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STUDIES OF FACTORS AFFECTING WORKFORCE PLANNING IN CONSTRUCTION WORKS

BADANIA CZYNNIKÓW WPŁYWAJĄCYCH NA PLANOWANIE ZATRUDNIENIA PRZY REALIZACJI ROBÓT BUDOWLANYCH

Abstract

Planning the course of construction works is complex and complicated, requiring reflection on many aspects related to the implementation of the project. High importance is placed on duration and cost of the project, as well as the separation of necessary resources. This article deals with the subject of planning the size of the workforce for a project, presenting widely available workforce planning methods, in accordance with academic approaches. A survey was conducted among Polish construction contractors – with differing scopes and ranges of activities, regarding practical methods for determining the size of the workforce. Factors that influence the size of a construction team were also investigated. The results obtained will develop with further research in this area.

Keywords: workforce planning, construction teams

Streszczenie

Planowanie przebiegu robót budowlanych jest zadaniem złożonym i skomplikowanym, wymagającym zastanowienia się nad wieloma aspektami związanymi z realizacją inwestycji budowlanej. Jednym z nich, mającym duże znaczenie dla czasu i kosztów przedsięwzięcia, jest rozdzielenie niezbędnych zasobów. W artykule podjęto temat planowania poziomu zatrudnienia dla realizacji robót budowlanych i przedstawiono ogólnodostępne metody planowania zatrudnienia, zgodne z podejściem akademickim. Przeprowadzono ankietę wśród polskich wykonawców budowlanych – o różnym zakresie i zasięgu działalności, na temat praktycznego sposobu ustalania wielkości zatrudnienia. Badano również czynniki, które wpływają na liczebność brygad roboczych. Otrzymane wyniki zostaną rozwinięte o dalsze badania w tym zakresie.

Słowa kluczowe: planowanie zatrudnienia, brygady robocze

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1. Introduction

Shaping the size of the workforce while guaranteeing the required level of expertise throughout the duration of the works is a matter that requires careful consideration. Widely available workforce planning methods, consistent with the academic approach, are based on work time standards, available, e.g. in builder's price books. The builder's price book contains information on the composition of the construction crew – areas of expertise, who should be included and the quantitative proportions between them. Please note that according to the builder's price book, for the fulfilment of each particular job, a planned construction crew should be included, and that the crew should remain unchanged until the end of work. In addition, and as a rule, each employee is treated as unqualified or qualified only in one area. Planners are often faced with the problem of matching entries in the builder's price book to the actual work. It is not always a representation of reality, or as accurate as we would like it to be.

In the literature available, it is not easy to find a good definition of how to plan the workforce, other than by using the database of builder's price books. To investigate what else guides Polish builders and what factors they take into consideration while selecting employees – a survey was performed. The purpose of this article is to present the results of research on the factors influencing the planned level of employment and to indicate the possibility of using results obtained in practice.

2. Factors affecting workforce planning in construction works

The project-based nature of the construction process entails concerns regarding resource planning at site level. Ensuring the adequacy of construction staff and the trades which make up project teams is a vital task. To assess long term staffing needs, an organization must be able to precisely determine the demand for personnel in each of the various discipline in advance. Skilled trades are difficult to just hire off the street as the demand arises. Instead, a method of estimating a project's requirement for personnel would help the organization in human resources planning, budgeting, and would also help each functional group to better plan its work. Labor costs make up a significant portion of the total cost of a construction project. It is therefore critical for contractors to assess the manpower required in executing future projects.

Factors affecting the level of employment of workers in the implementation of construction works are the subject of interest of researchers in many countries. One of the most extensive research projects on this subject was carried out in 2008, the results of which are presented in [1]. It was carried out in the Hong Kong construction market on the basis of 54 projects.

The construction method of an individual project determines the site labor input and mix of skills. The increasing use of prefabrication, production activities off-site, and the use of other engineering demanding construction methods would cause an increase in plant and equipment operators and prefabricated element erectors. The degree of mechanization and automation utilization also critically influences the labor demand at site level, as labor and capital are the major inputs. In general, the greater the input of capital, the less labor is required because automation tends to be labor saving. Labor requirement can also be affected

by the management skills of project team. Better coordination and utilization of plant and labor on site leads to a reduction in manpower requirements.

3. Research method and research sample

In order to discover the criteria which determines Polish building planning and the workforce required for the execution of construction works, a survey was carried out. The questionnaire is available on the Institute of Management in Construction and Transport of the Department of Civil Engineering of the Krakow University of Technology website from November 2013. The results presented in the article relate to the period from January 2014. Twenty two responses from construction contractors were obtained. The survey consisted of two main parts. The first part concerned the characteristics of the company and the second the method and basis of workforce planning, as well as the factors that in the respondents' opinion influence the decisions made.

In the first part of the questionnaire contained questions regarding six aspects characterising the company. These were: the scope of the company's activities, the average number of employees, the range of the company's activities, the average number of contracts for construction works per year, the average range of the value of contracts concluded, and the nature of participation in the investment process.

Multiple answers were only possible for the first question, where respondents could provide answers other than the four proposed options. The highest percentage of responses concerned industrial building. This is due to the desire to focus on this type of construction in the future in the authors' further research. Reaching the companies, whose scope of activity includes industrial building was somewhat of a priority, although the questionnaire was also addressed to Polish construction contractors or subcontractors dealing with a different ranges of activity.

In the case of the remaining questions in the first part, it was possible to mark only one answer, which excluded all others. The purpose of the second question was the classification of companies in micro, small, medium and large companies. The division was adopted pursuant to [2], only taking the number of people employed by the company into account. Most of the companies surveyed were medium to large enterprises. The third question inquired about the range of the company. The highest percentage of responders indicated the international market. More and more construction companies expand their operations beyond Polish borders, which can be taken as a good omen for the Polish economy. Only 16% of respondents focused exclusively on the local market, which has been identified as the area of a particular province. Fourth and fifth question concerned the contracts concluded by the company – their number per year and the average range of the value of a single contract. All companies that participated in the survey enter into at least 5 contracts per year, and more than 40% over 15 contracts per year. The average value of contracts concluded in almost 50% of cases exceeds 5 million zlotys.

4. Survey results

The second part of the survey examined how respondents determine the number of workers and the duration of the works in the construction schedule. It was possible to check more than one answer as well as to put down own answers not included on the list. Two companies took advantage of the possibility of providing their own answers. The results are shown in Fig. 1.

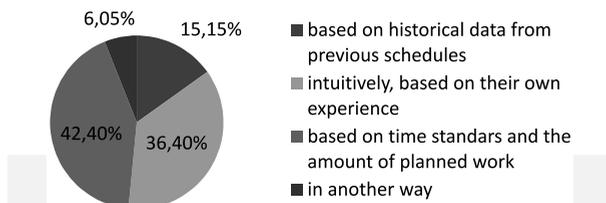


Fig. 1. Method of determining the amount of workers and duration of the works

Time standards and the amount of planned work were the most common basis for determining the amount of workers and duration of the works. This is compatible with most common academic approach. Using the standards given in the available database of builder's price books, the areas of expertise and their quantitative proportions are determined. The next step was to adopt the number of units deemed as leading in the execution of works under consideration and to proportionally select the level in other areas of expertise. And on what basis is the number of employees in the leading unit selected? To answer this question, 12 factors were evaluated, which in some way can affect the decision. If the planner chooses the number of employees intuitively, his intuition must also be influenced on different factors related to the implementation of the project.

Respondents evaluated 12 factors selected partly on the basis of the literature [1], partly based on discussions with contractors or proposed by the authors. In addition, each person filling out the questionnaire had a chance to add and evaluate factors which were not on the list, but which were important according to and for the respondent.

In the last question, the participants rated according to their opinion the level of influence of each factor regarding the employment decisions made. Calculations were then carried out based on the obtained data, according to the method described below.

Each factor was given an average score, using the rule:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^n x_i \quad (1)$$

where

x_i – evaluation mark assigned to criterion,
 N – general number of answers;

Importance index was obtained in the following way:

$$I = \bar{x} \frac{100}{5} \quad (2)$$

Thanks to these calculations, the rank of each response was obtained, allowing arranging the factors from most to least important.

Table 1

Average scores and validity indexes of factors

Name of factor	Average factor rating	Importance index
1. Imposed deadlines for the implementation of various works and the contractual deadline for completion of construction	3.55	71.0
2. Amount of work	3.50	70.0
3. Construction technology used	2.95	59.0
4. Type of work	2.87	57.4
5. Effective management of the project by the main contractor	2.86	57.2
6. Degree of prefabrication of materials	2.77	55.4
7. Degree of mechanisation of work	2.52	50.4
8. Employee qualifications	2.50	50.0
9. Physical conditions at the construction site (e.g. difficult geotechnical or hydrological conditions, physical obstructions)	2.50	50.0
10. Availability of workers	2.41	48.2
11. Degree of cooperation between the designer and the contractor	1.82	36.4
12. Contract value	1.20	24.0

Data presented in Table 1 shows that the factors having the greatest impact on the planned workforce are:

- Imposed deadlines for the implementation of various works and the contractual deadline for completion of construction,
- Amount of work,
- Construction technology used.
- Factors having the least impact on planning the workforce were:
- Availability of workers,
- Degree of cooperation between the designer and the contractor,
- Contract value.

Respondents also reported further factors that they believe are relevant to the planning of workforce. They are “Construction plan” and “Efficiency of employees”.

Most of the results were not surprising. It seemed obvious that contractors wishing to meet imposed deadlines will try to adapt the size of the team according to deadline requirements. Surprisingly, disregarding the contract value actually has a positive influence, although this being linked to the amount and scope of work, and normally exerts a strong influence on the number of workers. The reason for disregarding contract value is perhaps due to the fact that the value of the contract is not directly associated as a factor related to the size of the workforce and it doesn't always have a direct impact in this sense. It is also related to the cost of materials used, or special systems, which in the case of specialised facilities such as industrial facilities, can greatly affect the cost of the project.

Comparing results of the the Polish study with the one carried out in Hong Kong, we can however see that factors relating to the value of the contract were still rated very highly. The results from [1] indicate also that project labor demand depends not only on a single factor, but a cluster of variables related to the project characteristics, including construction cost, project complexity attributes, physical site condition and project type.

5. Possibilities for the use of research results

These results can help in making a model which can be used to predict the demand for workforce in a particular construction project.

Although a number of studies were conducted to predict the manpower demand at project level, they were merely modelling simple relationships between manpower requirements and construction cost or productivity rates. In [1] labor records and project information collected for developing labor demand prediction models, applying multiple regression analysis. 11 manpower demand forecasting models were developed for the total labor as well as essential trades. The models were then verified by comparing the predicted values with actual values. Accompanied by the results of the diagnostic tests, it was confirmed that the forecasting models are robust and reliable.

This is not the only method that can be used to build the model supporting workforce planning. It is planned to use the research carried out in Poland for the work on a model based on the principles of fuzzy logic. Previous studies have successfully demonstrated the use of fuzzy sets theory for quantifying the imprecision associated with planning in construction works [3–5].

In the simplest terms, the results of this research will help to determine the relationship between the factors and the number of employees. For this purpose, two sets will be built – a set of factors (Z) and a set of the workforce sizes (U). Most of the factors affecting the size of a construction crew are qualitative. Their value (impact) is defined verbally as “very important”, “important”, “totally insignificant”.

To define the problem and embody the parameters of the phenomena, it is planned to use the concept of fuzzy relations according to [6]. Each pair of arguments $(x, y) \Leftrightarrow (z, u)$ is assigned a rank (measure) of membership, which expresses the intensity of the occurrence of a relation between Z and U . It is assumed that the Z and U sets – as fuzzy sets, defined in terms of fuzziness, which can be linked together in a certain relation. This led to the definition of the concept of fuzzy relations in the following form [7]:

A binary relation R between two sets $Z = \{z\}$ and $U = \{u\}$ is such a relation, which is defined as a fuzzy set defined on the Cartesian product $Z \times U$:

$$Z \times U = \{(z, u) : z \in Z, u \in U\} \quad (3)$$

So it is a set of pairs:

$$R = \{(\mu_R(z, u), (z, u))\}, \forall z \in Z, \forall u \in U \quad (4)$$

where:

$\mu_R: X \times Y \rightarrow [0, 1]$ – the membership function of the fuzzy relation R .

Therefore, a fuzzy relation can be written in the form:

$$R = \sum_{z, u} \mu_R(z, u) / (z, u) \quad (5)$$

Fuzzy relations between Z and U will show to what extent the fuzzy factor affects the size of the workforce. For all of these relations, the following should be defined:

- The domain of fuzzy relation R , called the first projection of a fuzzy relation and marked $domR$:

$$\mu_{domR}(z) = \vee_{u \in U} \mu_R(z, u) \Leftrightarrow \vee_{i=1}^n z_i = \max\{z_1, z_2, \dots, z_n\} \quad (6)$$

- The range of fuzzy relation R , called the second projection of a fuzzy relation and marked $ranR$:

$$\mu_{ranR}(u) = \vee_{z \in Z} \mu_R(z, u) \Leftrightarrow \vee_{j=1}^m u_j = \max\{u_1, u_2, \dots, u_m\} \quad (7)$$

- The elevation of fuzzy relation R , called the global projection of a fuzzy relation and marked $h(R)$:

$$h(R) = \vee_{z \in Z} \mu_{domR}(z) = \vee_{u \in U} \mu_{ranR}(u) = \vee_{z \in Z} \vee_{u \in U} \mu_R(z, u) \quad (8)$$

whereas, when $h(R) = 1$, the fuzzy relation is normal, and if $h(R) < 1$ then it is subnormal.

Designing a model for planning a labor could provide a practical and advanced tool for contractors to predict the reasonable labor required for a new construction project at the initial stage, which is valuable to facilitate human resources planning and budgeting.

6. Conclusions

The planned level of workers necessary for the implementation of construction works has an influence on the final shape of the basic elements of the construction plan. In practice, this is based primarily on existing databases of work time standards and intuition. This article

has presented the results of studies on the effects of various factors on the adopted level of employment in the opinion of Polish contractors. The paper also presents possibilities for the application of the results, including the outline of a model based on fuzzy sets, which will be developed and expanded by the authors in further research.

References

- [1] Wong J.M.W., Chan A.P.C., Chiang Y.H., *Modelling and Forecasting Construction Labor Demand: Multivariate Analysis*, Journal of Construction Engineering and Management, Vol. 134 (9), 2008, 664-672.
- [2] Dz. U. 2004 Nr 173, poz. 1807, Ustawa z dnia 2 lipca 2004 r. o swobodzie działalności gospodarczej.
- [3] Kulejewski J., Ibadob N., *Harmonogramowanie budowy z uwzględnieniem rozmytych czasów wykonania robót*, Czasopismo Techniczne, 2-A/2010, 231-247.
- [4] Chao Li-Chung, Hsiao Chih-Sheng, *Fuzzy model for predicting project performance based on procurement experiences*, Automation in Construction, 28, 2012, 71-81.
- [5] Ke Hua, Ma Weimin, Ma Junjie, *Solving project scheduling problem with the philosophy of fuzzy random programming*, Fuzzy Optim Decis Making, 11, 2012, 296-284.
- [6] Kapliński O. (red.), *Methods and models for research in construction projects engineering* (in Polish), Komitet Inżynierii Lądowej i Wodnej”, Warszawa 2007.
- [7] Kacprzyk J., *Fuzzy Sets in Systems Analysis* (in Polish), PWN, Warszawa 1986.