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# USING TREND MODELLING TO SUPPORT PROJECT SCHEDULING, MANAGEMENT, AND PREDICTION

***Abstract.*** *Project management is implemented as a finite sequence of diverse decisions. Every decision-making is based on information. The broad spectrum of information contains various types of data. Data having an exact representation, e.g. phenomena described by equations. Data that cannot have such a representation, e.g. experience, intuition, feelings. Such trend modelling allows us to work with this type of data. The article deals with the use of trend modelling as a support for project management and prediction under uncertainty. The solution of a trend model is a set of scenarios. These scenarios represent possible project states. A multi-criteria trend decision process allows one to identify the optimal project state(s). Based on the set of scenarios, a transition graph can be created, which can be used to determine all possible paths to get to this optimal state. The application of trend modelling is shown in a model of a project based on a six-pointed star.*

***Keywords****: Project management, project management six constraints, project prediction, trend modelling, transition graph, trend optimisation*

**JEL Classification: C63, M10**

## 1. Introduction

Project success criteria are currently usually defined in project practice using the so-called iron triangle of project management. These are three variables, respectively, constraints (scope, time, cost) that must be managed primarily in each project (Schwalbe, 2015).

The validity of the iron triangle of project management in its traditional triple constraints of scope, time, and cost has been discussed both in academia and in project practice (Ebbesen and Hope, 2013). Some authors, such as (Chan, Scott, and Lam, 2002) use the term schedule instead of time. Other authors such as (Turner et al. 2010) use the term quality instead of scope. At the same time, they are considering a definition of quality. Does quality mean a measure of project



DOI: 10.24818/18423264/57.4.23.05

specification or measure functionality? They state that only different stakeholders can define what quality really means in the context of a particular project.

In the context of the iron triangle of project management, Chan, Scott and Lam (2002) categorise project success into three approaches. The first approach is based on the principle that a project is successful if it generally meets the customer's (client's) goals. The traditional measure of this approach is the so-called iron triangle of project management (time, cost, quality). The second approach, the so-called global approach, is based on the assumption that the success of a project is, in fact, much wider than the iron triangle project management, i.e., that the success of a project depends on other than only three limitations of the project. The third approach is based on the assumption that the success of the project is beyond the scope of the project. These are also factors beyond the iron triangle of project management and include issues such as customer satisfaction, business success, health and security, technical performance and sustainability (Chan, Scott, and Lam 2002).

The above was one of the reasons for introducing additional constrains into the traditional iron triangle project management model. Haughey (2021) describes the so-called "The diamond of project management", in which quality is perceived as a separate variable (constraint) that cannot be ignored and should be given equal importance in addition to scope, time and cost.

Despite the extension of the iron triangle to a quadrangle, some experts, as well as professional organisations such as the Project Management Institute, still do not consider this model detailed enough to capture all key project variables and recommend the use of a "Six-pointed star". Here, the traditional variables scope, time, cost were supplemented by the variables quality, risk, resource (see Figure 1). (Project Management Institute 2017)

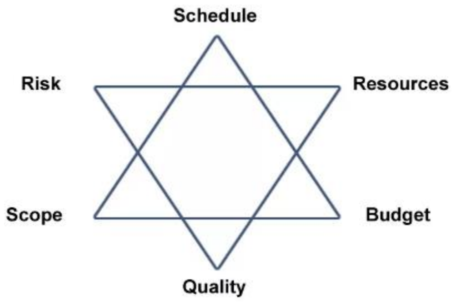


**Figure 1. The Project Management Six Constraints**
**(The Six-Pointed Star of Project Management)**

A key principle of the project iron triangle concept is the fact that all three variables are interdependent (Volner 2016). If the goal changes, the time and cost will also change. Thus, for example, with more money it is possible to increase the scope of the project or the same scope in a shorter time. Alternatively, the increase of scope increases the amount of time required, which also increases costs. On the contrary, shortening the time could lead to a reduction in quality and a consequent increase in costs, etc. This interdependence also applies in the extended model with six variables.

In any type of prediction, thus even in project success prediction, the very essence of the term prediction needs to be remembered. A prediction (Latin from prae – "before" and dicere – "to say") means a prediction or a forecast, a statement about the way things will happen in the future (Kazemzadeh, 2010). A prediction is usually used for estimates based on hypotheses or theories compared to the terms fortune telling or guessing, see (Korotkov and Wu, 2021). A prediction always involves a certain level of uncertainty, which is directly related to the forecasting time interval (so-called cone of uncertainty) (Zhu, Bard, and Yu, 2007). Generally, the longer the forecasting interval, the higher the degree of uncertainty. It is one of the essential pieces of knowledge that needs to consider in project success prediction. System approach and system thinking are other pieces of knowledge that need to be accounted in project scheduling and prediction. (Gerhards, 2020)

If project success prediction is to be successful, it must be based on thorough analyses of facts from the previous project progress, exact evaluation of the facts of the current project status, and the real impact of possible future project progress. Compared to well-structured projects (e.g., projects in construction, engineering) when well-structured methods of project status evaluation can be applied, there are also poorly structured projects (e.g., sustainability projects), in which soft methods are usually used for project status evaluation, see (Hans et al., 2007).

The above implies that two approaches to prediction may be implemented – quantitative (based on numerical evaluation of an objectively measurable indicator – project costs, time) and qualitative (based on a future trend estimate in terms of objectively measurable indicators, such as time and costs). (Verbeeck et al., 2017)

In practical project management, the qualitative approach to project prediction can be more valuable than the "exact" numerical expression with a high degree of error.

Qualitative or quantitative approach to project scheduling and prediction does not mean that the above principles should be underestimated. To the contrary, quality project scheduling and/or prediction can only be achieved by combining the exact methods or models (e.g., statistical analysis and probability models, fuzzy models, simulation models) (Watermeyer and Zimmermann, 2020) and soft methods (brainstorming, the Delphi method, formulating scenarios, trees of events) (Stock et al., 2021).

However, sufficient input data may not be available at the start of the project, which makes it difficult to apply the above methods and models. In such cases, it is useful to have an approach that still allows the formulation of the relevant model and its solution. This approach is described in the following.

The analysis of the dependencies between the variables of project management six-pointed star is the starting point for project prediction. The application of trend modelling for the analysis of the dependence of project management six-pointed star is the main goal of the article.

## 2. Material and Methods

All forms of human behaviour involve the implementation of decisions. Any decision-making requires information; let us continue to call it knowledge. The spectrum of knowledge contains data of a diverse nature. There are two main types of knowledge.

First, they are explicit knowledge having an exact representation, e.g. the laws of physics, numerically expressed characteristics, precisely defined concepts, phenomena precisely described by equations, data obtained by experimental measurements, statistical analyses, data based on inaccurately described phenomena, data burdened by the element of uncertainty, randomness, or ambiguity. These data provide accurate/certain knowledge. (Nonaka, 2008)

Second, they are tacit knowledge that for various reasons do not or cannot have such representation. They are of various types. For example, heuristics (data obtained from experience), engineering intuition, expert knowledge, etc. These data bring inaccurate/uncertain knowledge. (Wethyavivorn and Teerajetgul, 2020)

The description of every real phenomenon contains a vague knowledge of the phenomenon. (Xue and Deng, 2021) In this sense, it refers to the vagueness as an objectively existing phenomenon. Uncertainty is a phenomenon whose character is based on elements of inaccuracy, vagueness, and randomness. All forms of human behaviour consist in the implementation of various decisions, taking into account uncertainty. (Zellner et al., 2021)

Due to the nature of uncertainty, every decision is then weighed down by the risk aspect. Being able to correctly use vague data opens up the possibility of applications in key spheres, e.g. project management, management of businesses and institutions, implementation of modern information systems, etc. (Wu et al. 2019).

The idea is accepted that the best results can be achieved in applications by a combined heuristic approach using uncertainty handling methods and methods of an exact (classical) nature. In the next section, we look in more detail at the principles of trend modelling.

### *2.1. Trend modelling*

The terminology of trend modelling is based on the concept of quantitative modelling, in which certain knowledge is used. These are described in a precisely defined form, either by mathematical expressions containing variables of an exactly mathematical nature (e.g., equations, expressions with precisely defined values) or by data of a statistical nature obtained by approximate methods (Wang et al., 2018). The first type of knowledge is referred to as explicit, the second one as tacit.

Tacit knowledge is acquired through non-numerical heuristics, qualitative interpretation of experiments, engineering intuition, etc., all included under common-sense reasoning methods. Experts involved in modelling real-life phenomena generally use common-sense methods at the beginning, i.e., gather qualitative knowledge (Yang and Kang, 2020). Only in the next stage do they add quantitative knowledge to the model. It has proved necessary to have an effective "calculus" to deal with this knowledge. Trend analysis is such a calculus.

The process of creating trend models using trend analysis is called trend modelling. In a trend analysis, four values are considered – positive with the denote (+), negative with the denote (−), zero with the denote (0) and irrelevant with the denote (*), see (Dohnal and Doubravsky, 2015). For these values, two operations are defined – the sum with the denote + and the product with the Table 1 and Table 2. (Dohnal and Doubravsky, 2015)

**Table 1. Sum**

| + | (+) | (0) | (−) |
|---|---|---|---|
| (+) | (+) | (+) | (*) |
| (0) | (+) | (0) | (−) |
| (−) | (*) | (−) | (−) |

**Table 2. Product**

| • | (+) | (0) | (−) |
|---|---|---|---|
| (+) | (+) | (0) | (−) |
| (0) | (0) | (0) | (0) |
| (−) | (−) | (0) | (+) |

If this is obvious from the context, bracketing is omitted for the values.

When creating a trend model, each quantitative knowledge is transformed by a process called degradation to trend. For example, quantitative knowledge in form

$$F_{\text{quantitative}}(x_1, \ldots, x_n, c_1, \ldots, c_n) = 0, \qquad (1)$$

where $x_1, \ldots, x_n$ are variables, $c_1, \ldots, c_n$ are constants, with "incorporation" of constants into new (qualitative) variables degrades to knowledge of trend form

$$F_{\text{trend}}(X_1, \ldots, X_n) = 0. \qquad (2)$$

Creating a trend model is always connected with solving a specific decision-making task. Project management decision-making tasks are all about resource optimisation, in other words, maximisation or minimisation.

Decision making (especially in project management) is always multi-criteria in real terms. Criteria are given by a certain set of objective functions. Objective functions $F_1, \ldots, F_r$ can be expressed as a vector

$$(F_1(x), \ldots, F_r(x)), \qquad (3)$$

where x represents a vector of functions, $x = (x_1(t), \ldots, x_n(t))$. The variable $t$ represents time. Maximisation or minimisation is performed for each objective function. Each of the functions $x = x(t)$ describes the behaviour (trajectory) of the variable $x$. The dynamics of the behaviour of the variable $x$ are determined by its derivatives. The dynamics of the behaviour of the qualitative variable $X$ are given by the triplet

$$(X, DX, DDX) \qquad (4)$$

where $DX$ is the first qualitative time derivative of $X$ and $DDX$ is the second qualitative time derivative of the variable $X$. Higher derivatives may be considered, but their practical use is negligible.

In application tasks, we often have qualitative knowledge directly at our disposal, along with interpretations that capture the character of the behaviour. On the other hand, it happens that the sign of the second derivative is difficult to determine, and, as a result, it is ignored in the initial phase. Objective functions can already have a qualitative character in themselves; for example, for maximisation, an increasing trend is expected, for minimisation, a decreasing trend.

To describe a more complex type of behaviour of variables, especially relationships in their behaviour, pairwise relations that are of the shape of

$$P(X, Y). \quad (5)$$

The pairwise relations (5) represents that there is a certain (causal) functional dependence between *X* and *Y*. For example, if tasks complexities are increasing, then results accuracies are decreasing. Functional dependencies are based on the usual nature of economic patterns. For example, larger *X* values correspond to larger *Y* values, or alternatively, smaller *X* values correspond to smaller *Y* values. As a result, the phrase "if *X* increases, then *Y* increases" will imply "if *X* decreases, then *Y* decreases" and vice versa.

The above definition of a relation is a relationship between two variables – in this sense in relation terminology it is a binary relation. However, practice shows that binary relations are sufficient to produce trend models. Typical examples of pairwise/binary relations are given in Figure 2.

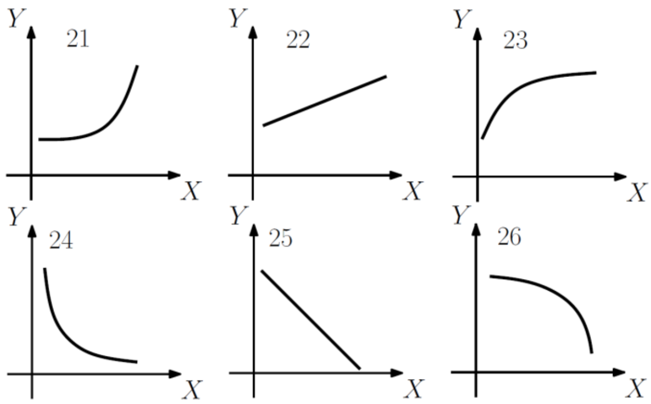


**Figure 2. Pairwise relations**

For example, relation No. 21 indicates that

- The relation is increasing, the first derivative d*Y* / d*X* is positive.
- The graph is convex, the second derivative $d^2Y / dX^2$ is positive (the speed of growth is increasing).

Numbers 21, 22, 23, 24, 25 and 26 are just marks of the pairwise trend relations for the first quadrant of a coordinate system (Dohnal and Doubravsky, 2015).

If we are not able to decide between the concrete of trend shape of relations (the second derivative is unknown), see Figure 2, two simple trend relations SUPport and REDuce are also used in this paper. The definitions are trivial:

SUP: if $X$ is going up (down) then $Y$ is going up (down) as well;
RED: if $X$ is going down (up) then $Y$ is going up (down) as well. (6)

As seen in Figure 2, the relations 21, 22, and 23 are the relations with a supporting effect, the relations 24, 25, and 26 are the relations with a reducing effect.

Creating a trend model is itself a combinatorial problem that requires enough creativity and the ability to capture the character of a real phenomenon. After its creation, a set of scenarios (also a solution) is found.

An $n$-dimensional trend model, studied in this paper, is represented by $w$ pairwise relations P (5). Each pairwise relations P represents a statement.

$$\mathrm{M} = (\mathrm{P}_1(X_{i1}, X_{j1}), \mathrm{P}_2(X_{i2}, X_{j2}), \ldots, \mathrm{P}_w(X_{iw}, X_{jw})) \tag{7}$$

When the model (7) is solved, the set of n-dimensional scenarios is obtained S($n$, $m$). There are m scenarios:

$$\mathrm{S}(n, m) = \{((X_1, \mathrm{D}X_1, \mathrm{DD}X_1), (X_2, \mathrm{D}X_2, \mathrm{DD}X_2), \ldots, (X_n, \mathrm{D}X_n, \mathrm{DD}X_n))_j\} \tag{8}$$

where $j = 1, 2, \ldots, m$.

Let the model M be described by the equation

$$X_1 + X_2 = X_3. \tag{9}$$

Then, for example, for the triplet

$$((X_1, \mathrm{D}X_1, \mathrm{DD}X_1), (X_2, \mathrm{D}X_2, \mathrm{DD}X_2), (X_3, \mathrm{D}X_3, \mathrm{DD}X_3)) = \\ = ((+\ +\ 0), (+\ 0\ +), (+\ +\ +)) \tag{10}$$

we conclude that it is the solution/scenario of the model M with the respect to Table 1.

After all scenarios for M are found, these are tested with respect to the specified conditions for minimisation or maximisation. This process is called polling (screening); it means the elimination of those scenarios that are in complete contradiction (contradiction) with the requirements of minimisation or maximisation trends. After screening, the scenarios are evaluated, and a decision is made.

For example, there are variables $X$, $Y$ and an objective function $F$ (dependents on $X$, $Y$) to be maximised. Assume that the qualitative model has the following three scenarios; see Table 3.

**Table 3. Maximisation of an objective function *F***

| | *X* | *Y* | *F* |
|---|---|---|---|
| 1 | + + − | + + + | + − − |
| 2 | + − − | + − 0 | + − + |
| 3 | + + − | + − − | + + + |

It appears that scenarios 1 and 2 are eliminated after the query as the purpose function declines. Scenario 3 can be considered optimal as the purpose function grows for it and in addition its growth rate increases.

### *2.2. Transition graph*

From the set of scenarios S, transitions between individual scenarios can be generated, resulting in a transition graph. A transitional graph H is an oriented graph.

$$H = (S, T). \tag{11}$$

Its nodes are the set of scenarios S (8) and

$$T \subseteq (S \times S) \tag{12}$$

is the set of the ordered transitions.

For example, a simple common-sense analysis of a harmonic oscillator indicates that a spring, which is moving downwards, must stop first and then it can move upwards. It means that just some transitions between two scenarios $S_i$ and $S_j$ are possible, and some transitions are not possible.

The possible transitions between scenarios are shown in Table 4. Then the transformations listed in the transformation table (Table 4) are based on basic properties of elementary functions of mathematical analysis, such as polynomial functions, rational functions, exponential functions, etc. (Dohnal and Doubravsky, 2015)

For example, an increasing function cannot change to a decreasing function without crossing a maximum. Therefore, the direct transition between the triplet (+ + −) to the triplet (+ − −) is not possible. On the other hand, a convex function cannot change to a concave function without crossing an inflection point. Therefore, the direct transition between the triplet (+ + +) to the triplet (+ + −) is not possible.

**Table 4. Table of transitions**

| | From | To | Or | Or | | From | To | Or | Or |
|---|---|---|---|---|---|---|---|---|---|
| 1 | + + + | + + 0 | | | 6 | + 0 − | + − − | | |
| 2 | + + 0 | + + + | + + − | | 7 | + − + | + − 0 | + 0 + | + 0 0 |
| 3 | + + − | + + 0 | + 0 − | + 0 0 | 8 | + − 0 | + − + | + − − | |
| 4 | + 0 + | + + + | | | 9 | + − − | + − 0 | | |
| 5 | + 0 0 | + + + | + − − | | | | | | |

Table 4 is not a dogma and can be modified according to the nature of the solved problem. Any path of the transition graph H is a trend description of a forecast or history. This means that the transition graph represents all possible future or past behaviours of the trend model M. Therefore, any forecast is identical to a choice of a path through the transition graph.

### 3. Results and Discussion

The case study deals with the task of predicting the state of a project. Project description is based on six variables; see Table 5, and the choice of variables is based. (Project Management Institute, 2017).

**Table 5. Project Management Six Constraints (Variables)**

| | |
|---|---|
| Time (Project time duration) | $X_1$ |
| Cost (Total project cost) | $X_2$ |
| Scope (Project outcomes) | $X_3$ |
| Resources (Total project resources) | $X_4$ |
| Risk (Risk appetite) | $X_5$ |
| Quality (Project declaration) | $X_6$ |

The project can be seen as a model and its solution as possible states of the project. The model description is expressed using the simple trend relations SUP, RED (6). These relations where the rate of change is not known. Using the common-sense method, a trend model $M_1$ was built containing 5 trend relations between six variables $X_1$, …, $X_6$, see Table 6.

**Table 6. Trend model $M_1$**

| | | | |
|---|---|---|---|
| 1 | RED | $X_4$ | $X_5$ |
| 2 | SUP | $X_4$ | $X_6$ |
| 3 | RED | $X_1$ | $X_2$ |
| 4 | SUP | $X_1$ | $X_3$ |
| 5 | SUP | $X_4$ | $X_2$ |

The solution of the model $M_1$ found 9 scenarios $S_1$, …, $S_9$, see Table 7.

**Table 7. Solution of the model $M_1$**

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|
| $S_1$ | + + + | + − − | + + + | + − − | + + + | + − − |
| $S_2$ | + + 0 | + − 0 | + + 0 | + − 0 | + + 0 | + − 0 |
| $S_3$ | + + − | + − + | + + − | + − + | + + − | + − + |
| $S_4$ | + 0 + | + 0 − | + 0 + | + 0 − | + 0 + | + 0 − |
| $S_5$ | + 0 0 | + 0 0 | + 0 0 | + 0 0 | + 0 0 | + 0 0 |
| $S_6$ | + 0 − | + 0 + | + 0 − | + 0 + | + 0 − | + 0 + |
| $S_7$ | + − + | + + − | + − + | + + − | + − + | + + − |
| $S_8$ | + − 0 | + + 0 | + − 0 | + + 0 | + − 0 | + + 0 |
| $S_9$ | + − − | + + + | + − − | + + + | + − − | + + + |

Table 7 shows that the $S_5$ scenario represents a stable, unchanged state of behaviour. From the nature of the solved problem, let us consider the variables $X_1$, $X_4$, $X_5$, and $X_6$ as the dominating variables that have an impact on the others. Then the variables $X_2$ and $X_3$ are chosen as objective functions and their character shows that the variable $X_3$ will be maximised and the variable $X_2$ will be minimised.

Table 7 shows that scenario $S_1$ maximises the objective function $X_3$ and minimises the objective function $X_2$ optimally. So, for other variables, you must apply $X_1$ (+ + +), $X_4$ (+ − −), $X_5$ (+ + +), and $X_6$ (+ − −), i.e. time increases quickly, resources decrease quickly, risk increases quickly and quality decreases.

It is relatively easy to generate a list of all possible transitions among the nine scenarios using the transformation table (Table 4). There are 16 transitions in the transition graph $H_{M1}$ (Figure 3). Its nodes are the scenarios S (Table 7) and the oriented arcs are the transitions between the scenarios S.

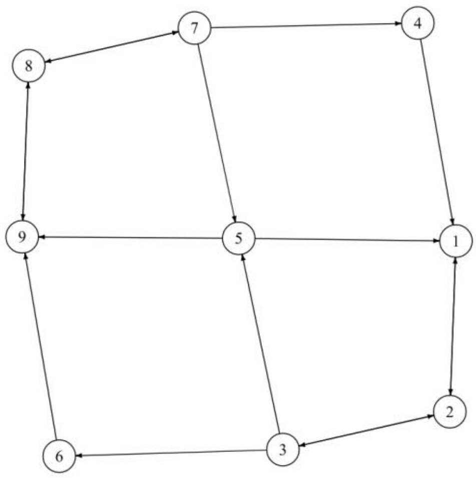


**Figure 3. Transition graph $H_{M1}$**

Let us consider node 9 (the scenario $S_9$) shows the current state of a project. From the previous part of the text is known that node 1 (the scenario $S_1$) shows the optimal state. From transition graph $H_{M1}$ all possible paths from node 9 to node 1 can be identify.

There are two possible paths: 9 → 8 → 7 → 5 → 1 and 9 → 8 → 7 → 4 → 1. Knowledge of these paths and Table 7 allows to realize such changes of variables $X_1$, $X_4$, $X_5$, and $X_6$ that will lead to the optimal state of a project.

The path 9 → 8 → 7 → 5 → 1 can generally be interpreted, with the respect to (4), for each variable as follows.

| | $S_9$ | $S_8$ | $S_7$ | $S_5$ | $S_1$ |
|---|---|---|---|---|---|
| $X_1$ | + − − | + − 0 | + − + | + 0 0 | + + + |

$S_9$: The project duration is shortening, while the rate of shortening is increasing.
$S_8$: The project duration is shortening, while the rate of shortening is stable.
$S_7$: The project duration is shortening, while the rate of shortening decreases.
$S_5$: The project duration is constant.
$S_1$: The project duration is extending, while the rate of extension is increasing.

In short: Gradually stop shortening the project duration. A graphical representation is shown in Figure 4.

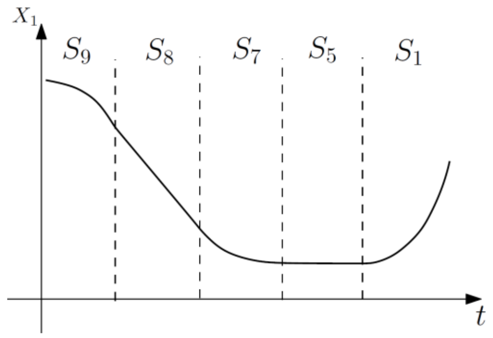


**Figure 4. Trend function of $X_1$**

| | $S_9$ | $S_8$ | $S_7$ | $S_5$ | $S_1$ |
|---|---|---|---|---|---|
| $X_4$ | + + + | + + 0 | + + − | + 0 0 | + − − |

$S_9$: Demands for project resources are growing, while the growth rate is increasing.
$S_8$: Demands for project resources are growing, while the growth rate is constant.
$S_7$: Demands for project resources are growing while the rate of growth is decreasing.
$S_5$: Demands for project resources are constant.
$S_1$: Demands on project resources are declining, while the rate of decline is increasing.

In short: Gradually reduce the demands on project resources. A graphical representation is shown in Figure 5.

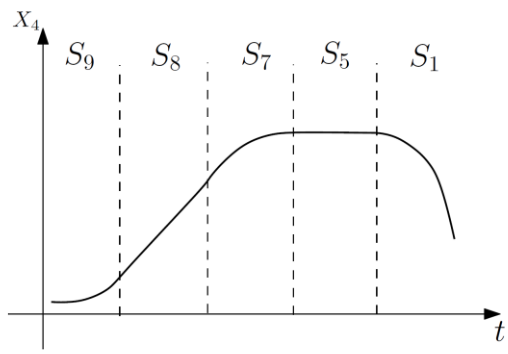


**Figure 5. Trend function of $X_4$**

| | $S_9$ | $S_8$ | $S_7$ | $S_5$ | $S_1$ |
|---|---|---|---|---|---|
| $X_5$ | $+--$ | $+-0$ | $+-+$ | $+00$ | $+++$ |

$S_9$: The project risk rate is decreasing, while the rate of decline is increasing.
$S_8$: The project risk rate is decreasing, while the rate of decline is stable.
$S_7$: The project risk rate is decreasing, while the rate of decline is decreasing.
$S_5$: The project risk rate is constant.
$S_1$: The project risk rate is increasing, while the growth rate is increasing.

In short: Gradually increase the project risk rate (risk appetite). A graphical representation is shown in Figure 6.

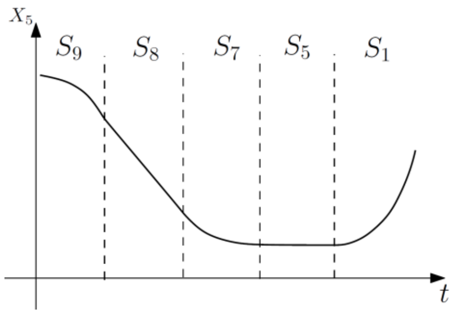


**Figure 6. Trend function of *X*₅**

| | $S_9$ | $S_8$ | $S_7$ | $S_5$ | $S_1$ |
|---|---|---|---|---|---|
| $X_6$ | $+++$ | $++0$ | $++-$ | $+00$ | $+--$ |

$S_9$: The project quality is increasing, while the growth rate is increasing.
$S_8$: The project quality is growing, while the growth rate is constant.
$S_7$: The project quality is increasing, while the growth rate is decreasing.
$S_5$: The project quality is constant.
$S_1$: The project quality is decreasing, while the rate of decline is increasing.

In short: Gradually minimise changes in the project declaration (quality). A graphical representation is shown in Figure 7.

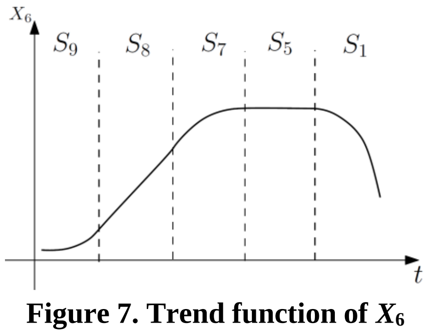


**Figure 7. Trend function of $X_6$**

In practice, each transition can be implemented through a series of specific activities that depend on a project. For example, in the text above, the conclusion is formulated for the variable $X_4$ (Resources): “Gradually reduce the resource requirements of the project.” Practically, it would mean for the project to manage resources (human, material), which are precisely allocated to the project, much more efficiently. Thus, to implement, in particular, the optimisation of the allocation of human resources on project activities in the context of time analysis of the project in order to achieve project objectives within the project constraints.

In the above example, the optimal solution, with the respect to $X_2$ and $X_3$, could be found in the set of scenarios, see Table 7. When adding another objective function, such as risk, and minimising it, it is no longer possible to find an optimal solution in the set of scenarios that satisfies the conditions imposed on all three variables $X_2$, $X_3$, and $X_5$.

In this case, we choose a solution (scenario) that is “as close as possible to the optimal solution”. Thus, we have to choose a compromise solution. This solution will, of course, depend on the specific project and the preferences of the project manager.

The identification of project states (defined on the basis of the Six-Pointed Star) and possible transitions between states provides the project manager with valuable information for implementing proactive responses to changes in the project development.

The transition graph H, see, e.g., Figure 3, shows all paths, which can lead to the ideal state and what project interventions (variables' changes) to implement. Thus, the project manager can make such interventions in such a way that the project always moves towards the ideal state if possible. That is, the trend model allows to predict the success of the project. This is the main contribution of the usage of the trend model in the project management.

Traditional methods for the evaluation of project progress that is directly linked to the problem of project scheduling, managing, and prediction are the Earned Value Management (EVM) Method (Vanhoucke, 2014), Percentage Method (Schwalbe 2015), and Milestones Trend Analysis (Lacko, 2004). Against these traditional methods, the trend modelling allows accounting for the past project progress, evaluating the current project status, and taking note of the expected future project progress, including any planned interventions in the project without knowledge of inputs in the form of numbers.

## 4. Conclusions

The current development of project management methods must focus on the area of project prediction. There are two main advantages, which show trending modelling seem to be very useful as a support of project prediction.

One of the main advantages of trend modelling includes the ability to formulate models without knowing specific numbers. For a particular project, there may not be enough data available at its beginning to use classical mathematical and statistical methods.

The second one is to add other variables to an already created model very easily. For example, the impact of a competing project, the introduction of a new technology, armed conflict, natural disasters, and political decisions can be taken into account.

It should be noted that optimisation algorithms known from graph theory can be used when the appropriate edge evaluation of the transition graph is defined. For example, the set of monitored variables can be divided into variables under management control and variables outside of management control. Then the transition graph can be searched for a path (current situation to the optimal state) that is as much as possible under management control. It should be noted that the above trend modelling approach is not intended to be a substitute for classical mathematical-statistical methods, but rather a complement to them in the phases of the project when no data are available for their use, but it is still necessary to have a quick idea of the possible development of the project.

***Acknowledgement.*** *This paper is supported by the Modelling and optimisation of processes in the corporate sphere; Registration No. FP-S-22-7977.*

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