infrastructure to residential buildings to public facilities.

The industry seems to accumulate knowledge and experience on a global scale in a very limited way. The investor, who tries to learn from his own mistakes (or the mistakes of team members), tries to avoid them by adding relevant clauses in subsequent contracts, which also generates legal costs. After all, there are no standards for construction or design contracts in Poland, and the FIDIC standards adapted by some investors are modified to such an extent that little remains of the original.

[4] *Operational Phase* according to ISO 19650-1:2019.

Is it finally a project or a process?

The unitary nature of a product realised in a dynamic environment brings with it another consequence at the level of construction process management. This is the **project nature of management**. Projects are undertakings directed to bring about a change in the environment having the following characteristics:

- complexity,
- uniqueness,
- team implementation,
- time limit,
- predetermined outcome/goal,
- implementation with limited resources (e.g. financial),
- a large group of loosely or not at all connected stakeholders.

As a project, the investment process fits into the cascade model defined by the Project Management Institute (PMI), in which successive phases follow one another, slightly overlapping. The cascade model for an investment project assumes a complete separation of the consecutive phases. On Fig. 3 shows the cascade model according to PMI. Different actors are responsible for the delivery of the products within the subsequent phases, which complicates the process. It can be assumed that the first three stages are carried out by the developer before the formal announcement of the intention to start the investment (analysis of need and cost-effectiveness analysis and preliminary design assumptions), and correspond to the concept and concept development. In subsequent stages, further stakeholders join in, each of whom pursues their own interests (design, construction - i.e. building). Finally, the facility is commissioned and the project team moves on to the next challenge.

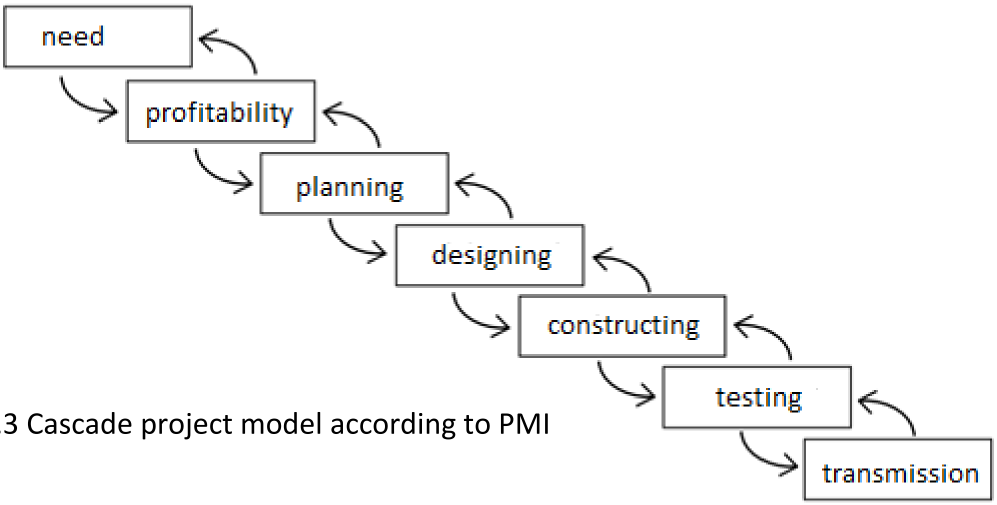

Fig.3 Cascade project model according to PMI

In addition, investment projects are costly, often spectacular and emotionally stirring, and therefore fraught with risk at almost every stage. The greater the impact of a facility on its surroundings, the greater the range of stakeholders and the need to manage them.

The project-based nature of managing long-term ventures in a fragmented environment also generates the difficulty of accumulating knowledge, learning and improving practices in such a way that each subsequent investment process and its product is improved (however we define excellence). Each participant in the process learns and improves on his or her own. The selection of participants for a particular investment project is often random, and each chain is only as strong as its weakest link.

The project-based method of investment management has another consequence for the life cycle of a building facility. Once the project is completed, the facility becomes the subject of a continuous process involving use, maintenance and ongoing upkeep. The facility passes into the hands of completely different people, specialised in these very activities. These people get to know the object, its character, its defects over time and have to deal with it. They rarely have the chance to participate in the design of a new facility and share their knowledge and experience about specific solutions, their functionality, durability or reliability.

For self-builders, the situation is somewhat better - they have a direct interest in the lifecycle efficiency of the building. However, this also varies.

The availability of limited resources available for use during the implementation of an investment project results in the need to monitor and control implementation costs already at the design stage. Underestimating the budget or specifying too costly solutions may end up with problems at the stage of tendering for construction works, construction or even the interruption of implementation. How important this issue is is illustrated by Fig. 3.

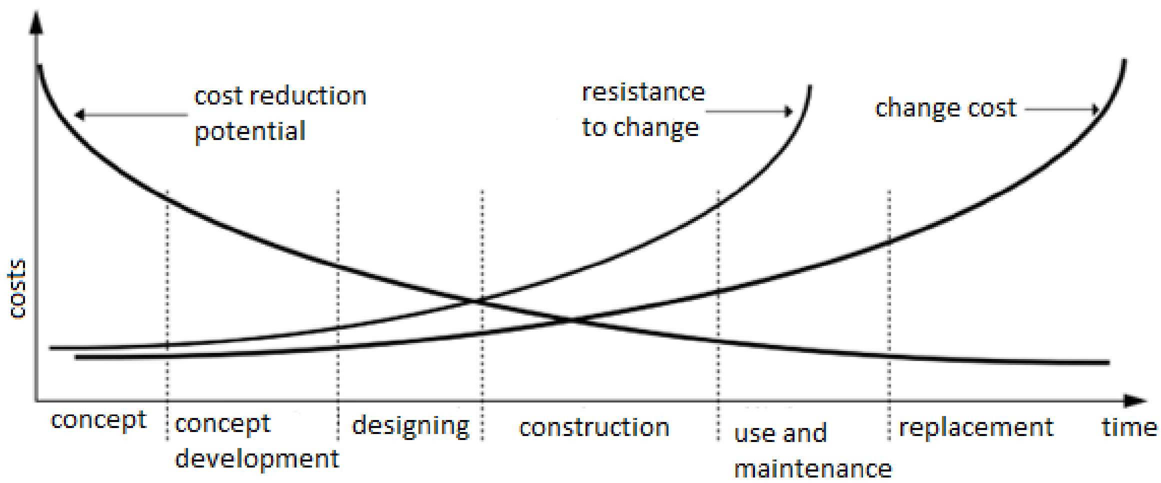

Fig. 1 Potential for reducing costs and switching costs over time

A decreasing cost reduction potential curve indicates a decreasing ability to reduce the cost of a realised facility over time as its definition becomes more precise. The increasing cost of change and resistance to change curves indicate that, with with increasing commitment to the investment project, resistance to change increases and the cost of implementing it. Even in the case of a change designed to reduce the cost of implementation, designed to make the cost of bringing in the facility fit within the planned budget. This indicates the great importance of the first stages of an investment project, when any change can be introduced at a relatively low cost. Investors often forget to control the budget at this stage and are surprised by contractors' offers. Looking for savings just before the start of construction is not only very limited, it usually results in a significant reduction in the standard of the building, negatively affecting its use. The impact of decisions made at the design stage on the completion price is one of the most significant issues in terms of project success.

What's not working?

Translating the above into capital projects, the cascade model implies a complete separation of the following phases: analysis (planning), design, construction, testing (acceptance) and handover. As a result, traditional construction struggles with, among other things:

the problem of poor quality - when a project is already underway, and design and execution errors are resolved at the inspection and acceptance stage

and execution errors are resolved at the inspection and acceptance stage, the cost of drastic changes is enormous; as a result, 'sub-standard' solutions are often created to save the budget;

- the impossibility of simply going back to a previous phase - if the client's initial requirements turn out to be flawed in some way or change during one of the project phases, the team has to practically start work on that part of the documentation from scratch;
- lack of control over progress and schedule - as the final documentation for release is only created towards the end of the project, you never really know how many man-hours it will take to complete; it would seem that the last 20% of the project, with subsequent client revisions and comments, typesetting, release, extends to 50-80% of the project duration;
- the inability to modify according to the client's expectations - the cascade model assumes testing and presentation only at the end of the project process; changes made during generate a loss of control over the schedule and therefore the project budget.

The project manager - especially at the stage of creating traditionally produced documentation - therefore has little control over the completion of the project on time and in accordance with the client's requirements. The exception, of course, is typical projects, where the designers' experience and knowledge of the client's requirements and local conditions is complete.

Are those involved in the investment process incompetent and unable to cope with the can they not cope with the challenges? Are the ordering parties, the investors unable to define the needs in a way that is understandable for the designer? Maybe designers do not have the imagination and skills to describe the investor's guidelines in the documentation? Or perhaps contractors use cheaper substitutes, lowering the standard and durability of buildings while increasing their energy intensity? There is also the possibility that users have too high expectations and are unable to appreciate what they have received. Worse still, they are not very good at handling and servicing this good, leading to excessive and accelerated wear and tear... Many more such clichéd statements could be quoted. However, it is undeniable that the industry is facing many challenges. Research shows that one of the more frequently cited key success factors, a barrier and also an area for improvement in the implementation of investment projects is communication. How is it possible that, in the 21st century, an industry operating according to an idea-design-implementation-utilisation pattern that has been known for hundreds, if not thousands of years, despite the availability of incredibly efficient means of information transmission, whatever it may be, still points to communication as one of the main barriers to an effective investment process? The two main reasons are:

- **the fragmentation of the market and the lack of standards for information exchange,** which would improve communication - this results in the majority of cases in having to adapt to the slowest runner; if the slowest runner is a participant in the process, which cannot be eliminated (e.g. a conservative investor who does not see the need for change or an authority that does not have the capacity to adopt new information exchange technologies), then the process will already be inefficient at the outset;
- **vague or imprecise definition of expectations -** investors understood as institutions are represented by people with different qualifications and experience in the execution of construction investments, which is particularly important for investors who are not specialised in one type of facilities, do not accumulate knowledge and do not use it in the subsequent process; in the case of non-specialised investors or investors taking their first steps, the definition of expectations may be vague, imprecise or simply unrealistic, and inconsistent guidelines will be the basis for the execution of the project; it is important to remember that design is done by successive approximations and the successive steps are subject to the investor's approval, whereas an incompetent or inexperienced investor will not be able to identify errors or deviations from his expectations; it happens that the steering committee of an investment project consists of people who do not understand

the technical documentation, the logic of the process and the importance of the successive steps.

Communication is the conveyance of a piece of information in a way that ensures that it is equally understood by the sender and the receiver. Miscommunication results in different interpretations and consequently a discrepancy between the expectations of the parties and the actions taken. Such a situation negatively affects the product of the investment process due to its unitary nature. Each time a building object is realised, it is the construction of a finished product. The inability to test a prototype, then optimise it, as is the case in the high volume industry, has many consequences.

When designing a car, the design team often matches mass-produced components to the needs of a particular model that will be produced in the thousands. In construction, the situation is the opposite. A unitary building consists of thousands of components, sub-assemblies and equipment, which the designer tries to select in an optimal way that meets the requirements of the developer and ensures the comfort and safety of users. The cost of realising this composition must furthermore meet the investor's budgetary assumptions. In addition, it must be remembered that design is a team sport. The number of people and organisations involved in drawing up the documentation (industry specialists, consultants, etc.) increases with the degree of complexity of the object to be realised. The communication of all participants in the project therefore seems crucial.

Project success or coincidence?

Project-based implementation management, a continuous maintenance process, different stakeholder groups at different stages of a building's life cycle, the diverging interests of the individuals and companies involved and many other factors affect a building facility during its life cycle. The developer is responsible for the organisation of the investment process and the outcome - the final product depends on his competence and will. The investor mainly influences the course of the investment process and how the object performs during its lifetime. There is no denying that investors, depending on their nature (public/private) or business model (construction and use/building for sale), have different value systems that influence the decisions made during the investment process. These decisions generally impinge on the entire life cycle of a building. The number of investor options is quite large, nevertheless the attitudes presented by the role players and their representatives indicate the primacy of current savings over long-term savings, even if the the latter is much greater. This is often due to the limited budget allocated for implementation and a separate budget during the maintenance period. This is not conducive to a life-cycle analysis of the facility, resulting in the construction of facilities that require excessive expenditure over their lifetime. This applies to both maintenance and energy consumption. In today's commercial real estate market, some investors see the implementation of solutions to reduce the impact of a facility on its surroundings as a way to gain a competitive advantage. However, how much of this is advertising and how much is a genuine concern for the environment is difficult to assess. for the environment. This is just one aspect through which investors' attitudes can be judged. They are reflected in the design guidelines, i.e. at the beginning of the investor-designer communication.

Design Guidelines, Functional and Utility Programme, Project Brief - these are terms describing the material which is a set of initial data provided by the investor to the designer. It is a general description of the planned facility, assumed parameters, ideas, goals and expectations presented in a more or less technical manner. The role of the designer is to develop technical documentation on this basis that meets a number of requirements. In addition to the obvious requirements of the client as set out in the guidelines, it is necessary that the facility is safe for the users and the environment, that it meets the planning conditions, that it can be built in the given environment within the budget and time frame set by the client. The better developed and clearer the guidelines are, the more likely it is that the designer will interpret them correctly. Practice shows, however, that this is not the rule. For various reasons, changes are made to the design documentation at successive stages of the investment process. The relationship between the possibility and cost of making a change during the investment process was mentioned above (see Figure 3). Once construction has started, the cost of changes increases dynamically. Ideally, therefore, all eventualities should be foreseen before the work starts. Is it possible for the works contractor to operate one, correct, coordinated version of the design documentation already from the tender, which meets the expectations of the investor and other stakeholders' expectations?

Indicators of project success are derived from the project definition and are: cost, completion date and quality, sometimes understood as scope. These indicators are interdependent; a change in one affects the other two. This is illustrated by the project management triangle shown in Fig. 4. The structure of the triangle is based on the information component, which can be understood as project documentation, but also any other information about the planned and implemented construction (investment information model). The methods of generating, exchanging, aggregating and processing information thus have a fundamental impact on all the success indicators of the implemented project.

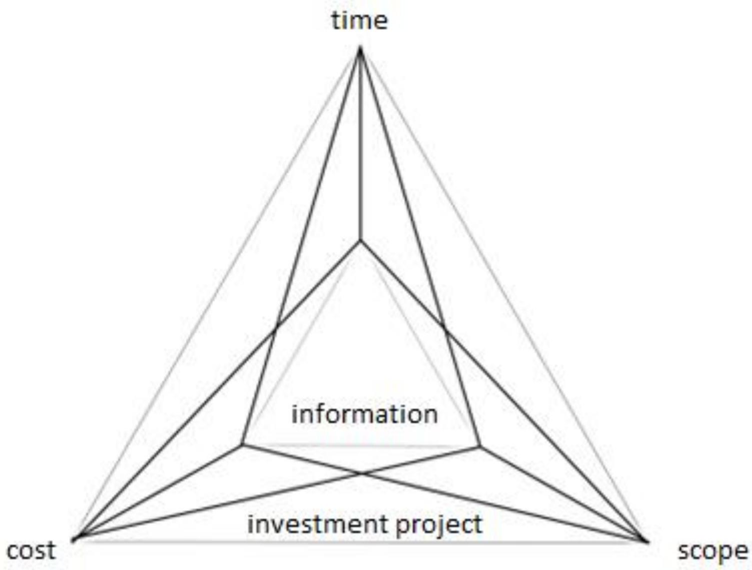

Fig. 2 Project management triangle
Source: own elaboration

Any market participant can list many problems known from experience, research or anecdotes resulting from the lack of adequate information at a certain time. This lack is the result of faulty communication during the investment process. This generates conflicts, costs, delays and a myriad of other inefficiencies in the investment process, which affects the human environment so much. Are we therefore able to manage information, its generation, storage and distribution in a way that improves the investment process?

Understanding Your Business

We will not solve problems by thinking in the same way as when we created them

Albert Einstein

The decision to implement BIM is important for the company, but it is only part of the wider issue of digitising the company. It is a strategic decision because, on the one hand, it means opening up to new opportunities and, on the other, it requires implementation costs. In order to be able to consciously estimate the benefits and costs of implementation in a specific company, it is necessary to know its current role in the investment process, its market position and how it generates competitive advantage. Only in this way will it be possible to consciously choose a BIM implementation strategy, select tools and adapt processes to the new way of doing business. This chapter begins with a brief overview of the business models of the various market players. It then describes the potential relationship of BIM to managerial areas of the investment process, such as the role of the manager, ways of contracting works, modern management methodologies, before moving on to describe the redefinition of strategy due to BIM and guidance on strategy implementation. This will allow discussion of the role of BIM in the company at a high strategic level and identify the benefits in specific cases.

Diverse ideas for success in construction

Entities in the construction industry

The construction industry in Poland is one of the most fragmented. One of the factors that differentiates companies is the business model. In the most general sense, this is the way in which a company turns available resources into revenue and, consequently, profit for the owners. Every company has a business model. It may be unconscious, but it certainly exists. It can be asked whether one needs to have a defined business model in order to start a company, or whether it is rather the result and description of some successful business idea. At certainly, many entrepreneurs set out to conquer the market with the idea of providing a certain value to customers in exchange for a certain remuneration, without a defined and described business model. Simply put, the business is a direct response to an identified need. Describing and becoming aware of the business model, on the other hand, enables it to be analysed, improved, adapted to the changing environment. One thing is certain - whatever the configuration, a good business model should be like a flywheel that, once set in motion, enables the growth and expansion of the business.

So how does this look in the construction industry? In general, the following entities can be distinguished in the life cycle of a construction project, with fundamentally different business ideas:

- investor - the entity that initiates the project, defines the need and provides the means for its implementation;
- advisor-like entities - use knowledge to describe how to meet a need;
- works contractors - use available resources to deliver the facility;
- owners, users of the facility - companies, entities that derive benefits from the existing facility;
- building maintenance, technical and administrative staff - those who take care of the good condition of the building and the comfort and safety of its users.

Representatives of each of these groups have a slightly different idea of business, some happen to be clients of others. Consultants sell knowledge, contractors sell construction services and investors bring buildings to fruition with the aim of selling or owning long-term and profiting from it. In this, long-term investors are similar to public investors, who generally build in order to own and use of a specific facility.

Apart from the business idea, players in the construction industry differ in their scale of operations, strategy, goals or values. In addition, there are diverse players in the market, from large enterprises to one-person businesses. These businesses are staffed by people who have different beliefs, experiences and as such show resistance to change. So what can such a technical and specialised tool as the BIM methodology bring to such a high level of business model management? Does the difference of several levels of management: from the tool level (the general perception of BIM), to the operations level, i.e. revenue generation, to the tactical and strategic levels, above which consideration of the business model is just beginning, allow these concepts to be combined at all? The simple answer is **YES**. This is because the full potential of BIM can only be realised if there is a complete alignment of the way the investment process is conducted with the principles of the BIM methodology. This, in turn, requires revising the business model at the level of objectives and ways of generating value and answering the question of what potential BIM brings and how the company should be adapted to exploit it. The diversity of players in the market results in, that there is no single good answer or template. Above all, different stakeholders may have different expectations from BIM which applies to both the company and the individual investment process.

In the beginning there was an investor...

On the organisational side, the entity that initiates the investment process, i.e. the investor, has the greatest influence on the course of the investment process. The investor provides funding, bears the risk and benefits from the investment. It may be debatable whether all investors use this influence to ensure the success of the investment.

Or is it the case that, as a result of a lack of competence, a desire to take shortcuts and seemingly be cleverer than the last time, and a number of other factors, the investor abdicates his or her high position and, as it were, gets carried away with the process and the clashing interests of the actors involved? As indicated above, the diversity of players in the market makes investors not a homogeneous but an internally diverse group. A division can be made according to several criteria such as ownership (public, private), specialisation (offices, flats, warehouse, etc.), time horizon of the investment (short-term for construction for sale, long-term for construction and use).

For almost any combination of options within the criteria, an example can be found:

- municipality - a public entity that builds public housing for rent,
- developer - a private entity that builds flats for sale,
- developer - a private entity building offices for sale,
- a public entity that builds and maintains national roads and motorways,
- a state-owned company developing residential, office and industrial buildings for sale and lease.

Every investor in the market can be characterised in a similar way, and still within subgroups they will differ. An additional differentiator may be the way in which project finance is raised or how investments are made. It seems clear that such a diversity of actors will result in a diversity of objectives, needs and expectations requiring analysis. Since, in the most general terms, the BIM methodology is a tool for improving the efficiency of business processes, at a strategic level the developer should weigh up the costs and potential benefits of carrying out an organisational change involving the implementation of BIM in the company. The benefits will depend on, among other things: the nature of the facilities being implemented, the scale of the business, the expected period of ownership of the facility being implemented. However, the key in identifying the benefits and defining the objectives of individual implementations is to look holistically at the issue of BIM in the organisation. Otherwise, there is the possibility of untapped potential. A very simple example would be the use of BIM models prepared for implementation to reduce the cost of preparing 3D visualisations or virtual walk-throughs for promotional purposes. The aim and effect at a strategic level is to force departmental staff to work together across the functional silos they were previously in and reduce the overall cost of running the business. More similar relationships that require a degree of openness on the part of the organisation's managers, who are often 'non-technical' people, can be identified. This demonstrates the validity of the thesis of the need to take a holistic view of the issue of BIM implementation in an investor organisation.

So what value can the implementation of BIM in an organisation bring to the developer? The palette of benefits realised by implementing full BIM throughout the lifecycle of a facility is very wide and includes such issues as:

- complete and internally consistent project documentation, free of conflicts between branches,
- the possibility to assess the designer's work on the basis of a 3D visualisation in virtual reality,

- more accurate cost planning, cost estimating and cost modification than the traditional model and making changes to cost estimates,
- the ability to visualise implementation schedules and make them more predictable,
- the possibility of visually checking the correctness of the contractor's billing,
- health and safety support during construction and operation,
- complete and structured as-built documentation,
- generation of advertising material and building presentations from 3D models,
- the use of three-dimensional models to improve social communication,
- collection of unlimited information on individual building components for the purpose of building management,
- full information on events during the life of the facility, operating costs, etc,
- reducing the costs of conducting multiple parallel analyses that are omitted in the traditionally conducted process and the possibility of using this to raise the profile of the investment (e.g. analysis of the environmental impact of a facility on the environment by controlling and minimising the carbon footprint).

The above list is not exhaustive, but it can be seen that some of the benefits are achieved in cooperation with other actors. For example, complete as-built information (however we define its content) is a tangible benefit for the investor, but is not completed by the investor. So how do we ensure that the benefits materialise? By defining the objective and designing the process and then carrying it out in a way that enables the objective to be realised. In terms of designing the investment process using BIM, it is worth distinguishing between public and private parties and private parties. Examples from the UK market show that public investors use industry standards and norms. An attempt to standardise the BIM process in Poland is the BIM Standard PL. Private entities, on the other hand, approach the issue less rigorously and individually define the objectives leading to the realisation of the benefits that a particular investor cares about.

In order for specific benefits to materialise, those involved in the production of building information need to be informed in advance of the purposes to be served by the models being prepared and the rules for their preparation. The business consequences of a lack of management and control over the BIM process and its products are wasted time and resources. Participants in the process without proper guidance and oversight will produce models and information that is inconsistent and not useful to other participants in the process who are also users of the information. For example, an opportunity to use a model to automate the work of a cost estimator may be lost if the designer does not incorporate such an expectation into their workflow. At fig. 6 shows how a designer can model a beam element supporting a floor slab. Only one of the three options is useful to the cost estimator (a), and all three can meet the designer's needs because, when generating the cross-section, it fills it with solid black (d). Leaving the designer free to do so can therefore result in additional costs or dissatisfaction for the cost estimator who, after all, has been given a 3D model. Why, then, has he not efficiently and quickly prepared a reliable cost estimate?

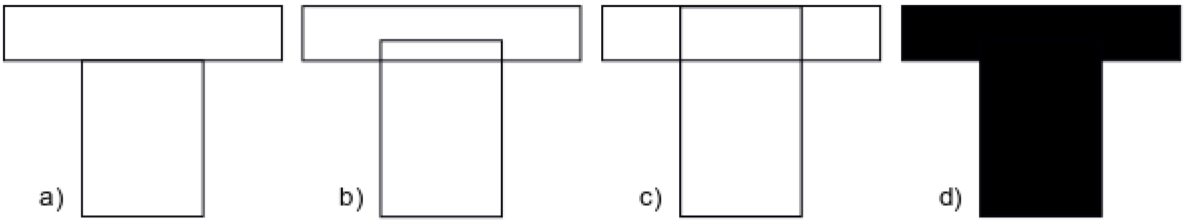

Fig. 6 Possibilities of modelling the floor support beam and the floor as independent components.
Source: own elaboration

In summary, the diversity of stakeholders, their objectives and the nature of the construction works being undertaken requires a thorough rethinking and design of the BIM process in terms of its objectives. The onus is on the developer, as he is responsible for the success of the project as a whole and defines the needs. In addition, the best results come from setting the rules of the game for all project participants as early as possible.

Designers, consultants - time is money

At the various stages of investment preparation, the investor generally makes use of the competence of external entities offering knowledge and experience. The consultant that no investment process can do without is the designer. The consultant's business model, in a nutshell, boils down to buying the competence of its staff in exchange for regular and predictable remuneration, estimating the time required to carry out a given assignment, and then selling the staff's competence in a way that ensures the survival and growth of the company. A key issue for the consultant is therefore the time spent on a particular assignment. Does BIM affect the turnaround time of designers and others whose business relies on knowledge and expertise? The simple answer again is YES. However, the impact can be both positive and as well as negative. What may be a benefit for one entity is a hindrance for another.

There is no doubt that the greatest burden of implementing BIM in investment processes is borne by those responsible for design. Implementation requires the purchase of three-dimensional modelling software, which is more hardware-intensive than two-dimensional design applications. There is therefore a need to invest in new hardware and train staff to use the new applications. However, new technologies make it possible to provide services in a new, more efficient way. Is it possible to reconcile the success of the project, which will be the direct success of the investor, with the objectives, survival and success of the design firm or other consultant?

As mentioned, consultants estimate time. It is in their interest to complete the assignment in the shortest possible time. In the case of BIM implementation, the time will largely depend on the developer, how the BIM process is defined and controlled. This is because there is a possibility that an unsupported model with properties like those presented in Fig. 8 will end up in the hands of the cost estimator, who will be left with no choice but to prepare cost estimates in the traditional way, without using the potential of BIM.

In summary, in order to improve the investment process at consultancy level, it is necessary to be aware of the requirements to be met by the other parties in the process in order to be able to provide services of the expected quality without exposing the company to unexpected difficulties. Here, however, we return to the definition of objectives and expectations, their communication and subsequent control at the subsequent stages of the investment process.

Contractor: however, you will be satisfied

The business model of a works contractor is to get the workmen to build the supplied materials according to the documentation provided, in a way that ensures revenue and growth for the company. Large contractors saw the value of digitalising processes, including BIM, some time ago and started to implement it regardless of the demand defined by the builder. The aim, of course, was to gain a competitive advantage, e.g. by better estimating risks or the volume of concrete in a structure. These implementations were intended to support the contractor's business objectives without any particular consideration for the various stakeholders in the investment process.

In addition to the interests of the contractor, the introduction of BIM in the overall investment process must take into account the way in which responsibility for information is contracted at each stage. Complete and error-free information provided by the investor at the tender stage is also of value to the contractor, who can estimate the investment risk more accurately with lower bid preparation costs. Current practice shows, however, that investors are not eager to take responsibility for quantity statements estimated from BIM models. This may have to do with an inability to verify the models provided by designers in terms of meeting requirements. Often, therefore, contractors using BIM in their business will prepare another model for themselves that meets their expectations and standards allowing them to prepare a tender for which they take full responsibility. With this approach, the benefits to the contractor's business will be the result of the benefits materialising at the level of the individual project.

The wider implementation of BIM in a contractor's company enables effective communication and settlement with subcontractors, as well as the planning and monitoring of works. This applies not only to the area of construction management, but also to support operations in terms of visualising risks or preparing for particularly difficult time-limited phases.

In summary: plan and monitor

The investor has the greatest influence on the investment and, ideally, it is the investor who should initiate the BIM process in a specific investment, in a form that generates value for their organisation. Properly defining the objectives of BIM implementation in an investment will allow the to properly design the process of generating and exchanging information, which, in turn, will enable the other participants in the investment process to work smoothly and really take advantage of the benefits of BIM.

A key consideration when determining the objectives for implementing BIM in a specific investment project is a thorough knowledge of the tools and opportunities provided by the methodology. This allows a realistic estimation of the cost-benefit relationship of implementation. The next stopper is to design the BIM process with the objectives in mind, so that data is collected when it is least disruptive. There is no point in depositing wall colour information at the concept stage as this can change many times. This will cause unnecessary inconvenience for the concept designer and may generate unnecessary cost. This information should be added to the database just before or just after the wall has been realised, when the final colour decision has been made or a specific colour from the manufacturer's RAL palette has been applied. When designing a BIM process, in addition to the definition of the data to appear in the database, it is necessary to know the construction process in order to determine the optimum moment to collect it.

BIM, if defined as a tool, process or methodology, represents an opportunity for business and its efficiency. However, it is up to the decision-makers, and later the users, to ensure that the hopes placed in it materialise and increase the efficiency of the organisation. The diversity of tools and stakeholders in the process means that there are no simple solutions or rules on how to structure the information mechanism in a way that fits all construction projects. For this reason, with an awareness of the possibilities of the technology and the costs of its introduction, it is necessary to define the objectives that we want to achieve by implementing the new methodology. To this end, the SMART goal-setting method, which is an acronym for the english words:

- ***specific***
- ***measurable***
- ***achievable***
- ***relevant***
- ***timebound***

Defining objectives in this way will allow the scale of success accompanying a specific implementation to be measured. For example, an implementation target might be to reduce the number of collisions revealed during implementation by 80%. An objective formulated in this way is **specific** and **measurable** (we assume that we have a benchmark, e.g. from previous investments). BIM allows for a thorough collision analysis eliminating 100% of collisions, so the target is **achievable**. Additional costs resulting from having to remove clashes on site make the target **relevant**, and the very definition of the project makes it **time-bound**. At the same time, if something cannot be measured, it cannot be improved. On the other hand, being able to express something in terms of a number is the first step towards relating the target to monetary values, which is the ultimate unit of comparison in the company. Tracking the cost of implementation and being able to value its benefits allows the ROI (*Return on Investment*) to be calculated. A methodical approach to the issue of BIM implementation in a single investment or the entire enterprise allows for an objective and global assessment of its effects in isolation from anecdotal facts and isolated incidents or failures cited by those reluctant to make the change. Implementation, like any change, will provoke resistance, but discussing facts and figures instead of beliefs and anecdotes is one form of convincing opponents.

The holy grail, the integrated process (IPD)

A contractual answer to attempts to improve efficiency in construction (e.g. Lean, Agile and Scrum) and to create conditions for the synergy of experience of all key players involved in a project is the Intergrated Project Delivery (IPD) process. It is a different form of investment delivery organisation from the ones described in chapter 2.2. It cannot be classified in a similar way to the more traditional and popular forms of investment and contracting of works and services, as there is no typical contractual relationship between the investor and suppliers of services or works. IPD relies on a team approach to the investment process, which allows for increase efficiency. The main participants, such as the investor, designers and contractor(s), organise themselves into a single organism in order to utilise the talents and experience of the members. This allows for the optimisation of the investment project's outputs and the acceleration of milestone deadlines, as well as an overall increase in the value of the product for stakeholders and customers, which takes place within the framework of a multi-stakeholder agreement governing the sharing of costs, risks and profits from the project. Since everyone is a stakeholder and knows its conditions, there is no reason to put the interests of the company above the success of the project. The asymmetry of information typical of normal contracts, resulting in a kind of tug-of-war, means that each party tries to gain as much as possible for itself without considering the situation of the other participants.

This situation is illustrated in Fig. 7. In traditional models, the project is "pulled" in the direction set by the investor, but the other participants in the process pursue their own objectives. In the case of the IPD model, all the participants involved have an interest in success, so they 'pull' the project in the same direction. Setting clear rules at the very beginning of the project sets the terms of cooperation for the key participants, increasing their motivation to work towards the success of the project. It also reduces the risk of claims between participants and increases their motivation to find amicable solutions. Another advantage of this solution is that it allows all participants to benefit from each other's expertise from the early concept and design stages. For example, the contractor's experience may be important for the design solutions adopted, which may be difficult or costly to change at a later stage.

Collaboration based on the IPD formula can be adapted using different types of formalisation of the parties' cooperation, and can also go well beyond the standard investment triad of investor, designer and contractor. Manufacturers of components or prefabricated elements, or user representatives in the case of more specialised facilities, such as factories or hospitals, may be included in the cooperation.

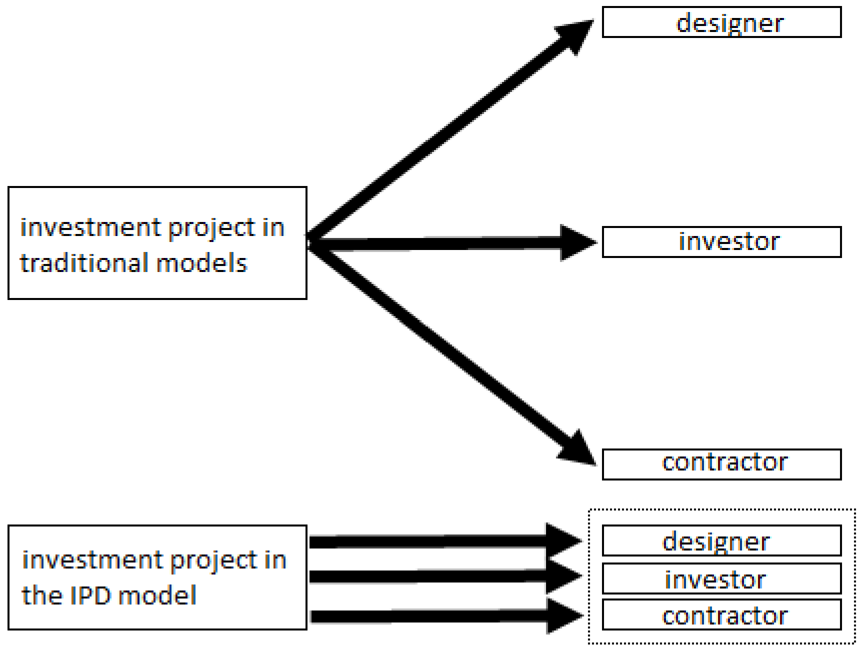

Fig. 7 Conceptual difference between traditional investment project management models and IPD
Source: own elaboration.

In order for the aforementioned reduction of asymmetries to result in increased trust and willingness of parties to cooperate for the benefit of the project, it is necessary to use tools that support process transparency, information sharing and cooperation between stakeholders. In traditional models of conducting the information process, the issues of cooperation and information exchange are not so challenging. The developer hands over the documents to the contractor (often the binding version is still the hard copy) and further communicates with the contractor by letters. In the case of IPD, this approach is not the case. The participants involved in the process need to have access to up-to-date project information at almost any time. This enables ongoing consultation of issues, elimination of clashes, planning, cost and change control at any stage of project preparation and implementation.

In the case of a large investment carried out in the traditional model, paper documentation grows into multiple binders. Such an approach in the IPD model does not make sense; IT tools need to be involved, which is another challenge. Most market participants use IT solutions, but since paper has been the ultimate medium of information so far, the ability to print from a given application has been sufficient. For IPD, it is necessary to establish how information is generated and exchanged in digital formats. In this context, a tool to support IPD is BIM, which enables the exchange of information and access to always up-to-date project data. In order for this exchange to actually take place, it is necessary to involve the entire team in the BIM methodology, and this from the very beginning.

Time and quality	• It is the fastest method as a result of the involvement and cooperation of all participants in an investment project from its early stages • the quality of the completed facility is in the interest of all participants
Costs and their variability	• all stakeholders have an interest in the success of the investment, in the best relationship between the costs and benefits delivered by the project • Baskets may be variable, depending on priorities, but project participants are aware of the consequences or benefits, hence it is easier to control changes
Flexibility and risk	• risk-sharing is agreed at the outset in the multilateral agreement governing the relationship of the participants • conducting the investment process requires transparency and trust, e.g. through the use of appropriate tools • the risk of claims between participants involved in the success of the project is reduced
Challenges for BIM	• there is a need to agree precisely on common information requirements and processes for their circulation in discussions between the parties • There is a need to involve the whole team and subcontractors in the implementation of the methodology (training, efficient tools, leaders)

tab. 1. Main features of the investment carried out in the IPD model
Source: own elaboration.

IPD in the formal sense is used abroad, mainly in the USA, for the realisation of complex public facilities, such as hospitals. As a rule, these are projects carried out for a public investor. The question should be asked whether, under Polish conditions, such an arrangement is at all possible. Is it possible to create an organisation of independent entities which set and follow rules such as:

- mutual respect and trust,
- share in the profits and benefits of all participants,
- collaborative decision-making and innovation,
- early involvement of key players,
- early definition of objectives,
- open communication,
- use of appropriate technologies,
- guided leadership in place of strict subordination.

These are the basics of IPD according to the American Institute of Architects (AIA), the institution that promotes IPD in the USA, the country pioneering the use of this method of investment delivery.

In commercial investments, traditional, non-integrated models may give the profit-maximising investor the illusion of greater control, of not having to share the profit, which also does not bode well for the future of this investment formula. Nevertheless, the integration of the process at the level of site information should be the goal of all market participants and regulators. It makes it possible to realise construction works while minimising resource consumption over the entire life cycle of the facility or maximising profit through full control of the process. On the other hand, the phenomenon observed mainly among residential developers cannot be overlooked. In times of boom, some of the biggest players in the market try to take on the roles of all participants in the process at the same time. In the organisation of such a developer, within a group, holding company or in some other formula, units with design, execution, supervision and even production and commercial competences are organised. Without going into the details of the organisation of cooperation between these entities, this is a form of integration of the investment process under one banner. The aim is to maximise the profit of the parent entity by capturing margins that would otherwise go to the service providers. Less often, it is about maximising value for users, customers or other participants by the fact of early involvement of an experienced contractor to consult on the project, which is the primary motivation in the IPD process. It can, of course, be argued that the developer's greater profit will positively influence his altruistic attitude and CSR (*Corporate Social Responsibility*) activities, for example by organising more than the minimum required green space on the estate. However, this seems to be an optimistic assumption. Furthermore, history shows that in times of economic downturn, such an extensive organisation, without an assured work front of thousands of dwellings, becomes a burden, reduced to ensure the survival of the developer. It would seem, therefore, that IPD in its original concept of integrating specialist players and sharing risk and profit with them on a clear basis is a better idea than taking control and controlling everyone from the top down.

In Polish conditions, full IPD can take the form of special purpose vehicles or multilateral agreements. The key to organising the process in this way is trust between the parties. Nothing builds it better than transparency and the possibility of mutual control using BIM.

Objectives, benefits and activators - why are we doing this?

The problem with no goals is that you can run around the pitch all your life and never score.

Bill Copeland

Every process, implementation or innovation should be initiated with a clear objective in mind. This may seem obvious, but the huge number of tenders and enquiries for BIM methodology does not provide a clear answer to the most important of questions: why BIM? What's more, a bunch of procurers and contractors don't know what to expect from the implementation beyond the vaguely defined 'efficiency gains'. So let's consider what the potential objectives of the various stakeholders might be, and what benefits can be achieved by implementing BIM.

When writing about a mature methodology, it would be appropriate to start with the ultimate goal, i.e. an efficiently managed, functional and sustainable construction facility. The role of the contracting authority is therefore to clearly define the needs in the investment process, based on a strategy defined, among other things, by the OIR and AIR documents. In practice, however, the various stakeholders in the process will pursue particularistic objectives alongside the better or worse defined objectives of the contracting authority. This chapter presents the most commonly pursued objectives and sample measures of their fulfilment. These will vary depending on the type of contract and the specifics of the project, but the list can give some idea of the method of creating real value on the basis of potential benefits. The following subsections refer to the most commonly used methods of using the methodology, the so-called 'activators' (*BIM* Uses), which are designed to achieve the set objectives in the subsequent stages of the facility life cycle.

Activators

In addition to those mentioned in the chapter above, the objectives and methods for implementing the BIM methodology are quite numerous. The number of described activators (methods of using BIM) for each stage of the life cycle of objects is constantly growing. You can find lists published by various organisations and institutions on the market.

In the context of selecting objectives and methods for BIM implementation, it is important to remember that, firstly, there are clearly described and documented benefits through which the implementation of the methodology can be ensured. By selecting objectives, we can choose those that best meet the real needs of the organisation or project. Secondly, abstracting from the particular benefits of each stakeholder in the process, the client's objectives and activators should go beyond the individual phases. As shown in fig. 8, published by Penn State University, some activators can and should be implemented during the full investment cycle.

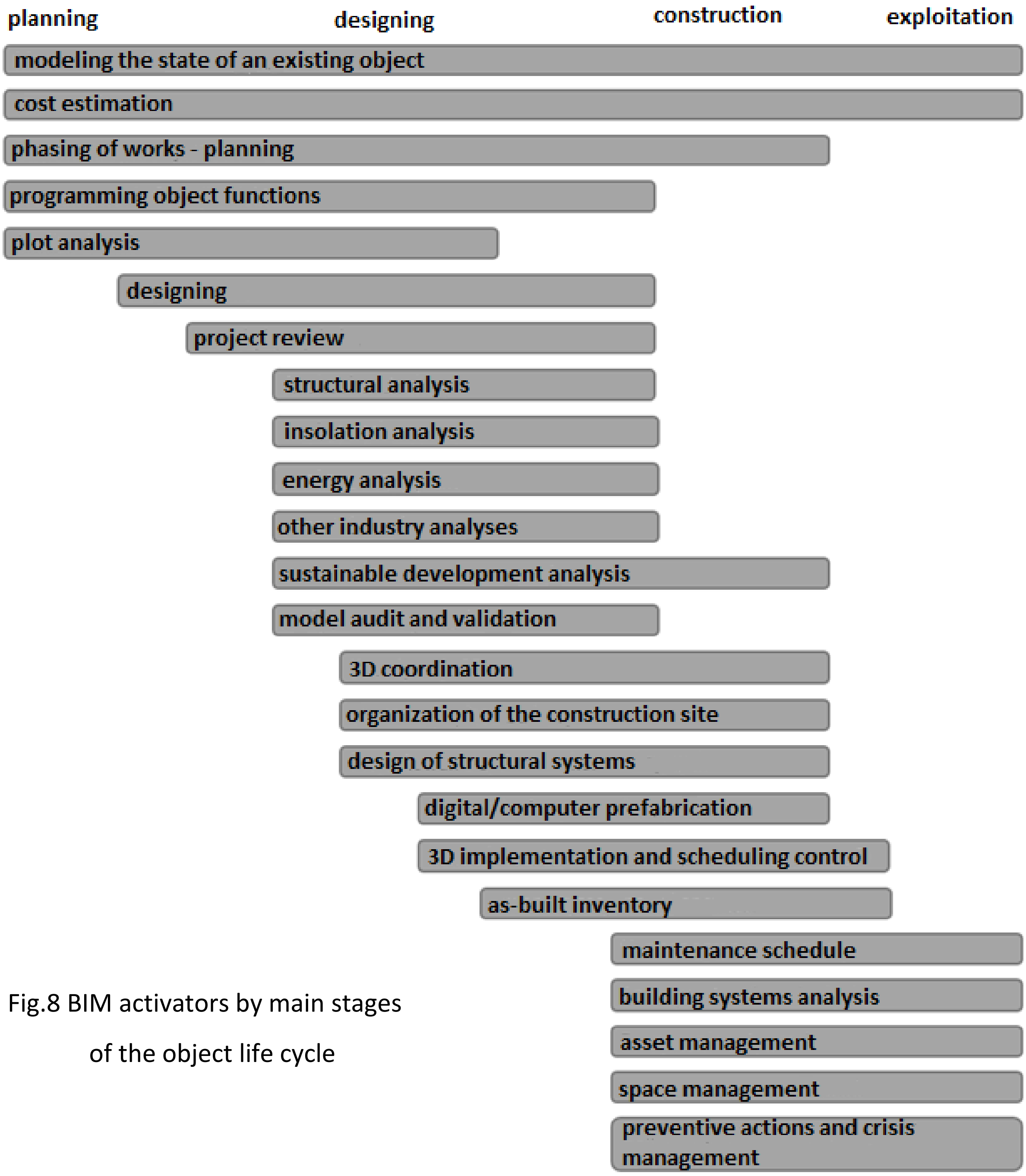

Fig.8 BIM activators by main stages of the object life cycle

When building the value of a project or offering to a client, it is good to consider which of the activators the organisation is able to use (realise) and which ones actually correspond to the objectives. For this will determine in practice what (the products of the methodology), who (the staff implementing, evaluating and utilising the results of the work), how (the software and processes implemented on the project), when (the timetable for implementing the BIM methodology) and for how much (the final project budget) will be done. The remainder of the book will help answer these questions.

First implementation - that is, your first time

Even the best big idea will only be as good as its implementation.

Jay Samit

We have already discussed what BIM is and what BIM is not. We have described what changes need to take place in the company and in teams preparing for the digital revolution, and how this revolution can change the work of designers, contractors and property managers. We outlined the tools and processes involved in implementing a project according to the methodology. It's time to think about the first implementation.

Depending on the situation, the first project in BIM may be limited to the implementation of the methodology in one company, cover only a section of the investment cycle or cover the entire process from concept to operation. However, regardless of the stage or scope of implementation and the type of implementing organisation (client, designer, GW), piloting involves very high risks for each of the parties involved. It is therefore very important that the team, and especially the decision makers, are aware of the potential challenges and rationally build their expectations of the end result.

The construction market - especially in Poland - is in a very interesting place. On the one hand, awareness of the methodology, or at least the fact that it exists, is relatively high. A lot of public tenders involving the use of elements of the methodology have been completed and a lot of companies boast about completing projects using BIM technology. On the other hand, we are far from considering BIM or even model-making tools as the market standard. The projects realised so far have been developed by BIM-fascists. Also, no one in Poland publicly shares any failures related to the implementation or procurement of BIM. Above all, there is a lack of benchmarks to compare projects using traditional methods and BIM. Instead, a lot of marketing material and statistics from foreign projects, where the first pilots were carried out more than 10 years ago, are published. Meanwhile, BIM is starting to be implemented outside the close circle of experts and is making its way into medium and small design offices and Polish construction sites. It is present in university education as well as numerous training activities in the market.

All this means that the next few years will be critical for the implementation and adoption of the methodology by a wide range of users. Of course, it can be said that good solutions and technologies will defend themselves. It can be assumed that the market will force change on its own, but the pace of change can vary drastically depending on the experience of the managers and directors implementing the projects. If the implementation leaders deliver on their promises and show the value of the methodology (however small), undoubtedly subsequent projects will be implemented more and more efficiently and closer to the BIM ideals of full collaboration. However, if unrealistic promises and implementation goals are not met, individual organisations may become discouraged with BIM for years to come. In turn, this will translate into a lack of progress in the implementation of the methodology in Poland.

In this context, it is particularly important to understand not only the potential benefits, but also the risks. The high rates described during presentations and in case studies are usually achieved by mature and experienced organisations. When deciding on a BIM pilot project, we need to take into account the realities of the market, the qualifications of our partners and the budget dedicated to implementation. It is likely that the positive effects of implementation will be small at first. Teams will have to adapt to the change in tools and the specifics of their work. Time previously spent on content-related work will be used for training, software configuration or strategy development meetings. These and other issues will translate into project budgets. On the other hand, companies that start working with the methodology early enough will have the opportunity to master the tools and processes as quickly as possible and prepare for the effects of the digital revolution. The implementation should be prepared like a marathon. All the elements related to change management discussed so far should be taken into account, such as vision, clearly defined goals, competence of the team, proper motivation and work culture, but also a clear and readable action plan. As usual with BIM, we need to ensure we have the right processes, people and technology in place. It is also very important to define measures of success and to anticipate potential risks. So let us consider how to prepare for the first project in BIM. In the following chapters, the key aspects of implementation are described from the position of the client and the contractor

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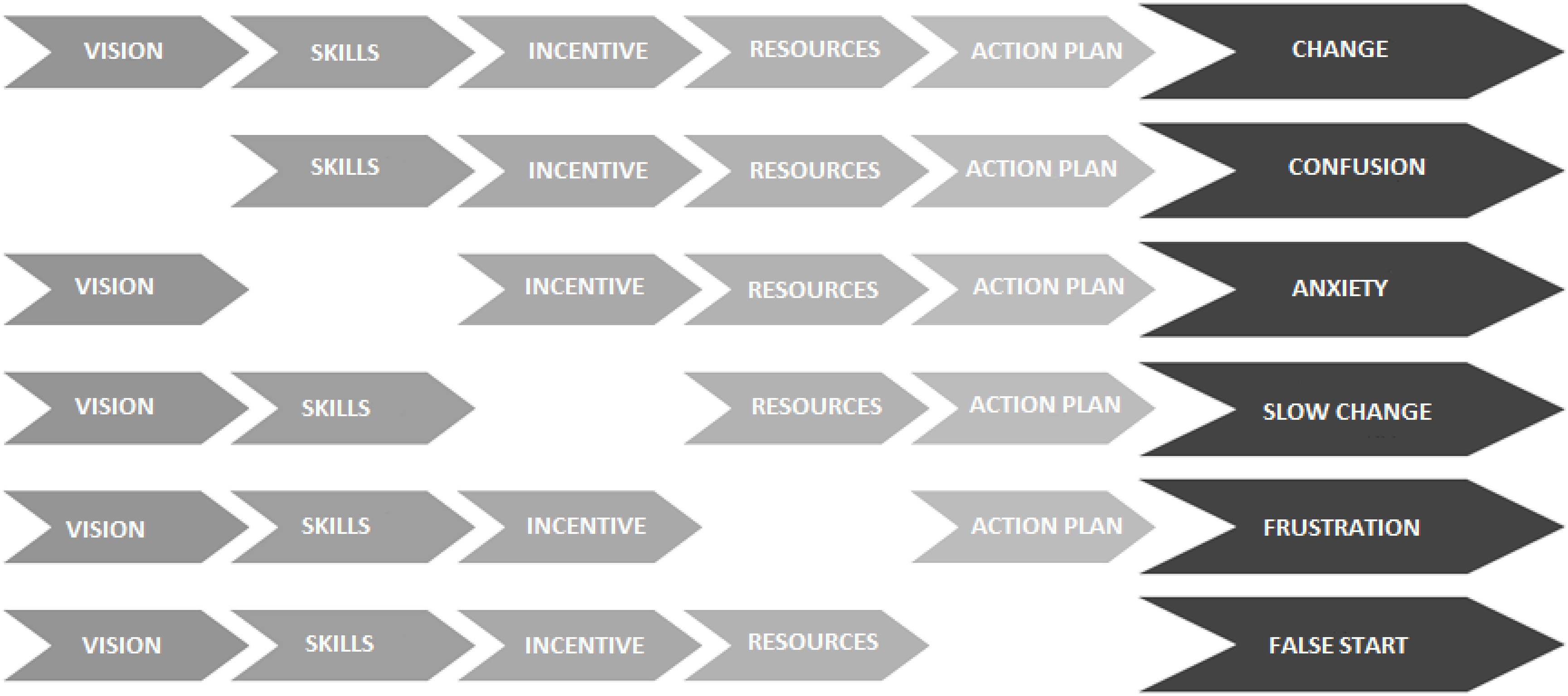

Fig. 9 Schematic representation of the elements of effective change management and the consequences of their absence

Source: own elaboration

PSDiK POLSKIE STOWARZYSZENIE DORADCZE I KONSULTINGOWE
SZKOŁA MANAGERA
SGGCCS SLOVENSKI GRADBENI GROZD CONSTRUCTION CLUSTER OF SLOVENIA

BIM marketing - how to spot a professional

Who is a professional? How do you know that the entity you invite to work on your project (consultant, designer, subcontractor) will meet your expectations? Since the organisation has already decided to incur the costs of implementing BIM, it should ensure that the service providers within the information process present the right competence. Otherwise, the implementation is likely to be a failure and the investment will not generate the expected return. Decision makers in the organisation will at best be reluctant to make changes since it has always been good and the one time they were persuaded ended in failure and unnecessary costs.

When looking for a reliable service provider, it is advisable to start with a definition of the needs in relation to the specific objectives guiding the implementation. On this basis, the contracting authority edits its requirements in relation to the information process. These are described in the EIR. The issue then comes down to the verification of bidders How can an organisation implementing BIM, which does not yet have much competence in this area, verify the competence of a bidder? How do you tell the difference between a BIM star throwing around arcane acronyms and a serious and experienced organisation? Thanks to the activities of many bodies promoting knowledge of BIM, it is not a secret knowledge. More implementations in public and private investments are adding to the pool of people with experience. BIM courses and certifications are becoming more and more popular as proof of acquired knowledge (not always experience). So how do you go about tendering? The answer seems trivial - invite someone more experienced to join. Someone who has participated or assisted in implementations and can confirm their experience with references. There is no point in saving on knowledge. When paying for it, it is worth ensuring the conditions for its sustainable implementation in the organisation. An experienced partner will allow objective and critical evaluation of the feedback obtained during the tender.

At this point, it is worth emphasising the role of the client who, when deciding to carry out a project using BIM, takes responsibility for shaping the information process by setting the framework, boundary conditions and objectives for the process. Even inviting experienced BIM consultants will not help if the client or developer does not answer the basic questions: why are we doing this and what do we expect at the end. Without a solid answer to these questions, the client is condemning himself to failure, not least because, without defining his expectations of the process, he has no way of defining his expectations of the competence of the people who are to lead and control the process. Conversely, talking about BIM without details is so-called ordering "BIM pieces once". - Everyone pretends to know what they are talking about, and in the end it turns out that we end up with an investment carried out in the traditional way, to which a 3D model is added, because after all it was supposed to be BIM.

Fortunately, BIM in Poland has a growing circle of fans, professionals and followers. Recognised postgraduate courses in BIM-led project methodology have been running at several universities for several years. There are also examples of public and private investments that have been carried out in accordance with the principles described in this book. It can therefore be concluded that the knowledge of a properly conducted BIM process in Poland is available and communicated in a methodical way. This is a good situation because it means that we have a recognised group of authorities in the BIM area to whom one can refer to or ask for support. In addition, a postgraduate course with a reputation leads one to believe that its graduates will live up to expectations. It can therefore be concluded that the pool of personnel capable of competently supporting a specific investment process using BIM is steadily growing. What tools, then, can be used to establish unequivocally that the chosen contractor, service provider or designer actually knows what they are talking about and is not just a shaman using specialist vocabulary to make an impression?

The first element of verification should be a well-defined set of requirements described in the ToR, EIR or tender enquiry. From the outset, it should curb the enthusiasm of non-competent entities. These requirements should include, in addition to a formal declaration, the ability to verify experience in key areas. How to carry out the verification? The basic tools are the analysis of reference documents, questionnaires or even tests for individuals performing specific functions on behalf of the contractor. Properly structured questionnaires, containing quite detailed questions about projects carried out so far, methods, processes and BIM tools, are of similar importance as a well-prepared request for proposal. They make the pool of casual bidders smaller. The benefit is mutual. The contracting authority does not have to bear the cost of analysing such a bid, and the bidder does not have to bear the cost of preparing it, knowing that it has little chance of slipping through the sieve of competence requirements. A broader view of the cost of employing a consultant to select a contractor will most likely show savings resulting from less work to be done in evaluating tenders. It will also reduce the likelihood of making a wrong choice, which carries a huge loss for the organisation or project. Detailed questionnaires are an increasingly common tool in tendering for designers and contractors on capital projects using BIM.

Examples of issues in questionnaires might be as follows:

- Describe briefly how the models are prepared and the range of information included.
- Describe how you create and share BIM models and flat documentation.
- Give details of the BIM software used in the organisation (in relation to specific process areas).
- Briefly describe how the company uses models to coordinate the project.
- How many software licences ... does the company have?
- What standards do you use in your daily work?
- Specific questions about people's experience and references for work carried out.

A thorough questionnaire also makes it possible to identify the gap between the client's needs and the contractor's capabilities. This makes it possible to plan a programme of training and competence adjustment in line with expectations. It is therefore an important tool for identifying information process risks.

slightly more absorbing tool, used so far by e.g. the General Directorate for National Roads and Motorways, Krakow branch, is the competency test for the position of coordinator and BIM Manager. The test took place before the selection of the contractor for the order "Development of comprehensive design documentation and accompanying studies for the task entitled "Construction of the Zator bypass within national road No. 28" together with obtaining administrative decisions and exercising author's supervision". The results of the competency test influenced the evaluation of the bids in the tender. The contracting authority stated that practical skills are more important than experience, which is still difficult to verify.

Something else is the already mentioned test models, which include representative excerpts from previous implementations or samples of the bidder's capabilities modelled according to the project requirements.

Identification of key risks

Information process risk assessment: ISO 19650, ISO 31500, PAS 1192-6

Risk is a word used to describe the uncertainty surrounding some human activity. In project management, the subject of risk management is a widely analysed area, since, as a rule, the materialisation of a risk carries a cost. Risk management is therefore introduced into a project to minimise losses resulting from the occurrence of an event with uncertainty. In simple terms, it consists of identifying the uncertain event, determining the probability of its occurrence and the cost to be incurred should it occur. The methodical approach to assessing and managing risk includes the steps listed below.

- Risk identification (source, events and consequences)
- Risk analysis
    - assessment of consequences
    - assessment of probability
    - assessment of the severity of the consequences
- Risk evaluation and planning of responses, actions, etc.
- Monitoring, prevention and response as planned

The ISO 19650 standard explicitly indicates that the contracting authority should conduct an information process risk assessment of the performance of the various task forces in discharging their responsibilities. The standard identifies risks related to:

- the assumptions made by the task force with regard to the information exchange requirements of the contracting authority;
- to meet the deadlines for providing information set by the contracting authority;
- the contents of the project information protocol;
- the achievement of the proposed information provision strategy;
- adopting the project's information standard, procedures and methods for developing information;
- Integration (or not) of the proposed changes into the project's information standard; mobilisation of the task team to achieve the required skills and capacity.

The risk register should be presented to the contracting authority by the contractor after the MIDP has been drawn up, as part of it. In practice, the register may take the form of a table in which specific uncertain events that may affect the course of the information process.

Practical example

In the example information process risk analysis process, the uncertainty generated by the sanitary installation design team was identified. They are known to be inexperienced in modelling a particular type of installation due to its unique complexity. Additionally, their team has recently been downsized due to a random accident. The risks identified are:

- failure to meet deadlines,
- coordination errors.

The risks in the next step are evaluated in terms of their consequences and probability. It is best to adopt a scale in two areas: severity and probability. Evaluation carried out in this way allows a fairly objective assessment of the actual severity of the risk and the need for attention. The ways of responding to the risks identified above may fall into one of the practical categories.

- Acceptance - risks with low probability and effect can be accepted by assuming additional reserve amounts in the budget without the need for an additional contingency plan.
- Mitigation - e.g. by tighter supervision and control.
- Attempt to avoid - e.g. by obtaining resources with relevant experience.
- Transfer - e.g. outsourcing tasks to another entity.
- Postponement - e.g. observation and postponement of other forms of response (maybe it will work).

In practice, the entire analysis is documented in a table called a risk register, periodically reviewed and updated. Table 2 shows an example of a record in such a register.

Lp.	Description of risks	Date of addition to the register	Risk owner, responsible person	Assessment of probability	Assessment of severity	Evaluator	How risks are addressed	Method of response	Status	Closing date
1.	Failure to meet deadline for coordination of sanitary installation models with construction	21/01/2020	Jan Kowalski	x	y	x * y	Mitigation	Frequent monitoring of work progress and introduction of internal control of MIDTP compliance	Open	

tab. 2 Example record in the BIM information process risk register
Source: own elaboration

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PART TWO

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Lean

Among the construction investment studies, there are some that include among the root causes of inefficiency in the sector:

- overstaffing,
- logistical collisions involving multiple crews,
- ineffective management of employees,
- expectation of work,
- weather,
- badly configured equipment,
- design errors,
- the need for design changes,
- material shortages.

One method that can bring about a significant increase in process efficiency and a reduction in the aforementioned losses, is the introduction of the Lean philosophy into construction project management. The term 'philosophy' has been deliberately used instead of 'methodology' or 'management system'. Most of the problems associated with Lean implementations in organisations is caused by the piecemeal application of methods and tools. Meanwhile, a successful implementation must be preceded by a complete change in work culture, thinking about design, waste, value and responsibility for each of these elements. However, before considering how Lean in practice can transform the construction sector, let us briefly introduce the history and background of this philosophy.

Fig. 10 Hierarchy of understanding and implementing Lean philosophy
Source: own elaboration

The history of Lean

Lean methodology has its roots in the manufacturing sector, specifically in Toyota's mass production of automobiles. In the late 1950s and early 1960s, the Japanese corporation created the Toyota Production System (TPS), which made it competitive with the US car industry and still today is one of the world's largest car manufacturers. Fig. 18 shows a comparison of the Toyota corporation's level of efficiency with its US and Japanese competitors. The curves show the number of cars produced per employee between 1965 and 1983, when the Japanese industry became a formidable competitor to the Americans thanks to technological and process innovations.

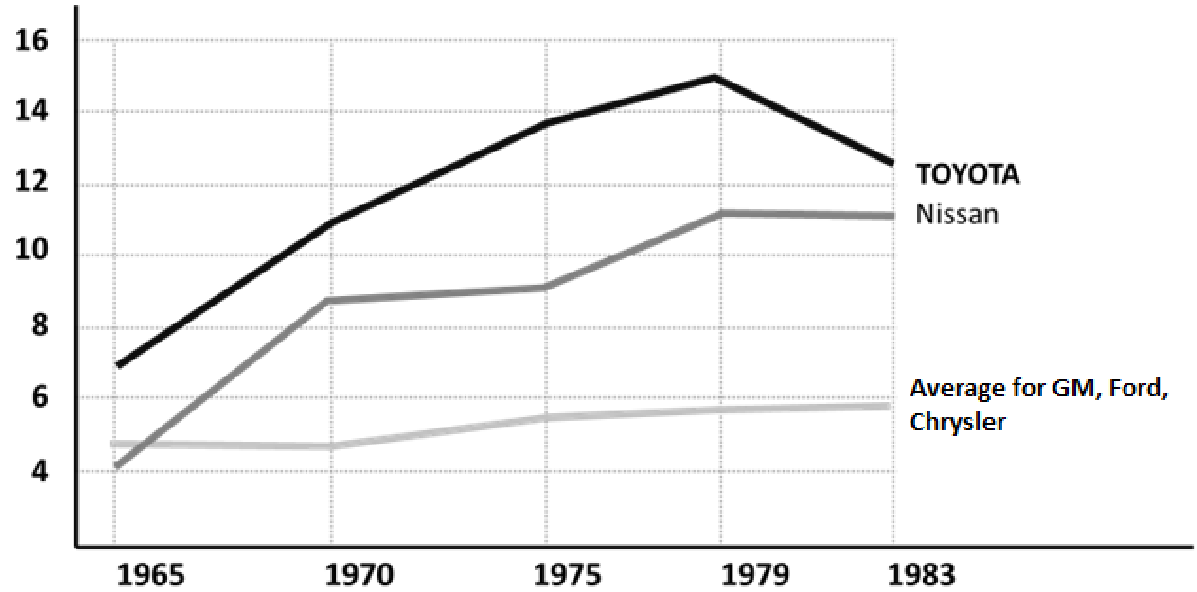

Fig. 11 Number of cars manufactured per employee after adjustment for differences in the Japanese and US markets

TPS was created by Sakichi Toyoda (father), Kiichiro Toyoda (son) and Taiichi Ōno (production engineer) as an adaptation of mass production methods developed in the United States and a response to Japan's economic problems after World War II. TPS revolutionised mass production by properly managing the production process, targeting:

- waste elimination,
- reducing duplication of work,
- reducing stock levels,
- achieving fewer man-hours,
- improving the competence and reducing inefficiency of employees.

The TPS system was also intended to dramatically speed up the response to changing customer needs. Compared to the relatively rigid production process of American cars, the possibility of variations based on combining and modifying individual components was a true revolution. The whole thing, however, would not have succeeded without a specific corporate culture. The system, illustrated by the so-called Toyota house (Fig. 19), is based on several basic concepts from which grew the tools and processes still used today all over the world - including in the construction sector.

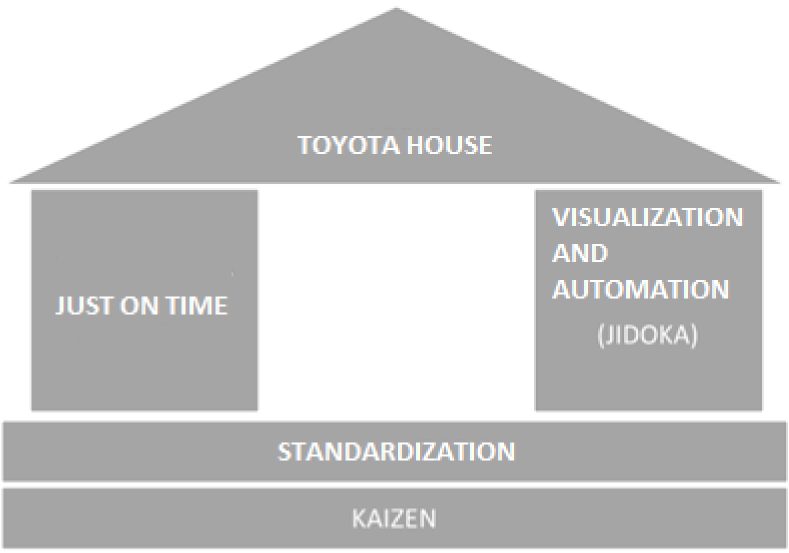

Fig. 12 Simplified schematic diagram of the TPS system
Source: own elaboration

The foundation of the philosophy is the concept of kaizen, which literally translates as 'change for the better'. In practice, it is the imperative to continuously strive for improvement at every level of the organisation and process. The second foundation is the need to standardise the activities performed on the basis of the best practices accumulated to date. The implementation of these two ideas requires strong employee involvement and continuous training. This theme will recur again and again, because the Lean philosophy, like the BIM methodology, is based on conscious employees who are committed and willing to change, and open-minded leaders who support their continuous development.

The two main pillars of the TPS are:

- just-in-time (JIT) production - the system assumed that the right part was being made and delivered to the right place at the right time; the aim was to plan the process to reduce to a minimum the number of materials in stock, products waiting for further processing and idle workers;
- Jidoka (visualisation of problems) - the system involved detecting and eliminating production problems and errors as quickly as possible (automatically) at their source, in order to reduce erroneous components and the need to repeat work once a process has been completed; the idea dates back to the early 20th century, when Toyoda, with his innovative loom, introduced an automatic interruption system into textile production.

From the very beginning, Toyoda was focused on eliminating waste at every stages of production. This was one of the main goals guiding process optimisation. However, unlike the traditional approach, where we try to maximise the efficiency of each process step, TPS involves balancing the whole. Instead of mobilising an employee to work hard (transporting an excess number of bricks), it is worth checking whether the effects of his actions will be used by subsequent employees (the possibility of overworking the bricklaying team). The US Training Within Industry (TWI) programme, implemented in Japan after the end of World War II in support of the post-war reconstruction of the country's economy, played a major role in the dynamic development of TPS. Toyota was one of the first Japanese companies to adopt TWI.

Paradoxically, in the 1990s, it was Americans who came to Japan to learn effective process management. In 1990, a group of researchers associated with the Massachusetts Institute of Technology (James Womack, Daniel Jones and Daniel Roos) published a book called *The Machine That Changed the World,* which described the methods implemented by Toyota. They called the TPS system LEAN (lean) manufacturing, as: **"it uses less of everything compared to mass production - half the human effort in the factory, half the production**

space, half the investment in tools, half the engineering work to develop a new product in twice the time".

In summary, Lean is, to quote Taiichi Ōno, one of the founders of the philosophy, 'a manufacturing phenomenon that aims to maximise the effect resulting from human effort. Lean is therefore a way of thinking aimed at rapid adaptation to change, elimination of waste and continuous improvement'.

Lean Construction

Lean in construction is promoted by the Lean Construction Institute (LCI), founded in 1997, which brings together builders, designers, contractors and software developers. The philosophy is to promote "collaboration, based on declared commitments and responsibility for their fulfilment and responsibility for fulfilling them. However, this requires a decisive change in the working culture and an increase in the level of trust between the various participants in the process. The hostile relationship and so-called silo approach that currently exists in the industry must change if the client's goals and objectives are to be achieved. In projects where the principles of the Lean philosophy are applied, teams should work together to use tools that support collaboration and efficient communication and look for ways to eliminate waste. Teams are also expected to continuously improve through continuous analysis of their activities and self-reflection.

The ideas behind LCI are in line with those of a mature BIM methodology, where efficient communication and transparency are key, but also continuous review and improvement of the and improvement of processes. As one might guess, simply transferring the principles and tools typical of industrial production to the realities of design or construction is not straightforward. The manufacturing and construction sectors have certain features in common, such as:

- the opportunity to optimise the process through the cooperation of the parties involved and staff education,
- the possibility of verifying the value delivered to the client at each stage of the investment cycle, e.g. through design analyses and the resulting conclusions, the number of necessary corrections and risks of on-site corrections can be reduced,
- the ability to identify and eliminate losses associated with wasted materials, inefficient planning, downtime during work or the need for unplanned fixes,
- the possibility of using the Pull System, i.e. planning focused on the end product rather than the sequence of events; in the construction sector, the Last Planner method has

gained popularity, which makes the final shape of the schedule dependent on the people responsible for actually carrying out the subsequent work - by planning from the end (the end product), the people on the 'front line' declare how much time and what conditions must be met in order for them to complete their portion of the work,

- the possibility of using methods of visualisation and identification of process problems - the idea of digital construction, of which BIM is a part, and the related analytical tools constitute a real revolution in this respect; the construction and analysis of a virtual twin of a facility, together with the simulation of processes, makes it possible to identify and eliminate some of the problems and eliminate some of the problems long before they occur on site or in during operation; the detection of design clashes, tracking of process downtime with the in processes using the CDE platform or planning site logistics in a virtual environment are in a virtual environment are just some of the possibilities.

In addition to similarities, the construction sector has its own specificities. Differences include:

- large variations between projects - even within a given type of site, investments vary due to local law, the environment or the structure of the contract and team,
- each supplier and subcontractor works on the basis of different contractual terms and conditions, which makes it very difficult to control and maintain continuity in the supply chain - both at the design stage (coordination of tradesmen and external experts) and at the implementation and operation stage (supply of materials, fluctuation of teams on site),
- investment projects are usually dependent on weather conditions - strong winds, low temperatures or prolonged heat can significantly hamper work on site, so one of the recommendations of Lean Construction experts is to use therefore one of the recommendations of Lean Construction experts is to use prefabrication whenever possible; moving even part of the work to a controlled shop environment reduces the amount of work that can be done on site. moving even part of the work to a controlled shop environment reduces man-hours in a hazardous construction environment, increases the quality of the individual components and makes the process partially independent of weather conditions,
- a high level of staff turnover in the construction sector - this is a significant handicap as Lean requires appropriate involvement of engineers and line foremen; turnover also means that real and profound change is only possible where it is initiated from the top by changing the culture of a particular company, rather than implemented *ad hoc* in a project.

Lean tools and techniques

The following are some of the most commonly used tools and techniques in the construction sector and techniques related to Lean. The summary is based on the authors' experience and a review of the global literature in this area.

Kaizen. PDSA (Plan, Do, Study, Act) - the idea of self-improvement requires appropriate methods. The most widespread method is the Deming cycle, named after its creator William E. Deming - an American statistician working in Japan. The cycle is sometimes called P-D-S-A (or P-D-C-A) after the names of the successive stages. It assumes the following steps in the process of improving products, services and processes:

- PLAN: plan in detail a test or change aimed at optimisation. Analyse the effects of the change, including negative ones, before action is taken. Identify success indicators and methods to measure them. Develop an implementation plan and involve the right people. For BIM, this can be a process of methodology planning by developing requirements on the client side (EIR) and the definition of methods on the contractor's side (BEP).
- DO: carry out a pilot implementation of the change on a small scale under controlled conditions. For BIM, this can be the moment to build the model according to the requirements of the phase as described in the BEP and annexes.
- STUDY (Check): thoroughly analyse the results of the experiment. Draw conclusions and discuss the test results and outcomes achieved. In the context of BIM, this can be the moment to carry out analyses of the models or processes involved in their creation and information exchange, and the time for summary coordination meetings.
- ACT: take the right action to implement an improved process standard. For BIM methodology, this means e.g. the moment to change design assumptions, optimise the standard of creation or exchange of information.

Last Planner System (LPS), Concurrent Engineering, Daily Team Meetings - methods of planning and organising work. Essentially, Lean relies on strong employee involvement in the process of scheduling project execution. The emphasis is on the overall efficiency of the process rather than maximising the efficiency of its stages. For this reason, it is essential to continuously track progress and making adjustments to the schedule based on declarations and reports from employees and line leaders. These methods aim to efficiently coordinate small teams that work in short iterative cycles (1-2 weeks) and communicate with each other virtually every day, reporting on progress. More about this approach to planning is written about in the chapter on agile management methods.

Visual management - a technique typically used in manufacturing processes, where the relevant components are labelled in a way that allows easy assembly. In construction processes, visual management can be implemented in a variety of ways, such as by locating clear signs related to site safety or marking components with tags or QR codes to enable their rapid identification, segregation during delivery and intuitive assembly. At the same time, visualisation can refer to appropriately structured information exchange processes. Appropriate labelling and filtering of elements in BIM models transferred between branches effectively prevents important information from being overlooked or missed. CDE systems enable clear reporting of important or delayed tasks. All of this is designed to work efficiently and making potential discrepancies and errors visible.

Poka-Yoke (detection of potential errors), Automatic process stopping - Lean implies reacting to potential errors in the execution of work at the earliest possible stage. The assumption is that it is better to stop a potentially faulty process than to continue it and risk rejecting the finished product and having to make corrections. This also applies to safety issues, where the employee is involved in looking out for potential hazards rather than just reacting to those already present, e.g. reporting an unsecured cable lying on the floor before someone damages it and sparks it. In addition to procedures, the factory uses appropriately configured machines to stop the production line in the event of faults. For the BIM methodology, for example, there are verification rules laid down in the EIR and BEP. The precise definition of procedures and checklists for the creation of information models is crucial. Specialised software helps to automate the validation process, e.g. with its help and a check file in mvdXML format it is possible to automatically detect inconsistencies and information deficiencies in the BIM model, and through predefined rules to automatically detect geometric collisions. For the information flow, such functions can also be performed by an appropriately configured CDE environment, where the process is stopped in the event of a negative opinion from one of the participants. Most importantly, however, is the culture of the company and the attitude of each of the employees, who, when they see errors, are encouraged to report them immediately.

5s (Visual Work Place) - this technique consists of configuring the workplace in such a way that every item needed to perform tasks is accessible and in its place. 5S is used among general contractors to organise and streamlining work on the construction site and ensuring a high level of safety for workers. However, the methods can also be applied to working in a BIM environment. Below are the elements of 5S along with examples of how the BIM methodology is used during implementation.

- 1S. Seiri (selection/sorting) - appropriate division and segregation of models and their components (division into branch models), but also appropriate configuration of hardware and software so that access to the most necessary functions is simple and transparent.
- 2S. Seiton (systematics) - systematising the naming of individual components (e.g. UniFormat, UniClass, Omniclass), maintaining appropriate naming of files and containers of information to make their subsequent use as efficient as possible, grouping tasks and elements.
- 3S. Seiso (cleaning) - cyclical audit and optimisation of models, e.g. by removing working views, unnecessary information from components, etc.
- 4S. Seiketsu (standardisation) - refers to the use of the previous 3S, but in principle this element can refer to the use of either an internal or external standard for the implementation of the methodology (ISO 19650, company standard, BEP).
- 5S. Shitsuke (self-discipline/self-improvement) - self-monitoring of the maintenance of the project standard, verification of solutions and optimisation and dissemination of the modified standard and good practices carried out by coordinators but also by rank-and-file employees.

Appropriate use of 5S can make a significant difference to the efficiency of the BIM team and the teams on site. Particularly in moments of hard work under pressure, an organised workspace (software environment) and the availability of the most necessary tools (specially designed and tested scripts, overlays, documentation templates) can speed up work, reduce stress and build team morale.

Value Stream Mapping - in Lean terms, a project is a seamless process, generating specific value for the client. In order to properly plan the delivery of value at each stage of a capital project, a step-by-step analysis is necessary. In this context, value mapping is even more important than in Lean Production, where the customer usually only analyses the final product. For efficient value management in BIM, there are EIRs and BEP, where individual project milestones are defined, but also detailed method products such as models, drawings, analyses, lists or visualisations. Depending on the stage of the project, tables of deliverables and tasks are agreed, as well as the detail and and scope of the information to be provided (MPDT, MIDP, TIDP). This makes it possible to identify and possibly eliminate redundant information and elements, and appropriately define the steps required to achieve individual milestones.

Integrated Project Delivery, Lean Project Delivery (LPD) - Lean encourages the closest possible collaboration and trust between all parties involved in a project. In order for such collaboration to take place, an appropriate contractual framework is needed. Thus, in recent years, several new types of construction contracts have emerged to support an appropriate working culture through appropriate contractual provisions. Leaving aside the differences between the different types of project conduct recommended by Lean experts, the common denominator is therefore collaboration and a focus on the final product.

Using Lean in a project

Implementing the Lean philosophy in a project involves a few basic steps. Since, as mentioned, BIM uses similar methods, references have been assigned to each of the points. These show the direct correlations between the Lean philosophy and the tools and methods of BIM.

Identification of values from the contracting authority's point of view (OIR, AIR, PIR, EIR, BEP)

The traditional approach is to focus on the client's enquiry and its implementation. What matters is what the client wants to build, what drawings and specifications they have provided and how to carry out the work described, while minimising their own expenditure. The Lean process involves recognising the client's actual need. We do not just ask 'what', but also 'why' he wants to build. This shift in emphasis allows us to build trust and understanding between the parties from the earliest design stages. Promoted by both BIM and LCI proponents, the Integrated Project Delivery (IPD) process promotes a better understanding of the client's needs and the commitment of contractors to fulfil them. However, regardless of the type of contract, the BIM methodology uses tools such as EIR, BEP to clearly define the objectives and information needs of the contracting authority and verify that they are met. Of course, the process of negotiating the terms and conditions cannot only be about the implementation of the BIM methodology, but about the contract as a whole. Each stage of the process should therefore start with a negotiation that includes not only the client's requirements, but also advice to properly understand them and possibly adapt them to the contractor's capabilities. It is good practice to conduct technical or innovation dialogues even before tendering.

Value stream definition (Data Drops, MPDT, MIDP, TIDP)

An adequate understanding of the contracting authority's objectives allows the definition of the processes and the successive stages required to achieve them. The value stream is a sequence of stages together with the identification of the information, human resources, equipment and materials required to perform them. Any element of the process that does not serve the achievement of the set objectives is redundant and should be eliminated. The counterpart to the BIM methodology is the agreement of the counterpart to the BIM methodology is the agreement with the client on plans with varying levels of detail covering the accuracy, scope and format of the information to be provided. The end result of the planning is the MIDP and TIDP tables are the final deliverables, which describe what is to be provided to the client as part of the project's milestones. Within subsequent project milestones the pitfall of BIM can be to 'overload' the client with documentation or analyses generated from the model. The key is to only create and deliver information that has been recognised by all parties as being relevant to the stated objectives. It is also important to remember that MIDP tables should be modified as the work progresses and the parties' needs change.

Elimination of waste (BIM dimensions, MPDT)

One of the primary objectives of the Lean philosophy is to eliminate or minimise any type of waste. However, to understand and, above all, identify and eliminate waste from projects, it is necessary to know the basic types of waste. The types of waste as defined by Lean are listed below.

- Overproduction - producing more products than the customer requires. It also refers to a situation where a job is done too early. Importantly, the client of the work may be the next person in the process, e.g. the plasterer after the bricklayer or the installation designer after the architect creating the concept. In the context of BIM modelling, information overproduction can be reduced by adhering to the LOD standard defined for the circumstances.

  Examples:

- generating and printing 10 cross-sections, visualisations or axonometries from the BIM model, although 2 characteristic ones are required to understand the project,

- modelling of geometry with a higher level of detail than the assumed level in the MPDT table.

- Idleness - employees waiting for the next batch of tasks or products of the preceding stage. Without clearly delineated tasks, it is sometimes the case that employees are engaged in unproductive activities that, in a world of social media and online shopping, distract even during busy times. An additional psychological aspect is the signal that loosening up will be the start of stress related to excessive duties and overtime in the future. It is therefore necessary to balance processes accordingly so that they do not generate downtime (e.g. by appropriately configured CDE platforms) or to plan them and move employees to other tasks in advance. Calming down time should be used for planned training or the development of internal research and development projects.

Examples requiring appropriate management of staff time:

- waiting for the materials necessary for a construction element (e.g. lack of bricks needed to build a wall),

- waiting for the client's decision on the appearance of the façade, resulting in a delay in the development of the execution details.

- Redundant processing- performing all or part of previously performed activities through a poorly designed process or to improve them unnecessarily. A properly designed Lean process assumes that any item that has once achieved sufficient quality is passed on for further processing. Unfortunately, in construction processes, it happens that individual team members review the same problems several times only to come to the same conclusions. It also happens that bureaucracy, aesthetic sense or innate perfectionism make them "improve" documents or elements that have already met the expectations agreed with the client. The additional work done on them is therefore unnecessary. This type of waste is particularly difficult to detect. The prescription is to standardise processes. In the context of BIM, appropriately created project templates, scripts or component libraries suitable for the type of project are key. Once implemented, they can serve for many years, significantly speeding up work. Global and company standards and tools that allow for the accumulation of knowledge created by individual employees are also helpful, such as a company Wiki page collecting good practices and experiences of the team. At the same time, clearly defined quality standards for information models (e.g. LOD levels), prevent unnecessary "enhancement" of models.

  Examples:

- completing the parameters of the BIM models required only at later stages of the project, resulting in the need to change them due to design changes,

- developing a CAD file configuration already made once for a new project or task.

- Unnecessary transport- consists of a misconfiguration of the supply chain, resulting in lengthy or poorly organised transport. This results in higher delivery costs and damage to products. Pointless delegations, which can be replaced by video conferencing or other forms of communication, also fall into this category. BIM methodologies can reduce this waste, e.g. model coordination tools can streamline the logistics process on site, ensuring just-in-time deliveries, while CDE platforms and Virtual Reality (VR) applications improve the remote communication process.

Example:

- GW's ordering of slightly cheaper-than-local material transported from abroad, causing delays and damage to materials - the losses can be greater than the savings from the unit price.

- Storage - means the freezing of capital in articles or work done and waiting to be used in the next stage of the process. The storage of products generates the need for adequate space and its administration. Particularly in the case of construction sites in city centres, such space can be extremely expensive (the need to sublet land for construction or storage facilities). At the same time, prolonged storage of construction products can result in damage. Unread emails and documents awaiting approval can also be a form of storage. In the context of the BIM methodology, the construction of information models is expected to enable more precise planning and, as a result, Just-In-Time execution of works. CDE platforms are expected to improve the circulation of messages and documents.

Example:

- the generation of documents, reports, e-mails which have a low impact on the project (nobody reads them) can be replaced by a constructive coordination meeting.

- Unnecessary movement - this is all the extra or excessively long activities needed to complete a task. The answer can be, for example, the 5S method to optimise the workplace and, in the case of BIM model production, standardisation and appropriate configuration of the software environment.

Examples:

- improperly configured toolkits or their unavailability result in the need to search for and reconfigure the workstation each time during subsequent tasks,

- Misconfigured directory paths, lack of shortcuts, unintuitive names lead to the need for lengthy and repeated searches for a file or information.

- Errors and defects - result in the need for corrections, wasted time and money. The only way to minimise the effects of errors is through an early quality control system built into every process step and a precise definition of their causes. This includes visualising problems at the earliest possible stage and treating problems as challenges. Errors overlooked at subsequent stages of the process tend to accumulate, which generates serious losses for the developer - especially at the implementation stage. Quality control is embedded in the BIM methodology. The model verification methods described in the EIR and BEP, as well as the specialised software for checking collisions and non-geometric parameters, are just some of the elements of quality assurance and continuous quality control.

Examples:

- erroneously constructed but accepted concrete floor elements make it impossible to carry out the finishing layers of the floors, necessitating the re-engagement of the crew and the transport of equipment already exported,

- Information deficiencies in the BIM execution models result in the need to create further information requests and design changes during the execution phase of the works.

- Untapped human potential - every person has a pool of skills and experience. When these capacities are not developed or a person is not matched to the tasks at hand, their talents, skills and knowledge are wasted. The authors' experience shows that employee potential is notoriously squandered. This can be caused by constant 'firefighting' (instead of prevention), a lack of due attention and respect for an employee's ideas or a toxic working environment. To counteract this, companies are implementing appraisal systems and periodic interviews with employees. In addition to verifying progress, these are designed to give employees the opportunity to speak out on issues of importance to the project or organisation, to give constructive criticism or, more importantly, to propose improvements. In view of the strongly changing environment of young engineers, this aspect seems to be crucial in building a modern BIM-ready organisation. Unfortunately, the lack of stability in the sector can generate difficulties in the process of adequately motivating and gratifying the most committed employees, which can be counteracted by, among other things, an innovative and flexible approach to procurement.

Examples:

- the failure to exploit the potential of the scripting engineers, whose skills could significantly improve BIM modelling,

- a lack of training for site workers who do not understand the need to optimise and tidy up the site, resulting in wasted man-hours and an increased level of risk of accident on site.

Development of a seamless process (EIR, BEP, MIDP)

An ideal project carried out in accordance with the Lean philosophy assumes a continuous, uninterrupted, reliable and fully predictable process. Of course, this is not achievable in practice, but a properly planned sequence of events, properly selected resources and clear communication between the parties to the process are key to keeping things running smoothly. When one stage is implemented late or ahead of schedule, information about it must reach everyone involved. Otherwise, there is waste such as idleness, unnecessary transport storage or unnecessary traffic. Both in the context of the creation of models and their subsequent use on the construction site (e.g. by means of a virtual schedule visualised with the model), it is necessary to define the information exchange processes accordingly. Consultation with the client and other stakeholders, but also appropriately configured CDE tools should serve this purpose.

Pull-Planing

Traditionally, planning a construction project is the responsibility of several people at the head of the at the head of the contractor's or contracting authority's organisation. The various stages and their duration are defined top-down, often without consulting the team that will practically carry out the various tasks. The efficiency of such a plan is measured by the effectiveness of each stage individually and so control is exercised focused on the acceptance of the individual parts.

As mentioned, the use of a suction system, typical of Lean Construction, requires the involvement of frontline workers in the scheduling work. Importantly in this context, as long as they do not have the opportunity to articulate needs or protest on unreasonable requirements, the schedule is unrealistic. One of the basic principles of such scheduling is: 'The word YES means nothing if you can't say NO'.

The suction system assumes that:

- the schedule is built 'backwards', i.e. from the finished product (e.g. finished project documentation, completed construction phase, handed over for use of the building structure) to the day when the activities start,
- stages and their duration are determined by frontline staff with the authority to make decisions and commitments,
- activities are initiated based on the needs of further stages of the process,
- efficiency is defined by verifying overall process throughput and minimising wastage,

- the control system is constantly being redefined on the basis of performance monitoring until the intended objectives are achieved.

The planning process starts by defining the main milestones - milestones - and their completion dates. Those involved in achieving the milestones meet and agree on the necessary activities and resources to achieve the goals, counting from the planned completion date. Time is counted without reserves. Once all milestones have been developed, the logic and efficiency of the process is examined. After possible optimisation, the earliest practical start dates for the milestone are defined, determined by the completion dates of all processes necessary to start the milestone.

Of course, this is very difficult in practice. It requires the full commitment of line leaders and works managers, who will define precisely and without undue optimism the time needed to complete a particular phase. At the same time, they need to define what work needs to be done before they can act. Pressure from the environment or the client must not be decisive factors. The declarations of each party must be taken into account, which is why it is important to involve experienced employees who have repeatedly performed and reported on similar work. The key is the fluidity of the process, not the efficiency or overtime of individual trades or teams.

Once the overall milestones and phase schedule have been established, planning enters into 1-2 week cycles, where declarations cover relatively small slices of work. In this way, any delays or overruns can be quickly checked and acted upon during subsequent meetings. The teams often use appropriate tools such as a whiteboard with coloured cards or software that simulates a whiteboard in a virtual environment. Tasks with a declared completion time are divided into planned in-progress and archive tasks. This makes it possible to allocate tasks to individual teams or individuals and to track performance during a given cycle. This supports transparent collaboration and forces people to take responsibility for declared deadlines and end products.

The LCI Institute has developed the Last Planner, a version of the suction system dedicated to the construction sector. This method has already gained its adherents and is used in many cases described in the industry literature, both at the design and construction stages A simplified working diagram of the Last Planner system is shown below.

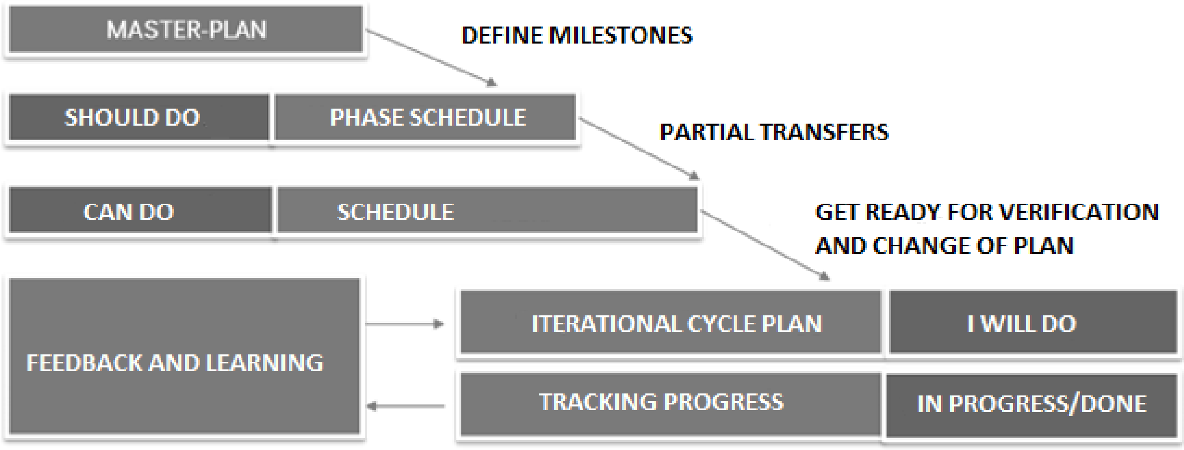

Fig. 13 Diagram of the planning process within the Last Planner system
Source: own elaboration

In summary, the suction system can be implemented in the following steps:

- define the phasing of the work,
- set completion dates for the phases (or milestones),
- using the sticky notes method, plan the sequence of tasks backwards from the completion date
- use actual durations of individual activities (no stocks or "wishful thinking" planning).
- re-check the scheduling logic for possible optimisations,
- determine the earliest practical start date for the process,
- decide which activities should be buffered or protected with extra time:
  - which activities are most at risk?
  - what are the risks?
  - what is the order of uncertainty?
  - allocate available time to the most vulnerable activities,
- check whether the team is comfortable with the timetable created, and if not, re-plan or move the milestone if possible.

Continuous improvement (Lessons Learned, CDE)

The need for continuous improvement in standardisation and loss elimination processes is at the heart of the Lean philosophy. Opportunities for improvement are identified, implemented and applied as part of the standard, thanks to the trust between the participants in the process and the commitment of the employees of each company. Employee awareness is particularly important. Ultimately, they are often the best placed to know where the greatest difficulties lie and what improvements can be to make. The improvement process should be carried out systematically and cyclically using adapted tools and procedures. In the context of BIM, virtually every element of the methodology should be continuously monitored. Iterative model production cycles should be systematically checked both from the content side (design verification, functional and performance analyses of the models) and from the workshop side (verification of correctness of nomenclature, completeness of parameters, etc.). Documents (EIRs, BEPs) related to the methodology should also be periodically assessed, revised and validated by both experts and project participants. Even global standards are subject to dynamic changes in the software and services market, resulting in the issuing of further revisions. So although the ideal is not achievable, striving for it is in the DNA of both Lean and BIM methodologies.

Finally, it should be noted that implementing Lean principles and tools in an unreflective manner will not necessarily produce the desired results. Examples from Japanese manufacturing companies show that drawing directly from the widely published Toyota methods has not translated into the to the same increase in efficiency. Each method should be analysed very carefully in terms of the specific project and organisation.

The construction industry has been relatively slow to evolve towards a new organisational culture, but the benefits of the Lean approach are encouraging more and more companies to change. A key challenge in adapting Lean in a company is therefore to change the work culture and build trust among employees - especially between companies. Lean is a thinking people system (Thinking People System). The creators of the Toyota phenomenon placed a premium on the continuous development and learning of employees. Most people want to do a job well and feel satisfaction from the value it generates. The company should therefore involve the employee in solving problems, improving quality and safety and minimising waste. Interestingly, many of the methods associated with the philosophy are being implemented by employees in the construction sector without being aware of their origin and history.

BIM methodology draws heavily on proven methods in the manufacturing industry for planning, optimising and controlling the information delivery process. Those involved in the methodology are particularly sensitive to the possibility (necessity) of change in the sector. BIM technology can therefore facilitate the understanding and implementation of a new work culture in companies where BIM is already a proven and accepted practice or be of interest to those organisations where Lean is being implemented.

Agile project management systems

History of Agile

In the mid-1980s, Japanese professors Hirotaka Takeuchi and Ikujiro Nonaka wrote the article *The New New Product Development Game*. It was published in January 1986 in the "Harvard Business Review". It described the work of the most productive teams from companies such as Hawlett-Packard, 3M, Honda and Fuji-Xerox. He found that when creating new products, the teams did not follow the most common cascading project management system. Instead, autonomous self-organising teams performed overlapping tasks faster and with greater flexibility, responding to changing needs. Subsequent years of research and analysis of implementations carried out in agile teams in Japan and the United States led to the 2001 to the publication of the *Manifesto for Agile Software Development*. The Manifesto was based on 4 basic principles.

"We are discovering new methods of programming through practising programming and supporting others in it. As a result of our work, we have begun to value it more:

- people and interactions from processes and tools,
- working software (product) from detailed documentation,
- cooperation with the client from contract negotiations,
- responding to changes from the implementation of the established plan.

This means that the elements written out on the right are valuable, but of greater value to us are those written out on the left."

So, like Lean, Agile puts the focus on people and the process that is adapted by them to best meet customer/market requirements. The manifesto is complemented by 12 principles to promote a collaborative culture in which change is normal and expected and the value offered to the customer stands above formal requirements.

It seems clear that the Lean philosophy and the ideas behind it were of great importance to the manifesto's creators. As P. Cappelli and A. Tavis, experts in human team management, point out, 'agile management methods are no longer exclusive to technology departments. They have reached other areas and functional verticals - from innovation development to manufacturing to marketing - and are now transforming the way employees are hired, nurtured and managed."

So while the Agile methodology will have limited application on site or even in the traditional design process, it can provide a framework for collaboration for teams delivering complex projects based on the BIM methodology. In order to understand how Agile can translate into efficient information modelling, it is necessary to take a closer look at the tools and techniques of agile management.

Cascade model vs Agile

The cascade model (Waterfall) is perhaps the most popular approach to project management in the construction sector today. It fits perfectly into the traditional approach to construction project delivery. The system is based on the decomposition of a project into individual phases, one after the other. The key features are a plan and clearly defined and unchanging requirements for the end product. The system is based on a simple sequence: do A - do B - do C. The next step cannot be started until the previous one has been completed. As you can easily guess, this method works, for example, perfectly for single processes on a construction site: build the foundations - build the floor on the ground - build the walls - build the ceiling - build the walls - build the roof. At the strategic level, project management through so-called traditional methods can produce excellent results. Wherever repeatability, predictability and standardisation are possible, it is worth using a clearly defined decision path and clear project phasing.

However, at the operational level, especially in the case of empirical processes (where knowledge results from experience and decision-making based on what has been learned), the cascade method may not work, among other reasons, because of the problems described earlier. Such processes should rather resemble a scientific experiment, following the PDSA cycle cited in the previous section: design, prototype construction, test, optimisation. The main difference between the cascading system and Agile methods is the iterative nature of the process. Agile involves cyclical design, build, test and release of correspondingly small portions of the project. It is the ability to revise small amounts of information frequently (every 3-4 weeks) that is key. In the case of software, this provided the opportunity to create and verify small portions of functionality or user interface before the finished product was even created. In the case of buildings, for example, increasingly complete BIM models can be released to continuously verify that the client's requirements have been met. Below shows a schematic comparison of the work steps in a cascade and an agile system. The cascade model should not be confused with the phases of project implementation; rather, they refer to the stages of a specific phase, such as the creation of project documentation.

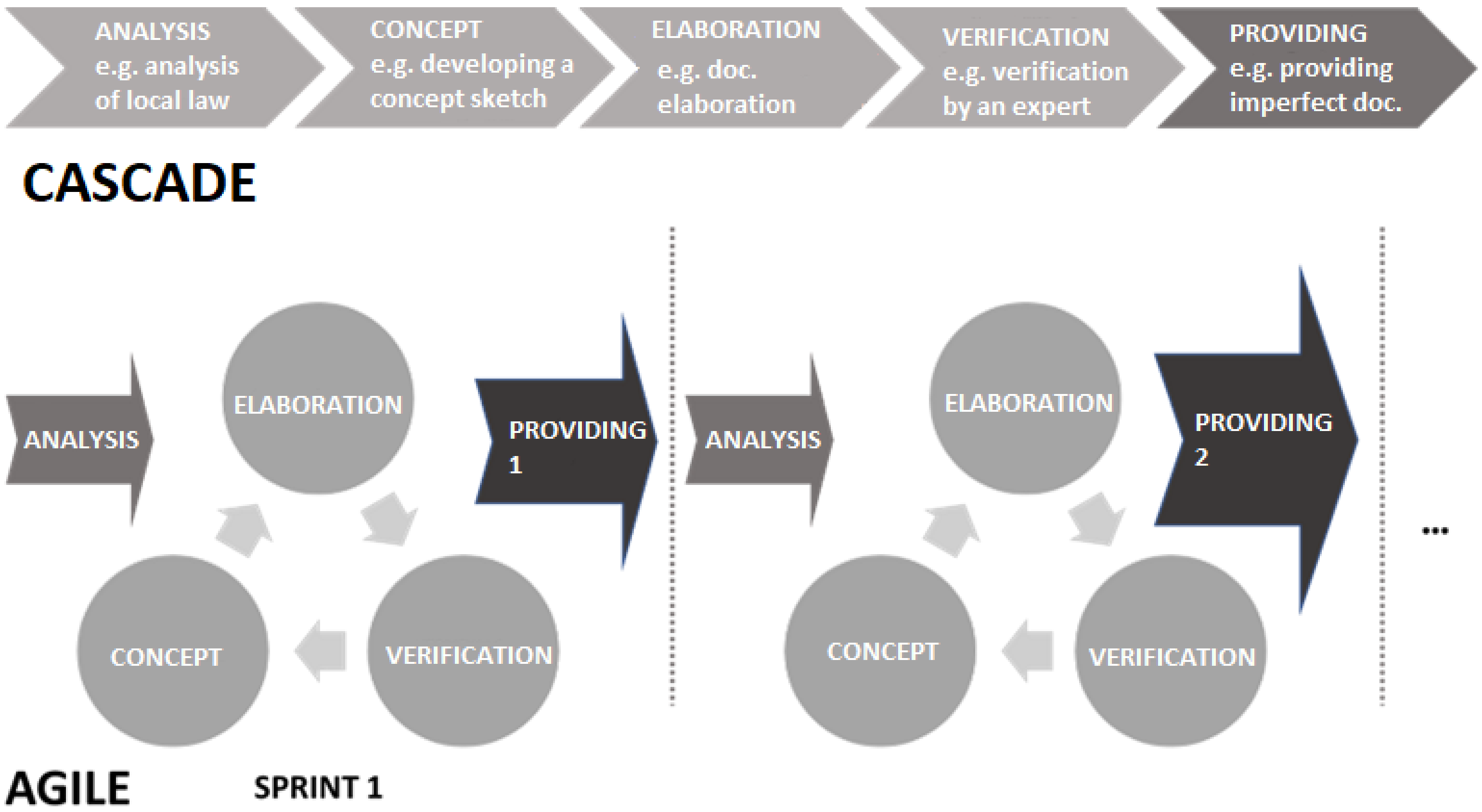

Fig. 14 Diagram of stages in a cascade and agile system
Source: own elaboration

For civil engineering projects, this approach is also crucial. Clearly, every project should be iterative. The designer often analyses hundreds of solutions (thought experiments, sketches, mock-ups, etc.) before arriving at a final solution. However, when using traditional forms of drafting, once the initial concept has been developed, the ability to make drastic changes becomes increasingly difficult as the documentation work progresses. In addition, flat-drawn designs require labour-intensive processing for analysis. A simple visualisation requires the creation of a separate 3D model to show the aesthetic qualities of the designed facility. The energy model is usually built once at the building design stage, and any adjustments are limited to optimising the thickness of the building envelope.

Meanwhile, using BIM technology, it is possible to continually test the model or parts of it and make adjustments without having to "redraw" the entire documentation. This also applies to the execution and operation phase of the project, where subsequent optimisations of the detailed design or possible changes can be checked in a virtual environment. Appropriate planning of successive Data Drops and the analyses applicable to them makes it possible to introduce a truly iterative process at almost every stage of project design and implementation.

In practice, in a cascade system, due to unforeseen circumstances, the time required for implementation (delays, postponements) and the team change. What is constant is the product defined at the project initiation stage. In Agile, the time and team remain mostly constant, while the requirements for the project change. The Agile motto is: fail fast - learn fast. Sometimes it is worthwhile to review the client's assumptions at the start of a project and, through continuous collaboration and dialogue, build an increasingly better product together with the client, rather than blindly focusing on the original plan. It should be emphasised at this point that product variability is not about uncontrolled quality reduction. On the contrary. It is about rationalising assumptions and building additional value, but within the framework of minimum requirements (so-called MVP) that are unchangeable. For the methodology, the basic requirements, which are not negotiable, can be found in the EIR or the contracting authority's ToR.

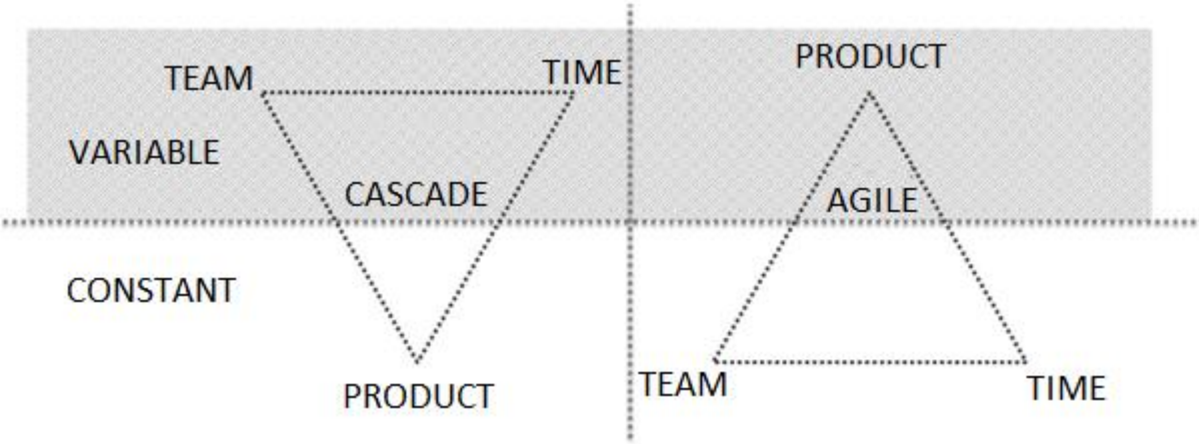

Fig. 15 Comparison of the Cascade and Agile systems in terms of key variables and constants in the organisation of work
Source: own elaboration

The second, perhaps equally important change in project thinking is team building and organisation. Agile teams are formed as self-organised small groups of specialists. Experts indicate that the optimal team is 6-7 people (+/- 2 people) [59]. In addition to the team members, the methodology distinguishes a number of support functions, but not managerial but rather support functions. Teams are organised on the basis of relationships, competences and specialities in terms of the tasks to be performed, which does not mean that a group cannot have a leader. As already mentioned, teams are supposed to be permanent and dedicated to a specific project. Shifting members between projects results in a significant drop in efficiency and the need to deploy to new tasks.

What does running a project look like in Agile? The details may vary depending on the specific method, but the basic elements are constant.

- The person responsible for the product (customer representative) presents a vision of the final product and, together with the team, defines the overall schedule (Product Backlog) by valuing the individual parts of the product in the context of the whole.
- The team begins to create the individual components of the product within 2-3 week iterative cycles.
- At the end of each cycle, the team presents the results of its work to the client representative and other stakeholders.
- There is a verification of the achievement of the objectives and a possible adjustment of the schedule.

- There is a review of working methods and implementation of improvements related to the product development process.
- The iterative cycles continue until a satisfactory final product is achieved or the time allocated to the project has expired.

It can be said, therefore, that even if a project is run using a traditional management system, it is worth considering whether agile methods will help to

in delivering the best possible products at the level of the individual teams' work. Agile can significantly improve the organisation and outcomes of work at an operational level.

Agile using Scrum as an example - artifacts, roles and events

As defined by the creators themselves, Ken Schwaber and Jeff Sutherland, Scrum is "a framework through which people can adaptively solve complex problems to produce products of the highest possible value in a productive, iterative way".

Scrum is a relatively simple and flexible agile management method. At the same time, it defines well the basic roles and techniques that creative teams can use. Importantly, although the essence of Scrum is small teams, the methodology can be adapted to several, or even more than a dozen collaborating teams forming a network. In addition to software development, Scrum is now used worldwide to validate processes, deliverables, in product and service development and in the management of organisations.

Scrum theory seems to fit well with BIM methodology, as the references and examples presented from design practice and the conduct of construction work are intended to demonstrate. The basic features of Scrum are listed below.

- Transparency - this includes clear and legible communication, as well as the use of clear rules for collaboration and product-related standards that are understood by all team members. For the BIM methodology, transparency is also key, e.g. all team members must use a common nomenclature, all team members must know the requirements for the products created (models, drawings, analyses, visualisations).
- Inspection - Scrum teams are required to systematically verify the delivered elements (increments and schedules of the project (Product Backlog, Sprint Backlog). At the same time, the inspection should not be carried out too frequently so as not to disturb the project. Good BIM practices assume cyclic control of information models and their

elements by selected persons, e.g. BIM manager/BIM coordinator for models, Information Manager for processes. The checks are carried out in accordance with agreed internal standards and data drops agreed with the parties.

- Adaptation - in the event of a product not conforming to expectations or an opportunity to improve the process, the team is required to develop and implement a fix as soon as possible. This is of course (like the rest of Scrum theory) linked to the Lean philosophy, which is to eliminate errors and problems as soon as they arise. Within the BIM methodology, eliminating errors and seeking to process optimisation is the key to success. This is to be ensured, among other things, by the use of appropriate tools to control models (specialised software) and processes (CDE platforms), but above all by the involvement of staff.

Artefacts

Within Scrum, there are 3 basic artefacts - elements that the team works on.

- The Product Backlog is a structured list of everything that is known about the development of a product at any given time. It is the sole source of requirements and elements to be realised in order to deliver the product. It represents a kind of timetable, but one that is subject to cyclical changes on the basis of successive iteration cycles, in order to make the product 'relevant, competitive and useful', in line with in line with customer and market requirements. The estimation of the time required to complete individual tasks, and thus the number of 'stories' in a Sprint, is at the discretion of the team. The product owner and Scrum Master may try to influence the team by building trade-offs and searching for optimisations, but the final decision rests with the people physically doing the work.
- Sprint backlog - it is made up of the tasks to be performed in a particular sprint and a detailed plan for their implementation. It is supplemented by ongoing activities, creating material for analysis at the end of the sprint.
- Increment - the value of all the elements delivered in a given sprint, along with the previous ones. An increment is a tangible result of the work done, which is evaluated when summarising the work in a given iteration cycle.

The most cumbersome can be the Product Backlog, the creation of which requires a lot of experience and close collaboration of the project team. The other artefacts are consequential. The Backlog usually consists of a roadmap and requirements for the project.

Roadmap - is a schedule of major milestones and a roadmap showing the development of the project and the possible overlap between the various tasks. An example visualisation of a simple project roadmap can be found in Fig. 16.

The roadmap should evolve as the product develops. When building the initial schedule, the possibility of parallel execution of parts of the tasks should be exploited to the maximum. The modelling of parametric components can be started even before the measurements are completed, thanks to piecemeal scans of individual parts of the building (doors, windows, equipment, etc.).

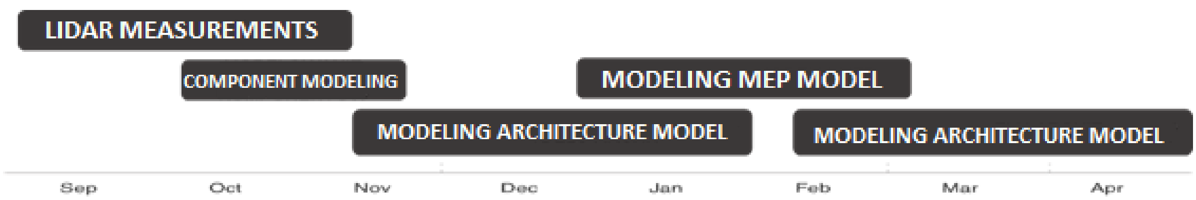

Fig. 16 Excerpt from an example of a road map of a BIM project involving the reconstruction of documentation for an existing facility

Requirements for the project - are often defined in a separate document (Product Requirements Document, PRD) produced by the client. In the context of BIM, the role of the document is played by AIR and EIR. Note that the creation of a document may require specialist knowledge, consultation and research, and the involvement of external specialists. However, when the client and the contractor team understand the objectives and communicate in the same language, the detailed requirements should be negotiated together. This process for BIM culminates in the agreement of the BEP document.

In this context, it is worth mentioning the Minimum Viable Product (MVP) requirements for the project. This is a set of requirements without which the product cannot be delivered. For a residential building project, the MVP might consist of: documentation to obtain planning permission, minimum required floor area of the flats. Since the Agile process is supposed to test the most optimal solutions in successive iterations and build value until the end of the process (the deadline for handing over the documentation), it is worth agreeing from the beginning on the requirements that need to be satisfied as soon as possible so that the project is not threatened by continuous revisions.

In order to efficiently manage the task breakdown and Backlog, it is necessary to break down the client's main vision into manageable parts for subsequent sprints. Some practitioners therefore use what is known as vision decomposition, which involves dividing and grouping tasks.

Themes - are general groups of tasks that require similar activities to be carried out, for construction projects these are e.g. surveying, modelling for a construction project, creating promotional materials. Themes can be said to identify the main objectives of an organisation and assign them to specific groups. In the context of BIM, they are created and form part of AIR and EIR . A good motif for a company offering an expedition to Mars would be "Safety first!".

Features or Epics - are a further subdivision of the vision into smaller parts. Features help to appropriately determine the importance of individual elements in the context of the project schedule (Backlog) and the needs of the client. They are a group of stories or, in the initial decomposition phase, can be created from stories that do not fit into a single sprint. The outcome of a Feature should enable users to do something, to gain a benefit, e.g. make a strategic decision. A feature is the creation of an architecture or design model at a given stage. Features allow the creation of MPDT tables.

User Stories - are the basic unit of work defined in Scrum. They allow real value to be obtained at the end of individual sprints. They must therefore be small enough, independent of each other, provide real value in the context of the sprint, be comparable to other stories, and allow for precise evaluation of deliverables, and be negotiable. A single sprint may consist of several stories. Stories can be created by defining the effect and expected gain within the project, e.g. "I would like to receive the current schedule realised in BIM 4D so that I can verify the assumptions for site logistics". The expected gain is the absence of logistical errors and financial losses due to delays in the works. The stories make up the MIDP table. Like each element of the MIDP table, each story should have a clearly defined set of requirements (acceptance criteria), the fulfilment of which enables it to be submitted for client assessment. However, it is important to remember that when creating a story, the focus should be on the end result you want to achieve and not necessarily on the tangible product (model, report).

Tasks - represent the smallest portion of work and are usually assigned to individual team members, who declare how many hours it will take them to complete each task. With this method, team members can more reliably anticipate the work of the following days, rather than planning well in advance. The progress of the tasks and the accuracy of the declarations are verified during daily meetings, a sticky notes board, trend charts such as burn-down/burn-up charts or specialised software. In the BIM methodology, tasks are defined by a TIDP table.

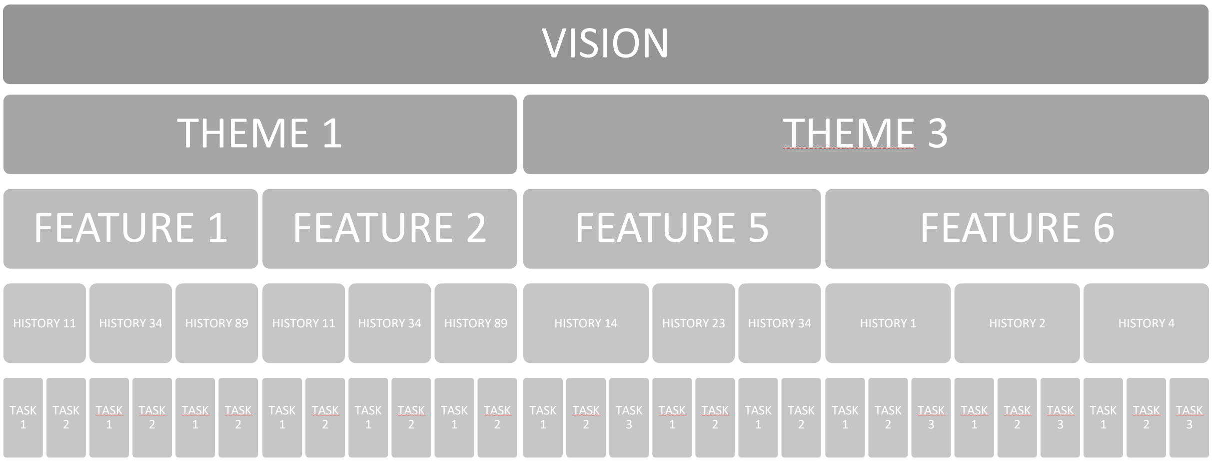

Fig. 17 Simplified vision decomposition diagram
Source: own elaboration

In this context, an increment can be defined by successfully realised stories, and a Sprint Backlog is nothing more than a set of tasks with methods for their realisation, assigned to a specific iteration cycle. It is good practice to keep the Product Backlog, Sprint Backlog and other methodology parameters in one place. Nowadays, more and more digital tools for agile process management are being developed, which, in addition to planning, allow for the control and visualisation of the progress of the implemented processes. Examples include the popular Trello, JIRA or Microsoft Project. Special tools for BIM are also being developed, e.g. Plannerly, where the functionality of sticky notes and Gantt charts has been combined with the ability to create documents or LOD levels, as well as visualise BIM models.

Roles

The simplicity of Scrum also translates into the number of roles and functions required on a project. The Scrum team consists of a product owner (Product Owner), a Scrum Master and a small development team of six to nine people (Development Team). A brief description of each role is given below.

Development team - a group of 5-9 people made up of professionals whose task is to deliver, at the end of each sprint, a 'completed' and ready for potential release, an increment - a value-added part of the final product. The assumption is that only members of the development team create the increment. The team should therefore gather in the members all the competences necessary to complete the task. Scrum teams are said to be organised in a similar way to special forces troops. Each member of the team should be selected on the basis of his or her broad competences at a high level of generality (e.g. the ability to model in a particular

BIM software or, to use a military analogy, the use of firearms) and a deep knowledge of the chosen specialisation (e.g. the ability to create scripts that automate work). Scrum theory states that, although individual team members may carry out separate tasks based on their specialities, responsibility for the work is shared by all. In practice, especially on large building projects, a team of seven people will not be able to produce complete documentation or even a single branch documentation. In the case of construction projects, a network of cooperating specialist teams and associated specialised rather, a network of specialist teams working together, with associated experts, specialists and suppliers. This requires organisation, of course, but it should be borne in mind that not every team and not under all circumstances needs to implement Scrum. However, if any decide to do so, the roles of Scrum Master and product owner become all the more important to maintain smooth communication between the separate groups. More about scaling the Agile methodology is written at the end of the subsection.

The Product Owner - is the person ultimately responsible for the end product and the value of the team's work in delivering it. His/her role includes presenting the vision and requirements of the customer to the team, managing, organising and clearly communicating the Product Backlog, controlling and optimising the value delivered by the team. The Product Owner may represent a group of customers (company management, etc.), but only he or she can change the timing and importance of individual sub-products. Those wishing to change the priority of a particular Backlog item must approach the product owner. This requires proper organisation of communication and respect for this role and the person who plays it. Within the BIM methodology, some assume that the role of pProduct owner should fall to the BIM manager. However, this is an incorrect assumption. Closer to this role is the so-called Information Manager who, in addition to the administration of the CDE, according to UK BIM Level 2, is to be responsible for the efficient exchange of information and checking its compliance with requirements. This role is often combined with the role of project leader on the client side. However, it is important to remember that the product owner must be as available and embedded in the work of the specific project as possible. Often, therefore, this role is assumed by the project manager, who is in closest contact with the client's representatives.

Scrum Master - this is the person responsible for implementing and improving the processes on a Scrum project. He or she is by definition the most experienced in the application of Scrum. He acts as a so-called servant leader (servant leader) for the team. At the same time, he/she supports the other stakeholders in understanding and using the Scrum processes. His primary role is to facilitate the work of the team and as a result, the smooth delivery of the product to the customer. In practice, the Scrum Master's tasks include technical assistance in managing the Backlog, facilitating and moderation of communication between the product owner and the team, providing subject matter support in the application of Scrum, providing resources and removing obstacles during the team's execution of tasks, supporting the organisation in implementing and ensuring the effectiveness of Scrum on ongoing projects.

A similar role for the BIM methodology is played by the BIM Manager. In mature organisations, this person is responsible for agreeing standards and methods for implementing the methodology in relation to the client's objectives. Contrary to popular belief, he or she is not primarily concerned with the coordination of models (this is more the role of a designated coordinator), but mainly controls the flow of information between stakeholders and supports the BIM engineers and other stakeholders to be fully effective. However, if an organisation wants to implement Scrum from scratch and the team lacks experience in this area, it is better to entrust the Scrum Master role to a specialist (e.g. an external trainer) who will plan the implementation accordingly, train the employees and prepare the selected people for further independent work.

Events

One of the main myths about the Agile methodology is that it lacks structure and principles. Meanwhile, Scrum not only defines the roles and responsibilities of team members. The system also defines a number of so-called events aimed at structuring the work. All of them have a predetermined maximum duration, but outside of a sprint, they can be ended earlier, once the goal has been achieved. The purpose of events is to minimise the need for other formal meetings to a minimum and, as a result, enable the team to work efficiently. Scrum events are detailed below.

- **Sprint** - is a slice of time (no more than a month, usually 2-3 weeks) during which the final product element(s) (increment) can be delivered ready for verification. Once the purpose of the sprint and the quality standards for assessing its effects are established, they remain constant until completion. Of course, the nature of Agile and the iterative nature of the process (continuous testing of deliverables within each cycle) mean that changes to the scope of a sprint may occur. There is nothing wrong with this as long as such changes do not jeopardise the sprint schedule and the product owner agrees to them. The underlying thesis behind such actions is that until we start working on a problem, we cannot 100% predict the exact specifics of the problem and the challenges it will face.
- Sprint planning - a meeting (no longer than 8 hours) to answer two questions: What can be delivered in increments for the sprint? How will we do the work necessary to achieve the goal? The team, based on the Backlog, selects the stories it will deliver within a given

period and declares the time required to complete each task. Of course, in practice, reaching agreement on this can be difficult, so Scrum Masters use a number of negotiation games (e.g. Scrum poker) and techniques to help the team reach consensus.

In the context of BIM teams, experience of the planned tasks is most important. Without it, a precise declaration of the time needed to achieve a goal can be very difficult. Sprint planning and control, as well as the entire Backlog, is carried out in a similar way to a suction system using similar tools (e.g. a sticky notes board or specialised software). As with Lean Construction, it is important that team members have the opportunity to negotiate the scope and methods of achieving the goal with the product owner and with each other. But what does this look like in practice? Below is an example scenario.

The aim of the sprint is to develop a design concept for interior architecture, a typical floor in an office building (so-called fit-out). The product owner defines the basic requirements - aesthetics, elements to be assessed (visualisations, projections, sections, VR application). The work is divided into individual tasks, such as modelling in BIM software of finishes, furnishings, coordination of industry models, completion of non-geometric data, etc. The individual team members then declare the time required to complete the individual tasks. As a result of the negotiations, aesthetic guidelines, the detail of the information assigned to the components, the level of geometric detail in relation to the Backlog and BEP, among other things, are established. During negotiations (or even during a sprint), it turns out that it is impossible to develop all tasks due to insufficient time. The scope of the sprint is renegotiated, in order to maintain the end goal and quality standards for the other incremental elements, the VR application, which is relatively least important to the client, is dropped. Its implementation is postponed to the next sprint.

During sprint planning, it is important to sort stories from the most important ones in the Backlog, but also ensure that the pace and rhythm of the iteration cycles is appropriate. It's not good if one iteration cycle lasts 5 weeks (because you have to do the 3 most important stories with a lot of man-hours) and the next week and the recaps throw the team out of rhythm. It is a good idea to group the stories so that each sprint takes about the same amount of time and generate a similar amount of material for review by the client. Instead of working days, points are often used to evaluate stories, which more abstractly define the estimated labour intensity. At Fig. 18 shows the schematic assignment of individual stories to sprints in order to maintain an appropriate rhythm (in this case 10-11 points assigned to stories located in individual sprints).

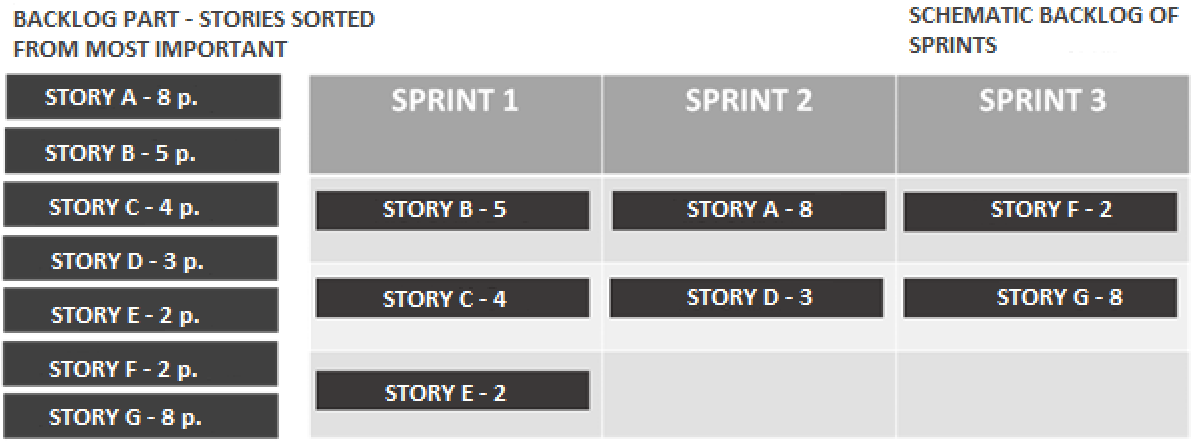

Fig. 18 Schematic process of organising the Sprint Backlog to achieve a uniform rhythm of work and verification
Source: own elaboration

Daily Scrum - a daily meeting of the development team (no longer than 15 minutes) that is an event for the team. It is intended to give all members an answer to 3 questions:

- What was achieved yesterday in the implementation of the sprint?
- What am I planning today as part of the sprint implementation?
- Do I see problems within the sprint implementation?

To quote *the Scrum Guide*, "Daily Scrums improve communication, eliminate other meetings, identify and remove obstacles, foster rapid decision-making and increase the knowledge level of the development team. It is a key meeting for the inspection and adaptation process." Importantly, Scrum is not used to solve problems, only to accentuate them. The team involved often meets after Scrum to discuss and resolve articulated challenges or to find a method to improve the work in case of anticipated delays. Scrum provides an opportunity for all team members to speak up, including those who otherwise do not feel confident enough to manifest their dissatisfaction or concerns about tasks. In BIM teams - especially on challenging projects - Scrum allows knowledge to be shared quickly when, busy with our own tasks, we don't have time to look at our colleagues' progress or problems. The dynamic development of the BIM methodology means that what is difficult and a barrier to efficient information modelling for one, may be a long-solved problem for another. Sprint aims to deepen communication between team members in this area as well.

For example, a newly recruited employee, who is shy by nature, struggles all day with the need to constantly correct the numbering of rooms on the floor plans. Meanwhile, after a sprint where the problem is articulated, a more experienced team member suggests using a rehearsed script to automate the process. When the team communicates poorly, ineffective modelling can go on for weeks. By having to articulate on a sprint, the problem becomes a challenge for the whole team and can be solved in an instant.

Sprint review - an event organised at the end of a sprint, lasting no more than 4 hours (sprints of 2-3 weeks usually end with shorter reviews). In project practice, such meetings can be likened to coordination meetings or group schedule reviews. The main difference, however, is the presence of team members and the informal nature of the event, which is aimed at stimulating discussion and obtaining feedback from key decision-makers invited by the product owner. An element of the review is the opportunity for responsible team members to present a given portion of the material (increment) - a demo. This allows for trust building, immediate feedback from key stakeholders and a better understanding of the customer's intentions. Team members learn 'first-hand' what they have done well and what needs to be improved, and can personally accept praise or reprimand from decision-makers.

In addition to the presentation and evaluation of the goal achieved, further product development is discussed - the next steps needed and their importance in the context of the entire Backlog. For example, at the end of the sprint, energy analyses were developed on the basis of the BIM models made. Their results are very unfavourable. The report is presented by the person responsible for carrying out the analysis and, with his insight, answers the concerns of the stakeholders still in the meeting. The decision of the contracting authority is to change the shape of the building. This will have a direct impact on the next sprint, which was to create a landscaping design. The results of the review are: a problem detected in time with the design, discussion of ways to avoid similar problems in the future, discussion of a possible solution, revision of the project backlog and, also importantly, the building of trust between everyone involved in the process.

Fig. 19 Effect of the retrospective - a board supplemented with ideas and comments from team members, on the basis of which a process improvement plan is created
Source: graph'it.

Sprint retrospective - a meeting in which the scrum team to analyse what has been done so far and how to optimise for future sprints (no more than 45 minutes for each week of the sprint in question). While the sprint review is to assess the value for the customer, the retrospective is an analysis of the technical aspects of the work itself. The team, with the assistance of the Scrum Master, examines what has been happening in terms of people's work, their relationships, processes and tools. All the positive elements and what went wrong are identified. The outcome of the retrospective should be a set of improvements written down and systematically implemented. There are many methods for conducting a retrospective. Workshops involving participants in describing their feelings about the process are used, e.g. by completing the categories 'start', 'stop', 'less', 'more', 'to keep' on a corkboard in the context of desirable and undesirable developments (see Fig. 19). Another method is to declare what made the team members 'irritated', 'sad' or 'happy' (MAD, SAD, GLAD method). Most important, however, is the participation of all team members and a culture of trust in which we do not blame each other for failures, but look for opportunities to improve.

Monitoring of work results

In line with the Lean philosophy, the work in Agile teams should also be rigorously evaluated. The main objective is not to distribute blame or praise, but above all to seek opportunities for improvement. Without performance metrics, improvement is difficult to achieve. Metrics related to running a project in the Agile methodology can be divided into those related to measuring the pace and quantity of work done and those that focus on the flow of value between the contractor and the client. They are intended to measure:

- results of the team's work and give an idea of the amount and type of value delivered to the client,
- the effectiveness of a particular Scrum team - its contribution to the overall success of the investment,
- the effectiveness of Scrum processes, e.g. their capacity, in order to implement improvements.

The following are some basic methods for examining the efficiency of processes and the teams implementing them.

Measuring performance - the main responsibility of the component owner. Indicators that can help measure the work done by component teams and the value delivered to the client are listed below.

- Sprint goal success. Verification that the objective defined at the planning stage has been achieved, through clearly defined metrics. For example, when planning the implementation of models, we verify that they have reached the level of detail defined in the BEP and MPDT. By defining sprint goals and then measuring how many sprints have achieved the goal, a qualitative assessment of the team's performance can be obtained.
- Avoided defects and incidence of defects. Ideally, the team should fully verify the partial products (stories) and avoid imperfections by understanding the client's requirements as well as possible. In practice, errors and misunderstandings will occur. It is therefore worth measuring the number of comments and corrections made to documents and analyses during sprint summaries.
- The speed and rhythm (aka cadence) of the Scrum team. It is useful to keep track of how many stories are delivered in what timeframe in successive sprints. This helps to estimate how much work the team can do in future sprints.
- Sprint Burndown Chart - The Sprint Burndown Chart is the classic representation of sprint progress. It shows the number of hours remaining to complete the stories scheduled each day during the current sprint. The summary will clearly show if the team has a chance to complete the sprint successfully.

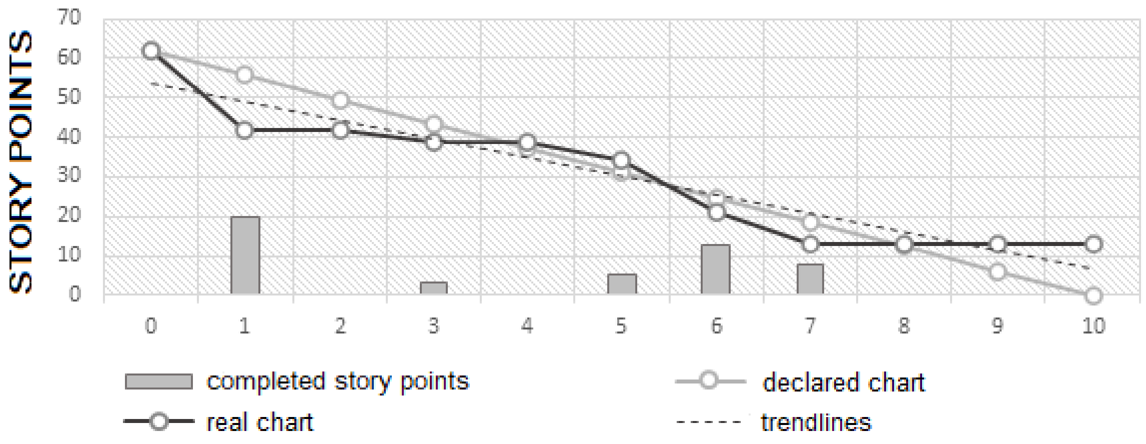

Fig. 20 Example Burndown Chart, indicating the pace of story execution during a sprint against assumptions
Source: graph'it.

Measuring business effectiveness as measured throughout the contract and the overall investment - a key responsibility of the project owner and the investment management team. Indicators that help assess the teams' effectiveness in achieving business objectives are listed below.

- Time to market with a finished product - this is the period during which the product starts to deliver value to the client, e.g. the time during which a tender can be executed on the basis of design documentation.
- ROI - return on investment for a project calculates the total value generated from the product compared to the cost of the sprint required to develop it. Scrum has the potential to generate ROI much faster than traditional project delivery methods because individual products can be deployed as soon as they are approved. With each sprint, Scrum teams create more and more added value, which can translate into real value for the client. While this is of limited use in site work (unless the facility is partially commissioned), iterative project work allows value to be given quickly, for example by generating promotional material even before the project documentation is completed.
- Capital transfer - measures whether it is worth continuing with a project under given assumptions, whether the economic value of the project exceeds its costs. For example, facility performance analyses can show huge future operating costs or errors that make implementation impossible.

- Customer satisfaction - there are several well-known indicators for measuring customer satisfaction. Using surveys and examining customer satisfaction indicators in workshops indicates whether teams are achieving their ultimate goal of delivering value to customers.

Monitoring the Scrum team - the primary responsibility of the Scrum Master. The indicators listed below can help the Scrum team in monitoring activity and identifying problems early on, before they affect work and product development.

- Sprint retrospective - the comments discussed during the retrospective show the overall state of satisfaction of the team.
- Team satisfaction - a periodic team survey is important to see how satisfied team members are with their work. It can also provide warning signs of organisational culture problems, team conflicts or process problems.
- Team retention - a low number of member changes within a team indicates a healthy working environment, while a high number of member changes may indicate the to the contrary.

It is a good idea to review individual metrics throughout the project and present them at sprint summaries and retrospectives.

Agile scaling

As already mentioned, not all teams involved in the process need to implement Scrum in order to agile manage one team. However, there are methods that allow the organisation of several or even a dozen Agile teams. These methods are used by large teams, including large Silicon Valley corporations. So how do you successfully introduce Scrum outside your own team? Here are some basic best practices.

1. Defining the minimum requirements for the end result of the work. It is often difficult for the client to clearly communicate the vision and key requirements. For BIM methodology, these elements should be included in the EIR. It is therefore good practice to divide the objectives and required BIM delivery methods into key (core) and additional ones. This way, with the support of the product owner, teams can focus on the key elements first.
2. Common Product Backlog. In line with Agile principles, the schedule indicating the highest priority issues at any given time will change as the work progresses. It is therefore important that it is organised with the participation of representatives from all teams and that everyone, not just managers, has access to the current version.

3. Ensuring the right IT infrastructure is in place. Firstly, it is necessary to invest in tools to coordinate a larger number of (usually dispersed) teams. These tools include, of course, CDE-type platforms (or whole ecosystems of them integrated in a common environment). At the design stage, it is good if we have a platform that allows us to work on central models in the so-called cloud. Another type of software needed will be a tool for maintaining and sharing the Backlog (project schedule). This is where the aforementioned tools such as JIRA or the cloud version of Microsoft Project can come to the rescue. It is important that the software is easy to use and provides quick access to the most up-to-date data.
4. Maintaining small teams. Regardless of the size of the business, full agility is required, achievable only by small, self-organised teams. Jeff Bezos has repeatedly mentioned that Amazon operates with a structure of teams that can eat two pizzas (*two-pizza rule*).
5. Keeping iteration cycles relatively short. As coordination and decision-making in larger groups increases the risk of process inertia, it is all the more important to pay attention to rapid implementation and verification of the increment.
6. Selection of the right product owner. This role should be performed by a project manager/manager who has the highest possible competence and knowledge of the project implementation and at the same time is in close contact with the decision makers on the ordering side. The role of product owner can be duplicated in individual teams, where it will be played, for example, by (information) managers of individual contractors.
7. Synchronisation of work. The work of the different teams needs to be synchronised in a way that allows joint coordination, meetings and deliberations. Although this seems obvious, in practice a clearly delineated and agreed framework (described, for example, in the BEP) is necessary to enforce a schedule for information dumps or updates of coordination models in the BIM software environment.
8. Choosing the right working framework. There are a number of established and proven Agile scaling methods. Among the best known are:
    - Large Scale Scrum (LeSS) - relatively the simplest method prepared in two *frameworks* (*frameworks*): LESS designed for 2-8 Scrum teams and LESS huge for up to dozens of teams working on a single product;
    - Scaled Agile Framework (SAFe) - the method assumes 4 frameworks depending on the scale and type of project - Essential SAFe, Large Solution SAFe, Portfolio SAFe, Full SAFe;
    - Disciplined Agile Delivery (DAD) - proposes a hybrid approach, unifying the best practices of many agile workflow frameworks such as Scrum, SAFe, Extreme Programming etc.;

- Scrum Of Scrums (SOS) - a method discredited by experts, mentioned mainly because it is quite popular. It assumes the building of Scrum teams at additional levels on the principle of a branching tree, where selected team representatives form teams at the next level of the organisation.

Each of the above methods has its own specificities, but in simple terms, the key is to add another level of coordination of work outputs and additional roles to support the product development process. LeSS supplements the planning stage with 'sprint 1 planning' carried out in the product owner team. This team consists of delegated representatives from the various work teams on a rotating basis.

Once the key stories have been selected and allocated to the sprint, 'Sprint 2 planning' is organised. During this event, the Sprint Backlog is already created in the working teams and tasks are assigned. Thanks to the presence of the representatives performing the work in the teams (and not only the managers), it is possible to carry out real planning together and clarification of concerns with the product owner. Similarly, retrospectives are conducted - first within teams and then between them. This provides an opportunity to improve the dynamics of work at each level of coordination. An exception to this rule are sprint summaries, carried out with the fullest possible participation of all team members and customer representatives. They are increasingly organised - at least in part - remotely, thus avoiding clusters. At the same time, the presence of engineers carrying out specific tasks provides the opportunity to ask very specific questions. Combined with information models ready for presentation and analysis, this allows direct discussion with decision-makers and instantaneous decision-making crucial for further work. The followingFig. diagram of the LeSS workflow is shown.

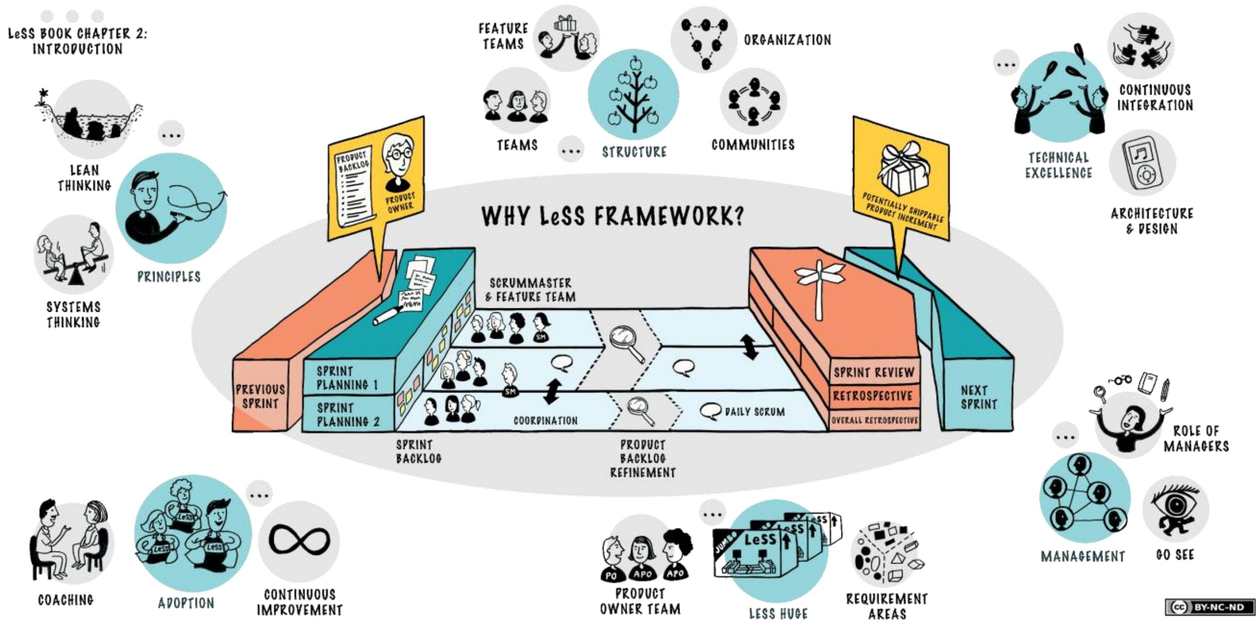

Fig. 21 Schematic diagram of the Large Scale Scrum (LeSS) work.

Summary of Part Two

As the creators write, Scrum (Agile) is easy to understand but difficult to master.

Above all, changing management requires a change of culture in the organisation. As with the Lean philosophy, the support of the organisation's decision-makers and the full commitment of the team are crucial. The typical aversion to variability in the construction sector - associated with loss of control - is one of the main obstacles to implementing the Agile methodology. The other is the lack of substantive support from leaders, who should act as mentors instead of 'managing'. Interestingly, both of these problems also apply to the implementation of the BIM methodology.

In order for Scrum teams to function smoothly, it is necessary to ensure that the necessary competencies are in place within the project to minimise the need for external support to carry out compartmentalised tasks. For individual members, a flat hierarchy within the team can prove problematic. Some employees like clear vertical structures, where the serial employee has a specialist, manager or director above him or her. Working in a Scrum team will probably not guarantee promotion by "serving" several years in the company. Rather, it is rewarded by deepening one's competences, becoming more fully involved and taking on more responsibility for the tasks entrusted. Of course, the names on the business cards can remain, but more important is the willingness to work together for the benefit of the client.

It is important to remember that not all tasks and teams require agile management. In the case of simple and repetitive processes, where precision and speed of execution are important, Scrum may not work. One can make the military analogy mentioned above and compare the regular army to special units. Both formations have their uses, although they are organised according to completely different principles. However, short work and verification cycles can be used almost anywhere, but especially where we do not know the precise method of arriving at an optimal result. As shown in Fig. 22 - even on a construction site, which is typically a cascading process, some agility can be woven into the daily work. For some projects, where documentation is refined during construction, this can be crucial. Agile can therefore be a good answer to the uncertainty surrounding both the changing needs of clients and users of construction facilities.

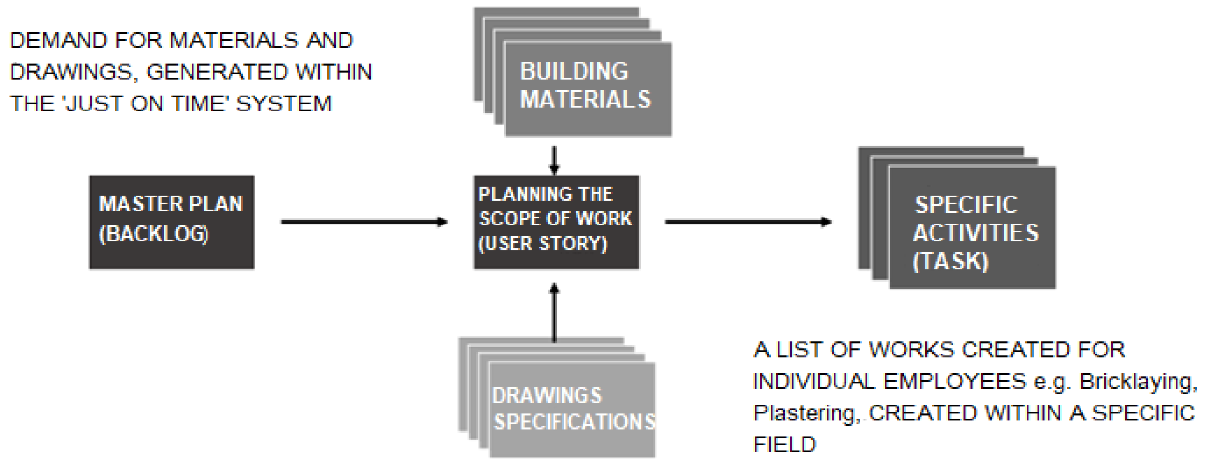

Fig. 22 User story planning scheme on site
Source: own elaboration

So how do we distinguish between traditional and agile organisations? Characteristics of the latter include:

- speed and flexibility of action taken,
- an efficient response to change and uncertainty,
- high quality and highly personalised products and services,

- willingness to create products and services with high information content and added value,
- the desire to seek and activate key competences among team members,
- rapid response to social and environmental issues,
- a synthesis of different technologies,
- integration both within and between companies.

It could be said that these characteristics should describe any team wishing to implement a mature BIM methodology. Both the Lean philosophy and agile management methods respond to the problems caused by the dehumanisation of mass production processes. The increasing volatility of the surrounding world and the need to respond quickly to the requirements of customers and users of buildings and infrastructure seem to require an increasingly flexible approach to investment processes. What was promoted as modern construction a dozen years ago is now often regarded as substandard. Building respect among project participants, responding quickly to change, focusing on data collection and analysis, the need for continuous learning and improvement, reducing waste and delivering the highest possible value to the customer are no longer the characteristics of a Lean organisation or an Agile team - they are the universal operating principles of modern companies.

In the context of this book, however, the most important point is that BIM methodology can be implemented (at least in part) without an in-depth knowledge of Lean or Agile, but no construction sector organisation will reap the full benefits of modern project management without the use of BIM.

PART THREE

Author: dr inż. Paweł Tadejko

Digital Twin – BIM on steroids

Digital twin and BIM are concepts related to information management about construction objects. However, there are big differences between them. In an ideal environment, a digital twin is the most complete picture (in digital form) of phenomena occurring in the real world. It may concern machines in the production hall, autonomous cars or intelligent buildings. The properties of an intelligent building arise as if by chance, because the digital twin is implemented thanks to the possibility of data processing real-time and constant updating of the state of objects and processes.

As we already know, Building Information Modeling is a process of designing and managing information about building objects during their life cycle. However, this is only a small subset of the data and information of the digital twin, most often "frozen in time". Somewhere in between is the smart building, which is a subset of the digital twin. An intelligent building uses control systems and data collected in them to more optimally control the parameters of building systems, such as air conditioning, lighting, heating, etc.

The digital twin tries not only to collect and present building data from all available sources to give us a **complete digital picture** of the building, but also gives us new possibilities. The digital twin is dynamic and allows us to manage and monitor a physical object via the Internet of Things (IoT), big data and artificial intelligence tools. This makes digital twin a more advanced tool and is considered the next generation in BIM development.

BIM at the stage of operation

Building Information Modeling, thanks to the use of digital tools and three-dimensional models, also allows for obtaining current and accurate description of the building during its operation. Over time, BIM will become an inseparable element of the design and construction process, and its use in the operation phase of a building is becoming more and more common. And not only because of formal procedures, ISO standards or SWZ requirements. BIM (and its extension in the form of a digital twin) at the stage of operation can bring measurable economic effects related to it keeping the investment.

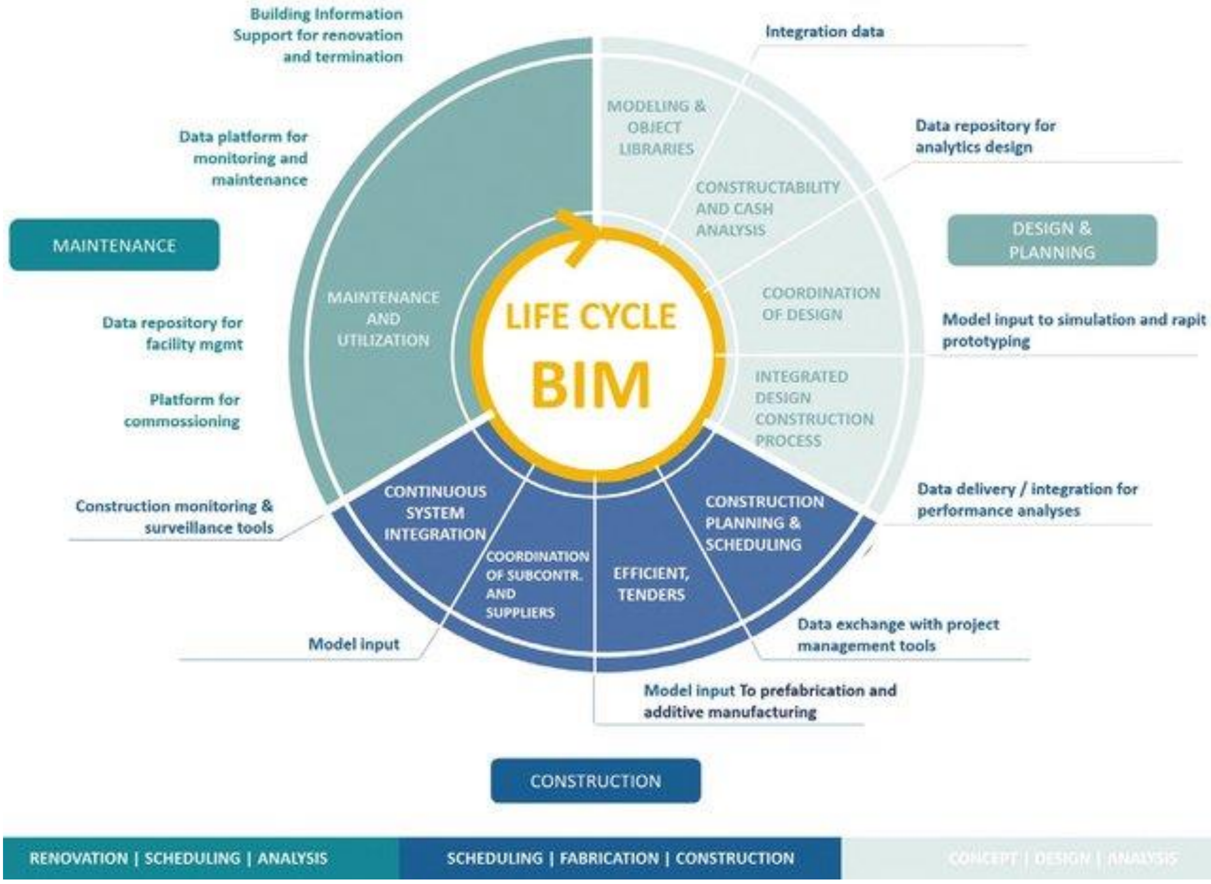

Fig. 23 The scope of the BIM model in the phases of design, construction and maintenance of buildings.
Source: Bocconcino, Maurizio & Turco, Massimiliano & Vozzola, Mariapaola & Rabbia, Anna. (2021). Intelligent information systems for the representation of the city - Urban survey and design for resilience.

In the operation phase, BIM can act as a facility management tool (providing current and accurate information about the facility), enabling e.g. quick identification and resolution of technical problems. It can also be used as a platform for analyzing data from monitored systems to better plan service and maintenance work.

Benefits of using digital twins in construction

Offering a high degree of interoperability and automation, digital twins have the potential to revolutionize several aspects of the construction business. In this section, we will focus only on selected benefits of using digital twins in construction.

The main advantages are of course:

• Better resource management

• Easier communication with stakeholders

• Decision making and planning based on more reliable data

• Automated progress monitoring

On the other hand, data aggregation and analysis, in particular with the use of machine learning, opens up new possibilities, e.g. such as:

- monitoring data collected from the installation regarding usage and performance in real time; presentation and visualization;
- possible "learning" of systems and designing optimization scenarios, based on the analysis of collected data;
- running simulations and testing of "what-if" scenarios, including security procedures;
- launching anomaly analysis and system failure forecasting systems - predictive maintenance systems;

Industry 4.0 technologies in BIM

Implementing the CDE platform as the first step towards project management in the BIM methodology is just the beginning. Full use of the possibilities of data analysis at the stage of investment operation requires not only the CDE platform, but also additional tools and systems for data storage and analysis.

“Internet of Things”, “Artificial Intelligence” (AI) and “Big Data” technologies are key technologies for Industry 4.0. Thanks to them it is possible to analyze large amounts of data collected from IoT sensors, in particular real-time analysis, necessary for control, operation of security systems and the use of Artificial Intelligence (SI) algorithms, e.g. in algorithms (predictive maintenance).

These technologies are the key to the Digital Twin idea in construction. Hence the reference to Industry 4.0, which is strongly based on technological pillars:

- IoT / IIoT - Internet of Things and Industrial Internet of Things - as technologies used to provide data from building facilities and installations in these facilities;

- Cloud Computing - in the classic form and in private cloud configurations, as well as edge computing (ang. fog/edge computing) - as a technology for storing data from a digital twin;
- Machine Learning - understood as algorithms and artificial intelligence tools that have the ability to learn without having to explicitly program the rules they are to follow.

The use of AI can take place as part of autonomous systems, but it can support the implementation of tasks for which decisions are made by humans. Interestingly, in recent years, there have also been publications that present the possibilities of using intelligent systems to support decision-making processes in the implementation of the lean maintenance concept, which allows to increase the operational efficiency of infrastructure. In particular, there are opportunities to use the artificial intelligence method to search for relationships between specific activities carried out as part of the lean maintenance implementation and the results obtained[5].

It can even be said that systems based on AI algorithms are a model implementation of the idea of self-improvement and implement the Deming cycle with the use of AI tools. The STUDY, CHECK step - by analyzing the results of the operation of building installations (as an equivalent of the AI learning process) - builds knowledge about the use of building objects. When, in turn, ACT - takes action to implement an improved control process for building systems. For the BIM methodology, this means the processes of exchanging information and correcting the way the installation works in relation to the design assumptions.

Good BIM practices at the stage of building operation

With the use of AI tools, the digital twin extends the BIM methodology to provide the client and facility managers with the right tools to handle MEP (mechanical, electrical, plumbing) and HVAC (heating, ventilation and air conditioning) and solve maintenance issues with digital twin: date of installation, materials, service life, etc. Good BIM practices at the operational stage of a building should take into account the following aspects:

1. Integration with building management systems: BIM should be tightly integrated with building management systems such as access control systems, fire protection systems and

[5] The Use of Artificial Intelligence Methods to Assess the Effectiveness of Lean Maintenance Concept Implementation in Manufacturing Enterprises, Applied Sciences - Design and Management of Manufacturing Systems, 2020, https://www.mdpi.com/2076-3417/10/21/7922

energy control systems. This integration allows to obtain current information about the technical condition of the building and enables a faster response to any problems.

2. Model update: The BIM model should be updated regularly to keep it current and accurate. Updates should be made in a timely manner, for example after changes to the facility or after renovations.
3. Team collaboration: During the operation phase of a building, it is important that the facility management team collaborate with each other and with other service providers. This cooperation allows us to obtain current information about the technical condition of the building and enables faster response to any problems.
4. Planning and review: BIM should be used for planning and carrying out regular inspections of the building. The BIM model can be used to plan maintenance work in both classic and using preventive maintenance systems.
5. Support in identifying and solving technical problems: BIM enables quick identification of potential technical problems and also helps to solve them. BIM models contain all the necessary information about the facility, including its structure, installations, functional layout and other important parameters. This allows maintenance or repair to be carried out quickly and easily if necessary.

Nanyang Technological University Singapore - Case Study

The Nanyang Technological University (NTU) EcoCampus[6] project in Singapore is one of the most interesting examples of using a digital twin to optimize the operation of installations in buildings, and thus also support the implementation of the Nearly Zero-Emission Building (NZEB) idea. It uses interactive 3D visualization and detailed master plan development to model energy use and optimize efficiency across the campus, along with detailed simulation and calibrated modeling of 21 campus buildings. The two-phased project used IES's[7] innovative ICL (Intelligent Communities Lifecycle) technology to provide high-level visualization and analysis of the campus' energy reduction test technologies.

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[6] NTU Singapore | IES, https://www.iesve.com/ntu-singapore, 2023
[7] IES Virtual Environment | The Leading Integrated Suite for Accurate Whole Building Performance Simulation
https://www.iesve.com/software/virtual-environment, 2023

NTU primarily wanted to understand, at the campus level, which testing solutions work best and determine the optimal scale and location of their use. Using actual operational data from utilities and NTU's Building Management Systems (BMS), IES was able to assess and identify opportunities to achieve optimal performance in existing operational buildings on campus using the innovative Ci2 process (Collect, Investigate, Compare, Invest).

Fig. 24 Campus Nanyang Technological University

IES sees ICL as the "digital twin" for sustainable design. The digital twin stays in sync with the physical object through sensors that allow it to capture a representation of the physical object at any time. All necessary tests, analyses, simulations, etc. can now be performed on the digital twin, instead on a physical object, using accurate data about it in real time, rather than assumptions about its properties.

During the 'capture' and 'research' phase, building information was collected and operational data imported into iSCAN to check for problems/defects in a selection of 21 buildings on the NTU campus. The following issues were highlighted: low and high CO2 levels, unstable off-climate temperatures, lower than expected return air temperatures, faulty energy meters, and temperature setting issues in staff offices and conference rooms. The first stage of implementation – only with the use of intelligent control of building installations brought the following results, Phase 1:

- 10% of estimated energy savings
- S$3.9M financial savings (singapore dollars)
- 8.2kt – carbon savings counter value

Data from designed BIM models, including geometric and non-geometric energy efficiency strategy and building component data, can be effectively analyzed using discrete event simulation modelling. Key efficiency indicators such as cost, time and energy efficiency improvements are outcomes specific to each strategy. Thanks to the use of AI tools based on machine learning algorithms that learned from data collected from the operation of the building, even better results were achieved in Phase 2:

- 31% of estimated energy savings
- S$4.7M financial savings (singapore dollars)
- 9.6kt - carbon savings counter value

Choice of solutions - challenges Digital Twin

The implementation of such advanced solutions presents us with many opportunities, but also many challenges. The data architecture in digital twin implementations in construction may vary depending on many factors, such as: project scale, business needs and technological limitations. However, some commonly used approaches are:

- Cloud computing: A lot of data, such as 3D models, air quality, traffic and noise data, can be stored in the cloud. The cloud enables access to data from anywhere and allows information to be shared between different users.
- Edge / Fog computing: For data that requires fast access and processing, such as sensor and sensor data, consider using edge or fog computing. In this approach, data is processed locally on devices and only the necessary information is sent to the cloud.
- Hybrid Architecture: A hybrid architecture can also be used where data is stored in the cloud and processed at the edge as needed. This allows us to combine the best of both approaches.

It is important that the data architecture is secure, reliable and flexible to allow for easy integration with other systems and services. It is also worth paying attention to costs and scalability to avoid problems related to growing needs as the project develops.

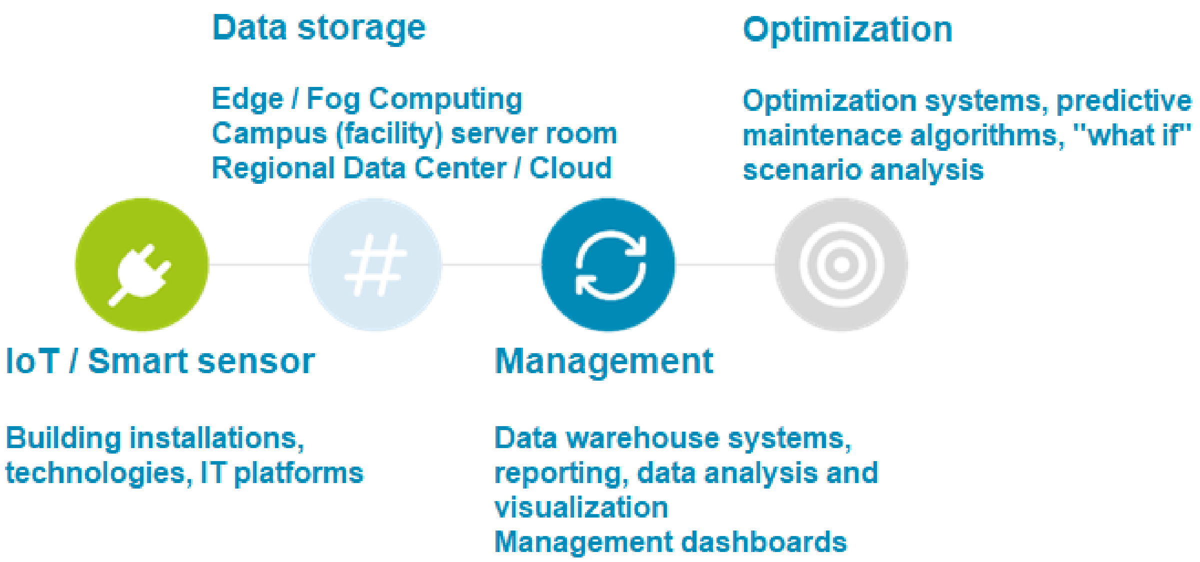

Fig. 25 Components of a digital twin implementation
Source: own elaboration.

If we look at the components of the implementation, it turns out that we have more questions of strategic importance there:

- How to design installations to help monitor KPIs?
- How to verify which technology providers have APIs that allow for easy integration?
- Where to store data - own data center or Edge/Cloud Computig?
- For what purposes may cloud computing be necessary?
- What storage and data warehouse systems to use?
- How to choose the components of data analysis, optimization and simulation?
- Which components to outsource and which to build yourself?

Key decisions are often assisted by technological partners, BIM experts or consulting companies. In the case of BIM and digital twin, more and more often key decisions must be developed together with technology suppliers from the IT industry. Because it is data that is called "gold" or "oil" of the 21st century, and organizations that are able to use data are "data-driven organizations". Without data and special systems for their storage and analysis, optimization systems, not only those based on AI, could not work.

SUMMARY

The project "Organization of a Manager's School for adult vocational education and training" was implemented in the period of March 1, 2022. – February 28, 2023 The goal of the project has been achieved - international cooperation has been established, allowing to improve the quality of work and practices of the involved organizations, ensuring the possibility of transformation and change leading to the improvement of each of the organizations.

As part of the project, there was a transfer of knowledge and practices in the use and implementation of instruments for digitization in construction, such as Lean Management, Building Information Modeling, Lean Construction, Agile management.

The project was implemented:

a conference opening the project introducing the substantive subject of the project, i.e. modern digital solutions in construction, Lean Management, BIM technology,

trainings on Lean Management in construction, during which issues were raised, e.g. digitization of processes in construction, industry 4.0, digital twins, information process risk management, information process planning workshop, building information about the facility, Lean Construction, Agile management, BIM, Lean management in practice, Agile elements in BIM design - two trainings were carried out - the first in Poland, attended by representatives of associated companies within the Polish Construction Cluster and the second one in Slovenia, which was addressed to representatives of companies associated within the Slovenian Construction Cluster,

- study visits to Polish and Slovenian companies, the purpose of which was to exchange experiences, learn good practices, learn about implementation solutions,

- conference summarizing the project, during which the developed effects of the project were presented.

The implementation of the project created an opportunity to discuss the practical aspect of implementing solutions related to digitization in the construction industry.

BIM technology will primarily improve the efficiency of the construction process - i.e. reduce the waste of time and materials. The design process is longer and more expensive - but this is due to the need for greater information saturation, better coordination of industries and more decisions to be made at the design stage. An accurate digital model of the building with all its components allows for better valuation, planning of works and supervision of implementation. Detailed design allows you to avoid conflicts that are costly and may affect the deadline for the implementation of the project.

It is also worth looking at the reasons for the lack of efficiency during the implementation of investments in the construction sector, which include:

- *Poor design – most often imprecise and uncoordinated – also due to the client's lack of decision.*
- *Differences between designers and contractors – solutions are designed incorrectly and/or expensive and require redesign during construction.*
- *Insufficient construction planning - insufficient coordination of individual contractors.*
- *Unreliability of individual subcontractors manifested by poor quality (requiring corrections) and delays. Delays are cumulative.*

Tomasz Perkowski, Architect / Product Developer, Unihouse SA

BIM will only allow for significant savings in the construction investment proces in the case when all participants of the construction process, including the Investor and contractors (and not only designers) will be able to navigate in BIM. Building information modeling (BIM) only as the coordination of the design process itself does not seem necessary, and in some cases it may even be a hindrance. Of course, it is easy to detect clashes between installations, but of course, this only matters when all design disciplines model the installations, keep an eye on each other, and remove clashes with each other. Managing information about the Investment from the beginning of its design to the management of an already functioning facility brings savings in renovations, reconstructions, services, etc. If the Investment is implemented in accordance with the design and subsequent updating of data at the facility management stage is a great facilitation, but it requires large expenditures on the part of all participants in the process from design to management. For this to happen, BIM must live from the beginning to the end of the object.

The lack of efficiency during the implementation of investments in the construction sector results from the lack of knowledge of the project, the purpose of the project and the lack of coordination on the construction site between the participants of the construction process. Invariably, for as long as I can remember - a significant lack of efficiency also results from the lack of sufficient decision-making on the part of the Investors and the attempt to transfer all responsibility for the Investment to the designer and contractor. If BIM is to be successful, the Investor must consciously move in it and actively participate. Even if the designer and contractors will work efficiently in BIM, without an active Investor, efficiency will still be lame.

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