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FLEXIBILITY IMPLEMENTATION IN CONSTRUCTION PROCESS ENGINEERING

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ABSTRACT

The disturbances of processes in progress are in construction production engineering basic problem making difficult planning both under in relation to time, as and costs. The conception of introduction of flexibility came into result of observation of problems alongside realization of runways, the roads of circling, customs terminals, driveway as well as assembly of facade of elevation of high buildings, where the serious factor was the perturbative weather. It seems, that having at command the different options of realization (learning e. g. on modification of process and/or the limitation of influence of disturbances - in case of negative scenario, as and the utilization the chances - in case of optimistic scenario) one could reach considerably better effects than depending on of realization based on one option (traditional method).

KEYWORDS

flexibility management, advisory system, construction process, construction engineering

1. INTRODUCTION

Construction industry differs from other areas of economy in many aspects. The dependence from realization conditions is one of key factor in this topic. Weather conditions for example could be characterized like very variable and very difficult in expectation. Skill of identification of these disturbances as components of risk and uncertainty as well as manage them in planning and realization stage have the key meaning for non - failure operation of construction enterprise. The basic problem related with disturbances mentioned above is the inconformity of plan and realization which can result to substantial losses (penalty for delay). Right flexibility management on operational level (consequential with technological and organizational options) lets possibility of considerable limitation of influence of these unfavorable phenomena thanks to liquidation of problem at source.

Analyzing the premises of presented approach one should found as basic topics:

- Changeability, risk and uncertainty occurring in construction engineering also on the operational management level (that is one of the basic elements of specificity of construction industry in comparison with others sections of economy),
- Influence of environment on manufacturing processes, the example of what is the weather

risk (with possibility of physical impact on it - similarly as in agriculture),

Incompatibility of planned and real run of construction processes (and important consequences for failure (non quality) operation in construction – demolition and rework),

Growing possibilities of collecting data, wireless transmission and the information processing which makes possible considerable rising efficiency of use of flexible approach,

Technological progress in construction industry generating wide game of options of flexibility (the modification of materials, automatics of processes, etc.).

The basic aim of flexible approach introduction in construction production is the possibility of assurance of production continuity in spite of operation in dynamically changing environment performing results answering to the requirements. Presented method founds the possibility of adaptation to variables conditions between system and environment. Generally there is no “the best” manufacturing option, it is necessary to be ready to shift from one flexible option to other as needed. The introduction of flexible idea requires some additional expenses of course. But it is more profitable to maintenance of equilibrium in the system, because the costs of working apart from equilibrium stage (cost of restoration process from system non-equilibrium to equilibrium stage, also) motivates such procedure. The most essential two actions of method proposed are:

- choice of production strategy based on the follow-up action run of realization of job on the ground the extreme examples from cases base (estimation of range of cost and time),
- monitoring the processes in progress enabling the correction of course of processes in dependent on real terms of realization as well as development of collection of cases.

Analyzed example shows on superiority of strategy based on mixed flexible tactics in comparison with remaining strategies.

2. THEORETICAL BACKGROUND

The fundamentals of the presented approach are based on: (1) the contingency theory [1] which taking into consideration situational context for every managerial action (e. g. flexibility option) and (2) the systems theory assuming maintenance of balance in a system through responding to risk and uncertainty on source level and concentration on key factor of risk and uncertainty. For analysis of source risk and uncertainty level flexibility management hierarchy must be considered. On the operational level, risk can be influenced proactively and physically through introducing an appropriate range of technological and organizational variants. These include both options focused on utilizing opportunities (e.g. process conditions are more advantageous than originally assumed) and threats prevention (e.g. implementation of thermal insulation shields preventing low temperature impact) which may seem to be significantly more effective and efficient than reactive options where the basic functional level is the project coordinator level and which primarily occur in the form of financial and time buffers.

3. FLEXIBILITY DEFINITION

Flexibility is a commonly encountered quality in everyday life, of key importance for biological survival, however hard to define because of its extensive range of application. In building process engineering, application of flexibility is focused on adaptation to variable production conditions, while the main point in typical flexible production systems is the adaptation of production range to the market requirements. The definition in terms of decision-making seems adequate to the described application in the building industry: the number of optional alternatives left over after one has made an initial decision [2]. The overall definition corresponding to the characteristics of the construction industry was given by Stabryla [3]: ‘flexibility as the opposite of rigidity is a quality enabling effective functioning of a system in terms of existing external conditions and with respect to internal operating capacity, its focus depending on the level of initiative and the system’s self-management capacity. Flexibility is therefore a specific form of system efficiency and a measure of its independence: it is determined for purposes of maintaining the balance, which may be the volume of effects and/or functional indicator of the system, such as resistance, reliability, or operating intensity'.

4. DECISION MODEL

The presented purpose of the proposed method is realized through choosing such sequence of controls of the sequence of processes during specific stages *(0, 1, 2,..., i,...,n)* that will lead to minimization of control quality function φ in the multiple-step decision process using the following data:

- object description, namely the f function generally described by the following equation (1):

  $$x_{i+1} = f(x_i, u_i, z_i), \quad (1)$$

- initial state x_0,
- set of initial actions a_0 aiming at activation of the flexibility options, jointly determined by the controls in stage *0* (initial stage) – u_0,
- required final state x^* specified by the object of contract
- control horizon n, being the control time determined by the n number of stages during which its quality is evaluated
- forecast of interruptions z'_i for each stage i
- control performance indicators: global Q_g and local Q_l.

The problem consists in determining the optimum sequence of decisions within the multiple-step decision process on the basis of selecting a relevant strategy of flexibility application. Because the sequence $u_0^*, u_1^*, ..., u_{n-1}^*$ stands for a schedule of building process implementation in specific consecutive stages, control may account for step-by-step assessments as well as overall evaluation for the entire duration of execution. We assume that z_i is the value of random variable Z_i with a density of $f_z(z)$. For given f, x_0, φ and f_z one has to determine the sequence of control decisions $u_0^*, u_1^*, ..., u_{n-1}^*$ that will minimize the expected value of the performance factor (2):

$$(u_0^*, u_1^*, ..., u_{n-1}^*) = \arg \min_{u_0, u_1, ..., u_{n-1}} \; \underset{z_0, ..., z_{n-1}}{E} \left[\sum_{i=0}^{n-1} \varphi(u_i) \right] \quad (2)$$

To calculate this formula, due to problems arising out of uncertainty and difficulty in fulfilling the stochastic independence postulate, the best solution would be to simulate operation of the analyzed subsystem in realization of a sequence of processes during individual stages, with the assumption of varying scenarios. From the perspective of the assumed flexibility options in execution of building processes, the above specified plan would be difficult to realize without making decisions in relatively short intervals determined by monitoring and forecasting capacity (using the forecasts for z'_i). The objective of the decision-making during the specific stages is to modify the base production system through application of flexibility tactics corresponding to foreseeable interruptions for the purpose of minimizing the local performance indicator Q_l:

$$(u_i^*) = \arg \min E\left[\varphi(x_i, u_{i-1}) \right] \quad (3)$$

where $Q_l = \varphi(x_i, u_{i-1}) = \varphi_u(u_{i-1}) - \varphi_x(x_i)$

during each stage (depending on process advancement), which indicates double-criteria problem consisting in minimizing costs and maximizing efficiency where the purpose function depends on the advancement of the sequence of processes during stage *i-1* for the given interruptions forecast z'_i for stage i. The global criterion shall be minimization of overall costs of implementing the strategy with preset final state x^* realized in the course of n stages (expression related to state x_i in the final stage with the assumption of $x_n = x^*$ can also be expressed in terms of costs of penalties for exceeding the contract deadline, and additional costs related to continued development outside the assumed control horizon):

$$Q_g = \sum_{i=1}^{n} \varphi(u_{i-1}) + \sum_{j=n+1}^{m} \varphi(u_{j-1}) \quad (4)$$

The basic problem with the above formulation of the decision-making issue is the availability of required knowledge, sufficient for making the decision, and conditions of decision implementation in probabilistic circumstances. Therefore, it would also seem justified to make decisions using simpler models as well.

5. ADVISORY SYSTEM

Introduced above theoretical foundations of flexibility implementation in construction production engineering require not only calculations and workings on numbers. This activity must be based first of all on generating the idea (options, tactics and strategies of flexibility), working out different conceptions, their rating and mutual comparing. Their improvement is supported on knowledge accumulation and deploying experience - first of all in case based learning. Utilization of the decision-maker's skill requires the emphases' here (choice of key factors of risk and uncertainty, choice of adequate scenario describing changeable surroundings, generating flexibility options, tactics and strategy) basing first of all on his knowledge and experience. The related with this one activities leaning on recognition of processes and objects of operations require different approach than traditional numeric calculation. The decision support using hybrid advisory systems it seems well-founded first of all with necessity of collecting , processing and contextual variant generating based on gigantic quantities of information. One should be underline, that idea of decision support system it is not new idea, and colossal expectancies placed in expert systems did not it find in practice of possibility of realization [4, 5]. As key causes of limited success of implementation of expert systems it is possible to mention below :

- the lack of profitability (the expenses intended on software design and running outperformed possible to on market the potential advantages evidently)
- the lack of possibility of automatic learning from examples on operating level [6]
- limitation of the decision-maker's role in process of system functioning (the dehumanisation of the system).

In aim to avoidance above-mentioned and others threats following specific requirements connected with flexibility management in construction process engineering were qualified (Table 1):

- the scenario analysis related with large changeability of surroundings (which containing both the external conditions: weather condition, soil, variables the accessibility of materials, human resources and equipment, and also internal consequences of changes, such as: variable workers and machines' efficiency, etc.), which it is hard to self - characterize using other methods (e. g. statistical distribution analysis)
- serial (cyclical) decision consequential with uniqueness in production nature (based not only on object of production in meaning of the design - solutions or material), but more often on each time unique type - composition of basic subjects engaged in building process also (client, contractor, designer, engineer - consultant), which in result guides to necessity the resolution the forming au courant problems (day by day, hour after hour) - the efficiency of manufacturing processes is anticipated hard carrying often the character of prototypical production
- granularity of information - working in conditions of pressure of time in the decision-making (processes in progress) the lack of detailed analysis for all acting factors makes difficult the precise qualification of the required information (the received information with regard on specific of construction engineering requirements can be with insufficient natures also - e.g. weather-forecast for rain not giving its time of appearance and intensity)
- dialogue working with decision-maker having in view the utilization both the possibility of computer information processing of (necessity of accumulation and processing of gigantic quantities of data, consequential from long decision chains and complicated connections of many units), as and the decision-maker's ability (e.g. in matter of possibility to generating the solutions or subjective opinion concerning risk or uncertainty)
- ability to collecting of knowledge and learning from examples - comparatively small quantity

of standard instruction for solving problems in construction engineering as well as the underlined already considerable fluctuations in the effects of action realized in different conditions

- specific management tools on each of level of hierarchy (with regard on conflicting criterions on particular level of management one should take under attention of difficulty in building of complex system, embracing the subcontractors', general contractor and client)
- utilization the possibility of physical impact on risk and uncertainty on source level (operational), which lets the possibility of effective and effective use of flexible approach
- application of simple system based on generally practical software - possibility of use this system on the job on construction site everyday
- considerable costs of repair or / and the renewed realization (with demolition option), which inducing to concentration on proactive actions (not corrective).

CONCLUSIONS

The introduced foundations of theoretical methods and implementation idea of flexibility management permits on extraction the following conclusions:

- The application of flexibility on operational level (contractor) is well-founded first of all by risk and uncertainty impact on source level
- The improvement of flexibility management has been supported on specialisation in definite field of construction activity (the assembly of facades, construction of roads, etc.)

The introduced approach could be applied in situations with considerable influence on realized processes of surroundings from one side as well as possibility of introduction of effective and efficient flexibility options - from second side

Table 1. Advisory system features

Construction engineering specific elements	Advisory system features
large changeability of surroundings	Scenario analysis
Prototypical like production	Serial (cyclical) decision-making
incompleteness and inaccuracy of information	Granularity of information
utilization both the possibility of computer information processing and decision-maker abilities	D*ialogue working with decision-maker*
Individual dependences of the workers and machine efficiency	*Learning from examples*
conflict of criterions on different management levels	*Specific systems for different management levels*
possibility of physical impact on risk and uncertainty	Working on operational (source) level
system on the job on construction site everyday	*simple system based on generally practical software*
considerable costs of repair or / and the renewed realization	*concentration on proactive actions*

The introduction of flexibility in construction engineering requires first of all the accumulation of knowledge and ability to learn (using e. g. hybrid advisory system)

Gradual extension of hybrid system (in measure of accumulation of information as well as improvement of co-operation of subsystem of collating the information and decision-making as well as application in practice these decisions) were proposed as a method of implementation of presented approach

Natural the following order of extension of system seems: simple advisory system, case based reasoning, simulation. In next stages one should foresee different modules also: automatic data collection in real-time, machine learning etc.

The advisory system should give coupling advantages inherent in computer tools of decision support possibilities (the possibility of cataloguing the gigantic number of examples and analysis of variants, precision of calculations, etc.) as well as the human capabilities (the utilization of unique talents, learning from, experience, creative possibilities, skill of anticipation, intuition, etc.

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