An Assessment Tool for Impacts of Construction Performance Indicators on the Targeted Sustainability of a Company

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Abstract. A construction company is a dynamic system capable of transforming and passing from one quality state to another while retaining its system quality due to its properties including:
- Effectiveness – ability to produce a result and to create products required by consumers;
- Flexibility – ability of the production system to adapt to ever-changing external environment;
- Durability – ability of the production system to produce results over a long period;
- Manageability – acceptability of temporary changes in functional processes in the desired direction influenced by control action;
- Reliability manifested in sustainable functioning that is ensured by the management system, cooperation with other production systems, and internal reserves. In this connection, the authors of this article have set an objective of selecting a descriptive and effective instrument of estimating losses of statistical control and, accordingly, the targeted sustainability of a construction company at the current stage of economic development in this country. They also expand on the notion of functional sustainability of construction companies as a dynamic production system. This article is focused on development of recommendations with a view of achieving the targeted functional sustainability level of construction companies in present-day conditions and disturbances. Therefore, sustainability is examined in this article as a multidimensional emergent property of a construction company viewed as a dynamic cybernetic system designed to manufacture construction products and to maintain its systemic quality in interaction with production processes.

1. Introduction
A construction company is generally understood as a production system as it has all inherent system characteristics. Operational characteristics of a construction company as a production system include:
- Goal orientation, i.e. the ability to develop construction projects, to perform construction and installation works, and to render services;
- Polystructural organization, i.e. concurrent functioning of interrelated subsystems, such as construction sites, workshops, sectors, services, divisions, etc., within the company as a system;
- Complexity determined by the polystructural organization of construction companies, employment of personnel as key elements, and external environment impacts;
- Openness in the form of close interaction between a construction company and the external environment in terms of material, technical, labor, innovation, financial and other resources.

Due to the need to develop the construction sector in scientific and technical terms, construction companies currently introduce more complex processes, complicated organizational structures, landmark solutions - organizational, economic, managerial, etc. Taking into account the fact that the construction process depends on many factors of stochastic nature, it becomes increasingly difficult to ensure proper and reasonable construction organization and target performance within the project time limits, within approved budget and with adequate quality.

Viewed from the systemic approach perspective, any company, including construction companies, must be a self-organizing system capable of being in a stable state and maintaining sustainability as a multidimensional system determinant. According to Jamshid Gharajedaghi, who wrote about managing chaos and complex processes [1], “multidimensionality is probably one of the most potent principles of systems thinking. It is the ability to see complementary relations in opposing tendencies and to create feasible wholes with infeasible parts”.

Peter Senge noted in his works [2], that “conventional forecasting, planning, and analysis methods are not equipped to deal with dynamic complexity. Mixing many ingredients in a stew involves detail complexity, as does following a complex set of instructions to assemble a machine or taking inventory in a discount retail store. But none of these situations is especially complex dynamically”, unlike the situation of changing production loads of construction companies.

In terms of the frequency of bankruptcies, the construction industry is ahead of all other types of business. According to the Construction Complex Rating Agency (CCRA), in 2016 the number of registered bankruptcies of construction companies grew by 17.3%. Insolvency was declared by 3,180 companies, of which an overwhelming majority (66%) is old-timers with over seven years of market presence. In 2017 Q3, some 700 more construction companies withdrew from the market, an all-time high according to statistics of the Center for Macroeconomic Analysis and Short-term Forecasting (CMASF).

Thirty four percent of the top managers of 6,000 construction companies interviewed by the Federal State Statistics Service (Rosstat) in March 2018 complained of insufficient orders (against 29% in December), while 40% believed that demand was less than normal and capacity utilization had dropped from 64% to 59%. In addition, the share of businesses facing the problem of customer insolvency had grown from 27% to 32%.

“The construction industry has been declining for the fifth year running. Real output has fallen by 11% against the maximum levels of 2013”, points out Kirill Tremasov, Director of Loco-Invest analytical department.

It may be concluded from the above that the construction industry’s crisis is systemic, rather than local. The state should make every effort to drive the industry forward; however, companies as participants in the investment construction process should also take steps to enhance resistance to destabilizing factors with a view of efficient functioning and staying afloat. This is particularly important taking into account that a business company is a primary component of the national economy.

A construction company viewed as an integrated dynamic production system can be analyzed as a system of interrelated positive and negative feedback loops [1]. This system’s main goal-directed idea is homeostasis, i.e. attaining equilibrium with the environment as a key element of survival. This is the line of argumentation of all researchers engaged in integrated dynamic system modelling [3;4;5;6;7].

In view of the dynamic nature of development and diversification of their operations, as well as particular features of the construction industry in terms of ongoing changes in controlled elements, construction companies are confronted with an acute need for strict efficiency control both over existing management structures and construction operations.

The methods applied in tackling the posed research problem involve a combination of synthetic and integrated approaches with the latter providing for review both of controlling and controlled subsystems in construction operations as a set of interrelated elements (organizational structure,
technical, technological and labor resources, procurement, cooperation, etc.). In this context, the systemic approach is both integrated and dynamic.

Sustainability of a dynamic production system is understood as its ability to function efficiently in a changeable probabilistic competitive environment.

Analysis of a construction company’s sustainability as a quality characteristic or property of a dynamic production system requires research methods distinct from deterministic approaches. Many authors interpret sustainability as an entitative and time- and space-varying quantifiable feature of a company characterized by multifactor, latent, non-additive, emergent, and normatively evaluable properties, and don’t believe that sustainability dynamics deserve any particular emphasis. What is important is that sustainability is a characteristic of a dynamic organizational and production system [8].

Construction companies that preform high-quality and, therefore, demanded construction operations, should, where possible, protect themselves from disturbances.

The main construction disturbances can be roughly divided into industry and general ones.

The most significant industry disturbances are:
• lack of effective mortgage lending;
• high-cost insurance of construction and installation risks for developers, lack of effective insurance;
• cost optimization;
• serviceability improvement;
• company branding;
• ensuring of company short- and long-term survival;
• increase in wages while improving working conditions.

The general disturbances are subdivided into external and internal ones.

External disturbances:
• low sales of end products due to a fall in effective demand;
• low, and in some cases, insufficient quality of domestic raw materials;
• lack of competitiveness as to materials and resources support, dealing with monopolists;
• turbulence;
• high interest rates of bank loans.

Internal disturbances:
• insufficiency of net working capital;
• outdated mechanical operations and lack of innovations;
• imperfect labor management;
• out-of-time logistics;
• insufficient qualifications;
• outdated marketing technologies.

Listed disturbances stress the diversity of organizational decisions. This diversity is largely connected to the diversity in construction activities.

To enhance organizational and technological immunity to the above disturbances, construction companies are forced to improve the performance of their organizational structures in order to maintain the calculated and planned technical and economic indicators [8].

In fact, many construction problems are resulted from confusing structure and a number of disturbances, which should be considered as the causes of failures and unacceptable deviations.

Success of a construction company emanates from interaction of the main processes: construction operations and their organization and management. All other functional elements of a construction company (economic, structural, HR and others) are considered to be derivatives of the main processes.

Sustainability of a construction company in the context of the static thinking paradigm assumes review of sustainability of production and management processes through the lens of estimated indicators of production, technical, technological, organizational, economic and other activities of a construction company.
Construction problems are mostly attributed to insufficiently streamlined structure and composition of indicators to be used for assessment of the causes (factors) of failures and inadmissible deviations. For the purpose of this study the structure and composition of indicators (statistical manageability indicators), and, consequently, the sustainability of a construction process are determined by the expert analytical method [9;10;11].

Sustainability of a construction company is ensured by sound production, technical, technological, organizational and economically viable solutions aimed at step-by-step coordination of estimated assessment indicators for construction operations with a view of preventing construction process disequilibrium [12;13].

Statistical controllability of a process is in fact an assessment of its variability (or variation – for individual indicators). Future behavior of controllable processes can be predicted with reasonable confidence. In our case, controllability of a construction process is viewed as an integral part of a set of statistical estimates for controllability of indicators over time.

A set of controlled indicators determined in a particular manner as an evidence of statistical controllability enables a conclusion on sustainability of the production process. This is true for indicators corresponding to the Pareto principle (some 80 percent of the entire notion of sustainability).

A production process affecting sustainable functioning of a company may be in two alternative states:

- With all or the main processes being statistically stable and, accordingly, manageable;
- With all or the main processes being statistically unstable and unmanageable.

Therefore, there is evidence of logical relationship between statistical stability of construction process assessment indicators and sustainability of a construction company.

The most complicated assessment is required by the threshold (near-threshold) condition of a construction company’s sustainability.

2. Methods

For the analysis and processing of mass data, the average value, much less often - the standard deviation is used. Some of these approaches are justified, since they are generally understood and accessible for practical and scientific application. In the process of research, the authors analyzed the methods most appropriate for assessment of construction company stability:

In connection with construction development and potential system-influencing disturbances, as well as for an intuitive graphic imaging by construction companies and prompt identification of disturbances in order to restore the target stability, Shewhart charts method (SCM) was chosen by the authors as the most reasonable for further research.

Due to the fact that this SCM was not used to ensure a guaranteed stability of a construction company, the author made a decision on the appropriateness of applying this tool in further research.

As argued by Walter Shewhart [14], the essence of statistical manageability is predictability. Predictability of indicators suggests sustainability of production processes affecting the functioning of a company in general. It is proposed to use graphical representation of estimated construction indicators in the form of special control charts in addition to numerical data convolution methods with a view of recording their variability.

Control charts are flow sheets with plotted control limits that signal the process’ exit from the state of sustainability. An overview of an indicator control chart (conventional values) is given in Figure 1. The process is characterized by stable manageable variation of individual values (X) within the upper and lower estimated limits.
Control limits of control charts are usually three sigmas on both sides off the central line $X$, which shows the mean value of the process and its stability. The $3\sigma$ control limits are calculated on the basis of sampling data.

According to empirical guidelines for control chart analysis, 67% of points should be within the $X\pm\sigma$ bar, some 95% of points — within $X\pm2\sigma$, and some 99% of data should not be off the mean value by more than $X\pm3\sigma$.

Control limits of individual values set the boundaries of the process’ stable behavior used as a benchmark for comparing its value in the next time interval or estimated indicators. In this context two alternatives are possible: observation (estimated value) agrees or disagrees with the estimated control limits.

In the first case, the process can be recognized as both stable and manageable.

If the process indicator values are outside the established control limits, it is assumed that the process is statistically unmanageable and, accordingly, the process stability is questioned. In this connection, measures are identified and taken for elimination of special assignable causes.

Despite all simplicity of plotting, control charts are an efficient graphical detection mode for the loss of statistical manageability and, accordingly, the targeted sustainability.

Research into a construction company’s sustainability requires collection of input data that should meet the following criteria:
- They should be confirmed by the company’s statistical and corresponding operational reports;
- They should be user-friendly and assessed in quantitative terms;
- They should be interpretable in the context of basic data.

Since most problems are due to an obscure structure of the factors that have an impact on the construction process, it should be noted that selected indicators should be accompanied by cause and effect diagrams.

Theoretical considerations, information sources, expert opinions, and the indicators of the Federal Statistical Service should be analyzed to select data that would characterize the construction process affecting statistical evaluation of sustainability of a construction company at the following stages:
1. Preparation and convolution of input data for construction indicators;
2. Control limits calculation and plotting control charts for indicators of construction process sustainability;
3. Analysis of the process statistical manageability on the basis of control charts. Search for and elimination of special (external) causes of excessive indicator variability;
4. Capability assessment of statistically unmanageable process. Allowances for process performance capacity in the prevailing situation;
5. Analysis of attained results and drawing up a final conclusion on the state of sustainability of the construction company.

The assessment method for a construction company’s sustainability provides for several statistical assessment iterations. In general terms, a quantitative assessment of sustainability of a construction company as a multidimensional characteristic can be presented as indicator Z:

\[ Z = F(X, b^j(t)) + \varepsilon(X) \]  

where:

- \( X \) is a vector of partial criteria as a sufficient determinant of sustainability of the construction company;
- \( b^j(t) \) is a vector of statistical characteristics of sustainability (variability) \( j \) over time \( t \);
- \( \varepsilon(X) \) is a random error value.

It should be noted that sustainability as a latent quality may not be measured by an objective absolute scale. For this reason, it is proposed to measure it by a ten-point scale. Partial criteria that determine sustainability of a construction company should also be assessed by a unified scale using standard unifying transformations as follows:

For indicators related to a construction company’s sustainability as a modelled integral property in a monotonically increasing dependence, the values of unified variables \( X \) are determined by a ten-point scale according to the following formula:

\[ X = \frac{(X - X_{\text{min}})}{(X_{\text{max}} - X_{\text{min}})} \times 10, \]  

where \( X_{\text{max}} \) and \( X_{\text{min}} \) are the maximum and minimum sample values.

For indicators related to the modelled integral property in a monotonically decreasing dependence, the values of unified variables \( X \) are determined by a ten-point scale according to the following formula:

\[ X = \frac{(X_{\text{max}} - X)}{(X_{\text{max}} - X_{\text{min}})} \times 10, \]  

From the perspective of the systemic approach and statistical thinking, the following general requirements to assessment indicators and sustainability criteria of a construction company have been identified taking into account the proposed methodological approaches and sustainability study methods:

- There should be sufficient indicators for a comprehensive assessment of the construction company’s emergent property. They should be grouped in conceptual and cause-and-effect blocks and limited in number.
- The indicators should be commensurate with the indicator system applied for assessment of the business and operations of the construction company and based on the current accounting and reporting procedures. Any new conceptual indicators that are not adapted to the construction indicator system should be avoided.
- Relative indicators reduced to capacity characteristics should be used to ensure a statistical approach to assessing the synthetic quality category and to reduce the total sample variance.
- The indicator system should be based on the indicators of technical, technological, organizational and management processes as the determining factors of a construction company’s sustainability.

The method proposed by the authors for a quantitative assessment of construction company stability is based on the theory and mathematical tool for quality synthetic categorization. For a quantitative assessment of the stability emergent property of the construction company, the recorded values are construction indicators, which sufficiently characterize the analyzed synthetic category stability of the construction enterprise and can be interpreted as partial criteria of this synthetic category. As the only integrated indicator of the construction company stability, we understand a weighted total of partial criteria. The weights of each criterion are conditioned on maximizing the explanatory value of the integrated indicator - the construction company stability.
The registration tool for variability of estimated construction performance indicators reviewed in this article will be used in further studies for streamlining statistical data with a view of developing determination methods for sustainability as a qualitative characteristic of a construction company.

References
[1] Gharajedaghi J 2010 Systems Thinking Managing Chaos and Complexity A Platform for Designing Business Architecture (Minsk: Grevtsov Books) 480 p
[2] Senge P The Fifth Discipline The Art and Practice of the Learning Organization
[3] Ginzburg A V, Baranova O M, Blokhina N S, Volkov A A, Garyaev N A, Ginzburg V M, Ignatov V P, Ignatova E V, Istomin B S, Kagan P B, Kitatseva E Kh, Kulikov V G, Sinenko S A 2014 Automated Design Systems in Construction (Moscow)
[4] Gusakov A A 2004 System Techniques in Construction (Moscow: ASV)
[5] Chulkov V O, Kazaryan R R 2009 Systemic Approach to Certification of Labor Saving Tools and Conveying Equipment for Construction Cargoes and Structures Industrial and Civil Engineering 2 58
[6] Topchyi D V 2017 Formation of an Informationally Integrated Project Management System in the Repurposing of Industrial Facilities RESEARCH ON RESEARCH online journal vol 9
[7] Lapidus A, Abramov I 2017 Formation of Production Structural Units within a Construction Company Using the Systemic Integrated Method in High-Rise Development Projects HRC 2017 (HIGH-RISE CONSTRUCTION-2017) E3S Web of Conferences 33 03066 https://doi.org/10.1051/e3sconf/20183303066
[8] Abramov I L 2018 Study of the Impact of Destabilizing Factors on Operational Sustainability of Construction Companies Construction Economics 6(54) pp 32-36
[9] Abramov I 2018 Systemic Integrated and Dynamic Approach as a Basis for Ensuring Sustainable Operation of a Construction Company IOP Conference Series: Materials Science and Engineering vol 463 Part 2 463 032038 https://doi.org/10.1088/1757-899X/463/3/032038
[10] Kazaryan R, Pogodin D and Shatrova A 2019 Aspects of scheduling processes and results of the reorganization of projects in high-rise construction objects E3S Web Conf. vol 97 04002 https://doi.org/10.1051/e3sconf/20199704002
[11] Volkov A A 2008 Formalization of Organizational Objectives for Construction Project (Process) Functional Management. Sustainability Herald of the Moscow State University of Civil Engineering 1 pp 347-351
[12] Lapidus A, Abramov I 2018 Systemic Integrated Method for Assessing Factors Affecting Construction Timelines MATEC Web of Conferences vol 193 05033 https://doi.org/10.1051/matecconf/201819305033
[13] Abramov I L 2017 Formation of Integrated Structural Units Using the Systematic and Integrated Method in High-Rise Construction Projects HRC 2017 (HIGH-RISE CONSTRUCTION-2017) E3S Web of Conferences 33 03075 https://doi.org/10.1051/e3sconf/20183303075
[14] Wheeler D, Chambers D 2016 Understanding Statistical Process Control. Business Optimization Using Shewharts Control Charts (Moscow: Alpina Publishers) 410 p
[15] Sukhina N Yu, Leshova Yu V, Primakova V O 2016 Management of a Company’s Financial Sustainability in the Context of a Financial Crisis A collection of articles of international research-to-practice conference Scientific Research and Development in the Globalization Era
[16] Pleshkov S Yu 2014 Economic Sustainability of a Construction Company’s Operations: Calculation and Assessment Methodology: Ministry of Education and Science of the Russian Federation (The Ural Federal University) Publishing House of the Ural Federal University 59
[17] Gusakov A A 1974 Organizational and Technological Reliability of Construction Operations (in the Age of Automated Design Systems) Stryizdat 252 p