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# Time and Cost Schedule Dynamic–Hidden Trojan Horses

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**Abstract:** Investment projects are not the only ones where significant complications in their implementation may occur. The fundamental question, how to specify threats hidden in time series, is one of the most important types of knowledge arising from the basic schedules' documentation. Feasibility studies, project proposals, organizational and production procedures, research projects, and others are major resources of information. The reason why to specify threats hidden in time series is the high cost of not revealing hidden threats. An illustrative clarification of the cost is given on the current data of nuclear power plants. Wherever one works with schedules and resources, the above-mentioned issue may appear. Undeniably, valid data is discoverable ex post in accounting, documentation, or even in the documentation of the preparation and implementation, and in the analyzes of the mechanisms for non-compliance with deadlines and cost increases. For implementation (i.e., ex ante use), the majority of projects are created by expert intuitive decision-making. In terms of content, these are sources of errors from the past, lacking analytical quantitative support (suffering from the so-called evidence shortage). Production schedule time series comprise: (a) cumulative volume, (b) speeds, and (c) accelerations. More recent, in addition to statistical analysis, is the focus on the long-term memory of time series and to the application of the Hurst exponent as indicators of predictability (ex-ante). This article offers a procedure for how to reveal hidden chaotic states in the time series of a project's output information. If it is possible to find chaotic behavior in the output information, these states must be searched for and removed in the original source model—the implementation project. Exceeding contractual terms and implementation costs leads to a threat to the economic basis—the collapse of the initial idea of the project's economy. As an example, nuclear power plant projects are shown. The article broadens the perspective of ex ante decision-making.

**Keywords:** long-term memory; time schedule; time series; production speed; cash flow analysis; risk; decision; sustainability; management; Hurst exponent

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## 1. Introduction

The current successful economy of GDP growth in the last few centuries is accompanied by demands for increased production, requiring production productivity and the transfer of performance to profitability. Those trends are reflected in a newly targeted concept of Industry 4.0 [1,2]. This mainly happens at the expense of business ethics, natural resources, humanitarian principles, climate issues, and other influences [3–6]. From the point of view of the development of theory in economics, it is useful to admit that these are known as dynamic issues, but their forecasts are not known. Future development is threatened by unknown risky behavior, uncertainty, turbulence, and chaotic states.

The key idea is based on tracking the output information from complex implementation structures. If these outputs show stability, it is possible to presume a stable future course of their implementation. The research question in this context can be formulated as: Can the symptoms of chaotic behavior in the output information indicate similar features inside the design of the source model? In other words, we are trying to pay attention to the possibility of hidden chaotic states in the implementation structure (project, schedule) based on the indications of chaotic outputs.

The theoretical economic ideas are about maintaining equilibrium to create a stable state, but dynamic processes notoriously occur over time. Models of thinking in the category of "exact" deterministic mechanisms and their confrontation with the opposite pole, open sets of dynamic processes, are not new. Confusing, chaotic application space in the past has been changed due to the development of computational capacities and nonlinear models that brings positive results. In reality, the decision space is burdened with change, events, turbulence, instability, imbalance, and disorder. The credibility of decision-making is threatened by models that do not consider the so-called known-unknown. The result is the dominance of the empirical model in use, where its deterministic time and cost plans can serve as a hypothetical Trojan Horse for its users, with devastating consequences. An illustrative example deals with the time and cost schedules of investment projects relating to nuclear power plants [7–9].

The structure of the economy (macro), in its substance, is filled with application areas of the economy (micro). From a historical point of view, there have been various disturbances (e.g., depression, crisis) which, subsequently, caused a chain of unstable reactions in certain segments of the economy [10]. Microeconomic disturbances, and their ability to transfer to subsequent technical, technological, and social areas, are specific and special in their effects. The majority of professional areas affected by the failure state are looking for alternative solutions. Decisions are still pragmatic (subjective) in nature and miss their targets. Micro-disruptions can have devastating links to downstream elements of the affected economic segment. The resulting effect can lead to the destruction or attenuation (devastation) of other interconnected functional parts. The search for alternative solutions (e.g., reorganization, restructuring, reform, and others) has not yet been satisfactorily resolved due to multiple factors of economic influence. The theory of nonlinear dynamic processes qualifies as a branch point [11]. The difficulty of the mentioned state lies both in the factual interpretation and in the choice of the right path to a new stable state. Forecasting the effect of accepted changes on the structure (the mechanism) of other internal processes requires strengthening the apparatus of indicators. In general, the theory of dynamic processes is oriented to two possible consequences:

- a transition to a status called chaos, or
- a transition to a higher form of arrangement—the so-called dissipative structure.

Higher forms of organization are generally more demanding on resources (e.g., energy, knowledge, information, etc.). So far, the verifiability of tool effectiveness to secure bases from chaotic situations is the subject of research. The statement in [11] mentions that a new stabilized arrangement can arise spontaneously, by self-organization, and has a physical and objective principle. The projection into economics is more difficult to interpret. From the economic point of view of resource costing liquidity, including the loss of income during the project life cycle, the costs exceed the investment resources many times over.

Among professionals, there is a widespread idea that there are new technical skills that bring economic effects. However, the fact is that the effects are available at the expense of higher energy inputs of resources, which are necessarily covered by the need for higher profit. For example, the following could be mentioned:

- materials (new, higher quality, demanding to manufacture and process),
- work effort (need to increase skills, education, employment, etc.),
- technological equipment (machines, robotics, informatics, etc.),
- energy sources (nuclear, hydrogen, solar, etc.),
- informational (data, SWOT analysis, new theoretical knowledge of synthesis and design, decision-making, etc.).

A comprehensive analysis by Dorothy Neufeld is given in [12,13]. Her comments in response to the economist Joseph Schumpeter's theory of "creative destruction", proposed in 1942, are inspirational nowadays. Creative destruction suggests that business cycles operate under long waves of innovation. The [14] different waves of innovation mentioned in [12], from water power in 1775 to robots and drones in 2020, result in an innovative trend. Innovation is consistently considered an essential tool for micro-development from the modern point of view. An innovation is identified as an investment for purposeful development. It undoubtedly co-creates the basis for economic development. Figure 1 focuses on the link between innovation and economic exploitation over a period of time.

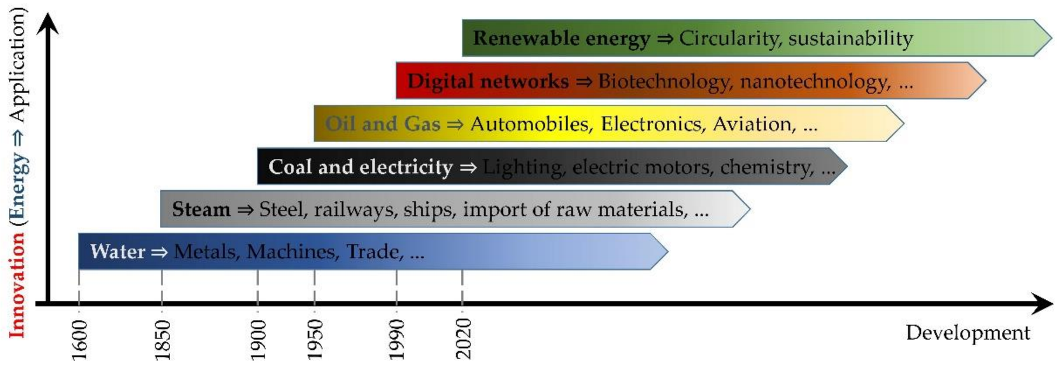


**Figure 1.** Innovative structure, waves of innovation, years 1600–2020. Source: authors according to [12,15].

The neglected fact is that the necessary development of economic theory has been underestimated so far. Equilibrium states are generally considered basic attributes. States close to equilibrium, and their influence on economic development, are frequently neglected. The consequence is that the indicators of threats to the rationality of decision-making about possible (mostly technically conditioned) development trends and their economic feasibility leave space for subjective decision-making. The rationality of such processes is as problematic as it is risky. A number of illustrative examples can be found: the financial crisis, currency crisis, hyperinflation, devaluation, banking crisis, credit crunch, bank run, recession, economic bubble, inflation bubble, stock market bubble, real estate bubble, overproduction, underconsumption, demand shortfall, deindustrialization, wage-price spiral, innovation, invention, labor migration, and more [16–19].

Earlier in time, in the same vein, an economist, Hamburger L., published the links between investment and savings in [20]. Subsequently, the economist Samuelson published in [21] an explanation of the business cycle and oscillation behavior. The economist Kaldor [15] is an important personality dealing with the non-linear cyclical model. However, his reasoning did not create the prerequisites for the improvement of macro- and microdynamics.

Figure 1 indicates how innovations are based on energy resources. How do they enable the subsequent expansion of new areas of innovation? More demanding, i.e., more expensive, inputs of resources necessarily require the compensation of higher levels of benefits (revenues). With a certain tolerance for expediency, it can be stated that every transition from one historical energy level to a higher one has been accompanied by crisis phenomena (such as bifurcations, turbulence, and chaos). Technical and economic changes burden consequences; they rearrange resources, knowledge, efforts, the status of social groups, etc.

The solution procedure will focus on the investigation of output information in the form of time series of production rates. The implementation is accompanied by risk effects caused by price fluctuations or the inappropriate planning of resources. The output information may contain hidden chaotic states leading to excessive deadlines and cost overruns. By demonstrating these states in the outputs, it is possible to assume their occurrence in the source model—the implementation project. The analysis leads to the creation of a simulation cycle which identifies these states and guides the designer to adjustments that strengthen the project's resistance to chaotic behavior due to risks.

## 2. Materials and Methods

The economic consequences of disparities in the design and implementation of technical projects often balance on the edge of economically viable benefits (examples are large investment projects; nuclear power plants are undoubtedly among them) [22,23]. The efforts aimed at sustainable development in this regard are reflected in the resonant concept of the circular economy [24–29]. The International Atomic Energy Agency and the PRIS are dedicated to the issues of exceeding deadlines and costs. Eight implementations of nuclear power plants are listed in Table 1. They deviate from the framework of term and cost standards. The generally achieved construction delays range around one year. According to data registered by the IAEA, 58.5% of 31 implementation projects reported delays.

The scheduling of resources is the domain of subjective trial-and-error interventions. The applications occur across many scientific disciplines. The example from the field of nuclear energy was chosen for its economic robustness in the research, and especially the application-investment area. From the data in Tables 1 and 2, the disproportions of demanding technology are evident. The economics of investment return, and the shortening of the life cycle accompanied by the costs of deconstruction, are generally devastating. In addition, there exists the issue of the deconstruction of permanently shut-down reactors. The IAEA–PRIS database lists in [29], for the years between 2021 and 2022, only six reactors newly connected to the network (capacity (5310 MWe) compared to 10 shut-down reactors (capacity 8668 MWe) worldwide. The need for resource scheduling is also dominant. It is proven by the branch profile of responses in the Web of Science Core Collection database for the term "schedule/scheduling", which has more than 400,000 responses (see Appendix A). Responses for the scheduling of non-linear processes reveal a still poorly resolved issue, falling to fractions of responses or even units of published works.

The technical and economic interconnectedness is documented by the duration of implementation together with the achieved productivities of the final outputs, as well as the MWe of the project. Although attention is paid to the implementation documentation, the breakdown of a project into time and cost arrangements is a weak point in the preparation and control of large-scale investments. Evaluation processes, including used SW support, tend to use traditional empirical a posteriori procedures. The calculations of the characteristics of the design dynamics and implementation represent a petrified development potential. The barrier of hardware computing capacity for large-scale tasks is gone. Even for large-scale projects, with thousands of activities and simulation calculation iteration, calculations of analysis can be implemented and interpreted [8,30,31].

**Table 1.** Nuclear plants with excessive construction time. Source: authors according to IAEA [22,29,32,33].

| Reactor/Country | Constructor | Nominal Power (MWe) | Beginning of Construction | Connection to the Grid | Time (Month) |
|---|---|---|---|---|---|
| ANGRA 2/Brazil | KWU | 1350 | January/76 | February/01 | 301 |
| KALNIN-3/Russia | FAEA | 1000 | October/85 | November/05 | 241 |
| VOLGODONSK-1/Russia | FAEA | 1000 | September/81 | December/01 | 243 |
| MOCHOVCE-2/Slovakia | SKODA | 440 | October/83 | April/00 | 198 |
| KHMELNITSKI-2/Ukraine | PAIP | 1000 | February/85 | December/05 | 250 |
| ROVNO-4/Ukraine | PAA | 1000 | August/86 | April/06 | 236 |
| COMANCHE PEAK-2/EUA | WH | 1215 | October/74 | August/93 | 226 |
| WATTS BAR-1/EUA | WH | 1270 | December/72 | May/96 | 281 |

**Table 2.** Comparative indicators based on productivity. Extended calculation. Source: authors.

| Reactor | Time (Month) | Time (Year) | Months (MWe) Productivity | Productivity Divergence | Construction Divergence |
|---|---|---|---|---|---|
| ANGRA 2 | 301 | 25.1 | 4.485 | 0.347 | 4.500 |
| KALNIN-3 | 241 | 20.1 | 4.149 | 0.011 | −0.500 |
| VOLGODONSK-1 | 243 | 20.3 | 4.115 | −0.023 | −0.333 |
| MOCHOVCE-2 | 198 | 16.5 | 2.222 | −1.916 | −4.083 |
| KHMELNITSKI-2 | 250 | 20.8 | 4.000 | −0.138 | 0.250 |
| ROVNO-4 | 236 | 19.7 | 4.237 | 0.099 | −0.917 |
| COMANCHE PEAK-2 | 226 | 18.8 | 5.376 | 1.238 | −1.750 |
| WATTS BAR-1 | 281 | 23.4 | 4.520 | 0.381 | 2.833 |

The data in Table 1 allow the calculation of nominal power productivity (MWe/construction months). This indicates the productivity of the project scope in relation to the output purpose unit (MWe). The spread between the implementation intensity achieved at Comanche Peak–2 (EUA/US), 5.376 MWe/months, and Mochovce (Slovakia), 2.222 MWe/months, represents almost 2.5× lower productivity of nominal power per month during the implementation of the power plant. The calculation is given in more detail in Table 2: Comparative indicators based on productivity. A high disparity in construction time divergence (years) arose between the power plants Angra 2 and Mochovce-2 (4.500 + ABS(−4.083) = 8.583 years.

Expressed in time, this shows a difference of 8.583 × 12 = 103 months. Converted to the loss of the average 4.138 nominal power (MWe/months) calculated in Table 2, the disparity of 4.138 × 103 = 426 MWe is the equivalent (approx. 50%) of the output power capacity of one power plant.

An investigation of construction times in years is shown in Figure 2. The data is divided into about 15% of nuclear power plants with unusually long construction times and deadline-relevant realizations—85%. The illation of cost implications is proportional to t. The data in Figure 1 highlight the underestimation of the cost consequences in time–cost scheduling. The focus of the article's motivation lies precisely in this area. The indicators of defects in the time–cost scheduling are absent in the implementation documentation, both in the implementation of large-scale investment projects and in the design and preparation phase of project implementation. This often initiates the beginning of a process that has the character of an introduced critical conceptual error. The identification of critical points in proposals and time–cost scheduling is generally a weak point of practiced micro-dynamics.

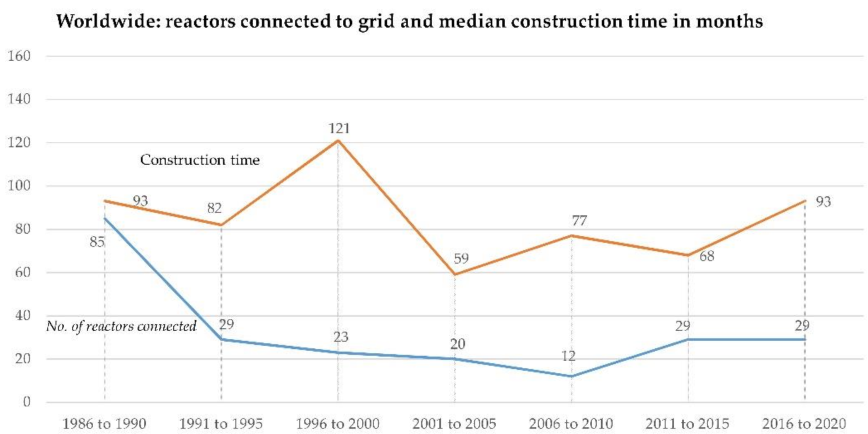


**Figure 2.** Construction time (years) of nuclear power plants (2006–2016). Source: authors according to [29].

## 3. Model and Data

The idea foundation of evaluating the states of designs and implementation models, in general, is the ability for reflective compilation of future implementation situations (with follow-up graphs, causal dependencies, formulas, etc.). This structure is marked as an organizational chart—$TAB_{Org}$. If we want to consider that the content of the model is complex (if it contains, for example, legal, contractual, technological, microeconomic, and other segments), the model is stated as:

$$TAB_{Complex} = \{TAB_{Org} \cup TAB_{Jur} \cup TAB_{Cont} \cup TAB_{Budg} \cup \ldots\} \tag{1}$$

where $TAB_{Org}$ is the structure of the organizational chart, $TAB_{Jur}$ is the structure of the legal regulations and standards, $TAB_{Cont}$ is the structure of the contract documents, and $TAB_{Budg}$ is the structure of the cost documents and budgets.

Each of the listed $TAB_{(\bullet)}$ in (1) has its own calculation algorithm. In the sense of the Church–Turing computability thesis, computable functions are exactly the functions that can be calculated using a mechanical calculation device, given unlimited amounts of time and storage space. Exaggerating the generality, let us consider the successors of mechanical calculators as a category that Church–Turing also covers. Equivalently, this thesis states that a function is computable if and only if it has an algorithm.

The significant outputs of $TAB_{(\bullet)}$, time–cost scheduling projects and the time series of resource layouts, are outputs with the following properties:

- they are based on the resource layout of individual activities ($A_1, A_2, \ldots, A_m$);
- and allow the creation of a resource layout for:
- characterizing the $TAB_{Complex}$ project as a whole,
- deriving its other characteristics.

In more detail, the basic structure of the project output calculation is described as:

$$\begin{gathered} P_{Outputs}(A) = [D_A, t_{Start}, t_{End}, \{Q_t\}, \{Q_t{}'\}, \{Q_t{}''\}, \{Q_t{}'''\}] \mid G_{Org}(A) \\ \text{for } \forall i \in m, \forall t \in n \end{gathered} \tag{2}$$

Costing for $P_{Outputs}$, (2) shows works [31,32], where:

- D–is the set of durations $D = (D_1, D_2, \ldots, D_m)$, where $Q_i > 0, \forall i \in m$;
- Q–is the set of quantities $Q = (Q_1, Q_2, \ldots, Q_m)$, where $Q_i > 0, \forall i \in m$;
- $\{Q_t{}'\}, \{Q_t{}''\}, \{Q_t{}'''\}$ are the time series of the production speeds, speed acceleration, and acceleration impulses, for $\forall t \in n$;
- $G_{Org}(A)$ is the organizational structure of all activities (network structure).

To assess the properties of the individual proposals of the time–cost scheduling project $TAB_{(\bullet)}$, the time series of production rates $\{Q_t{}'\}_{Project}$ was chosen. This is the main economic output; it characterizes the economic and technical levels of the project proposal.

An example of the devastating effects of the low productivity of the construction of nuclear power plants, with the consequence of long construction times, was given in the introductory part of this article. These include increased construction costs, lost revenue from the sale of MWe, reduced lifetime, and others (deconstruction, security measures, environmental impact, etc.).

## 4. Simulation

To bring the $TAB_{(\bullet)}$ calculation closer to reality, a simulation of externalities was introduced into the calculation. The volatilities of the input parameters make it possible to assess the induced consequences (+ and −). These include changes in the project, work organization, subcontractors, technologies, material inputs, and others. A schematic notation (2), extended by simulations, changes the scope from (internal) activities to the project as a whole, including external influences in the form of

$$P_{Outputs}(\text{Project}) = \{TAB_{(\bullet)} \mid Sim_{(\bullet)}\} \tag{3}$$

Or, more precisely,

$$P_{Outputs}(A) = \{\{[D_A, t_{Start}, t_{End}, \{Q_i\}, \{Q_t{}'\}, \{Q_t{}''\}, \{Q_t{}'''\}] \mid G_{Org}(A)\} \mid Sim_{(\bullet)}\}\} \\ \text{for } \forall i \in m, \forall t \in n \quad (4)$$

Each calculation of simulation [34,35] provides outputs for induced (changed) inputs. The externalities are simulated processes reinstated into states that can occur during their implementation. In this context, simulation has a wider application meaning. It uncovers the potential of input volatility or, in other words, the dynamics of the potential for positive or negative effects over time.

It complements the structure of possible management measures with quantitative indicators. It allows us to distinguish the expected from the unexpected or extremely unexpected situations. It evaluates the data of expert proposals for new possibilities of interpretation in areas such as project management, technical design, production processes, and others. Furthermore, it supports an expert comparison of the variants:

- Variant (1)–targeted interventions to increase the stability (robustness) of the project, and
- Variant (2)–anticipation of the consequences of ex ante forecasts.

The stages of the simulation sequence are described schematically:

Process formation ($G_{Org}$, elements, links, budgets, contractual relations) $\rightarrow$ Externalities (Generating the inputs of simulation calculations of variants 1, 2, etc.) $\rightarrow$ Decision making (interpretation, indicators, economic impacts, solution management).

The quantification of simulation outputs is shown on the three simulation outputs of the project $P_{Outputs}(A)$:

1. A representation of the production rate outputs of three selected simulation courses $P_{Outputs}(A)^{Var1}$, $P_{Outputs}(A)^{Var2}$, and $P_{Outputs}(A)^{Var3}$ from the spectrum Sim 1 to Sim 100 is shown in Figure 3 for the linear variant. Each simulation run (1 to 100) carries out a (specific) variant of the project externalities; a deterministic calculation takes place with a linear distribution of resources of individual activities A without changes in organizational or technological links in the structure.
2. The evaluation of changes in the structure of ties and content of activities A is a separate task. It is a proposal for new default projects such as $P_{Outputs}(A)^{Var1}$, $P_{Outputs}(A)^{Var2}$, $P_{Outputs}(A)^{Var3}$. Their evaluation requires new calculations of $TAB_{(\bullet)}$. The goal is to reveal the properties of $P_{(\bullet)\,Outputs}(A)$ projects throughout the simulation. Simulations capture divergences, volatility, rarely occurring extreme execution courses, resource requirements, and completion dates. The combination in $\{TAB_{(\bullet)} \mid Sim_{(\bullet)}\}$ and $G_{Org}(A)$ with its outputs brings surprising results, in many cases. In particular, $\{Q_t{}'\}$ outputs can draw attention to so-called rarely occurred phenomena. They make it possible to recognize threats in advance during the implementation of projects. They open the way for further adjustments and changes to the substantive technical or organizational time course of the project solution.

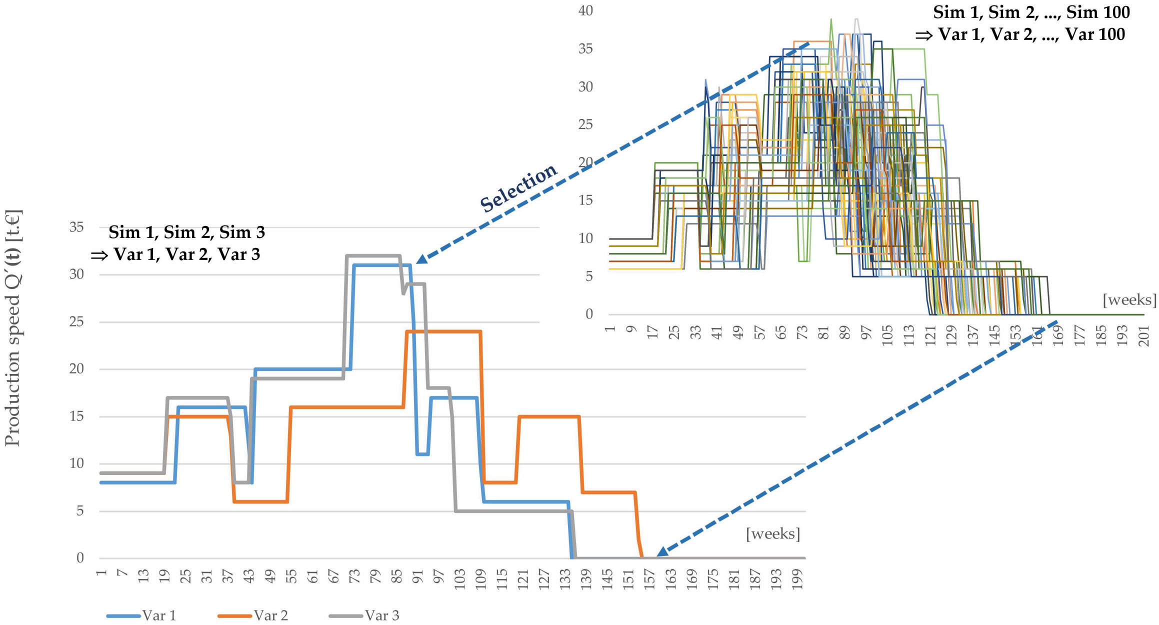


**Figure 3.** Var 1, 2, 3–assessment of project production speeds and durations–linear distribution of resources. (Source: authors).

## 5. Illustrative Example of Linear and Logistic Resource Schedule

An illustrative example of the linear distribution of resources on individual activities presented in Figure 3 will be compared with the resource schedule for Ai using the logistic function. The solution is to give an answer to the question: to what extent the linear simplification of the distribution of resource consumption is verifiable, and what kind of risks it brings? Figure 4 shows the graphical representation of time series data of the production rates $Q'(t)$ based on the logistic function. Subjectively, the distribution of resources using the logistic function can be considered more realistic. On the other hand, the subjective assessment of the course of the production rates of the linear distribution of resources shows lower volatility (Figure 5) compared to the variant with the logistic distribution of resources during the implementation of the project.

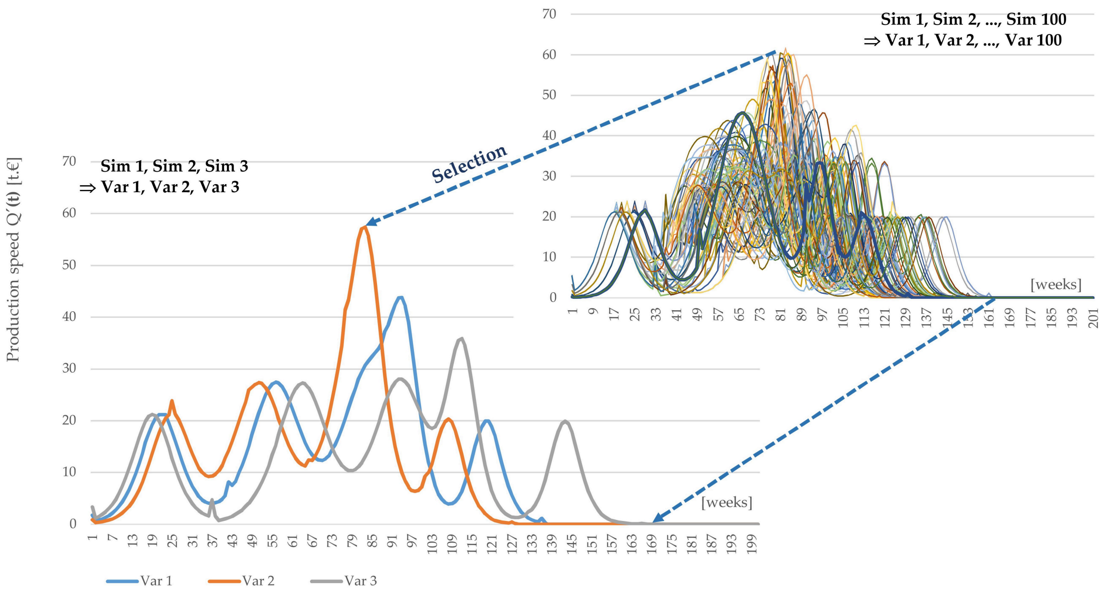


**Figure 4.** Var 1, 2, 3–assessment of project production speeds and durations–logistic distribution of resources. (Source: authors).

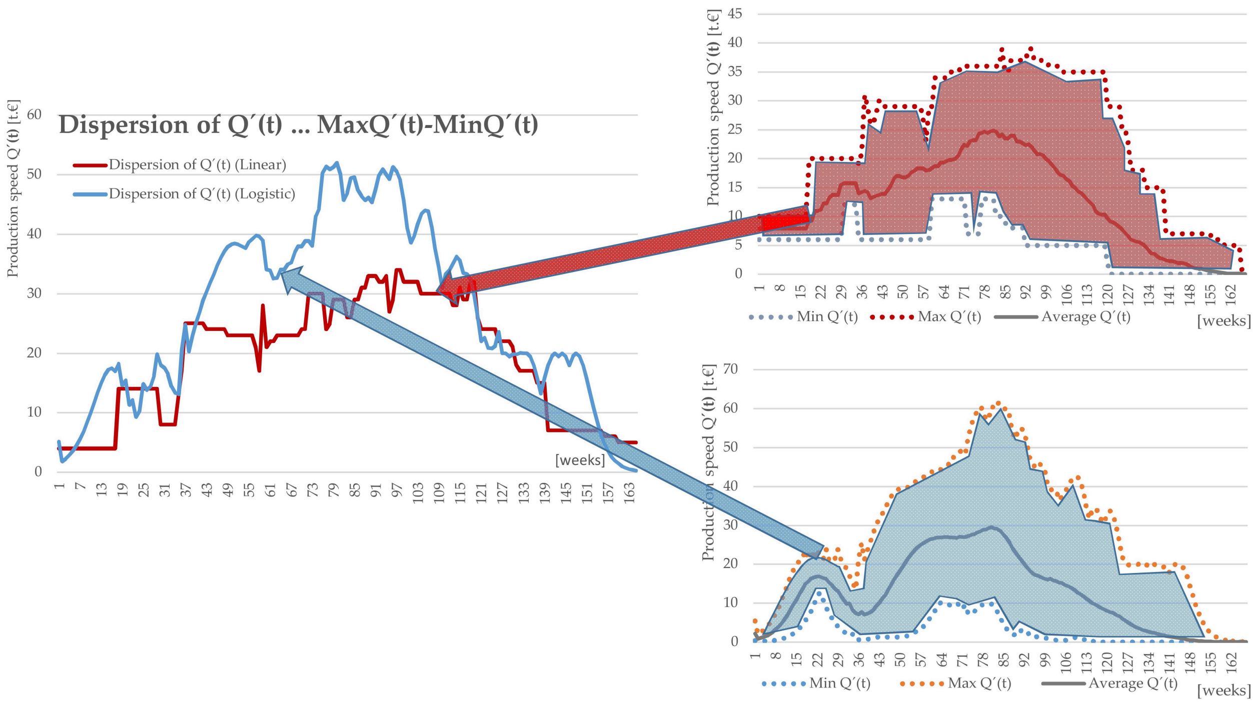


**Figure 5.** Dispersion of production rates Sim (100×), time series Max $Q'(t)$–Min $Q'(t)$, linear and logistical resource distribution. (Source: authors).

A comparison of the durations of both variants shows negligible deviations. The evaluation of the durations from the simulations is shown by the graphs in Figure 6. The structure of the frequency of occurrences shows more significant differences. The idealization of production processes during linearization can be misleading. Interpretation can lead to a fictitious positive assessment of situations, creating introduced errors in management assessment and decision-making. In order to objectify the evaluation, it is possible to expand the characteristics by other substantive indicators. Their role should be to recognize the behavior of the proposed time schedule of the $G_{Org}$(A) during implementation. The trajectory of the simulation iterations is stated in Figures 3 and 4. Each simulation of a dynamic production process is microeconomically relevant. It is a spectrum of responses to the influence of externalities. The statistical apparatus provides important information about states and so captures the properties of the time series.

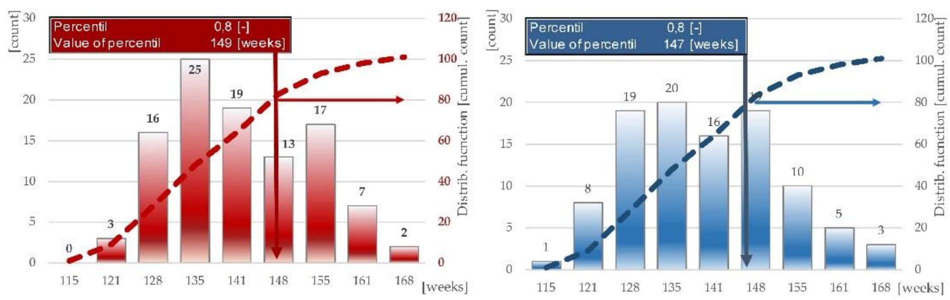


**Figure 6.** Frequency distribution of the end-date values and their distribution function (linear and logistical variant). (Source: authors).

By properties, it is meant the interpretive availability, using examples:

- the volatility of resource needs one time interval;
- the characteristics of the time distribution of the process implementation;
- fault propagation;
- the occurrence of emergency situations;

- block cycle production.

Microeconomically, the diversification of material influences and the influence of timeline implementation is essential. It is part of the configuration of project economic admissibility, i.e., the return of resources, revenue percentage, etc. Macroeconomics devotes its main efforts to aggregation, the conversion of multiple economic phenomena into the diction of economic regularities. There is an evaluation of probabilistic approaches and the trajectory of dynamic models. Microeconomic models face the inflation of the data scope from the exposure to externalities and the varied potential of the possible/permissible/organizational/production variants of solutions. The need for tools for large data set evaluation is caused by the number of elements by which the process (project) is formed. Expert, mostly partial, intuitive evaluations are exposed to significant risks of error. The demonstrated example of the resolution between the linear and non-linear distribution of resources is based on tracking and statistics frequency. A comparison of factual content in Figure 3 versus Figure 4 gives attention to the difference in volatility (Figure 6) and its configuration (optimistic stylization by linearization) in a simulated hypothesis of possible realization courses. For many projects, the acceptance of a linear schedule is an established mistake. Interventions in the organizational structure of $G_{Org}$ project lead to the creation of variants. The need for their quantified assessment is as necessary as it is underdeveloped.

Recognizing the characteristics of the proposal brings both the knowledge of threats (risks) and the potential opportunities (benefits).

## 6. Case Study–Extension

The characteristics in Figure 6 have been constructed for 100 simulation runs of the illustrative example. The time series $\{Q_t'\}$ of the productivities (production rates) of the $TAB_{(\bullet)}$ project is a data source for evaluating the project properties. It characterizes how the project was designed from a technical, technological, and organizational point of view. An answer to the following question is expected: to what extent does the method of resource distribution in individual $TAB_{(Lin)}$ or $TAB_{(\mathrm{Log})}$ activities regulate the properties of the project as a whole? In this case, there is a comparison of the variants $TAB_{(Lin)}$ and $TAB_{(Log)}$:

- Variant 1–$TAB_{(Lin)}$–linear distribution of resources of individual activities A provides a time series $\{Q_t'\}_{Lin}$; see Figure 3.
- Variant 2–$TAB_{(Log)}$ –logistical distribution of resources of individual activities A provides a time series $\{Q_t'\}_{Log}$, solved under the same conditions; see Figure 4.

The Hurst (H) exponent was chosen as the basic indicator for the time series evaluation. It is considered an indicator of dependence, an indicator of long-range dependence, or a long-term memory of a time series. It belongs among the initial indicators of the possible presence of chaos in the investigated time series. It ranges between zero and one.

- Values approaching the extremes of 0 and 1 point to the significant deterministic nature of the process.
- If the Hurst exponent values lie between 0 and 0.5 or 0.5 and 1, this indicates the presence of deterministic chaos:
    - $H < 0.5$ anti-persistent, (temporary, non-recurrent),
    - $H > 0.5$ persistent and has long-term memory (permanent),
    - $H = 0.5$ stochastic.

The calculation of H exponents for cash-flow, $\{Q_t'\}_{\mathrm{Lin}}$ and $\{Q_t'\}_{\mathrm{Log}}$, is based on the data of Figures 3 and 4. It indicates that the implementation of the processes in $TAB_{(Lin)}$ and $TAB_{(Log)}$ have a significant deterministic disposition, and a long-term positive autocorrelation (high productivity values in a time series will tend to continue with high values in the future); the time series data are significantly persistent with a long-term memory and with an indication of the possible presence of chaos.

*6.1. Linear Variant*

The values of H exponent approach the limit of 1.00, closer to a more deterministic behavior compared to the distribution of resources on activities based on a logistic function. It can be stated that the volatility shown in Figure 5 is lower for the linear distribution of resources than for the distribution of resources using the logistic function. The time series of H indices, created from the data of the simulated production speed courses in Figure 7, shows persistent behavior and has a long-term memory. The presence of chaotic behavior in some simulations cannot be ruled out. In Figure 7, partial deviations of the H coefficient from the deterministic state are visible. Their frequency is for each set of simulation iterations, an individual fingerprint of the accepted changes.

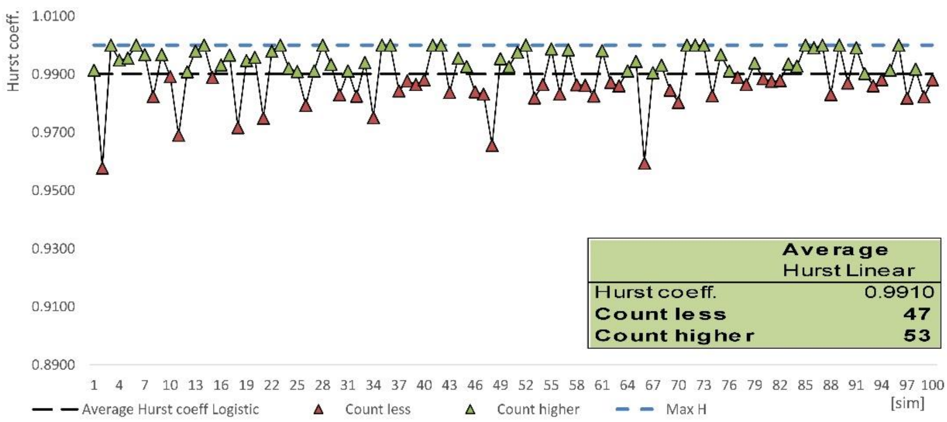


**Figure 7.** Value under- and above-average of Hurst coefficient (linear variant). (Source: authors).

*6.2. Logistics Function of Resource Distribution*

The volatility shown in Figure 5 is higher for the logistic nonlinear resource distribution than for the resource distribution by the linear function. The time series of H indices is created from the data of the simulated production speed courses in Figure 8. The linear variants show persistent behavior and have a long-term memory. The presence of chaotic behavior in some simulations cannot be eliminated. In the representation of Figure 8, there are noticeable, especially more pronounced, slumps from the deterministic state than in the case of the linear resources distribution.

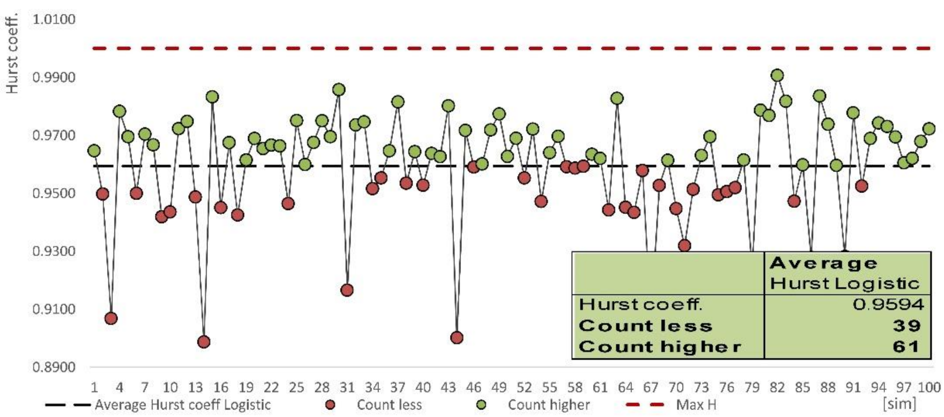


**Figure 8.** Value under- and above-average Hurst coefficient (logistic variant). (Source: authors).

The linear variant shows almost half the difference (0.056) between the minimal and maximal value of the H coefficient compared to the logistic variant (0.092). The graphic representation is presented in Figure 9. The non-linear function of resource distribution—the Hurst logistic—shows higher differences between the minimal and maximal values of H–

coefficients than the linear course of H–coefficients. Through interpretation, it was found that logistic functions are more suitable for practical applications of resource distribution.

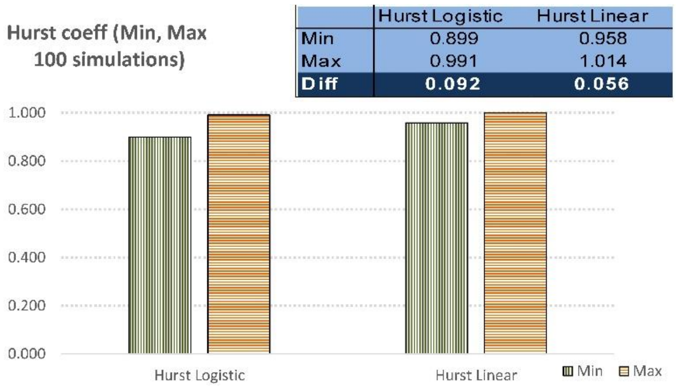


**Figure 9.** Min and max values of Hurst coefficient (logistic and linear variant). (Source: authors).

Relatively small differences are given by masking the positive and negative deviations in the calculation of the arithmetic mean. The sum of the distances measured from the maximal limit of the Hurst coefficient means a more expressive description of the difference between the logistic and linear distribution of resources in production process activities. The higher the value is, the greater the total distance from the maximum H–coefficient, i.e., the extreme of deflection in the model of the implementation process (Table 3).

**Table 3.** Sum of distances from max. Hurst coefficient. (Source: authors).

| **Sum of Distances from Max. Hurst** | |
|---|---|
| Distances Logistic | 4.0644 |
| Distances Linear | 0.9041 |

The use of a linear distribution of resources in the activities of individual production processes has a closer connection to the limit of deterministic behavior—value 1. It is closer to deterministic behavior. The distance for the logistic distribution function increases to 4.0644 in an illustrative example, according to Tab. 3. In individual stages, it significantly becomes more distant from the deterministic limit of 1.00. A separate issue is the detection of long-term memory of time series data and the indication of chaotic states in their factual structure, for example, the links between activities, durations, proposed production rates, and more. This creates a prerequisite for creating suitable software.

The entire simulation process, including the evaluation, can be seen in Figure 10. The upper part examines the original reference project up to the phase of obtaining the evaluation characteristics. If the project proposal is accepted but does not carry out the feasibility conditions, it is stopped as unsuitable for implementation (Stopping of the project). Otherwise, a cycle of the project proposal correction with simulation (Proposal revision) is started, which ends with a comparison with the reference state (Comparison with reference project). When it shows improvement, it can be assumed that there may not be hidden chaotic conditions in the project and a recommendation for its implementation is expected. The opposite case returns the project proposal in the cycle to the state of correction (Proposal revision) and its further evaluation.

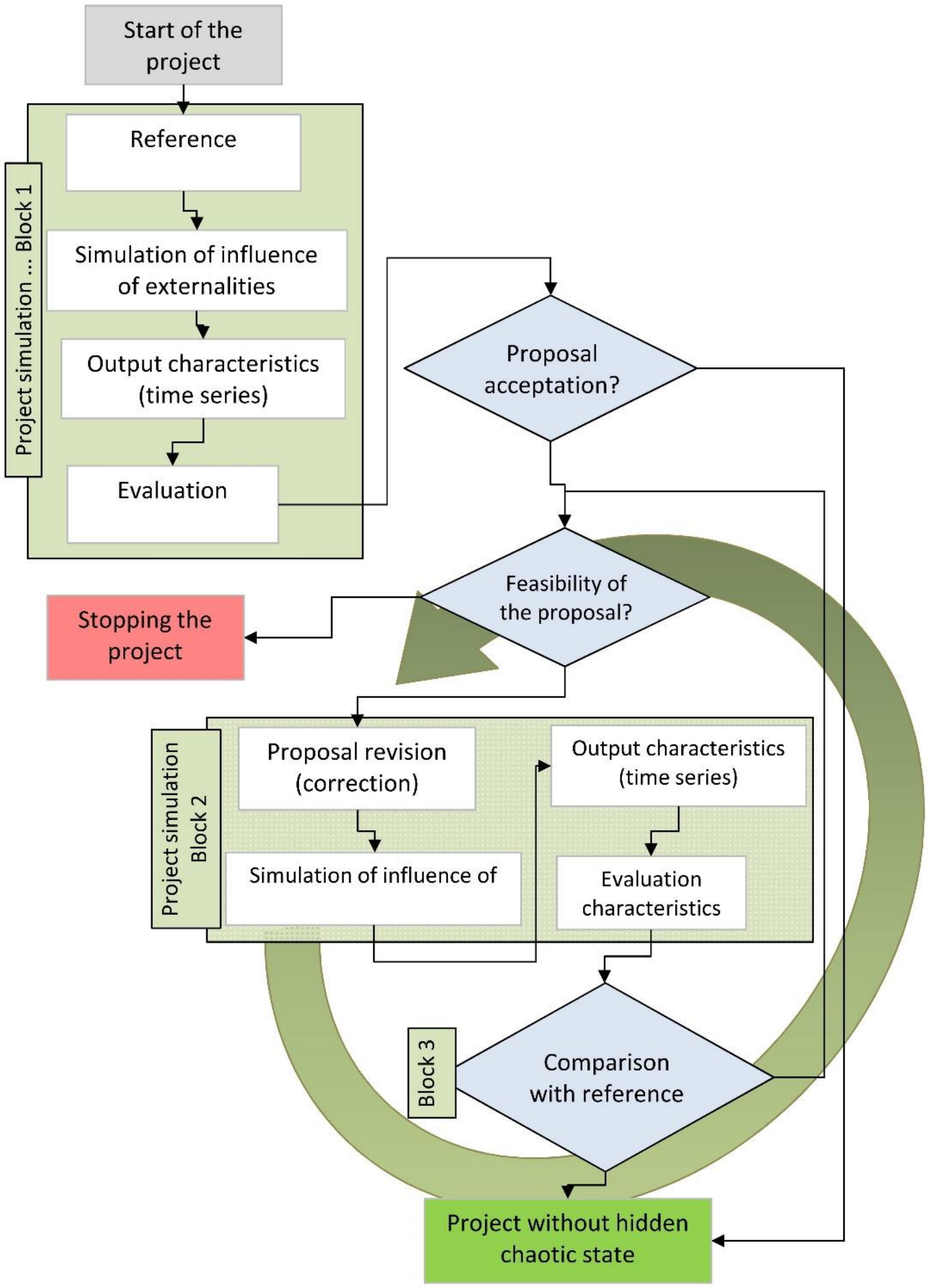


**Figure 10.** The simulation circle flowchart. Source: authors.

## 7. Conclusions

The quality of the result is influenced by the quality of the design phase. A project's implementation is undeniably a partial phase of its life cycle. It ensures the construction of a new investment work or property. Actors are authorized and legally bound by the signatures of contractual relations. Each project proposal is documented, among other things, by organizational technical and technological documentation. The key document is the time schedule (Reference proposal in Figure 10) of acquisition costs–project design, project implementation, operation of the work, cycles of maintenance, renewal, modernization, and deconstruction.

The time schedule is a hypothesis about the implementation of partial activities and is simply generally understood as a proposal implementation with limits, based on costs and durations. The reality is that project implementation often falls short of expectations. The disparities between hypotheses and realizations (Comparison with reference project in Figure 10) are numerous and economically painful. Publications such as [36–39] and analyzes such as [32,40] deal with the study of the phenomenon of multiple costs and term extensions. The intermittent implementation of investment projects, unfinished projects, and the deconstruction of projects before the start of use or during the lifetime of the investment are an indispensable warning. The present article offers a methodological tool (with the flowchart in Figure 10) for the early indication of potential threats and introduced errors as a response to the specification of the threat of the implementation of different projects. The schedule of works is undeniably one of the key documents of the substantive content of the project, linked to the contractual relationships about deadlines and costs, with spillovers to property supply determinants [41], including housing affordability [18], policy responses [5], and possibly social tensions [42]. The recognition of competence also faces conflicts of interest.

The task, an illustrative example of scheduling, is considered in the interpretation as a singular element of the processing. The subsequent partial blocks in Figure 10 solve: the Block 1 Externality realization forming the block by simulating the source model as potential ex ante states. The Block 2 Risk simulation creates input modifications based on the input resource model for scheduling. At the end of Block 3, the Evaluation uses the Hurst exponent as an indicator of long-term memory and the predictability of the simulated data (ex ante).

For example, for applications in physics [11], mathematical statistics [43–45] are a certain vision of the possible. They deal with the theoretical basis of dynamics, thermodynamics, etc. In this context, it is difficult to admit that the non-linearity, discontinuity, and randomness of the proposed solutions would be a good image for understanding a deeper idea. However, if we deepen our knowledge, we reduce skepticism about the unknown [46].

A schedule that is recognized and revised in time as a document will not act as a potential Trojan Horse in the project life cycle. The difficulty is the fact that the development of physics, mathematics, and statistics is based on tasks of a relatively small scale, for example, a few well-analyzed differential equations. The economy of designing projects and their implementation is burdened by the scope and the dimension of the input parameters. Multiple internal influences in the project solution, together with weakly formalized models and externalities, worsen the transparency of design. The alternation of purposive intuition for objective methods loses many of the elegant and available principles of classical theory for large-scale tasks [47].

The key idea expressed at the beginning of the text can be discussed on the basis of Figures 7 and 8. For the linear variant of resource extraction, the indicative values of the H-coefficient move less from the limit boundary, i.e., they show signs of deterministic behavior. In the case of the logistic variant of the output information, the implementation structure of the project must also be analyzed. The answer to the research question mentioned in the introduction is yes; in the case illustrated in Figure 8, attention should be paid to the possibility of hidden chaotic states in future implementation. After revising this structure, it is possible to repeat the entire simulation apparatus and carry out a new evaluation, according to the cycle in Figure 10. The form of the process is thus a tool for evaluating the individual variants. The suggested procedure reflects the empirical proposal, which does not have the ability to perceive the presence of hidden chaotic states in the complex structure. The project can accept situations with extended deadlines or increased costs, but not in a chaotic manner.

Extensive data sets can solve not only the consequences but also the causes of critical situations in large-scale economic and technical projects [35,48–50]. Let us conclude with the convenience of generalization in the sense of [11]. The Trojan Horse causes chaos in designing projects, but it is an environment for finding ways out, bifurcation nodes with the potential for new, variant, or alternative solutions to the problem.

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## Appendix A

The generality of the method is focused on the nonlinear dynamics of the schedule processes. The use of the Hurst exponent is the first necessary step for further analytical activities. The documentation, established in practice for the implementation of large-scale investments, mainly applies approaches working with subjective estimates and a linear derivation of input parameters. The consequence is the extension of project implementation time and the introduction of chaotic conditions during rectification measures. Published studies attempt to address this. However, the frequency of outputs does not yet include the tools of the economic application area, as can be seen from the sectoral profile of responses in the Web of Science Core Collection database for the term "schedule/scheduling" (see Figure A1).

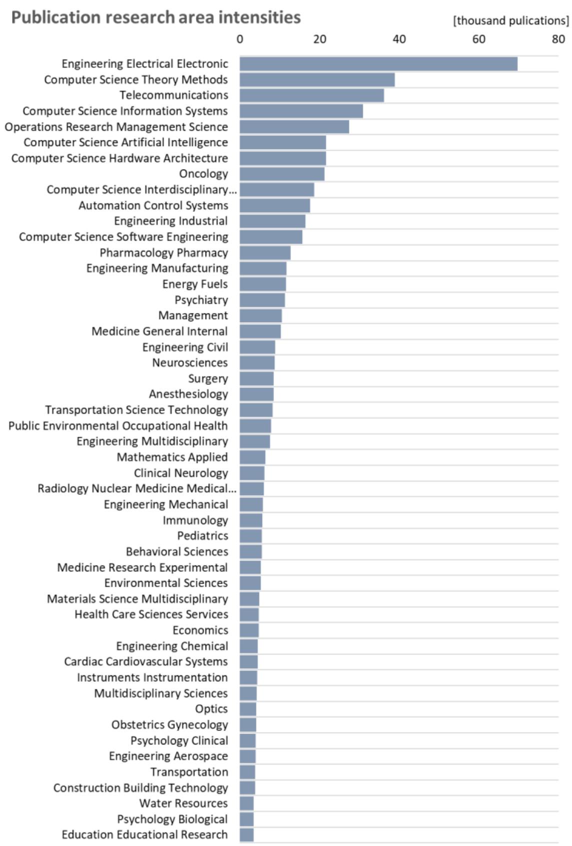


**Figure A1.** Publication research area intensities. Source: authors according to data of Web of Science Core Collection.

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