Probabilistic analysis of projects viability

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Abstract: There are proposed probabilistic approach for analysis of projects viability in application to developed and used systems. The measures for projects viability analysis during given time are estimated by probability of maintaining viability, risk of non-viability, mathematical expectation of projects profitableness, relative projects profitableness. Project viability is researched in dependence on the expected frequency of real critical influences on viability of system (defining the beginning of influencing), mean time before viability loss (when an "admissible level of viability" may be lost after the beginning of influencing), the mean time of recovering admissible viability, time between the end of previous viability system analysis and the beginning of the next one, the time of system viability analysis, system profitableness in time unit during maintaining viability and during the time of viability loss (there may be damages), given time for prediction, the given minimum of profitableness. Some possibilities of the proposed probabilistic analysis of projects and portfolio viability are demonstrated by examples of development and operation of football stadiums.

Keywords: Analysis, model, probability, project, system, viability

1 Introduction

System analysis of projects viability is recommended by standards of system engineering to confirm ongoing viability **-** for example, by ISO/IEC/IEEE 15288 "Systems and software engineering — System life cycle processes", ISO/IEC TR 24748-2 "Systems and software engineering — Life cycle management — Part 2: Guide to the application of ISO/IEC 15288", ISO/IEC/IEEE 12207 "Information technology — Software life cycle processes" etc. According to ISO/IEC/IEEE 15288 system is considered as combination of interacting elements organized to achieve one or more stated purposes. Viability includes: confirmation of project progress towards achieving established goals and objectives, complying with project directives, development according to system life cycle policies, processes, and procedures, prove that the project remains viable. Projectы viability is used often during portfolio management process on enterprise to initiate and sustain necessary, sufficient and suitable projects. Projects are evaluated by different measures, for example, by indicators continuing need for the service, acceptable investment benefits, based on statistics and expectations. In turn, for developing adequate measures of risks counteraction it is required the quantitative definition of admissible risk level. Thus the admissible risk means, that the project is viable with the worst-case outcome, defining an admissible level of viability.

Note. Risk is understood as effect of uncertainty on objectives. Notes: 1) An effect is a deviation from the expected — positive and/or negative; 2) Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process); 3) Risk is often characterized by reference to potential events and consequences, or a combination of these; 4) Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence; 5) Uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood (according to ISO Guide 73).

Considering an actuality of different system engineering views uniting not only statistics and expectations indicators but also probabilistic analysis in terms "probability of success" or "risk of non-viability" in conditions of uncertainties, the approach for building new models which is intended to do system analysis of separate project viability and to predict risks for portfolio of projects under different threats, is proposed. The approach is based on author's models and develops the existing approaches [1-24]. The ideas of approach can be applied also by using another probabilistic models which supported by software tools and can predict on a level of probability distribution functions (PDF) [25-28].

2 Proposed model for separate projects

Every separate project can be presented and researched as "black box". The proposed model of separate project allow to estimate "probability of success" in providing system viability during given prognostic period and "risk of non-viability" considering consequences. A probabilistic space (Ω, B, P) for estimation of operation processes in "black box" is built [1-28], where: Ω - is a limited space of elementary events (two events for project viability analysis are defined: «viability is provided» and «viability is lost»); B – a class of all subspace of Ω-space, satisfied to the properties of σ-algebra; P – a probability measure on a space of elementary events Ω. Such space (Ω, B, P) is intended for probabilistic analysis of project viability in application to developed system.

For a project there is considered the next way of providing system viability in conditions of uncertainties. These conditions are formalized as flow of different threats influencing viability. Dangerous influence on project viability is acted step-by step: at first a danger source of threats is occurred and after occurrence a threat begins to influence. A time before occurrence of real significant influencing viability (defining a beginning of influence) is random value which can be distributed by PDF of time between neighboring occurrences of danger source $\Omega_{occur}(t) = P(\tau_{begin} \leq t) = 1 - \exp(-\sigma t)$, $\sigma = 1/T_{begin}$, for project T_{begin} logically means planning horizon. And time before viability loss (when defined "admissible level of viability" is lost after beginning of influencing) is random value which can be distributed by PDF $\Omega_{before\ loss}(t) = P(\tau_{before\ loss} \leq t) = 1 - \exp(-t/\beta)$, β is mathematical expectation or mean time. Project viability is provided before "admissible level of viability" is lost after a beginning of influencing. Project viability is lost only after threat influence when "admissible level of viability" is lost - see Figure 1. To detect danger influences from different threats or consequences (which are connected with a loss of "admissible level of viability" after a beginning of influencing), periodical system analysis of project viability is carried out. The lost project viability can be detected only as a result of such system analysis. After finishing every system analysis project viability is considered as recovered on "admissible level of viability" or project is subject to closing or transforming to another viable project.

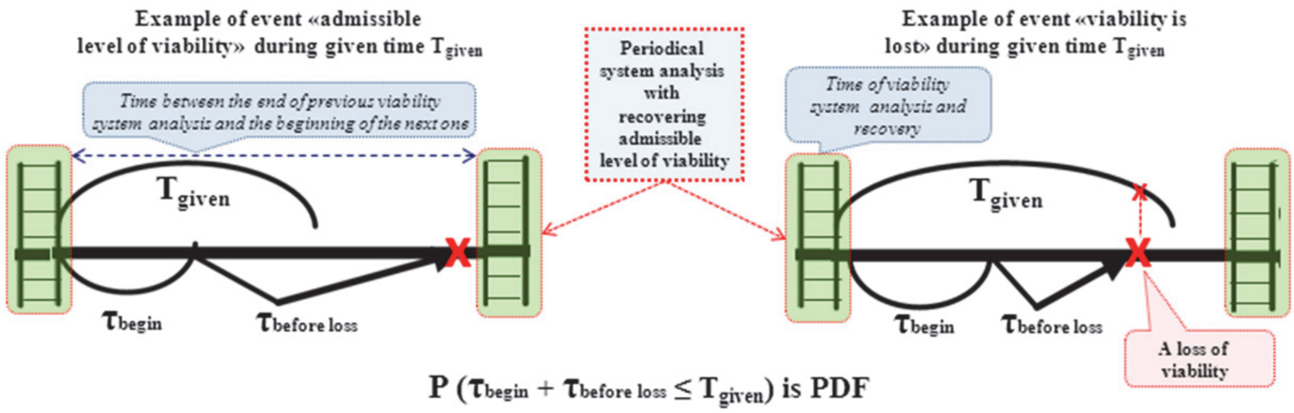

Figure 1 – Some elementary events to project viability during given time

There are possible the next variants: variant 1 – the given prognostic period T_{given} is less than the sum of established time between the end of previous viability system analysis and the beginning of the next one T_{betw} and the time of system viability analysis T_{diag} (i.e. $T_{given} < T_{betw} + T_{diag}$); variant 2 – the assigned period T_{given} is more than or equals to this sum (i.e. $T_{req} \geq T_{betw.}+T_{diag}$).

For a given prognostic period T_{given} the next statements describe the proposed model (see [5, 9-12]).

Statement 1. For variant 1 under the condition of independence of considered characteristics the probability of maintaining project viability is equal to

$$P_{(1)} = \begin{cases} (\sigma - \beta^{-1})^{-1} \left\{\sigma e^{-T_{given}/\beta} - \beta^{-1} e^{-\sigma T_{given}}\right\}, \text{ if } \sigma \neq \beta^{-1}, \\ e^{-\sigma T_{given}}\left[1 + \sigma T_{given}\right], \text{ if } \sigma = \beta^{-1}. \end{cases} \quad (1)$$

Statement 2. Under the condition of independence for considered characteristics the probability of maintaining project viability for variant 2 is equal to:

measure a)

$$P_{(2)}(T_{given})=N((T_{betw}+T_{diag})/T_{given})\, P_{(1)}{}^{N}(T_{betw}+T_{diag})+(T_{rmn}/T_{given})\, P_{(1)}(T_{rmn}), \quad (2)$$

where $N=[T_{given.}/(T_{betw.}+T_{diag.})]$ – is the integer part, $T_{rmn} = T_{given} - N(T_{betw}+T_{diag})$;

measure b)

$$P_{(2)}(T_{given})=P_{(1)}{}^{N}(T_{betw}+T_{diag})P_{(1)}(T_{rmn}). \quad (3)$$

The probability $P_{(1)}(T_{rmn})$ of maintaining project viability within time T_{rmn} is defined by (1).

Assumption: the probability distribution functions (PDF) exist for all input characteristic (for random values). Thus the probability of maintaining project viability during the given prognostic period (i.e. probability of success) may be computed as a result of use the model.

For an identical consequences a risk to lose viability ("risk of non-viability") is an addition to 1 for a probability of maintaining project viability $R(T_{given})=1-P(T_{given})$.

The main output of modeling is probabilistic measure of maintaining project viability during given time T_{given}. If probabilities $P(T_{given})$ for all points $T_{given.}$ from 0 to ∞ are computed, it means a trajectory of the PDF depending on time between system analysis for improvements according to project, expected frequency of real significant influencing viability of system (defining the beginning of influence), mean time before viability loss (when "admissible level of viability" may be lost after beginning of influencing); the mean time of recovering admissible viability; time between the end of previous viability system analysis and the beginning of the next one; time of system viability analysis.

3 Estimations of mathematical expectation of project profitableness and relative project profitableness

For calculation a mathematical expectation of project profitableness $M(T_{given})$ for a given prognostic period T_{given} the next formula is proposed:

$$M(T_{given}) = T_{given}\, [E_{maintain}\, (1- R(T_{given})) + E_{loss}\, R(T_{given}))], \quad (4)$$

where

risk $R(T_{given})$ to lose viability within time T_{given} is estimated by using $P(T_{given})$ from (1)-(3);

$E_{maintain}$ is system profitableness in time unit during time of maintaining viability (in conditional units);

E_{loss} is system profitableness in time unit during time of lost viability, it may be damages (with negative value in conditional units).

Note. For high level of damages the value of $M(T_{given})$ may be negative. It means an non-viability of project.

For calculation a relative project profitableness $L(T_{given})$ for a given prognostic period T_{given} the next formula is proposed:

$$L(T_{given}) = 100\% \cdot [M(T_{given}) - M_{min}(T_{given})]/ M_{min} (T_{given}), \quad (5)$$

where

mathematical expectation of project profitableness $M(T_{given})$ for a given prognostic period T_{given} is estimated by (4). For the given period T_{given} the value of $L(T_{given})$ may be negative. For a long period it may mean an non-viability of project;

M_{min} is given minimum of profitableness for a given prognostic period T_{given} (in conditional units). It is supposed for project viability M_{min} is positive value.

4 Approach to predict risks for portfolio

Portfolio is a set of different projects, every for which has proper level of viability. For risks prediction a portfolio is presented as combined serial structure of "black boxes". It means a viability of portfolio is provided if "AND" viability for 1-st project, …, "AND" viability for the last project of portfolio are provided. Also we define that a viability of portfolio is not provided if at least for one project «viability is lost».

PDF of time before viability loss for every project of portfolio may be estimated by (1)-(3) and by calculations for all points $T_{given.}$ from 0 to ∞.

Let's consider the elementary structure from I independent projects. Let's PDF of time before viability loss for i-th project is $B_i(t)$, i.e. $B_i(t) = P (\tau_i = \tau_{begin} + \tau_{before\ loss} \le t)$, i=1,…,I, then time between losses of viability for portfolio is equal to a minimum from I times τ_i: non-viability of 1-st or…or I-th project. For this case the PDF of time before viability loss for portfolio is defined by expression

$$B(t) = P(\min (\tau_1,\ldots,\tau_I)\le t)=1-P(\min (\tau_1,\ldots,\tau_I)>t)=1-P(\tau_1>t)\cdot\ldots\cdot P(\tau_I>t) = 1 - [1-B_1(t)]\cdot\ldots\cdot [1-B_I(t)]. \quad (6)$$

For calculation a mathematical expectation of portfolio profitableness $M_{portfolio}(T_{given})$ for a given prognostic period T_{given} the next formula is proposed:

$$M_{portfolio}(T_{given}) = M_1(T_{given})+\ldots+ M_I(T_{given}), \quad (7)$$

where

mathematical expectation of i-th project profitableness $M_i(T_{given})$ is estimated by (4).

Note. For high level of damages $M_{portfolio}(T_{given})$ may be negative. It means non-viability of portfolio.

For calculation a relative portfolio profitableness $L_{portfolio}(T_{given})$ for a given prognostic period T_{given} the next formula is proposed:

$$L_{portfolio}(T_{given}) = [L_1(T_{given}) +\ldots+ L_I(T_{given})]/I, \quad (8)$$

where

relative i-th project profitableness $L_i(T_{given})$ for a given prognostic period T_{given} is estimated by (5).

$L_{portfolio}(T_{given})$ may be negative. For a long period it may mean an non-viability of portfolio.

All these ideas for probabilistic analysis of projects viability are partly supported by the software tools "Mathematical modeling of system life cycle processes" – "know how" (registered by Rospatent №2004610858), "Complex for evaluating quality of production processes" (registered by Rospatent №2010614145) and others [5,9-12, 14-24].

5 Examples

Example 1. Consider the viability of the project to build and operate a football stadium for 20,000 seats. For demonstrating the proposed approach we use plausible input. Let the construction and installation cost is \$100 million, which must be justified. Let's put the expected return on investment period in Russia is equal to 10 years, i.e. M_{min} = \$10.0 million in a year.

The average cost of tickets to the international or important domestic football match and popular shows put equal to \$50. Let such events appear an average of 10 per year, the occupancy rate is close to 100%, i.e. the yield from one are \$1 million and \$10 million for a year. Considering fact that about half of them go to the organizers of the forum, the benefit according to the plan is about \$5 million.

The average cost of tickets to city events is \$10. Let such events be planned 20 per year, the occupancy rate is 50%, i.e. the yield from one event is \$0.1 million, per year – \$2 million. Total plan – \$7 million per year. This is far from enough to return on investment in 10 years. Moreover, uncertainties significantly worsen these figures.

If the business planning for the stadium is carried out for a period of 2 years, then the threats of underfunding will arise every 2 years, the control of the stadium's performance is monthly with the recovery of a disturbed viability for 3 months (the concept of non-viability in this case includes not only the stadium unavailability for the events, but also underfunding because of underutilization). In this case, the predicted risk of non-viability will be about 0.73 for 10 years.

The dependencies of a risk R of non-viability on given prognostic period (varying from 5 years to 20 years) and on parameter σ (where planning σ^{-1} is planning horizon) show - it is necessary to reduce the frequency of threats to the normal operation of stadium (connected with underfinancing) – see Figures 2 and 3. I.e. it is necessary to increase the planning horizon to at least 5 years - then the frequency of threats is reduced to 0.2 per year.

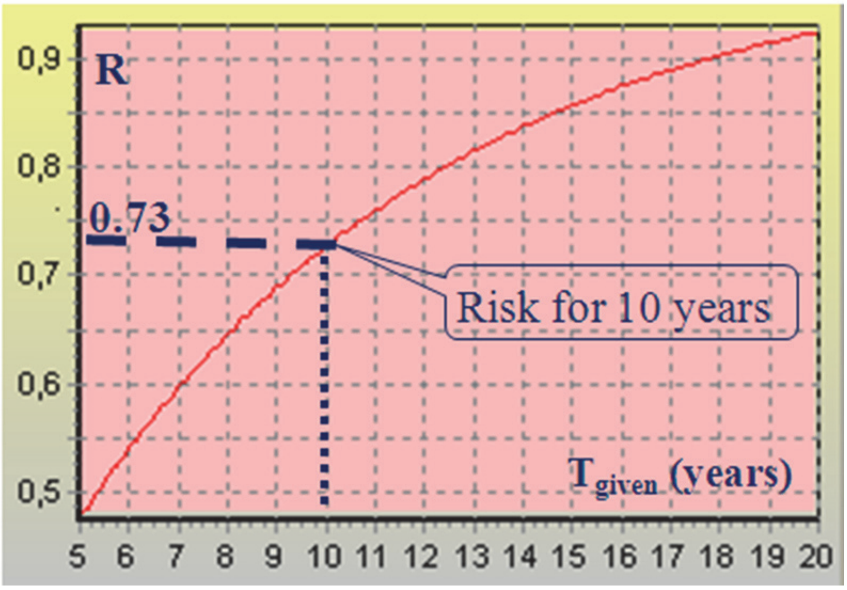

Figure 2 – The dependence of a risk R of non-viability on given prognostic period, varying from 5 years to 20 years (for example 1)

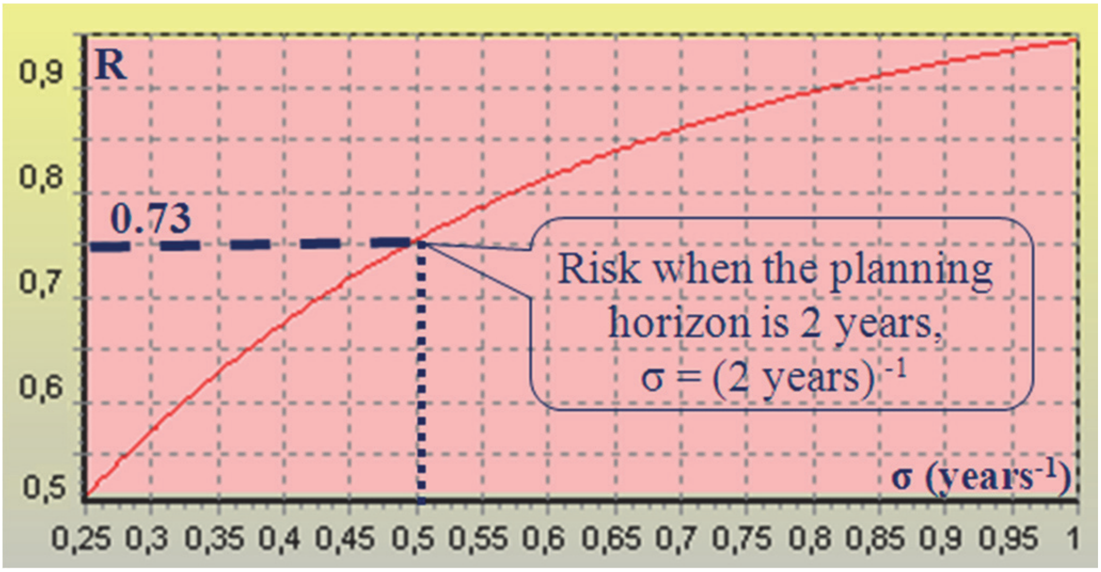

Figure 3 – The dependence of a risk R of non-viability on parameter σ, where σ^{-1} is planning horizon (for example 1)

Estimations of mathematical expectation of project profitableness $M(T_{given})$ and $L(T_{given})$ for T_{given} =10 years are:

M(10 years) = 10 [5 million x 0.27 + 2 million x 0.73] = $28.1 million,

L(10 years) = 100% x (28.1-100.0) /100 = -71.9%.

These estimations have the next interpretation: with such approach to business, the stadium will not return on investment in 30 years.

Example 2. We increase the planning horizon of the stadium to 5 years, thereby reducing the frequency of threats to 0.2 per year under the same conditions as in example 1. In this case, the predicted risk of non-viability will be 0.41 instead of 0.73 - see Figures 4 and 5.

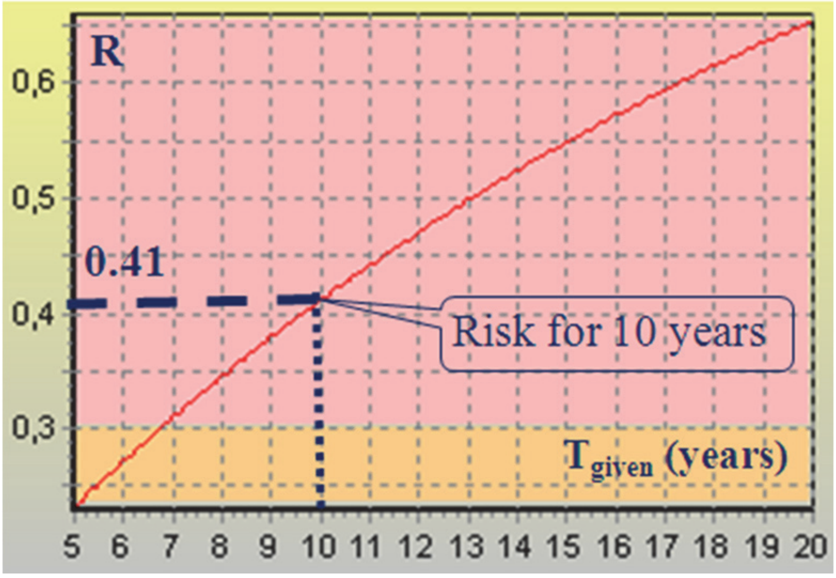

Figure 4 – Dependence of risk R of non-viability on given prognostic period, varying from 5 years to 20 years (for example 2)

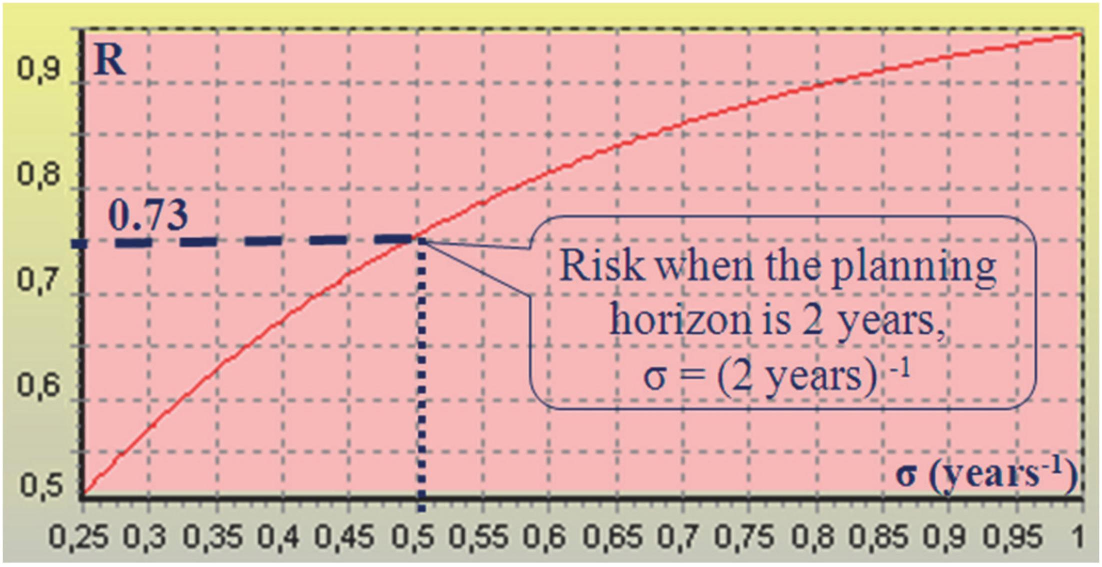

Figure 5 – The dependence of a risk R of non-viability on parameter σ, where σ^{-1} is planning horizon (for example 2)

The dependencies of a risk R of non-viability on given prognostic period (varying from 5 years to 20 years) and on parameter σ (where planning σ^{-1} is planning horizon) show - in the face of uncertainty, planning for 10 years will not significantly reduce the risk of non-viability (it will be slightly below 0.3).

Estimations of mathematical expectation of project profitableness $M(T_{given})$ and $L(T_{given})$ for T_{given} =10 years are:

M(10 years) = 10 [5 million x 0.59 + 2 million x 0.41] = $37.7 million,

L(10 years) = 100% x (37.7-100.0) /100 = -62.3%.

These estimations have the next interpretation: it is necessary to find other ways to increase the viability of such stadium.

Example 3. In addition to planning for 5 years at a constant cost of tickets, we will introduce the following changes compared to examples 1 and 2.

Let the number of top football events and popular shows be 30 per year instead of 10 from examples 1 and 2 (developing ice performances, circus shows, artistic gymnastics, art exhibitions, museum exhibitions, other sports, where state has good positions – hockey, volleyball, basketball etc., popularizing them), occupancy is about 100%, i.e. the yield from one event will be about $1 million, for the year – $30 million, of which about half goes to the organizers of forums. I.e. benefit is about $15 million.

And let the number of urban activities be 60 per year instead of 20 from examples 1 and 2, the occupancy rate is still 50%, i.e. the yield from one will be $0.1 million, per year – about $6 million.

For 5 years planning horizon and the same conditions the estimations of mathematical expectation of project profitableness $M(T_{given})$ and $L(T_{given})$ for T_{given} =10 years are:

M(10 years) = 10 [15 million x 0.59 + 6 million x 0.41] = $113.1 million,

L(10 years) = 100% x (113.1-100.0) /100 = +13.1%.

I. e. under these conditions, the return on investment of the project for 10 years is mathematically justified.

Example 4 The world Cup -2018 held in Russia led to the problem of preservation and effective use of the rich legacy of 12 stadiums and the created (modernized) infrastructure. The total contribution of the preparation and holding of the 2018 world Cup to the gross domestic product (GDP) of Russia amounted to more than 950 billion rubles for 2013-2018, which is equivalent to about 1% of the annual GDP.

Let's try to quantify the answer to the question -What about viability of the 2018 FIFA world Cup legacy? – see Figure 6.

Figure 6 – The 2018 FIFA world Cup legacy was developed

Leaving behind the stadiums of Moscow and St. Petersburg, we assess the risk of non-viability of the hypothetical portfolio of the state of 9 stadiums, such as those in which the matches of the world Cup 2018 – see Figure 7. From the point of probabilistic analysis view portfolio is logically complex system uniting 9 subsystems. Viability of portfolio projects is provided if "AND" viability for 1-st project, …, "AND" viability for the 9-th project are provided. Also we define that a viability of portfolio is not provided if at least for one project «viability is lost».

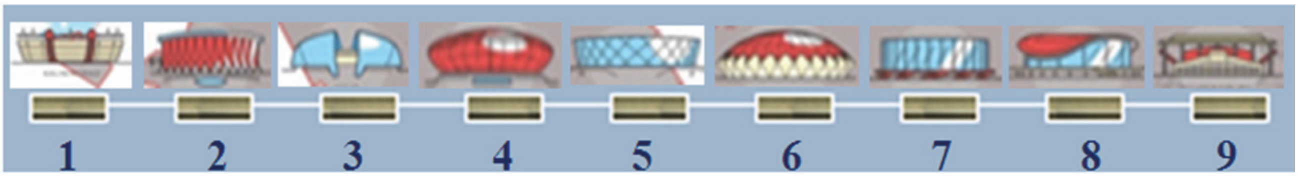

Figure 7 – Portfolio is complex system from the point of viability probabilistic analysis view

Let's take the input of example 3 as input for every project of this example. Calculations show that the risk of portfolio non-viability within 10 years of operation will be more than 0.98 – see Figure 8.

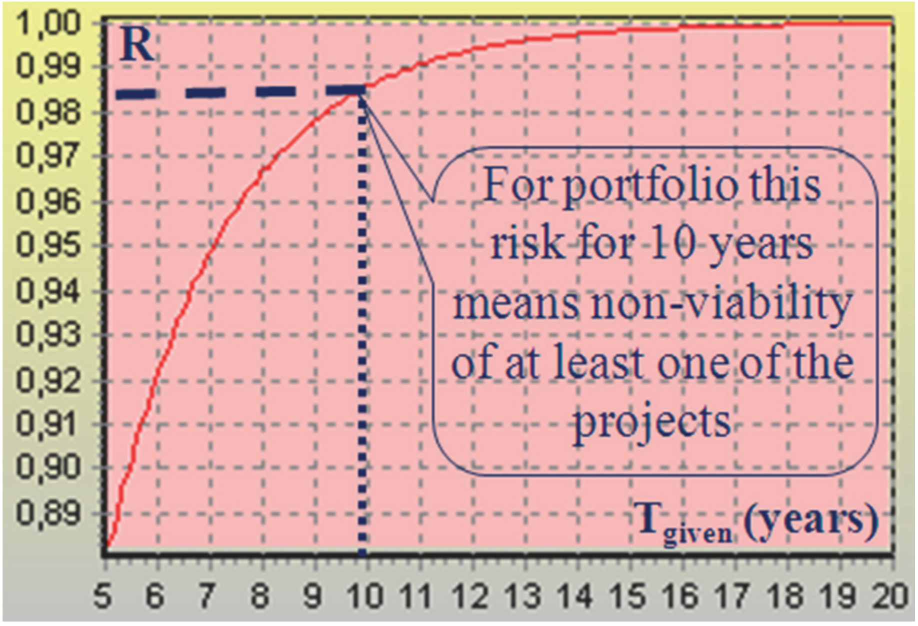

Figure 8 – Dependence of risk R of non-viability on given prognostic period, varying from 5 years to 20 years (for example 4)

A comparison with the dependence on Figure 4 for one stadium for the entire portfolio says it is impossible to preserve the viability of all 9 stadiums long time, if the care of them is completely left to the state. Largely precisely for this reason "The Concept of the 2018 FIFA world Cup legacy" was been approved by the Order of the Government of the Russian Federation No. 520-R of 24 July 2018. Responsibilities for the preservation of the 2018 FIFA world Cup legacy were distributed between the state and business.

Example 5 – for comparison.

Investments for the new stadium in Turin, commissioned in 2011, amounted to 120 million euros. Capacity includes 41,000 seats, including about 4,000 VIP seats, season tickets – 23,000 seats. In a year, the stadium serves about 27 matches, ticket prices are from 30 to 110 euros, the average attendance is about 77%.

With an average ticket price of 50 euros, the revenue from ticket sales of 14.5 million euros per year, subscriptions of 300 euros bring another 6.9 million euros. VIP-places bring more than 40 million euros per year. Total seasonal revenues from football exceed 60 million euros (https://www.sports.ru/tribuna/blogs/antonio/363879.html). That is, even if you do not take into account the business income from additional business activities, the share of which is about a third, the return on investment will be 2 years. This is one of the standards of viability of a sports project!

Conclusion

1.The proposed approach allows to do system analysis of projects viability and portfolio viability by probability of maintaining viability, risk of non-viability, mathematical expectation of projects profitableness, relative projects profitableness. Project viability is researched in dependence on the expected frequency of real critical influences on viability of system, mean time before viability loss, the mean time of recovering admissible viability, time between the end of previous viability system analysis and the beginning of the next one, the time of system viability analysis, system profitableness in time unit during maintaining viability and during the time of viability loss, given time for prediction, the given minimum of profitableness.

2. Some possibilities of the proposed probabilistic analysis of projects and portfolio viability are demonstrated by examples of researching development and operation of football stadiums with using plausible input. The probabilistic results of the research explain quantitatively the reasons of the "The Concept of the 2018 FIFA world Cup legacy" approved by the Order of the Government of the Russian Federation.

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