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Research paper

The importance of criteria used in performance measurement systems in Czech construction companies

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Abstract: A growing number of Czech construction companies now recognise the importance of supplementing traditional financial measurements with a wider range of non-financial measurements as well. A significant number of organisations are adopting different models of performance measurement to implement business improvement strategies. The main aim of our research was to elucidate the importance that Czech construction companies attach to the individual criteria used in measurement systems. Original data were collected using a questionnaire survey. The answers were quantified in terms of the frequency of occurrence and relative importance index. The results show that traditional measurement criteria such as time and cost are still the most important for construction companies measurement systems. Positive finding is that certain new areas of measurement are increasingly being incorporated into measurement practice and their importance for Czech construction companies is growing rapidly, especially in the area of measuring the productivity of workers and craftsmen together with the productivity of subcontractors. The environmental impact of construction is still one of the least important areas in the measurement systems of construction contracts in Czech construction companies.

Keywords: performance measurement, importance, evaluation, criterion, system, efficiency

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1. Introduction

As the construction industry rapidly evolves, it is necessary to continuously improve the systems to measure the performance of construction contracts. A very wide range of different measurable criteria is already available, but not all criteria are equally important to all companies. Some of the newly introduced criteria can often be quite neglected in some construction businesses that have been accustomed to measuring more traditional criteria such as price, time and quality [1]. Yet, the importance of some of the newer criteria is increasing considerably [2]. For example, measuring environmental impact may become one of the essential considerations for construction companies in the future, given the increasing demands for sustainability in the construction industry, environmental concerns and care for the surrounding built environment. In view of the current scarcity of raw materials on the market and overall demand that far outstrips supply, it is increasingly important for companies to produce as little waste as possible and to recycle waste [3]. Moreover, companies that can measure a wider range of criteria gain very valuable data for evaluating and implementing improvements to existing processes, thereby significantly increasing the efficiency of their business [4]. This paper investigates the relative importance construction companies in the Czech Republic attach to each performance criterion. Firstly, the literature overview section presents a wide range of criteria used to measure performance. The following sections outline the methodology used and the actual survey results supplemented by discussion and commentary. The conclusion section includes suggestions for potential future research.

2. Performance measurement systems and their measurable criteria

The most traditional measurement systems, such as the Iron Triangle, have usually focused on measuring time, cost and scope [5]. In particular, financial criteria were considered to be of paramount importance. Among the financial criteria that were and still are measured in many systems today is the deviation from the budget [6], which is measured over the course of the contract from the beginning to the end. Particularly popular is the periodic measurement at predetermined milestones in the construction schedule. It expresses the difference between the earned value and the actual cost in progress [7] and is part of earned value management [8]. Indexing is a very popular recent method of measurement, which involves the measurement of performance by individual indices, the number and form of which are continuously evolving. A widely used measurement index in financial criteria is the cost performance index, which expresses the proportion of budgeted costs to actual costs [9]. In the area of efficiency measurement, cost-effectiveness is a widely measured and very useful index for determining the effectiveness of different projects over time. Many measurement systems have improved over time and expanded the range of measurable criteria. The KPI model [10] is one such system and it has been continuously evolving since its creation to meet the changing needs of the construction industry. Simi-

larly, the Excellence model, managed by the European Foundation for Quality Management (EFQM) [11], is also being continuously developed. The Organization for Standardization, known by the acronym ISO, and its issued standardizations are now an integral part of the work and procedures of many construction companies. These standardizations and quality management systems introduce a wide variety of measurable indicators. In many cases, they lead to continuous improvement of the operation and efficiency of not only the management of enterprises, but also the management of construction contracts as such [12]. Modification of these models has brought a very important contemporary measurement criterion, namely the predictability of construction costs [13]. This criterion is particularly important for accurate and clear project planning and subsequent checks of how the plan has deviated from reality during the actual construction. The second traditional area is the measurement of time-related criteria. Here, the basic criterion is the adherence to the expected project duration linked to the effectiveness of the planned schedule [14] with respect to the actual construction duration. Another very commonly measured criterion is the work overrun rate, expressing the number of time units (e.g., days) by which the project exceeded the planned duration of works [15], i.e., it measures the overrun of the planned schedule. Communication between individual participants is also an important factor influencing the achievement of the planned construction time [16]. The work quality criterion has become an integral part of quality measurement systems. Here, there are several measurable criteria that are important for the successful outcome of a project [17]. For example, the frequency of defects in the work, where the goal is to have the number of defects as close to zero as possible. Each defect brings a significant risk of reducing the efficiency of the project and interferes with the project schedule. There are different levels of defect severity that need to be taken into account in the actual measurement. It would not be useful to assign the same importance to a defect that can be easily rectified as to a defect that is of high severity and may result in a work stoppage or even the need to remove and rebuild an already completed structure. Another criterion for the quality management of construction work is the repair rate [18], which expresses the number of repairs actually carried out. This criterion can also express the possibility that a defect is detected, but not subsequently repaired, because it is assessed that it does not prevent the use of the structure or its part and is addressed, for example, by offering a discount or a technical adjustment of adjacent structures. The criterion of the number of complaints raised by the client is a good information input for the construction company for the evaluation of the quality management of individual contracts in ex-post measurements, during the actual use of the building [18]. It is therefore a very complex criterion that can be continuously measured both during the execution of the work, when the stakeholder for reporting complaints during the construction is the technical supervision of the investor, who is also involved in the completion of the construction work and the subsequent handover of the work to the investor, and for quite a long time during the actual use of the buildings when the reporting stakeholder is the facility management. Based on this data, the construction company can also subsequently assess and evaluate the individual project teams over the long term and thus evaluate their effectiveness in terms of construction contract management. Occupational safety is another important measurement area that can

have a major impact on the construction company in terms of employee satisfaction and the expenditure to repair damage incurred by construction crews during the contract [19]. Every damage event has a negative financial effect on the company, not to mention the risk of potential legal action by competent public authorities. In the Czech Republic, there is an elaborate system of standards and legislative decrees that regulate the obligations of construction companies in terms of the protection of the health and safety of their employees, and failure to comply on the part of construction companies carries the risk of sanctions should an inspection by public authorities or the investor's safety supervisor find any violations. Another measurable criterion is the accident rate [19], which indicates the ratio between the daily incidence of accidents and the number of days worked on a contract. The site safety cost ratio is also a measurable criterion, expressing the ratio of costs incurred to the total income from the contract. A complementary criterion, but one that has a very important impact on the company's safety management, is the cost of training workers in occupational safety. Here, the emphasis is on how much time has to be spent on training the workers on the necessary aspects of occupational safety on the construction site. A very topical area is measuring the impact of the construction on the environment and its surroundings. This topic has been quite neglected by construction companies in the past. With the current emphasis on the sustainability of construction in connection with preventing further climate change, however, this approach is rising in importance. One of the first measurement criteria to be used in construction practice is the proportion of construction waste to the size of the building [20]. This criterion combines both an environmental and a financial perspective, where companies strive to produce as little waste as possible, both in terms of the amount of individual materials wasted and in the amount of non-recycled packaging material, which is an increasingly significant item in the cost of construction contracts. The impact of construction on its surroundings is often a hotly debated topic [21], both during the actual construction and in the course of the building's use. Construction companies are particularly concerned with measurement during construction. The construction process strongly influences the surroundings [22] of the site and, therefore, it is necessary to eliminate these impacts as much as possible. The first of these criteria examining the impact of construction on its surroundings is the amount or ratio of noise emissions [23]. The results are obtained by measurements in situ, with the main focus being on compliance with applicable noise limits; secondarily, the noise level in the surroundings in proportion to the size of the construction is examined. In the case of buildings, this coefficient can be related to the gross floor area of the building, and in the case of roads and similar civil engineering structures, the length may be used instead. The next criterion is the dust particle emission ratio [24], which is again measured by selected methods and instruments directly in and around the construction site. Since the burden on the surroundings is the highest in the summer months and during excavation works, preventive measures such as sprinkling the construction site with water must be adopted based on the measurement results. The amount of dust particles is also influenced by transport, whether transport on the site itself, transporting earth or rubble, or transport of materials needed for the actual construction work. A criterion that is especially related to environmental sustainability in

the construction industry is the rate of recycled material use, which expresses the ratio of the amount of recycled materials to the total amount of waste produced on-site [25]. The aim of an efficient construction business is to continuously increase the amount of recyclable materials for both environmental and financial reasons. Productivity is another major area of measurement [26], containing several measurable criteria that are crucial for construction companies. The first criterion relates to the company's leadership and management, i.e., it mainly refers to management staff in various positions such as project managers. This criterion is called management productivity and expresses the ratio of the construction company's revenues to the number of managers. The second criterion in this area is the measurement of the productivity of workers and craftsmen. This is a very important criterion, especially in direct construction, and has a key impact on the construction contract during its execution, affecting both the ability to meet the planned price and the adherence to the contract time schedule. A specific criterion, widely used in countries where the majority of contracts have a single general contractor who then procures the vast majority of supplies and work from subcontractors, is the measurement of subcontractor productivity [27]. Related to this is the proper management and scheduling of the work by the general contractor [28], ensuring a smooth transition and cooperation between subcontractors. There is also the need for a thorough procedure in acceptance of the work, ensuring that each individual subcontractor has carried out the work correctly and flawlessly and the subsequent subcontractor will then have no problem in continuing their work on the site. Measuring the ability of construction companies to manage project risks has become increasingly popular over the past decade [29]. A more traditional measurement criterion in this area is the rate of change in contract volume, measuring the cost incurred by not executing part of the construction contract. A number of factors can influence the change in contract volume and reflect both less work required and errors in the project documentation [30]. More often, however, there is a need to carry out additional work, especially in the case of reconstruction of existing buildings. An insufficient technical survey often leads to the discovery during the execution of the work that the project documentation does not correspond to the real conditions on site, e.g., due to the worse condition of the structures to be repaired or other unexpected deviations from the expected condition. In complex reconstruction works, this may involve very large sums of money to be spent over the anticipated construction budget, as well as very significant time delays. In practice, there have been cases where the entire construction project was halted for many years and the site mothballed while disputes were being resolved. This may also result in protracted lawsuits between the client and the contractor. The renovation of the building of the Institute for the Study of Totalitarian Regimes in Prague [31] is a very unfortunate example from the Czech construction practice, where insufficient building technical surveys and poor project documentation caused the construction work to be stopped for many years and followed by litigation between the client and the contractor. A less traditional criterion, but one that is rapidly growing in popularity among construction companies – especially in light of global events after 2020 in connection with the Covid-19 pandemic – is the contingency rate [32], which expresses the expected probability of occurrence of any unforeseen events such as

a pandemic, an unexpectedly fast rise in inflation, a sharp rise in the price of building materials, a shortage of foreign construction workers due to their returning home due to a military conflict, as well as floods, storms and strong winds, which are becoming more frequent due to the effects of climate change. In practice, the area of on-site security, which includes both the rate and frequency of theft of materials, is often greatly underestimated. A high theft frequency rate can have an immeasurable impact on the financial and time efficiency of contracts and must be addressed as diligently as all the other areas.

3. Methodology

For the purpose of the research presented in this paper, an online questionnaire divided into three sections with a number of sub-questions was chosen as the data collection method. The content of the questionnaire has been carefully developed, especially in terms of defining the performance measurement criteria. The compiled list of measurement criteria is based on the review of available literature as well as on previous findings of the authors of this study [33]. The questionnaire has been pre-tested in order to check the clarity of the questionnaire and its suitability to the participants. Based on the feedback received, the content was fine-tuned. The initial section of the questionnaire included general questions designed to identify the type and size of the construction company including the length of the respondent's experience in the field. The next section focused on basic questions on the measurement of construction contracts, i.e. whether the company even measured contracts at all and if so, at which stages of the project. The main part of the questionnaire concerned measurement criteria and their relevance to construction companies. Here, respondents were asked to assign to each criterion the importance of being measured as seen by the company on a Likert-scale from 1 to 5, with 1 being the least important and 5 the most important. Each subsection addressed a different area of construction contract measurement, namely financial, time, quality, safety, environmental impact, productivity, risk management and construction security. Each subsection also had specific measurable criteria (selected based on the literature survey) listed and clearly defined. In total, 285 were contacted and 59 fully completed questionnaires were received during the spring of 2022, representing 20.7% response rate. Data for each question were analysed according to the specific nature of the question and in the first instance quantified through relative frequency of occurrence. The importance of individual criteria for construction companies is also analysed using the Relative Importance Index (*RII*). The formula (3.1) for calculating *RII* is given below, where *RII* – is Relative Importance Index; W – is the weight given to each factor by the respondents from 1, 2, 3, 4 and 5 for very low, low, moderate, high and very high, respectively; A – is the highest weight (i.e., 5 in this case) and N – is the total number of respondents.

$$RII = \frac{\sum W}{(A * N)} \tag{3.1}$$

4. Results and discussion

The initial part of the questionnaire sought to establish the area of the construction industry in which the respondents operated. The traditional division of construction production was chosen (Table 1).

Table 1. Percentage share of respondents according to their specialisation in the construction industry

Construction sector	Relative frequency (%)
residential and public construction	44
industrial construction	29
transport and civil engineering construction	14
water building construction	11
other – energy sector	1
other – eco-buildings	1

Almost half of the respondents (44%) came from the civil construction sector (residential and public construction), which was not unexpected since most companies in the construction industry operate in this area. A total of 29% of respondents were active in the industrial construction sector, while 14% and 11% did business in the transport and civil engineering construction and water building construction, respectively. The next question inquired about the length of the respondents' experience in the construction industry. A very positive finding is that almost half of the respondents (i.e. 48.3%) who completed the questionnaire have more than 10 years of experience in the field, and more than 70% of the respondents have more than 5 years of experience overall (Table 2).

Table 2. Length of respondents' experience in the industry

Length of experience	Relative frequency (%)
0–2 years	6.9
2–5 years	22.4
5–10 years	22.4
Over 10 years	48.3

From this perspective, it can be assumed that the research sample is of sufficient quality in terms of the professional qualifications and experience of the respondents. The next question focused on the size of the construction company where the respondents work. Most of the respondents (44.1%) work for small companies with 10 to 49 employees, which also make up the largest share of companies in the Czech construction industry in general. Almost equal results were obtained for medium-sized and large companies which make up around a quarter of the respondents, while micro companies are represented the least (6.8%). Next came one of the most crucial questions for the distribution of companies for

our research, namely whether the companies measure their construction contracts or not. As can be seen from the percentage of responses to this question (Table 3), there are still about 12% of companies that do not measure their contracts at all, a rather unfortunate finding given that the construction industry in highly developed countries is rapidly developing in digitalisation of processes [34].

Table 3. Level of performance measurement of contracts in companies

Evaluation of contracts	Relative frequency (%)	Measurement level	Relative frequency (%)
Yes, we do measure contracts	88.1	Only after the contract's completion	17.6
		During the performance of contract and after its completion	82.4
No, we do not measure contracts	11.9	–	–

This means that there is still more than a tenth of Czech construction companies that have not even started measuring their contracts, let alone implementing sophisticated digital measurement models. To the remaining 88% of companies that do measure their contracts to increase efficiency, we asked the question of whether they measure contracts only after they are completed or also during the performance. A total of 82.4% of the companies that measure the performance of their contracts do so both during and after the contract. This is an optimal situation in terms of managing a construction contract, as continuous measurement allows companies to identify any major discrepancies in time and thus avoid financial and time losses. Measurement after completion only serves an analytical function and does not enable self-corrective intervention during the contracted performance itself. It allows to correct the procedure for the next contract, but it still puts the company at a significant disadvantage compared to businesses that measure contracts during their implementation. The next section focused on individual measurable criteria and their relevance to construction companies. It was divided into 8 subsections according to the different areas of measurement. The results are summarised in Table 4.

The results show that the traditional areas of measurement are still the most important for Czech construction companies, with the project duration (*RII*-0.854) and deviation from budget (*RII*-0.862) criteria being assigned the highest importance by the respondents. It is clear that financial and time measurement concerns are fairly dominant. However, the productivity area, which is not usually included in the traditional areas, also showed a very interesting result. The productivity of workers and craftsmen, as well as the productivity of subcontractors, scored very high. The area of the environmental impact of construction showed only a very small percentage among the concerns assigned the highest importance and also scored the smallest value of *RII*. This indicates that companies underestimate this area and its popularity in terms of measurement is not growing. In terms of the overall order of importance of the criteria, the meeting of project's expected duration was ranked

Table 4. Importance of individual criteria for construction companies

Area	Criterion	Significance					*RII*	Rank
		1	2	3	4	5		
Financial	Deviation from budget	1.9%	0%	11.5%	38.5%	48.1%	0.862	1
Financial	Cost performance index	1.9%	1.9%	9.6%	48.1%	38.5%	0.838	3
Financial	Cost effectiveness	0%	2%	19.6%	51%	27.5%	0.792	6
Financial	Predictability of construction costs	1.9%	13.5%	30.8%	36.5%	17.3%	0.708	11
Time	Meeting project's expected duration	0%	2%	9.8%	39.2%	49%	0.854	2
Time	Work overrun rate	0%	0%	21.6%	58.8%	19.6%	0.781	8
Quality	Frequency of defects	2%	0%	17.6%	54.9%	25.5%	0.788	7
Quality	Repair rate	2%	3.9%	27.5 %	47.1%	19.6%	0.742	10
Quality	No. of complaints raised by client	2%	2%	13.7%	62.7%	19.6%	0.777	9
Occupational safety	Accident rate	2%	15.7%	29.4%	25.5%	27.5 %	0.708	11
Occupational safety	Occupational safety cost rate	2%	23.5%	41.2%	17.6%	15.7%	0.631	15
Occupational safety	Occupational safety training cost rate	11.8%	33.3%	27.5 %	17.6%	9.8%	0.550	21
Environmental impact	Construction waste rate	5.9%	39.2%	17.6%	31.4%	5.9%	0.573	19
Environmental impact	Noise emissions rate	7.8%	37.3%	29.4%	23.5%	2%	0.538	22
Environmental impact	Dust particle emissions rate	7.8%	41.2%	31.4%	15.7%	3.9%	0.523	23
Environmental impact	Use of recyclable materials rate	3.9%	27.5 %	49%	13.7%	5.9%	0.569	20
Productivity	Management productivity	2%	27.5 %	23.5%	27.5 %	19.6%	0.658	13
Productivity	Productivity of workers and craftsmen	0%	5.9%	9.8%	43.1%	41.2%	0.823	4
Productivity	Subcontractor productivity	0%	3.9%	13.7%	45.1%	37.3%	0.815	5
Risk management	Contingency rate	3.9%	29.4%	33.3%	27.5 %	5.9%	0.592	18
Risk management	Change in the contract volume rate	3.9%	27.5 %	31.4%	29.4%	7.8%	0.608	17
Construction security	Materials theft rate	3.9%	17.6%	41.2%	23.5%	13.7%	0.638	14
Construction security	Materials theft frequency	3.9%	19.6%	45.1%	23.5%	7.8%	0.612	16

as the most important, with deviation from the budget coming second and productivity of workers and craftsmen coming third. The last places were taken by environmental criteria and occupational safety. The quality area also ranked quite high in all three of the selected measuring criteria, but the number of complaints raised by the client clearly dominates. The occupational safety measurement area did not perform as well as expected. The occupational safety training cost criterion came at the tail end of all the measurable criteria from all the areas of measurement.

5. Conclusions

This paper examined the measurement of construction contracts in the Czech construction practice with regard to the relevance of each measurement area and its individual criteria for the construction companies. The results show that a full 88% of companies do measure their contracts in some manner, with a significant majority measuring the contracts both during the execution of works and after completion. The advantage of doing that lies mainly in the fact that the measurement and the evaluation of its results allow the construction companies to change and improve their processes on a continuous basis, i.e. already during the performance of a construction contract, which gives them the opportunity to constantly improve their efficiency. For theoretical implications, this study empirically explores the existing conditions of performance measurement systems of Czech construction companies by identifying the importance of individual criteria. In such a way, it complements the current body of knowledge in the field by data representing one of the "newer" European Union member states. For managerial implications, this study reveals prospective performance areas currently unused. However, their inclusion in performance measurement systems by construction professionals can be expected in the near future. This detailed survey can serve as a basis for further research directions covering, for example, comparison of the the measurement and evaluation of construction contracts according to their complexity and type, e.g. study the effect of measurement and the evaluation of its results on the efficiency of new building construction as opposed to the reconstruction of existing structures.

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