A new method combining BIM and GIS data to optimise the sustainability of new construction projects in Switzerland

Autor/s

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Abstract

The UN 2030 Agenda for Sustainable Development relies on national municipalities to successfully implement the Sustainable Development Goals (SDG). Research indicates many of the SDG are related directly or indirectly to activities in the construction industry. Achieving the SDG requires instruments which are able to digitally model various sustainable development scenarios. However, it is still unclear exactly what has to be modelled and how. This paper presents initial findings from the GEOBIM project. The aim was to investigate and show the extent to which it is possible to support the optimisation of the sustainability of construction projects by using BIM and GIS data. A major problem with today's construction projects is that too often sustainability and digitization are still viewed as two separate topics. This is due to industry uncertainty about to what extent it is possible to benefit from synergies between the two areas. The Swiss certification system developed by the SGNI (Swiss Sustainable Building Council) is used as the basis for the analysis. The system is divided into 7 groups of criteria, with 22 individual topics. The criteria cover the most important sustainability aspects, including key topics, e.g., sustainable development, life cycle management and digitization. A total of 343 indicators are evaluated. The GEOBIM project includes a demonstrator where it is possible to explore and show exemplarily, how the sustainability criteria of the international DGNB system can be supported to a large extent by BIM and GIS data. The findings will be used to develop a new method, which allows a systematic analysis and use of existing BIM and GIS data to optimise the sustainability of construction projects. One of the key findings from combining existing BIM and GIS data is that it allowed a variety of sustainability aspects to be more easily visualised and understood. The corresponding possibilities can be demonstrated exemplarily using the example of the demonstration project. Virtual and augmented reality technologies enable exploring new and innovative ways to improve the design of buildings with respect to sustainability. An example is the visualization of a large number of sustainability aspects as part of the planning process. This enables clients to check and control at an early stage, whether the planned building really supports their specific needs and meets sustainability and other user requirements. The results illustrate the use of BIM- and GIS-data for the optimization and visualization of the sustainability of buildings as part of certification processes, which make digital planning valuable in the long term. In order to achieve a multifactorial optimisation of the sustainability of real estate also requires a high level of understanding of the complexity in the planning-accompanying processes. The project specifically shows how an efficient and sustainable combination of the two methods is possible within the framework of Lean Planning and Construction Management. This is highly relevant and will be absolutely necessary in the future in order to be able to significantly reduce the economic costs of sustainability certification through the intelligent use of this new methods and the resulting synergies.

Introduction and Importance

In the face of the climate crisis, many companies around the world have decided to align themselves with the goals of the 2030 Agenda. 17% of the SDG targets are directly dependent and 27% of the targets are indirectly dependent on these sectors' activities from the construction industry [12]. To translate them into practice, these companies often work with already established Corporate Social Responsibility (CSR) instruments. An important part of CSR is sustainable procurement, whether of consumables, furniture, infrastructure, or buildings. As with products, the consideration of the entire life cycle of buildings is also of great importance in terms of holistic life cycle thinking. When constructing new buildings, the aim is to use the investments made to generate the highest possible added value in all three dimensions of sustainability - economic, ecological and social. In the case of larger construction projects, this is a major challenge due to the complexity of the influencing factors to be taken into account and the complexity of the planning and construction processes. The design and construction team and the portfolio holders are therefore increasingly using sustainability certificates when constructing new buildings and when redesigning existing properties in order to ensure the sustainability of the measures. This creates increasing market advantages for construction companies that know how to digitally transform their planning and construction processes in terms of efficiency and also to optimise the sustainability of the resulting structure.

In the European context, proof of the sustainability of investments in Real Estate (RE) will become an unavoidable necessity in the future within the framework of the EU taxonomy. Within this process, the requirements will also increase. However, sustainability certificates are considered demanding and require the synchronous processing of a large amount of information, as topics such as life cycle assessment, climate resilience, circularity, pollution, water consumption and biodiversity must be considered in an interrelated and networked manner. This applies not only to new buildings, but also to the sustainable transformation of existing buildings, sites, and neighbourhoods. Sustainability certificates are of central importance in the implementation of the 2030 Agenda in the RE industry. If a rapid implementation is to take place in a large scale within the next few years, this will result in huge and yet unsolved challenges. Two strategies are conceivable as solutions. 1) reducing or greatly simplifying the sustainability requirements in the certification systems, or 2) digitalisation could be actively used to simplify and automate certification processes and thus significantly accelerate them. The first approach would be economically sustainable, but not in terms of its impact. A certification system can also be seen as a modelling of all the interrelationships relevant to the sustainability of a building. If this modelling is simplified too much, the risk arises that no meaningful conclusions to optimise sustainability can be generated with it, since the complexity of the modelling no longer corresponds to the complexity of the real interrelationships. For these reasons, the second approach using digitisation seems to make more sense in order to be able to respond adequately to the existing challenges of achieving the goals of the 2030 Agenda.

The project "GEOBIM - GIS and BIM -based collaboration framework for the simulation of sustainable development scenarios for areas and communities" examines, among other things, the potential for digital support of certification processes, which can be achieved through the intelligent use of GIS (Geographic Information System) and BIM (Building Information Modelling, Method & Management) is created in order to accelerate processes, reduce costs and increase the resulting added value [4].

1. Research question

This article focuses on the project results, which deal with the following sub-questions

- How can sustainability certification be supported now and in the future by including information from GIS databases and BIM models?
- How do GIS and BIM actually come together in the demonstration project? How does GIS and BIM lower the certification costs and how does the certificate make the use of BIM really worthwhile?
- What is the value of visualising sustainability trade-offs for accelerated, "lean" governance of decision-making processes within lean planning and construction management?

- How can the two complex processes of sustainability certification and GeoBIM-based planning be designed and methodically combined in such a way of co-complexity management that a win-win situation can be created for everyone involved?
- What innovations are already being implemented in Switzerland in relation to the IPD- (Integrated Project Delivery) and the Design Build approach, where the proposed model can be based on?

2. Preliminary work and state of research:

In the Swiss construction and real estate industry, BIM has become increasingly important in the last 10 years. During this time, most large construction companies and architects' offices have managed to partially convert the technologies and methods they use to incorporate BIM. Nevertheless, there are still many uncertainties in understanding and knowledge gaps in the practical implementation in Switzerland in order to comprehensively use the potential of BIM [19]. Unfortunately, far too little is known about the possibilities of using BIM in connection with sustainability issues such as Life Cycle Assessment (LCA). Possible reasons for this are a lack of methods, workflows and tools [14]. The standards of Building Smart and BauenDigitalSchweiz also lack direct coordination with sustainability assessment systems.

The GeoBIM enabled SGNI sustainability assessment needs to take into account the established BIM industry standards such as the ISO 19650 [13], the international classification systems “Industry Foundation Classes” (IFC), “Construction Operations Building Information Exchange” (COBie) but also the established Swiss eBKP-H structure developed by CRB organisation in Switzerland. Moreover, in order to make sure that the SGNI required information for certification is available, the building owners should make use of BIM information requirements which include: Organisational Information Requirements (OIR), Asset Information Requirements (AIR) and Exchange Information Requirements (EIR) to ensure that information is captured allowing the real estate organizations and building owners to certify and monitor the sustainability performance of real estate.

For SGNI re-certification, an up-to-date Asset Information Model (AIM), often referred to as the “As-Built BIM” model is essential. This is defined as a structured repository of information needed for making decisions during the lifecycle management phase of a building. For some sub-criteria, a Digital Twin containing the live connections of data and information that ties the virtual and real buildings together. Live data generated by sensors can give valuable insight and transparency into the sustainability performance of real estate during operation.

Lean construction management (LCM) and BIM are increasingly often used together because of the synergies with respect to integrated project delivery [11]. BIM can enable LEAN goals such as reducing waste, increasing transparency, elimination of unnecessary process stages. Besides that, SGNI certification can take advantage from better management of information, a benefit that has been attributed to BIM and lean integrative principles [18]. Lean management has been adopted in the recent past due to its abilities to improve productivity and efficiency in the building industry [8] and it shows great potential in increasing sustainability, which can support the SGNI certification scheme.

BIM and GeoBIM has already been shown to have a significant impact on sustainable construction. The literature review shows some important benefits of BIM and GeoBIM for sustainable construction in relation to lifecycle management:

- Estimating energy performance for the whole building life-cycle [1]
- Supporting the calculation of payback period for sustainable components
- Daylight Simulation
- Deconstruction, rubble management/recycling
- Cost Estimating
- Increased accuracy (precise building quantities and cost calculation)
- Increased collaboration and transparency [16]
- Visualising in 3D alternative sustainable design solutions
- Possibility to combine 2 or more analysis for trade-offs (i.e., environmental and cost impact) [2]
- Assess design solutions based on lifecycle costs or environmental impact
- Supporting the calculation of environmental impact for the whole building lifecycle
- Solar energy related analysis, planning and maximising the solar energy generation with PV

Immersive technologies are disruptive tools based on spatial mapping or context awareness capabilities which enable new interaction possibilities between the real-world and digital twins [7]. Such innovative immersive computing platforms have great potential to better understand and visualise the sustainability SGNI criteria in a GeoBIM environment.

With regard to the sustainability instruments used, over 25 instruments and systems are in use in Switzerland [5]. In addition to the international systems of BREEAM, LEED and DGNB, there are also widespread national systems such as Minergie and SNBS [15]. In Switzerland, about every fifth new building is certified with one of these standards. However, the system architecture of these assessment tools is very different. Most of these are organized by topic. The international DGNB system stands out here with an actor-based basic logic. The Swiss DGNB system of the SGNI, expanded by 52 indicators, has the broadest range of topics of all systems used in Switzerland with a total of 343 indicators (new construction) [17]. Compared to the original German system, the corresponding Swiss pilot criteria also cover the topics of CSR, digitization and integrative planning processes to a greater extent.

Previous studies have shown that in the Swiss DGNB system (V17) of the SGNI, the choice of building materials and building products has a direct influence of 53.1% and an indirect influence of 80.5% on the overall rating [6]. In addition, reuse products and recycling products are taken into account and the dismantling ability and recycling degree of all important material fractions are also evaluated. The influence of materialisation and the recyclability of materials is thus very large overall [9]. As part of the planned BIM-based certification (BIM planning certificate) of the SGNI from 2024, it is planned to coordinate the certification processes even more closely with the BIM-based planning processes.

For this, however, it is necessary to consider them together with the corresponding cooperation models such as IPD and Design Build approaches. In the Swiss Design Build approach from The Branch, one of the leading dialogue and collaboration RE platforms in Switzerland, various collaborative workgroups work together, each made up of planning, engineering, construction and executing companies with regard to an integrated process model for the project management. An important success factor is a common understanding of values and the implementation of a common value culture. More and more new service models for the optimization of buildings over the entire life cycle of real estate will develop from this.

3. Methodology:

As a basis for the comparison between the GIS&BIM-based planning process and the certification process for sustainability, the situation in Switzerland was analysed. Relating to BIM planning, many basic documents exist in Switzerland, which were prepared by the BauenDigitalSchweiz association. The definitions from the BIM execution model [3] proved to be the most relevant for the comparison. Regarding sustainability certification, the SGNI process definitions for the application of the Swiss DGNB system in Switzerland were chosen as the basis.

The methodological procedure for investigating the research question is divided into the following steps:

1) In a first step, it is investigated for which aspects from the SGNI's Swiss DGNB system GIS-based data or data sources already exist in Switzerland that could be used directly or indirectly for a criteria-based sustainability assessment. A distinction is made between the availability of data sets at (a) national, (b) regional (or at cantonal level) and (c) local (at the level of individual municipalities). Then the Swiss DGNB system is analysed to determine which criteria and indicators can be supported by information from BIM models or a BIM-based planning process. A distinction is made as to which information is already available as standard in three-dimensional BIM models and which of the aspects examined could be modelled and visualised in a BIM model at all.
2) In a second step, a demonstration project is used to specifically analyse which framework conditions must be defined in order to be able to use the combined information from GIS and BIM optimally, so that the resulting synergies for certification and the reduction of certification costs result and decision-making processes are optimally supported be able.
3) In a third step, it is examined to what extent the SGNI certification processes and the BIM-based planning processes of BauenDigitalSchweiz as well as the GIS data integration can be coordinated via a coordinative process model in such a way that possible synergies are optimally used and a sustainable and digitally supported Lean Planning and Construction Management is made possible. Based on this, it should be clarified what innovation is already being implemented in Switzerland in relation to new performance models with IPD and Design Build approaches with a work group organization across the entire real estate lifecycle.

4. Results:

As part of the analysis of the GIS databases currently in Switzerland, 81 GIS datasets (2 local, 24 regional and 55 national) were identified, which can be used to support the sustainability assessment of RE.

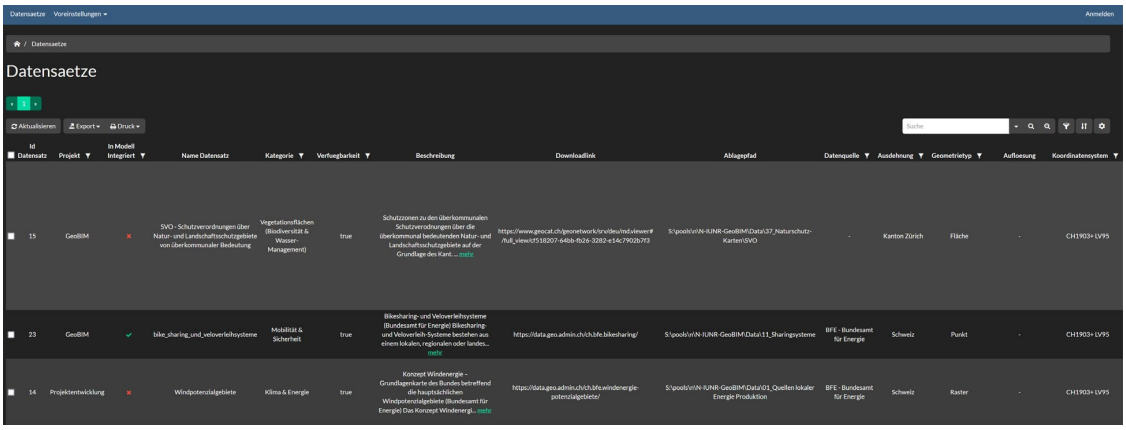

Fig. 1: Structuring of the data sets in the developed database solution

With the Swiss DGNB system of the SGNI, 15 of 49 or approx. 1/3 of the criteria (with a total of 38.5% weighting) can be digitally supported, albeit to a different extent.

support of the assessment		modest	moderate	substantive
ENV1.1/2.1	Eco-balance of the building			
ENV1.2	Risks to the local environment			
ENV1.3	Responsible resource extraction			
ENV2.2	Drinking water demand and waste water volume			
ENV2.3	Land take			
ENV2.4	Biodiversity			
SOC1.6	Amenities inside and outside			
SOC1.7	Security			
TEC1.3	Quality of the building envelope			
TEC1.7	Immission control (noise/light)			
TEC3.1	Mobility infrastructures			
SITE1.1	Hazard compensation (resilience)			
SITE1.2	Radiation to the district (use of synergies & impulse effect)			
SITE1.3	Integration traffic / infrastructure			
SITE1.4	Post local usage offer			
DES1.1	Building culture (surrounding context, spatial planning)			

Fig. 2 GIS supported criteria set

This means that certifications can theoretically be supported digitally via GIS-based information much more than expected at the beginning of the analysis. For future, standardised integration into practice, further steps are required. For example, the GIS datasets were mostly collected for other purposes and therefore often do not "fit" the certification requirements with absolute precision. In order to solve the problem, we propose to integrate poorer data quality into the evaluation in the future by means of a risk premium. In addition to the use of GIS data, the type of criteria and indicators that can be supported by information from BIM models was also examined. A virtual building model is also a good facilitator for very many assessment-criteria, be it in the support of the energy, material, ecological and life cycle cost balancing or the simulation of lighting, safety, indoor climate, energetic or acoustic aspects or in the verification of further topics such as accessibility, risk material analysis, building flexibility, ease of disassembly. The most important criteria in the DGNB system are life cycle assessment (LCA), life cycle costs (LCC) and building resilience* (LCR), each with approx. 10% of the total weighting. However, these criteria are also the most difficult to calculate and require a large amount of information from many parties involved, which are not only building- specific, but also have a strong impact on operation and use.

(*Long-term usability, for example in case of changing climate conditions or changing needs on the part of the users, flexibility, convertibility, maintenance planning, maintenance and replacement of Building Technology components).

BIM is relevant in this context in all its forms of integration, be it 1) 3D-based model integration, 2) methodological process integration as well as 3) documentation-specific information integration [10]. Within the framework of the analysis of the pilot project and various certification projects on the part of the SGNI, three basic types of integration could be confirmed.

1) *3D-based model integration:* The 3D model is of great importance to ensure the consistency of

the different verification methods, as LCA, LCC as well as LCR must rely on an identical element and mass model. If the verifications are BIM-based, the mass model must be checked only once and the comparative consistency comparison is omitted.

2) *Methodical process integration:* Within the scope of the building audit (certification) accompanying planning and construction, a large amount of information is required so that many stakeholders must be addressed and activated promptly. BIM as a method for systematic (operationalised and automated) information gathering and standardised communication can significantly reduce the investigator's time expenditure.

3) *Documentation-specific information integration:* The difficulty in collecting the necessary basic information for generating characteristic values is that it is a continuous development process in planning, where changes are occurring almost constantly across a huge variety of data sources. The demand for the traceability of the verification requires a systematic filing logic and versioning when storing the relevant data, documents, plans, file notes, e-mails, etc. BIM-based information structures are particularly helpful in this context.

The analysis was also able to show that a large number of criteria can already be supported as standard with existing three-dimensional BIM models. The figure below also shows which criteria could be supported and visualised via a BIM model.

support of the assessment		modest	moderate	substantive
ENV1.1/2.1	Eco-balance of the building			■
ENV1.2	Risks to the local environment			■
ENV1.3	Responsible resource extraction			■
ENV2.2	Drinking water demand and waste water volume		■	
ENV2.3	Land take		■	
ENV2.4	Biodiversity			
ECO1.1	Building-related costs in the life cycle		■	
ECO2.1	Flexibility and capability to transformation		■	
ECO2.2	marketability			
SOC1.1	Thermal comfort			■
SOC1.3	Acoustic comfort			■
SOC1.4	visual comfort			■
SOC1.5	User needs to influence			
SOC1.6	livability quality inside and outside	■		
SOC1.7	Security	■		
SOC2.1	Accessibility & Design for All			■
TEC1.1	Fire protection		■	
TEC1.2	sound insulation		■	
TEC1.3	Quality of the building envelope		■	
TEC1.4	Use & integration of building technology	■		
TEC1.5	Ease of cleaning	■		
TEC1.6	Ease of dismantling & recycling			
TEC1.7	Immission control (noise/light)	■		
TEC3.1	Mobility infrastructures	■		

Fig. 3 BIM supported criteria set

The challenge in practice is that builders, but also various other parties involved in practice, often have very little background knowledge of sustainability. The sustainability criteria, on the other hand, are sometimes very abstract and often explained using standards and mathematical formulas. A visualisation of the criteria for the respective materially affected building components can be of great help in understanding the extent to which the building components are affected by the individual sustainability requirements.

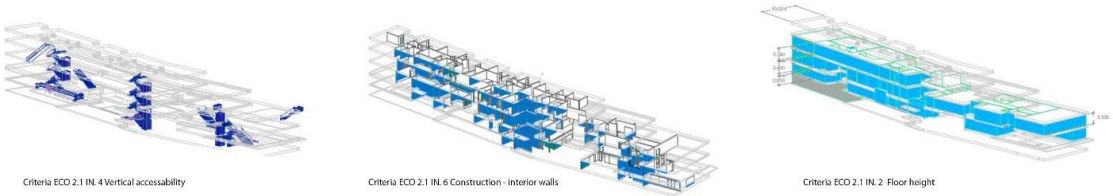

Fig. 4 Visualisation model: Related components to specific sustainability aspects (e.g. flexibility) in different colours at indicator level

However, this requires an assignment matrix between the 343 indicators in the DGNB System and the 500-1000 building components in reality as well as a visualisation logic in order to be able to automatically visualise the criteria based on the affected components in the future. Another advantage is that in team meetings (ICE sessions) relevant conflicting goals can be easily displayed and possible solution variants can be better understood and discussed more easily using the colored display. The review of this concept in the demonstration project has shown that in the future standard definitions (mapping structures) will be required for representation. The digital demonstration project is intended to test the possibilities for this. Depending on the use case, different types of visualisation at the level of the related components are conceivable:

- E.g. conflicting goals at the level of the partial qualities: visualisation of the three performance dimensions (social, ecological and economic) in red-green-blue with color gradations for the individual criteria
- E.g. evaluation at the level of the individual criteria: visualization with award logic: blue for Platinum (80-100%), green for Gold (65-80%), orange for Silver (50-65%) and red for not fulfilled (< 50%)

Unfortunately, only specific CAD/BIM software, such as ArchiCAD, support this type of colour object overwriting. It will therefore be a future task to enable the technical transfer of this colour mapping schemes between different BIM-enabled software solutions.

However, the greatest added value in the decision-making process can be generated in the comparative evaluation of different project and execution variants. The stakeholders involved can view all relevant sustainability aspects virtually in the case of new construction projects or in augmented or mixed reality mode on site in the case of existing buildings and discuss them as a team. In particular, this way of working would enable builder-owners to play a much more active role during the various planning phases to better understand the project, to identify their own needs more specifically, to make decisions more quickly and to better control the project overall.

The added values can be summarized as follows:

- Improvement of the certification result (increase in building value by up to 5%)
- Improved inclusion of the customer's needs
- Increasing the cost-benefit ratio through the systematic reduction of conflicting goals
- Systematic identification of opportunities and risks with regard to sustainable building quality
- Increase in the resulting project quality through iterative project optimisation processes

With regard to the connection of GIS and BIM in the same pilot project, a technical workflow was developed and tested as to how GIS data sets (from ArcGIS) can be imported or integrated into BIM models (Revit, ArchiCAD) via using standard interfaces but with an intelligent data mapping and a rule set for graphical overrides. One of the challenges here is to define the type of representation (colors for spaces or objects, circles for distances, etc.) and the definition of the observation limits (distance to the project in kilometres, municipal area, region/canton, etc.). It has been shown here that no mapping standards relevant to sustainability have yet been defined in Switzerland. However, as part of the project, the first prototypical definitions are being created as to which categories appear useful for which type of criteria as a base for such a new standard.

Based on the project results, we propose that in the future GeoBIM models should also be created at municipal and urban level in order to improve sustainable area development by modelling relevant sustainability aspects and simulating corresponding development scenarios. GeoBIM models enriched with GIS data can be used to improve the modeling and simulation of sustainable area development. From the GIS side, there is mainly information on potential in the area of climate protection (local energy resources, local synergy potential, etc.), building resilience (heavy rain, flooding, earthquakes, etc.), biodiversity (microclimate, soil conditions/percolation capacity, vegetation, etc.) and networking (corridors in the air, in the water, on land and in the soil) for plants and animals, transport connection (area development on foot, by bicycle, by public transport, etc.), technical infrastructure (supply and disposal, media connections, connectivity, etc.) and various other aspects relevant to sustainability.

In principle, these aspects can also be researched and found individually. In practice, however, this is often done not detailed enough, incorrectly or not at all, since it is unknown that GIS sources and data sets already exist that could be used for this purpose. Above all, the project was able to show that in principle it is possible that BIM models can be systematised and automatically enriched with all relevant GIS data using the developed workflow. This saves time, improves data quality and uses existing data in an intelligent way.

For the integration of the developed GeoBIM-based steps from for the optimisation of the building quality with regard to sustainability in the process landscape of BIM, it is necessary to carry out the iterative testing and optimisation processes with regard to the relevant sustainability criteria in parallel with the BIM quality assurance processes (e.g. collision checks) and the coordination of the respective specialist models. Future developments should provide that the existing sets of rules for quality assurance can be successively supplemented with those from the area of sustainability assessment. In the future, this would enable an automated and standardised preliminary check for many criteria and indicators and thus also help to improve quality assurance when optimizing sustainability within the framework of certification. Standardised colour coding can also help to make the testing and optimisation

processes easier and faster for complex projects.

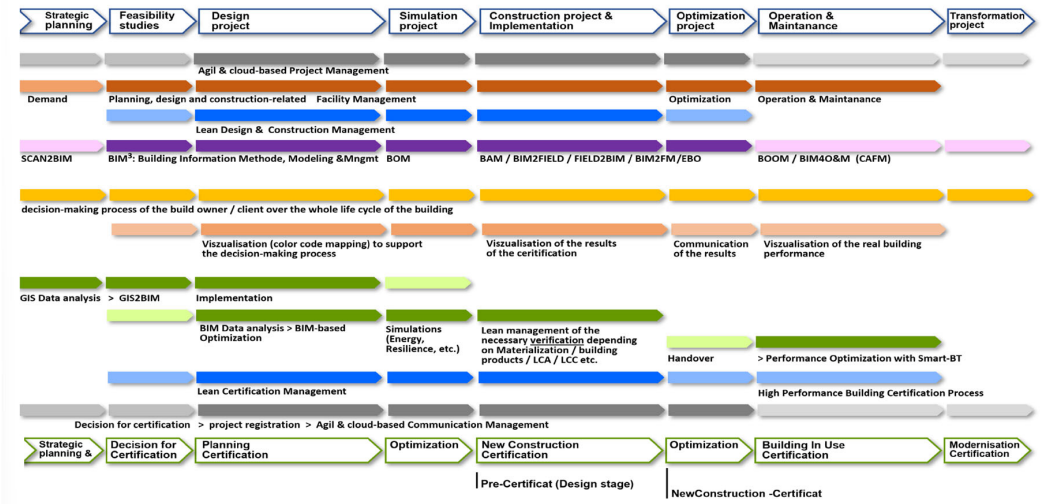

Fig. 5 GeoBIM-based coordination of the BIM&LCM processes with the certification processes

For integration into the new integrated and lifecycle-based process models for project management with Design Build or IPD approach, it would also be helpful to be able to map the proposed colour coding alternatively in the structure of the involved workgroups, parallel to the proposed color coding according to the sustainability dimensions (criteria cluster). This makes particular sense if more and more trade-based contracting models are to be implemented in the future.

5. Discussion

The certification of buildings in Switzerland with comprehensive sustainability systems such as DGNB, LEED or SNBS generates costs of approximately 50,000 to 250,000 euros, depending on the instrument and the quality level aimed at. If, as with the Swiss DGNB system of the SGNI, the support and synergy potentials of the automated inclusion of GIS- and BIM-based data and information are considered, the high economic benefit of this measure can be quickly estimated if more and more building projects are planned and realised BIM-based in the future.

As part of the analysis of the different process models of BIM-based planning according to BauenDigitalSchweiz and DGNB certification according to SGNI, it was determined that so far in the real certification projects, mutual synergy potentials have only been used to a very limited extent and no connecting elements have been integrated into the process models. The SGNI intends to implement a BIM-based certification process in the next few years. At SGNI, the inspection process is currently carried out in two stages via the planning and new construction certificate. Within this framework, all information must be available comprehensively and based on the corresponding project status to be able to start with an audit. This is necessary for a "normal" project in order to compare all information on the different criteria at the same level of information. If the proofs drifts too far apart in time, it loses its significance in the overall context of the project.

If the project is planned GeoBIM-based, there is only one virtual building model. This reduces the risk of specific sustainability verifications being "detached" from the real status of the project. In future, this will make it possible to carry out the inspection and optimisation of the various sustainability aspects as part of the planning certificate in a staggered manner or as required within the framework of a Lean Certification Process with the aid of BIM-based workflow management tools. This new type of agile verification will then allow the builder-owner to design the decision-making processes and thus also the control of the planning to optimise investments in sustainability much more efficiently and precisely than is possible with a conventional planning process. With the developed process methodology, the integration of GIS Data and the early use of BIM, the sustainable choice of products and the resource-saving use of construction products could be significantly supported in the future.

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