Quantitative analysis of the efficiency and productivity of the activity of human systems

Part 1: Graphical analysis of the nonlinear functional relationship between team productivity and team size[1]

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Abstract

The functional relationship between the number of people who implement a project of an arbitrary nature and the effectiveness or productivity of their activities remains one of the topics of important and ongoing discussions in the field of project management.

The study of this functional relationship by statistical methods faces great difficulties because of its extreme complexity and because of the unreliability of the statistical methods themselves.

Therefore, a more promising approach to investigating this problem is the principle-based top-down analytical approach to which this article is devoted.

The analytical approach to the problem is based on the method of equations of state for project work, but before the quantitative presentation of the results of research, it is important to have a qualitative graphical interpretation of the problem, which is what the first part of the article is devoted to.

Key words: State equations of projects, system level project parameters, productivity, team size, non-linear relationships, project failure

Introduction

One of the main criteria for the progress of human life and, in general, at the level of civilization are the productivity and efficiency of human systems of various scales, and

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productivity characterizes relatively simple human activities, while efficiency characterizes their more complex and large-scale activities.

For example, if the productivity of a simple and homogeneous production process can be adequately measured by the amount of output per unit of time, then the same measure cannot be used to measure the rationality and purposefulness of activities at the state level, since it does not objectively reflect the essence of such a complex system.

To do this, it is more expedient to use similar in meaning, but in essence a more complex and comprehensive characteristic, that is, efficiency, which in simple cases can be equated with productivity.

If we approach this problem from the point of view of the completeness of the quantitative description of systems, then in cases where one criterion is practically enough to describe the activities of people, it is convenient to use the criterion of productivity.

And in cases where the activities of people can be objectively and adequately described by more than one criterion, which differ from each other in the degree of their importance and, in addition, they have functional relationships with each other, then it becomes necessary to use characteristics such as efficiency.

Thus, if we consider the activities of a project team as an example of a relatively simple human system, then it can be characterized by its productivity with sufficient adequacy for practice, of course, taking into account the problems and difficulties in this area.

If the activities of the same development team are viewed as part of a larger system, that is, in the customer - vendor - market chain, then naturally, evaluating the results of such activities will need to deal with more general characteristics such as efficiency.

When evaluating the productivity of project teams, it is usually assumed that they have the necessary information, financial and organizational support and the problem of evaluations is associated with the complexity of the project and the risks of its failure, the size of the team, the duration of work and the productivity of people.

If the problem of project assessment is considered in this limited context, then in the current situation, even in this area, there are many unresolved issues related to the imperfection of the corresponding quantitative models, low reliability of statistical methods, unreasonable and arbitrary decisions based on them, etc. [1].

In particular, there are several reasons for the imperfection of estimation methods in this area, the most important of which is the insufficient level of study of objectively existing universal functional relationships of a fundamental nature between project parameters, which does not allow correctly interpreting project statistics and using them in practice.

This circumstance is also one of the main reasons for the high percentage of failures in the field of project work [2].

In this area, as the practically unchanged statistics of project failures over the past 20-30 years shows, it is not possible to radically change the situation with the help of tactical or local solutions.

In general, in order to make qualitative changes in the management of the activities of human systems, and in particular in the field of project work, methodological or paradigmatic changes are first of all necessary.

In this case, a paradigm shift means the gradual introduction of analytical thinking instead of statistical in this area, as was done in various areas of higher development, including physics, economics, biology, and so on.

In particular, the point is that the bottom-up statistical interpretation of project data should be replaced by a top-down interpretation of an analytical nature based on principles.

In general, this approach should gradually become dominant for the entire field of big data, where the entire set of statistical methods, now known as analytical, should be replaced by a truly analytical top-down methodology.

In the field of top-down development of analytical project management methods, it is very important to know the nonlinear functional relationships between the project parameter at a qualitative level in order to avoid internal contradictions in these relationships [3].

Many attempts to obtain such functional relationships statistically over the past 40-50 years have yielded conflicting fragmentary results that are not of great importance for practice.

One of the main goals of this work is to show that these nonlinear functional relationships are solutions of the state equations of projects, considering them with qualitative graphical means in the first part of this article and analytically in the second part of the article using simple mathematical models.

These problems are covered in detail using an analytical top-down approach in a number of works by the author, which, having a mathematical nature, are difficult to access for practical applications [1,3,4].

For this reason, this paper focuses on graphical analysis of nonlinear relationships between project parameters, focusing on the functional relationship between the productivity of the project team and the number of people in it.

The equation of state of the project team activity as a source of nonlinear functional relationships between project parameters

Let us consider the project activity of a group of N people, which in the period T must complete the project of the size W and the difficulty D with the productivity P, the equation of which will have the following form [4]

$$N * T * P = W * D \qquad (1)$$

This equation is a deterministic balance condition between the complexity $C = W * D$ of the project and the ability $N * T * P$ of people to overcome this complexity.

This equation contains many nonlinear functional relationships of a fundamental nature between the system parameters of the activities of project team, of which this paper will consider the relationship between the performance of team P and team size N.

Non-linear functional relationship between the performance of the project team P and the number of people N

This nonlinear functional relationship is due to two main trends, for the analysis of which we will consider the activities of a group of people pursuing a common goal, which on average has the following pattern.

The meaning of the first tendency associated with an increase in the number of people N in a working group is related with the fact that a team performing activities of complexity $C = W * D$, depending on the nature of the work, must have a certain amount of knowledge and skills.

Each team member has a certain amount of knowledge and skills that may or may not be enough to successfully complete the work.

Each newcomer to the group brings with him a new set of knowledge and skills not previously available in the team that fills in the gaps in this area.

In this sense, each new person increases the overall or resulting performance P of the project team.

But on the other hand, the more people N in the group, the less likely it is that a newcomer will bring new unique knowledge and skills with him.

Because of this, the dependence of the productivity of the project team P on the number of people N will have the form of a saturation function (Fig. 1).

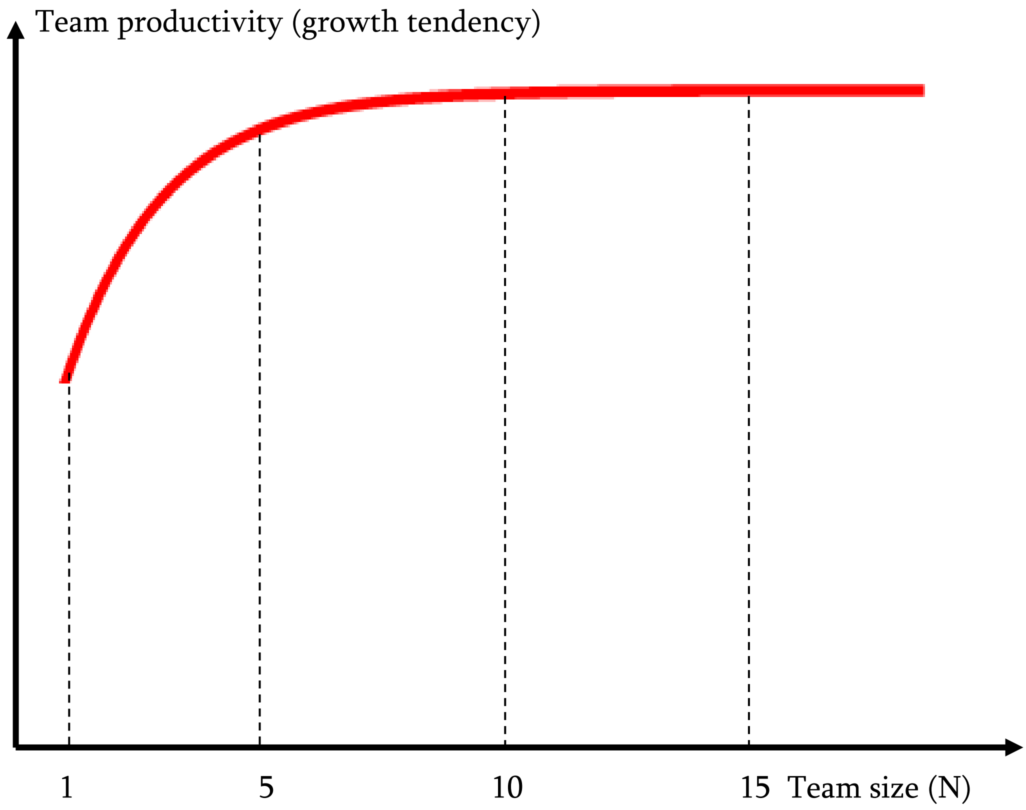

Fig. 1 Each new member of the development team with the necessary new knowledge and skills contributes to an increase in the productivity of the team, which has the appearance of saturation.

The second trend is that each new person joining the project team increases the time it takes to coordinate the activities of people and interpersonal contacts to discuss the progress of work, and in this sense reduces the overall productivity of the team (Fig.2).

Because of these two tendencies, the resulting dependence of the productivity of the project team P on the number of people N, in cases where a new member joins the team harmoniously, without contradictions and conflicts, on average, has the form of the AB curve shown in Fig. 3.

In this figure, point A is the average productivity of a one-man team.

The number of people at which the productivity of a team reaches its maximum value depends on the nature of the work performed, the characteristics of the people and usually ranges from 2 to 7.

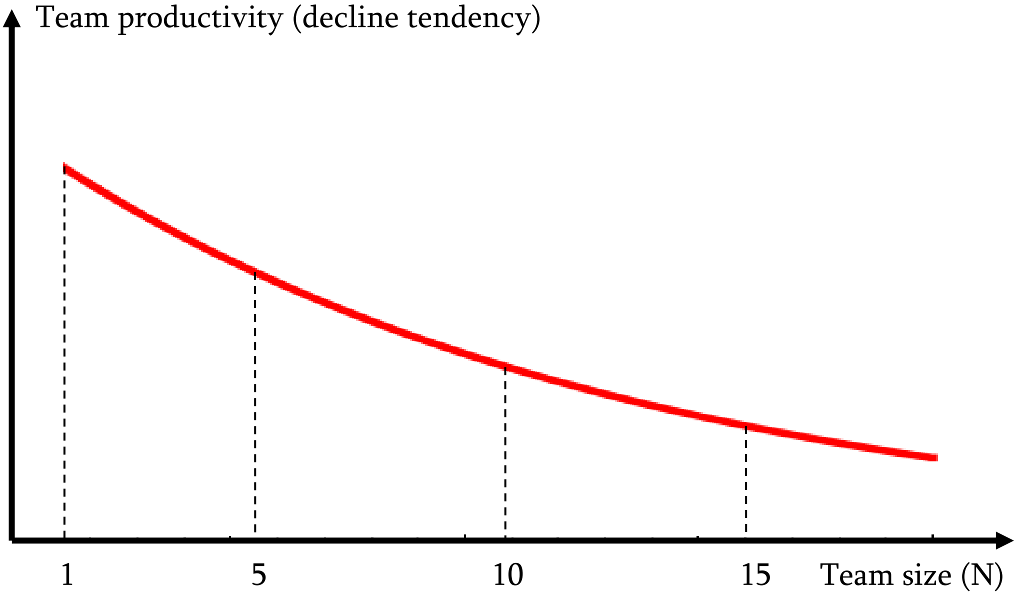

Fig. 2: As each new member of the development team is added, the time spent coordinating, communicating, discussing, and reviewing work increases, resulting in decreased team productivity.

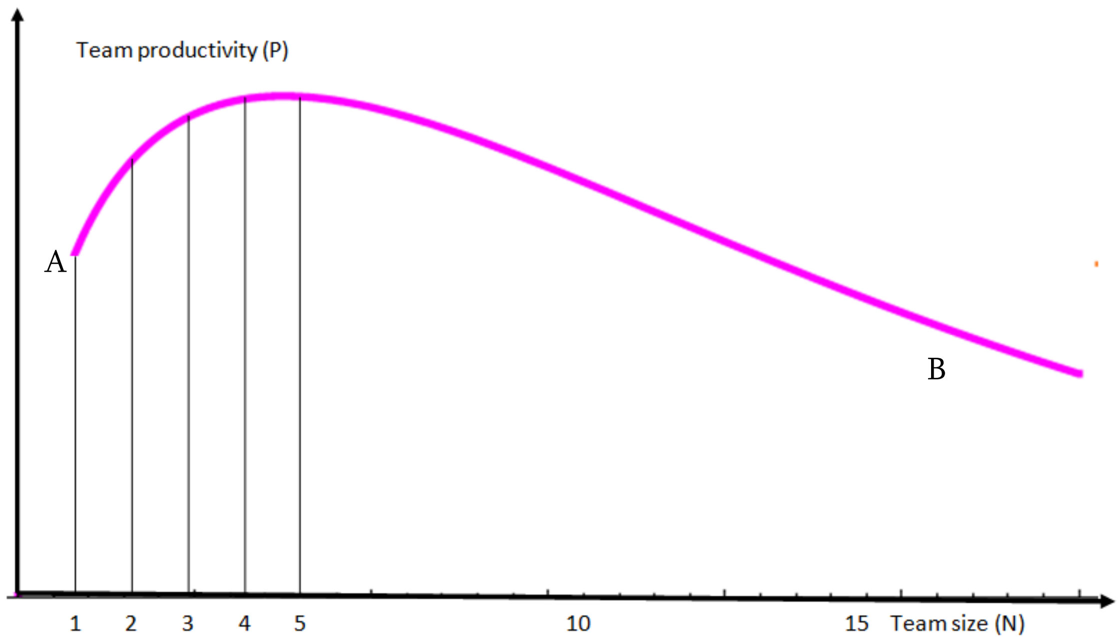

Fig. 3: With a good organization of the activities of project team, as a result of two trends in people's productivity, team productivity can have a maximum. Initially, the productivity of a team can increase by combining the experience, knowledge and skills of new people, but a further increase in their number leads to a decrease in productivity due to an increase in the time to coordinate work.

In addition, it is obvious that the clearer and simpler the nature of the work performed by the team, the larger the executing team can be, since in such cases the need for coordination of work and related discussions quickly decreases.

But in real life it is not always possible to have an ideal picture similar to that shown in Fig.3, because there is always a problem of human compatibility, interpersonal and intergroup tensions and conflicts, therefore the area of functional dependence $P(N)$ has a more diffuse nature and is located between two curves shown in Fig. 4.

Here, in addition to the AB curve, which represents an optimistic scenario for building a project team, there is also an AD curve, which represents a pessimistic scenario for building a development team.

Each point in the $P(N)$ functional field between these two AB and AD curves corresponds to one project.

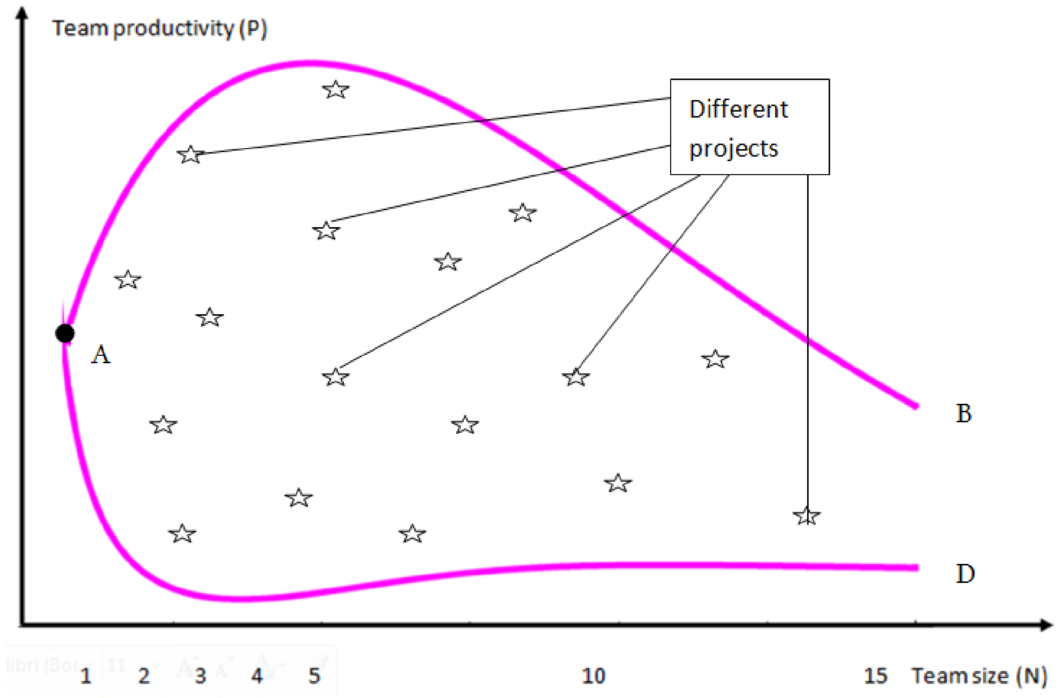

Fig. 4: General picture of the field of functional dependence $PvsN$

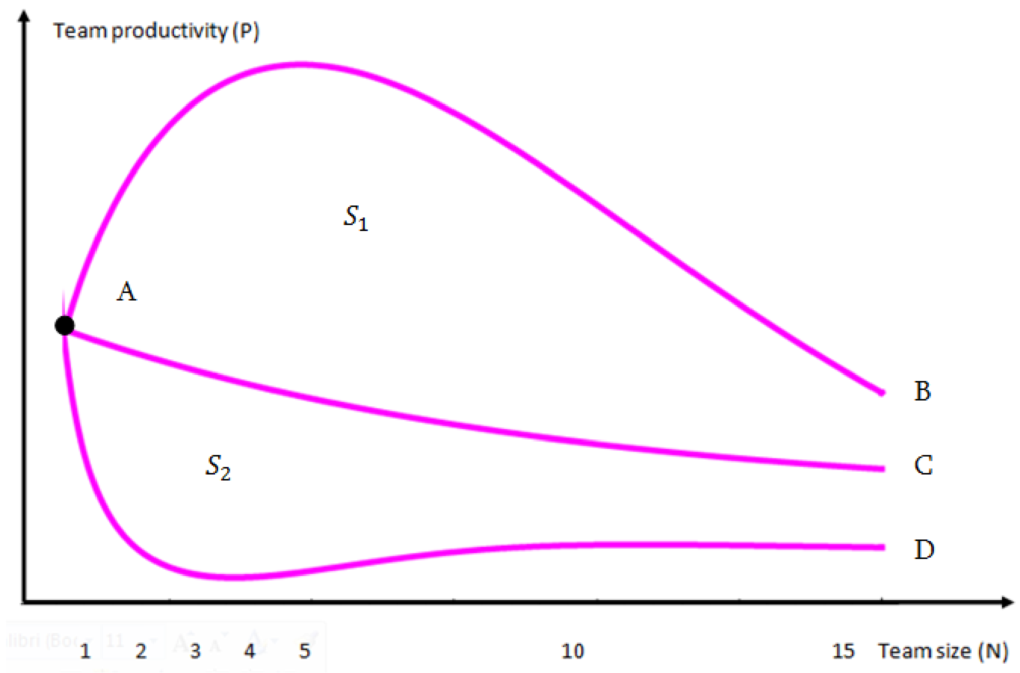

Fig. 5 The $P(N)$ functional dependence field is divided into two parts of curve AC. Above this curve are amplifier project teams that increase the average productivity of team members, and teams below the curve, on the contrary, reduce the productivity of team members due to their less favorable creative atmosphere.

The AD curve in this figure represents a mode of low human compatibility, when each new team member contributes to some extent to the advancement of the project work due to his experience, new knowledge and skills, but with less productivity, since he, in addition to increasing the time spent on internal contacts, also, somewhat incompatible with other team members.

In addition, the field of functional connection $P(N)$ shown in Fig. 4 also contains another characteristic AC curve shown in Fig. 5.

This curve divides the functional field $P(N)$ into two parts S_1 and S_2, which, respectively, describe the working atmosphere in project teams, which act either as an amplifier or as a attenuator for the productivities of team members.

Fig. 6 provides a more detailed discrete picture of project team building, where the average productivity of people increases or decreases as each new team member is added, depending on how compatible the newcomer is with other team members.

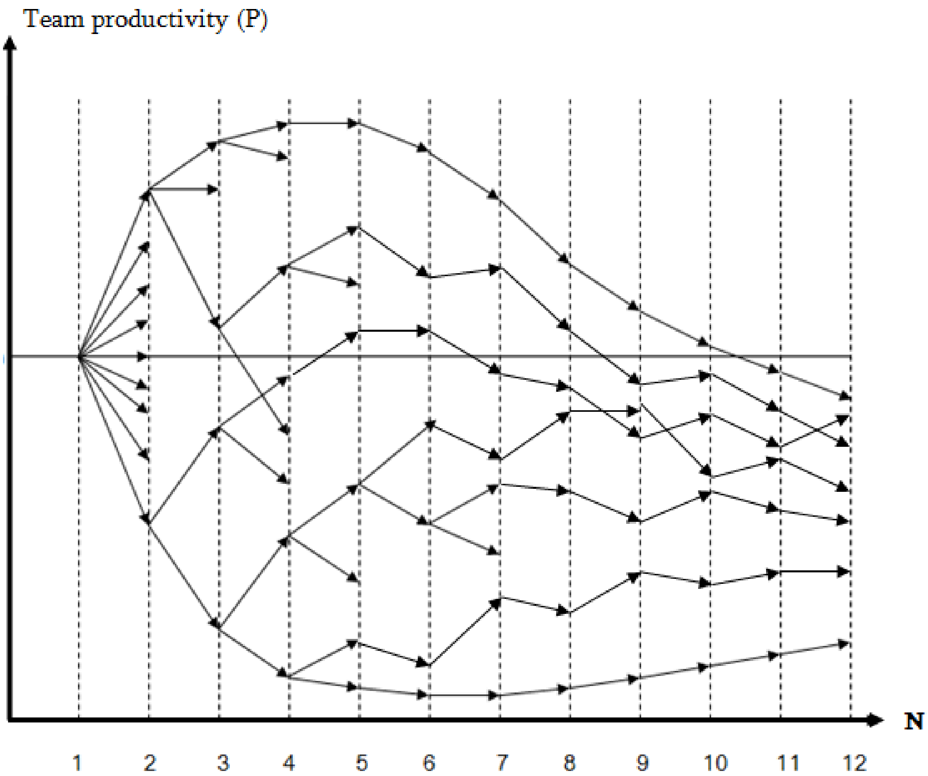

Figure: 6 Image of the change in average productivity of a development team member as new team members are added. As the team grows, a positive management effect is felt, as a result of which the variance in productivity decreases

In addition, Fig. 6 also allows us to identify another trend that accompanies an increase in the number of people on a project team and is associated with a decrease in the dispersion of their productivity.

The positive effect of management and a decrease in the spread of productivity of people as their number in the project team grows

If the role of management in small project teams is not so great, then as the team grows, it steadily grows due to the coordination of work, the correct organization of communication between people and their cooperation, regular checking of work results, prevention of potential internal conflicts, etc.

This is especially important when analyzing the failures of medium and large projects, in which it should be borne in mind that the management of these projects is, in fact, a small team within a large team and, therefore, has all the main characteristics and peculiarities of small teams, including a large variation in productivity.

In this regard, of great interest is the fact that in small project teams there is a large variation in productivity, which is presented in the form of maximum and minimum productivity between the values of N = 2-7.

Since in large projects, in fact, a small management team implements management-type subprojects as a small team, its management efficiency will vary widely.

This means that the wide variation in productivity of a small project management team can be one of the main reasons for such projects to fail.

In addition, since in large project teams the professional levels of people at lower levels of the hierarchy do not differ much due to the large number of people, the differences (for example, in the form of success or failure of the project) of the results of the work of these large teams can be explained mainly by differences in the qualities of small management teams or a wide range of their productivity.

Conclusions

Life experience and analysis of project works show that, although such activities are accompanied by many random events, they also contain stable tendencies that can form the basis of the mathematical description of project management.

Trends associated with the number of people in project teams and the productivity of their activities can be represented in the following sequence.

1. A targeted increase in the number of people in project teams leads to an increase in the total experience, knowledge and skills necessary for the implementation of the project, which contributes to an increase in the productivity of the team, the growth of which has the form of a saturation function (Fig. 1).

2. A further increase in the number of people after such saturation can be carried out only for the purpose of controlling the degree of parallelism in the execution of project work, in the sense of managing their duration.

3. The second trend is that each new person joining the project team increases the time spent on coordination of work and interpersonal communication and, in this sense, reduces the overall productivity of the team.

4. The next stable trend is that as the number of people increases, the role of individuals gradually decreases and is accompanied by an increase in the interchangeability of people, which reduces the risk of not completing work on time if the person leaves.

5. Another trend accompanying the increase in the number of people in project teams is associated with the dispersion of their productivity, which initially increases and reaches its peak in the range of 2-7 people per team.

6. A further increase in the number of workers in the project team leads to an improvement in the organization and coordination of work, which in turn leads to additional loss of time and, as a result, to a decrease in productivity, but at the same time putting the whole process in a more manageable framework, which leads to a decrease spread of productivity.

7. The further increase in the number of people leads to the emergence of hierarchy within the team, as a result of which the workflow becomes more manageable, which leads to relatively lower but stable productivity of people, which, in turn, will have less variation.

8. When analyzing successes and failures in large project teams, it should be borne in mind that management in large teams is an independent small team within a large team.

9. In fact, in large projects, a small management team implements a management subproject, which is essentially the same for all large and medium-sized projects, regardless of their field of application.

10. This means that management teams in the implementation of management subprojects have all the characteristics of small teams, including a wide variation in productivity, which can be one of the main reasons for the failure of large projects.

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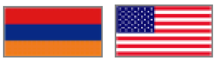

Dr. Pavel Barseghyan is a consultant in the field of quantitative project management, project data mining and organizational science. Has over 45 years' experience in academia, the electronics industry, the EDA industry and Project Management Research and tools development. During the period of 1999-2010 he was the Vice President of Research for Numetrics Management Systems. Prior to joining Numetrics, Dr. Barseghyan worked as an R&D manager at Infinite Technology Corp. in Texas. He was also a founder and the president of an EDA start-up company, DAN Technologies, Ltd. that focused on high-level chip design planning and RTL structural floor planning technologies. Before joining ITC, Dr. Barseghyan was head of the Electronic Design and CAD department at the State Engineering University of Armenia, focusing on development of the Theory of Massively Interconnected Systems and its applications to electronic design. During the period of 1975-1990, he was also a member of the University Educational Policy Commission for Electronic Design and CAD Direction in the Higher Education Ministry of the former USSR. Earlier in his career he was a senior researcher in Yerevan Research and Development Institute of Mathematical Machines (Armenia). He is an author of nine monographs and textbooks and more than 100 scientific articles in the area of quantitative project management, mathematical theory of human work, electronic design and EDA methodologies, and tools development. More than 10 Ph.D. degrees have been awarded under his supervision. Dr. Barseghyan holds an MS in Electrical Engineering (1967) and Ph.D. (1972) and Doctor of Technical Sciences (1990) in Computer Engineering from Yerevan Polytechnic Institute (Armenia).

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