Key success factors for small design offices in the bidding process

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Author contributions statement

M.A. conceived and conducted the experiment, M.A. and D.B. wrote the main manuscript text, D.B. provided resources, M.A. and D.B. prepared the tables and figure, M.A. analysed the data, M.A. and D.B. curated and validated data, M.A. project administration. All authors reviewed the manuscript and have approved the submitted version.

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Competition in the design office market is high, therefore it is important to be aware of the conditions determining the competitive advantage, thus increasing the bidding effectiveness. For this reason, the aim of the article is to identify key success factors (KSF) increasing successful bidding of a small design office. The factors were identified and then analysed based on a literature review, expert interviews and using Group Consensus Cluster Analysis (GCCA) - the module of the AHP method clustering a group of decision makers into smaller subgroups with higher consensus. To examine the managerial implications, a KSF analysis was conducted from the perspective of the bidding effectiveness of the selected small design office. The results indicate that 'technical skills and experience' is the factor most influencing the potential of a small design office. Nevertheless the entire proposed procedure provides important guidelines on how to use the organisation's strengths for its development and what needs to be improved in its operation.

Highlights:

- Detailed analysis of key success factors (KSFs) of the design office operation.
- KSFs subjected to the AHP method using Group Consensus Cluster Analysis (GCCA).
- Managerial implications based on KSF analysis from the perspective of the bidding effectiveness of the selected small design office.
- Combining AHP method with the KSF analysis provides the company with important guidelines regarding strategic efforts.

Keywords: AHP, Building Design Management, construction project, key success factors analysis, project management efficiency, SME, multi-criteria decision support

List of abbreviations:

AEC - architectural, engineering, and construction industry

AHP – Analytical Hierarchy Process

BDM – Building Design Management

BIM – Building Information Modeling

CSF – Critical Success Factors

GCCA - Group Consensus Cluster Analysis

KSF – Key Success Factors

Introduction

Effective Building Design Management (BDM) is important for both efficiency and quality of final documentation, and the design phase plays a key role in this process (Emmitt & Ruikar, 2013; Knotten et al., 2017). Due to the intensive technology development, the importance of the design process in the construction industry has increased and the role of the structural designer has started to include tasks which traditionally belonged to other professions (e.g. architects, cost estimators, project managers, designers of other branches), which generates additional challenges (Emmitt & Ruikar, 2013; Z. Liu et al., 2019).

There are a number of different methods of improving project management processes. The starting point is a selection of the investment method (construction management, management contracting, design and build, project management), but this decision belongs to the investor. From the point of view of structural designers, it is therefore important to know the conditions that increase their efficiency and competitiveness. The set of such conditions, deciding on the potential market advantage and development possibilities of a particular organisation, is called key success factors (KSF) (Gierszewska & Romanowska, 2016; Knotten et al., 2017).

The subject of BDM in the architectural, engineering, and construction industry (AEC) has been addressed i.e. in publications (Antwi-Afari et al., 2018; Emmitt & Ruikar, 2013; Gray & Hughes, 2000; Knotten et al., 2017; Z. Liu et al., 2019), but there is still no broader perspective on KSF improving the design process (Knotten et al., 2017). Most publications only discuss factors from specific areas (e.g. project specifics, contractual arrangements, project management in general, information technology) (Herath & Chong, 2021; B.-G. Hwang & Lim, 2013; Knotten et al., 2017; B. Liu et al., 2016) or from the perspective of individual participants of the investment process (B.-G. Hwang & Lim, 2013; B. Liu et al., 2016) however without indicating the most important factors. As a result, managers have to act intuitively, which usually does not ensure optimal performance.

In the opinion of the authors and experts participating in the research, small design offices (employing up to 10 people), are in a particularly difficult position in the construction market. Their brand and quality of services are not widely known, and at the same time, they have to compete with larger and more experienced offices. For this reason, the aim of the article is to identify key success factors increasing successful bidding. The size of an organisation significantly impacts its operation and efficiency, therefore the authors have focused on identifying factors that are particularly important from the perspective of a small organisation. The factors are presented from the perspective of a bidder wishing to increase its chances in the bidding process. However, the design office must also be aware of the expectations and factors attractive from the investor's position, thus the perspective of the analysis conducted considers the interests of both parties.

A several elements in the article can be considered a novelty:

- in previous studies, the success of the project was considered regardless of the organization' size;
- using a new iteration of the AHP method, proposed by Goepel (Goepel, 2022);
- indication of the factors determining success in the bidding process;
- detailed analysis of key success factors (KSFs) of the small design office operation;
- KSFs subjected to the AHP method using Group Consensus Cluster Analysis (GCCA);
- managerial implications based on KSF analysis from the perspective of the bidding effectiveness of the selected small design office;
- combining the AHP method with the KSF analysis provides the company with important guidelines regarding strategic efforts.

The subsequent sections of the article are organised as follows. The second chapter describes the research methods used in the study. The third chapter presents the results in the form of KSF obtained from the literature review and expert interviews, which were further subjected to the AHP method and KSF analysis for the selected company. The final chapter presents conclusions in the form of managerial implications along with suggestions for future research.

Research methods

Key success factors in the area of BDM were determined using qualitative and quantitative methods. Following a literature review and expert interviews, the KSFs were summarised and subjected to the AHP method in the expert evaluation process using the latest group decision-making module - Group Consensus Cluster Analysis (GCCA) (*AHP Online System (AHP-OS)*, 2022). In order to examine the managerial implications of the proposed approach, based on the weight ranking obtained from the group AHP method, a KSF analysis was conducted from the perspective of the bidding effectiveness of the selected small design office. The application of the above methods is justified by corresponding decision-making problems in the literature (B. Hwang & Lu, 2013; B.-G. Hwang & Lim, 2013).

Analytical Hierarchy Process

The AHP method, developed by Saaty (details of the method are presented, i.a., in the publication (Saaty, 1990)), is a well-known, comprehensive and effective multi-criteria method for solving complex decision-making problems based on expert opinion (Khatwani & Kar, 2017). The method helps decision-makers to prioritise between considered options (factors), criteria and sub-criteria in the decision-making process, thus supporting the selection of the best one (Miszewska et al., 2020). Numerous applications of the AHP method in supporting economic, technical and social decisions confirm its usefulness, especially in cases where some assessment criteria are of a qualitative nature and where experience and expert knowledge are the main sources of judgements of a subjective nature (Jaskowski et al., 2010; Wu et al., 2022).

The traditional AHP method is implemented through four following steps:

(1) Problem definition by building a hierarchical model,

(2) Evaluation by pairwise comparisons,

(3) Determination of local and global preferences (weights),

(4) Classification of decision alternatives.

To determine the relative importance of factors in the expert evaluation process, a traditional nine-point Saaty scale (Saaty, 1990) is used.

When assessing pairs of criteria, it is necessary to check the consistency of the assessments and for that purpose, the Consistency Ratio (CR) has been proposed. A matrix containing pairwise comparisons can be considered sufficiently consistent if CR < 0.1. What comes from the evaluations made by the experts is a scale vector, which shows a numerical value representing how important each criterion or alternative is (Tomczak & Rzepecki, 2017).

This paper adopts a modified, latest version of the AHP method - GCCA, which allows to use and cluster of the assessments of an expert group (Goepel, 2022). This approach should be considered novel, as it was first presented in a publication by Goepel (Goepel, 2022) in April 2022. Although it is mathematically possible to calculate an aggregated score of evaluations for a group of experts, this approach is not applicable in all cases (Tomczak & Jaśkowski, 2022). It is therefore necessary to analyse group evaluations and find a measure of their consensus. Such a measure was proposed, i.a., by Goepel (Goepel, 2022) by introducing a consensus index using Shannon entropy as a measure of agreement between decision makers. Based on the concept of diversity in ecology, the division of Shannon entropy into alpha and beta components was used to develop a clustering algorithm to identify potential subgroups of decision makers with higher levels of consensus.

Key success factors analysis

Key success factors (KSF), also called in the literature critical success factors (CSF) (Antwi-Afari et al., 2018; Herath & Chong, 2021; B.-G. Hwang & Lim, 2013; Tu et al., 2018), are the criteria that are considered to be the most important and at the same time decisively influencing the competitive position and development opportunities of an enterprise (Gierszewska & Romanowska, 2016). According to Rockart (Rockart, 1980) they can be defined as a few key areas of activity where favourable results are absolutely necessary for a manager to reach his/her goals. Other times they are defined as the most important skills and conditions necessary for success in the relevant market (B.-G. Hwang & Lim, 2013). Key success factors help an organisation to stand out from its competitors, thus building positive, strong and stable relations with the environment in which it operates.

The KSF analysis is particularly helpful in the process of assessing a company's resources and skills. As a starting point, the most important criteria (factors) for the analysed company are listed. It is assumed that about 20% of all factors have a significant impact on 80% of the company's results, and therefore the company does not have to be dominant in all areas. Important are those criteria that determine competitive advantage and provide opportunities for development. The KSF also vary from business to business and industry to industry, so an effective KSF analysis usually requires finding 3 to 6 industry-specific factors. The usefulness and veracity of the analysis are contingent on the correct selection of these factors (Gierszewska & Romanowska, 2016).

Results and discussion

The initial summary of the KSF was developed as a result of a literature review and interviews with experts involved in the design process.

The literature review process began with an in-depth search of publication databases. As a result, a preliminary overview of the most important (in the opinion of many authors) KSFs in the area of construction management / design management process was developed and validated through expert interviews. In order to maintain the integrity and quality of the data obtained from the interviews, eight constructors (including entrepreneurs) with a minimum of 10 years of experience in the industry were involved in the research. Furthermore, the experts participating in the research evaluated the prepared KSF overview from the perspective of their experience in small design offices. The results of the review and its analysis are presented in the following subsections.

The second step of the research aimed at determining the ranking of KSFs from the point of view of successful bidding using a new module of the AHP method - GCCA. For that purpose, interviews with experts were conducted again. To ensure the high quality of results, the methodology was explained to the interviewees and care was taken to maintain consistency in the responses. The resulting data were analysed using the AHP-OS software (Goepel, 2018), which allowed to create a KSFs ranking. In order to explore the managerial implications of the proposed solution, based on the weight ranking obtained in the AHP method, a KSF analysis was conducted from the point of view of small design office's successful bidding.

Literature review and expert interviews

The diversity of projects in the construction industry is large, and so are the client groups - from individual clients, through public investors, to commercial clients from various industries, but the basics of structural design, based on structural engineering knowledge, and assessing the economic attractiveness of an offer are analogous. It is, therefore, possible to identify a limited number of factors which may be decisive in the context of evaluating the offer of a particular design office.

The problem of key (and also critical) success factors in the area of construction projects have been addressed by a number of authors. Herath and Chong (Herath & Chong, 2021), as well as Chan et al. (Chan et al., 2004), provided a general summary of CSF for the construction management process. Koutsikouri et al. (Koutsikouri et al., 2008) and Doğan et al. (Doğan et al., 2016) identified CSF in the design process from the perspective of multi-discipline projects and effective collaboration in the construction industry. Knotten et al. (Knotten et al., 2017) indicated that project team skills, communication and decision-making process are crucial in the BDM area. Meanwhile, Hwang and Lim (B.-G. Hwang & Lim, 2013) pay attention to CSF from the perspective of individual participants of the investment process, presenting, i.a., the key factors from the investor's point of view, and thus important also for the potential bidder. A summary of the KSF (CSF) in the area of AEC projects is presented in Table 1.

Table 1. Key (critical) success factors or the main factor groups (components) in the area of AEC projects (own study)

No	Authors / Researchers	Key (critical) success factors / groups / components
1.	Hwang and Lim, 2013 (B.-G. Hwang & Lim, 2013) *(CSF for owners / investors)*	(1) Adequacy of plans and specifications (2) Adequate planning and control techniques (3) Constructability (4) Realistic obligations/clear objectives and scope (5) Site inspections (6) Sufficient working drawing details (7) Contractual motivation/incentives (8) Capability of consultant key person (9) Owner's satisfaction with delivered project (10) Risk identification and allocation
2.	Herath and Chong, 2021 (Herath & Chong, 2021) *(key project components for project management success)*	(1) Project Human Resources Management (2) Project Design Package (3) Project Management Efficiency (4) Project Stakeholder Management (5) Project Budget
3.	Knotten et al., 2017 (Knotten et al., 2017) *(KSF in BDM)*	(1) Communication (2) Decision making (3) Planning (4) Client (5) Interface management (6) Team management (7) Risk management (8) Knowledge management

		(9) HSE focus (10) Performance evaluation
4.	Chan et al., 2004 (Chan et al., 2004) *(factor groups affecting the success of a construction project)*	(1) Project-related factors (e.g. type, size, complexity of a project) (2) Project procedures (procurement and tendering method) (3) Project management (e.g. communication, planning) (4) Human related factors (e.g. technical skills and experience) (5) External environment (e.g. technology advancement)
5.	Koutsikouri et al., 2008 (Koutsikouri et al., 2008) *(factor groups in construction design projects)*	(1) Management (2) Design team (3) Competencies and resources (4) Project enablers

The success of the bidding process significantly depends on awareness of expectations and factors attractive from the investor's perspective. Therefore, considering the results of the conducted research (B.-G. Hwang & Lim, 2013) it should be stated that the key factors are those influencing the time of project implementation. Time optimisation is important at all stages of the construction investment process, whereas a professional project, developed with the use of advanced software, enables not only a more precise budget estimation but also, i. a. early clash detection. It allows avoiding many problems at the implementation stage, which results in reducing the duration of the entire project (Chien et al., 2014). The design phase, due to its enormous impact on the time of investment implementation, is therefore of key importance for the investor due to its reputation, return on investment and benefits resulting from the possibility of full utilisation of the completed facility. For the bidder, being a small design office, means a necessary increase in efficiency and quality of design work.

Based on the literature review, it can be observed that most publications discuss factors from the perspective of construction project success in general regardless of the organisation’ size . There is still no detailed analysis on KSF improving the design process. Furthermore, there is no such analysis in relation to the operation of a small design office willing to increase its bidding success.

In order to identify the factors crucial for increasing the effectiveness of design work and, as a result, the successful bidding process, a preliminary list of KSFs (Table 1) was presented to the experts involved in the design process. Experts in their daily work deal with managing entire offices (two of them), leading project teams (three of them) or directly designing civil engineering structures (three of them).
The professional experience of experts ranges from 5 to 25 years. What is important, each of them works or worked in the past in a small design office. Thanks to these facts, their assessments give a reliable view of the obtained results. As a result of the interviews, a set of three key groups of success factors in the SME sector were identified, which include: project management, project team and project software package. The selected groups of success factors and the associated KSFs (Table 2) are described in the following subsections.

Table 2. KSF and factor groups affecting the success of a small design offices in the bidding process (own study)

No	**Factor group**	**Key success factors**
1.	Project management	(1) Planning (2) Team management (3) Commercial awareness
2.	Design team	(1) Technical skills and experience (2) Training facilities (3) Inter-disciplinary team working
3.	Project design package	(1) BIM (2) Other tools

Project management

Proper project management should be considered as a starting point in the process of optimising the basic project parameters, such as project scope, cost and implementation time. Balancing them is essential to ensure the quality of the final product, but also to meet the conditions and deadlines set in contracts.

The specific nature of a small design office results in shorter communication channels and, consequently, less inertia in the decision-making process compared to larger organisations. They are also characterised by a more flexible approach to planning, nevertheless still, from the perspective of limited human resources, it is important to properly coordinate works considering the parallel execution of several projects. In this area, the key role is played by the project manager, who, in a small organisation, must possess not only skills in the field of human resources, motivation and organisation of a design team, but also have the competencies of a consultant aware of business issues. Effective project management is therefore an indisputable basis for design process time optimisation and supports the effective implementation of other processes in the organisation.

Design team

The fundamental factor in building the potential of a small design office is a competent and experienced design team. The key to success is therefore selecting the appropriate composition of the design team, having access to adequate training facilities and being equipped with all the necessary tools.

A small design office, aiming at the successful competition, must rely on highly qualified employees, which translates into the quality and efficiency of work. As a result, the design team can not only develop their own projects but also support other organisations through outsourcing, supporting companies that either does not have a design department or cannot handle a large number of orders. From the investor's perspective, it is also important to be able to cooperate in an interdisciplinary team and provide additional services (beyond the basic scope of the design service, e.g. site inspections, participation in workmanship and assembly). All the above-mentioned factors make the offer more comprehensive, which translates into time savings and more efficient cost management for the investor.

Project design package

Designing structures is an extremely complex and time-consuming process. The design documentation, which arises in various phases of the construction project and in different branches, must be coherent and clearly interconnected. Various software packages effectively assist in this sophisticated process. Initially, these were relatively simple applications for static calculations, making drawings and simple spreadsheets, which have grown into sophisticated design support tools.

An important argument in favour of advanced software is increasing the effectiveness of design work while maintaining quality requirements, which results in a high standard of documentation. Assuming a sufficient level of skills and experience of the design team, the use of the above-mentioned software can significantly affect the economic attractiveness of the submitted offer and thus increase the competitiveness of small design offices.

According to experts - experienced designers of engineering structures - the right software package provides the basis for facilitating the design process, therefore tools increasing work efficiency were analysed in more detail.

A. Building Information Modelling (BIM). BIM is not only 3D modelling but a broad concept covering the process of creating and managing a digital model of any building object at all its stages. The use of such a model significantly facilitates the design process, investment implementation and its operation, but also provides a reliable and multi-component information database, which can be used in the decision-making process (Abrishami et al., 2014; Cavalliere et al., 2019).

Experts indicate that BIM technology in European countries such as e.g. Croatia, Poland, Austria, and France is currently applied mainly to detect clashes related to sanitary, electrical and tele-technical networks (*Stan wdrożenia BIM w Europie w 2021 roku*, 2021). Meanwhile, BIM has a much greater potential. It helps to prevent defects, optimise costs and accelerate the construction process. Studies investigating cost-effectiveness resulting from the implementation of BIM indicate a reduction of up to 40% in unforeseen budget changes, cost estimate accuracy up to 3%, a reduction in cost estimate generation time up to 80%, savings up to 10% in contract value due to clash detection, and a reduction in project execution time up to 7% (Chien et al., 2014). Once the project is completed, all the created files constitute an information database for the facility operation stage, improving cooperation with building managers and extending the lifespan of the investment (*Stan wdrożenia BIM w Europie w 2021 roku*, 2021).

Representatives of construction companies emphasize that thanks to visualizations, schedules and cost estimates (BIM in 4D and 5D dimensions), as well as multifaceted simulations and analyses, they are able to plan works better, which contributes to reduced implementation time, and thus to greater customer satisfaction, increased profits and the possibility of continuing cooperation (Chien et al., 2014; Davidson et al., 2020). They also note that the application of BIM technology brings spectacular effects primarily in the implementation of large and very complex projects. However, this opinion should be verified. In practice, there are examples of implementation of smaller investments and positive effects resulting from the use of BIM, especially in the context of time spent on the design process (Grzyl et al., 2019).

The benefits of using BIM were recognised by various national governments leading to diverse legislative actions. Some countries, have already implemented mandatory use of BIM in public procurement (e.g. United Kingdom, Austria). Others require the use of BIM in all projects exceeding a certain budget (e.g. in Germany, these are projects over €100 million). In some European countries the obligatory use of BIM in public procurement is forthcoming, e.g. in Poland the obligation of using BIM in projects above €10 million is scheduled for 2025 and in all other public procurements, without a budget threshold, for 2030. Nevertheless, in many countries, due to the lack of relevant legislation, standardised software and the absence of a single approved BIM standard, its use remains in the realm of recommendation. Furthermore, research shows that in a country such as Germany, where the percentage of construction companies using BIM is at 70%, there is hardly any use of BIM in small design offices (*Stan wdrożenia BIM w Europie w 2021 roku*, 2021). In commercial projects, in most cases, BIM is theoretically not obligatory, nevertheless its use is already a basic criterion for assessing the attractiveness of an offer.

A summary of other benefits, but also threats, strengths and weaknesses resulting from the use of BIM in small design offices is presented in Table 3.

Table 3. SWOT analysis – use of BIM in small design offices (own study based on the interviews with experts and (Chien et al., 2014; Davidson et al., 2020; Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022; Ullah et al., 2022))

Strengths (S)	Weaknesses (S)
- multibranch coordination (Ullah et al., 2022) - reducing design clashes at the early stage (Stojanovska-Georgievska et al., 2022) - prefabrication of building components (Stojanovska-Georgievska et al., 2022) - reduction of the project implementation time (Chien et al., 2014; Davidson et al., 2020) - flexibility for revisions to the underlying documentation - higher design quality - more accurate cost estimates (Chien et al., 2014)	- high initial cost (software, training) (Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022) - lack of expertise (Manzoor et al., 2021) - lack of software compatibility (Chien et al., 2014; Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022) - the price of a construction design using advanced BIM is significantly higher than a traditional one - longer time for model developing (Stojanovska-Georgievska et al., 2022)
Opportunities (O)	**Threats (T)**
- greater competitiveness in the bidding process - using BIM builds a good image of the company (part of competitive advantage) - BIM is already or will be obligatory in public procurement in many European countries - digitalization ensuring subsequent savings	- lack of available skilled personnel (Chien et al., 2014; Stojanovska-Georgievska et al., 2022) - lack of BIM standards and guidelines; unclear legal liability (Chien et al., 2014; Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022) ; - insufficient governmental support (Stojanovska-Georgievska et al., 2022) - lack of awareness regarding the potential of BIM (Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022) - low and inadequate offer of BIM trainings (Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022) - cultural barrier (resistance to change) (Manzoor et al., 2021; Stojanovska-Georgievska et al., 2022)

B. Other tools. Parametric design. The dynamic development of BIM technology caused the standard functions of the programmes to be often insufficient to optimise design solutions. Therefore, it is possible to create individual scripts, which can increase the automation of work.

An example of the implementation of such solutions is Autodesk Dynamo and Trimble Tekla, which give the user a lot of possibilities to create individual algorithms. A significant advantage is the fact that these programmes are adapted to people with different levels of IT knowledge. For less advanced designers, it has been created the visual design, which does not require writing typical code. On the other hand, more experienced users can use the traditional coding method, using, for example, the Python language.

Parametric design is very effective when there are many repetitive actions to be performed in a given task. Creating individual scripts and including them as an extension of the basic functions of 3D modelling software caused the time spent on solving design process problems to be significantly reduced and the number of possible errors to be minimised.

Parametric design is considered to be one of the main trends that will be crucial in the near future. Design offices with proficiency in the possibilities offered by parametrization will be able to streamline the processes of creating: documentation, geometry and information management of the BIM model.

Calculation macros. The nature of the design process means that the solution to design issues is based on algorithms. These derive directly from design standards, but also from the experience of designers. For this reason, design offices create their own calculation macros.

The environments for creating such macros are usually Excel or Mathcad. The specific characteristics of both these programmes mean that algorithms for the solution of various design issues can be created easily and efficiently.

The most common macros are element dimensioning algorithms (such as procedures for dimensioning a steel beam with lateral-torsional buckling or for dimensioning the reinforcement in a two-way bent reinforced concrete column) and advanced design cases (such as procedures for checking the load capacity of a reinforced concrete element under fire conditions or for determining the load capacity of foundation piles under complex soil conditions).

Individual software settings. In construction modelling programmes such as Autodesk Advance Steel or Trimble Tekla, for example, appropriate user settings have a very important role in efficiency. These settings significantly influence both, the 3D modelling process and the generation and processing of 2D documentation. Each element of the 3D model can be given functions or attributes, with the help of which the model itself can be managed more efficiently in later stages and the documentation can be generated more quickly. Furthermore, the settings also affect other important aspects of using BIM in design, such as checking for inter-branch clashes or exporting models to files with different extensions for later loading in other spatial modelling programmes.

When it comes to the generation of 2D documentation, it is very important to prepare correctly formatted sheets, set the print style appropriately and properly parameterise the drawing processes that are responsible for the quality of the automatically prepared drawings. Predefined styles and processes do not allow the generation of documentation that can be passed on to the client. Also, well-defined options related to bills of materials allow the automatic and efficient production of material lists associated with an object. All these aspects can have a significant impact on the time it takes to issue the final documentation that goes to the developer or construction site.

Analytical Hierarchy Process - GCCA

The AHP method was used to prioritise the identified KSFs (Table 2). Therefore, the decision problem was decomposed into the following levels:

- Goal: to determine the KSFs ranking for small design offices affecting successful bidding;
- Criteria (KSFs): planning, team management, commercial awareness, technical skills and experience, training facilities, inter-disciplinary team working, BIM, other tools.

Considering the required consistency and the corresponding measurement accuracy, eight KSFs affecting the main goal were finally selected for the AHP analysis. According to the research, too large number of compared elements (greater than 9) is cognitively challenging for human beings and thus can result in less accurate priorities (Saaty, 1990).

The KSFs weights were extracted using available online AHP-OS software using the latest module for group decision analysis - GCCA (*AHP Online System (AHP-OS)*, 2022). The group session involved eight experts - experienced designers of engineering structures - who explained the methodology and care was taken to maintain consistency in their responses. A nine-point Saaty scale (Saaty, 1990).was used to determine the relative importance of factors in the expert evaluation process. An example of a pairwise comparison and consolidated priorities for the expert no 7 were presented in Table 4 and Table 5.

Table 4. Aggregation of individual judgments for the expert no 7 (own study based on (*AHP Online System (AHP-OS)*, 2022)

	1	2	3	4	5	6	7	8
1	1	0.33	5.00	0.14	7.00	3.00	0.14	3.00
2	3.00	1	5.00	0.33	7.00	5.00	0.33	7.00
3	0.20	0.20	1	0.20	3.00	1.00	0.11	1.00
4	7.00	3.00	5.00	1	7.00	5.00	0.33	3.00
5	0.14	0.14	0.33	0.14	1	0.20	0.11	0.33
6	0.33	0.20	1.00	0.20	5.00	1	0.14	0.33
7	7.00	3.00	9.00	3.00	9.00	7.00	1	9.00
8	0.33	0.14	1.00	0.33	3.00	3.00	0.11	1

Table 5. Consolidated priorities for the expert no 7 calculated in AHP-OS online software (*AHP Online System (AHP-OS)*, 2022)

Criteria		Priority	Rank
1	1.Planning	8.8%	4
2	2.Team management	16.3%	3
3	3.Commercial awareness	3.5%	7
4	4.Technical skills and experience	23.5%	2
5	5.Training facilities	1.8%	8
6	6.Inter-disciplinary team working	3.8%	6
7	7.BIM	37.5%	1
8	8.Other tools	4.7%	5

As a result of calculations conducted with the online AHP-OS software, the final weights of the individual KSFs, and consequently also the weights of the factor groups, were obtained (Tables 4 and 5). ‘Technical skills and experience’ of designers, ‘team management’ and the ability to work in a BIM environment were rated highest by the experts. Criteria such as ‘training facilities’ and ‘other tools’ in the context of successful bidding were rated as the least important. At the same time, a high consistency ratio can be observed between the evaluations of the expert group (CR_{max}=1.9%) and the individual evaluations, where CR does not exceed 10%.

Table 6. Consolidated Global Priorities matrix (own study based on (*AHP Online System (AHP-OS)*, 2022))

Participant	**1.Planning**	**2.Team management**	**3.Commercial awareness**	**4.Technical skills and experience**	**5.Training facilities**	**6.Inter-disciplinary team working**	**7.BIM**	**8.Other tools**	**CR_{max}**
Group result	**9.7%**	**18.4%**	**6.1%**	**30.9%**	**4.5%**	**9.1%**	**17.8%**	**3.6%**	**1.9%**
Expert 1	10.0%	15.3%	3.4%	38.0%	2.5%	6.4%	22.5%	1.9%	9.5%
Expert 2	4.6%	20.3%	6.8%	32.6%	3.4%	14.1%	16.1%	2.1%	7.8%
Expert 3	44.0%	17.2%	5.3%	18.0%	3.6%	4.0%	3.3%	4.7%	8.5%
Expert 4	8.8%	17.3%	11.8%	25.0%	4.0%	21.9%	8.8%	2.3%	8.9%
Expert 5	7.1%	9.5%	2.7%	37.0%	4.9%	6.8%	30.0%	2.0%	9.8%
Expert 6	9.8%	18.8%	6.3%	22.8%	11.1%	5.9%	14.0%	11.2%	9.7%
Expert 7	8.8%	16.3%	3.5%	23.5%	1.8%	3.8%	37.5%	4.7%	9.8%
Expert 8	2.9%	18.3%	8.3%	27.9%	5.1%	13.9%	21.4%	2.1%	8.0%

Table 7. Priorities (weights) of KSFs and factor groups affecting the success of a small design offices in the bidding process (own study based on (*AHP Online System (AHP-OS)*, 2022))

No	**Factor group**	**Key success factors (KSFs)**	**Weight**	**Rank**
1.	Project management	1. Planning	0.097	4
		2. Team management	0.184	2
		3. Commercial awareness	0.061	6
2.	Design team	4. Technical skills and experience	0.309	1
		5. Training facilities	0.045	7
		6. Inter-disciplinary team working	0.091	5
3.	Project design package	7. BIM	0.178	3
		8. Other tools	0.036	8

GCCA allows measuring the consistency of experts' judgements using two indicators: the relative homogeneity index S and the average AHP group consensus indicator (S_{AHP}). If the consensus index is 0, then the priorities of all experts are completely different, if 1 then they are identical. In the conducted study relative homogeneity S = 86.5%, which indicates high homogeneity of assessments, while S_{AHP}, according to Table 6, can be described as moderate (71.9%). The difference in the values of these two indicators is due to the use of a limited rating scale ranging from 1 to 9 (Goepel, 2022). Both indicators are higher than 70%, so clustering decision makers with higher levels of consensus, according to [23], is not required.

Table 8. Qualitative wording scale for AHP consensus indicator (Goepel, 2022)

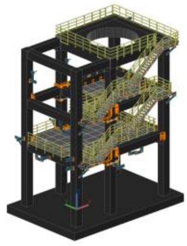
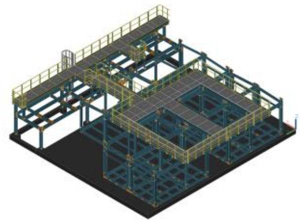
Consensus S_{AHP}	0% - 50.0%	50% - 62.5%	62.5% - 75%	75% - 87.5%	87.5% - 100%
Word scale	very low	low	moderate	high	very high

KSF analysis

The KSF analysis was limited to the list of factors developed for the AHP method and assumed to be complete, i.e. including the most important factors from the company's main areas of operation. The potential of a small design office from the perspective of successful bidding was assessed according to a subjective five-point scale based on the implementation of three different construction projects (Table 7) completed by company X (company details withheld). Although empirical studies are not sufficient to validate the theoretical framework, case studies can contribute new and valuable insights (Knotten et al., 2017).

Considering methodological correctness, the potential of company X was compared to the ideal KSF profile (Table 8). In this context, the market leader satisfies the criteria in the KSFs list to the greatest extent (Gierszewska & Romanowska, 2016). This allows for a more objective assessment, and when extending the evaluation to a larger number of companies within the sector, it facilitates the creation of a ranking list that enables a precise, points-based determination of the distance separating the evaluated company from its competitors.

Table 9. Selected structural designs completed by company X (own study)

Object	**High-bay warehouse**	**Refinery etailer**	**Ammonia refrigeration plant**
			
Capacity	40.627 m3	1.640 m3	890 m3
Description	- a facility for the storage of food products - composed of a high part (cold chambers) and a lower part (loading and logistic-social part)	- the structure is part of a technological installation on the premises of the refinery - the installation is responsible for increasing the yield of light products, i.e. petrol and diesel, thus increasing the efficiency of crude oil processing - the object is used to foundation one of the units – vacuum column	- the facility is designed to increase energy efficiency in a poultry meat production plant - support structures are used to foundation the equipment (tanks, condensers, pumps, exchangers) - refrigerated containers are used for the construction of the modular machine room (with compressors and electrical cabinets)
Challenges	- the steel structure has been designed with large spans in mind - to maximise storage space for products	- reinforced concrete and steel structure founded on a foundation slab with piles - technological requirements imposed a high class of fire resistance of the object (resistance of 120 minutes during a hydrocarbon fire)	- part of the structure (engine room) was designed as finished modules and arrived on site ready-finished
Design aids	- Autodesk Robot Structural Analysis Professional – calculation model of the object - GEO5 – calculation of foundation - Autodesk Advance Steel – modeling of steel structures - Allplan – modeling of reinforcement structures - Excel: calculation macros to specify dimensioning of reinforcement elements	- Autodesk Robot Structural Analysis Professional – calculation model of the object - GEO5 – calculation of foundation - Autodesk Advance Steel – modeling of steel structures - Allplan – modeling of reinforcement structures - Excel: calculation macros to specify dimensioning of reinforcement elements, fire analysis of steel and reinforcement elements	- Autodesk Robot Structural Analysis Professional – calculation model of the object - GEO5 – calculation of foundation - Autodesk Advance Steel – modeling of steel structures - Allplan – modeling of reinforcement structures - Excel: calculation macros to specify dimensioning of reinforcement elements
Lead times	- using traditional methods: 10 weeks - using BIM: 4 weeks	- using traditional methods: 12 weeks - using BIM: 6 weeks	- using traditional methods: 7 weeks - using BIM: 4 weeks

The KSF analysis assumes that around 20% of all factors have a significant impact on 80% of the company's performance. Therefore, it can be observed that ‘technical skills and experience’ play a key role in the successful bidding of a small design office, followed by ‘team management’ (highest weighted scores; Figure 1). Both factors received equal-weighted scores for both company X and the market leader, so it can be concluded that company X's potential in the market is high. The factors whose weighted scores most diverge from those of the market leader are ‘planning’ and ‘training facilities’. Small design offices, due to a small number of structural designers, are flexible in their approach to market needs, which unfortunately adversely affects the ability to plan and execute work in accordance with the determined schedule. It may have a negative impact on the time optimisation of a specific project. ‘Training facilities’ are also not a strong point of a small design office, nevertheless, in the experts' opinion, they are of relatively small importance compared to other KSFs.

Table 10. KSF analysis for company X against the market leader (own study based on the global priorities determined in the AHP analysis)

No	**Key success factor**	**Rating (1-5)**		**Weight**	**Weighted score**	
		Company X	**Market leader**		**Company X**	**Market leader**
1.	Planning	2	5	0.097	0.194	0.485
2.	Team management	4	4	0.184	0.736	0.736
3.	Commercial awareness	5	5	0.061	0.305	0.305
4.	Technical skills and experience	5	5	0.309	1.545	1.545
5.	Training facilities	2	4	0.045	0.090	0.180
6.	Inter-disciplinary team working	5	4	0.091	0.455	0.364
7.	BIM	4	4	0.178	0.712	0.712
8.	Other tools	4	5	0.036	0.144	0.180
			SUM:	1.000	4.181	4.507

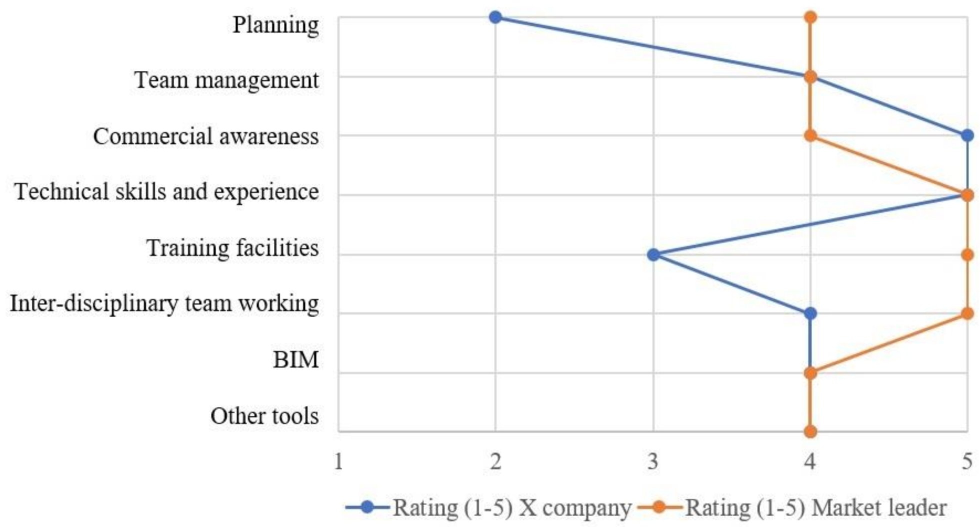


Figure 1. The potential of a small design office from the perspective of successful bidding (own study)

Conclusions

The purpose of this paper was to identify the KSFs for a small design office wishing to increase its effectiveness in the bidding process. As shown, while most publications discuss factors from the perspective of overall construction project success, a detailed analysis of key factors in the context of the design operation was still lacking. For that purpose, the AHP method and its new iteration in the form of GCCA were used, followed by KSF analysis.

The results of the research indicate that ‘technical skills and experience’ is the factor most influencing the potential of a company, which is particularly important for small design offices with no established brand on the market. The starting point in the process of successful bidding, however, should be proper project management, in particular team management and appropriate work coordination of the design team, considering the implementation of several projects in parallel. Effective management is therefore the basis for design process time optimisation and thus makes it possible to submit an attractive offer. Almost as important as ‘team management’ proved to be the use of advanced software supporting the design process, such as BIM. An appropriate project design package allows to increase the effectiveness of design work, and multi-discipline coordination results in a high standard of documentation, assuming, however, that the design team has an appropriate level of skills and experience.

The proposed research procedure combining the AHP method with the KSF analysis allows to organise the knowledge about the analysed company and to express it in meaningful numerical values. Moreover, by using evaluation based on group decision-making, it was possible to achieve a synergy effect of knowledge and experience of several experts. Such an assessment not only identifies the company's position in the sector but also provides important guidelines about where to focus strategic efforts, how to use the organisation's strengths for its development and what needs to be improved in its operation.

Despite the criticism that has been raised against the AHP method in terms of, i.a., the subjectivity of the final rankings (the result of the subjectivity of individual assessments and the use of a traditional nine-point Saaty’s scale), as well as the errors in the assessment aggregation procedure, it should be emphasised that these assessments were made by experts and that the applied module of the AHP method - the GCCA - makes it possible to increase the consistency of group assessments.

In the authors' opinion the topic of competitiveness of small design offices requires further research due to the growing interest of investors in an end-to-end service. This involves the design office supporting the client at every stage of the project implementation, from the initial concept to the final commissioning and handover of the investment for use. From this point of view, the key aspect is the selection of appropriate employees who can comprehensively meet customer requirements. This relates directly to substantive issues and an adequate approach to increasingly demanding investors.

The topic of the AHP method using group consensus cluster analysis has a great potential, therefore it is planned to conduct analogous research on a wider group of respondents.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abrishami, S., Goulding, J. S., Rahimian, F. P., & Ganah, A. (2014). Integration of BIM and generative design to exploit AEC conceptual design innovation. *Journal of Information Technology in Construction (ITcon)*, *19*(21), 350–359.

AHP Online System (AHP-OS). (2022). https://bpmsg.com/group-consensus-cluster-analysis/

Antwi-Afari, M. F., Li, H., Pärn, E. A., & Edwards, D. J. (2018). Critical success factors for implementing building information modelling (BIM): A longitudinal review. *Automation in Construction*, *91*, 100–110. https://doi.org/10.1016/j.autcon.2018.03.010

Cavalliere, C., Dell'Osso, G. R., Favia, F., & Lovicario, M. (2019). BIM-based assessment metrics for the functional flexibility of building designs. *Automation in Construction*, *107*, 102925. https://doi.org/10.1016/j.autcon.2019.102925

Chan, A. P. C., Scott, D., & Chan, A. P. L. (2004). Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management*, *130*(1), 153–155. https://doi.org/10.1061/(ASCE)0733-9364(2004)130:1(153)

Chien, K.-F., Wu, Z.-H., & Huang, S.-C. (2014). Identifying and assessing critical risk factors for BIM projects: Empirical study. *Automation in Construction*, *45*, 1–15. https://doi.org/10.1016/j.autcon.2014.04.012

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M., & Rahimian, F. P. (2020). Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: A proof of concept study. *Frontiers of Engineering Management*, *7*(3), 396–403. https://doi.org/10.1007/s42524-019-0039-y

Doğan, S. Z., Çalğici, P. K., Arditi, D., & Günaydin, H. M. (2016). Critical Success Factors Of Partnering In The Building Design Process. *METU Journal of the Faculty of Architecture*, *32*(2), Art. 2. https://doi.org/10.4305/metu.jfa.2015.2.4

Emmitt, S., & Ruikar, K. (2013). *Collaborative Design Management*. Routledge. https://doi.org/10.4324/9780203819128

Gierszewska, G., & Romanowska, M. (2016). *Analiza strategiczna przedsiębiorstwa*. PWE Polskie Wydawnictwo Ekonomiczne.

Goepel, K. D. (2018). Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS). *International Journal of the Analytic Hierarchy Process*, *10*(3). https://doi.org/10.13033/ijahp.v10i3.590

Goepel, K. D. (2022). GROUP CONSENSUS CLUSTER ANALYSIS USING SHANNON ALPHA AND BETA ENTROPY. *Submitted for Publication*, 14.

Gray, C., & Hughes, W. (2000). *Building Design Management*. Routledge. https://doi.org/10.4324/9780080500409

Grzyl, B., Migda, W., & Apollo, M. (2019). Building Information Modeling in Small and Middle Sized Buildings – Case Study. *IOP Conference Series: Materials Science and Engineering*, *603*, 1–10. https://doi.org/10.1088/1757-899x/603/3/032077

Herath, S., & Chong, S. (2021). Key Components and Critical Success Factors for Project Management Success: A Literature Review. *Operations and Supply Chain Management: An International Journal*, *14*(4), 431–443. https://doi.org/10.31387/oscm0470314

Hwang, B., & Lu, T. (2013). Key success factor analysis for e-SCM project implementation and a case study in semiconductor manufacturers. *International Journal of Physical Distribution & Logistics Management*, *43*(8), 657–683. https://doi.org/10.1108/IJPDLM-03-2012-0062

Hwang, B.-G., & Lim, E.-S. J. (2013). Critical Success Factors for Key Project Players and Objectives: Case Study of Singapore. *Journal of Construction Engineering and Management*, *139*(2), 204–215. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000597

Jaskowski, P., Biruk, S., & Bucon, R. (2010). Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment.

Automation in Construction, *19*(2), 120–126. https://doi.org/10.1016/j.autcon.2009.12.014

Khatwani, G., & Kar, A. K. (2017). Improving the Cosine Consistency Index for the analytic hierarchy process for solving multi-criteria decision making problems. *Applied Computing and Informatics*, *13*(2), 118–129. https://doi.org/10.1016/j.aci.2016.05.001

Knotten, V., Lædre, O., & Hansen, G. K. (2017). Building design management – key success factors. *Architectural Engineering and Design Management*, *13*(6), 479–493. https://doi.org/10.1080/17452007.2017.1345718

Koutsikouri, D., Austin, S., & Dainty, A. (2008). Critical success factors in collaborative multi-disciplinary design projects. *Journal of Engineering, Design and Technology*, *6*(3), 198–226. https://doi.org/10.1108/17260530810918243

Liu, B., Huo, T., Meng, J., Gong, J., Shen, Q., & Sun, T. (2016). Identification of Key Contractor Characteristic Factors That Affect Project Success under Different Project Delivery Systems: Empirical Analysis Based on a Group of Data from China. *Journal of Management in Engineering*, *32*(1), 05015003. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000388

Liu, Z., Jiang, L., Osmani, M., & Demian, P. (2019). Building Information Management (BIM) and Blockchain (BC) for Sustainable Building Design Information Management Framework. *Electronics*, *8*(7), Art. 7. https://doi.org/10.3390/electronics8070724

Manzoor, B., Othman, I., Gardezi, S. S. S., Altan, H., & Abdalla, S. B. (2021). BIM-Based Research Framework for Sustainable Building Projects: A Strategy for Mitigating BIM Implementation Barriers. *Applied Sciences*, *11*(12), Art. 12. https://doi.org/10.3390/app11125397

Miszewska, E., Niedostatkiewicz, M., & Wiśniewski, R. (2020). The Selection of Anchoring System for Floating Houses by Means of AHP Method. *Buildings*, *10*(4), Art. 4. https://doi.org/10.3390/buildings10040075

Rockart, J. F. (John F. (1980). *The changing role of the information systems executive: A critical success factors perspective*. https://dspace.mit.edu/handle/1721.1/2010

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, *48*(1), 9–26. https://doi.org/10.1016/0377-2217(90)90057-I

Stan wdrożenia BIM w Europie w 2021 roku. (2021, listopad 16). PlanRadar. https://www.planradar.com/pl/stan-wdrozenia-bim-w-2021-roku-porownanie-7-krajow/

Stojanovska-Georgievska, L., Sandeva, I., Krleski, A., Spasevska, H., Ginovska, M., Panchevski, I., Ivanov, R., Perez Arnal, I., Cerovsek, T., & Funtik, T. (2022). BIM in the Center of Digital Transformation of the Construction Sector—The Status of BIM Adoption in North Macedonia. *Buildings*, *12*(2), Art. 2. https://doi.org/10.3390/buildings12020218

Tomczak, M., & Jaśkowski, P. (2022). Harmonizing construction processes in repetitive construction projects with multiple buildings. *Automation in Construction*, *139*, 104266. https://doi.org/10.1016/j.autcon.2022.104266

Tomczak, M., & Rzepecki, L. (2017). Evaluation of Supply Chain Management Systems Used in Civil Engineering. *IOP Conference Series: Materials Science and Engineering*, *245*, 072005. https://doi.org/10.1088/1757-899X/245/7/072005

Tu, J.-C., Lee, Y.-L., & Wei, M.-Y. (2018). Analysis and Research on the Key Success Factors of Marketing Ugly Fruits and Vegetables. *Sustainability*, *10*(8), Art. 8. https://doi.org/10.3390/su10082783

Ullah, K., Witt, E., & Lill, I. (2022). The BIM-Based Building Permit Process: Factors Affecting Adoption. *Buildings*, *12*(1), Art. 1. https://doi.org/10.3390/buildings12010045

Wu, L., Gan, C., Xu, Z., & Hui, J. (2022). Multi-dimensional quantitative model of communication network value. *Scientific Reports*, *12*(1), Art. 1. https://doi.org/10.1038/s41598-022-12501-0