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MULTISYSTEMIC MODELING TO IMPROVE FORECAST ACCURACY IN CONSTRUCTION MANAGEMENT

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Process modeling and simulations provide indispensable support during project preparation, construction process planning, and execution. Realistic correlation modeling in construction management and/or economics is crucial to inform meaningful, beneficial process simulations. Inductive approach to reflecting reality in a (computation) model enables prospective consideration of the object or process under study and related analyses. This method aids decision making in construction management related projects and contributes to developing new computation models. Linking the management of chances and risks to construction process modeling is thus an essential tool for systematically making and implementing decisions in construction management and economics. Forecast-based conclusions regarding future developments or events require computation models to be developed based on hands-on experience and practical feasibility whilst relying on sound theoretical assumptions, required abstraction levels, simplifications, and considering their mathematical implementation. The resulting model is linked to model objects for which it was developed and to which it is applied. Model objects may include entire buildings or structures, contract sections, or individual structural components, such as those for which construction processes and logistics as well as construction times and costs are determined. Monte Carlo simulations are applied to systematically account for uncertainties. Derived models should be closely related to the aspects and societal challenges of interdisciplinarity, simulation, and digitization. This paper outlines the requirements that a multisystemic model should fulfill to increase forecast accuracy.

Keywords: Project preparation time, Construction costs, Construction time, Productivity, Management of chances and risks.

1 INTRODUCTION

Forecast-based conclusions regarding future developments or events require computation models to be developed based on hands-on experience and practical feasibility whilst relying on sound theoretical assumptions, required levels of abstraction, and simplifications, and considering their mathematical implementation.

Reflecting reality in a (simplified) computation model is an inductive thought process that enables indirect consideration and analysis of the object under study (Töllner 2010). As a rule, real systems can never be completely identified or represented, which is why it is usually inevitable to only consider certain sections of such a real system. Models are generally characterized by three main criteria or features:

- Representation feature: models are representations of real or theoretical systems or originals (social, technical, socio-technical systems, or cyber-technical systems).
- Reduction feature/simplification: models do not capture all attributes of the represented system but only those relevant to fulfilling the intended purpose.
- Pragmatic feature: links between models and originals are purpose-driven; the model replaces the original for limited periods of time. Use of the model is restricted to certain theoretical or real operations (Töllner 2010).

The use of (computation) models can be pictured as a relational triangle involving the model subject (i.e., its developer or user), the model itself, and the model object, or real system. In this setting, the model subject intends to achieve specific targets related to the model object, such as forecasting construction costs, and develops or uses a model for this purpose. This model then represents the model object in an idealized or abstract form. We refer to Jockisch and Rosendahl (2010) for a classification of various models in business administration, economics, and the engineering sciences as well as in an interdisciplinary context. This paper refers to, and discusses, classifications proposed by different authors.

Calculating construction costs and times requires an abstraction of reality or of prevailing cause-effect relationships. This level of abstraction is achieved by introducing a computation model, which represents real processes whilst inevitably incorporating simplifications. “Desktop tests”[1] are carried out to revise, expand, and improve the computation model in order to rectify linkage and model errors. Validation is applied to prove the applicability of the computation model to reality, resulting in calibration and adjustments if and when required. To enhance validity, it is useful to integrate into the model mathematically described interactions that were derived from practice (including from expert surveys), such as non-linear curves representing losses of productivity or increases in labor consumption rates.

2 MODELING IN PROJECT MANAGEMENT, CONSTRUCTION MANAGEMENT AND ECONOMICS

Any model will interact with the model subject and the model object. The model subject is the developer of the model, but it can also be its user. Provided the model can also be used by third parties, individuals who were not involved in the modeling stage can also apply it in specific ways. The model is linked to model objects for which it was developed and to which it is applied. Model objects may include entire buildings or structures, contract sections, or individual structural components, such as those for which construction processes and logistics as well as construction times and costs are determined (see Figure 1).

Any modeling will necessitate a related understanding in order to fully comprehend systems and to reflect the required processes or existing dependencies. A key aspect of modeling is to delimit the model to other systems and processes. Such limits must be defined and documented in a clear and plausible manner so as to enable users who were not involved in the modeling exercise to apply the model according to its intended purpose.

The type and focus of models to reflect interdependencies in construction management and economics will vary depending on the individual project phases. Modeling requirements essentially depend on whether we are dealing with forecasting or planning processes and on the

[1]A desktop test is the check of a computation algorithm or of a routine for its correctness. For this purpose, a deterministic computation model must be developed in which results are known, and can be subsequently reviewed, for a defined input.

project phase(s) considered. Generally speaking, models exist for *ex ante*, *inter actio* and *ex post* analyses. Figure 1 shows the multisystemic model as a hexagonal pyramid that forms the basis for analyses, forecasts, comparisons, decisions etc.

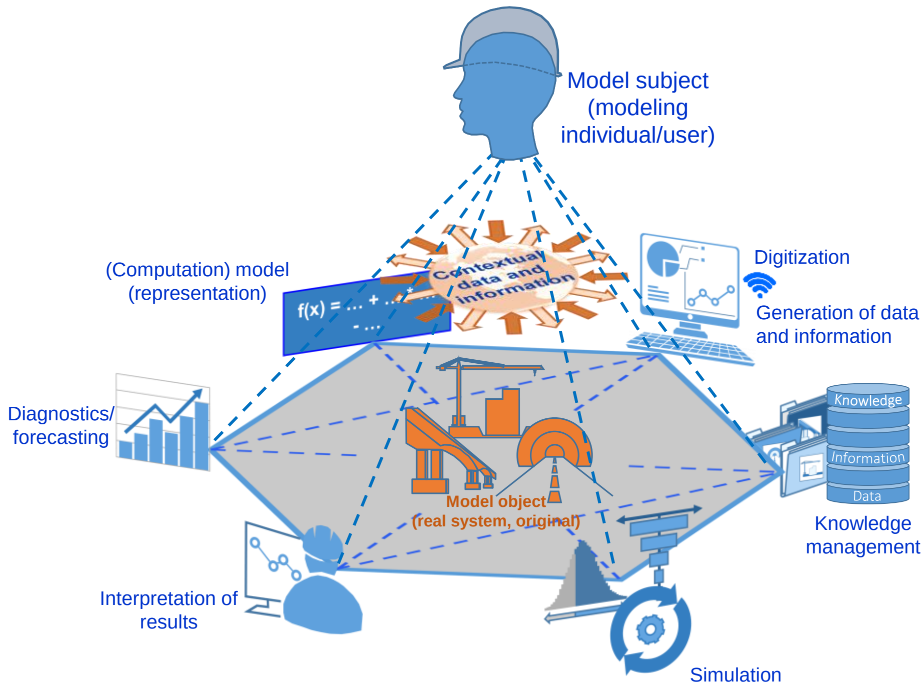

Figure 1. Multisystemic modeling.

"One cannot not model!" The author of this paper has modeled this statement on the famous Paul Watzlawick[2] quote "One cannot not communicate!" Why is this statement, "One cannot not model", correct? Any human being will use models, either consciously or unconsciously, for their actions, decisions, forecasts, plans, etc. Likewise, organizations require and apply models for corporate forecasting, planning, and decision-making processes.

Furthermore, models should be clear, plausible, and capable of being communicated, particularly if model developer and user are not one and the same person. A modeling exercise is at the very beginning of any analysis or development process.

But how can we systematically proceed from models to accurate, usable outputs? A hexagonal pyramid is a good means to represent this progress. This multisystemic pyramid should create the basis for achieving individual project break-even and thus ensuring long-term corporate profitability. The individual triangles forming the pyramid are described below.

2.1 First Triangle

The model subject, i.e., the human being, initially faces the challenge of having to develop a model suitable for a specific task. Such a model can be a check list, an equation, or a simulation

[2] Paul Watzlawick was an Austrian/American communications scientist, psychotherapist, sociologist, philosopher, and author.

– and it will inevitably strongly interact with the model object because the model itself is developed as a reflection of the model object (Kummer 2015). At this stage, the following important questions should be asked: What should the model capabilities include? To which project phases should it be applied? What data and information base is available, and what degree of detail will be possible or useful in the specific phase? Will a deterministic model suffice, or should a semiprobabilistic or probabilistic model be developed?

2.2 Second Triangle

Valid data and information is required to arrive at solid, usable outcomes as a result of applying the model. Where does this data and information come from, and how should it be created for a new project? To some extent, data is generated in automated processes, such as weather data that provides information on temperature trends or humidity curves. Humans present on the construction site must first identify information on the effects of such variables on the site's production system and then document it in an accurate and plausible manner. This process is essentially determined by the specific mode of understanding and subjective judgment of situations by the individuals performing related actions.

2.3 Third Triangle

Digitization should enable the capture of real-time data and information. Such information can be utilized for the current project and should also be systematically entered in the knowledge base. Knowledge is a crucial, and in some areas most important, factor within the planning and production system. Contextual application of models should be improved based on existing knowledge and performance indicators taken from the knowledge base.

2.4 Fourth Triangle

The next triangle is formed by the model subject, model object, and simulation. This setting should enable the following:

- Systematic consideration of uncertainties
- Analyses of a variety of scenarios
- Large number of computing operations (iterative steps)
- Optimization
- Forecasts
- Consideration of correlations etc.

2.5 Fifth Triangle

The fifth triangle comprises the model subject, the model object, and the interpretation of results. In digitization and simulation, the type and representation of generated results are important. Distribution functions are an appropriate means to visualize and communicate the chance/risk ratio, for example.

2.6 Sixth Triangle

The last triangle involves the human being, the model object, and diagnostics/forecasting. Diagnostics are used to replicate the course of past events. Forecasts attempt to simulate the future as realistically as possible.

This multisystemic consideration of the hexagonal pyramid is crucial for holistic modeling. This pyramid is highly relevant not only to research but also to practical applications. Contextuality is essential for ensuring high-quality results when applying the model to construction projects.

In project management, construction management and economics, models are developed and used for various purposes. They are created, for example, for organizational, selection, decision-making, assessment, management, control, safety and security, forecasting, and comparison processes.

The model subject defines the targets to be achieved with the model under development. In this respect, it is crucial to break down targets into "essential", "priority", "nice to have", and non-targets.

3 UNCERTAINTIES IN MODELS

Any abstraction or simplification performed as part of developing such a model will be associated with uncertainties, which can be grouped into aleatoric and epistemic uncertainties in the case of engineering problems (see Figure 2).

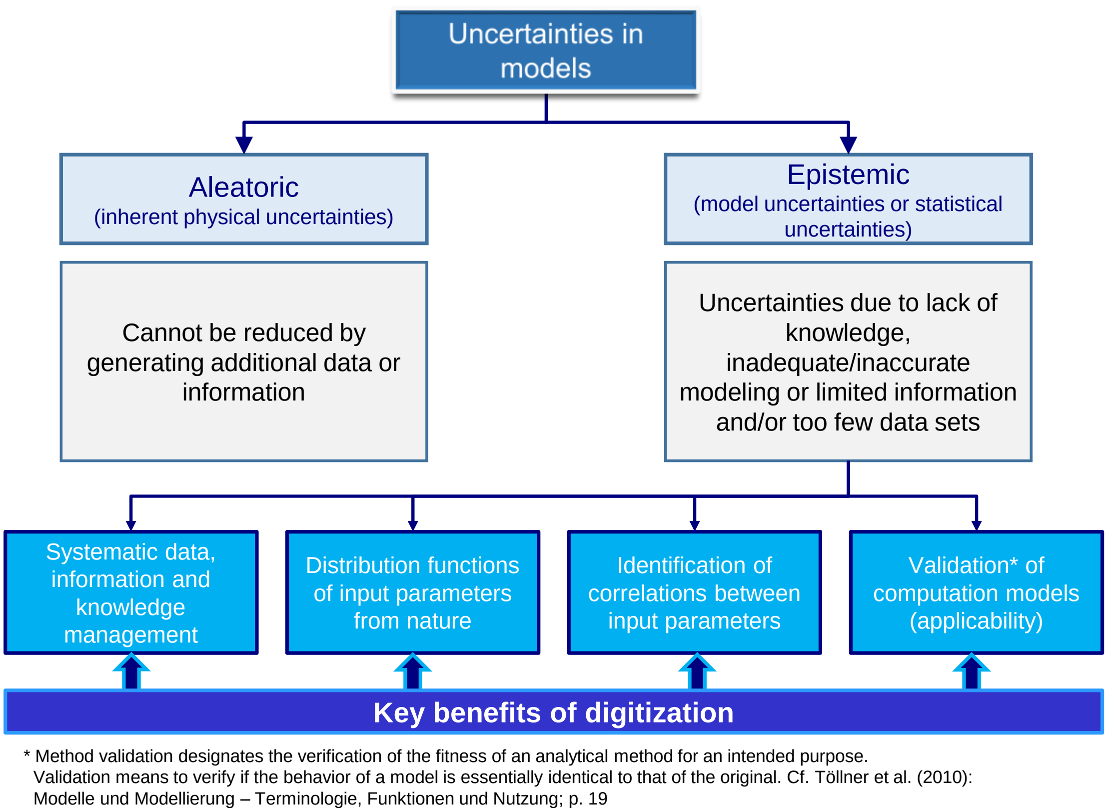

Figure 2. Uncertainties in models and simulations.

Aleatoric uncertainties result from the fact that the world is (co)determined by the element of chance. Capturing additional information will not reduce existing aleatoric uncertainties. On the other hand, epistemic uncertainties result from lack of knowledge, inadequate or inaccurate modeling, or limited information and/or too few data sets.

This is where the huge benefit of digitization comes into play: systematic data, information and knowledge management makes it possible to represent systemic or natural spreads of input parameters by data fitting using distribution functions, and to integrate these spreads into the calculations. Furthermore, interdependencies of input parameters can be captured in the form of correlations and also be incorporated in the computation model (Hofstadler and Kummer 2017). In-depth analyses also use copulas to reflect dependencies between input parameters.

4 CONCLUSIONS

Realistic modeling essentially requires a thorough understanding and intimate knowledge of the subject matter or area under study. System and process limits should be defined relatively generously at the beginning of the modeling exercise. Modeling is then restricted to the main aspects of the analysis on the basis of precisely defined targets.

Calculations and forecasting require abstraction of reality or of prevailing cause-effect relationships by establishing a computation model, which represents real processes but also inevitably includes simplifications. "Desktop tests" are carried out to revise, expand, and improve the computation model in order to rectify linkage and model errors. Validation is applied to prove the applicability of the computation model to reality, resulting in calibration and adjustments if and when required.

To enhance validity, it is useful to integrate into the model mathematically described interactions, such as non-linearities, correlations, copulas, or uncertainties expressed as ranges and distribution functions, that were derived from practice (including from expert surveys, experiments, and site surveys).

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