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Theoretical comparative analysis of cascading, iterative, and hybrid approaches to IT project life cycle management

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Abstract

The absence of a common and universal approach to IT project management allows us to formulate a problem to analyze and study when choosing the most efficient project management methodology. The relatively small number of scientific works summarizing practical experience of a theoretical approach allowed us to formulate a generalized mathematical model for a common IT project lifecycle estimation in this work using waterfall, agile or hybrid approaches for the project management. Based on the advantages and disadvantages of existing methodologies that we revealed, it appears that use of agile approaches within stages of the cascade methodology approach improves the process of IT project management compared to a pure cascade implementation. Moreover, the recursive application of an iterative approach at certain stages of the project implementation worsens the characteristics of the project life cycle and can be used only to reduce a certain class of project risks. The results of our study allow us to propose a semi-empirical method for project planning estimation accuracy and attainability of the declared project implementation characteristics. All of this should have a positive impact on the effectiveness of the IT project management strategy choice.

Key words: IT project management; iterative methodology; Agile; waterfall; hybrid methodology; model analysis.

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Introduction

Despite their long history [1], the discussions considering advantages and disadvantages of cascade and iterative approaches to IT project life cycle management in general and software development in particular have continued until recently [2, 3]. Starting from 2009, PMI recommends a hybrid version of the project management methodology (PMBOK-4) [4], in which the cascade WaterFall (WF) methodology is used for strategic planning [5], and the main project stages are implemented iteratively (Agile) [6]. In recent years, much attention has been paid to the comparative analysis of risks connected with the use of WF [7] and Agile [8, 9] modifications, to the necessity of adapting flexible project management approaches to the characteristics of the subject area (banking, medicine) [10–12], to the optimization of the structural combination of flexible and cascade methodologies [13], etc. In most cases, however, when describing WF shortcomings, the authors of scientific articles, books and reports at conferences rely on numerous accumulated data on project realization or implementation failure using the cascade methodology [14], while the advantages of Agile are mainly demonstrated with the help of successful implementation examples of relevant projects [15–17].

Thus, the "opponents" of a flexible methodology always cite the lack of representative statistics on the Agile projects' implementation, any specific features of the subject area for the successful application of the iterative approach [18] and the lack of a clear system structure and project management processes using iterative approach modifications. The "compromise" outcome is the hybridization of various schemes that combines the elements of the project life cycle management processes clear planning [19] and possibility of relatively effective achievement of the practical results through the use of the iterations at key stages of the project [20, 21]. In this article we consider the question of the existence of an optimal ratio of the discussed management practices application in IT.

1. Concept

According to the general approaches to project management [22], one distinguishes the stages of initialization, planning, implementation and completion of a project (with a cascade approach). Moreover, typical variants of project life cycle models are presented in [23] and can be described, for example, within the framework of a generalized model:

$$\rho(t) = \rho_0 \cdot t^k \cdot \exp(-\gamma \cdot t), \qquad (1)$$

where $\rho(t)$ is the share of work completed by time t;

γ, k – parameters that define particular forms of life cycle models;

ρ_0– normalization factor ensuring the fulfillment of the condition

$$\int_0^\infty \rho(t)\,dt = 1.$$

Representation (1) allows us to describe the dynamics of project P completion degree from time τ using the expression

$$P(\tau) = \int_0^\tau \rho(t)\,dt = 1 - \exp(-\gamma \cdot t) \cdot \sum_{n=0}^{k} \frac{\tau^n \cdot \gamma^n}{n!}. \qquad (2)$$

Consider the individual cases k = 1, 2, 3, 4 describing typical particular models of the project life cycle:

$$\rho(t) = \gamma^2 \cdot t \cdot \exp(-\gamma \cdot t), \qquad (3a)$$

$$\rho(t) = \frac{\gamma^3}{2} \cdot t^2 \cdot \exp(-\gamma \cdot t), \qquad (3b)$$

$$\rho(t) = \frac{\gamma^4}{6} \cdot t^3 \cdot \exp(-\gamma \cdot t), \qquad (3c)$$

$$\rho(t) = \frac{\gamma^5}{24} \cdot t^4 \cdot \exp(-\gamma \cdot t). \qquad (3d)$$

According to (2), they correspond to particular models of the project dynamics:

$$P(\tau) = 1 - (\gamma \cdot \tau + 1) \cdot \exp(-\gamma \cdot \tau), \qquad (4a)$$

$$P(\tau) = 1 - \left(\frac{(\gamma \cdot \tau)^2}{2} + (\gamma \cdot \tau) + 1 \right) \cdot \exp(-\gamma \cdot \tau), \qquad (4b)$$

$$P(\tau) = 1 - \left(\frac{(\gamma \cdot \tau)^3}{6} + \frac{(\gamma \cdot \tau)^2}{2} + (\gamma \cdot \tau) + 1 \right) \cdot \exp(-\gamma \cdot \tau), \qquad (4c)$$

$$P(\tau) = 1 - \left(\frac{(\gamma \cdot \tau)^4}{24} + \frac{(\gamma \cdot \tau)^3}{6} + \frac{(\gamma \cdot \tau)^2}{2} + (\gamma \cdot \tau) + 1 \right) \cdot \exp(-\gamma \cdot \tau). \qquad (4d)$$

Figure 1 shows several variants of life cycle models and corresponding models of dynamics of project completion degree.

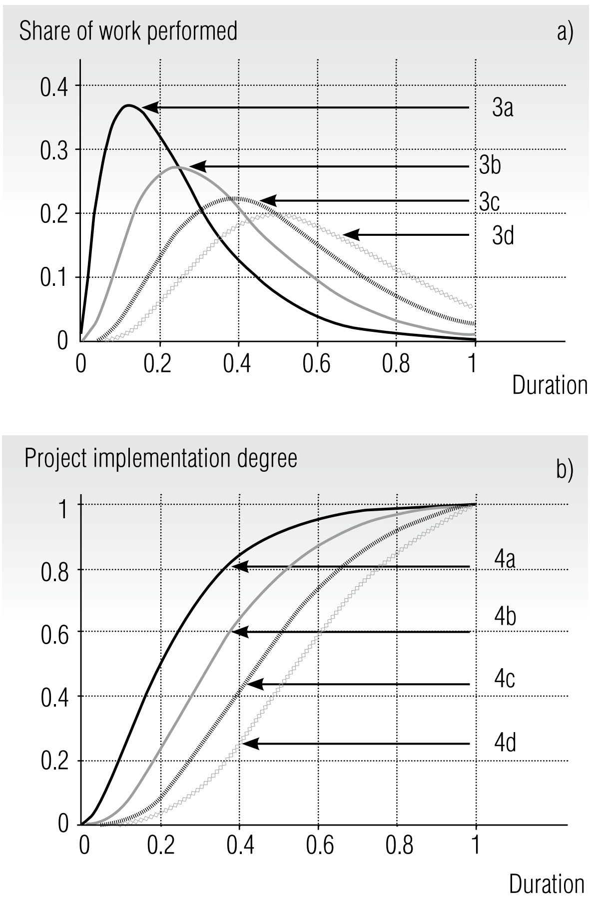

Fig. 1. Variants of life cycle models (a) and dynamics of the project completion degree, (b) depending on the normalized duration of its implementation (for γ = 1)

To simplify further calculations, we chose a way to represent the model functions in a piecewise linear form (for example, highlighting the stages of the life cycle):

$$P(\tau) \cong \begin{cases} a_1 \cdot \tau + b_1,\ \tau \in [0;\ 1{,}25 \cdot \tau_1) \\ a_2 \cdot \tau + b_2,\ \tau \in [0{,}75 \cdot \tau_1;\ 1{,}25 \cdot \tau_2) \\ a_3 \cdot \tau + b_3,\ \tau \in [0{,}75 \cdot \tau_2;\ 1{,}25 \cdot \tau_3) \\ a_4 \cdot \tau + b_4,\ \tau \in [0{,}75 \cdot \tau_3;\ \tau_4]\ , \end{cases} \quad (5)$$

where $a_3 > a_2 > a_4 > a_1$ with $k = 4$, we obtain a simplified model of the project dynamics under the cascade paradigm of planning and management (*Figure 2*).

2. Advantages and disadvantages

According to the cascade paradigm, the end of the previous and the beginning of the subsequent work "overlap" by about 25%. As a result, an advantage is achieved over the relay paradigm, in which the end of the previous work coincides with the beginning of the next one. The "time overlapping" degree of the project implementation neighboring stages determines the difference between cascade and relay planning and also affects the parameters of the lines equations, the segments of which form a graph of a piecewise-linear function that describes the project realization dynamics. The parameters of linear equations that describe the discussed lines were found by the least squares method [24].

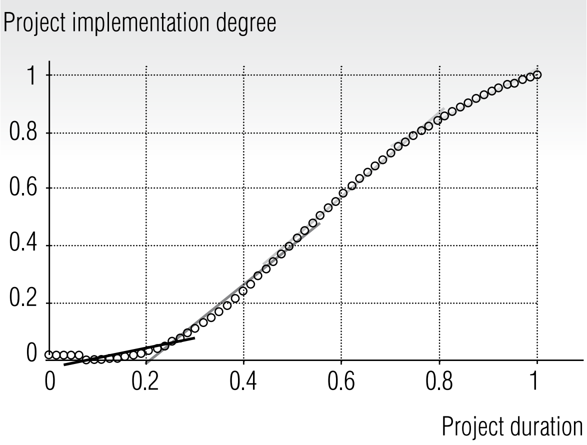

Fig. 2. Dynamics of an abstract project completion degree formed (4d) and the corresponding piecewise–linear model (5) are represented by circles and line segments, respectively

Note that the very emergence of a cascading approach to project management owes its origin to the application of an iterative approach to the relay planning paradigm, because the possibility of actual overlapping in time of the end of the previous and the beginning of the subsequent work is associated with the allocation of the basic and improved versions of the implementation of each stage of the work. As a result, the subsequent work may begin at the end of the basic component execution of the previous work, rather than at the end of all modifications and corrections to the previous work.

A well-known drawback of the cascade (and, especially, relay) approach is the absence of possibility of coordination with the customer about the list of executed works and intermediate results in the course of project performance [25, 26]. The introduction of elements of iterative approaches to solving certain groups of tasks within the framework of a cascade "strategic plan" of the project is actually a modern standard of project management [27, 28]. To illustrate the advantages of such a hybrid approach, one can, for example, divide a rough piecewise-linear model of project execution dynamics into two/four successively executed subprojects (since resources are limited, in the model case considered the impossibility of parallel subprojects execution is postulated even with the use of a purely iterative approach to project management). Assuming that in the model case for any abstract project, the Pareto principle is observed (80% of the tasks are completed in 20% of the time, 20% of the tasks are performed in 80% of the time), we will estimate distinctions in time of achieving the executed works level of 80% at division of the project into subprojects and redistributing the order of the stages that implement the elements of an iterative approach [29]. F*igure 3* shows the corresponding graphs.

It is evident that at simple division of the project into subprojects taken as a basis the cascade approach, the time to reach 80% of the entire project slightly increases compared to the basic project implementation plan. However, there is an increase in the project implementation speed at the initial stages. Dividing a project into subprojects promotes an increase in average speed at initial stages of a project implementation and, as a whole, is expected to equalize the average speed of the project performance (i.e., effectively reduces the likelihood of schedule disruption). The possibility of parallelizing the work improves the situation radically. However, within the framework of this article, it is assumed that the resources are extremely limited and fixed, so that parallel work is impossible.

Obviously, even with such a model representation, the time to reach the local target indicator of the project initial stages is reduced by 4% and 14% by dividing the project into 2 and 4 subprojects. Consequently, the widely used work division into separate tasks and operations is proved to be mathematically justified from the most general assumptions.

3. The greatest efficiency

There is a question about "maximum possible utility" of applying an iterative approach for a "cascade" project, the predicted execution dynamics of which are described by a given piecewise-linear functional proportion dependence of successfully completed work share on the project realization duration. Since the main advantage of the iterative approach is the possibility of dynamically reconciling the sequence of stages, we consider the model (5) of the "cascade" project, in which we abandon the requirement to follow the project stages "one after another." Obviously, under the conditions of fixed resources, it is assumed that the speed of each stage cannot be changed. As a result, only the sequence of work can be coordinated with the customer. It is also obvious that, from the customer's point of view, the most effective project plan is one with 80%

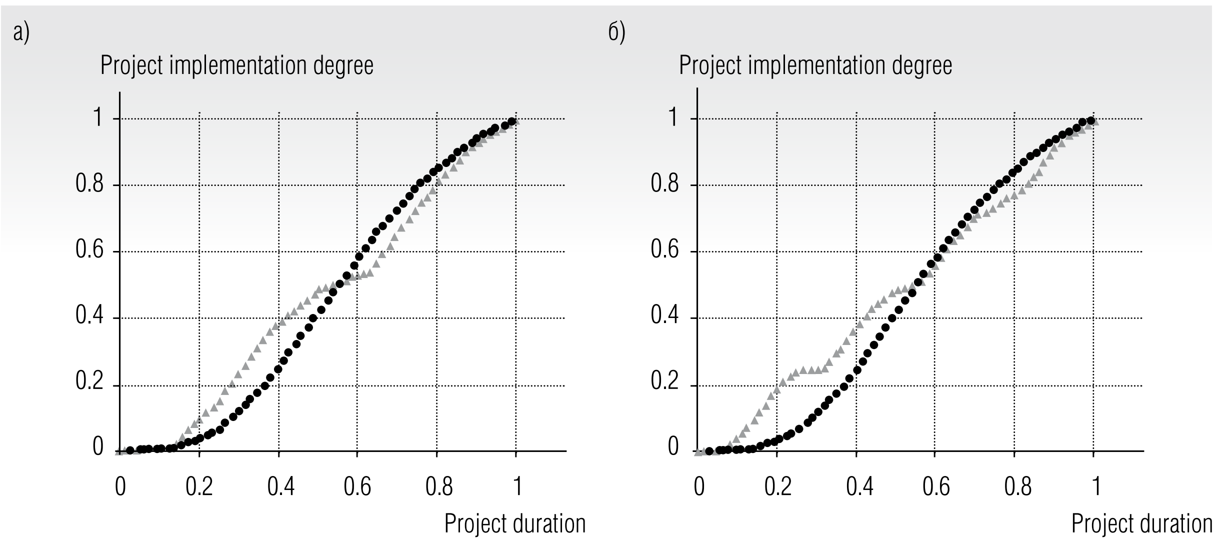

Fig. 3. Dynamics of the project completion degree, formally divided into two (a) and four (b) subprojects. The circles represent a theoretical model degree dynamics of the life cycle realization. Triangles represent the corresponding piecewise–linear models

of the result achieved as quickly as possible. Thus, the only effective strategy for rearranging work is to transfer the stages characterized by the largest value of the first-order derivative $dP/d\tau$ to the initial positions in the sequence of stages. Taking into account the ratio $a_3 > a_2 > a_4 > a_1$ between the model parameters (5) chosen as an example, the considered example of an effective rearrangement of the work sequence will take the following form:

$$P(\tau) \cong \begin{cases} a_3 \cdot \tau + c_1, \tau \in [0;\ \tau_1) \\ a_2 \cdot \tau + c_2, \tau \in [\tau_1;\ \tau_2) \\ a_4 \cdot \tau + c_3, \tau \in [\tau_2;\ \tau_3) \\ a_1 \cdot \tau + c_4, \tau \in [\tau_3;\ \tau_4] \end{cases}, \qquad (6)$$

where c_1, c_2, c_3, c_4 are found from the condition that gaps of the first kind are absent.

The iterative approach applied to the planning stage to the cascade model (5) provides the possibility to implement several project execution options. Obviously, considering the fact that the resources are fixed for the

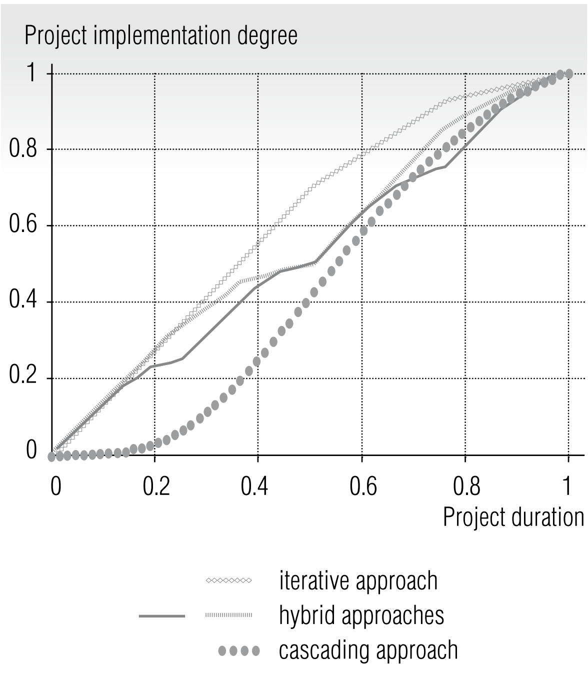

Fig. 4. Dynamics of the project implementation degrees at iterative, hybrid and cascading approaches to project planning and management

models, there are no piecewise-linear functions that provide faster achievement of the target indicator of 80% than the cascading line in *Figure 4*. To confirm this hypothesis, we will use the technique that was used to demonstrate the differences between the hybrid and cascade approaches. We break down the model project (6) into two/four subprojects, each of which implements an iterative approach. The corresponding dependences are presented in Figure 6. This shows that, from the customer's point of view, 80% efficiency of the project is achieved for 63% (using a purely iterative approach), 73% (splitting into two subprojects with epy rearrangement of the work sequence) and 79% (splitting into four subprojects with epy rearrangement of the work sequence) of the time designated to achieve the project aim.

Thus, the most effective strategy for achieving the project aim is to apply a purely iterative approach directly to the project, rather than to its individual stages highlighted during the use of the cascading planning paradigm.

Conclusion

Although purely model tasks have been considered and the iterative approach for the implementation of the conceptual cascade project cannot be fully applied in practice (as, for example, the initialization stage will probably be the last one), significant advantages and disadvantages of iterative, hybrid, and cascade approaches were demonstrated precisely with the help of mathematical models, rather than specific implementations of the corresponding projects.

If we ignore the tough requirements of standards, we would consider works on the content and to structure the project on the basis of "the principle of the greatest derivative." Then the more iterative approach is used, and the more effective it is perceived by the customer for the project implementation plan.

Finally, there are observations from real-life cases: a large number of successful projects (at least in IT [30]) are implemented according to the following scheme: "first do, then sign an agreement," which matches the model recommendations exactly (6), despite the apparent violation of the project execution process logic. ■

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