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FLEXIBILITY APPROACH IN THE RUNWAY PAVEMENT USING FLEMANCO METHOD

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Abstract. The pressing problems of managing construction processes reveal themselves in discrepancies between plan and execution which seems to result in considerable measure from dependence on the changing environment. High variability, dynamics and uncertainty of execution conditions generate disturbances which could be avoided by applying flexibility – creating a range of executive options enabling adjustment to changing environmental conditions. The principal advantages of implementing the proposed FLEMANCO (FLExibility MANagement in the COnstruction industry) method include better consistency between planning and an actual course of execution, lower changes in costs and execution time by considering various scenarios of execution conditions, the possibility of loss prevention and taking advantage of opportunities connected with the changing environment etc. The presented example concerns concreting a runway, although similar problems occur in concreting roads, yards, bridges as well as erecting high buildings, earthworks etc.

Keywords: flexibility, construction process, monitoring, construction engineering, construction management, runway, FLEMANCO method.

1. Introduction

The dependence of the construction industry on the surrounding environment the considerable variability, dynamics and uncertainty of which generate disturbances to the construction processes resulting in different effects (e.g. stoppages, delays, conflicts, reworking, additional works etc.) is one of the principal features defining its specific character. One can point out to the construction processes the execution of which is a subject to particular risk and uncertainty due to the environmental influence (e.g. weather) with the possible generation of heavy losses e.g. the construction of roads, highways, logistics yards, airfields, earthworks, erection work etc. The typical action in such case is to compensate the effects of disturbances by creating time and cost buffers. A reactive approach makes possible to take into account the effects of disturbances in the form of the expected delays, losses or additional costs reflected in the extended contract period and additional execution costs. However, due to forecasting disturbances and monitoring the environment as well as the processes underway it, is possible to undertake proactive activities aimed at reducing the effect of disturbances on the construction processes. Certainly, in the majority of cases, the approach briefly described in this paper can only be applied to defined risks. Hence, the natural consequence is to assess uncertainty and risk divided into causes coming within the scope of the proposed method and the others (to which the classical approach based on disturbance compensation by means of time and cost buffers can be applied). When analyzing various concepts dealing with the proposed approach one can distinguish the following:

- the concept of buffering introduced by Kapliński (1973, 1978) while studying the problem of harmonization of cyclical construction processes (the practical application was based, e.g. on intermediate containers for ready-mixed concrete);
- the possibility of applying the principles of flexible production systems functioning in the concrete industry (Reichelt 1987);
- adjusting the concept of flexible production previously connected with various diverse activities (e.g. from designing and prototype production to computer-controlled manufacturing) to the construction industry (Halpin 1987), upon the example of processing stone materials;
- the activities aimed at reducing non-homogeneity by the superposition of the construction processes illustrated with examples concern-

ing production concentration (Kapliński 1993; Kapliński 1974);
- the indication of the flexibility role in response to changing working conditions which quite often is an important taboo in engineering design activities (de Neufville 2000; de Neufville 2004);
- Thomas and Hormann (2006) have shown the advantages of applying the buffers by pointing out the reasons for using flexibility under changing conditions of execution;
- applying flexibility in managing construction projects (Olsson 2006) focusing principally on flexibility strategies at the tactical level;
- indicating the need to balance the dynamics of the environment with the dynamics of management at the construction site (Telem *et al.* 2006);
- indicating both external and internal uncertainty factors justifying the application of flexibility (Mayer and Kazakidis 2007) in relation to the mining industry;
- the new approach to uncertainty (and risk) as an element of development (Perminova *et al.* 2008) which requires management based on three key learning from examples and sense making as the enablers of flexibility and quick decision-making in response to the analyzed situation.

The possibility of utilizing the opportunities and reducing the losses resulting from the changing operational conditions is the principal advantage of the proposed method. The losses may concern the costs and the time as well as the reliability and other factors of importance for both the current results of contractor activities and his competitive position.

2. The Basis of the Flexible Approach

The presented approach is based on four principal foundations:
- the theory of contingency,
- the theory of organizational equilibrium,
- the law of requisite variety,
- systematic approach.

The theory of contingency, according to which the correct actions in the sphere of management depend on particular parameters connected with a given situation (Bartol *et al.* 2007), is the opposite of the theory based on the search for universal principles applicable to any situation. It should be emphasized that the first approach to the subject of contingency introduced by Lawrence and Lorsch (Lucey 1995) evolved into the dynamic contingency was understood not as adjustment in reaction to something but as the application of the proactive attitude (Volberda 1999). From the point of view of the proposed approach, the theory of contingency is of fundamental importance, since it assumes the adjustment of the executive options to the specific conditions of execution.

The management in accordance with the theory of organizational equilibrium – according to the assumptions made by its authors (Koźmiński and Obłój 1989) – can be understood as the execution of a string of equalizing processes which guarantee that equilibrium will be maintained. Obviously, it will require gathering certain assets securing the effective functioning of the organization under unfavourable conditions. The maintenance of equilibrium (even if we allow, e.g. for extra costs) is more profitable from the point of view of the organization, since the costs of the functioning of the organization outside the state of equilibrium and the costs of restoring the equilibrium justify such a course of action. If we apply the theory of organizational equilibrium to the proposed approach based on the introduction of flexibility, it concerns the situations where the losses connected with not achieving the planned results of the construction processes are relatively high in relation to the costs of activities necessary for the equilibrium to be maintained. The law of requisite variety (Ashby's Law (Booher 2003; Lewis and Stewart 2003)) is closely linked to the previously introduced theory of equilibrium. According to this law, two conditions are the basis for maintaining the equilibrium of the system at a given stage:
1) the system had to remain in equilibrium at the preceding stage,
2) the necessary diversity of controlling actions has to be available (equal or higher than the diversity of variables characterizing the environment).

The law of requisite variety points out to the need for diversification of the operational tactics enabling adjustment to the unstable environment (taking into account the interpretation concerning the organizational equilibrium from the basic tactics (with no flexibility) through various flexibility tactics up to stopping processes under unfavourable conditions).

One of the basic assumptions of the theory of systems is based on the utilization of the possibility of achieving equilibrium in the system through decentralization (Piotrowski 1996). Accordingly, the quick restoration of equilibrium and adjustment to changes is only possible when pro flexible actions are undertaken at the place of potential disturbances – at their source (or close to it). It is justified, therefore, to create quasi-autonomous subsystems which relieve the higher management problems by providing the most efficient actions at the level of the processes. The second assumption of the theory of systems directly applicable to the proposed approach consists of focusing on the key areas as opposed to multidirectional activities. A consistent application of such assumption when implementing flexibility means the analysis of risk and uncertainty factors in order to define the most significant one (for which appropriate activity options and tactics are generated afterwards). In relation to the remaining risk and uncertainty factors, other methods are used, e.g. traditional reactive compensation for disturbances by creating time and cost buffers.

3. The Definition and Basic Types of Flexibility

If we consider flexibility as an idea of improvement to planning and monitoring the execution of construction processes, the equivocal character of this term should be taken into account. Although we can accept flexibil-

Table 1. Basic types of flexibility

Source	Active flexibility	Passive flexibility
Mendelbaum (1978)	Action The ability to respond to change by taking an appropriate action	State The innate capacity to function well in more than one state
Eppink(1978)	Active The response capacity of the organization	Passive The possibility of limiting a relative impact of a certain environmental change
Evans (1991)	Agility Offensive Ex ante action	Robustness Defensive Ex ante action
Presented approach	Adaptability	Robustness

ity as a common feature of everyday life and critical importance for our existence, however, it is difficult to be defined eluding analysis or synthesis. In general, flexible systems are designed to aid the process of production in struggling against variable environmental conditions while maintaining the goals of the process. It should be emphasized that professional literature contains many definitions of flexibility and unfortunately, certain terms related to them are contradictory (Schewchuk and Moodie 1998). However, if we consider a wide range of flexibility application, one should not be surprised by the problems of defining, classifying or assessing flexibility (Pereira and Paulre 2001). When we base our considerations on the definitions of flexibility presented by various authors (Eppink 1978; Evans 1991; Upton 1995), our attention should be focused on the definitions of flexibility, and first of all, on production in the flexible production systems where the emphasis is put on achieving as favourable results as possible while taking into account possible product changes (hence the scope and speed of change are frequently used as the measures of change). The Upton's (1995) definition 'flexibility is about increasing range, increasing mobility or achieving uniform performance across a specified range' is a typical illustration of such approach. The definition is consistent with the notion of flexibility, characteristic for the majority of economy branches aimed at adjusting to the changing market demand. Assuming that this approach is focused on the changing demand for production resulting from the changing requirements of customers, it is necessary to indicate important difference in that sphere concerning the construction industry. By way of analogy to the generally used term 'customization', in case of the construction industry, the term 'conditionalization', i.e. adjusting to the conditions of execution, could be proposed since the variability of the conditions of execution is of key importance in construction processes. A general definition also covering the specific character of the construction industry has been presented by Stabryla (2005), 'flexibility, as the opposite of rigidity, is a property which enables the efficient functioning of the system regarding the existing external conditions and connection with the internal ability to act and its steering depends on the system's level of initiative and capacity to control itself. Therefore, flexibility is a particular form of effectiveness of the system and a measure of its independence; it can be defined for the purposes of maintaining the state of equilibrium understood as the level of effects and/or an indicator of functionality of the system, e.g. durability, reliability or intensity of operation'. It seems that the above definition can be supplemented by the approach from the point of view of decision-making: 'the number of optional alternatives left over after one has made an initial decision' (Mandelbaum and Buzacott 1990).

Two basic types of flexibility should be taken into account when analyzing the possibility of introducing it. They are differently described by various researchers. The most universal classification divides flexibilities into active and passive. The terms of adaptability and robustness were used while preparing the proposed method; however, many other designations presented in Table 1 can be encountered depending on the assumed application concept.

4. The Aim of the Proposed Method and the Prospective Benefits

The proposed FLEMANCO (FLExibility MANagement in the COnstruction industry) method is supposed to improve the planning and execution of construction processes by reducing the influence of disturbances based on the possibility of adjustment focused on the flexible approach. The principal functioning of this method is focused on physical action against risk and uncertainty at the operational level (process) with the use of technological and organizational variant generation. The introduction of flexibility consists of actuating certain options in the initial phase available at the subsequent phases of the execution of the process depending on the conditions of the environment. The essence of the method consists of selecting the appropriate options of flexibility in response to forecasted/monitored changes during the execution of a string of processes. The aim of monitoring the ongoing processes is to track the progress of the processes and costs and to compare them with the assumptions of the plan. If the results of monitoring are taken into account in selecting the tactics of flexibility, better adjustment to the conditions of execution can be achieved (which enables the utilization of occasional opportunities and prevents from prospective risks). The introduction of the proposed approach to flexibility into planning and monitoring construction processes constitutes the opposite of the typical concept of planning the construction industry aimed at a single execution option (without allowing for flexibility) which, together with the changing conditions of execution, may lead to considerable losses (either we continue work on risk quality problems or suspend work and prepare for stoppage costs and possible penalties in case of delays) and inability to take the advantage of opportunities.

The principal prospective advantages of applying the proposed FLEMANCO method include:

- better consistency between process planning and execution,
- smaller range of variability in the planned costs and completion date after assuming various scenarios of execution conditions,
- lower susceptibility to disturbing construction processes (higher reliability),
- reduction in the costs of executing a string of construction processes,
- possibility of preventing losses and using opportunities resulting from the changes in the conditions of execution and from monitoring ongoing processes.

5. Model Description

The presented purpose of the proposed method is realized through choosing the sequence of the string controls of processes during specific stages (0, 1, 2, ..., *i*, ..., *n)* that will lead to minimizing 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:
- $x_{i+1} = f(x_i, u_i, z_i)$,
- initial state x_0,
- set of flexibility tactics ft_1, ft_2, ..., ft_l describing conditions for applying flexibility options,
- required final state x^* as specified by the object of a contract (or the settlement period within the range of contract execution),
- control horizon *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 of 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 implementing the construction process in specific consecutive stages, control may account for step-by-step assessments as well as for the overall evaluation of the entire duration of execution. From the point of view of occurring interruptions (as a key problem of analyzed flexibility management), it seems reasonable to implement a division into the periods of development (such as months or seasons – when analyzing the impact of weather on building processes). Various restrictions are formulated for individual development periods based on such factors as project advancement analysis, an observed impact of the environment etc. We are analyzing a discrete dynamic object for:

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

where: $x_i \in X$ is the state vector, $u_i \in U$ is the control vector, and $z_i \in Z$ is the vector of interruptions. 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:

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

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

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

where: $Q_l = \varphi(x_i, u_{i-1}) = \varphi_u(u_{i-1}) - \varphi_x(x_i)$for each stage finding a solution of a double-criteria problem consisting of minimizing costs and maximizing efficiency where the goal 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 the minimization of the 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 the costs of penalties for exceeding the contract deadline and additional costs related to continued development outside the assumed control horizon):

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

The basic problem of the above formulation of the decision-making issue is the availability of required knowledge sufficient for making a decision and conditions of decision implementation (risk or uncertainty).

6. The Idea of FLEMANCO Method

The proposed method is based on the general algorithm of the procedure presented in Fig. 1.

The first group of activities consists of defining the limits of the subsystem enabling an assessment of system operation under quasi-closed conditions, i.e. with a limited influence of other subsystems. Certainly, we assume that the method will be used by specialized contracting organizations focused on achieving the competitive edge because of gathered knowledge concerning the chosen field of activity. The following information can be admitted as the examples of separate subsystems: operations of concreting a road, bridge, runway, logistics yard, assembling the facade of a high-rise building etc. Tracing the limits of the subsystem enables assessing the efficiency and effectiveness of the functioning of individual flexibility tactics and strategies. In view of the seasonal character of the construction industry, it is very important to define the time limits of operating the subsystem. The next package of activities is aimed at analyzing the risk and uncertainty having influence on the subsystem. It consists of defining the opportunities and risks resulting from the influence of the environment, analyzing the possibilities of monitoring and forecasting changes and of acting on the subsystem with the aim of reducing the risks and utilizing prospective opportunities. The classification of the risk factors into critical ones (on which the

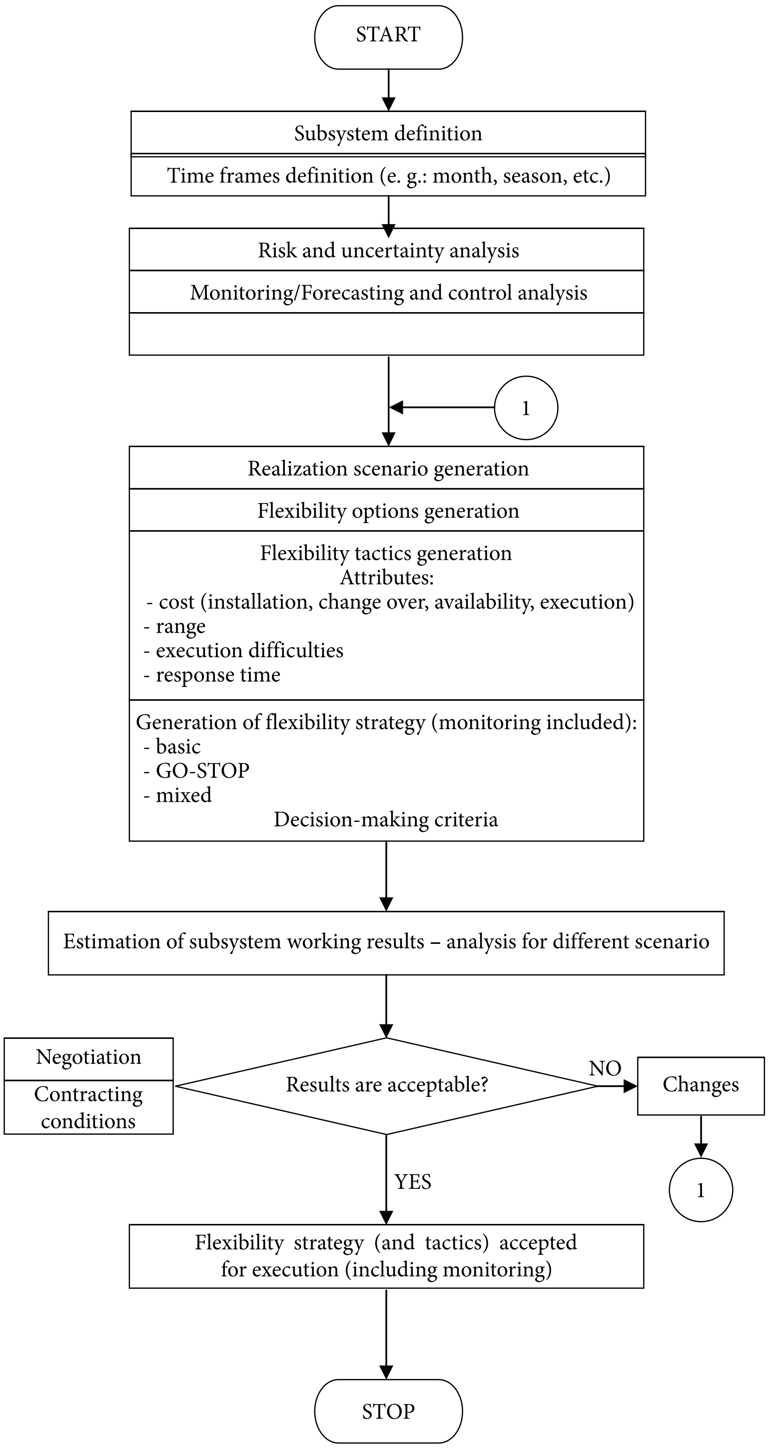

Fig. 1. Flexibility management concerning the idea of construction industry (FLEMANCO)

operation of the system will be based) and those the influence of which will be reduced, e.g. using typical time and cost buffers, is of fundamental importance. The next task is to generate possible flexibility options, tactics or strategies together with the scenarios of execution conditions. The most important flexibility options are those understood as the variants of physical reaction to risk and uncertainty. The conditions for applying these options in case of the occurrence of certain environment states are defined by flexibility tactics. The strategies of flexibility define the control algorithm, i.e. the application of individual flexibility tactics depending on the conditions of execution (on the basis of monitoring or forecast).The next step consists of assessing the quality of subsystem functioning for various flexibility strategies based on the simulation of their functioning for sample runs (the results of these calculations are the basis for negotiating contract terms). The adjustment to contract requirements makes it necessary to introduce changes in the sphere of flexibility options, tactics and strategies as well as in assessing the time and cost of executing a string of processes. Activities at the stage of planning yield the final result of the accepted solution in the sphere of tactics and strategy with monitoring. The stage of execution consists of three phases: implementation, typical execution and conclusion. The confirmation of correct assumptions made at the stage of planning is the principal element at the implementation stage (it is assumed that a detailed monitoring will be provided to enable possible corrections, e.g. in the sphere of tactics adjustment to forecasts etc.). Monitoring at the stage of typical execution makes it possible to choose flexibility tactics on the basis of comparing the progress of work and total costs with the plan (for the current stage) as well as to forecast the conditions for the execution at the following stage. Particular care is required when concluding the execution of a string of processes when special tactics have to be used (e.g. exceeding the maximum possible daily output by working at night or by increasing the capacity of the applied machines and devices) in case of an unfavourable course of the processes and the assumed date of completion being at risk. The use of such tactics comes from the risk of additional costs (losses and penalties connected with exceeding the contract date for completing the execution of the string of processes).

Particular attention must be paid to decision making criteria. In the approach presented, a bi-criterion model as a compromise result of a very simple model (one criterion) and a more sophisticated solution (e. g. multi-criterion methods (Antuchevičienė *et al.* 2006; Brauers *et al.* 2008; Jakimavičius and Burinskienė 2007; Kaklauskas *et al.* 2006 and 2007; Morkvėnas *et al.* 2008; Roy 1990; Su *et al.* 2006; Turskis *et al.* 2006; Turskis 2008; Zavadskas *et al.* 2006, 2007, 2008) were chosen.

7. An Example of Applying FLEMANCO Method – Concreting of Runway

The attempts to use the proposed method were made in regard to constructing an airfield runway as the example of processes at high weather influence risk. The limits of the subsystem were defined by focusing on the operation of concreting (production, transport and casting concrete mix as well as curing and maturing concrete). Since work was performed in summer, the rain was assumed as the key disturbing factor. The principal flexibility options included the possibility of applying screens in the form of roofs protecting the surface of freshly cast concrete (in case of rain) from a destructive impact of rain as an example of active flexibility (adaptability) and surface modifier accelerating the process of hardening fresh concrete as an example of passive flexibility (robustness). These two basic flexibility options were used to generate four flexibility tactics: two of those concerning the screens in the form of roofs (one – designated R1 – assuming cooperation with meteorological stations warning about expected rain and the other (designated R2) based on monitoring the weather situation near the construction site) and another two connected with applying a modifier hardening the surface of fresh concrete to survive from a destructive influence of rainfall (H1 and H2 – times for achieving immunity – 1.5 and 2.0 hours respectively).

The following task having prepared flexibility tactics is to define their effectiveness and efficiency in relation to executive conditions (based on scenarios corresponding to the weather forecast). An example of the results of effectiveness and the efficiency of five flexibility tactics (the fifth – NF – without flexibility, in addition to the above-mentioned four R1, R2, H1, and H2) for NORM scenario is shown in Fig. 2. From the point of view of the course of goal function, R2 tactics is the currently preferable one, although if it becomes necessary to increase the rate of work, R1 tactics could be applied. Otherwise, we could take an advantage of a chance to overtake the plan by using H1 tactics.

When we start generating strategies, the following basic ones could be taken into account: MONO

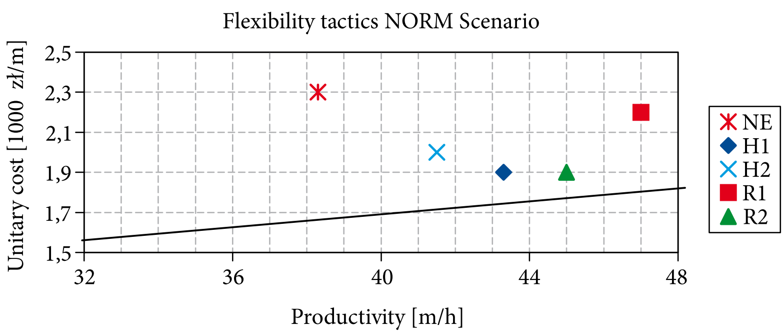

Fig. 2. Comparison of flexibility tactics in runway concreting for NORM scenario

(assumes the application of one flexibility tactics), GO-STOP (strategies assuming work suspension in case of less favourable conditions), BEST FIT (assumes adjusting flexibility tactics to the forecasted execution conditions) and mixed strategies. Traditionally, the strategy used for concreting runways combines MONO (no flexibility) and GO-STOP strategies.

The following process execution strategies were used at the planning stage:

- The first strategy consisting of applying no flexibility tactics (designated NF) in case of SUN or OPT forecasts, Roofs 2 (designated R2) tactics in case of NOR forecast and Roofs 1 tactics (R1) in case of PES or NEG forecasts and execution stoppage (designated ST) in case of EXN forecast as shown in the following:

  S1: (SUN→NF, OPT→NF, NOR→R2, PES→R1, NEG→R1, EXN→ST)

- The second strategy consists of applying no flexibility tactics in case of SUN or OPT forecasts, Roofs 2 (R2) tactics in case of the processes running in accordance with the plan (PLA) or Roofs 1 (R1) in case of the processes execution less advantageous than planned (SLO) or Hardener 1 (H1) tactics in case of the course of the processes better than planned (FAS) for NOR forecast or Roofs 1 (R1) in case of PES or NEG forecasts and STOP (ST) for EXN as shown below:

  S2: (SUN→NF, OPT→NF, NOR→R2 | PLA, NOR→R1 | SLO, NOR→H1 | FAS, PES→R1, NEG→R1, EXN→ST)

- The third mixed strategy used for analysis utilizes no flexibility tactics in case of SUN or OPT forecasts, Roofs 2 (R2) tactics in case of the processes running in accordance with the plan or Roofs 1 (R1) in case of the processes execution less advantageous than planned or Hardener 1 (H1) tactics in case of the course of the processes better than planned for NOR forecast and work stoppage (designated ST) in case of PES, NEG or EXN forecasts which can be expressed as (notations PLA, SLO and FAS as for strategy S2):

  S3: (SUN→NF, OPT→NF, NOR→R2 | PLA, NOR→R1 | SLO, NOR→H1 | FAS, PES→ST, NEG→ST, EXN→ST)

- The fourth mixed strategy is based on using no flexibility tactics (NF) in case of SUN, OPT, NOR or PES forecasts and on stopping work in case of NEG or EXN forecasts:

  S4: (SUN→NF, OPT→NF, NOR→NF, PES→NF, NEG→ST, EXN→ST)

- The fifth strategy uses no flexibility tactics (NF) for all five weather forecast types with work stoppage in case of extremely unfavourable forecast EXN:

  S5: (SUN→NF, OPT→NF, NOR→NF, PES→NF, NEG→NF, EXN→ST).

The assessment of effectiveness consisted of monitoring the progress of work and costs in time in order to define the ranges of time and costs for executing a string of the processes of constructing a runway of the assumed length (15 000 m) at the planned time (25 days).

Fig. 3 presents monitoring results for strategies complying with the above descriptions of S1, S2, S3, S4 and S5 for the analyzed case (SUBOPTY) and the course of the processes as planned.

If we assess the course of the processes using various strategies at the a/m diagram, high effectiveness of S3

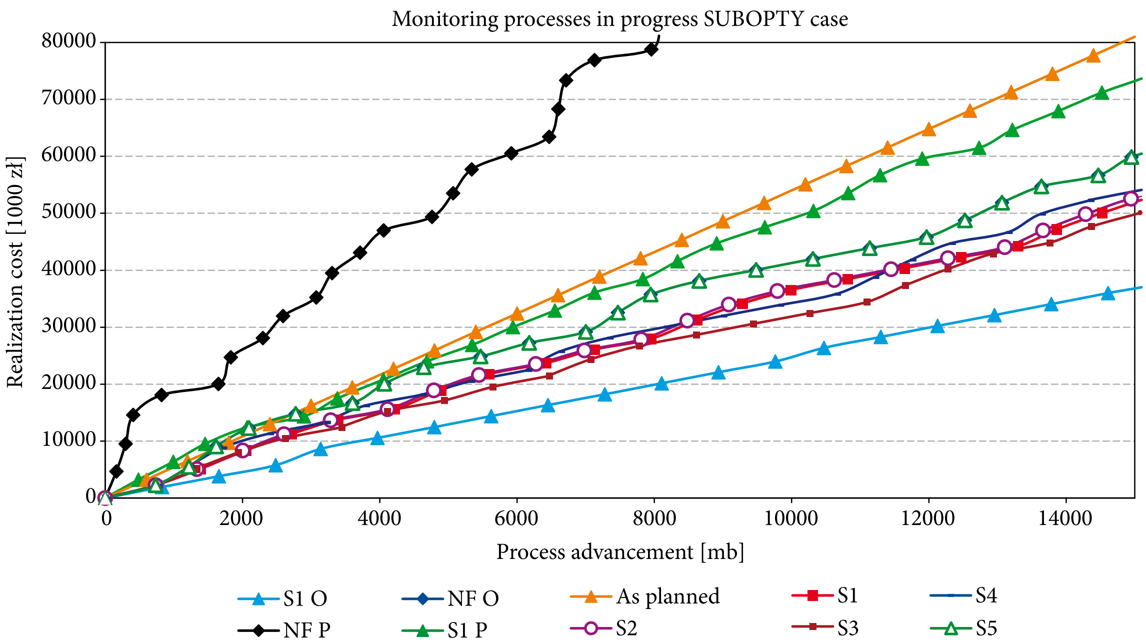

Fig. 3. Monitoring the processes of runway concreting in progress for SUBOPTY case

strategy can be seen. It also can be noticed that even under favourable execution conditions, it is more efficient than S4 or S5 strategies. It was confirmed by the summary of analyzing the courses of SUBOPTY, NORMAL and SUBPESY cases the results of which are summarized in Table 2 and presented in a graphic form in Fig. 4.

Table 2. Runway pavement cost for different strategies and realization conditions

Strategy	Cost in different realization conditions [10^3 ZLP]		
	SUBOPTY	NORMAL	SUBPESY
S1	51 951	58 134	71 250
S2	52 675	59 949	72 279
S3	50 057	58 470	70 885
S4	54 010	70 043	92 030
S5	60 021	74 105	108 843

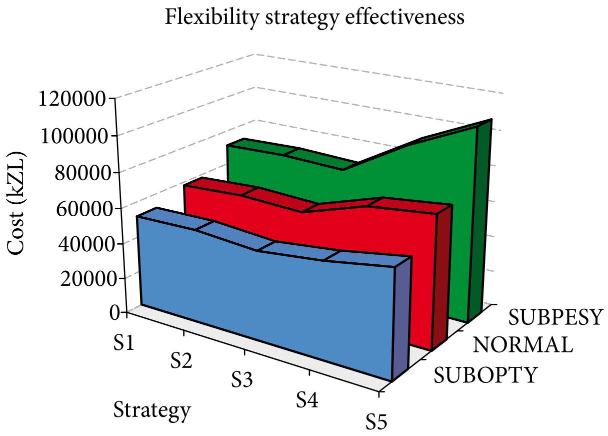

Fig. 4. Flexibility strategy effectiveness for runway pavement

It can be stated that with reference to the analysis of the presented results, the strategies based on flexible adjustment of execution tactics to the conditions of execution (S1, S2, and S3) are considerably more efficient than the traditional ones (S4 and S5 strategies without flexibility) even if we take into account the possibility of work stoppage in case of less favourable execution conditions (S4 strategy). The advantage of S1, S2 and S3 strategies over the remaining ones was confirmed by the calculations of both the risk and uncertainty conditions – see Table 3. Generally, strategy S3 was the most effective one in all analyzed situations but in some cases, differences between the latter strategy and other flexible strategies were not very significant.

8. Conclusions

The presented general idea of FLEMANCO method and the case study make it possible to draw the following conclusions:

- Flexibility as the means for reducing the influence of disturbances caused by the changing environment shows considerable potential for improving the management of construction engineering processes.
- The presented concept is based on the proactive approach and the possibility of physical reaction to risk and uncertainty (resulting from the specific character of construction industry) at source, as an element facilitating the efficiency and effectiveness of flexibility management.
- FLEMANCO method enables protection against prospective risks and facilitates the utilization of occurring opportunities.
- Certainly, an effective application of flexibility strategy requires specific conditions, e.g. a large scale of operations, a high capacity of processes, high susceptibility to disturbances, the possibility of disturbance forecasting, efficiency in controlling flexibility options etc.
- Technical progress in the construction industry and other fields (e.g. data gathering, transfer and analyzing, aiding decision-taking processes) provides the ground for a dynamic development of the proposed approach due to ever growing possibilities of generating flexibility options and tactics

Taking into account the amount of data necessary for analyzing the efficiency and effectiveness of flexibility tactics and strategies, the possibility of applying a hybrid advisory system operating on the basis of popular software needs to be pointed out (assuming it is used on the site on a constant basis). An effective and efficient application of flexibility is based on a systematic gathering of knowledge (learning) from the examples of applying various flexibility options, tactics or strategies under diverse conditions.

Acknowledgements

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Table 3. Estimation of pavement strategies cost for risk and uncertain conditions [in kZL]

Conditions Criteria	Uncertainty				Risk*		
	Wald	Hurwicz	Laplace	Savage	20-50-30	20-60-20	30-50-20
Strategy S1	71 250	61 601	60 445	1 894	60 832	59 521	58 902
Strategy S2	72 279	62 477	61 634	2 618	62 193	60 960	60 233
Strategy S3	70 885	60 471	59 804	336	60 512	59 270	58 429
Strategy S4	92 030	73 020	72 028	21 245	73 433	71 234	69 631
Strategy S5	108 843	84 432	80 990	37 958	81 710	78 236	76 827

*N.B.: For risk decision conditions different parity (probability) for realization conditions was taken into consideration (SUBOPTY, NORMAL and SUBPESY – accordingly)

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