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# FACTORS AFFECTING WORKFORCE AT CONSTRUCTION SITE

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The article presents the results of research carried out in construction companies among employees involved in the organisation and management of construction projects. The research concerned factors and their impact on decisions regarding the planning of quantitative employment workforce at a construction site. Based on individual assessments of individual factors, average assessments were calculated and hierarchies of the factors examined were made. In the second part of the article, the dispersion coefficient of relative classification was used to assess the reliability of the opinions collected. The content presented is a continuation of the work of the authors on the subject of employment planning at the construction site.

*Keywords*: construction, employment planning, assessment of expert opinion

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# 1. INTRODUCTION

Construction projects are characterized by their significant individuality. They differ in the way they are designed, the choice of technology and the materials used, the location of the construction site, as well as the cost and the time of implementation. Planning the implementation of a construction project is a difficult and complex task, requiring the contractor to consider many aspects of the execution of work related to time, costs and quality. The construction product should be of good quality to meet customer requirements. Research by [21] emphasized that quality control in the case of construction projects should take place both during the preparation of the construction project and during the construction phase. Particular attention should be paid to the building materials used, the good quality of which can be guaranteed, for example, by quality control during the purchase process [21]. For both the investor and the contractor of works, the accuracy of estimating the planned costs of the project implementation is of great importance. In the literature one can find many works on cost issues in construction [5, 9]. The least expected result for both parties is exceeding the planned budget and looking for reasons for differences in planned and actual costs of implementation [17]. Nowadays, the analysis of the costs of newly constructed buildings is often performed for the whole life cycle of a building [19, 20]. The project cost parameter is directly related to the time of its implementation [4]. In order to effectively estimate the construction project duration many models and methods have been proposed in the literature [7, 8,10]. Despite the development of methods supporting planning in time, the authors [12, 13] stress that delays in the completion of projects are a common problem in modern construction [1,14]. One of the stages of the process of planning a construction project in time is the decision of the contractor concerning employment at the construction site. Careful planning of hiring the appropriate number of employees at the construction site, supported by calculations, has a positive impact on its preparation and conduct.

The aim of the article is to create a hierarchy of the analysed factors affecting the planned employment on the construction site as well as to assess their impact on the basis of the contractors' opinions obtained. This assessment is subjected to verification in the next step based on the dispersion coefficient of relative classification, thanks to which a conclusion regarding the credibility of the opinions obtained can be made.

## 2. PLANNING WORKFORCE AT A CONSTRUCTION SITE

The nature of the construction process - because it entails the necessity of planning the consumption of resources during the project implementation - makes the provision of appropriate employees creating work teams a very important task. Active resources, i.e., among others workers, construction equipment, construction machines along with an operator, etc., are particularly important in the construction process, because they directly affect the working time [15].

In addition to working time, another important measure of a construction project is the financial outlays incurred for the implementation of the investment. The costs related to employment form a significant part of the total investment cost [22], which also in the aspect of budget planning confirms the validity of determining the employment on the basis of a detailed analysis and not only intuitively. In order to estimate long-term employment for the entire project, the contractor must determine the demand for employees at every stage of the work well in advance. A shortage of resources at a particular stage of implementation can limit the production and reduce productivity, while their surplus will waste resources. Sustainable employment will minimise the sudden increases in employee remuneration costs, and thus the costs of the entire construction.

Reliable planning of construction implementation in the field of employment estimation also reduces the risk of failure to meet the deadline or even the risk of inability to complete the project, or the risk of the contractor suffering huge material losses caused by attempts to implement the investment, for which, for example, the necessary resources are not available or this availability is limited.

The results of the research presented in [18] show that the most common basis for determining the number of employees and the time needed to complete the work are the time standards and the amount of planned work (42.40% of cases). It is disturbing, however, that as much as 36.40% of contractors who participated in the study do it intuitively, on the basis on intuition and experience. Not fully thought-out actions can be the cause of unnecessary losses, of both money and time, and one has to be aware that the effectiveness of organisational solutions is measured by the costs of lost time. This criterion was formulated by the forerunner of the scientific organisation of work - Karol Adamiecki.

Widely available workforce planning methods, consistent with the academic approach, are based in Poland on work time standards, available, e.g. in builder's price books. However, the construction knowledge database is criticised both by scientists and practitioners. The reasons for this are, among other things, the outdated technologies on which the implementation of work is based, and the fact that the outlays are related to undefined machines, and the work processes often have unspecified conditions of their performance, etc. [16]. A solution to this problem is the creation of internal labour cost databases created by the contractors for their needs, adjusted to the work standards of a given construction company and its employees.

In literature on the subject, one can find information that, apart from planning employment based on working time standards, quantitative techniques based on statistics are usually used. In 2002 a model of active resource planning based on the so-called employment multiplier was developed [22]. The authors of [22], based on a simple regression analysis, further developed the model for estimating overall employment using a non-linear relationship between employment and construction costs. This method was in line with the conclusion made in 1995, i.e. that the employment for the implementation of a project is strongly related to labour consumption, project type and the amount of work of a certain type.

An analogous approach was presented in 1999 [22], when the results of an international survey of performance indicators are published, and on their basis a new approach to the problem dedicated to construction in France, Germany and Great Britain was created. According to this method, performance indicators form the basis for estimating employment. Performance indicators [22] have been defined as labour intensity in manhours per square metre of constructing one floor of a building.

In the USA, researchers at the University of Texas have developed a prediction system for employment volume based on data from projects implemented by the Texas Department of Transportation. The regression equations developed at that time also took into account the type of project and the costs of its implementation [22], and its creators made the conclusion that the construction costs and project type are excellent prognostic factors. The authors in [2] used a similar regression analysis for motorway projects at the Department of Transportation in South Carolina in the USA.

The methods discussed above are based on a fixed employment rate, determined for various types of buildings or structures. Such categorisation allows using the appropriate multipliers to reflect the impact of technology and configuration of teams involved in various types of work. However, in terms of employment volume decisions, for most models, strictly defined coefficients generate certain limitations. The model must be verified each time in case of any changes in the technology used or employment configuration. In practice, this requires a lot of effort, and regular and frequent verification of the coefficients is critical for the results of the obtained forecast.

Summarising this overview of the employment selection methods, it can be concluded that the surveys conducted for the purposes of employment estimation usually concerned simple relations between the demand for resources and the cost of implementation or the performance indicator. Other potential determinants have so far been rarely scientifically evaluated. Statistical methods were used most frequently in scientific works to model the size of employment.

## 3. FACTORS AFFECTING PLANNED WORKFORCE

The existing models show that the function of employment demand should be based on the equation that takes into account the size of the project and its type. However, other factors affecting the employment level of workers in the execution of construction works have also recently become the subject of scientists' interest. One of the widest studies on this subject was carried out in 2008 and its results and developed mathematical models for predicting the amount of employment in the design phase are presented in [22]. The results obtained showed that the demand for employment does not depend on a single factor, but on a group of variables related to the project's characteristics.

Using pilot studies [22], several additional factors that affect employment at the construction site have been identified. These include technology, the level of mechanisation, the complexity of the project, the capabilities of the management team, outlays on electricity and mechanical services. Taking into account the impact of these factors, a new way of estimating employment size was developed, taking into account the impact of the factors examined at that time. Again, the multiple regression analysis was chosen by the authors [22] as the most suitable method to show the relationship between variables.

Research on the impact of factors in the employment planning process has also been carried out on the Polish construction market by the authors of this work. Factors included in the study conducted are: the amount of work, type of work, availability of employees, contract value, completion date, level of material prefabrication, level of mechanisation, project management, work technology, physical conditions at the construction site, contractor's cooperation with the designer and employee qualifications. In order to determine the size of their impact on the planned employment volume, questionnaire surveys were carried out among Polish building contractors in which a 50% responsiveness rate was achieved in response to the inquiries sent. The survey questionnaire was filled out by 38 persons who deal with the organisation of construction projects on a daily basis. The results presented in the article refer to the period from January 2014 to January 2015.

Participants in the study assessed the impact of each of the twelve factors on planned employment in a five-point Likert scale, widely used in questionnaires for assessing the acceptance level of the examined phenomenon or point of view [6]. The assigned scores ranged from 0 to 4, where 0 meant no impact, 1 - low impact, 2 - medium impact, 3 - high impact and 4 - very high impact. For each factor, the average score was calculated according to:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{n} x_i \tag{3.1}$$

where:

$N$ - total number of responses, $x_i$ - rating awarded to the given factor.

Figure 1 presents the factors together with their average ratings in the order from the most to the least important in the opinion of the study participants. The factors that received the highest rating are the completion deadline and the amount of work. The contractor's cooperation with the designer and the value of the contract were considered the least important factors.

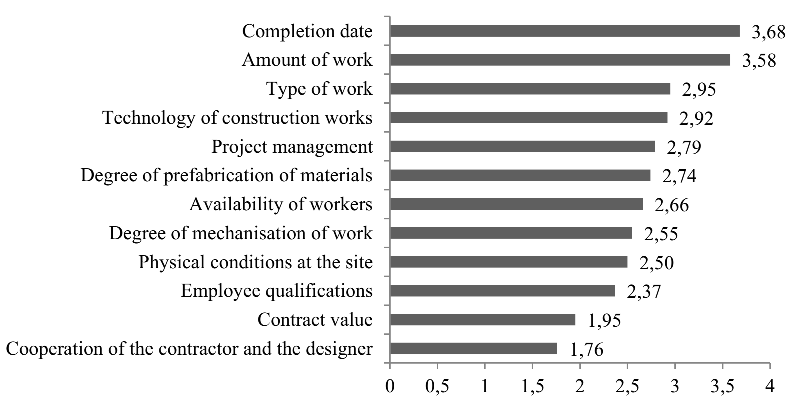


Fig. 1. Average assessment of factors affecting employment

Source: Own elaboration

The disadvantage of using surveys may be the quality of the information obtained, which is often biased. However, a reliable assessment of complex socio-economic phenomena is not possible in practice without referring to the opinions of researchers and experienced practitioners [3].

Therefore, it is important to assess the consistency of the opinions obtained. According to the so-called the coherence theory of truth, a thing is true if it is internally consistent, if consent [3] exists is regard to it. If the conformity of the opinions issued by the group of respondents is on a sufficiently high level, general judgements can be made on their basis [3].

In connection with further analysis, the results of the study were subject to the assessment of consistency of the respondents' opinions. Each factor was considered individually. In the first step, the resulting impact assessments for each factor were divided into three groups. This division was made on the basis of the designated positions of the extreme quartiles (Q1 and Q3) for each ordered series of assessments assigned by the respondents. This procedure was used to ensure that very low or very high assessments attributed to factors by some contractors were also included in the construction planning model developed by the authors and did not disturb average assessments – since the arithmetic mean is susceptible to extreme results.

On the basis of the location of nQ1 of the first quartile and nQ3 of the third quartile in an ordered series of responses, each of these series was divided into three sets:

- A set of assessments with a low impact of the factor on planned employment - below the first quartile (responses from n=1 to n=8);
- A set of assessments with a medium impact of the factor on planned employment - above the first quartile and below the third one (responses from n=9 to n=30);
- A set of assessments with a high impact of the factor on planned employment - above the third quartile (responses from n=31 to n=38).

Next, in each of the sets of responses, the consistency of the respondents' opinions was checked in regard to the assessments of the factor's impact on the planned employment volume. The consistency of the respondents' opinions was assessed on the basis of the dispersion coefficient of the relative classification h, which is a statistical measure of variability for the nominal scale of variables and has already been used in surveys conducted in the construction industry [11]. The values of coefficient h for assessing the impact of individual factors on planned employment volume were calculated in accordance with:

(3.2) $$h = \frac{k}{k-1}\left(1 - \sum_{j=1}^{k} f_{rj}^2\right)$$

where:

k - the number of categories of responses in the r-th question,

$f_{rj}$ - the frequency of j-th category in the r-th question.

The value of the coefficient is in the range [0, 1] and should be as small as possible, which indicates a greater consistency of the respondents' opinions. The values of the coefficient h for three sets of factors influencing the planned employment volume are summarised in Table 1.

Table 1. Values of the coefficient h for the assessed factors. Source: Own elaboration

| Name of factor | *h* for the set of low assessments | *h* for the set of medium assessments | *h* for the set of high assessments |
|---|---|---|---|
| Amount of work | 0.66 | 0.29 | 0.00 |
| Type of work | 0.59 | 0.37 | 0.00 |
| Availability of workers | 0.27 | 0.50 | 0.00 |
| Contract value | 0.27 | 0.70 | 0.47 |
| Completion date | 0.47 | 0.21 | 0.00 |
| Degree of prefabrication of materials | 0.47 | 0.29 | 0.59 |
| Degree of mechanisation of work | 0.63 | 0.44 | 0.00 |
| Project management | 0.27 | 0.44 | 0.27 |
| Technology of construction works | 0.47 | 0.11 | 0.00 |
| Physical conditions at the construction site | 0.63 | 0.44 | 0.47 |
| Cooperation between the contractor and the designer | 0.47 | 0.37 | 0.66 |
| Employee qualifications | 0.51 | 0.60 | 0.59 |

The dispersion factor h is very sensitive to even small differences in responses. Determining whether the obtained result is close enough to zero, which would indicate the reliability of the results obtained for each of the sets, is a key issue for the purposes of the analysis conducted. Based on [23], it was assumed that the value of the coefficient h:

- Below the threshold value at the level of the 10th percentile of the distribution of dispersion factor results for a five-point scale of responses will mean that the respondents are very much in agreement,
- Below the threshold value at the level of the 25th percentile of the distribution of dispersion factor results for a five-point scale of responses will mean that the respondents are moderately unanimous.

According to [23], the value of coefficient h at the 10th percentile level for the adopted five-grade scale is 0.658, while for the 25th percentile the value of coefficient h is 0.766.

Only in three cases results were obtained for the value of the dispersion coefficient of relative classification below the threshold value of the 10th percentile and above the threshold value of the 25th percentile, which, according to the adopted interpretation rule, indicates a moderate agreement of the respondents' opinions. In 33 cases, the results showed very high consistency of the respondents' opinions.

## 4. CONCLUSIONS

The article discusses the issue of planning the volume of employment at a construction site. The results of own research on the impact of various factors on employment planning are presented. The strength of the impact of each factor on the discussed issue was determined based on the opinions of building contractors who deal with the issue of selecting construction workers in practice on a daily basis. The paper presents the average assessments of factors that are within the range of assigned assessments, i.e. from 0 to 4. The consistence of the opinions provided was verified on the basis of the dispersion coefficient of relative classification, after the division of the results into three sets of assessment validities: a set of low assessments, a set of medium assessments and a set of high assessments. The assessment of opinion consistency confirmed the high consistency of the respondents, and this fact will allow the use of the results of the research presented in the construction of a mathematical model for quantitative planning of employment at a construction site.

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## CZYNNIKI KSZTAŁTUJĄCE ZATRUDNIENIE NA BUDOWIE

*Słowa kluczowe*: budownictwo, planowanie zatrudnienia, ocena opinii ekspertów

**STRESZCZENIE:**

W artykule przedstawiono wyniki badań przeprowadzonych wśród wykonawców budowlanych, dotyczących czynników mających wpływ na decyzje dotyczące planowania zatrudnienia na budowie.
Najczęściej przyjmowaną podstawą do ustalenia liczby pracowników, a także czasu realizacji roboty budowlanej są normy czasowe i ilość planowanej roboty budowlanej. Wykonawcy stosują opracowane przez siebie i na własne cele normy czasowe lub korzystają z ogólnodostępnej bazy norm, tj. np. Katalogów Nakładów Rzeczowych. Jednak na planowaną liczebność pracowników na budowie wpływa również szereg czynników. Aby określić wielkość ich wpływu przeprowadzono badania ankietowe wśród polskich wykonawców budowlanych. Kwestionariusz ankiety wypełniło 38 osób zajmujących się na co dzień organizacyjnym przygotowaniem przedsięwzięcia budowlanego, co w stosunku do wysłanych zapytań dało prawie 50% responsywności. Zaprezentowane w artykule wyniki dotyczą okresu od stycznia 2014 roku do stycznia 2015 roku.
Wadą zastosowanej metody badawczej może być jakość uzyskiwanych informacji, często nieobiektywnych. Jednak rzetelna ocena złożonych zjawisk społeczno – gospodarczych nie jest w praktyce możliwa bez odwoływania się do opinii badaczy i doświadczonych praktyków. Dlatego istotną kwestią jest ocena zgodności uzyskanych opinii. Według tzw. koherencyjnej teorii prawdy prawdziwe jest to, co jest wewnętrznie spójne, co do czego istnieje zgoda. Jeżeli zgodność wystawionych przez grupę respondentów ocen jest na odpowiednio wysokim poziomie, można na ich podstawie formułować sądy ogólne.
Czynniki, które zostały ujęte w przeprowadzonym badaniu to: ilość robót, rodzaj robót, dostępność pracowników, wartość kontraktu, termin realizacji, stopień prefabrykacji materiałów, stopień zmechanizowania robót, zarządzanie projektem, technologia robót, warunki fizyczne na placu budowy, współpraca wykonawcy z projektantem oraz kwalifikacje pracowników. Respondenci badania oceniali siłę wpływu każdego z dwunastu czynników na planowane zatrudnienie w pięciostopniowej skali Likerta, wykorzystywanej powszechnie w kwestionariuszach ankiet do oceny stopnia akceptacji badanego zjawiska czy poglądu. Przypisywane oceny zawierały się w przedziale od 0 do 4 , gdzie 0 oznaczało brak wpływu, 1 – wpływ mały, 2 – wpływ średni, 3 – wpływ duży i 4 – wpływ bardzo duży. Dla każdego czynnika obliczono średnią ocenę.
W dalszej analizie wyniki badania ankietowego zostały poddane ocenie zgodności opinii respondentów. Każdy czynnik i przypisane mu oceny wpływu na planowane zatrudnienie rozpatrywany był indywidualnie. W pierwszym kroku, uzyskane oceny wpływu dla każdego czynnika zostały podzielone na trzy grupy. Podziału tego dokonano na podstawie wyznaczonych położeń kwartyli skrajnych (Q1 i Q3) dla każdego uporządkowanego szeregu przypisanych przez respondentów ocen. Konsekwentnie podział ten zostanie wykorzystany w dalszej pracy naukowej autorki w zakresie badanego tematu, a konkretnie w budowie modelu matematycznego do planowania zatrudnienia na budowie. Zabieg ten zastosowano, aby oceny bardzo niskie albo bardzo wysokie przypisywane czynnikom przez niektórych wykonawców również zostały uwzględnione w modelu a równocześnie nie zaburzały ocen średnich.
Na podstawie położenia pierwszego trzeciego kwartyla w uporządkowanym szeregu odpowiedzi każdy z tych szeregów podzielono na trzy zbiory:

- zbiór niskich ocen wpływu czynnika na planowane zatrudnienie – poniżej pierwszego kwartyla (odpowiedzi od n=1 do n=8);
- zbiór średnich ocen wpływu czynnika na planowane zatrudnienie – powyżej pierwszego kwartyla, a poniżej trzeciego kwartyla (odpowiedzi od n=9 do n=30);
- zbiór wysokich ocen wpływu czynnika na planowane zatrudnienie – powyżej trzeciego kwartyla (odpowiedzi od n=31 do n=38).

Następnie w każdym ze zbiorów odpowiedzi sprawdzano zgodność opinii respondentów, co do wystawionych ocen wpływu czynnika na planowane zatrudnienie. Zgodność opinii respondentów została oceniona na podstawie współczynnika dyspersji względnej klasyfikacji h, który jest statystyczną miarą zmienności dla skali nominalnej zmiennych i był już stosowany w badaniach ankietowych prowadzonych w obszarze budownictwa. Wartość współczynnika zawiera się w przedziale [0, 1] i powinna być jak najmniejsza, co świadczy o większej zgodności opinii respondentów.

Współczynnik dyspersji h jest bardzo wrażliwy na nawet niewielkie różnice w odpowiedziach. Stwierdzenie czy uzyskany wynik jest wystarczająco bliski zeru, co świadczyłoby o wiarygodności uzyskanych wyników dla każdego ze zbiorów, jest dla celów prowadzonej analizy kluczową kwestią. Przyjęto, że wartość współczynnika h:

- poniżej wartości progowej na poziomie percentyla 10 rozkładu wyników współczynnika dyspersji dla pięciostopniowej skali odpowiedzi będzie oznaczała, że respondenci są bardzo zgodni,
- poniżej wartości progowej na poziomie percentyla 25 rozkładu wyników współczynnika dyspersji dla pięciostopniowej skali odpowiedzi będzie oznaczała, że respondenci są umiarkowanie zgodni.

Wartość współczynnika h na poziomie percentyla 10 dla przyjętej pięciostopniowej skali wynosi 0,658, natomiast dla percentyla 25 wartość współczynnika h wynosi 0,766. Tylko w 3 przypadkach uzyskano wyniki dla wartości współczynnika dyspersji względnej klasyfikacji powyżej wartości progowej percentyla 10 a poniżej wartości progowej percentyla 25, co zgodnie z przyjętą regułą interpretacji świadczy o umiarkowanej zgodności opinii respondentów. W 33 przypadkach uzyskano wyniki świadczące o bardzo wysokiej zgodności opinii respondentów.

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