TECHNICAL TRANSACTIONS 6/2017
CZASOPISMO TECHNICZNE 6/2017
CIVIL ENGINEERING
DOI: 10.4467/2353737XCT.17.096.6572

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# Application of unmanned aerial vehicles for revising dispersion of time of key undertakings

# Wykorzystanie bezzałogowych platform latających do aktualizowania dyspersji czasu wykonania kluczowych przedsięwzięć

**Abstract**
The paper summarizes the concept of using unmanned aerial systems for construction work monitoring. Mobile drones can be used for determining the current stage of a given subtask in a complex construction project. Such control allows more adequate determination of the completion time of a given task, leading to more effective project schedule management.
**Keywords:** drones, construction works, project

**Streszczenie**
W pracy zostanie przedstawiona koncepcja wykorzystania bezzałogowych platform latających do monitoringu prac budowlanych. Mobilność dronów pozwala na ich wykorzystanie do wyznaczania aktualnego stanu w jakim znajduje się podzadanie złożonego projektu budowlanego. Kontrola wpłynie na dokładniejsze wyznaczenie czasu zakończenia danego zadania, a tym samym na lepsze zarządzanie harmonogramem całego projektu.
**Słowa kluczowe:** dron, prace budowlane, projekt

## 1. Construction project planning

Construction projects are connected with the development and execution of strategic and operational plans, which determine how the task goals are achieved [9]. Construction project planning-related documents include: a schedule, execution plan, budget, financing and cash flow plans, and a resource plan.

Construction work planning is often computer-aided; computer programmes eliminate most errors, e.g. when some tasks or resources overlap or are duplicated. In order to begin scheduling, one needs to gather information on the tasks required to complete a project, their duration, relations between them, resources needed for these tasks, their amount and availability.

In the literature of the subject, there are different ways of presenting the sequence of tasks implemented at various phases of scheduling. The paper describes the division into pre-launch phases (phases A1 and A2) and phase B implemented in the course of a project:

A1: Project scheduling, which ensures high chances for meeting the final deadline of a project and determination of the deadline acceptable for all project stakeholders;

A2: In the case of missing the project's planned deadline, one prepares a risk assessment, defines causes and undertakes steps to minimise the risk.

B: Verification of the planned deadline on the basis of controls undertaken in equal time intervals. Moreover, revision of chances of meeting the deadline and undertaking of certain steps to enhance meeting the project's deadline. In case of failure, revision of the deadline and presentation of all consequences of the above [11].

The aforementioned phases are the basic ones and their execution ensures constant control over both operational and strategic planning of a construction undertaking.

Delays in construction projects are often not taken into account in the schedule planning phase, mostly due to difficulties in estimating possible construction work delays and final deadlines of given processes.

Delays can be analysed by various techniques, including:

- CPM,
- PERT,
- the global impact technique where one plots all individual delays on a schedule, and when summed up, excluding their concurrence, they give a total overrun of the project's duration,
- the breakdown technique, based on the critical path method (CPM), takes into account all types of delays and the simultaneousness of their occurrence,
- the snapshot technique where one distinguishes periods of delaying events and compares them while analysing both as-planned and revised schedules,
- the time impact analysis, similar to the snapshot technique, where delaying events are focal points,
- the net impact technique, non-related to the CPM network, with the major difference that the revised schedule takes into account net effect of all delays [1].

Construction work planning is a process that requires large experience and know-how on the possibility of the occurrence of unexpected events affecting, to a large extent, the time of completion of a construction project. According to the research team, efficiency of planning, and also of construction undertaking implementation, can be increased by application of new technologies, such as drones.

## 2. Unmanned aerial vehicles and time of key construction projects

Nowadays, unmanned aerial vehicles (UAVs) are one of the fastest developing technologies. They are increasingly used in various construction undertaking and large companies active in the construction industry apply drones in their specialised programmes. UAVs serve mostly as observation devices [10]. Live viewing of activities undertaken on construction fields, current tracking of equipment operation, work optimisation, and increased safety are a small fraction of what these devices offer. Drones can be easily equipped in an additional observation module, IT, or any other state-of-the art devices, which significantly increases their abilities [10].

Most of all, small flying machines can be equipped in a wide array of sensors and scanners detecting radiation or creating a map of a given area. Drones play the role of "scouts", automated cartographers, and eyes of professionals in places they sometimes cannot reach on their own. Komatsu, one of the leading producers of construction equipment, introduces drones to its research and development programmes. UAVs measure construction fields from the air and send data to the computer, which creates a 3D terrain model. This way, measurements are ready within hours, not days. Basing on the model, excavators and bulldozers can perform given construction works without operators. 3D models of which position and attachments will be remotely controlled are transmitted to smart machines by cloud computing.

Fig. 1. Quadrocopter assisting in construction works
(source: komatsu.com)

In many cases, the application of unmanned aerial vehicles is much cheaper than regular methods. A drone does not need an airstrip, it is controlled from the ground and it does not consume litres of petrol. Therefore, its application is not cost intensive. Close observation of high objects does not pose a problem either.

## 3. Methods

As opposed to projects from other areas of economy, in construction undertakings, one should take into consideration a wide array of factors affecting the time of completion of a project. They include: design documents, a relatively long duration of construction works, weather conditions, or background conditions. From the economic point of view, the duration of an entire construction undertaking should be as short as possible, and the duration of key stages should be revised as often as possible. Therefore, there is the need for modelling of construction undertakings in such a way that it adequately reflects the course of real construction processes and precisely estimates their completion times. New technologies are of great help in such processes.

Continuous software development allows creating more and more precise models, which reflect a better investigation of problems. One should mention here, inter alia, laser scanning: terrestrial (TLS – Terrestrial Laser Scanning), airborne (ALS – Airborne Laser Scanning), and mobile (MLS – Mobile Airborne Laser Scanning), as well as photogrametry: terrestrial, mobile (MMS), and airborne. Not to forget about georadar measurements (GPR – Ground Penetrating Radar). Each of the aforementioned technologies allows developing products that are useful in designing, construction, as-built measurements, or road object monitoring.

The literature on project management and scheduling proposes numerous methods to reduce the duration of undertakings. One of them is reduction of time of given processes (time-cost trade off problem), which is directly related to an increase in costs. Depending on the type of undertaking, higher costs can arise from the introduction of shift work, extra hours, working on public holidays, or application of state-of-the-art materials or mounting system work in a given project. The relation between time and costs of processes can be modelled by linear relationship, non-linear relationship or in the discrete form [5, 7–9].

One can distinguish the following algorithms: Critical Path Method (CPM), time-cost analysis (CPM/MCX), and Program Evaluation and Review Technique (PERT), the probabilistic method of project planning and control; they are applied in network scheduling [6, 12]. As in CPM, the core of PERT is the critical path analysis. The difference between both

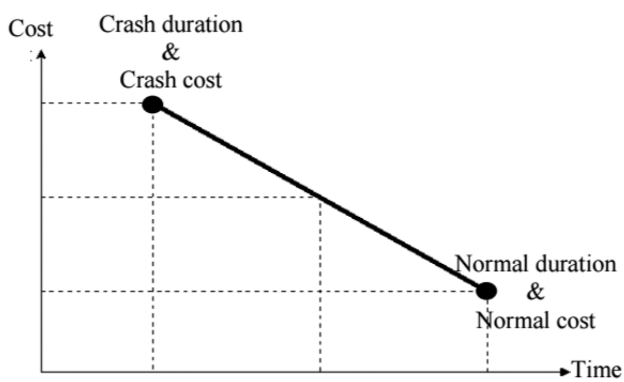


Fig. 2. Linear relationship between time and cost of execution

methods is that in CPM time is defined, whereas in PERT it is a random variable; an advantage of the latter technique. Due to such approach to time of tasks a project is composed of, statistic methods can be used to estimate risk related to completion of individual tasks, groups of tasks, and an entire project on time, and determine probability of their accomplishment in a pre-defined time.

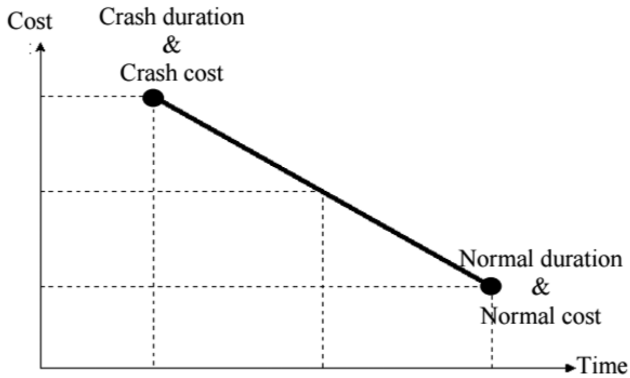


Fig. 3. Non-linear relationship between time and cost of execution

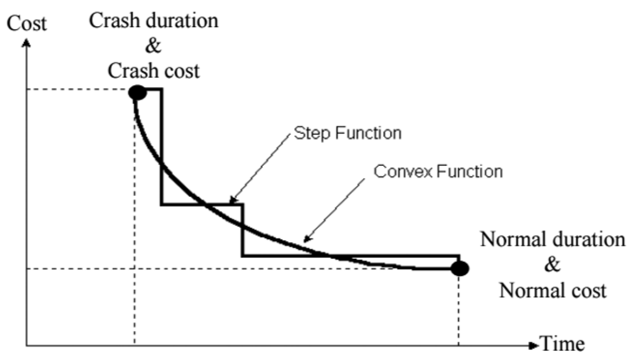


Fig. 4. Discrete relationship between time and cost of execution

PERT arbitrarily assumes that the time distribution is a beta distribution. It is the continuous density function as follows:

$$f(t) = H(t-a)^{p-1}(t-b)^{q-1} \tag{1}$$

$$\text{for } a < t < b \tag{2}$$

where:

$a, b, p, q$ – parameters of the distribution,

$H$ – normalisation constant depending on the parameters.

In PERT these parameters are replaced with three values, relatively easy to determine [6, 12]:

- optimistic time estimate ($a = C_o$),
- most likely time estimate ($C_p$),
- pessimistic time estimate ($b = C_{pe}$).

Basing on these variables, one estimates the expected time of a given task, the basis of the critical path analysis, and the expected time variance, which determines the expected difference between the expected time and the real time of accomplishment of a given task. An estimate *t* is most often based on the weighted:

$$T_{[r} = \frac{C_o + 4C_p + C_{pe}}{6} \tag{3}$$

$$\sigma^2 = \frac{\left(C_{pe} - C_o\right)^2}{36} \tag{4}$$

One of the biggest problems in using network methods is determination of time of given tasks. However, often in case of similar projects, such linear projects (road construction), the estimation of duration of given tasks is highly probable.

## 4. Estimation of statistical parameters in construction undertakings by means of drones

The increased deployment of modern technologies and more advanced computerisation take place not only in the automotive industry (for example, autonomous self-driving cars by Tesla or Google), but also in the construction industry, as it was mentioned in the previous chapter. A construction investment, understood as a process, is divided into four crucial stages:

- programming,
- designing,
- execution,
- operation.

The execution phase of any construction project is of high importance due to the significant costs it generates. Cost reduction in this phase allows a significant reduction of costs of the entire investment. Cost optimisation can be introduced in this phase of an investment project, inter alia, by proper scheduling of construction works. It turns out that the old saying "time is money" applies even in the construction industry. Optimisation methods used in the industry include network methods, which were described in the previous chapter on the example of CPM and PERT. It should be noted that construction undertakings – as most of the projects undertaken in non-laboratory conditions – are subject to uncertainty. Such uncertainty may be related with various aspects of project implementation, for example ensuring financing continuity; however, the present paper is limited only to the optimisation of execution time of given construction work stages. PERT is a simple, probabilistic method based on the assumption that statistical parameters of probability distribution for time of given project's phases (including the execution of a construction undertaking) can be estimated by means of the set of three pre-defined parameters:

- optimistic time estimate,
- most likely time estimate,
- pessimistic time estimate.

The aforementioned CPM is a specific, deterministic example of the PERT method where the pre-defined values of the estimates are equal.

It is assumed that the use of unmanned aerial vehicles (constructed as the so-called flying wings, or multicopters), equipped in the set of sensor, allows mass (and as a consequence) cheap control of construction field in complex construction projects. UAV's can be used in planning part of a project to collect data about the conditions of work implementation. Moreover, UAV's can be used in the execution stage of the project for the identification of the state of works execution. Data accumulated in this way will be used for development of a wide database with times of subsequent phases of a large number of construction investments. Such database could contribute to a reduction of uncertainty with respect to time of subsequent planned actions. Basing on PERT:

- estimated time of subsequent phases can be determined with larger precision (due to a wide data base with objective data),
- pessimistic and optimistic times can be subject to decreased dispersion in relation to the estimated time of execution due to more precise estimation of variability in time (dynamics).

Determining statistical parameters by means of previously conducted research will limit uncertainty with reference to dispersion of time parameters describing the time probability distribution for the execution of a given construction project phase. However, it may turn out that construction works will be subject to an array of abnormal random events (permanent and long-term precipitation, strong winds, frequent construction equipment failures, etc.). In such a case, the time of the investigated undertaking will go far beyond the typical confidence interval. Early detection of an anomaly in the course of a given undertaking will be also possible by means of permanent monitoring with unmanned aerial vehicles. Such application of drones will allow an immediate introduction of changes in scheduling of projects, which turned out to be difficult to model due to the occurrence of rare random events. Task scheduling with uncertain statistical parameters of time distribution for subsequent phases, as random parameters of the Erlang distribution or normal distribution, is more broadly investigated by Bożejko, Rajba, and Wodecki [2, 3], as well as Hejducki and Rogalska [4].

## 5. Summary

The paper proposes and describes the concept of using unmanned aerial vehicles for developing databases with times of execution of subsequent phases in construction projects. Such database will offer more precise planning and execution of complex construction undertakings due to better understanding of the parameters describing the probability distributions of the time of subsequent phases of a construction undertaking. The authors plan to conduct research using drones to verify their assumptions.

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