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Formation of production structural units within a construction company using the systemic integrated method when implementing high-rise development projects

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Abstract. Development of efficient algorithms for designing future operations is a vital element in construction business. This paper studies various aspects of a methodology required to determine the integration index for construction crews performing various process-related jobs. The main objective of the study outlined in this paper is to define the notion of integration in respect to a construction crew that performs complete cycles of construction and assembly works in order to find the optimal organizational solutions, using the integrated crew algorithm built specifically for that purpose. As seen in the sequence of algorithm elements, it was designed to focus on the key factors affecting the level of integration of a construction crew depending on the value of each of those elements. The multifactor modelling approach is used to assess the KPI of integrated construction crews involved in large-sale high-rise construction projects. The purpose of this study is to develop a theoretical recommendation and a scientific methodological provision of organizational and technological nature to ensure qualitative formation of integrated construction crews to increase their productivity during integrated implementation of multi-task construction phases. The key difference of the proposed solution from the already existing ones is that it requires identification of the degree of impact of each factor, including the change in the qualification level, on the integration index of each separate element in the organizational and technological system in construction (integrated construction crew).

1 Introduction

In the conditions of increasing requirements [1] to the quality of works and given the current shortage of skilled resources in the labor market, quality labor has turned into a key element in construction operations.

Developers [2] who employ significant numbers of skilled workers carrying out integrated construction and assembly operations have a clear competitive edge vs. all other construction market participants. Construction business is set up and grows in an environment where standard operational requirements are applied. All structural subdivisions

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of such an organization, including construction crews are often operating with their labor force strength and qualification at the levels lower than what is required for optimal operations (in work zones and sub-areas).

The proposed comprehensive and systemic approach to contracting market includes the following requirements to standard construction teams which must have qualified workers with a large number of skills capable of performing multi-task operations.

A critical task of this study is to define the concept of universality for production units, including construction teams and explore the impact of a variety of destabilizing factors on their operations [3].

Part of that job is to define the notion of integration applied to a construction crew implementing complete cycles of construction and installation works in order to find optimal organizational solutions [3,4].

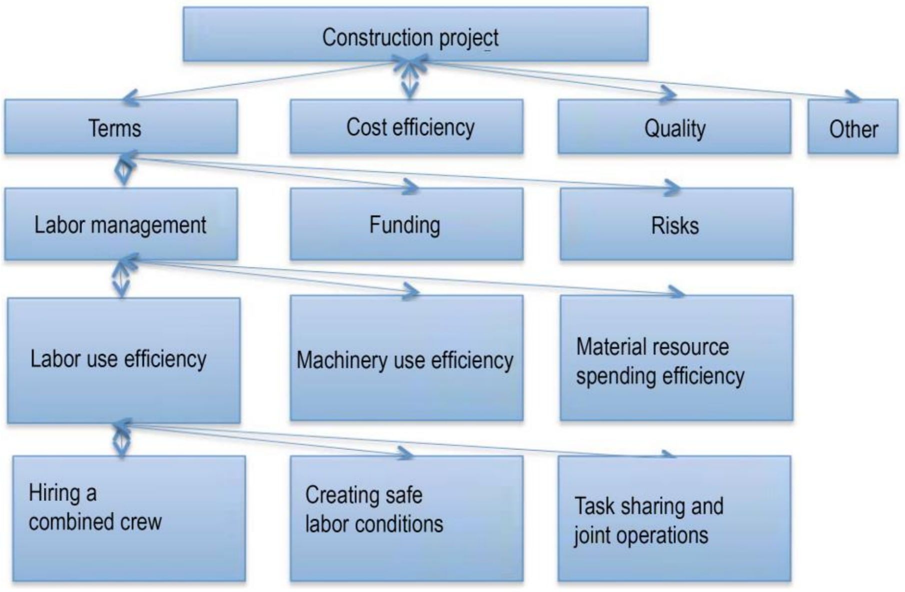

Fig.1. Key factors affecting optimal implementation of a construction project.

Our study was based on works associated with design of organizational structures of large-scale construction processes using a wide range of implemented solutions, including the study of the integral efficiency potential model [4,5] with regard to organizational and technological solutions of construction sites, allowing to take into account the impact of organizational, technological and management decisions in the implementation of a construction project.

We have also studied several papers [6,7,8] on how to approach the task of optimizing allocation of labor during the planning phase of construction and installation works. Labor resources are made up of workers organized as construction crews, and their number and workload is one of the key factors in the planning process affecting the overall schedule of construction operations.

Another paper [9] is quite interesting in the sense that it proposes a methodology for a quantitative assessment of the following key factors affecting the quality and efficiency of masonry operations: compatibility, compliance and craft.

There is another study [10] which argues that productivity growth does not depend on performing a maximum number of tasks regardless of the calendar schedule, workload increase or the number of hours worked. Performance improves when the work schedule becomes more predictable, making it possible to align the workload with the labor resources in the most optimal way.

Following our analysis and research, the first steps were taken to develop a model that allows one to theoretically develop and practically define the integration index for an integrated production crew. The model is based on the key factors affecting the end result of the overall construction process, including vocational training; level of skills; labor productivity; labor management; absence (presence) of violations of labor discipline, and the degree of integration of production processes performed by construction crews.

As noted earlier, studies that dealt with similar tasks and labor resources (construction crews) [7] were carried out prior to our study. In our work, however, we have tried to approach the problem in a significantly more profound way and focus on the methodology for determining the integration index for integrated construction crews engaged in construction operations. Our methodology was developed on systemic and integration approach and principles in order to produce the required construction project deliverables.

2 Methods

One of the main aspects in solving the problem of optimizing the systemic integrated method of performing a full cycle of construction and installation works is the need to create an algorithm in which an integrated construction crew will play a significant role. This structural unit may usually be formed right at the initial stage of the project, with clearly formulated tasks primarily focusing on labor productivity, quality and deliverable deadlines [11].

We have developed an algorithm for achieving the set task, which can be graphically described in the following way:

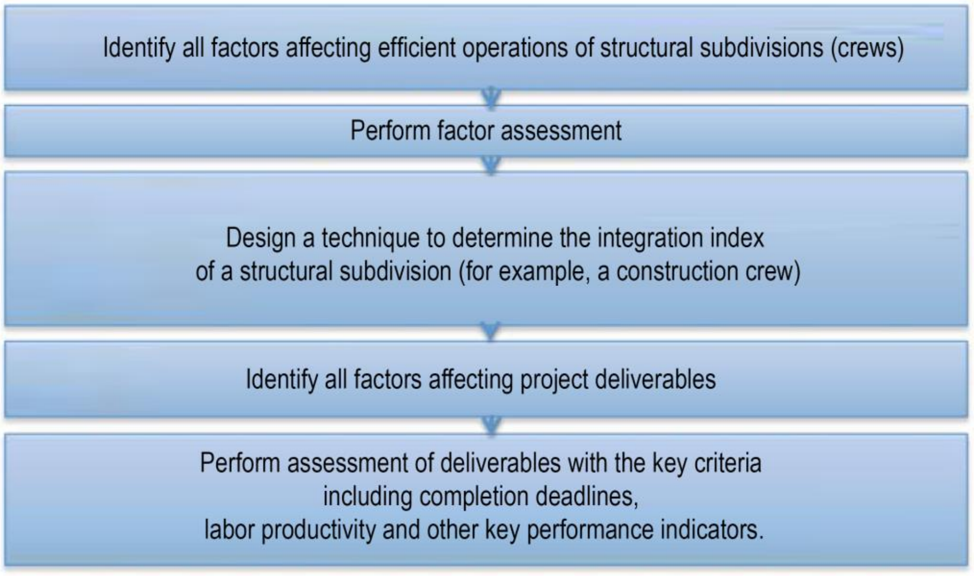

Fig. 2. Algorithm for optimizing the systemic integrated method.

○ identify all factors affecting efficient operations of structural subdivisions;
○ perform factor assessment;
○ design a technique to determine the integration index of a structural subdivision (for example, a construction crew);
○ identify all factors affecting project deliverables;

○ perform assessment of deliverables with the key criteria including completion deadlines, labor productivity and other key performance indicators.

On-site studies carried out at a number of construction operations have shown that an integrated construction crew is the most effective operational unit. The advantage of an integrated crew comparted to any individual forms of performing construction works is explained by the team work model which makes it possible to deliver all required final results in a construction project [11,12]. From the point of view of construction system engineering, an integrated construction crew is assumed as a subsystem within a system, the latter being a large-scale construction project. Let's review the key factors of variable significance affecting the subsystem whose variability depends on the behavior of the subsystem and the system as a whole and grouped into the external and internal categories.

The external factors include:

- Project funding;
- Site location;
- Climate conditions.

The internal factors, with their variability affecting quality deliverables, include:

- qualification level;
- labor efficiency of unit crews inside an integrated construction crew;
- effective compliance with performance quotas set for specific climate conditions;
- organization of labor within construction crews;
- material incentives;
- loss of working time when distributing work scopes among crews, units and other performers of specific jobs;
- loss of working time due to injuries or illnesses;
- loss of working time due to violation of labor discipline;
- number of crews performing similar jobs;
- degree of overlapping jobs performed by integrated construction crews, units and other contractors;
- projected non-attendance.

All these factors have a probabilistic nature.

Following analysis, all key factors are identified and assessed.

Factor assessment needs to be carried out via expert assessment method, prior job deliverable assessment method, and performance tests applied to a specific crew.

As an example, let us take some conventional deliverables obtained with the application of the above-specified methods. In the mathematical assessment of the integration index of a crew working in a large-scale construction project, we would suggest applying the multi-factor system modeling method [11,12].

To start with, we need to assess the significance of each factor affecting the result (FAR).

- high qualification level (FAR = + 1)
- low qualification level (FAR = -1)
- high level of experience (FAR = + 1)
- low level of experience (FAR = -1)
- high crew unit performance (FAR = + 1)
- low crew unit performance (FAR = -1)
- high labor organization within a construction crew (FAR = + 1)
- low labor organization within a construction crew (FAR = -1)
- high loss of working time during transfer of work scopes among crews, units and other contractors (FAR = + 1)

- low loss of working time during transfer of work scopes among crews, units and other contractors (FAR = -1)
- high loss of working time due to violation of labor discipline (FAR = + 1)
- low loss of working time due to violation of labor discipline (FAR = -1)
- large number of crew units performing the same processes (FAR = + 1)
- small number of crew units performing the same processes (FAR = -1)
- large number of overlapping jobs performed by construction crews (FAR = + 1)
- small number of overlapping jobs performed by construction crews (FAR = -1)
- large number of overlapping jobs performed by construction crew units (FAR = + 1)
- small number of overlapping jobs performed by construction crew units (FAR = -1)

In order to build a mathematical model of the studied processes, we need to add another factor describing former employer recommendations. That recommendation “k” assumes a “0” value if the assessment of performance of works is extremely negative and is backed with documents and relevant acts, while factor k = 1 means the crew has performed the previous scopes of work with no complaints regarding its performance and no failures due to their fault. As a result, the information obtained and required for participation in the selection process and characterizing the significance of each factor affecting the result (FAR) must be formalized in a general mathematical model. The integration index for a production crew, Ccc (integrated construction crews), is calculated by the formula:

$$C_{cc} = k\sum_{i=1}^{n} V_i = k(V_1 + V_2 + \ldots + V_n), \quad (1)$$

Where V_i is the aggregate FAR and “k” is the factor of former employer recommendations.

Job applicant assessment:

$-9 \leq$ Ccc ≤ 0 – crew is excluded from participation in the project;
$0 <$ Ccc ≤ 4 – crew is a weak candidate for participation in the project;
$4 <$ Ccc ≤ 7 – crew is an average-level applicant for participation in the project;
$7 <$ Ccc ≤ 9 – crew is the highest-level applicant given preference for participating in the project.

After the analysis, these factors are evaluated for their integration levels. Crew performance indicators are used in further assessment to obtain the results that will be used for project implementation status timeline estimates.

Identification of the all required parameters and their evaluation with the help of the algorithm and mathematical models will make it possible to justify the need for combining labor resources in a multipurpose integrated construction crew.

3 Conclusions

The proposed solution of the problem is essentially different from all modern solutions, because the need to identify the level of impact of each factor, including changes in qualification levels, on the integration index of a separate element of the organizational and technological system in construction (integrated construction crew).

We have developed theoretical recommendations and scientific and methodological provisions of organizational and technological nature critical for efficient formation of integrated construction crews with the aim of increasing their productivity in the integrated implementation of all phases of high-rise construction projects.

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