

# 27 OPTIMAL ALLOCATION OF STANDARDIZED APPLICATION SOFTWARE PACKAGES TO BUSINESS PROCESS STEPS: A SIMULATION STUDY BASED ON COMMUNICATION AND AUTOMATION COSTS

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## Abstract

*Most research on the utilization of standardized application software packages in large companies is focussed on introducing a certain package for entire processes or even the entire company. A mix of existing, mostly individual applications and selected modules of different standardized application packages, however, may be superior in certain situations. A cost-based model for information systems optimization is presented. A cost-minimal allocation of software packages can be determined for every set of communication costs associated with information flows between modules and automation costs associated with process steps. Moreover some general hypotheses on software package introduction in large companies are validated by a large number of optimization series basing on the underlying decision model.*

*The paper presents the general decision model, its application to evaluate package allocation, and general simulation results.*

**Keywords:** Business package evaluation, cost-based decision model, business package introduction, simulation studies.

## Introduction

As a matter of fact, large companies are able to achieve significant productivity increases by introducing communication standards and standardized application software packages (business packages) to support their complex, distributed business processes. Furthermore, it is normally regarded as a matter of fact that a communication standard or an integrated business package should be introduced for entire processes or even the entire company. But it may be more efficient to use a communication standard only for selected communication tasks or to use a business package to support only selected steps of a business process. As a consequence, different communication standards and/or different business packages could simultaneously be introduced. Although the problem of optimal configuration of communication standards/business packages is relevant for many (mostly large) companies, it has so far not been addressed in detail.

When looking at the company's information system from an abstract point of view, it can be regarded as a directed network of process steps connected by information flows. A cost-based model of information systems optimization is introduced in the next section. It allows us to derive an optimal allocation of business packages to process steps for every combination of communication costs associated with information flows and automation costs associated with process steps, respectively. Since each business package integrates a communication standard, standardization and automation costs for process steps may jointly be considered.

Using the decision model, we can derive an optimal allocation of business packages to process steps with respect to discounted automation and communication costs. Moreover, this approach has been used to evaluate alternative business package introduction scenarios for one of the world's largest mechanical engineering companies. The company's present information system was compared with a SAP R/2 as well as a Baan Triton 3.1 business package introduction. The case study and lessons learned from the application of our model are summarized in the third section of this paper.

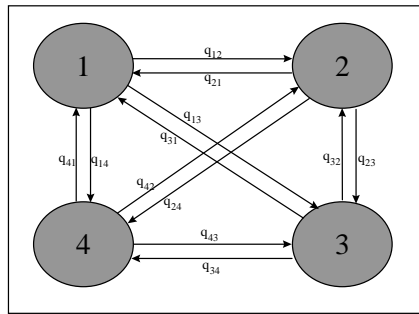
A more general insight on business package introduction can be created by using the decision model for simulation studies. In this particular investigation, we executed a simulation series comprising about a thousand optimizations assuming a fixed cost interval for the specific business packages. After this, we gradually changed the cost interval of one business package or the network size and analyzed the effect it had on the result. Each optimization, however, generates an optimal allocation (e.g., one of the packages should be introduced for the entire process, none of the packages should be introduced, certain packages should be introduced for certain process steps in a mixed allocation). Hence, an optimization series results in a probability distribution for these allocations. Simulation studies are presented in the third section. The paper closes with a summary and outlook on future research.

### Optimization of Business Package Allocation

The introduction of business packages to support business processes is interpreted as an investment optimization problem. Thus a general information systems model is presented first. The linear problem is described and an optimization procedure basing on that general model is then suggested.

#### Information Systems Model Based on Communication and Automation Costs

An information system is interpreted as a directed general network (Buxmann 1995). Every node represents a business process step (or task) that is executed by a human or a machine, respectively. Moreover, the nodes are connected by directed arcs which represent information flows. Thus a maximum of  $n \cdot (n-1)$  arcs can exist in a network comprising  $n$  nodes. Figure 1 illustrates a simple information systems model comprising four process steps and 12 information flows  $q_{ij}$  (information flow from node  $i$  to node  $j$ ).



**Figure 1. Information Systems Model**

In general, there are two possibilities of cost reduction in this general model: On the one hand, standardization (which generates node-specific costs) could be used to reduce arc-specific communication costs. On the other hand, automation (which also generates node-specific costs) could be used to reduce node-specific process step execution costs. Integrated business packages combine both aspects: Since different nodes are supported, software modules are introduced together with communication standards (e.g., remote function call/application link enabling for the SAP R/3 package) so that communication and process execution costs are simultaneously cut. However, different business

packages are accompanied by different communication standards. Hence, communication costs as well as process step execution costs must be considered if overall process costs are to be minimized.

#### Decision Model for Optimal Business Package Allocation

Each process step  $n$  can be supported by no package or by a package  $a \in S$ . If  $S$  comprises  $m$  different packages, a total of  $2^m$  different allocations exists (Buxmann 1995).

An optimal allocation minimizes the sum of discounted automation and communication costs

$$K = \sum_i \sum_s k_{is} \cdot X_{is} + \sum_i \sum_j \sum_s c_{ijs} \cdot Z_{ijs} \rightarrow Min!$$

subject to

$$(1) \quad 2 \cdot z_{ijs} \leq x_{is} + x_{js} \quad \forall i, j \in I; i \neq j, s \in S$$

$$(2) \quad \sum_s z_{ijs} \geq 1 \quad \forall i, j \in I; i \neq j$$

The following parameters are used:

$k_{is}$ : Discounted total costs of introducing business package  $s$  to support process step  $i$ . Total automation costs include nonrecurring investment, recurring software costs, recurring labor costs, and recurring operating costs (Anselstetter 1984; Henize 1981; Ferstl and Sinz 1993).

$c_{ijs}$ : Discounted total communication costs between nodes  $i$  and  $j$ , if these nodes are supported by **the same** business package  $s$ . Total communication costs result from manual data entry or time-consuming transformations and can be reduced by communication standards.

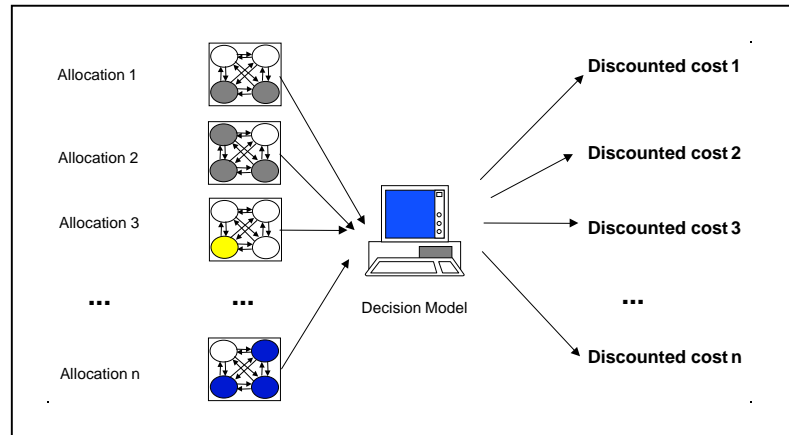
$x_{is}$ :  $\begin{cases} 1, & \text{if process step } i \text{ supported by package } s \\ 0, & \text{else} \end{cases}$

$z_{ijs}$ :  $\begin{cases} 1, & \text{if process step } i \text{ and process step } j \text{ are supported by package } s \\ 0, & \text{else} \end{cases}$

Restrictions (1) and (2) are used to force auxiliary variables  $x_{is}$  and  $z_{ijs}$  to be assigned correct values: (1) forces  $z_{ijs}$  to be 0 if the sum of  $x_{is}$  and  $x_{js}$  is less than 2 for any  $s$ , i.e., if these process steps are not supported by the same business package. If the sum of  $x_{is}$  and  $x_{js}$  is 2 for business package  $s$  (i.e., both process steps are supported by the same business package),  $z_{ijs}$  may be 0 or 1. In this case, (2) guarantees that  $z_{ijs}$  must be 1 for at least one package  $s$ .

In the following, we focus on arc-specific communication and node-specific automation costs as far as the superiority of the business packages is concerned. Whereas a change of node-specific costs only influences the total costs of the business packages introduced by the factor  $n$ , the effect on arc-specific costs is multiplied by the factor  $n \cdot (n-1)$ . As a consequence, we have to take into account that changes of costs take effect in different ways as far as business package introduction is concerned. This was also the reason why we did not additionally consider arc- and node-specific profits (such as automation profits). The effect of profits is analyzed in detail in Leist and Winter (1998) as well as in Leist (1998).

The cost optimization represents a linear programming problem (cf., appendix). Thus we use the cooperative simulated annealing (COSA), a hybrid search method, combining the basic principles of two major paradigms of heuristic search to solve this problem: simulated annealing (developed on the analogy of thermodynamics) and genetic algorithms (developed on the analogy of the theory of biological evolution) (Wendt and Koenig 1997).



**Figure 2. Application of the Decision Model with Respect to Total Costs**

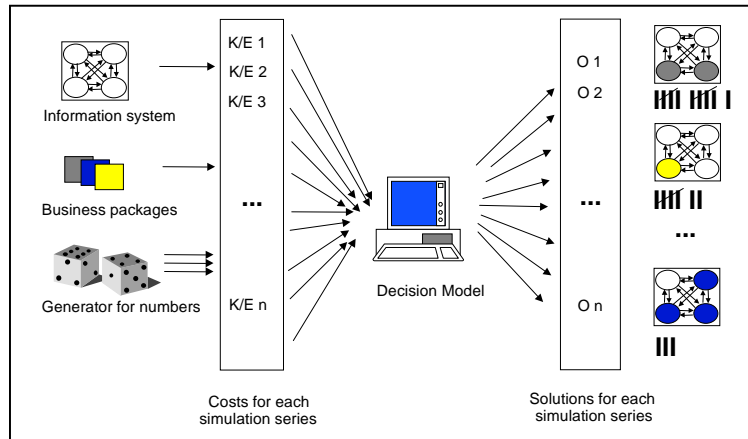
## Applications of the Decision Model

The decision model can be applied in two different ways:

1. An allocation of business packages to process steps can be evaluated with respect to total discounted costs. Thus the most profitable solution from a set of alternative allocations can be identified (see the first subsection) basing on that calculation. This type of application is illustrated in Figure 2: Business package A is used for supporting two process steps by allocation 1 and three process steps in allocation 2, respectively. Allocation 3 uses business package B to support one process step, and in allocation  $n$  the entire process is supported by business package C.
2. A more general insight on business package introduction can be gained by using the decision model for simulation studies. Thus three general hypotheses on the effects of process complexity, cost composition (automation costs vs. communication costs), and business package variety are analyzed by simulation (see the second subsection). This type of application is illustrated in Figure 3: a random generator generates a large number of communication/automation costs within a specific interval for an information system and a set of alternative business packages. Afterward, the number of allocations is counted, and a probability distribution of business package allocation is derived.

### *Application to a Large-scale Business Package Introduction Case*

The process focus is order processing, i.e., we cover all information processing tasks ranging from customer order entry to final assembly completion report. Each relevant

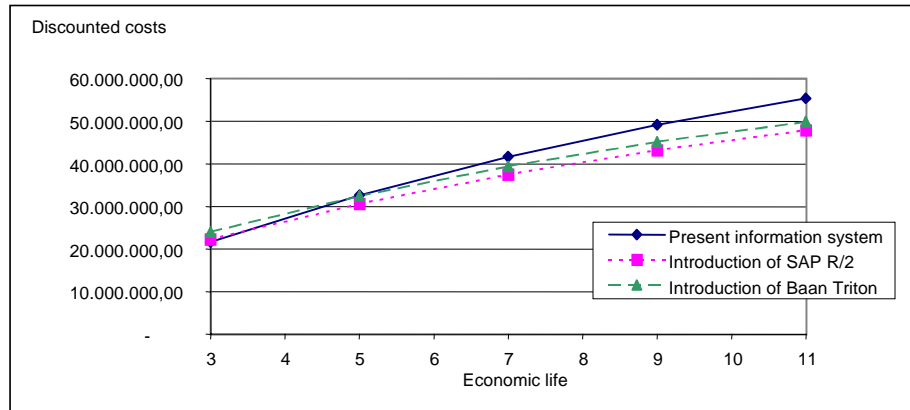


**Figure 3. Application of the Decision Model for Simulation Studies**

process step is analyzed with respect to automation costs and communication costs. Therefore, the introduction of the business package SAP R/2 and the business package Baan Triton 3.1 for all applicable process steps is analyzed as being alternative software solutions to the company's present information system. Automation and communication costs are estimated by conducting interviews with sales, production, purchasing, and IT managers as well as consultants. Furthermore, we have extracted process data for specific types of information processing tasks from reports of the respective project teams in order to estimate costs. Since profits were expected to be equal for all alternative configurations, they have been ignored in the analysis. The results are illustrated in Figure 4.

Since only costs have been regarded, all alternatives (including the present solution) generate negative amounts. The curve shapes are explained by the most important costs:

- **Present information system** (individual software with legacy components): No investment is necessary (no new solutions have to be introduced), but high operating costs occur due to inefficient/incomplete software support and a high amount of maintenance. For example, personnel costs are approximately 700,000 DM per year higher than for the other alternatives. In addition, communication costs, which result from many complex, partly manual interfaces, are higher by approximately 260,000 DM per year.
- **SAP R/2 Rel. 5:** This business package significantly reduces the number of interfaces and allows on-line access to most data resulting in low communication costs. Investment costs are high (one-time payment of about 6 million DM), but operating costs are significantly reduced (e.g., personnel costs for executing tasks by approximately 700,000 DM per year). However, not all process steps can be supported due to functional limitations (e.g., forecasting for product variants).



**Figure 4. Discounted Business Package Costs**

- **Baan Triton 3.1:** Impacts are similar in comparison to the R/2 solution apart from less operating cost savings. Moreover, a decisively higher investment is necessary because, given the company's mainframe infrastructure, Baan's client/server architecture requires significant additional hardware (approximately 1,200,000 DM higher costs for implementing the network).

Since the economic life of the planned investment is longer than three years, the R/2 alternative is superior with regard to total discounted costs. Of course, this calculation results from the individual conditions of this case and must not be mistaken as a general assessment of these business packages.

### *Simulation Studies for Analyzing Business Package Introduction Rules*

The decision model presented in the second section cannot only be used to calculate cost effects of a certain business package configuration. Moreover, we can use repeated optimizations based on an even distribution of certain costs to validate general hypotheses on the effects of process complexity, cost composition, and business package variety on package introduction decisions.

It is counted for each series of 1,000 optimization runs:

- how often a single business package is allocated to the entire process in an optimal solution,
- how often a single business package is allocated to a subset of process steps, while the remaining process steps are not supported by any package in an optimal solution,
- how often different business packages are allocated to different process steps in an optimal solution, and

- how often none of the software packages is allocated to a process step in an optimal solution.

If a software package is introduced for the entire process or if none of the packages is introduced for any process step, this is called a “homogeneous solution.” A “heterogeneous solution” is given if a single business package is allocated to a subset of process steps or when different business packages are allocated to different process steps in an optimal solution.

If an information system is interpreted as a general network comprising process steps and information flows, the **complexity of the network** should have a significant influence on business package introduction decisions. Since communication costs are related to arcs and automation costs are related to nodes of such a network, the **composition of total costs** should also be of some significance. Finally, the probability of heterogeneous solutions should be related to the total **number of alternative business packages**.

The automation costs and communication costs of the following analyses correspond to parameters  $k_{is}$  and  $c_{ijs}$  of the general decision model. The parameter values (especially the cost intervals) were chosen so that the expected total cost, on complete introduction, are equal for every package. This condition is essential to generate a decision problem. Otherwise, the complete introduction of a business package, with the lowest expected total cost, would always be the most advantageous. The cost intervals incorporated in this research cover only a small section of an enormously large number of ways cost intervals can be identified. This investigation should be interpreted as a basis for further research, on which further hypotheses can be built and parameter values can be expanded.

### Effects of Cost Composition

Hypothesis 1: The less significant communication costs are for the total costs of a business package, the more probable an introduction of this package is for the entire process. This results from the fact that the more process steps to which a business package is allocated, the more the advantages of low communication costs can be exploited. If communication costs are important, a homogeneous solution is superior to a heterogeneous solution.

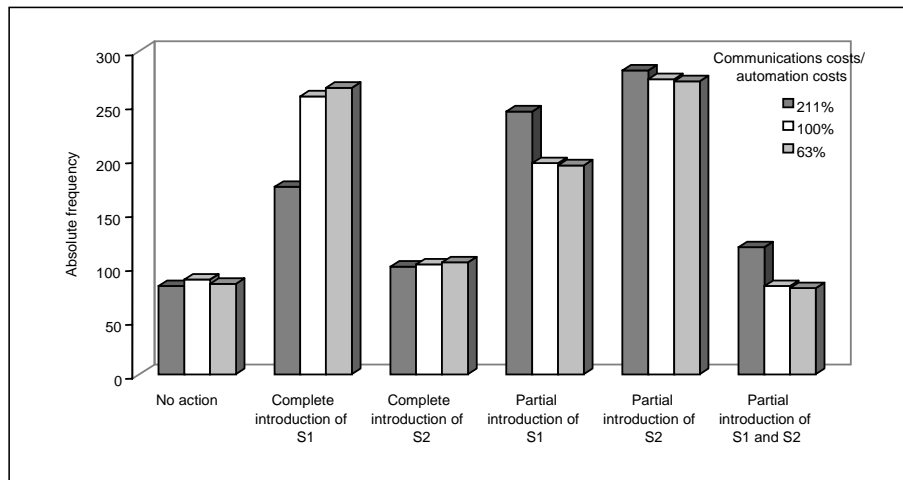
The simulation comprises three series, each with 1,000 runs. The analyzed process is assumed to comprise 10 steps. Furthermore, communication costs of business package S1 are reduced, and automation costs are correspondingly increased from series to series. Costs are evenly distributed within the intervals in Table 1.

Again, if no business package is allocated to a specific process step, we assume that communication costs between this process step and any other process step connected to it are 1,000 units.

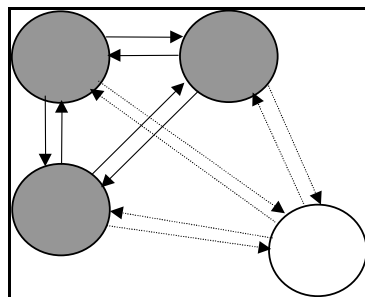
Figure 5 summarizes the results of three simulation series for three different cost compositions.

**Table 1. Cost Intervals for Composition Simulation**

Communication costs/ automation costs	Communication costs		Automation costs	
	S1	S2	S1	S2
211%	[900; 1000]	[950; 1000]	[0; 900]	[0; 450]
100%	[800; 1000]	[950; 1000]	[0; 1800]	[0; 450]
63%	[700; 1000]	[950; 1000]	[0; 2700]	[0; 450]



**Figure 5. Effects of Cost Composition on Business Package Introduction**



**Figure 6. Increasing Significance of an Additional Node**

As expected, the probability of introducing S1 for the entire process increases with decreasing communication costs. Figure 6 illustrates that the advantages of low communication costs gain importance with an increasing number of process steps to which a business package is allocated. However, one additional node creates another six information flows in an information system comprising three nodes linked by six information flows.

Although the rise of homogeneous S1 solutions is not proportional to the drop of communication costs, Hypothesis 1 is validated.

The decreasing significance of low communication costs can be interpreted as follows: Due to

the high number of information flows (e.g., 90 in a 10 step process), the average variation of auto-generated values is smaller than the average variation of (node-specific) automation costs. Exceptionally high automation costs, therefore, often cannot be compensated by low communication costs. The lower the average communication costs are, the higher the average variation of automation costs will be and, as a consequence, the more often high automation costs will not be compensated. Hence, a decreasing communication costs share of total costs is not completely reflected by an increasing probability of homogeneous solutions.

### Effects of Process Complexity

Hypothesis 2: With increasing complexity of the process network, the introduction of one single business package for the entire process becomes more probable. This results from the fact that, for each additional node in the network, a growing number of additional information flows has to be considered. While this effect is in general insignificant, it has an important consequence with regard to homogeneous solutions: The higher number of information flows for each additional node (and, as a consequence, the greater importance of communication costs) is going to make it more probable that the same business package that is used for the already existing part of the network is allocated.

The simulation comprises three series with 1,000 runs each for a process comprising 5, 10, and 15 steps, respectively. Costs are evenly distributed within the intervals from Table 2.

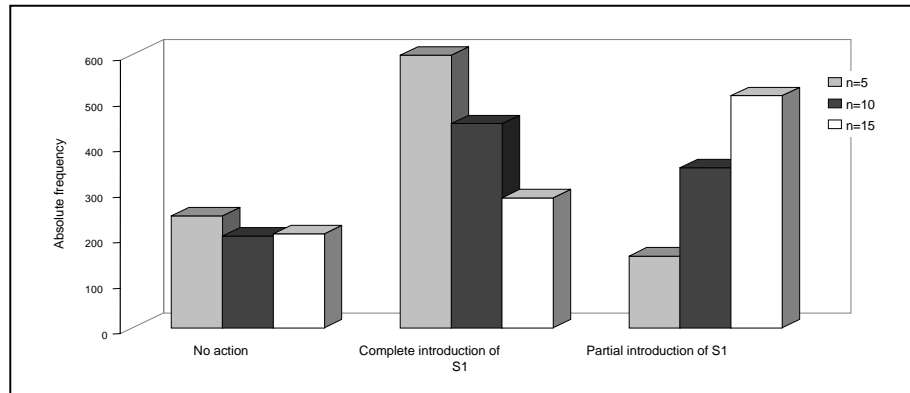
If no business package is allocated to a certain process step, we assume that communication costs between this process step and any other process step connected to it are 1,000 units.

Figure 7 summarizes the results of three simulation series for three different process complexities.

A complete introduction of one single business package can only be observed for simple processes. For complex processes, it is most probable that business package S1 is partially introduced. In contrast to Hypothesis 2, the probability of a business package introduction for the complete process decreases with increasing process complexity. This observation could be justified as follows:

**Table 2. Cost Intervals for Process Complexity Simulation**

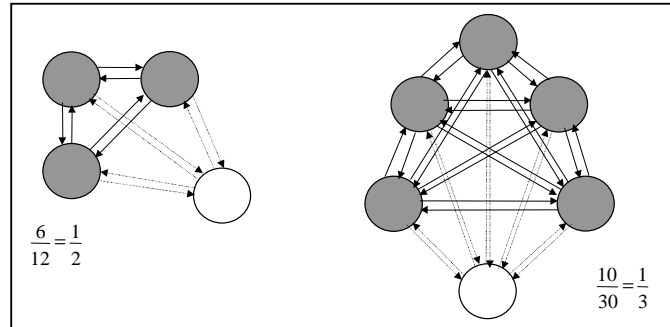
	Communication costs	Automation costs
Network size	S1	S1
n=5	[950; 1000]	[0; 200]
n=10	[950; 1000]	[0; 450]
n=15	[950; 1000]	[0; 700]



**Figure 7. Effects of Process Complexity on Business Package Introduction**

- With increasing size of the network, the number of potential, heterogeneous solutions grows exponentially. Although evenly distributed around the same average profitability, some solutions may have exceptionally low costs for certain information flows or exceptionally low costs for certain process steps, so that they are only allocated to these nodes, and a heterogeneous solution becomes optimal. “Uneven” effects become evident when average total costs for simulation series are calculated: For a network comprising 5 (10) nodes, average total costs are 102.43 (284.5) units below the expected average of 21,000 (90,000) units.
- Hypothesis 1 implies that every additional node increases the advantages of a homogeneous solution because the number of additional information flows (and the significance of low communication costs) is rapidly increasing. More specifically, the allocation of business package S1 to the  $n^{\text{th}}$  node of a network implies the standardization of  $2(n-1)$  information flows. But if the amount of additional information flows per additional node is related to the total number of information flows in the entire network, the significance with regard to the information flows of an additional node decreases.<sup>1</sup> As a consequence, both the advantages of homogeneous solutions as well as the negative effects of incompatibility diminish with respect to communication costs. Therefore, the more complex a process is, the more efficient it is to allocate a certain business package to selected, optimally supported process steps. This effect is illustrated in Figure 8: While additional flows created by an additional node account for 50% of the total number of flows in a four node-network, they account only for 33% of the total number of flows in a six node-network.

<sup>1</sup>The portion of additional, standardized information flows with respect to the total number of information can be calculated as  $\frac{2(n-1)}{n(n-1)} = \frac{2}{n}$ .



**Figure 8. Decreasing Significance of an Additional Node**

**Effects of Business Package Variety**

Hypothesis 3: With an increasing number of business packages, a heterogeneous solution becomes more probable. The more business packages regarded, the higher the probability is that a certain business package supports a process step extremely well while being of no significant use for other process steps. Hence, a partial introduction for this single process step may justify higher communication costs of such an “incompatible” package, resulting in a heterogeneous solution.

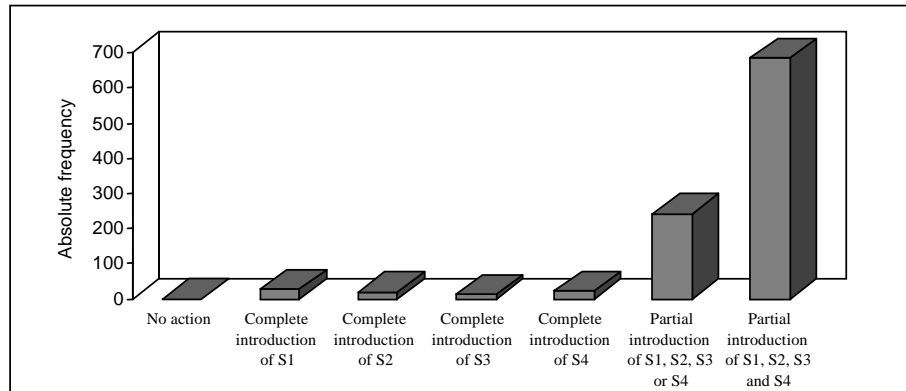
The simulation comprises two series with 1,000 runs each for a process comprising 10 steps. While taking only two alternative business packages into account in the first series, we analyze four in the second series. Furthermore, we assume that business packages S1, S2, S3, and S4 have identical costs.

We again assume that if no business package is allocated to a certain process step, communication costs between this process step and any other process step connected to it are 1,000 units. In addition to this, we assume that the process analyzed comprises 10 steps.

Figure 9 summarizes the results of the second simulation series.

**Table 3. Cost Intervals for Business Package Variety Simulation**

Communication costs	Automation costs
S1, S2, S3, S4	S1, S2, S3, S4
[950; 1000]	[0; 450]



**Figure 9. Effects of Business Package Variety on Business Package Introduction**

In contrast to all other simulation series in which homogeneous solutions dominate, heterogeneous solutions are by the far most probable in the second series. This results from the fact that with each additional business package, it is more probable that a certain process step is supported with exceptionally low costs. The respective business package is included in the optimal solution for that reason, but is not allocated to all process steps because the exceptional performance is limited to a single process step or a few process steps, respectively.

Thus, we get an obvious effect of the number of products taken into account on business package decisions. The more products we consider, the more products included in optimal solutions even if average profitability is identical. Therefore hypothesis 3 is validated by the simulation results.

## Summary and Outlook on Further Research

In this paper, we have addressed the problem of introducing business packages to support business processes from an analytical point of view. Moreover, we have, based on a general model for automation/standardization decisions in information systems, reproduced a company's decision problem and identified an optimal configuration. Furthermore, this model has been used for simulation studies to validate the following hypotheses:

1. **The less significant communication costs are for the total costs of a business package, the more probable an introduction of this package is for the entire process.** Simulation studies have proven that the more process steps to which a business package is allocated, to, the more the advantages of low communication costs can be exploited, resulting in an allocation of this business package to all process steps. Although this hypothesis was validated, it became evident that the effect becomes less significant with progressively declining communication costs.

2. **With increasing complexity of the process network, a heterogeneous solution becomes more probable.** Although communication links (and communication costs) become more important with growing network complexity, the simulation results do not validate the hypothesis that this effect favors homogeneous solutions. On the contrary, with a growing number of process steps, it becomes more and more probable that a business package develops an exceptionally good performance and is, therefore, included in the optimal solution. Since, moreover, the significance of additional information flows decreases in larger networks, negative effects of incompatibility diminish, too, and heterogeneous solutions become more and more probable.
3. **With an increasing number of business packages, a heterogeneous solution becomes more probable.** It seems reasonable to assume that the more business packages that are taken into account, the higher the probability is that a certain business package supports a process step extremely well. Hence, a partial introduction for this single process step may justify higher communication costs of such an “incompatible” package, resulting in a heterogeneous solution. This hypothesis was validated by simulation.

The results are not surprising because similar strategies can be observed in many large companies that use business packages. Often more than one business package is utilized for those complex processes that can efficiently be supported. Although proprietary communication mechanisms imply high interpackage and low intrapackage communication costs and, therefore, support homogeneous solutions, multipackage configurations are superior in certain situations and are going to become more attractive as open architectures for business packages emerge.

Business package introduction, replacement of legacy applications, outsourcing of selected process steps, etc. constitute typical decision problems of upper IS/IT management. The aggregate view on information systems presented in this paper allows support of such decisions by supplying specific cost information and providing general rules with regard to information systems development.

However, cost information represents an important basis for decisions, but can only be determined with difficulty. Moreover, we have to take into account various qualitative aspects when introducing business packages, such as the realization of competitive advantages by using business packages. Normally these aspects cannot be expressed by costs. Moreover they cannot directly be considered in the decision model, but it is nevertheless possible to take them into account later on, for example, in the form of a balance sheet of arguments. The analysis of qualitative aspects as well as the results gained can point out how expensive the realization of specific competitive advantages may be.

Future work will concentrate on the refinement of the cost and profit parameters of the general model (and validation of respective hypotheses) and on the derivation of critical values for automation and standardization decisions.

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## Appendix: Solution Approach

A branch and bound approach should be used to solve the linear programming problem described in the paper. Although an optimal solution can always be generated, however, branch and bound algorithms tend to be very time consuming for complex problems.

Buxmann and Wendt (Buxmann 1995; Buxmann and Wendt 1994) used an extended simulated annealing approach to solve a similar problem: Optimal standardization decisions were efficiently identified even for large problem dimensions in order to minimize communication costs in information systems. The so-called COSA algorithm

(Wendt 1995) combines genetic algorithms (Goldberg 1989) with simulated annealing (Kirkpatrick, Gelatt, and Vecchi 1983).

In contrast to linear programming, the heuristic nature of simulated annealing cannot guarantee that an optimal solution is generated. However, we could prove that optimal solutions were generated for 96.6% of the problems for a series of 1,000 runs in a reasonable time. Therefore, we use the COSA algorithm to identify optimal business package introduction decisions.