# Equilibrium of Human Labor in the Light of Supply and Demand Model from Microeconomic Theory

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## Abstract

In order to develop modern quantitative methods of project management it is important to examine the balance and equilibrium of human labor which is established between the complexity of work and the professional capacities of its performers.

In this paper a number of equilibrium conditions of human labor are derived based on two quantitative definitions of total effort. These equilibrium conditions can be applied for the solution of many problems of project management.

By analogy with the models of supply and demand of microeconomic theory the concept of partial equilibrium of human labor is introduced and a qualitative analysis of its equilibrium proceeding from the considerations of the risk of not completing the work within the prescribed time is performed.

*Keywords: Equilibrium and balance of human labor, speed of work, supply and demand model, equation of equilibrium, quantitative project management*, *partial equilibrium, microeconomic theory.*

## Introduction

For the rational organization of human labor and in particular for project management purposes it is necessary to clarify the concept of equilibrium of the process of work and give it a clear quantitative interpretation.

Intuitively, when speaking of the balance or equilibrium of work on projects, people mean the successfulness of the work flow and related other similar interpretations. But as the project management practice and especially the serious challenges posed by the frequent failure of projects indicate, the traditional methods that are based on the intuition and experience of people are gradually forced, at least in part, to give way to quantitative methods.

Despite the fact that these quantitative methods are still imperfect, they play a positive role in the management of projects by presenting a more structured and detailed view of the problems under study, and thereby facilitating the increase of quality of the intuitive decisions of managers.

The shortcoming of existing quantitative methods in this field is that they are not able to adequately represent the phenomena and processes related to the management of the work of people. As a result, estimates and forecasts made on the basis of these quantitative methods have unsatisfactory accuracy for the practical purposes of project management.

That is why the existing methods of quantitative project management cannot be considered as self-sufficient, and therefore they have a secondary role for the dominant qualitative methods in the field of project management. This is one of the major challenges of modern project management. Addressing these challenges and the further progress in this area is connected with creation of the new generation of quantitative methods of project management.

It is already impossible to ignore the problem and pretend that everything is fine in the project management realm today. Even if we are not able to understand the completely and explain the general problem of mass failure of projects, we should be able to explain a comparatively narrower scale problem – causes of unacceptably low accuracy of the existing methods of project estimation.

It has long been time to recognize that the real cause of all the problems with inaccurate project estimations is the lack of adequate methods and theories of representation of phenomena and processes related to project and program management. At the same time we continue to make use of inaccurate statistical methods and mental models in the estimation of projects.

This state of affairs with the problems of quantitative project management can be considered as at least strange, which may only be explained in terms of short-term business goals.

It is not difficult to imagine the low level of quality and accuracy of the methods of the contemporary quantitative project management, if we exclude the corrective interventions of experts during the usage of the corresponding project management tools.

This applies to all current methodologies in project management, including earned value management, system dynamics and methods of risk analysis and estimation.

We have so many unexplored quantitative laws, relationships and unaccounted factors in this area that it is difficult to directly link some moderate success in project management with progress of quantitative methods in it [1].

Consequently the successful solution of the problems of project estimation and overcoming the crisis in this area is clearly linked to the development of basic quantitative techniques for a correct interpretation of existing project data and obtaining universal functional relationships between project parameters.

**What is the ideal quantitative project management?**

The main objective of the development of quantitative methods in any field of knowledge is to use the actual material in the specific area for the construction of adequate theories and methods. It can be done by combining the generalized analysis of data and the experience in the specific field. It is necessary to pay special attention to the fact that this is not about building methods based directly on the available data. Instead, this is about construction of quantitative methods, which are the result of generalization of data.

There is a huge difference between these two approaches because in the first case a quantitative method depends on the specific data and thus has very limited use. In the second case, the quantitative methods are not directly dependent on the specific data. Moreover, these methods are invariant with respect to specific data. For this reason, methods based on the generalization of facts are more versatile and therefore can be widely used.

Usually the development of quantitative fields of knowledge begins with the first approach, which is an empirical stage of development, and gradually moves to the second approach, the construction of more advanced quantitative methods.

In this sense, project management still largely is in the first stage of development. At the same time it makes limited attempts to create high-level quantitative methods to assess the second, more powerful theoretical approach.

The majority of the attempts to move to more advanced quantitative methods in project management should be approached with great caution in order to avoid confusion and to ensure a clear distinction between the above two approaches.

The point is that usually a straightforward approach to the process of generalization of knowledge leads to attempts to expand the circle of the issues. More specifically, in the field of project management this straightforward approach seeks to address all significant issues at the enterprise and market level. Of course, this is an important area of research, but at the present time to overcome the crisis in the area of quantitative project management there is a need for a theoretical and mathematical generalization of a very different nature. This is a generalization of the problem in depth, not breadth. This is a need for a generalization, which will be able to produce a breakthrough in solving the problems of project estimation and to increase its accuracy to at least the minimum requirements of the industry.

This means that we need to make a clear distinction between a superficial generalization of business nature and a generalization of scientific nature, the goal of which is to find accurate solutions for at least simple tasks of project estimation and change management.

In summary, in contrast to the existing piecemeal and fragmented quantitative project management solutions it is necessary to develop generalized quantitative methods that are able to treat each new problem or task as a special case.

This was the way of development of such highly developed quantitative sciences like physics, mathematical biology, mathematical economics, control theory and others.

And this is the way that the development of an ideal quantitative theory of project management must follow too.

**Problems of basic research in quantitative project management**

Intuition, experience, and common sense reasoning are widely used for decision making in project management. These decision making approaches are based on the belief that there are strong functional relationships between project parameters.

If such stable relationships between the parameters of the projects did not exist, the above mentioned considerations and decisions would be pointless.

The main purpose of a consistent quantitative theory of project management is obtaining these stable functional relationships that govern daily activities of experienced managers on the basis of a unified methodology and fundamental principles.

The fact that the parameters of projects, development teams and project environment could have a probabilistic nature does not change the statement of the main problem, because the marked functional relationships can have a probabilistic form too.

History of the highly developed quantitative sciences indicates that they are usually based on the principles of a general nature. Typically these principles are related to the laws of conservation, equilibrium and balance conditions and other basic ideas and concepts.

For the purposes of establishing conditions of successful implementation of projects, and in general in order to adequately represent the successful work of people it is important to quantify the problem of equilibrium and balance of their work and, in particular, the equilibrium of projects.

**The problem of equilibrium and balance of the process of human labor**

Quantitatively, this balance or equilibrium can be represented by the two definitions of total effort needed for the work [2]. In the simplest case, when the number of work performers has a constant value $N$ within a time interval $T$, the total effort can be defined as

$$E = NT \qquad (1)$$

The same total effort can be defined as the ratio of the complexity of work $W$ and productivity $P$ of work performers

$$E = \frac{W}{P} \tag{2}$$

By combining these two definitions of total effort we will obtain a very simple in appearance, but very complex in content the following equation, which is the condition of work equilibrium

$$NTP = W \tag{3}$$

In other words, in this condition, the right side of equality (3) is the required amount of work $W$, and the left side is the ability $NTP$ of work performers to overcome this complexity or amount of work $W$.

**Equilibrium of human work with a variable number of work performers**

The equilibrium condition considered above is valid for the static case, when the number of working people $N$ is constant and independent of time. Usually project works are dealing with the more general dynamic case, when the number of working people changes over time. In carrying out this type of work the dynamic work demand leads to the changes of the number of working people, thereby providing a dynamic equilibrium or balance in the project work.

With the dynamic changes of the number of working people the equilibrium condition discussed above can be considered as valid only for short time intervals $\Delta t$, when the number of people can be considered as a constant. Assuming that in the small time interval $\Delta t$ people are performing $\Delta W$ amount of work, the equilibrium condition will have the form

$$N * P = \frac{\Delta W}{\Delta t}, \tag{4}$$

which may be called a point or interval condition of the equilibrium of work.

During the execution of projects very often the number of working people has a constant value between the neighboring milestones. In such cases the equilibrium condition (3), obtained for the static mode is applicable for each phase. So a simple static equilibrium model of work can also be applied to analyze the more complex case of dynamic variability of the number of working people.

**The universal nature of the condition of equilibrium of human labor and its other interpretations**

Because of the absence of any restrictions during the derivation of the equilibrium condition, it has a universal character and can have wide practical applications including the work of one person, the work of the project team, the pipelining of projects, and many others.

In particular, the equilibrium condition of human work can have different interpretations. For example, in the case of a constant number of people it can be in the form

$$N*P=\frac{W}{T}. \quad (5)$$

This condition can be interpreted as a balance or equilibrium between the required throughput $\frac{W}{T}$ and the resulting productivity of the development team or simply the power of the team $N*P$.

In a more detailed analysis the complexity of work $W$ can be represented as a product of the size of work $S$ and work difficulty $D$.

$$W=SD \quad (6)$$

Taking into account (6) expression (5) will have the form

$$\frac{N*P}{D}=\frac{S}{T} \quad (7)$$

It will be a condition of equilibrium on the one hand between the number of working people $N$, team productivity $P$, and the difficulty of work $D$, and on the other hand, with the size of work $S$ and the planned duration of work $T$.

If we consider that the ratio $\frac{S}{T}$ is the average speed of work $V_S$, the equilibrium condition (7) takes the form

$$V_S=\frac{N*P}{D} \quad (8)$$

Similar to the equilibrium condition (4) can be obtained another form of this condition for a small time interval $\Delta t$ and corresponding small size of work $\Delta S$.

$$\frac{N*P}{D}=\frac{\Delta S}{\Delta t} \quad (9)$$

Here the ratio $\frac{\Delta S}{\Delta t}$ is the point or interval speed $V_S(t)$ of the implementation of work

$$V_S(t)=\frac{N(t)P(t)}{D(t)} \quad (10)$$

This expression simply means that the speed of work $V_S(t)$ as a function of time is directly proportional to the number of working people $N(t)$ and team productivity $P(t)$, and inversely proportional to the difficulty of work $D(t)$.

**Analogy with the partial equilibrium from microeconomic theory: Risk related supply and demand equilibrium in human labor organization**

To clarify the meaning of equilibrium in human labor organization let's make some analogies with the partial equilibrium of microeconomic theory [3, 4], the purpose of which is the use of models such as supply and demand in quantitative project management.

Different interpretations of the equilibrium in human labor organization show that it is possible to make analogies between demand and complexity related parameters of work and between supply and productivity related parameters of work.

Following the logic of the basic laws of supply and demand, let's consider the equilibrium and non-equilibrium states between the complexity of the work and the number of work performers.
Clearly, if the same work will be done by more people, then it would reduce the risk of not completion of work within the time stipulated by the plan (or increase the probability of completion of the work during the same time).

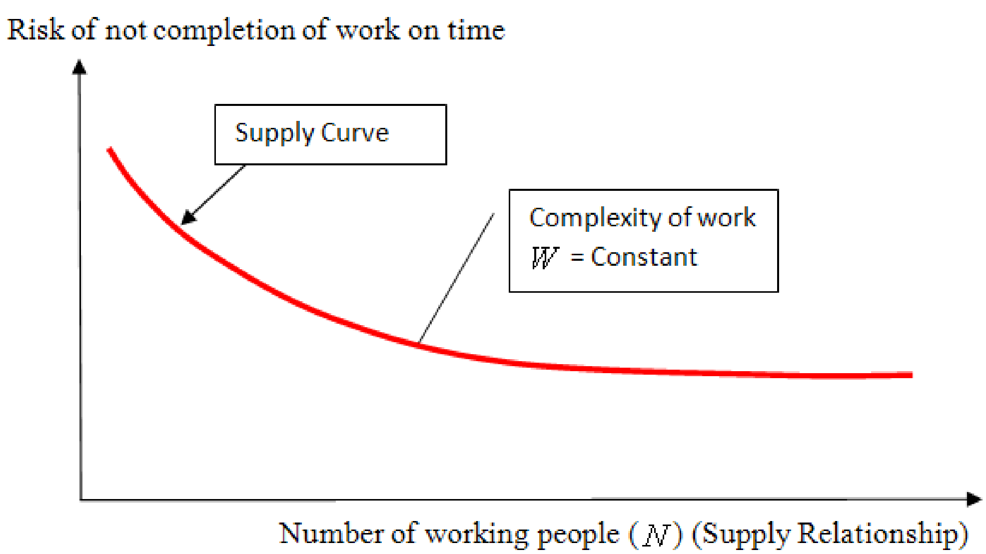


Fig.1 For a fixed complexity of work the increase in the number of working people reduces the risk of non-completion of work within the planned time or increases the likelihood of completion of the work within the same time.

It is also clear that with a constant value of work complexity the increase in the number of work performers will increase the risk of non-completion of work within the planned time. The qualitative picture that combines these two cases is shown in Fig.1.

If we keep the same number of working people and change the complexity of the work, we get a different pattern. So, if we increase the complexity of the work, while leaving unchanged the number of working people, it will lead to an increased risk of non-completion of work within the planned time.

Conversely, reducing the complexity of the work with a constant number of work performers will reduce the risk of non-completion of work within the planned time.

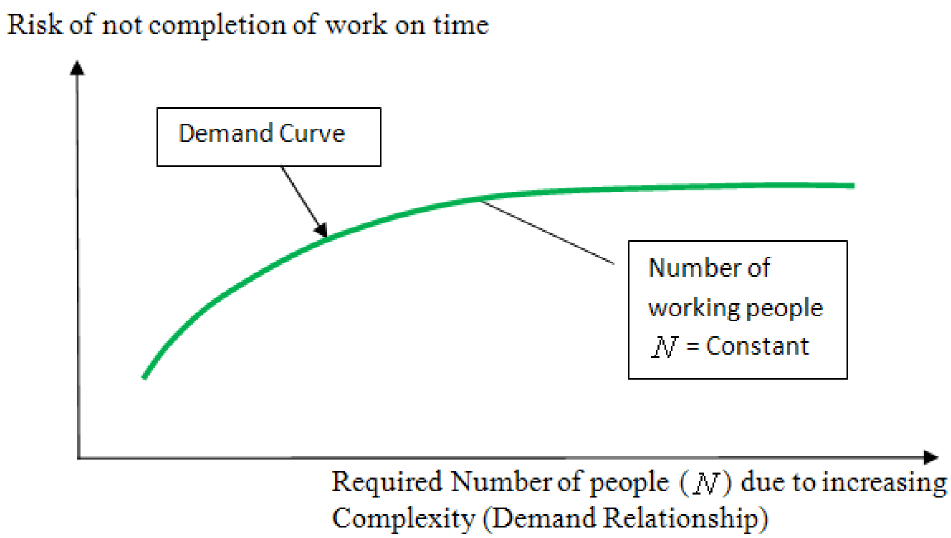


Fig.2 For a fixed number of the work performers the growing complexity of work (which is equivalent to the growing needed number of the work performers) leads to increased risk of non-completion of work within the planned time.

The qualitative picture of the latter two cases is shown in Fig.2, where the horizontal axis is the required number of people to complete the work. This takes into account the fact that in parallel with the increase of the complexity of work the required number of people increases too.

Since in both discussed cases the horizontal axis has the meaning of the number of people, we can combine the two corresponding pictures (Fig.1 and Fig.2) and get a new qualitative picture, which is presented in Fig.3.

This graph represents a qualitative picture of the balance or equilibrium between the complexity of the work (as a demand) and the number of working people (as a supply) with respect to risk of non-completion of work on time. At the point of equilibrium the number of working people and the required their number are equal.

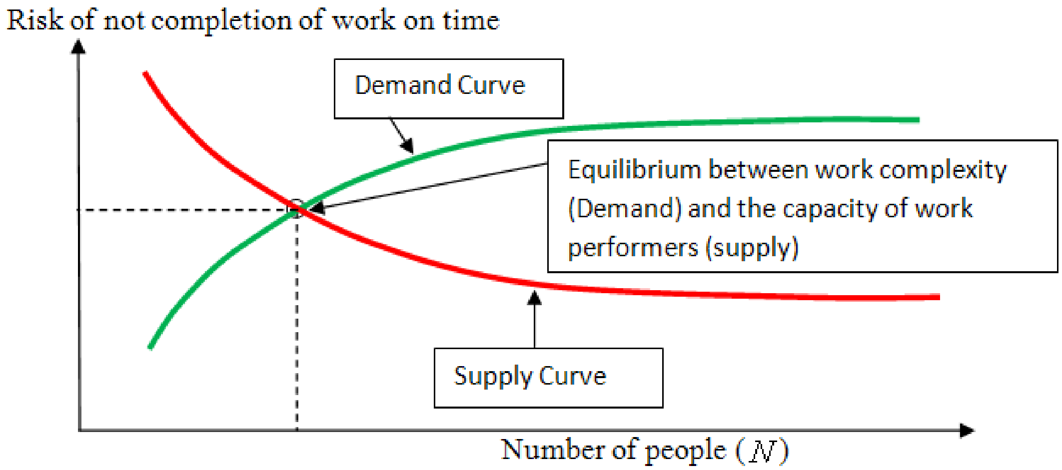


Fig.3 Demand and Supply Curves of human work with the number of people and equilibrium risk

### Directions of future research

Using standard approaches developed in microeconomic theory [3,5] one can explore the qualitative effects of the imbalance or deviation from equilibrium on the risks associated with the work process, the influence of different type of changes on the equilibrium of work, and so on.
One can also carry out a similar analysis with quantitative methods, which requires the use of balance equations and relationships obtained above.

Besides the further research in the field of quantitative project management must take into account the achievements of mathematical economics, in particular, in the analysis of partial and general equilibrium of systems.

For the purposes of further research in this area it is necessary to take into account that mathematical economics and classical thermodynamics are the sciences, which may serve as a guide for the development of quantitative methods of fundamental nature in organization science, and, in particular, in the field of project and program management.

### Conclusions

1. Quantitative models of the balance of human work provide a new approach to many estimation problems of project management.

2. In particular, with the aid of quantitative equilibrium conditions of work one can explore the balance between the different parameters of the project and thus ensure the sustainability of their implementation.

3. In this sense, at all stages of the project implementation it is especially important to ensure the balance between complexity, cost and planned time of works. It is also true for finding equilibrium between over cost, over time and underperformance of not completed projects.

4. Use of rich approaches and methods of microeconomic theory in the field of human labor research will more clearly present the meaning of the equilibrium of project works and its different interpretations.
5. Precise quantification of the equilibrium state of human work will create good preconditions for the study of different deviations from that state of work.

6. This, in turn, will improve project estimates related to earned value evaluations, different types of diagnostics and risk estimates.

## Appendix

Dimensionality analysis for the equilibrium condition of projects (7)

For the two definitions of total effort we can have the following dimensionality forms

$$E(Effort) = N(Person)T(Week)$$

and $E(Effort) = \dfrac{S(Element) * D(\dfrac{ComplexityUnits}{Element})}{P(\dfrac{ComplexityUnits}{PersonWeek})}$

With the aid of these forms dimensionality analysis of the expression (7) will give

$$\frac{N_{av}(Person)T(Week)}{D(\dfrac{ComplexityUnits}{Element})} = \frac{S(Element)}{P(\dfrac{ComplexityUnits}{PersonWeek})}.$$

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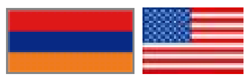

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