14th World Congress in Computational Mechanics (WCCM)
ECCOMAS Congress 2020
19 – 24 July 2020, Paris, France
F. Chinesta, R. Abgrall, O. Allix and M. Kaliske (Eds)

# SIMULATION PROJECT MANAGEMENT BY MODIFIED GAUSS S-CURVE

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**Key words:** Project management, cash flow, S-curve, 3D model – MGSC, FEM mesh.

**Abstract.** Contemporary project management rises to the level of various associative groups, going beyond project management (PM) in a specific, defined activity. Processes not directly related to one activity are becoming more important. Planning a process group by cash-flow methods or S-curve defines the given process one-dimensionally, while using modified Gaussian curve enables process simulations with two-dimensional or 3D modeling. Any financial condition of the project is modeled or simulated by two variable function and today's popular iterative numerical mathematical methods suitable for software mathematics, i.e. computer operations, depending on duration and cost or amount of project investment. Therefore, using a new method of Modified Gaussian S-Curve (MGSC) for modeling and simulating creates an nM model of project execution with the possibility of PM initial optimization and monitoring process group. Future project reliability is measured and regulated by given MGSC inverse curves.

## 1 INTRODUCTION

Rapid development of business process management technology (BPM) has also accelerated the establishment of project management (PM). New CAD, BIM, Digital Twins (DT) and SMART technologies and methodologies within Integrated Information Systems (IIS) have contributed to daily monitoring [1] method of companies and project management systems. Project system planning and regulation, i.e. process group planning, supervision and control are essential to these new methods. Although standardization technology does not follow the path of the Third and Fourth Industrial Revolution, programming alongside operational research has made the development of dynamic structural programming (DSP) method [2] possible. This method, combined with operational research as a tool for optimal project management, transforms the static construction organization project (COP) into dynamic COP or dynamic project management (DPM) processes referred to as PM. Introducing a company-wide Enterprise Resource Planning (ERP) system [3] is a key investment requiring huge resources and it can significantly affect an organization's future competitiveness and performance. Therefore, modeling an Application Programming

Interface (API) [4] creates tools that can help facilitate research related to Building Information Modeling (BIM). Robotics enables technological expansion beyond organizational limits and it is therefore necessary to establish dynamic models of norms using vector planning [5] and improve them by optimizing production processes [6]. Thus, problems are eliminated through model standardization of business processes. A business system strives to optimize its economic and organizational elements. Closing the gap between organizational solutions and technological advances creates a production model with DT and cyber-physical systems (CPS) [7].

The industry is simultaneously searching for new ways of keeping up with rapid data transformation through CPS subset which is already being used in process automation, especially in the digital world. Therefore, numerical mathematical iterative equations [8] contribute to algorithms as an IT tool in defining DT, CPS and model standardization of construction production by DSP method. Simulation tools such as Matlab applications [9] become an informative aid in defining CPS analytically and graphically.

It is difficult to clarify the S-curve because of its inaccurate definition in a 2D system with process and risk occurrence acting as aggravating factors. Specifically, current engineering S-curve observation and definition by linear equations seem to pose a problem. Computer graphics developers specializing in CAD and DT tools use iterative, linear Casteljau, Bezir and Hermite equations to calculate curvature. However, the 2D problem is already being solved by contemporary software, supported by differential equations using Runge-Kutta system in finite element methods and utilizing topographic 3D representations of various spatial shapes and designs.

Consequently, MGSC describes the continuous 3D S-curve defined by iterative equation with two variables and a nonlinear system. By adding a coefficient or risk variable, a chase-flow curve simulation is created based on previous project functioning, with the simulation function closely resembling project reality.

PM simulation with MGSC provides an iterative and more precise way of defining MP budget. By developing new computer graphics technology based on iterative equation, MGSC becomes the basis of probability for almost all daily activities including business processes with PM planning inside a business system and connecting to business applications via BIM, DT and AI systems.

State and methods of planning and defining the cash flow curve are described at the beginning of the chapter review, followed by presenting the origin of MGSC with previous research equations. Also, an IT manager can use simulations of initial risk as a variable so the project plan can be defined more accurately.

## 2 S-CURVE METHOD FOR ANALYSIS AND PLANNING

Planning is essential in management and poses a big problem in every business system. Obsolete and outdated norms distance us from reality and an organization cannot keep up with the rapid technological development. This backlog can be cleared by replacing the static management of a construction organization project with the dynamic POG organization [10], a precondition for precision planning and reducing business risk in contemporary planning and monitoring within the PM process groups. Nowadays, SWOT analysis gathers non-quantitative data representing system resource capabilities and deficiencies. The historical development of mathematics [11] has enabled computerized process modeling (Fig. 1) complemented by DSP method in construction work.

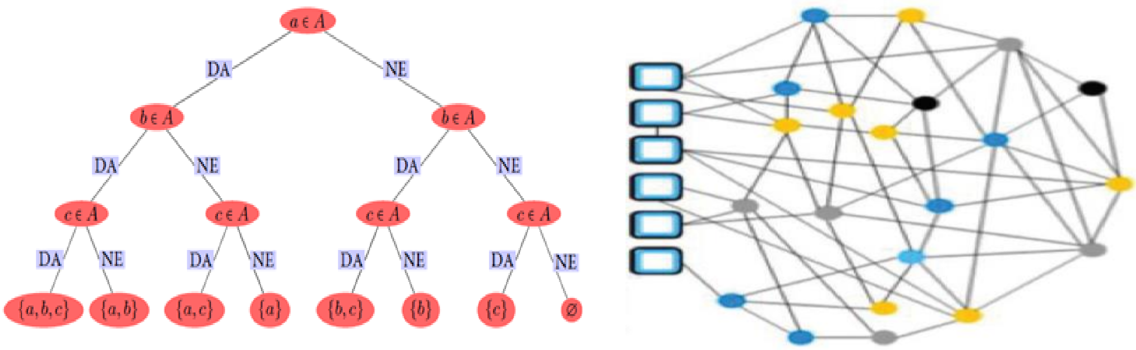


**Figure 1**: Binomial set (*Nakić*) and cyber-physical-production-system (*Faller, Höftmann*)

The method improves operational research and dynamic programming. All the combined factors provide optimal control in terms of achieving process maximum or minimum, calculated by recurrence equation (1).

$$fn(p)_j = G(p) + fn - 1(p)_{j,k} \tag{1}$$

The equation defines the final process stage fn($p$)$_j$ in regard to the initial G($p$) and the previous fn-1($p$)$_{j,k}$. In this way, all processes are functionally linked but also suitable for simple and unified systems. Multi-stage processes are defined by vector states via recurrence equations. Nowadays, along with stochastic variables used in given systems and thus the planning processes of the PERT system, the S-curve is complemented further by Earned Value Analysis (EVA) curve. In practice, divergence from planned duration and cost can be identified in accordance with project plan and realization. Various mathematical solutions appear as a result of differentiating events and conditions of a project scenario or one of its parts. The GERT model [12] is close to the PERT model and can also be compared with the queueing theory model [13]. Attempts at PERT, i.e. simulating an activity’s most likely time as well as the probability of the sum of events in system stage and condition [14], create linear algebraic equations defining the dimensions of risk. However, it is possible to define multiple EVA scenarios for projects (Fig. 2) since a single project scenario does not correlate with other projects.

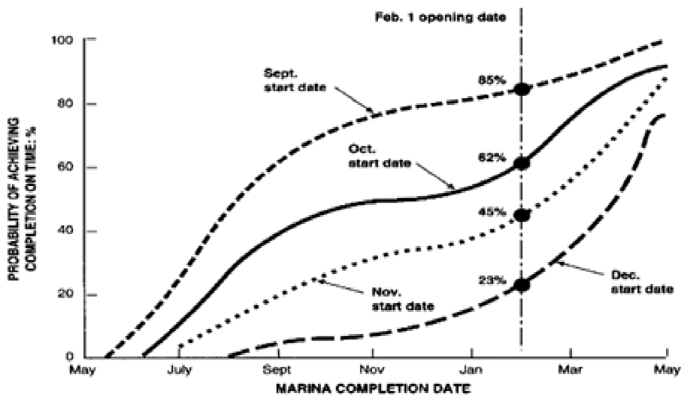


**Figure 2**: Estimated project duration and cost (*Godfrey, Halcrow & Partners*)

In recent years, probabilistic forecasts of project performance, as well as software use of stochastic S-curves in generating stochastic S-curves and simulations, display dispersion deviation [15] from the S-curve according to Gaussian density function of cost and time distribution (Fig. 3). However, the one-dimensionality of these curves or 2D function representations remains a problem.

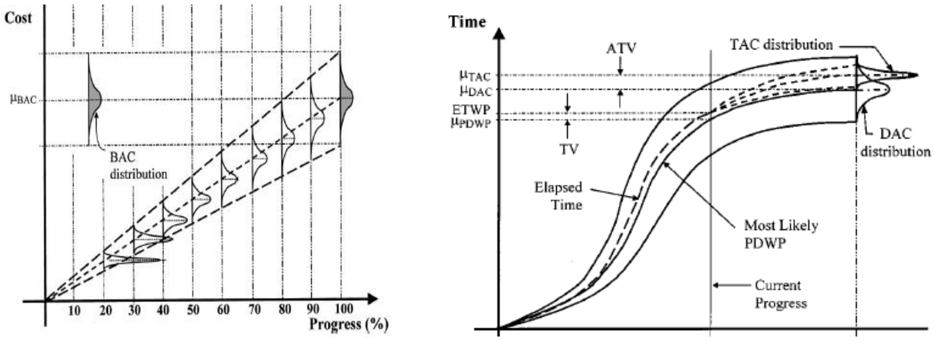


**Figure 3**: Probabilistic dispersion of project cost and duration (*Barraza, Back & Mata*)

New methods of PM risk management provide new variables which make case-flow diagram forecasting more accurate, so various governments started using Risk Analysis and Management Method (CRAMM) developed by the British government and OCTAVE (Operationally Critical Threat, Asset and Vulnerability Evaluation) which provides security risk assessments and plans. Identifying and quantifying risks is nevertheless difficult.

## 3 MODIFIED GAUSSIAN S-CURVE

Graphic representations of finalized and planned company projects show a bell-shaped differentiation, more precisely, a deviation of situation curves or cash flow project curves (Fig. 4). The distribution of natural and business events usually follows the Gaussian normal distribution which sparked the idea of defining an S-curve using Gaussian normal distribution. For initial definition of the given curves, the statistical model of defining quadratic linear equations by Gaussian least-squares method [16, 17] was applied on finalized and planned projects (Fig. 4) of the given company. The results can be seen in Mathcad software with realization dispersion curve observed as a semicircle above and under the planned straight curve.

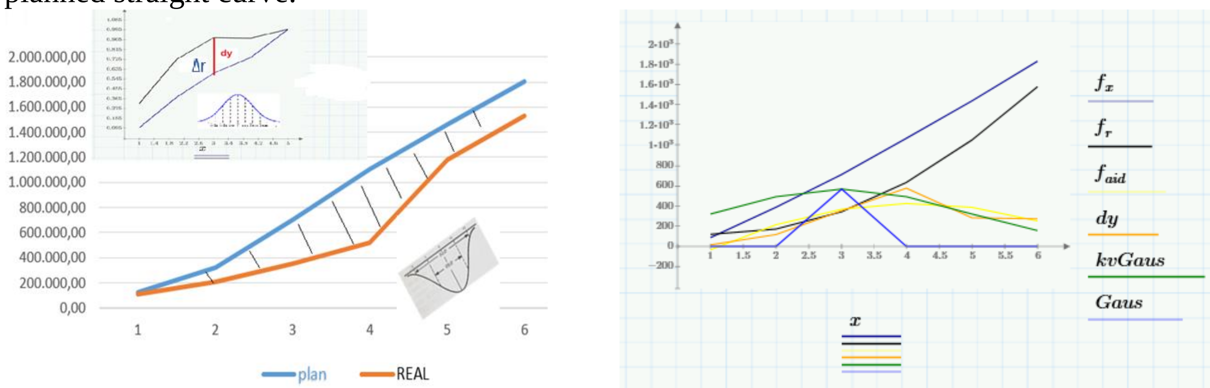


**Figure 4**: Project data distribution curves of the company Međimurje Graditeljstvo

The angle of the set domain increases as project number grows, i.e. data is more scattered. Therefore, the equivalent measure enabling data comparison by functions *t* (time, month) and *T* (costs or situations month by month) is introduced. The common Gaussian dispersion model displays deviations in project finances which is made possible by comparing distribution of the difference between situations, more precisely, S-curves of planned and finalized projects.

For a given project, planned and finalized discrete functions *y* i *r* are written in equation (2) while their difference *dy* or *f(x) – f(r)* is a discrete curve and a replacement continuous Gaussian curve in equation (3).

$$f(x) = a1 + a2 \cdot x + a3 \cdot x^2 \quad (2)$$

$$kvGaus = \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}} \cdot e^{\frac{-(x-\mu)^2}{kv \cdot \sigma}} \quad (3)$$

Based on a number of projects and links of the Gaussian equation's main variables to field data or situations in construction, a new general definition of MGSC [18] was created as function of production time and project cost or project situation equation (4).

$$kvsGs(x,T) = \lambda kv \cdot \int_0^x \frac{1}{(a \cdot T + b) \cdot \sqrt{2 \cdot \pi}} \cdot e^{\frac{-(x-\mu)^2}{kv \cdot (a \cdot T + b)}} dx \quad (4)$$

The equation is merely a prototype of the real S-curve in function *T* (costs), *x* or *t* (*time*) and constant *kv* with a value of 10,000. Parameters *λkv*, *a* and *b* for a specific project are fixed (Fig. 5).

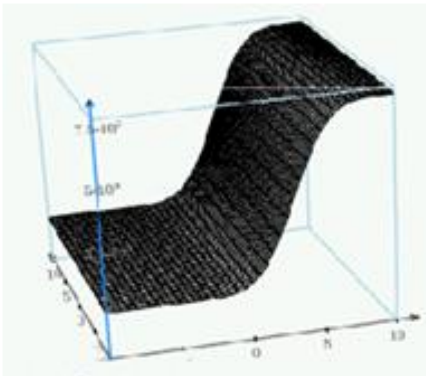

**Figure 5**: Modified Gaussian S-curve

## 4 MGSC SIMULATIONS

Since EVA or S-diagrams are popular nowadays, adding quantified risk will improve PM and make decision-making more realistic with MGSC. According to the first assumption, risk distribution is based on Gaussian distribution. Previously executed projects prove that project deviation happens mid-project approximately and equals half of the investment at a given point (Fig. 6). Therefore, in the second assumption, *dy*, the difference between planned and final S-curve is identified with *Δr*, i.e. financial deviation is identical to the equivalent risk magnitude.

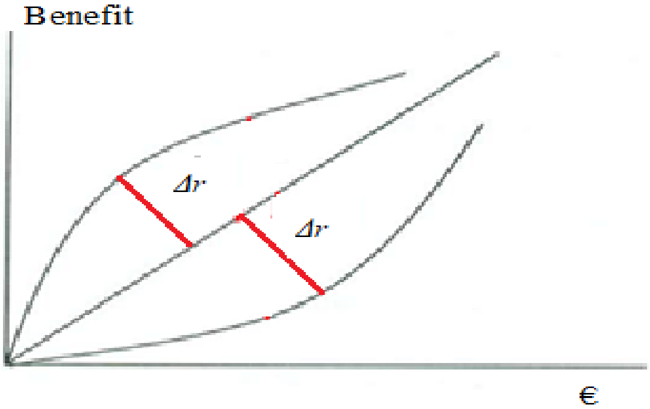


**Figure 6**: Utility – risk dispersion

Utility function does not only link probability and number of events into a function dependency but can also quantify risk. Methods of Monte Carlo simulations and Beta risk are trying to be quantitative but are still subject to intuition coefficients. TREEPlan as well as Monte Carlo and PERT modeling and simulation are used to collect and analyze risk data by number-rendering based simulations which are a matter of chance, so decision-making may also be accidental. The initial step in construction, bidding, is always marked by uncertainty and risk. However, a clear tabular overview of possible measures can be created by intuitively defining or estimating percentages and probabilities while taking into account possible uncertainties in all further activities or events. Measures of maximization criterion of maximin or minimaximin can be used to intuitively or experientially define the decision based on EVA criteria [19]. Adding risk parameter *λr* to MGSC equation creates a new risk-modified Gaussian S-curve (RMGSC) (4) (Fig. 7) suitable for simulating and generating as accurate a chase-flow or S-curve as possible.

$$skvGr(x,T)=\lambda r\cdot \lambda kv\cdot \int_0^x \frac{1}{(a\cdot T+b)\cdot\sqrt{2\cdot\pi}}\cdot e^{\frac{-(x-\mu)^2}{kv\cdot(a\cdot T+b)}}dx \quad (5)$$

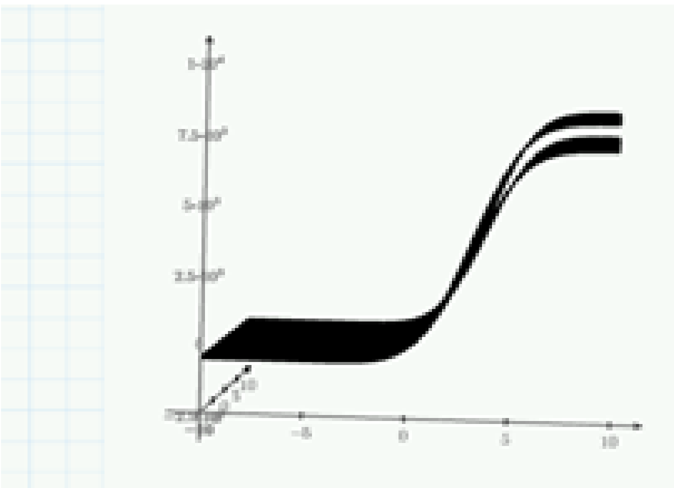


**Figure 7**: MGSC and RMGSC

Risk coefficient $\lambda r$ was developed from the relation between planned and finalized MGSC equation. This coefficient increases the S-curve value and we can easily estimate project risk in regard to the plan. Thus, RMGSC number rendering creates a project development simulation while including all possible risk scenarios (Fig. 8).

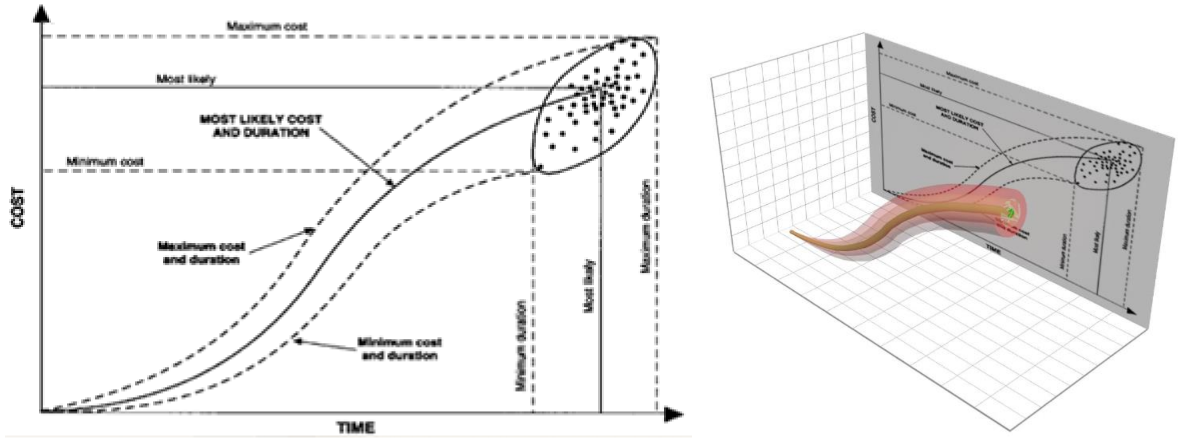


**Figure 8**: Project simulation using risk dispersion and variables *t* and *T* (*Barraza, Back & Mata & author*)

Finally, simulations based on natural processes according to the Gaussian distribution are normal, but it was observed that the MGSC curve in all directions can simultaneously display a natural wave (Fig. 9), which should be used for new FEM mesh and computer graphics technologies based on iteration MGSC equations as the basis of probability of almost all natural events.

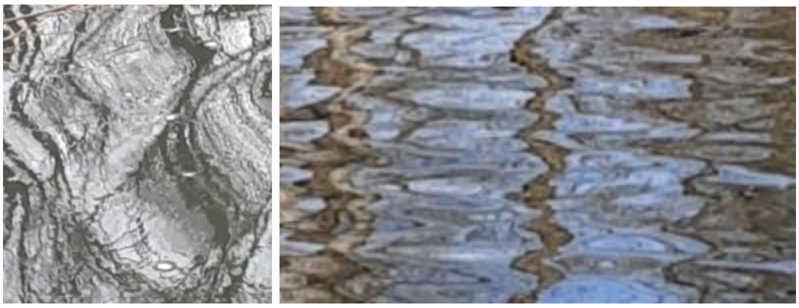

**Figure 9**. Radial natural wave - in the direction of the x and y axes of the shadows trees on the Mura River

## 5 CONCLUSION

Iterative mathematical models are key algorithms (codes) for new CAD, DT and CPS systems. Existing software algorithms for defining curves shift the point of direction y' or a sequence at a certain interval with a given weight sequence. A series of monitored intervals is required to define the S-curve while MGSC resolves this in a single given interval, although not completely automatically. It is necessary to gather more statistical field data and update the proposed linear model with more realistic coefficients.

MGSC is becoming a flexible tool for defining project future in terms of duration and time. Therefore, vector representation of the S-curve as a function of two main project variables creates a modern 3D model of project execution, or more precisely, investment monitoring by simulating project regulation. Measuring or quantifying risk by means of standard deviation or standard deviation of $\sigma$ MGSC events creates project risk probability or RMGSC equation. For the hypothesis to be accurate, it is necessary to have an appropriate database allowing determination of the probability magnitude, i.e. risk coefficient $\lambda r$ and consequently a direct calculation of risk impact on duration, cost and quality. What is expected is further automation in defining time and cost component shifts in the S-curve regarding the functional complement of the risk variable.

The combinatorial equation [20] includes all planned activities and event vectors by homogeneous Markov processes in millions of combinations, optimizing the critical path in production process at a certain S-curve interval.

For the risk coefficient $\lambda r$ to be as realistic as possible, it is necessary to explore the database of finalized and planned projects in more detail. In the next step, it is recommended to educate a creative team manager of corporate security who also has competencies and skills of an IT manager [21] and use a new simulation tool for business project perspectives. A viable business model using artificial intelligence (AR) [22] and CPS can bring FEM mesh technological and organizational breakthroughs in project management standards.

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