Simulation and Optimization
in Manufacturing, Organization and Logistics

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Abstract

The paper gives some basic ideas about optimization and discusses actual architectures of complex information systems, which include optimization systems or modules. The optimization system is presented as an example for a practical solution of optimization tasks.

Introduction

Computer-based optimization has become increasingly important in the last few years. This demand is caused by a more difficult economical situation, where efficiency of all processes is more and more necessary.
Optimization tools can improve the effect of other analysis tools like simulation systems or decision support systems some times. Although the whole task of analysis and optimization is more complex than before, the connection of both tool classes reduces the needed amount of time and personal staff dramatically. Instead of having a high-qualified simulation expert, a optimization tool can automatically evaluate simulation results and will try new scenarios. The results of optimization tools, like the number of the best strategy for the next week of operation, could be presented to traditional working staff without any additional teaching or difficult explanations. The fast development of computer power allows more practical and more complex tasks.

Basic methods of optimization

There is a very large bandwidth of available methods and tools. Optimization methods can be divided into two large groups (see figure 1). On the one hand is the large group of continuous parameter optimisation methods, while on the other are the discrete optimisation methods (Krug ARENA/ISSOP Handbook 1997).
Within the broad spectrum of continuous methods, the first to be considered (and this is a point worthy of criticism) are the deterministic methods. These are also called discrete mathematical parameter optimisation methods, which can be applied to static, non-discrete, non-stochastic optimisation problems. In the literature, these deterministic methods are often called hill-climbing strategies, because they method of searching for the optimum (maximum) is similar to a blind mountain climber, who tries to climb from a valley to the highest peak. For minimisation problems, the direction is reversed accordingly.
These methods currently dominate in the solution of technical optimisation problems. In the second column of Figure 1 the random methods are shown, which are becoming increasingly important in computer-based optimisation. They are used when the deterministic algorithms of column 1 are unsuccessful or unusable. These methods vary the values of the variables according to random, rather than deterministic rules.
Many deterministic optimisation methods, in particular those that require the gradient of the target function, can have convergence difficulties at points where the parameters have discontinuous derivatives. A narrow valley leads to the same problem when the finite step sizes are larger than the width of the valley. In this case, all attempts to obtain improvements in coordinate directions or by using local test steps to determine a new direction will fail.
Evolutionary algorithms are oriented towards results from observations of the natural evolution of living organisms. Using natural evolution as a basis for optimisation is justified, since it has been repeatedly shown that plants and animals have adapted themselves optimally to their environments. By contrast to deteministic or pure random methods evolutionary algorithms considers a set of solutions called a population. Each solution is correspondingly called an individual. In genetic algorithms, solutions are also called chromosomes. By analogy with biology, each component of a chromosome is called a gene. According to the nature, the values of this chromosomes are change like in a mutation and new population are generated by a recombination of chromosomes. The advantage of evolutionary algorithms consists in the combination of randomness and a stepwise selection of better population, were bad population can live also some specific time interval.
According to the endless number of optimization tasks, **there is no best algorithm**. For practical applications there should be a number of different applicable strategies !

Proceedings 14th European Simulation Symposium
A. Verbraeck, W. Krug, eds. (c) *SCS Europe BVBA, 2002*

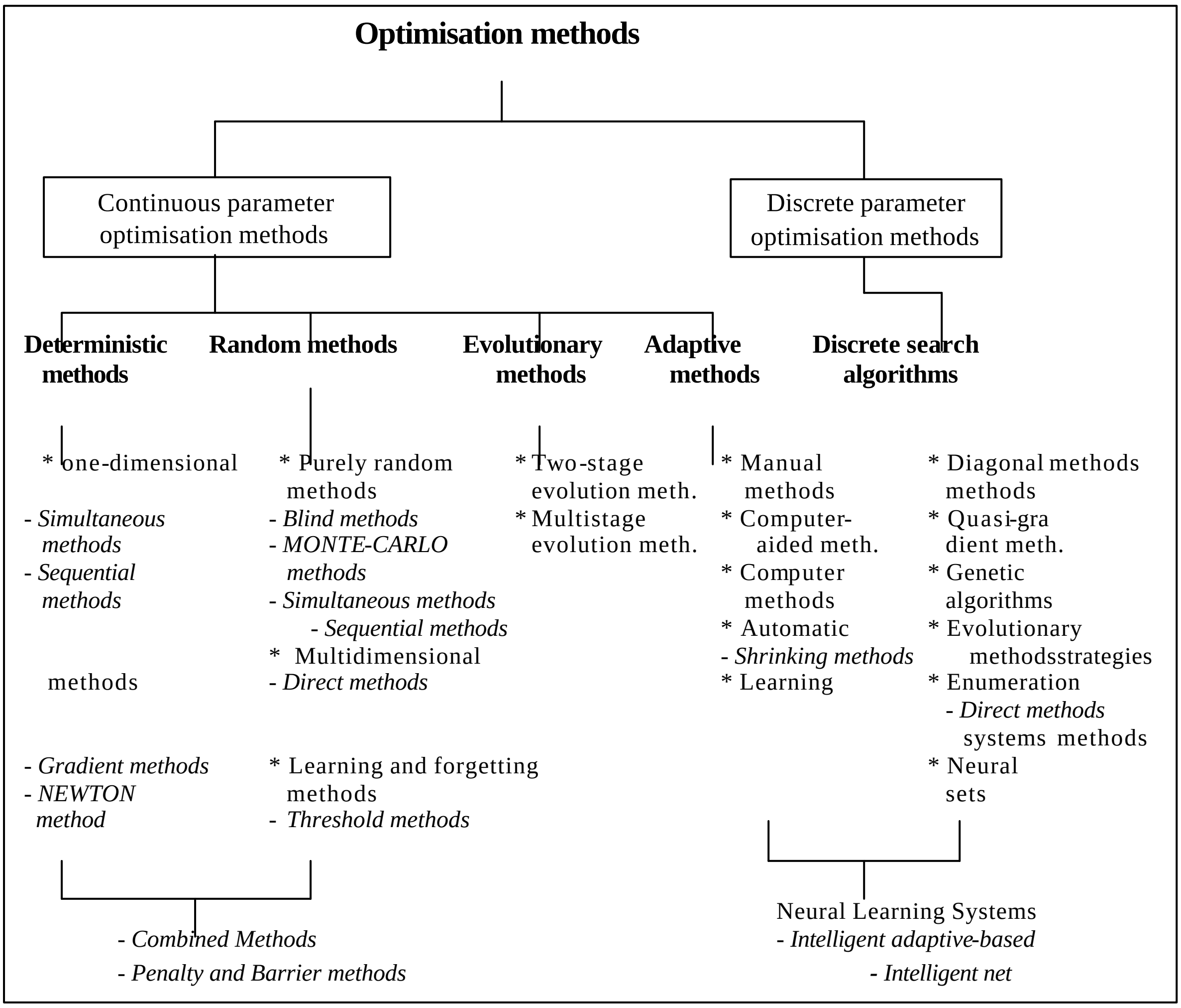

Figure 1: Classification of optimisation methods

Finding an optimal solution for a problem by building a model and running a simulation has always been the goal. Until now, however, it was usual to define the model a priori with certain parameters, and then to simulate, in order to see "what comes out", i.e. a human performs optimization by hand. He or she compares and evaluates results, fixes new parameters, and re-starts the simulation. This approach is very time-consuming, and the probability of finding an optimal solution in this way is relatively low.

With complex processes, which contain a large number of possible combinations of parameters and several mutually contradictory target criteria (costs, utilization, throughput etc.), it is practically impossible to perform a manual optimization. This is also true for manufacturing sequencing.

One solution is to use software with powerful optimization strategies which is coupled with the simulator. This optimization software must be able to access the model and to modify the values of model variables, read the simulation results that are relevant to the goals, and to determine the optimum (or a compromise).

Industrial applications of optimization and simulation

Europe`s Producing companies and especially Small and Medium-size Enterprises (SME) have to participate in dynamic networks and virtual factories in order to exploit (within alliances which are limited in time but not in distance) market chances that are hardly accessible for a single enterprise. Within such constantly self modifying environments the processes of organization, production and logistics have to be evaluated and optimized continuously. This requires the integration of comprehensive process models, efficient simulation and optimization tools as well as systems for Workflow Management, PPC, etc. via standardized interface. Various surveys have identified problems with the decision making process which are related to using methods that do not reflect the dynamic aspects of the manufacturing environment. The Paper aims to overcome these problems by producing integrated methods and tools, based on simulation, and optimization, to support effective decision making at all levels, from strategic to operational, of the company production, planning and control and business reengineering. The main theme is

to support decision making associated with the whole life cycle of products, but also included is evaluation of the impact of these decision making support tools on the personal using them, the organizational structure, and the Logistics management aspects of the company.
The Performance by integration of intelligent tools will be implemented in a software package. Existing state-of-the-art tools for PPC, analysis, simulation and optimization will be integrated into this software. The integrated systems SAP-R3 and ARENA/ ISSOP will be validated by solving actual problems in industry under virtual enterprise conditions.

Typical software architectures

Today, a number of powerful software systems individual are available for most of the a afore-mentioned tasks, e.g. tools for

- Order processing
- Material management
- Production planning and control
- Enterprise Modeling and analysis
- Workflow management and Standards
- Statistical evaluation of processes (e.g. average processing times, frequency of changes between different media or organizational units, process-oriented cost calculation etc.)
- Dynamic analysis (simulation and optimization) and visualization of processes.

Well known examples for such systems are SAP-R/3, ARIS, BAAN-DEM, STEP, CIM-OSA, EXPRESS, CRIMP, BIASS, ARENA, AUTOMOD, CIMPLE, ISSOP etc..

However, all these systems, though providing more or less elaborated interfaces for information exchange, are not systematically integrated so that they do not form a homogeneous platform for the user. Consequently, planning and business process reengineering usually is performed as shown in figures 2 and 3 .

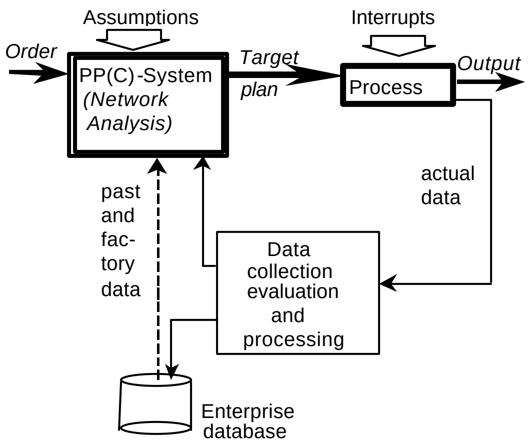

Figure 2:

Conventional production planning cycle without simulation support

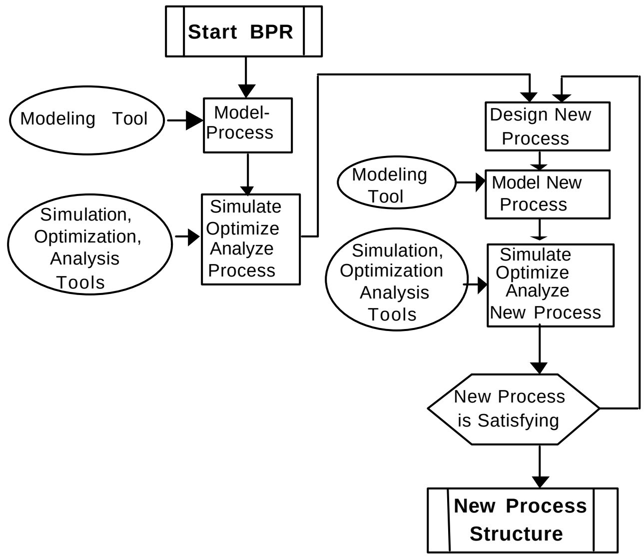

Figure 3:

Conventional BP improvement without integrated tool support

Complete product models, descriptions and related data may be exchanged using PDDI (Product Definition Data Interface), PDES (Product Data Exchange using), STEP (Standard for the Exchange of Product Model Data), EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport). In particular, STEP will be relevant for standard interfaces.
Actual PPC systems mainly use network analysis as a planning mechanism. Thus, temporal data like transportation time, machine preparation time, processing time, fault time etc. are modeled by input values that enter the calculation as fixed entities, although they are, in reality, subjected to variations.

Network analysis tries to cope with that restriction by calculating the values each from an optimistic value, a pessimistic value and from the expectation (Erkollar and Mayr 1997). For reasons of simplicity, however, often only average values are considered. Thus, what actually happens in reality and the danger emerging from deviations are considered only insufficiently so that bottlenecks and delays are not always transparent to the planner.

To sum up, producing companies actually face the following problems in Manufacturing and Logistics:

- There is no common proceeding model for computerized modeling, simulation and optimization.
- There is only few flexibility in the available planning and controlling mechanisms.
- There are no integrated means for evaluation, analysis, simulation and optimization.
- There are no means for automated re-design and re-structuring of models based on optimization results.
- There are rarely means for the iterative improvement of process dynamics.
- The interfaces of the different tools are poorly coordinated and therefore do not allow for an effective integrated use.

Consequently, comprehensive process models are needed as well as a coupling of powerful tools for simulation and optimization in connection with automated mechanisms for Workflow Management, PPC, CAD, CAE etc.. A standardized interface might guarantee the integration that is necessary for efficient computer supported cooperative work within a dynamic network of SME's. Moreover, in order to achieve the goal of capturing and sharing the knowledge of the partners within a virtual enterprise reference models have to be used. Such reference models are available as results of fore-going projects.

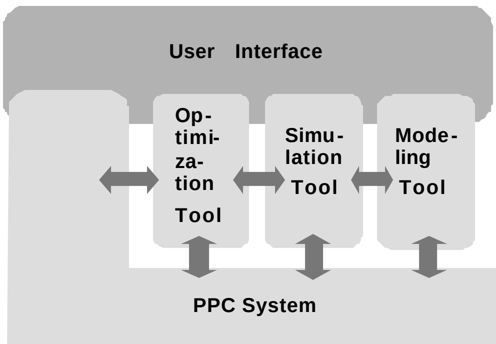

Figure 4:
Interconnection and integration

Objectives (or aims) are variable process parameters of the simulation model that result from a simulation run, e.g. mean flow time of orders, machine utilization, manufacturing costs etc.
After the objective are weighted, they are used as a substitute objective function.

The ISSOP-optimization tool

To achieve the level of system integration that SME's need for an successful participation in virtual enterprises/networks on a global market, the optimization tools ISSOP was developed under the following goals:

(1) Integration of the reference models for distribution, procurement, order flow and production control into the context of the usage within an SME network.

(2) Development of a Toolset which allows the coupling and exchange of data between existing subsystems for PPC, modeling, simulation and optimization (see figure 4). This interface will enable, among others, a (virtual) manufacturer to consider and exploit deviations that might occur during production in order to detect and implement an optimal solution for a given planning task. A particular step of this approach is the automatic extraction and transformation of the PPC's network into a simulation model in the format that is expected by the resp. system. The simulation results again are transferred to an optimization tool. The optimization results then are fed back into the PPC system (see figures 3 and 4).

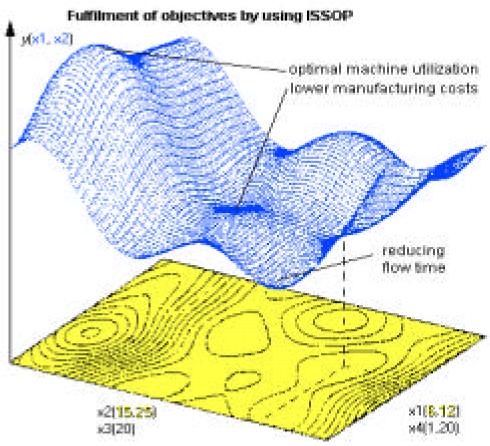

Figure 5: Optimization Results in the Production Planing

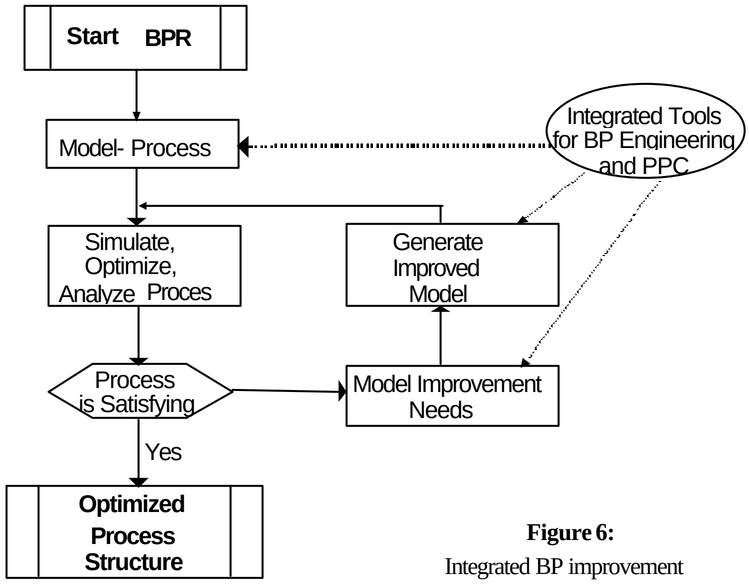

Figure 6:
Integrated BP improvement

(3) Test and validation of our approach within a real live environment, i.e., by an application case study within an SME network. The improvements in speeding up production planning and control, in raising the quality of its results and in reducing costs will be measured and evaluated.

(4) Development of new mechanisms for process optimization: The change of industrial business by the globalization of markets inside and outside of Europe requires a comprehensive reorganization of enterprise structures. In this context, an important aspect is virtual enterprise reengineering based on a static process analysis as well as on a dynamic analysis that consists in validating and optimizing the (virtual) order and business processes to the highest achievable efficiency (see figure 6, 7). The results gained here will be important for industry branches like metal-working industry, processing engineering, electrical engineering/electronics, etc..

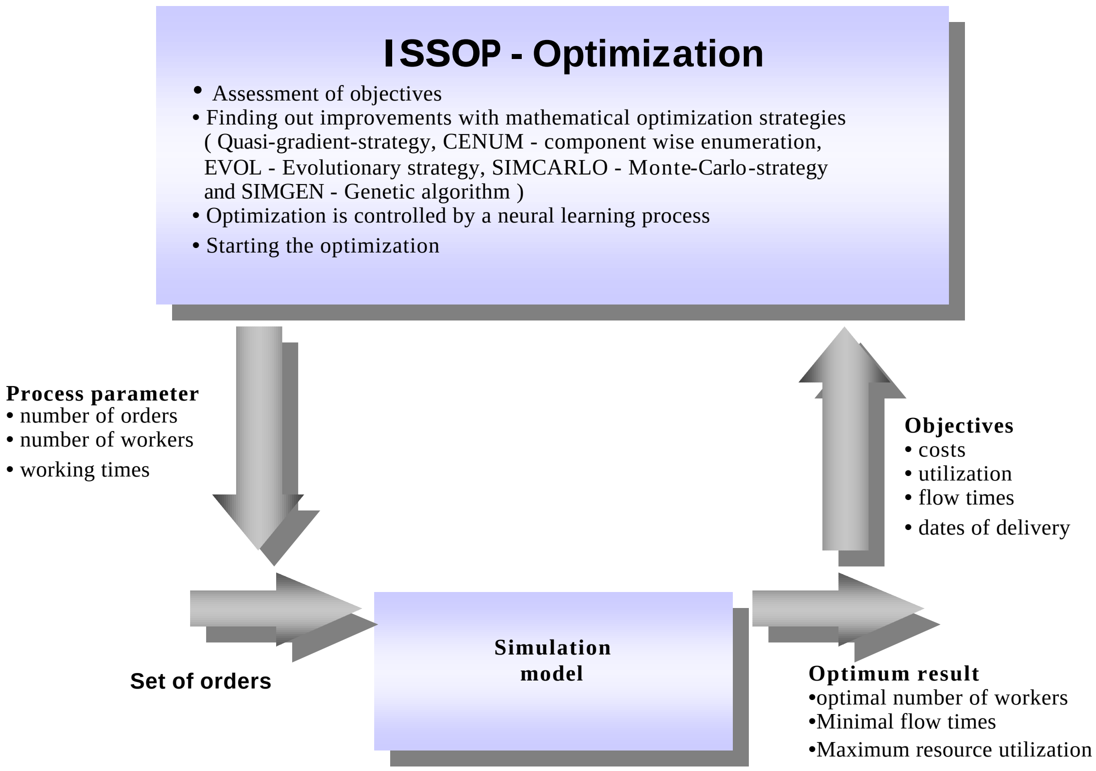

Figure 7: Simulation and Optimization in Order Processing

The Simulation and Optimization of order processes in Manufacturing, organization and Logistics in focused of variation by number of orders, number of workers, working time etc. is seen in Figure 6. In the end on the optimization in coupling with simulation will be solved the new set of orders in connection with objectives of cost, utilization, flow time and dates of delivery.

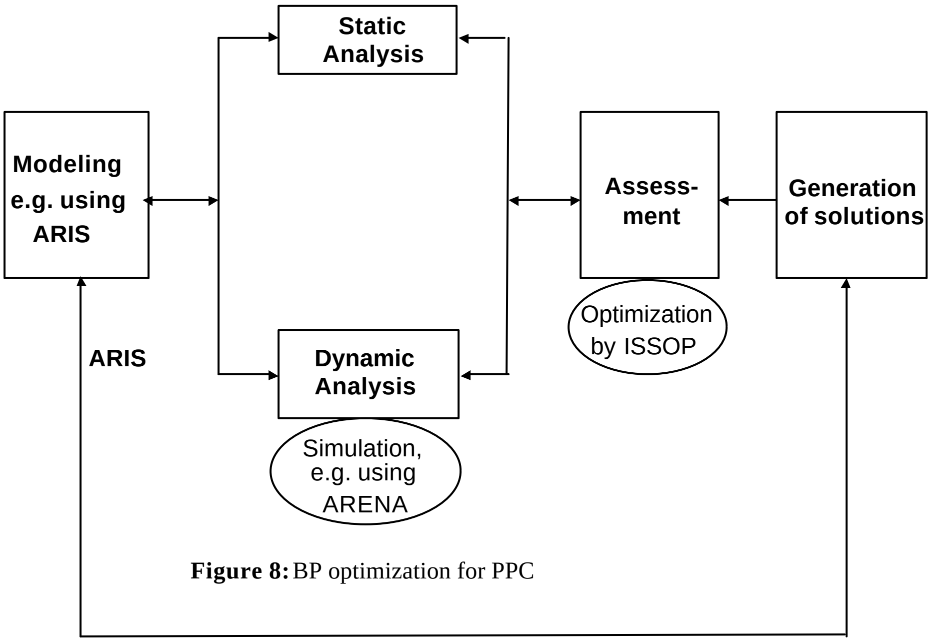

Figure 8: BP optimization for PPC

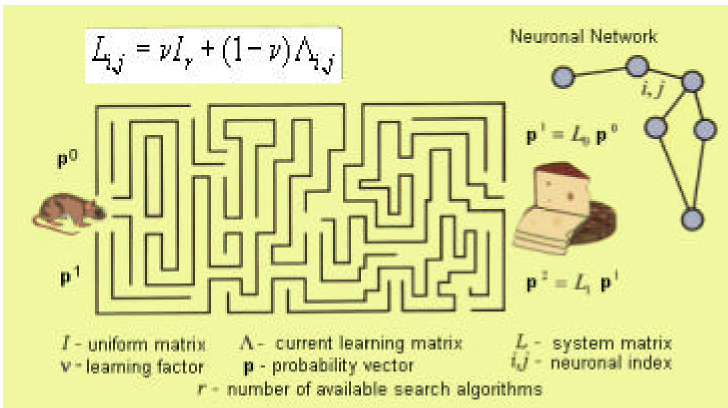

Figure 9: Neuronal Learning process

The ISSOP learning process is based on a labyrinth problem similar to the biological systems that can be found in nature. Therefore the neuronal network will be solved on a mathematical basis solving the system matrix L illustrated on the picture below. From optimization problem to optimization problem in SME's better optimization results will be obtained by means of different optimization strategies.

These strategies are implemented in ISSOP (see fig.7).

In addition to the business process models as such, the following aspects have to be considered:

- Process goals and objectives as well as evaluation criteria,
- Strategies for directed search and optimization in connection with a neuronal learning algorithm, seen in Figure 9,

- Representation of possible changes and variations within a process model (e.g. change of sequence, paralleling, change of resources assignment etc.),
- Reference models and module libraries to be used for generating new process structures,
- Representation of restrictions and logical dependencies (e.g. concerning the exchangeability of functions).

It is not intended or expected to reach a complete automation of business process development. The process designer rather will be provided with a means to select the most appropriate process out of a number of promising and tested alternatives.

Conclusion

The DUALIS team had analyzed the problem of effectiveness in 14 firms in Saxony. The result was, that Single-User-systems in the planning, production and control, for instance only PPC and separately WORKFLOW Management systems and single SIMULATION tools have been the effectiveness of 20 to 40 % lower then the Integration of this systems.
So the success of optimization technologies depends on the combination of optimization tools with other Information Technologies for PPC, and Workflow Management Systems. Simulation- and Optimization Tools and Standard Interfaces will be changed continuously. This is the best strategy for getting a maximal synergy and a wider usage of optimization and simulation tools.

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