RELIABILITY LEVEL OF THE PRODUCTION SCHEDULE
DESIGN IN THE CONSTRUCTION COMPANY

Assist. Prof. Velina Yordanova

Introduction

The advance of modern market economy is characterized with significant complexity of relations between economic entities. This determines the need to seek different methods and means to increase probability for adequate decision making process connected with managing the company. The efficiency of economic activity of the construction company is closely related with well prepared and reliable production schedule, which is the basis for providing economic sustainability\(^1\) and stability of the enterprise.

Looking for resources to enhance reliability of the production schedule is of utmost significance in market orientated economy. With reference to this, one has to take into account the impact of random factors regarding human and technical resources when defining the production capacity of construction enterprises.

The objective, set in the present research is to put forward economics-mathematical model to assess reliability level when developing the production schedule of the construction company.

Achieving this goal requires solving the following issues:

1. Specifying the peculiarities of the production schedule of the construction company.
2. Working out analytical indicators for assessment of production schedule reliability.
3. Designing an economics-mathematical model for assessing the reliability level in the development of the production schedule of the construction enterprise.

The paper supports the thesis that the production schedule takes the central position in the management of the construction enterprise and measuring its reliability has an utmost significance for its efficient operation.

1. Characteristics of the construction company production schedule

Perfection of business planning is one of the significant factors for efficient production and economic activity in each company. Development of well-grounded production schedule of the company is an important core direction for it. The production schedule is a determinant

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\(^1\) For the purpose of the present research, we assume that the economic sustainability of a construction enterprise can be characterized as a guarantee for its profitable, operational activity by raising efficiency of production resources and production management, stable financial situation, sustainable development of production capacity and social development of staff through self-funding in the dynamic environment.
in the company’s business plan. It has a decisive role in defining the development guidelines of a company’s production, the volume, type and quality of produce.

Tangibly construction output comprises:

- Production processes of building and assembly activities at construction sites;
- Processes of production of construction articles, semi-manufactured articles, assembly items in subsidiary manufacture of construction companies;
- Servicing of production processes of construction and assembly activities and manufacture of articles, semi-manufactured articles, assembly items in subsidiary manufacture (acquiring and delivery of construction mechanisms, materials, resources, raw materials, horizontal and vertical transportation of construction mechanisms and materials on the construction sites, activities in organizing and maintaining the construction sites, organization and management of construction production, etc.).

That is why when designing the production schedule for the construction enterprise one has to consider and render an account of the following components:

- The processes of manufacture of construction and assembly works;
- The production processes when construction mechanisms and articles, semi-articles, installation items in subsidiary production are manufactured;
- Production processes for servicing the manufacture itself, as well as the construction company.

The production schedule should be perceived as a basic section and document in the business plan and “represents an assignment for the volume of the construction and assembly works, the type of buildings and installations (a list of construction sites) and the deadlines for bringing them into use, assigned to the construction enterprise (chief constructor) for a defined planned term”.

However, in considering the process of production resources utilization when developing a construction product one should bear in mind the circumstance that the project and design decisions for the buildings and facilities under construction influence significantly the extent of their use in fulfilling construction and assembly works. It is not necessary to give reasons that, firstly, different project decisions of same design elements require different costs for labour, resources, power, mechanization working time and, secondly, not all the applied project and design decisions for the buildings and facilities elements are technologically feasible and cost-effective in the plan of the production schedule. That is the reason why in developing the production schedule one has to report on the rationality of the project and design decisions for buildings and facilities, drawing up and applying fewer resources in construction units.

Therefore, the strive to fully encompass the whole cycle from design of the building to bringing it into use, is definitely considered an important characteristic of the construction company production schedule: investments – purchasing the land (expropriation) of land (lots) for construction – design – construction – putting into possession – utilizing (sale) of ready-built objects.

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Another characteristic that one has to report on when developing a production schedule of such kind of investment – construction structures, finds expression in their contingent integration with other similar organizations, taking part in financing, designing, material and technical procurement of construction and assembly works, fulfillment of construction output (possibly as subcontractor) and implementation of the completed object. This calls for considering the construction enterprise as a systematic formation of effective sections for achieving the main objective – creating a complete construction product (efficiently functioning object for social, public or industrial purposes) in short terms and at optimal costs of financial, material and human resources and its realization at the real estate market, considered „as a system of economic and law relations, originated on the basis of interactions of goods and money turnover “3.

It should be noted, that the construction company production schedule is distinguished by the fact, that the result of its implementation (construction output) is directly connected with the land. Therefore, the immobility of the construction output determines the mobility of the construction process. This causes mobility of all resources (materials, labour, equipment), continuous organization of construction production, expedient export of some construction processes outside the construction site, effective delivery planning, rational use of mechanization in the implementation of the production schedule.

In so far as the processes of construction production are sufficiently multilateral and with various aspects, in support of the above stated, one should barely expect the content and quality of the production schedule to be developed making use of only several indicators. In our opinion, a whole set of indicators is required which allows planning the standard of construction production for all its components.

In developing the production schedule of the construction enterprise, the following key indicators for the different lifecycle phases of the construction site could be drawn in order to improve the system of utilization of production resources. (table. 1).

### Table 1

Phases and indicators for drawing up the production schedule

<table>
<thead>
<tr>
<th>Phase</th>
<th>Indicators</th>
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</thead>
<tbody>
<tr>
<td>Economic validity and object design</td>
<td>Site cost estimation</td>
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<td></td>
<td>Site resource consumption</td>
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<td></td>
<td>Operational costs</td>
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<tr>
<td>Preparation for construction</td>
<td>Preparation for construction costs</td>
</tr>
<tr>
<td>Construction and equipment installation</td>
<td>Construction costs</td>
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<tr>
<td></td>
<td>Construction and assembly duration</td>
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<tr>
<td></td>
<td>Construction quality</td>
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<tr>
<td>Completion of construction object</td>
<td>Financial result</td>
</tr>
<tr>
<td></td>
<td>Realization of construction output costs</td>
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<tr>
<td></td>
<td>Cost-effectiveness</td>
</tr>
<tr>
<td>Exploitation</td>
<td>Financial result</td>
</tr>
<tr>
<td>Modernization</td>
<td>Renovation costs</td>
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</tbody>
</table>

It should be noted, that other quantitative indicators\textsuperscript{4}, showing the dynamics of construction output processes are known, namely, the extent of implementation of production standards (labour costs), fund facilities of the construction companies, mechanical equipment of labour, indicators for construction mechanization use in time, power and productivity, indicators for efficient preparation of construction site, etc. The above mentioned indicators could widely be used to evaluate the intensification of construction production after the fulfillment of the production schedule.

The ensuing items should also be taken into consideration when developing the production schedule of the construction enterprise:

- The actual outcome data of the company production schedule fulfillment from preceding periods;
- Information about output volume for preceding years;
- Estimates about demand for the construction production offered by the company;
- Observations on quality of the construction and assembly activities and the output (according to the list of items and range);
- Calculating the company’s available production capacity and its structural subdivisions;
- Mapping out initiatives to renovate construction output, improving its quality and reducing operation costs, construction site update, technical renovation of construction mechanization, reconstruction of production processes, etc.

A well-developed and well-designed construction company production schedule needs to define accurately:

- the type of construction output (buildings and facilities) and the volume that needs to be produced;
- the deadlines for buildings completion and their transfer for occupancy;
- the company’s facilities to undertake additional construction and assembly activities in case of unexpected offers;
- the standard and quality system for the completed construction and assembly activities;
- the volume of required resources and mechanization for accomplishing the construction processes and the system of their acquisition;
- facilities for conservation of construction sites or project termination, etc.

It should be noted, as a conclusion to this part of the study, that the peculiarities of the production schedule, stated above, do not exhaust the wide range of different isolated cases that exist. In our opinion these characteristics are typical for most of the company production schedules in the construction sector.

2. Reliability of the construction company production schedule

Providing a reliable production schedule turns out to be an important strategy in conditions of competition. A reliable schedule is the one which provides for the needed resources, materials, fuels, power, human, economic, financial and other resources for the period of completion of the particular construction site and the company as a whole. At the preliminary stage of development ensuring the reliability of the production schedule requires researching and estimating market needs, thus, it is made market orientated and responding to the market demand and customers needs. Hence, the production schedule reliability is the significant factor, which ensures enhanced level of utilization of means and tools of trade, its productivity, quality and efficiency of construction and assembly activities and the company’s operation as a whole.

Developing a reliable production schedule of the construction company requires reporting on peculiarities of construction and assembly activities, ensuing from the production immobility and discontinuity of construction sites, the individual and unique character of the building process and construction output, the long duration of the building process, etc. One of the practical approaches for handling the reliability issue of the production schedule lies in the development of a set of analytic indicators for assessment of business processes management of the construction company.

Analysis of theory and practice of economic system management, the study of specific characteristics of construction companies and construction output allows us to draw the conclusion that, for that particular case, it is advisable, to structure the set of indicators in the following way:

- management of the company as a whole unit;
- management of the types of activities;
- management of the company’s functional subdivisions;
- management of the construction sites lifecycles.

Performance appraisal of the construction company as a whole unit ought to be orientated to the subsequent indicators: cost effectiveness; net assets; reinvestment ratio, company’s accrued surplus value, financial figures.

All calculated indicators are compared to the ones from the base period in the production schedule and conclusions are drawn about availability of adequate reliability. Having no pretensions for comprehensiveness, we could recommend the indicators, exposed in table 2 for analyzing the results from the different types of activities.

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5 Here we use strategy for a general model of activities, required for achieving the goals set in the production schedule through coordination of production capacities and rational resources allocation in the construction company.

6 Business-processes are perceived as a combination of mutually connected types of activities, using resources and converting them into valuable for consumers produce, within the organizational structures reflecting the functional links and relations. Barkanov, A. S. Sovershenstvovanie biznes-procesov deyatelnosti stroitel’nykh organizacii. Ekstroitel’stvo, 2005, № 3.

In the present study, we think it is correct to stress the fact that indefiniteness is an essential feature of the business process, characterized by imbalance in commercial, production and financial goals of the construction company. Therefore, random factors influence the system of analytic indicators for business processes management appraisal, hence, upon reliability of production schedule, which calls for directing our attention towards their reporting.

The analysis of the production activities in the construction enterprise shows that the overall impact of random factors in their most diverse combination and dissimilar nature, in the long run leads to a diversion of the real duration of the performed activities and the real costs of the resources used, from the meanings, adopted in the initial plans and work-schedules. If it becomes possible to forecast diversions of real work parameters from the planned ones as a result of total impact of random factors and their quantity assessment, an opportunity arises to report the probability nature of construction activities.

To calculate probability for flawless accomplishment of some construction processes is connected with significant difficulties in their computation and can be fulfilled only for some periods, chosen in advance. In the subsequent uses of probabilities for construction company flawless work, it is advisable to approximate some of their tabular values with preliminary well selected functions. The very form of the approximating functions underlying the econometric research ought to be logical to the assumption for rationality of the construction company, for consistency and efficiency of its activities. In short, econometric studies, as well as ‘pure’ theoretical economic analysis are based on analysis of statistics data about the explored human and technical resources. It should be noted here, that the empirical meanings support to a great extent the impact of random factors and reporting the mistakes when using these meanings is very difficult. An attempt is made, further on the basis of functional

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### Table 2

<table>
<thead>
<tr>
<th>Activities trends</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Deadlines for project costs cover</td>
</tr>
<tr>
<td></td>
<td>Relative use of resources for designed objects (according to the basic types of resources)</td>
</tr>
<tr>
<td></td>
<td>Yield upon investments</td>
</tr>
<tr>
<td>Construction</td>
<td>Costs for sites construction</td>
</tr>
<tr>
<td></td>
<td>Cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>Real duration of construction</td>
</tr>
<tr>
<td>Production of materials and mechanisms</td>
<td>Production costs for mechanisms</td>
</tr>
<tr>
<td></td>
<td>Cost effectiveness</td>
</tr>
<tr>
<td>Sites exploitation</td>
<td>Operational costs</td>
</tr>
<tr>
<td></td>
<td>Cost effectiveness</td>
</tr>
</tbody>
</table>
dependency between indicators for production resources used and production capacity\(^9\) to report on the random factors impact which leads to the reduction of efficiency of given resources. The real quantity of production capacity \(PR_m\) at the end of a definite base period, if stemmed from the volume of accomplished construction and assembly activities for previous periods and reporting on the efficiency of human and technical resources used and changes in work structure for the period planned, can be determined by the formula\(^10\):

\[
PR_m = V_f \left( \frac{D_t}{K_t} + \frac{1 - D_t}{K_{ch}} \right)
\]

(1)

Where the following designations are used:

- \(V_f\) – volume of construction and assembly activities accomplished with company own resources for the base year, in thousand levs.;
- \(D_t\) – the share of mechanically accomplished work in the total volume of the real accomplished construction and assembly activities, in relative unit;
- \(K_t, K_{ch}\) – coefficients, defining the use of technical and human resources, available in the construction company.

The meanings of \(V_f\) and \(D_t\) in the formula should be considered as determinant quantitative, whose value can be determined on the basis of reported data. As regards the meanings of \(K_t\) and \(K_{ch}\), it should be noted, that they are random variables, subject to the impact of internal and external destabilizing factors upon the level of utilization of both technical and human resources. It means that the production capacity quantity as function of \(K_t\) and \(K_{ch}\) also appears to be a random variable; to determine it one ought to be familiar with the function of distribution of given coefficients.

Coefficients \(K_t\) and \(K_{ch}\) can assume different meanings, therefore by definition, they are random variables\(^11\). When the distribution function of random variables is known, one can find their distribution functions by which it is possible to define all probable meanings of \(K_t\) and \(K_{ch}\) and the probabilities for their attainment.

For definiteness let us assume, that probabilities \(P(t)\) can be calculated for argument values divisible by \(t\), i.e. \(t_k = kt\), where \(t_k\) is the time, when there is no interruption of construction and assembly processes under the impact of random factors, \(k = 1 \div n\). For shorter designation, let \(P(t_k) = p_k\). As an option for approximating these probabilities let us use the formula:

\[
\varphi(t_k) = \begin{cases} e^{-\lambda t} & \text{when } \kappa = 1, \\ e^{-\lambda t} \cdot (k-1)^{\kappa-1} \cdot \kappa! & \text{when } \kappa \geq 1, \end{cases}
\]

\(^9\) By production capacity we mean the volume of construction and assembly activities which the company can complete with its own resources for a fixed period of time by using the human resources, construction machines and mechanisms in the most efficient way.

\(^10\) The formula is adapted and elaborated on the basis of the evaluation stated in the article: Serov, V.M., B. A. Furman, T. B. Nikanorova, Estimation of the conditions and the effectiveness of the intensive production // Ekonomika stroitelstva 2004, № 10, s.15.

where the parameter $\lambda$ is known, but the quantities $\alpha$ and $\beta$ need to be defined by the condition, according to which the multitude of values $t_k = kt$ where $k = 1 \div n$ guarantees the inferior limit of maximum deviation of $p_k$ from $\ln \phi(t_k)$, i.e.

$$\max \max_{k \in \mathbb{N}} \left| p_k \lambda + (k - 1) \alpha \lambda + (k - 1)^2 \beta \right|$$

(2)

To simplify the expressions above the following symbols can be used $b_k = \ln p_k \lambda + \lambda t_k, x_1 = \alpha t_k, x_2 = \beta t_k$. The expression (2) then will be of the following type:

$$\max \max_{k \in \mathbb{N}} b_k + (k - 1) x_k + (k - 1)^2 x_k$$

In this way the problem for finding the quantities $\alpha$ and $\beta$ can be shown as a problem of linear optimization:

Find the minimum of the linear form

$$G(X) = x_1$$

with limits

$$b_k + (k - 1) x_k + (k - 1)^2 x_k \leq x_1,$$

$$b_k + (k - 1) x_k + (k - 1)^2 x_k \geq -x_1,$$

$$x_k \geq 0, \; x_k \geq 0, \; x_k \geq 0, \; x_k \geq 0, \; \exists k = 1 \div n.$$

(4)

For example, when $k = 4$ the system will have the following limits:

$$x_1 + x_2 + x_3 \geq -b_2,$$

$$2x_1 + 4x_2 + x_3 \geq -b_3,$$

$$3x_1 + 9x_2 + x_3 \geq -b_4,$$

$$-x_1 - x_2 + x_3 \geq b_2,$$

$$-2x_1 - 4x_2 + x_3 \geq b_3,$$

$$-3x_1 - 9x_2 + x_3 \geq b_4.$$

(5)

It should be noted that the inequalities where $k = 1, i.e. x_3 \geq -b_3$ and $x_3 \geq b_1$ do not belong to the system (5), because $b_1 = 0$ and, tangibly, they meet the requirement for a positive number.

To solve the newly obtained problem of linear optimization, it is advisable, to use its duality, which, in this case, will be of the type:

$$\max : G(Y) = -b_2 y_2 - b_2 y_2 - b_2 y_2 + b_2 y_2 + b_2 y_2 + b_2 y_2,$$

if

$$y_1 + 2y_2 + 3y_3 - y_4 - 2y_5 - 3y_6 \leq 0,$$

$$y_1 + 4y_2 + 9y_3 - y_4 - 4y_5 - 9y_6 \leq 0,$$

$$y_1 + y_2 + y_3 + y_4 + y_5 + y_6 \leq 1,$$

$$y_1 \geq 0, \; y_1 \geq 0, \; y_1 \geq 0, \; y_1 \geq 0, \; y_1 \geq 0.$$

(7)

Solving the problems (6)-(7) requires introducing additional positive variables, which will perform the functions of basic ones.

As long as the planned production capacity represents a stochastic value we ought to use probabilities (reliability levels) for implementation of the production schedule. Depending on this exponent when implementing the distribution functions, its value is defined and later used in the following calculations. It should be noted here, that practically, the reverse problem might be solved in scheduling – to determine
reliability for meeting the production schedule depending on the set probability values $K_t$ and $K_{ch}$.

Conclusion

The efficiency of economic activity in the construction company is closely related to the well designed production schedule. It is the basic and most significant section in the construction company’s business plan. So, when developing it, we think it is necessary to report on the reliability level which will ensure capacities proportion and coordination and effective use of available resources. With regard to this, the uncertainty when reporting on reliability is a significant issue because it directly influences the aims set. A great number of random factors cause diversions, which reduce reliability and this fact should urge us to find ways to forecast and report on them while designing the production schedule.

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Abstract

A reliable production schedule is an important prerequisite for the achievement of good economic results on the part of the construction enterprise and for ensuring rhythmical and effective work in its functioning. In this respect in the present article there are considered the peculiarities of the production schedule, which we believe it is necessary to consider during its development. Taking into consideration the characteristics of construction production there is made an attempt at proposing an economic and mathematical model for assessing the level of reliability in the formation of a production schedule for the construction enterprise.

Keywords: production schedule, reliability, construction enterprise.