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Deficiencies of technical specifications in tender documentation for construction project

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Abstract:
In the context of tender documentation for construction projects in the Czech Republic, technical specifications define the content and scope of work to be conducted using drawing documentation and a list of works, supplies and services. In practice, such documents are often burdened with errors (deficiencies) that can have different causes and impacts on the success of a project in terms of cost, time and quality. This study aims to explore the perception of the probability of occurrence and degree of impact of errors from various perspectives including risk factors, causes, possible effects, responsibility and the role of stakeholders. Data collected from experienced construction professionals in the Czech Republic show that documentation errors mainly affect project constraints in terms of cost and time and are often underestimated by investors concerning their impact and the probability of occurrence. Several recommendations are formulated to serve as preventive measures contributing to the elimination of errors and their early detection.

Keywords:
construction project; responsibility; risk; stakeholder; technical specifications; tender documentation

1 Introduction

The process of selecting a contractor to deliver a construction project requires an extensive exchange of information, documents and contracts [1], which in Czech is generally referred to as tender documentation [2]. Documentation quality is of utmost importance as finalised documentation dictates the outcome of a project [3]. In practice, ensuring the quality of documentation is one of the major challenges faced by stakeholders due to high level of complexity. According to Qazi et al. [4], complexity must encompass different facets of project contexts including technical, organisational, environmental and socio-technical dimensions. In the construction industry, the facets involved include: project implementation comprising a large number of diverse and often highly specialised activities (technical aspect), a large number of stakeholders involved in a project (organizational aspect) [5], implementation of construction investments that significantly affect the environment and long-term sustainability (environmental aspect) [6], and communication and trust among stakeholders [7], which play a pivotal role in the success of a project (social-technical dimension).

In the case of public procurement within the European Union (EU), the scope and contents of tender documentation are defined by national legislative requirements [8-11]. In the Czech Republic, the requirements specifically include Act No. 134/2016 Coll. (Public Procurement Act) [12] and Decree No. 169/2016 Coll. (Decree on determining the scope of documentation of a public contract for construction works and an inventory of construction works, supplies and services with a statement of acreage) [13]. Procurement in the private sector is not governed by any specific legislative regulations; therefore, the process relies solely on the cooperation between the designer, contracting entity and contractor [14].

Tender documentation includes drawings and budget details (technical specifications), along with other important documents such as commercial terms, supplier qualification requirements (basic, professional, economic and technical qualifications) [15, 16], estimated price, tender price calculation requirements, evaluation methods and other requirements specified by the contracting entity according to selected specific tender procedures [17, 18]. As some of the tender documentation requirements are formal in nature, this study focuses exclusively on technical specifications of tender documentation, comprising implementation documentation (drawings) and a list of works, supplies and services (construction budget).

The quality of technical specifications of tender documentation can be defined as flawless implementation documentation including all lists, reports, drawings, details and other requisites related to the national legislative requirements [19].

If the technical specifications of tender documentation are wholly or partially incomplete or incorrect, contractors are unable to submit a correct bid or guarantee adherence to such a bid; for example, concerning a fixed price for their work [20]. Exceeding the specified investment costs has a significant impact not only on the economic efficiency of a project but often on the binding deadlines and ultimately on the work quality. The main aim and interest of investors involve minimising risks and ensuring project success in terms of cost, time and quality, which is in line with the Iron Triangle [21, 22].

1.1 Deficiencies in documentation as a project risk

Deficiencies in documentation can negatively impact the implementation of a construction project; thus, their occurrence can be considered one of the associated risks. According to Akintoy and Fitzgerald [23], the main causes of errors include poor practical knowledge of construction processes considering budgeters, time pressures for budgeting, incorrect drawings and variability in subcontractor prices. Dosumu [24] identified the most errors in drawings, followed by the list of works, and then the specifications.

Juszczyk et al. [25] conducted a detailed investigation of errors in project documentation with respect to public contracts in Poland. Their results identified the most common errors in technical specifications, namely: incorrect ordering of specifications, incompatibility of specifications with standards and other documents, and copying texts from other documents.

Furthermore, other types of errors including the incompleteness of project documentation [8, 20]; poor coordination of issues related to building statics [8, 25]; insufficient description [8, 26]; and poor graphic design such as incorrect drawing of structures shown (thicknesses and type of lines) or illegibility of annotations or notes [20] have been identified.
Detailed identification of errors in technical specifications of tender documentation has been conducted [27]. Based on a review of available literature and information obtained from interviews with construction practitioners, a list containing a total of 52 errors is compiled and presented in Tables 1 and 2. Errors are divided into two categories: errors related to (1) drawings and (2) a list of works, supplies and services.

Table 1. List of identified errors in project documentation [26]

Description of error in drawing documentation	Source
Communication between investors and general designers	[27]
Coordination and partitioning of subparts	[27]
Design error - minimum toilet dimensions, wrong composition	[24-26]
Designer incompetence	[27]
Discrepancies between an actual situation and project documentation	[27]
Errors in design due to carelessness in drawing	[27]
Failure to conduct probes and surveys	[27]
Failure to consider site design	[27]
Failure to consider technical facilities	[27]
Failure to observe the investor’s specifications	[27]
Graphic design - incorrect (non-standard) drawing of structures, or unclear dimensions or notes	[20]
Changes in project documentation not approved by investors	[27]
Inadequate specification of intent and assignment - air conditioning/ventilation	[27]
Incomplete project documentation	[8, 20]
Incorrect drawing annotations	[27]
Incorrect material specification	[27]
Insufficient annotations	[8, 26]
Insufficient description and characterisation of materials	[27]
Investor’s ignorance of project documentation requirements and scope	[27]
Poor architectural and construction solutions (ACS) coordination - cut-outs, compositions and reports	[8, 25, 26]
Poor coordination of building technical equipment (BTE) and other areas	[8, 25]
Poor preparation, ignorance of materials	[27]
Poor structural engineering coordination (statics)	[8, 25]
Poor survey - failure to accurately plot the existing situation	[27]
Poorly designed technical facilities	[27]
Poorly prepared earth handling	[27]
Process coordination	[27]
Specification of an assignment - scope of construction permit documents (CPD) and construction implementation documentation (CID)	[27]
State subsidies - completely different project documentation scope	[27]
Wrong implementation details	[24, 26]

From the description of errors, they are identified to have different natures and are expected to have variable significance in the achievement of project goals.

Table 2. List of identified errors in the list of works, supplies and services [26]

Description of error in the list of works, supplies and services	Source
Breakdown of budget - deductible/non-deductible	[27]
Earth management - removal, disposal	[27]
Earthworks - calculation of volumes, soil classes	[27]
Failure to reflect changes in project documentation	[27]
Failure to specify drainage, subsoil ventilation	[27]
Failure to specify price system - price corrections for additional work	[27]
Incorrect calculation methodology - formwork	[27]
Incorrect description of items	[24]
Incorrect price system	[27]
Incorrectly selected items	[27]
Installation without materials (item does not include material)	[27]
Insufficient description of non-database items (r-items)	[24, 25]
Lack of clarity/inconsistency of budget	[27]
Missing bill of quantities	[27]
Missing budget - construction contractor	[27]
Missing items	[27]
Movement of bulk materials	[27]
Price level inconsistency	[27]
Provisions for repairs and non-uncovered structures	[27]
Quantity calculation error	[24]
Specific items - specifications	[27]
Surrounding influences, building on the property boundary	[27]

1.2 Research gap in the context of project performance management

The performance of a construction project is a highly complex subject, as performance can be monitored and measured in several specific directions, typically in terms of three core performance areas (cost, time and quality). The Iron Triangle concept has gained great popularity due to the good and easy measurability of criteria; nevertheless, Pollack et al. [28] discussed the disputability of one of the criteria. While a general consensus on time and cost criteria exists, the status of quality is less certain. First, quality can be seen as product quality and process quality (can be divided into sub-criteria). Second, quality is more subjective than time and cost. Last, some researchers refer to scope instead of quality [29]. For this study, the quality criterion seen as product (facility) quality is considered, which can be measured, for example, by the number of defects [30].

The Iron Triangle itself cannot capture the success of a project from a broader perspective [31], and additional areas are included for project-level performance, such as productivity, safety, stakeholders, satisfaction and sustainability domains. Performance sub-domains focus on certain specific aspects of construction projects that can affect the overall outcome of a project, represented by the Iron Triangle. From this perspective, documentation quality can be considered as a new additional performance sub-domain that affects project-related time, cost and quality targets.

The success of a project depends on a wide range of factors [32] and one of the numerous determinants is the quality of technical specifications of tender documentation. Although specific studies on errors in the documentation of construction projects are available (in the context of technical specifications of tender documentation), to the best of the authors'

knowledge, sufficiently specific and comprehensive evidence on how significantly deficiencies in documentation can affect project outcomes is limited.
Therefore, this study aims to answer the following four key questions:

- RQ1: How often do errors in the technical specifications of tender documentation occur and what is the expected degree of impact on project performance?
- RQ2: Which areas of project performance (cost, time and quality) are most affected by the shortcomings?
- RQ3: How does the perception of errors differ in the context of the stakeholder’s role in a project?
- RQ4: Who bears responsibility for errors?

2 Materials and methods

As presented in Section 1.1, a comprehensive list of 52 errors in technical specifications of tender documentation was compiled [27]. The list included various types of errors reported in available literature or encountered by construction professionals concerning the preparation and execution of construction projects, regardless of their actual significance.
To achieve the objective of this research, the first step involved a reduction in the number of errors by removing negligible errors without further investigation, as the original list of errors [27] was highly extensive.
The reduction was performed in cooperation with a panel of experts who, by consensus, removed the errors that were considered to be negligible in terms of their overall impact on a project. Hence, the list was reduced to 26 and 12 errors relating to drawing documentation and the list of works, supplies and services, respectively. The 38 errors that made it to the final list were coded (Table 3) for follow-up interviews and analysis.

Table 3. Final list of errors

Code	Error description (DD … drawing documentation-related error; BC … list of works, supplies and services-related errors)
DD 01	Poor coordination of building technical equipment (BTE) and other areas
DD 02	Poor architectural and construction solutions (ACS) coordination - cutouts, compositions, reports
DD 03	Incomplete project documentation
DD 04	Poor structural engineering coordination (statics)
DD 05	Communication between the investor and general designer
DD 06	Design error - minimum toilet dimensions, wrong composition
DD 07	Poorly designed technical facilities
DD 08	Coordination and partitioning of subparts
DD 09	Errors in design due to carelessness in drawing
DD 10	Wrong implementation details
DD 11	Process coordination
DD 12	Insufficient annotations
DD 13	Specification of the assignment - scope of construction permit documents (CPD) and construction implementation documentation (CID)
DD 14	Failure to consider technical facilities
DD 15	Failure to consider site design
DD 16	Poor survey - failure to accurately plot the existing situation
DD 17	Discrepancies between the actual situation and project documentation
DD 18	Failure to conduct probes and surveys
DD 19	Designer incompetence

DD 20	Poor preparation, ignorance of materials
DD 21	Inadequate specification of intent and assignment - air conditioning/ventilation
DD 22	State subsidies - completely different project documentation scope
DD 23	Changes in project documentation not approved by the investor
DD 24	Failure to observe the investor’s specifications
BC 01	Quantity calculation error
BC 02	Missing items
BC 03	Missing bill of quantities
BC 04	Incorrectly selected items
BC 05	Earthworks - calculation of volumes, soil classes
BC 06	Movement of bulk materials
BC 07	Earth management - removal, disposal
BC 08	Incorrect description of items
BC 09	Missing budget - construction contractor
BC 10	Installation without materials (item does not include material)
BC 11	Failure to reflect changes in project documentation
BC 12	Specific items - specifications

To answer the research questions, primary data were collected through in-depth semi-structured interviews. Regarding the sample size, different authors have recommended different numbers of respondents. Creswell [33] recommended conducting between 5 and 20 interviews. Galvin [34] gave an ideal range of 8-17 interviews, while Hennink et al. [35] stated that 9 interviews were sufficient to achieve objective explanatory value. Therefore, a total of 16 interviews with experts active in the Czech construction market was conducted between February and May 2023. Targeted interviewees were selected according to the following criteria: (a) having relevant experience in the area under study and (b) including different project stakeholders according to their role in a project. Thus, (a) the data obtained were sufficiently relevant and had informational value, and (2) the interviewees were able to present different perspectives and describe specific aspects within the project lifecycle. The basic description of the respondents as given in Table 4 were divided into three groups:

- project preparation (designers, budgeters, architects);
- project implementation (construction companies, technical supervisors, construction preparers);
- investors (main investor, investor’s representative).

Interviews were structured into two parts. The first part questioned the basic characteristics of the respondents (Table 4), while the second part was intended to reveal their views and experiences in relation to documentation deficiencies perceived as project risks. Accordingly, qualitative data were collected on a total of 36 documentation errors, particularly, respondents were inquired: (1) when was the error discovered – at what stage of the construction work life cycle; (2) how was the error discovered – during what activity; (3) what specific impact did the error have on the project in the context of the Iron Triangle; (4) can any measures be proposed to prevent such an error from occurring? Furthermore, data on the probability of occurrence and degree of impact for all 36 documentation errors were collected using a 5-point Likert scale (1 - almost uncertain, 2 - unlikely, 3 – fifty-fifty, 4 - likely, 5 – almost certain; 1 – negligible, 2 - minor, 3 - moderate, 4 - significant, 5 - severe).
The interview was organised as an open-ended debate allowing for an in-depth discussion of relevant topics and providing the necessary supportive interaction between the interviewer and individual respondents. Responses were recorded in writing on a spreadsheet for further analysis.

For this study, the interviews were analysed to reveal the details and characteristics of individual errors encountered by the respondents in their practice. The deductive approach was applied to the aforementioned predetermined topics based on existing knowledge. Most of the interviews lasted approximately 60 min, although the time varied from 40 to 90 min.
The Czech Republic was chosen as the study area because it is an EU member state with a developed construction market, where numerous large multinational construction companies operate.

Table 4. Profile overview of the interviewed experts

	Qualification	Total experience (years)	Usual investment amount (EUR million excl. VAT)	Respondent group
Respondent 1	Associate professor	over 15	2-6	Investor
Respondent 2	Master’s degree	1-5	2-6	Implementation
Respondent 3	Master’s degree	5-10	1-2	Implementation
Respondent 4	Doctoral degree	10-15	1-2	Preparation
Respondent 5	Master’s degree	10-15	2-6	Preparation
Respondent 6	Master’s degree	1-5	1-2	Implementation
Respondent 7	Master’s degree	10-15	0,5-1	Preparation
Respondent 8	Master’s degree	1-5	0,5-1	Preparation
Respondent 9	Doctoral degree	5-10	2-20	Preparation
Respondent 10	Master’s degree	10-15	2-8	Implementation
Respondent 11	Master’s degree	10-15	2-8	Investor
Respondent 12	Master’s degree	5-10	1-2	Implementation
Respondent 13	Master’s degree	10-15	1-2	Implementation
Respondent 14	Doctoral degree	5-10	2-20	Investor
Respondent 15	Master’s degree	over 15	1-2	Implementation
Respondent 16	Master’s degree	over 15	2-20	Investor

2.1 Processing data related to risk assessment

The first step involved assessing the respondents’ perception of documentation errors in terms of risk parameters, such as the probability of occurrence and degree of impact (effect on the project). Specifically, descriptive statistics were used to rank the identified risk factors according to the mean scores. The analysis examined the perception at the level of the whole sample and separately considered the role of respondents in a project (investor, implementation, preparation). The focus was primarily on the top three errors, both from the perspective of the sample as a whole and the three stakeholder roles.
Risk management theory defines the value of a risk as the product of its probability of occurrence and its impact on a project [36, 37]. Given the nature of the data collected for this study (use of the 5-point Likert scale), risk was depicted and assessed using a risk matrix [38–40]. The matrix has some limitations [41-43], such as modelling risk without correlation of risk factors. Therefore, the risk matrix was modified in various ways. Duijm [42] recommended adding a probability consequence diagram with continuous scales to the matrix. However, matrices based on two-dimensional probability and impact assessment still prevail in literature and are practice [44], mainly due to their simplicity and versatility. Therefore, the assessment of the probability of occurrence and the impact was conducted using the two-dimensional form of the matrix, and any correlations are subject to further research leading to the development of methodological measures and advanced proposals to manage the identified risks.
On the horizontal axis, the matrix evaluated the degree of impact (in an adjusted interval according to the mean score: almost uncertain 1,00-1,80; unlikely 1,81-2,60; fifty-fifty 2,61–

3,40; likely 3,41-4,20; almost certain 4,21-5,00), while the vertical axis, the probability of occurrence was evaluated (in an adjusted interval according to the mean score: negligible 1,00-1,80; minor 1,81-2,60; moderate 2,61-3,40; significant 3,41-4,20; severe 4,21-5,00). The available literature provided three [38, 39, 42], four [45], or five risk zones [46] for evaluating the risk level, depending on the size of the matrix. For this research, a 5×5 matrix with three risk zones was selected, as recommended by Duijm [42]: High-risk zone, medium-risk zone and low-risk zone.

Furthermore, the difference between risk assessment and the perspective of individual stakeholders was observed. By comparing the mean scores for the probability of occurrence and degree of impact, any significant difference between the values was observed, with the threshold set at a difference >1,0.

2.2 Processing of qualitative data

Section 2.1 describes the method used to evaluate the numerical data. In addition to the probability of occurrence and the degree of impact, the interviewed experts provided non-numerical information for each error, focusing on (1) when the error was discovered, (2) how the error was discovered, (3) what specific impact the error had on the project in terms of the Iron Triangle, (4) whether any measures could be proposed to prevent such an error from occurring, and (5) who was responsible for the error. Particularly, the errors identified as significant in the risk matrix assessment (primarily those falling in the high-risk and medium-risk zones) were analysed and discussed further.

3 Results and discussion

This section presents the analytical results of two types of project documentation errors (errors in drawing documentation and those in the list of works, supplies and services) from the perspective of perceptions of the probability of occurrence, degree of impact, comparative errors among stakeholders and responsibility for errors.

3.1 Errors and risks of drawing documentation

Table 5 shows mean scores and ranks of the perceived probability of occurrence of drawing documentation errors, while Table 6 relates to the perceived degree of impact. The most frequent errors in project documentation from the perspective of the whole sample were DD09 (mean score 3,31), DD10 (mean score 3,06), DD01 and DD02 (mean score 3,00). The errors with the highest degree of impact were DD19 (mean score 3,94), DD22 (mean score 3,63) and DD03 and DD15 (mean score 3,38). Contrarily, the majority of errors scored less than 3,00; where five errors even had mean scores between 1,00 and 2,00. Thus, errors in project documentation generally tended to have an average or below-average probability of occurrence.

From the perspective of the degree of impact, the achieved mean scores were generally higher; specifically, no error was characterised by a mean score lower than 2,00; while the number of errors with a mean score above 3,00 was higher when compared to the probability of occurrence. The errors with the highest impact mean score were DD19 (mean score 3,94), DD22 (mean score 3,63) and DD03 and DD15 (mean score 3,38).

In general, all errors in project documentation only impacted the price and schedule of the resulting work. None of the respondents in the interview mentioned a deterioration in the final quality of work as a possible consequence of a specific error. An error in documentation did not lead to a poorly executed design. Conversely, the implementation team often observed the errors and used the inaccuracy as an opportunity to claim additional work or to postpone contractually binding deadlines.

Table 5. Perception of the probability of occurrence of errors in drawing documentation from the perspective of investors, preparation team and implementation team

Error description	Error code	Whole sample		Investors		Preparation		Implementation	
		MS	Rank	MS	Rank	MS	Rank	MS	Rank
Poor coordination of building technical equipment (BTE) and other areas	DD 01	3,00	3	2,75	4	3,00	4	3,14	6
Poor architectural and construction solutions (ACS) coordination – cutouts, compositions, reports	DD 02	3,00	4	2,25	11	3,00	5	3,43	3
Incomplete project documentation	DD 03	2,94	5	2,75	3	3,20	2	2,86	7
Poor structural engineering coordination (statics)	DD 04	2,06	16	1,25	23	3,00	3	1,86	18
Communication between the investor and general designer	DD 05	2,38	10	2,75	5	2,80	7	1,86	17
Design error – minimum toilet dimensions, wrong composition	DD 06	1,69	22	1,75	17	2,00	20	1,43	23
Poorly designed technical facilities	DD 07	1,75	20	1,50	19	1,20	24	2,29	12
Coordination and partitioning of subparts	DD 08	2,06	17	2,25	12	2,60	12	1,57	22
Errors in design due to carelessness in drawing	DD 09	3,31	1	3,00	2	3,20	1	3,57	2
Wrong implementation details	DD 10	3,06	2	2,25	10	2,80	8	3,71	1
Process coordination	DD 11	1,75	21	2,00	15	1,80	22	1,57	21
Insufficient annotations	DD 12	2,94	6	2,75	7	2,60	11	3,29	5
Specification of the assignment – scope of construction permit documents (CPD) and construction implementation documentation (CID)	DD 13	2,38	11	2,00	14	2,80	6	2,29	11
Failure to consider technical facilities	DD 14	2,38	12	2,50	9	2,60	10	2,14	16
Failure to consider site design	DD 15	2,13	14	2,00	13	2,20	18	2,14	15
Poor survey – failure to accurately plot the existing situation	DD 16	2,69	8	2,75	6	2,60	9	2,71	9
Discrepancies between the actual situation and project documentation	DD 17	2,63	9	3,00	1	2,20	17	2,71	8
Failure to conduct probes and surveys	DD 18	2,88	7	2,50	8	2,40	14	3,43	4
Designer incompetence	DD 19	2,13	15	1,75	16	2,40	13	2,14	14
Poor preparation, ignorance of materials	DD 20	2,00	18	1,50	20	2,00	19	2,29	13
Inadequate specification of intent and assignment – air conditioning/ventilation	DD 21	2,31	13	1,75	18	2,40	15	2,57	10
State subsidies – completely different project documentation scope	DD 22	1,63	23	1,25	22	1,80	21	1,71	20
Changes in project documentation not approved by the investor	DD 23	1,94	19	1,50	21	2,40	16	1,86	19
Failure to observe the investor's specifications	DD 24	1,50	24	1,25	24	1,80	23	1,43	24

**MS denotes Mean Score*

Table 6. Perception of the degree of impact of errors in drawing documentation from the perspective of investors, preparation team and implementation team

Error description	Error code	Whole sample		Investors		Preparation		Implementation	
		MS	Rank	MS	Rank	MS	Rank	MS	Rank
Poor coordination of building technical equipment (BTE) and other areas	DD 01	3,06	10	2,75	9	2,80	12	3,43	6
Poor architectural and construction solutions (ACS) coordination – cutouts, compositions, reports	DD 02	2,75	18	2,50	15	2,40	17	3,14	12
Incomplete project documentation	DD 03	3,38	3	2,25	19	3,80	3	3,71	2
Poor structural engineering coordination (statics)	DD 04	3,13	7	3,00	8	2,80	11	3,43	8
Communication between the investor and general designer	DD 05	3,06	11	2,50	13	4,00	1	2,71	22
Design error – minimum toilet dimensions, wrong composition	DD 06	3,13	8	2,50	16	4,00	2	2,86	19
Poorly designed technical facilities	DD 07	3,19	5	2,50	17	3,40	8	3,43	7
Coordination and partitioning of subparts	DD 08	2,38	23	2,25	21	2,40	18	2,43	24
Errors in design due to carelessness in drawing	DD 09	2,06	24	2,25	18	1,20	24	2,57	23
Wrong implementation details	DD 10	3,06	9	2,25	20	3,00	9	3,57	3
Process coordination	DD 11	2,75	20	2,25	22	2,60	16	3,14	15
Insufficient annotations	DD 12	2,81	16	2,50	14	2,60	14	3,14	13
Specification of the assignment – scope of construction permit documents (CPD) and construction implementation documentation (CID)	DD 13	3,00	13	2,75	11	3,60	5	2,71	20
Failure to consider technical facilities	DD 14	2,63	21	2,75	10	2,20	22	2,86	18
Failure to consider site design	DD 15	3,38	4	3,25	7	3,60	7	3,29	10
Poor survey – failure to accurately plot the existing situation	DD 16	2,88	15	3,25	5	2,20	21	3,14	14
Discrepancies between the actual situation and project documentation	DD 17	3,00	12	3,25	4	2,40	20	3,29	9
Failure to conduct probes and surveys	DD 18	3,13	6	3,25	6	2,40	19	3,57	4
Designer incompetence	DD 19	3,94	1	4,00	1	3,60	6	4,14	1
Poor preparation, ignorance of materials	DD 20	2,94	14	3,50	2	2,80	13	2,71	21
Inadequate specification of intent and assignment – air conditioning/ventilation	DD 21	2,75	19	2,75	12	2,60	15	2,86	17
State subsidies – completely different project documentation scope	DD 22	3,63	2	3,50	3	3,80	4	3,57	5
Changes in project documentation not approved by the investor	DD 23	2,44	22	2,00	24	1,60	23	3,29	11
Failure to observe the investor's specifications	DD 24	2,81	17	2,25	23	3,00	10	3,00	16

**MS denotes Mean Score*

Figure 1 shows the risk matrix for project documentation. The matrix was constructed based on the probability of occurrence and degree of impact for the whole sample according to Tables 5 and 6. Following the 5-point Likert scale, the mean scores from Tables 5 and 6 were assigned to the risk matrix quadrants, as shown in Figure 1 (0,8 interval). From Figure 1, most of the detected errors fell into the medium-risk zone, while errors DD 06, 08, 11, 23 and 24 fell into the low-risk zone.

The errors in project documentation with the highest risk were divided into two main areas, where comparable impacts on the project were found and similar measures for their elimination could be proposed, namely:

- errors in project documentation (DD 01, 02, 03, 10, 12, 19);
- poor documentation (DD 16, 17, 18).

Errors in project documentation, missing parts thereof or missing details had a particular impact on the schedules according to the findings of this study, where the identified deficiencies required remedy or were supplemented by the designer.

Risk matrix		**Impact**				
		Negligible (1,00-1,80)	Minor (1,81-2,60)	Moderate (2,61-3,40)	Significant (3,41-4,20)	Severe (4,21–5,00)
Probability	Almost uncertain (1,00-1,80)	-	-	DD06, 11, 24	DD22	-
	Unlikely (1,81-2,60)	-	DD08, DD23	DD04, 05, 07, 13, 14, 15, 20, 21	DD19	-
	Fifty-fifty (2,61-3,40)	-	DD09	DD01, 02, 03, 10, 12, 16, 17, 18	-	-
	Likely (3,41-4,20)	-	-	-	-	-
	Almost certain (4,21-5,00)	-	-	-	-	-

Legend: [42]

Low risk zone
Medium risk zone
High risk zone

Figure 1. Risk matrix for drawing documentation

According to the experts' opinion, errors in documentation such as those in DD 02, 03, 10, 12 and 19 could be prevented by selecting a good contractor for project documentation. References/experience, such as aspects that should be taken into consideration as a qualification requirement or evaluation criterion when selecting a contractor were cited. An important point made by the experts was to not focus on the references of a company as a whole but on the experience of specific members of the project team. An example where a company had demonstrated 20 years of experience with design work in the field was cited, but the documentation was effectively produced by a student/intern without the necessary experience and completed training.

The errors caused by the lack of probes and poor surveying (DD16, 17 and 18) were mainly due to the unwillingness of investors to pay for proper surveying (3D scanning of buildings). The domain required contractors and designers to be educated: investors should understand that saving a few hundred euros on (for example) a geotechnical survey would be insignificant compared to the problems that could arise when (for example) a different class of soil is found during excavation and the load bearing capacity has to be recalculated and new foundations designed, thereby resulting in long delays and an increased final price of buildings. A similar case could be considered for reconstructions and the lack of probing of existing structures.

3.2 Errors in the list of works, supplies and services

The mean score and ranks of the perceived probability of occurrence of errors in the list of works, supplies and services are presented in Table 7, while Table 8 presents the results relating to the perceived degree of impact. In terms of the whole sample, the most frequent errors in the list of works, supplies and services included BC02 (mean score 3,38), BC01 (mean score 3,13) and BC05 (mean score 2,31). The errors with the highest impact were BC02 (mean score 3,63), BC10 and BC11 (mean score 3,44), and BC09 (mean score 3,25). On observing the overall frequencies, only two errors had a value higher than 3,00, while most of the errors ranged between 1,80 and 2,31. Thus, the occurrence of errors in the budget was average to below average. In terms of the degree of impact, all errors ranged between 2,56 to 3,63. Thus, the impact of each was moderate to significant.

Table 7. Perception of the probability of occurrence of errors in the list of works, supplies and services from the perspective of investors, preparation team and implementation team

Error description	Error code	Whole sample		Investors		Preparation		Implementation	
		MS	Rank	MS	Rank	MS	Rank	MS	Rank
Quantity calculation error	BC 01	3,13	2	3,50	2	2,60	3	3,29	2
Missing items	BC 02	3,38	1	3,50	1	2,80	1	3,71	1
Missing bill of quantities	BC 03	2,19	5	1,00	10	2,20	8	2,86	3
Incorrectly selected items	BC 04	1,81	10	1,00	11	1,80	10	2,29	5
Earthworks – calculation of volumes, soil classes	BC 05	2,31	3	2,00	3	2,80	2	2,14	7
Movement of bulk materials	BC 06	2,00	8	1,75	7	1,80	11	2,29	6
Earth management – removal, disposal	BC 07	2,06	6	1,75	6	2,40	7	2,00	10
Incorrect description of items	BC 08	2,06	7	2,00	4	2,00	9	2,14	8
Missing budget – construction contractor	BC 09	1,75	11	1,00	12	2,40	6	1,71	12
Installation without materials (Item does not include material)	BC 10	1,56	12	1,50	9	1,20	12	1,86	11
Failure to reflect changes in project documentation	BC 11	2,00	9	1,50	8	2,40	4	2,00	9
Specific items – specifications	BC 12	2,25	4	1,75	5	2,40	5	2,43	4

**MS denotes Mean Score*

Table 8. Perception of the degree of impact of errors in the list of works, supplies and services from the perspective of investors, preparation team and implementation team

Error description	Error code	Whole sample		Investors		Preparation		Implementation	
		MS	Rank	MS	Rank	MS	Rank	MS	Rank
Quantity calculation error	BC 01	3,00	6	3,25	3	2,40	10	3,29	4
Missing items	BC 02	3,63	1	3,75	1	3,00	4	4,00	1
Missing bill of quantities	BC 03	2,88	9	2,50	12	3,20	3	2,86	10
Incorrectly selected items	BC 04	3,00	7	2,75	10	2,80	8	3,29	5
Earthworks – calculation of volumes, soil classes	BC 05	3,13	5	3,00	4	3,00	5	3,29	6
Movement of bulk materials	BC 06	2,81	11	2,50	11	2,80	9	3,00	9
Earth management – removal, disposal	BC 07	2,81	10	2,75	8	3,00	7	2,71	12
Incorrect description of items	BC 08	2,56	12	2,75	7	2,20	12	2,71	11

Missing budget – construction contractor	BC 09	3,25	4	3,00	6	3,00	6	3,57	3
Installation without materials (Item does not include material)	BC 10	3,44	3	2,75	9	3,80	1	3,57	2
Failure to reflect changes in project documentation	BC 11	3,44	2	3,50	2	3,60	2	3,29	7
Specific items – specifications	BC 12	2,88	8	3,00	5	2,40	11	3,14	8

**MS denotes Mean Score*

Figure 2 shows the risk matrix for the list of works, supplies and services. Most of the detected errors fell into the medium-risk zone, while errors BC 08 and 09 fell into the low-risk zone. Notably, error BC02 (missing items) was the only one assigned to the high-risk zone.
The errors in the list of works, supplies and services with the highest risk were divided into three main areas where comparable impacts on the project were found and similar measures for their elimination could be proposed, namely:

- budget errors due to ignorance or inattention (BC01, BC02, BC03, BC04, BC10 and BC12);
- failure to take account of changes in project documentation when preparing the budget (BC11);
- insufficient knowledge of the technology of excavation and movement of bulk materials (BC05, BC06, BC07).

Risk matrix		**Impact**				
		Negligible (1,00-1,80)	Minor (1,81-2,60)	Moderate (2,61-3,40)	Significant (3,41-4,20)	Severe (4,21-5,00)
Probability	Almost uncertain (1,00-1,80)	-	-	BC09	BC10	-
	Unlikely (1,81-2,60)	-	BC08	BC03, 04, 05, 06, 07, 12	BC11	-
	Fifty-fifty (2,61-3,40)	-	-	BC01	BC02	-
	Likely (3,41-4,20)	-	-	-	-	-
	Almost certain (4,21-5,00)	-	-	-	-	-

Legend: [42]

Low risk zone
Medium risk zone
High risk zone

Figure 2. The risk matrix for the list of works, supplies and services

Particularly, error BC02 (missing items) was the only error classified in the high-risk zone. In interviews, this error was often compared to BC01. In particular, respondents 14, 15 and 16 noted that they considered missing items in the budget to be significantly more serious. They reasoned that if the item was completely missing from the budget, the specific price of the work as designed (e.g., unit price per 1 m^3 of concrete for the foundation structure) was not

contracted. Here, the contractor may put a significant premium on the additional work needed compared to the previously agreed scope of work. On the other hand, if the item is not missing from the budget and “only” the quantity is erroneous (BC01), a correction will be made to the actual quantity during invoicing, but the contracted price of the item in question will not change.
Errors in the budget that are caused by failure to reflect changes in the drawing documentation (BC11) in the budget, i.e., changes to the project documentation after submission of the budget, are relatively easy to resolve and can be dealt with in two ways. The interviews revealed that this error can be eliminated by properly recording all changes, modifications and additional requirements using an online platform so that all construction project participants have a complete picture in real-time (i.e., using the Common Data Environment (CDE) means). The second option is to prepare the budget only after the delivery of all materials and approval of the final documentation by the investor. This option is considerably simpler but has an impact on the deadlines for the submission of the complete technical specifications of the tender documentation.
Errors in the budget due to ignorance or inattention (BC01, BC02, BC03, BC04, BC10, BC12) were found to have a particularly significant impact on the price of the work. Missing items or incorrectly calculated quantities were most often only discovered at the time of invoicing when quantities were missing or in excess. The missing bill of quantities caused complications, especially in invoicing individual parts of the contract. The interviewed experts often mentioned the need to cross-check at least the main items in the pricing process. Unfortunately, all project participants were usually under pressure from deadlines for submitting bids and not enough time was allocated for such cross-checking.
Another significant error in terms of the risks concerning the list of works, supplies and services is the lack of knowledge of the excavation technology in terms of soil movement, backfilling, temporary storage or disposal (BC07). This error often arises due to the failure of the designer to define the requirements for soil handling. The budgeter must then ask the designer, the investor or even the construction contractor (if known) how the earthworks will be carried out or when and where the excavated soil will be taken.

3.3 Comparison of perceptions of errors among stakeholders

This study recognises three types of construction project stakeholders, namely stakeholders representing investors, the preparation team and the implementation team. In Sections 3.1 and 3,2; numerical values for probabilities of occurrence and degrees of impact were presented for the whole sample as well as individually for each stakeholder. Tables 9 and 10 present these data in one place, with the identification of errors where a significant difference in risk perception was found (values marked with *).
In the case of errors in drawing documentation, four errors with a significant difference in perception of the probability of occurrence (DD02, DD04, DD07 and DD08), six errors where there was a significant difference in perception of the degree of impact (DD03, DD05, DD06, DD09, DD16 and DD23) and two errors where a difference was found for both risk parameters simultaneously (DD10 and DD18) were found. Thus, for half (12 out of 24) of the errors, a significant difference was found between stakeholders, which is also reflected in the risk matrix. The values from investor respondents were mostly lower, while the mean score values from preparation and implementation respondents were higher. In general, investors tend to underestimate errors, while the preparation and implementation teams are more likely to appreciate the real potential impact of errors on a project.
The risk matrix (Fig. 3) clearly illustrates these differences. In contrast to the values for the whole sample (Fig. 1), when marking out the individual stakeholders, several errors also fall into the high-risk zone. These are errors DD02-R, DD03-P, DD03-R, DD05-P, DD10-R and DD18-R, which are perceived as such by preparation or implementation teams, while from the investors’ perspective, no errors are placed in the high-risk zone; where DD03-P refers to the drawing documentation error no. 2 perceived by preparation stakeholder group.

Table 9. Probability of occurrence and perception of the degree of impact of errors in drawing documentation as compared among the stakeholders

Error code	Investor's probability of occurrence (MS)	Investor's impact on project (MS)	Preparation probability of occurrence (MS)	Preparation impact on project (MS)	Implementation probability of occurrence (MS)	Implementation impact on project (MS)
DD 01	2,75	2,75	3,00	2,80	3,14	3,43
DD 02	2,25*	2,50	3,00	2,40	3,43*	3,14
DD 03	2,75	2,25*	3,20	3,80*	2,86	3,71*
DD 04	1,25*	3,00	3,00*	2,80	1,86*	3,43
DD 05	2,75	2,50*	2,80	4,00*	1,86	2,71*
DD 06	1,75	2,50*	2,00	4,00*	1,43	2,86*
DD 07	1,50	2,50	1,20*	3,40	2,29*	3,43
DD 08	2,25	2,25	2,60*	2,40	1,57*	2,43
DD 09	3,00	2,25*	3,20	1,20*	3,57	2,57*
DD 10	2,25*	2,25*	2,80	3,00	3,71*	3,57*
DD 11	2,00	2,25	1,80	2,60	1,57	3,14
DD 12	2,75	2,50	2,60	2,60	3,29	3,14
DD 13	2,00	2,75	2,80	3,60	2,29	2,71
DD 14	2,50	2,75	2,60	2,20	2,14	2,86
DD 15	2,00	3,25	2,20	3,60	2,14	3,29
DD 16	2,75	3,25*	2,60	2,20*	2,71	3,14
DD 17	3,00	3,25	2,20	2,40	2,71	3,29
DD 18	2,50	3,25	2,40*	2,40*	3,43*	3,57*
DD 19	1,75	4,00	2,40	3,60	2,14	4,14
DD 20	1,50	3,50	2,00	2,80	2,29	2,71
DD 21	1,75	2,75	2,40	2,60	2,57	2,86
DD 22	1,25	3,50	1,80	3,80	1,71	3,57
DD 23	1,50	2,00	2,40	1,60*	1,86	3,29*
DD 24	1,25	2,25	1,80	3,00	1,43	3,00

For example, DD02 and DD10 errors are perceived by the implementation team to be in the high risk zone, while investors perceive these errors to be in the low risk zone. In terms of the risk matrix, these are significantly conflicting risk assessments across stakeholders; therefore, good communication between them is of high importance and is one of the prerequisites for the successful completion of the project. Usually, an information asymmetry exists between stakeholders (the situation in which one of the two or more stakeholders is better informed than the other(s) [47]), which should be eliminated through an appropriate and open communication platform. In this way, appropriate communication exchange helps to reduce errors that might result from a lack of knowledge [48].

The above errors can be divided into two areas where there are comparable impacts on the project or similar measures can be proposed to eliminate them. These are errors in project documentation (DD02, DD03, DD05 and DD10) and poor documentation (DD18). These impacts and measures have already been described and discussed in Section 3.1.

Risk matrix		Impact				
		Negligible (1,00-1,80)	Minor (1,81-2,60)	Moderate (2,61-3,40	Significant (3,41-4,20)	Severe (4,21-5,00)
Probability	Almost uncertain (1,00-1,80)	-	DD06 - I, DD08 - R	DD04 - I, DD06 - R, DD07 - P	-	-
	Unlikely (1,81-2,60)	DD23 - P	DD02 - I, DD08 - P, DD10 - I, DD16 - P, DD18 - P	DD23 - R	DD04 - R, DD05 - R, DD06 - P,	-
	Fifty-fifty (2,61-3,40)	DD09 - P	DD05 - I, DD07 - R, DD09 - I,	DD03 - I, DD04 - P, DD16 - I	DD03 - P, DD03 - R, DD05 - P,	-
	Likely (3,41-4,20)	-	DD09 - R	DD02 - R,	DD10 - R, DD18 - R	-
	Almost Certain (4,21-5,00)	-	-	-	-	-

Legend: [42]

Low risk zone
Medium risk zone
High risk zone

Figure 3. The risk matrix for project documentation – comparison among stakeholders

Table 10 shows data for errors in the list of works, supplies and services. The most significant mean score differences for probability of occurrence are found in errors BC03, BC04 and BC09, and in errors BC02 and BC10 for degree of impact. No errors were found for which there were significant differences for both risk parameters simultaneously.
As in the case of project documentation errors, the general conclusion is that investors tend to be less aware of risk than the preparation and implementation teams and are therefore more likely to underestimate the risk. Examples include BC03, BC04 and BC09, where investors rate the probability of occurrence at the lowest possible value of 1.0, whereas the preparation and implementation teams are aware that these risks may occur.
These differences can also be seen by looking at the risk matrix (Fig. 4) where all errors from the investors' perspective fall in the low risk zone. However, when compared to Figure 3, the distribution of errors is comparable. Most of the errors fall in the medium risk or low risk zone. Only the error labelled BC02-R (R=implementation) falls in the high risk zone. This error has already been discussed in more detail in Section 3.2.

Table 10. Probability of occurrence and perception of the degree of impact of errors in the list of works, supplies and services as compared among the stakeholders

Error code	Investor's probability of occurrence (MS)	Investor's impact on project (MS)	Preparation probability of occurrence (MS)	Preparation impact on project (MS)	Implementation probability of occurrence (MS)	Implementation impact on project (MS)
BC 01	3,50	3,25	2,60	2,40	3,29	3,29
BC 02	3,50	3,75	2,80	3,00*	3,71	4,00*
BC 03	1,00*	2,50	2,20*	3,20	2,86*	2,86
BC 04	1,00*	2,75	1,80	2,80	2,29*	3,29
BC 05	2,00	3,00	2,80	3,00	2,14	3,29
BC 06	1,75	2,50	1,80	2,80	2,29	3,00
BC 07	1,75	2,75	2,40	3,00	2,00	2,71
BC 08	2,00	2,75	2,00	2,20	2,14	2,71
BC 09	1,00*	3,00	2,40*	3,00	1,71	3,57
BC 10	1,50	2,75*	1,20	3,80*	1,86	3,57
BC 11	1,50	3,50	2,40	3,60	2,00	3,29
BC 12	1,75	3,00	2,40	2,40	2,43	3,14

Risk matrix		Impact				
		Negligible (1,00-1,80)	Minor (1,81-2,60)	Moderate (2,61-3,40)	Significant (3,41-4,20)	Severe (4,21-5,00)
Probability	Almost uncertain (1,00-1,80)	-	BC03 - I, BC09 - I	BC04 - I, BC10 - I	BC10 - P	-
	Unlikely (1,81-2,60)	-	-	BC03 - P, BC04 - R, BC09 - P	-	-
	Fifty-fifty (2,61-3,40)	-	-	BC02 - P, BC03 - R,	-	-
	Likely (3,41-4,20)	-	-	-	BC02 - R	-
	Almost Certain (4,21-5,00)	-	-	-	-	-

Legend: [42]

Low risk zone
Medium risk zone
High risk zone

Figure 4. The risk matrix for the list of works, supplies and services – comparison among stakeholders

3.4 Responsibility for errors in technical specifications of tender documentation

The next issue examined in this paper is the origin of the error (who caused it), the definition of responsibility (who is responsible for the error) and the associated actions (who must correct the error, who pays for the consequences). For these purposes, it is necessary to distinguish

between publicly funded projects (public procurement subject to the relevant laws and regulations) and private projects.
As mentioned in the introduction, in public procurement, the content and scope of the technical specifications of tender documentation are defined by legislation [8-11]. According to the Czech legislative framework, the contracting authority is responsible for the quality, content and scope of the entire tender documentation, including the technical specifications, even if the errors are caused by the designer, budgeter or other parties. In the case of other countries, it is necessary to assess how local legislation addresses these legal issues, as such regulations may vary significantly from one country to another.
In most cases, the errors that are the subject of this research were caused by the project designer (designer or budgeter). Worthy of note are errors DD05, DD13, DD21 and DD22, which were also caused by the contracting entity, in particular by poor specifications, communication or general ignorance of the scope of work required.
In the above context, the errors identified must therefore be resolved by the contracting entity in collaboration with the designer who drew up the technical specifications. The designer will, in effect, remedy the defects and deficiencies identified in his work as part of the warranty. It then depends on the specific terms of the contract between the client and the designer whether the client can claim penalties for errors in the project documentation and thereby reduce the cost of the additional work required. In this context, it is appropriate to consider the use of an incentive/disincentive mechanism to reward excellent performance and penalise poor results [49].
Procurement in the private sector is not governed by any specific legislative regulations and, therefore, relies solely on the cooperation between the designer, the contracting entity and the contractor [14]. The outcome, therefore, depends on the specific terms of the work contract, which determine who is responsible for errors in the technical specifications and who is liable to pay for any additional work.
Respondents 6, 13 and 15, as representatives of the contractor, observed in practice that they were warned (before budgeting) by a ‘strong and experienced’ developer (contracting entity) that there would be zero acceptance of possible additional work, even in case of errors in the documentation. In these cases, the responsibility for errors in the technical specifications was shifted from the contracting entity to the contractor. On the other hand, respondents 3 and 12 mentioned a similar experience in public procurement, namely that any additional work would be paid for by the contracting authority. Thus, it can be concluded that when standardised FIDIC-type contracts [50] are not used, the distribution of responsibility in contractual relations often depends on the bargaining power and position of the parties involved.

4 Conclusions

Although there is a consensus among experts on the importance of the quality of the technical specifications of tender documentation in relation to the success of the project, there is a lack of substantial knowledge on how deficiencies in the documentation can affect the project, how they are perceived as risk factors by the various stakeholders in the construction project, and how this issue is practically addressed in the context of liability. Specifically, this research addresses four research questions to fill this gap in the available literature.
The presented findings revealed that in relation to RQ1, errors in the technical specifications of the tender documentation occur mostly unlikely and with moderate impact, however, it is obvious that drawing documentation errors more often get a fifty-fifty rating for probability in contrary to the list of works, supplies and services related errors. The investigated set of errors mostly affects the performance of the construction projects in terms of cost and time, while the findings point to the fact that quality is typically not affected (RQ2). Regarding RQ3, it can be concluded that stakeholders who are involved in the project during its implementation generally perceive errors more significantly as they can better imagine real consequences from their own practical experience when compared to stakeholders on the investors' side. The responsibility for errors depends on whether the project is public or private (RQ4). For public projects, the

responsibility bears the investor, in the case of private projects the question of responsibility depends on the provisions of the specific work contract.

4.1 Theoretical and managerial implications

The findings presented in this paper have significant theoretical implications. In particular, they broaden the understanding of how deficiencies in the technical specifications of tender documentation can affect the implementation of construction projects and how these are perceived differently by different stakeholders. The findings highlight the need for the application of stakeholder theory in the construction industry. The results presented also underline the need to address the underestimation of the situation due to insufficient knowledge or lack of information on the part of some stakeholders.
The research presented also has several managerial implications. Notably, errors in the technical specifications do not cause poorly executed construction; on the contrary, the implementation team will often discover the errors and use this opportunity to claim additional work or request a postponement of contractually binding deadlines. In general, the errors analysed primarily affect the price and schedule of the final work, but not the quality. Construction professionals should consider the selection of good contractors based on references relating to individual members of the entire project team, the checking of technical specifications by an independent experienced person – the ‘project supervisor’ – before the drawing documentation with the budget is submitted to the investor, and enhanced communication between the parties involved (using a common data environment) are among the essential factors that positively contribute to the elimination of errors in the technical specifications of the tender documentation. Finally, due attention must be paid to the issue of contract management in the context of allocating responsibility for errors.

4.2 Limitations and Future Research

The data presented relates to Czech construction practice and legislation, which limits the generalisability of this research. However, the results are, with certain limitations, transferable to other countries, especially within the European Union, which is subject to a basic uniform overarching legislation in the field of public procurement. Notably, that situations, where several errors occur simultaneously and interact, have not been examined in detail.
The second limitation opens up new avenues for research. Further study of the errors presented has the potential to explore the possible collateral effects on construction projects in a broader context. Future research should also focus on the development of an advanced control mechanism that would effectively reduce the occurrence of errors.

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