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Working Paper — Digitized Version

The usage of an interactive modeling system

Manuskripte aus den Instituten für Betriebswirtschaftslehre der Universität Kiel, No. 127

Provided in Cooperation with:

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Suggested Citation: Schmidt, Reinhart (1983) : The usage of an interactive modeling system, Manuskripte aus den Instituten für Betriebswirtschaftslehre der Universität Kiel, No. 127, Universität Kiel, Institut für Betriebswirtschaftslehre, Kiel

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Nr. 127

The Usage
of an Interactive Modeling System

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April 1983

Paper presented at the TIMS/ORSA meeting
in Chicago on April, 25 - 27, 1983.

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1. Introduction

The evolving role of decision support systems is evident from the text books which appeared since 1978 [1] [2] [4] [8] [9] [17]. However, it seems that the common interest in establishing user-friendly, accepted systems has displaced the question how quantitative methods of operations research should be integrated into such systems. Moreover, while there is much empirical research on the management of information systems - see [3] [10] - we must state a lack of empirical research on decision support systems. Therefore this paper aims at

- showing how OR methods are integrated into a DSS
- reporting on the user behavior of such a system, and trying to find out some factors which are related to the efficiency of the system.

The research is based upon PLASMA II, the PLanning System for Mathematical Applications on a dialog basis, developed since 1976 at the Institute for Business Administration of the University of Kiel, Chair of Finance [13] [14] [15]. The usage of this system is investigated by looking at the user behavior of eighty-two advanced students of business administration and economics. It follows from the design of the problem by the students and the control of the modeling process by automated documentation, that this investigation on user behavior is not just a simple application report, it is also a report on a special type of experiments. The experimental method has some disadvantages concerning the complexity of the problem given. On the other hand the limitation to some well-defined problem elements allows for controllable conditions and statistical testing of hypotheses.

In the following we first discuss the underlying DSS, i.e. PLASMA II, because the user behavior certainly depends upon the features of the used DSS. Second, we present and discuss

the results on the system's usage.¹⁾ Finally, we summarize our findings and give hints for further research.

2. The PLASMA II Modeling System

PLASMA II tries to support the construction and execution of mathematical programming models, especially linear models. To ensure flexibility with respect to the problem formulation, it is not restricted to linear programming but can also handle multiple objectives via goal programming [15] and via MOLP. While most of the financial planning languages stress upon data management and report construction, the main guideline for the development of PLASMA II has been the demand for a powerful matrix generator. An empirical evaluation of different DSS shows that the modeling language has a high weight as a criterion for DSS selection [5]. PLASMA II is implemented on the PDP 10 of the computing center of the University of Kiel and it is mainly based upon FORTRAN.

The main concept of PLASMA II is the separation of the model structure, the data, and the methods [13]. This separation enables the system's user to handle these three elements in a very flexible way. In its current version, the system contains menu tables for the selection of procedures. It is intended to combine the menu selection principle with a proper command language.

Table 1 shows the incorporated procedures on the highest menu level. There are other menu tables on lower levels, especially for the handling of data, objectives, and reports.

1) Thanks are due to Udo Reimers for his support in programming the programs for automated documentation.

Table 1: PLASMA Main Menu Options

Procedure	Purpose of the procedure
MOK	Constructing a model or manipulating a model structure
UEB	Translating a model structure into an internal structure
AUF	Matrix generation by combining an internal model structure and data
DAT	Manipulating data (inserting, updating, deleting)
ZDF	Defining objectives and manipulating goal-data
RDF	Defining items to be printed in a report
REP	Generating reports
GOA	Execution of a goal program
RS1	Execution of a linear program by ordinary simplex-method
RS2	Execution of a linear program by ordinary simplex-method (using external storage)
RVS	Execution of a linear program by revised simplex-method
MIX	Execution of a mixed integer program
SYS	PLASMA systems information and instruction
DRU	Printing the results of an OR-model just executed
DEL	Deleting files (Password)
MLP	Leaving PLASMA and returning to monitor-level (password)
ERR	Sending user error-messages or user remarks to PLASMA systems management
LGT	End of session (logout)

The structure of the user's interaction with the system is shown in Figure 1. The abbreviations there refer to Table 1. The normal modeling process begins with MOK, UEB, DAT, ZDF. Then model structure, data, and objectives' specification are combined via AUF. It follows the application of an OR algorithm, e.g. RS1 or GOA. Finally reports are defined via RDF and executed via REP. The results of a model execution can be stored in a data file becoming an element of the data bank.

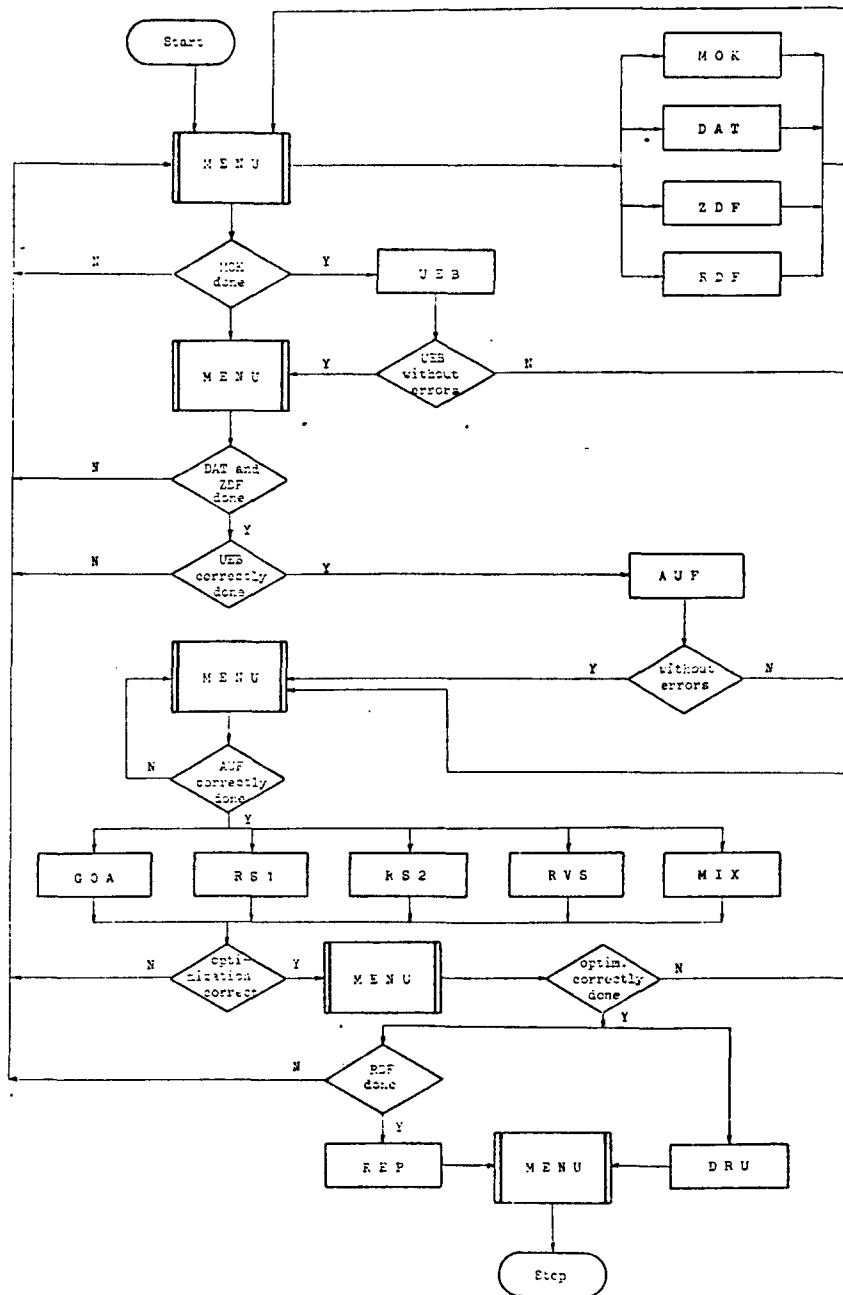


Figure 1: Structure of the Interaction Process

Special attention was drawn to a user-oriented file structure (see Figure 2). Every user administrates his own file directory under which there exist or may exist:

- model file directories (M.FD)
- data file directories (D.FD)
- file directories for objectives (G.FD)
- a report file directory (R.FD).

These file directories can be named by the user. On the lowest level we find files for models or parts of models (M.F), data (D.F), objectives (G.F), and reports (R.F). These files are also named by the user. Thus, it is possible to combine a model with different data sets and to get different reports for input or output data.

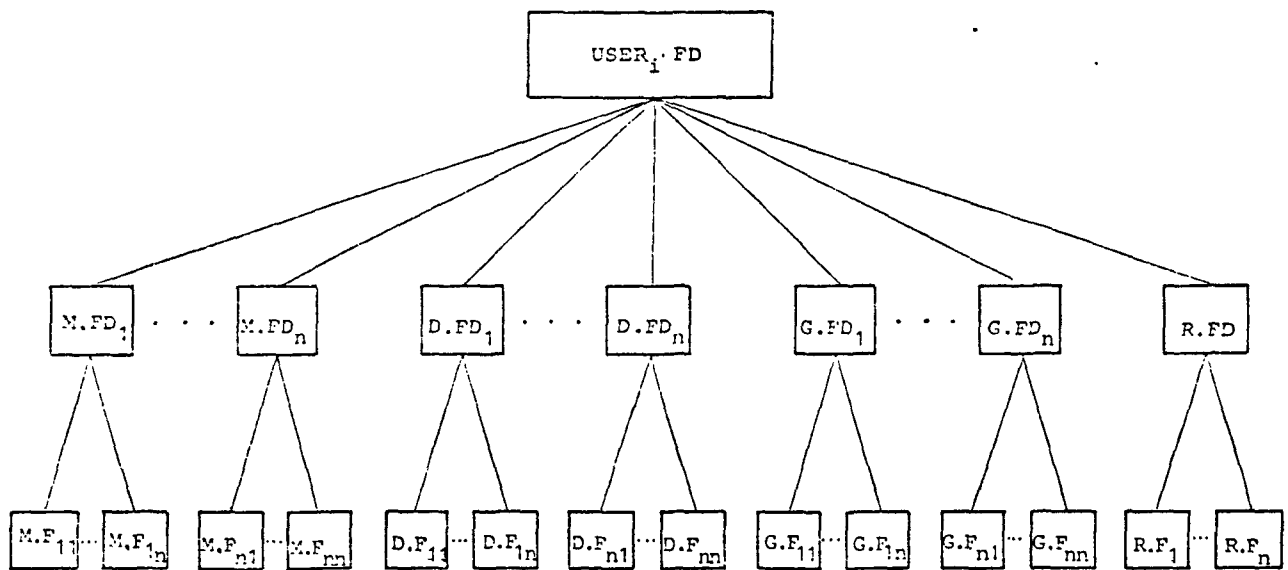


Figure 2: PLASMA User Files Structure

The main feature of PLASMA II is the powerful syntax. It has a few reserved words only and allows for up to sixteen indices and up to eighty characters for the name of a variable or a constant. Repetition of equations or inequalities for different index values is possible, and expressions can be handled by the sum operator. The definition of indices may be done by using leads or lags. Figure 3 demonstrates some of the syntax characteristics, containing a model close to usual mathematical formulation and created by one of the students. The formulation could have been done closer to natural language, but in this case the student decided to use abbreviations for the variables.

MODELL SPARTENVORSCHLAEGE
SATZ ZIEL DER SPARTEN

$[(C(I,S,V) - KAPKOST(S,V)) * X(I,S,V) : I=1,N] = ZIEL(S,V) : S=1,S1, V=1,V1;$
SATZ NEBENBEDINGUNG FUER SPARTENVORSCHLAG T=1983

$[IAUS(I,S,V,T) * X(I,S,V) : I=1,N] = B(S,V,T) : S=1,S1, V=1,V1, T=1983, 1987;$
SATZ NEBENBEDINGUNG FUER SPARTENVORSCHLAG T=1984, 1987

$[(IAUS(I,S,V,T) - IEIN(I,S,V,T-1)) * X(I,S,V) : I=1,N] \leq R(S,V,T) : S=1,S1, V=2,V1, T=1984, 1987;$
SATZ ZIEL DER ZENTRALE

$[(C(I,S,V) * L(S,V)) * X(I,S,V) : I=1,N, S=1,S1] + [FC(J) * Y(J) : J=1,M] = ZIELZ(V) : V=1,V1;$
SATZ LIQUIDITAETSBSCHRAENKUNG FUER PERIODE T=1983

$[(IAUS(I,S,V,T) * L(S,V)) * X(I,S,V) : I=1,N, S=1,S1] - [FEIN(J,T) * Y(J) : J=1,M] \leq [EXO(K,T) : K=1,K1] + BF(T) : V=1,V1, T=1983, 1987;$
SATZ LIQUIDITAETSBSCHRAENKUNG FUER PERIODE T=1984, 1987

$[(IAUS(I,S,V,T) - IFIN(I,S,V,T-1)) * L(S,V)) * X(I,S,V) : S=1,S1, I=1,N] + [FAUS(J,T) * Y(J) : J=1,M] \leq [EXU(K,T) : K=1,K1] + BF(T) : T=1984, 1987, V=1,V1;$
SATZ BERUECKSICHTIGUNG DER PERSONALKAPAZITAET

$[PERSANF(I,S,V,T) * X(I,S,V) : I=1,N, S=1,S1] \leq PERSKAP(T) : T=1983, 1987, V=1,V1;$
SATZ BERUECKSICHTIGUNG DER ABGATZHOECHSTMENGE

$[PRUD(I,S,V,T) * X(I,S,V) : I=1,N, S=1,S1] \leq ARS(T) : T=1983, 1987, V=1,V1;$

Figure 3: Model Formulation Using PLASMA-Syntax

3. Empirical Study of the User Behavior

3.1 Experimental Design

On the occasion of a course on investment and finance for advanced students of business administration and economics, we demanded for a solution of a multiperiod capital budgeting problem. The students first had to formulate the mathematical program in the lecture-room, then they tried to solve the model by the use of the PLASMA II system. In order to look at the influence of different problem formulations on the user behavior, we divided the students into two groups ($N_1=21$; $N_2=61$). The assignment was done by the students themselves, and they did not know the type of the problem before. They were only informed that they would have to formulate a special model based upon the subjects which had been exercised with them during the course (capital budgeting, corporate modeling).

The actual two problems of capital budgeting then were nearly the same, they only differed with respect to the objective function (problem 1: maximization of present value according to ALBACH; problem 2: maximization of dividends, given the terminal wealth according to WEINGARTNER/HAX). The problem was defined in a purely verbal manner on one page - without any numerical data, but detailed economic structure. As argued in [12], we were interested in the structure and not in the numerical characteristics of the problem. Furthermore, we demanded a mathematical formulation of the model from all students, so that the investigation is not concerned with the discrimination of users and non-users of a model (see [6] for this approach).

The overall design of the experiments is shown in Figure 4. It should be noted that at steps 3 and 9 the students got marks for their works. This review was one part of the semester's course requirements. So they were motivated to do proper work when formulating and implementing the model.

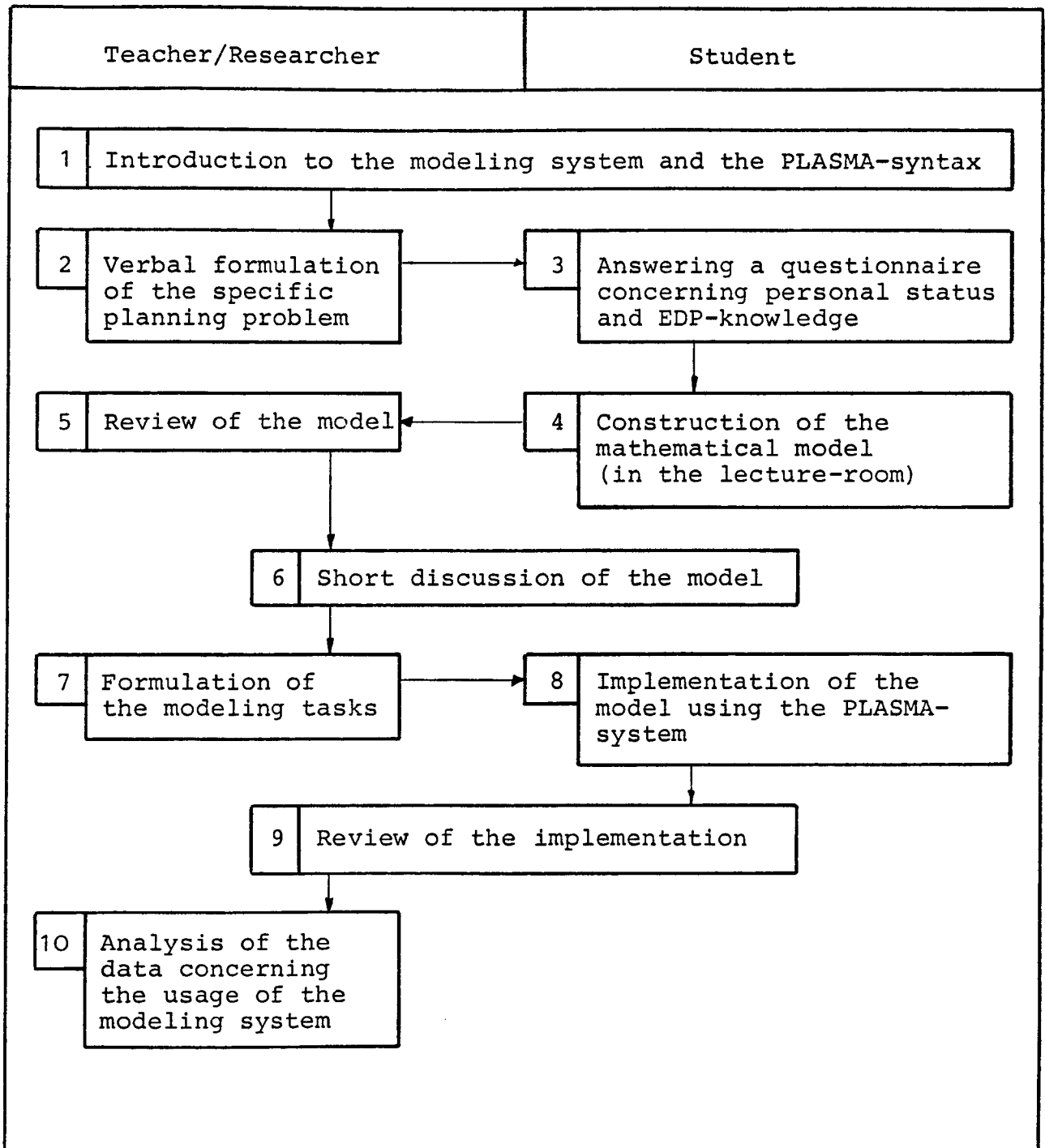


Figure 4: Design of the Investigation

The analysis of the data concerning the system's usage was based upon automated protocols which contained:

- the called type of PLASMA procedures
- the time when such a procedure was called.

Thus, it was possible to study the user behavior with respect to the procedures chosen and over time.

3.2 Results on User Behavior

First we present descriptive results on the user behavior, afterwards trying to explain differences concerning certain factors. If not mentioned otherwise, the results refer to the eighty-two students who arrived at an implementation of the model.

Table 2 reports on the calls of the different menu options. It can be seen from this table that the main procedures of activity are in the areas of model construction (MOK), model translation (UEB), matrix generation (AUF), data management (DAT), and MLP - the call of this procedure mainly indicates the usage of the PDP 10 editor or of the printer. The high percentages of MLP show the strategy to "save" the results at each step of the modeling process. This may be explained by the fact that 28 % of the students did not have any EDP experience.

Table 2: Calls of Menu Options

	Mean value	Standard deviation	Mean value (%)
MOK	20.21	14.98	9.20
UEB	34.67	20.12	15.60
AUF	35.73	18.84	15.98
DAT	21.90	15.86	9.46
ZDF	10.65	6.92	4.77
RDF	7.76	6.84	3.39
REP	14.66	12.96	6.47
GOA	6.09	5.28	2.66
RS1	13.68	9.41	6.20
MLP	45.70	21.97	21.62
Other	10.73	-	4.65
ALL	221.78	99.81	100.00

In Figure 5 - being based upon a complex evaluation routine - we show the cumulative frequencies for the calls of the different menu options. To do this, we first had to compute the total elapsed time for each user at the terminal; perhaps the user conducted his work on several days. The total elapsed time was set equal to 100 % for each user. Then it was observed which menu option had been called in which time-period - relative to the total elapsed time of the user.

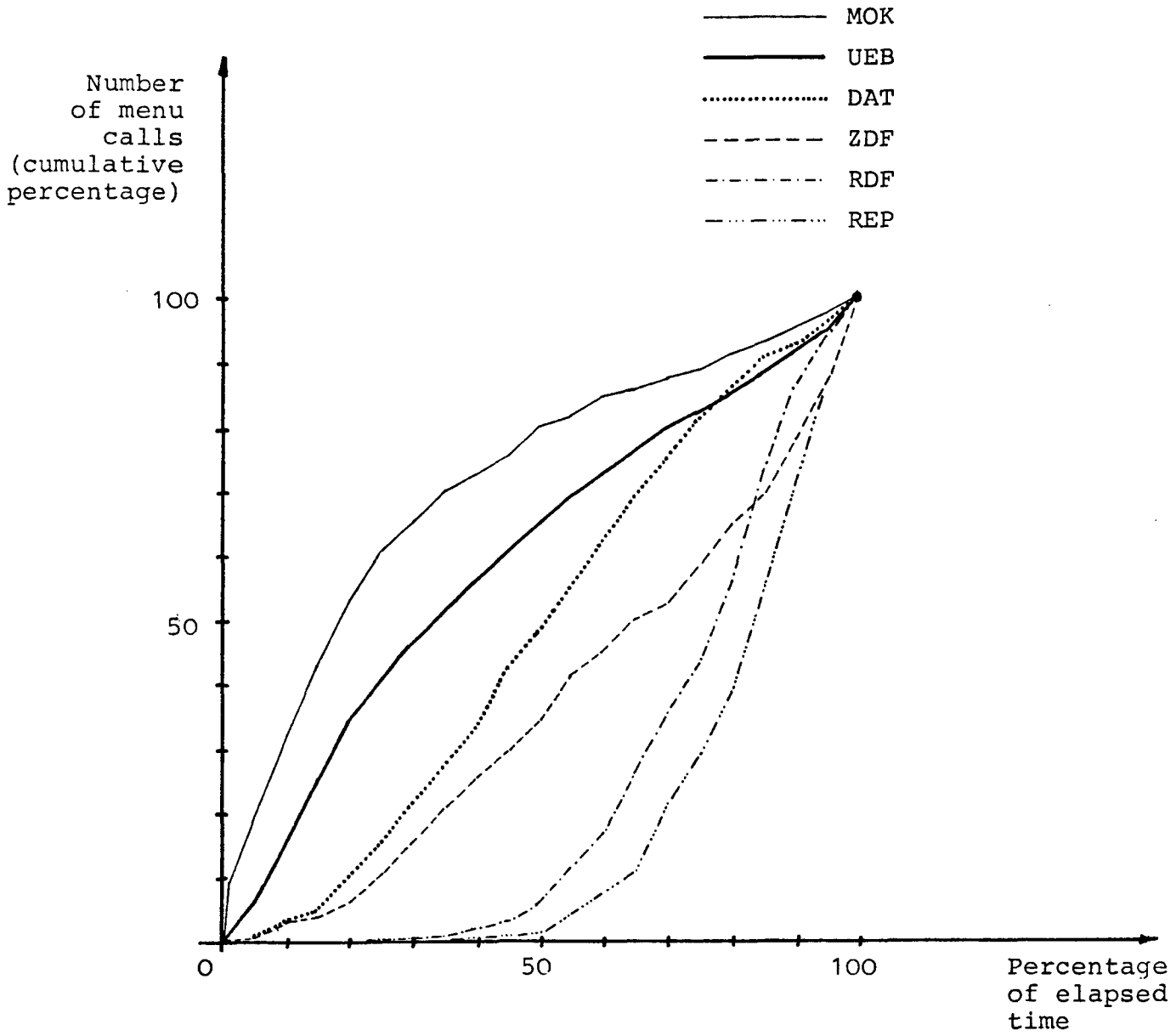


Figure 5: Calls of Selected PLASMA-Procedures
during the Modeling Process

Figure 5 clearly shows the ongoing process of modeling:

- model construction
- model translation
- data management
- goal definition
- report definition
- report generation.

On the other hand, the intersections of two of the cumulative functions in Figure 5 demonstrate that the users came back to earlier stages of the modeling process after they had arrived at a solution which did not satisfy them. Thus, in general they corrected (or just repeated) some earlier steps.

In Table 3 we present figures for the transition from one menu call to another. The figures in the diagonal give hints on presumable mistakes of the users because in general a repetition is not a normal procedure in the modeling process. Comparing these repetitions with the "Total"-column in Table 3 shows the troublesome options, especially the first four options, report definition, and report generation. The interpretation of these results must be conducted cautiously: A mistake can be caused by lacking capabilities of the DSS or by clumsiness and lacking understanding of the problem. It seems that the mistakes concerning the reports were mainly caused by an unsatisfactory architecture of the reporting procedures while the other mistakes probably indicate problems in the solution technique and the understanding of the solution process. This is confirmed by the return of the users to menu options which were called earlier, especially just before the call of the menu call in question.

Table 3: Frequencies of Transition between
Menu Options

To From	MOK	UEB	AUF	DAT	ZDF	RDF	REP	GOA	RS1	MLP	Other	Total
MOK	540	771	30	65	16	2	4	0	2	137	86	1653
UEB	320	694	795	94	49	3	4	2	8	787	86	2842
AUF	55	253	671	176	106	4	15	408	931	240	71	2930
DAT	51	90	368	557	119	16	43	4	5	488	55	1796
ZDF	11	74	348	37	205	7	6	14	8	136	27	873
RDF	5	19	16	11	4	147	307	1	3	98	25	636
REP	16	34	40	51	14	149	456	3	16	392	28	1199
GOA	9	17	51	14	60	14	8	31	5	254	30	493
RS1	27	54	135	112	22	23	96	14	77	456	105	1121
MLP	388	749	431	602	240	237	241	18	49	515	227	3697
Other	157	88	45	77	38	34	22	4	18	243	143	869
Total	1579	2843	2930	1796	873	636	1202	499	1122	3746	883	18109

Moreover, Table 3 gives evidence that users partially deviate from the normal modeling sequence, just by gaming or tasting the capabilities of the DSS. This was especially observed for students of computer science - as it came out from a deeper investigation of this type of behavior.

Finally, we tried to find out some factors which may explain the differences in the users' behavior. In step 3 of Figure 4 above we collected data concerning the chosen study program, the sex, and different types of EDP-orientation. In Table 4 we report on differences with respect to these factors and to the type of the underlying problem.

Table 4: Output of the Modeling Process:
The Influence by Selected Variables

Independent Variable	Dependent Variable	Mean values		Kruskal-Wallis test: level of significance
Study program chosen (N=73)	P1 ET UEB AUF ZDF GOA ALL	Business administration	Economics	0.038 0.138 0.085 0.093 0.010 0.010 0.099
		18.33	16.97	
		19:34:30	22:52:11	
		30.12	39.03	
		31.02	38.65	
		8.60	13.00	
		4.95	7.26	
		198.36	245.55	
Sex (N=82)	ET DAT RS1 ALL	Male	Female	0.021 0.018 0.073 0.058
		22:33:25	18:36:58	
		24.87	16.18	
		15.20	10.75	
		238.17	190.18	
Type of problem (N=82)	ERP MOK UEB AUF ALL	Albach	Weingartner/Hax	0.204 0.002 0.003 0.006 0.002
		21.89	18.23	
		26.57	18.02	
		47.14	30.38	
		45.57	32.34	
		282.00	201.05	
EDP-knowledge (N=82)	P1	No	Yes	0.048
		16.26	18.54	
Programming course (N=82)	P1 SZ UEB DAT ZDF ALL	17.56	19.05	0.091 0.105 0.082 0.088 0.088 0.147
		0.08	-0.27	
		36.30	29.26	
		22.75	19.11	
		11.32	8.42	
		229.83	195.11	
Computer science for economists (N=82)	ET	22:08:50	17:07:57	0.016
	ERP	19.81	16.31	0.073
	MOK	21.64	13.80	0.112
	UEB	36.70	25.60	0.037
	AUF	38.16	24.87	0.014
	DAT	23.39	15.27	0.098
	ZDF	11.37	7.40	0.037
	RDF	7.46	9.07	0.344
	REP	13.76	18.67	0.288
	GOA	6.21	5.53	0.899
	RS1	14.69	9.20	0.026
	ALL	232.45	174.13	0.044

As dependent variables for the user behavior we chose the following items:

- the number of called menu options (symbols for the different types see in Table 1)
- ALL: total number of called menu options
- P1 : number of points received from the review of the problem formulation
- ET : elapsed time, i.e. total connect-time of the user
- SZ : standardized time for the formulation of the problem in the lecture-room (different groups for the two defined problems)
- ERP: proxy for user error.

From Table 4 we can conclude (by applying the nonparametric Kruskal-Wallis test):

1. The chosen study program significantly influences P1, ET, and the main option calls of the DSS. Students of business administration perform better than students of economics.
2. Females show a better performance regarding the elapsed time and some menu calls.
3. The two defined planning problems cause a different modeling behavior though they are very similar. This may result from problems when summing up in the liquidity constraints of problem 1.
4. EDP-knowledge and the study of a programming language seem to make the mathematical formulation of a decision problem easier.
5. The study of computer science (for economists) leads to a better handling and interaction, but the levels of significance for the options RDF, REP, and GOA show that there exist also some unsatisfactory characteristics of the investigated DSS.

4. Conclusion

We investigated the behavior of eighty-two advanced students of business administration and economics concerning the usage of PLASMA II, a decision support system implemented at the University of Kiel. The empirical results show that there exists a "normal" structure of a modeling process. Deviations from this process structure are caused by several factors: insufficient system architecture or description, lacking intellectual capabilities of the users, and gaming and "tasting" the system by the users.

Further research should try to isolate these influences to get hints for proper DSS construction. Though the empirical user behavior again demonstrates the necessity for more user-friendliness, one should not forget the possibilities of human learning. The learning process has not been investigated here. There seems to be a need for more research on the dynamics of DSS usage.

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