Proceedings of the 1991 Winter Simulation Conference
Barry L. Nelson, W. David Kelton, Gordon M. Clark (eds.)

MEASURING THE USER ACCEPTANCE OF GENERIC MANUFACTURING SIMULATION MODELS BY REVIEW OF MODELING ASSUMPTIONS

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ABSTRACT

Simulation experts know very well that there are similarities between the models they build for different manufacturing systems. In a previous study, a group technology (GT) classification and coding scheme for discrete manufacturing simulation models was developed by observing those similarities, and generic discrete manufacturing simulation models were constructed based on the GT scheme. This article describes a measure of user acceptance for these generic models. The user acceptance measure is based on review of modeling assumptions and computed as the percentage of assumptions that are acceptable to the user. The assumptions, which describe the modeling options that are available in generic models, provide the user a detailed account of the capabilities and limitations of generic models. Hence reviewing the assumptions proves to be a most efficient means of informing the user about the generic models and measuring the user acceptance.

1 BACKGROUND

The area of discrete manufacturing, having a wide variety and large number of problems to which simulation can be applied, is an excellent candidate for developing a simulation model taxonomy. It appears that subsets of manufacturing systems demonstrate enough similarity so that the concepts of model classification and generic model building based on this classification may be applicable. The similarity between the simulation models was observed by some authors including Doukidis and Paul (1985). Others, such as Elsaz (1986) and De Swaan (1983), suggested classification of simulation studies to identify generic model modules.

A taxonomy of discrete manufacturing simulation models based on a group technology (GT) classification approach, focusing on both the user goals and physical system characteristics, was developed by Ozdemirel, Mackulak, and Cochran (1990a). The GT classification and coding scheme was validated by reviewing 115 application oriented simulation studies selected from the literature. These studies reported simulation models that were developed for studying different aspects of various discrete part manufacturing and assembly systems. As the studies were analyzed, common structural properties of the models and simulation goals were identified, and a "digit" was created in the GT scheme to represent each common property or goal. The review proceeded by adding new digits to the scheme as more common properties were observed in the models. The GT scheme took its final form when it was possible to GT code all the aspects of a significant portion (more than 70 percent) of discrete manufacturing models. The estimated size of the GT scheme is 78 digits. Nineteen of the digits are for representing the user goals, and the remaining digits are for the physical system characteristics.

The reviewed studies were GT coded using the final form of the scheme. These GT codes were classified by means of cluster analysis to identify generic model modules, and fourteen generic modules were developed based on the results of the cluster analysis. The generic modules were implemented by using PC version of the SIMAN simulation language. The total number of lines of SIMAN code for fourteen modules was 2500. Forty generic models were created by taking the feasible combinations of these modules, and the models were stored in a generic model base. The GT scheme and the generic model base were incorporated in a model building system. The system was intended as the preprocessing module of an intelligent simulation system, namely GUIDES (Generic User-friendly Intelligent Design Environment for Simulation). Development of the generic model base and the model building system was discussed in detail by Ozdemirel, Mackulak, and Cochran (1991). An overview of the configuration of GUIDES is given in the following section.

The GT scheme is essential for development of a generic model base and an intelligent simulation environment. A model building system based on the generic models approach provides automation of simulation model development by reducing the process into selection of one of the generic models and configuration of this model to create a user specific model. This significantly improves the efficiency of model building by non-expert modelers, because no user programming is required. The need for model verification which is necessary in specific applications is also eliminated with pre-existing generic models. Furthermore, construction of simplified and more efficient models is possible, because inefficiencies due to computer coding by inexperienced modelers are eliminated.

The user acceptance of generic models is essential to prove feasibility of the generic modeling concept. The main question regarding the user acceptance is: does a generic model adequately represent the user's system? Balci and Nance (1985) view the match between the actual problem and the communicated problem (in the model) as part of the model credibility. Oren (1981) proposes that the acceptability of the model must be tested with respect to the real system structure and goals of the study. The same issue is referred to as the conceptual model validity by Sargent (1984a and 1984b) and Shannon (1981), and structural validity by Zeigler (1976). The purpose of this article is not to address the overall validity of generic models, but to introduce a practical method of measuring the user acceptance in terms of the match between the real system structure, and the model structure and assumptions.

2 CONFIGURATION OF GUIDES

The model building system is developed based on the GT classification and coding scheme and the generic model base. The model building system constitutes the preprocessor of a higher level intelligent simulation system, namely GUIDES. The model building process in GUIDES is schematized in Figure 1. The model building system is concerned with GT code generation for the user's problem, generic model selection, model configuration, and generation of specific user models. GUIDES has other modules for post processing, including experimental design and statistical output analysis, which will not be discussed here. Outputs of the model building system, the GT code for user goals and the specific model, are used as inputs by the post processing modules for automatic execution and analysis. The operation of the system is described in the GUIDES User's Manual (Ozdemirel, Mackulak, and Cochran 1990b).

The generic model base was implemented on a personal computer using PC SIMAN. The model building system consists of the generic model base and an interactive user interface which is programmed in Turbo Prolog (approximately 8000 lines of code) and runs on a Compaq 386 machine. The user interface has two main parts: an expert system for model selection and a model configuration program.

For model selection, the expert system interrogates the user as to the scale and scope of his problem, so as to determine whether the model building system has sufficient skills. Once the model building system proves to be capable, the expert system, based on the knowledge of the GT classification and coding scheme, guides the user through a series of questions that attempt to define the GT code for user goals and physical system characteristics. Eventually, the GT code generated by the expert system is used to select the best fitting generic model for the user's problem. Prior to the selection of a particular generic model, the expert system allows the user to review assumptions of generic models to generate a measure of user acceptance. The assumption review process will be discussed in the following section.

The next step, which is beyond the scope of this article, is to create a specific model by configuring the selected generic model. A generic experimental frame which defines the input data requirements of a generic model constitutes the basis for model configuration. A model configuration program assists the user in this process through various menus and windows. At the end of the configuration phase, a specific experimental frame is created in SIMAN format in which the user's input data are stored. The specific model consists of this experimental frame and the selected generic model structure. It is in executable form and ready for post processing.

3 MEASURING THE USER ACCEPTANCE BY ASSUMPTION REVIEW

The introductory screen of the GUIDES expert system for model selection is given in Figure 2. The expert system performs three major functions: (1) directing the initial questioning phase to determine if the system is capable of handling the user's problem, (2) measuring the level of user acceptance through assumption review, and (3) generating the partial GT code for the user's problem and choosing the best generic model for the application. These functions can be summarized as follows.

(1) Meta-level query: The initial questioning phase to decide whether the system is capable of handling the user's problem is performed under the meta-level query. Question responses at this stage compare the scope and general capabilities of the model building system versus the user's requirements and the nature of his manufacturing process. The user answers each question as yes or no, or he may require an explanation

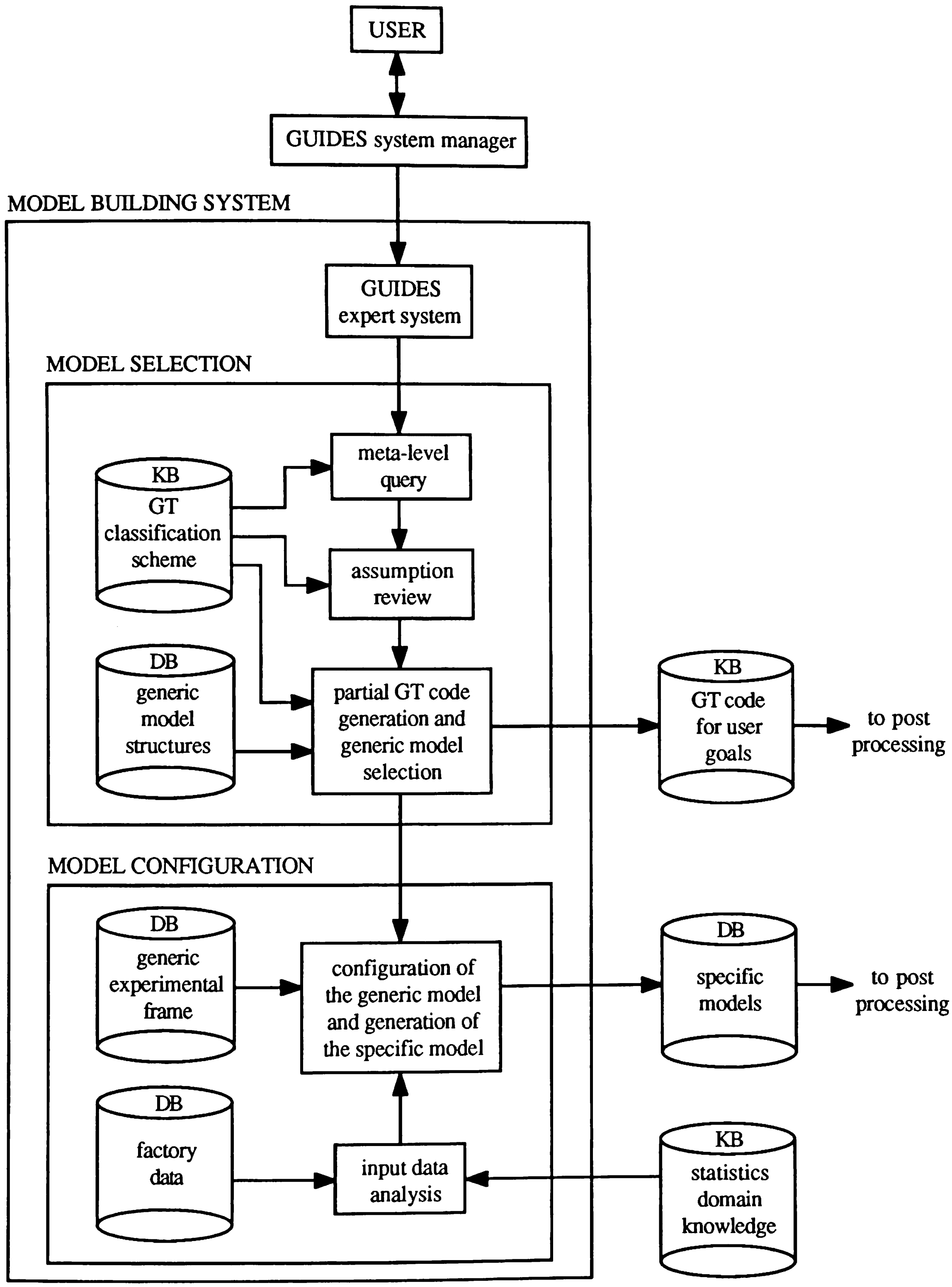

Figure 1. Model Building in GUIDES

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GUIDES

GUIDES EXPERT SYSTEM GETTING STARTED

GUIDES expert system operates in three phases:
1. Meta-level query: You will answer a series of
   questions about your manufacturing system. The
   expert system will determine if GUIDES is
   capable of modeling your specific application.
2. Review of assumptions: If you like, you will
   review general modeling assumptions of GUIDES.
3. Model selection: The expert system will assist
   in selection of a generic model for your
   application.

When answering the questions, please select the
the option which best describes your process. You
may ask for explanations at any time.

Press any key to continue!
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Figure 2. Introductory Screen of the GUIDES Expert System

as to why a certain question is asked. At the end of the meta-level query, the expert system draws a conclusion regarding whether the system can satisfactorily model the user's problem.

(2) Assumption review and measuring the level of user acceptance: Upon the successful conclusion of the meta-level query, the user may choose to review assumptions of the generic models. Assumption review results in generation of a user acceptance measure. As the review proceeds, the user is asked if he accepts or rejects each of the assumptions. At the end of the review session, the percentage of assumptions that are accepted is computed and displayed as the user acceptance score.

Three types of assumptions are included in this review process.

- Modeling options that are defined by the GT scheme and available in the generic models. For example, various types of work stations available, number of secondary resources such as machine tool operators that can be assigned to each work station, material handling options, alternative ways of generating job arrivals at the shop floor, various queue disciplines and balking options, equipment breakdown options, and so on. These assumptions basically define the capabilities of the generic models.
- Modeling options that are defined in the GT scheme, but omitted from the implementation of generic models, because they were observed in only a few of the reviewed studies. For example, inspection without rework, simulation of the loading/unloading of material handling equipment, and the same operation sequence for different job types.
- Typical assumptions that are made in traditional simulation studies, such as a job can be processed at one machine tool at a time, or a machine tool can process one job at a time.

The first two types of assumptions are different from the traditional concept of modeling assumptions in that they define all the modeling options available in the GT scheme and capabilities of generic models in general. Different modeling options that are provided in the GT scheme and implemented in the generic models are listed as assumptions, as well as those that are ignored in the implementation. Hence, these assumptions reflect the limitations of the generic models as well as their strengths. By reviewing the assumptions, the user will be aware of the modeling options that are provided by the generic models and their limitations, and state his opinion on the sufficiency and acceptability of these options. Hence the acceptance scores provide a measure of the user's acceptance of generic models.

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------------------------------ GUIDES ------------------------------

        ---------- REVIEW OF ASSUMPTIONS ----------
        You may review the assumptions          Acceptance
        regarding:                                score(%)
                                                ----------
        Work Stations and Secondary Resources     92.31
        Material Handling                         87.50
        Jobs                                      90.91
        Service Times and Operation Routings      90.00
        Work-In-Process Storage Areas             80.00
        Equipment Breakdowns and Maintenance     100.00

Use arrow keys to select and press <CR>. <ESC> to end assumption review.
```

Figure 3. Assumption Review Menu and User Acceptance Scores

The assumptions of generic models are grouped under six headings as in the assumption review menu given in Figure 3. The user may choose to review any group of assumptions, accepting or rejecting each assumption in the group. As an example, the first screen from the review of work station assumptions is shown in Figure 4. At the end of the review process, the acceptance scores are computed separately for each assumption group and displayed in the menu as seen in Figure 3.

The assumptions are grouped by the simulation entities and modeling aspects they are concerned with. The purpose of the grouping is partly to simplify the review process, so that the user does not have to review a large number of assumptions concerning different modeling aspects all at once. Instead, the assumptions are listed in a logical order, and the user can relate the assumptions concerning the same modeling aspect. Another reason for grouping of assumptions is to generate a more sensitive user acceptance measure. Because a different measure of acceptance is generated for each assumption group, it will be possible to see which aspects of generic models have higher acceptability than the others. The major sources of unacceptability can be detected at the first sight, and generic models can be revised to overcome these deficiencies.

(3) Partial GT code generation and model selection: Review of assumptions is followed by the generic model selection. The expert system assists the user in this selection through a number of menus. The option chosen by the user from each menu is used to determine a certain GT digit. The partial GT code is defined when all the selections are made. A generic model is selected based on this code and displayed to the user. At the end of the model selection phase the selected generic model is known to the model building system and ready for configuration. The remaining digits of the GT code are decided as the model configuration proceeds.

4 RESULTS

The model acceptance decision is initiated by the potential user (Ayal, Hempel, and Cattin, 1978). Hence, the best way of testing the GUIDES expert system is to let simulation modelers with various levels of experience try the system. For this purpose, managers and engineers from various companies using simulation for different purposes, were invited to Arizona State University. Following a brief demonstration of the software, they used the system to select and configure generic models. Their suggestions were invaluable, particularly in providing a better user interaction and a clearer view of the generic model structures.

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GUIDES
REVIEW OF ASSUMPTIONS

Assumption 101:                                                  yes
The generic models in GUIDES allow for definition of 50 work      no
stations, maximum. The following types of stations are allowed:
- Machining stations.
- Assembly stations.
- Inspection stations.
- Fixture loading/unloading stations.
- Batch size independent processes.
- Common storage area for work-in-process.

     Is Assumption 101 acceptable?

Assumption 102:
A primary resource which is automatically defined for each station
may have one or more parallel identical servers. A server may
process one job at a time.

     Is Assumption 102 acceptable?

Use arrow keys to select and press <CR>. <ESC> to end assumption review.
```

Figure 4. Sample Assumption Review Screen for Work Stations

The user acceptance of generic models is measured through the assumption review process discussed in the previous section. Assumptions provide a detailed account of the capabilities and limitations of the generic models. They describe the functional flow of the model structures as well as the configuration requirements to generate specific models. Hence reviewing the assumptions provides a most efficient means of informing the user about the generic models. Another approach would be to ask the modeler to read the code of the generic model produced, however the intended user cannot be expected to know the simulation language well enough to understand the code.

An on-line review of the assumptions by members of the invited industry panel was not possible, because of the time required. Instead, a written list of assumptions in the form of a survey was distributed to the panelists. They were asked if each assumption was acceptable, or to explain why an assumption was rejected. The same survey was given to graduate students taking an advanced course on simulation in manufacturing systems at Arizona State University. Many of the students responded the survey by considering their own work environment at a manufacturing company.

The results of the survey are summarized in Table 1 by a relative cumulative frequency distribution of the acceptable assumptions. A frequency histogram is also given in Figure 5. The total number of responders is $n = 22$, and the total number of assumptions is 52. The average number of acceptable assumptions is $\overline{X} = 47.727$ (91.78 percent) with a standard deviation of $s = 2.995$.

The normality of the relative frequency distribution must be tested in order to construct a confidence interval for the number of acceptable assumptions by using the t-distribution. The Kolmogorov-Simirnov goodness-of-fit test is chosen to test for normality because the sample size ($n = 22$) is small. The hypotheses for the test are:

H_0: The probability distribution of x_i is normal,
H_1: The probability distribution of x_i is not normal,

where x_i represent the number of acceptable assumptions.

The test statistic for the Kolmogorov-Simirnov test is defined by Conover (1980) as

$$T = \max_x |F(x) - S(x)|$$

where $F(x)$ is the hypothesized cumulative distribution function, and $S(x)$ is the empirical distribution.

Table 1. Relative Cumulative Frequency Distribution of Acceptable Assumptions

Number of Acceptable Assumptions, x_i	Cumulative Frequency of Number of Responders	Relative Cumulative Frequency, $S(x_i)$	Standard Normal Variable, z_i	Normal Frequency, $F(x_i)$	Absolute Difference, $\|F(x_i)-S(x_i)\|$
≤41	0	0.0000	-2.08	0.0188	0.0188
≤42	2	0.0909	-1.75	0.0401	0.0508
≤43	2	0.0909	-1.41	0.0793	0.0116
≤44	3	0.1364	-1.08	0.1401	0.0037
≤45	6	0.2727	-0.74	0.2296	0.0431
≤46	8	0.3636	-0.41	0.3409	0.0227
≤47	10	0.4545	-0.08	0.4681	0.0136
≤48	11	0.5000	0.26	0.6026	0.1026
≤49	13	0.5909	0.59	0.7224	0.1315
≤50	18	0.8182	0.93	0.8238	0.0056
≤51	21	0.9545	1.26	0.8962	0.0583
≤52	22	1.0000	1.59	0.9441	0.0559

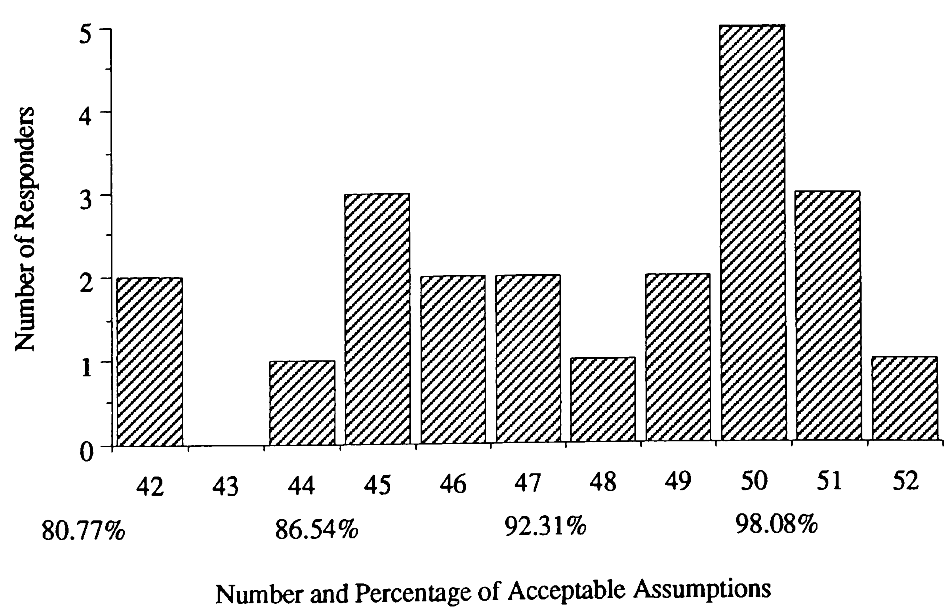

Figure 5. Relative Frequency Histogram of Acceptable Assumptions

The absolute differences between the empirical frequencies and normal frequencies are calculated in the last column of Table 1. The maximum of these differences (T = 0.1315) is compared with the following $1 - \alpha$ quantiles.

$1-\alpha$	0.80	0.90	0.95	0.98	0.99
$w_{1-\alpha}$	0.221	0.253	0.281	0.314	0.337

The value of T is insignificant at any level of α, hence H_0 cannot be rejected. A confidence interval for the number of acceptable answers can now be calculated using the t-distribution, assuming normality.

α	$(1-\alpha)100\%$ Confidence Interval $\bar{X} - t_{\alpha/2}\frac{s}{\sqrt{n}} < \mu < \bar{X} + t_{\alpha/2}\frac{s}{\sqrt{n}}$	
0.10	$46.628 < \mu < 48.826$	[89.67%, 93.90%]
0.05	$46.399 < \mu < 49.055$	[89.23%, 94.34%]
0.01	$45.919 < \mu < 49.535$	[88.31%, 95.26%]

5 CONCLUSION

In this article a measure of user acceptance for generic discrete manufacturing models is introduced. The user acceptance measure is based on review of modeling assumptions and computed as the percentage of assumptions that are acceptable to the user. The assumptions, which describe the modeling options that are available in generic models, provide the user a detailed account of the capabilities and limitations of the generic models. Hence reviewing the assumptions proves to be a most efficient means of informing the user about the generic models and measuring the user acceptance. The assumption review process and the user acceptance measure are implemented within the framework of an intelligent simulation environment. An expert system guides the user through the review of assumptions and generates the user acceptance scores.

In conclusion, although certain modifications can be made in the generic models to eliminate some of the rejections concerning the assumptions, the model acceptance, in general, is fairly high (91.78 percent). This acceptance value proves that the concept of generic modeling is feasible, and its implementation has potential use for simulation modeling in manufacturing systems.

ACKNOWLEDGEMENTS

This work was supported by the National Science Foundation's I/UCRC for Manufacturing and Automation, and the Institute for Manufacturing and Automation Research. The facilities of the CIM Systems Research Center and the College of Engineering and Applied Sciences at Arizona State University also provided support.

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REFERENCES

Ayal, I., Hempel, D. J., and Cattin, P. (1978). "Management of the Model Development Process." Proceedings of the 1978 Winter Simulation Conference, 231-239.

Balci, O. and Nance, R. E. (1985). "Formulated Problem Verification as an Explicit Requirement of Model Credibility." *SCS Simulation*, 45:2, 76-86.

Conover, W. J. (1980). *Practical Nonparametric Statistics* (2nd ed.). New York, NY: John Wiley and Sons.

Doukidis, G. I. and Paul, R. J. (1985). "Research Into Expert Systems to Aid Simulation Model Formulation." *Journal of the Operational Research Society*, 36:4, 319-325.

Elsaz, M. S. (1986). "The Applicability of Artificial Intelligence Techniques to Knowledge Representation in Modelling and Simulation." *Modelling and Simulation Methodology in the Artificial Intelligence Era* (M. S. Elsaz, T. I. Oren, and B. P. Zeigler, eds.), 19-40. Netherlands: Elsevier Science.

Oren, T. I. (1981). "Concepts and Criteria to Assess Acceptability of Simulation Studies: A Frame of Reference." *Communications of the ACM*, 24:4, 180-189.

Ozdemirel, N. E., Mackulak, G. T., and Cochran, J. K. (1990a). "A Group Technology Classification and Coding Scheme for Discrete Manufacturing Simulation Models." Submitted to the *International Journal of Production Research*.

Ozdemirel, N. E., Mackulak, G. T., and Cochran, J. K. (1990b). User's Manual for GUIDES - Generic User-Friendly Intelligent Design Environment for

Simulation. CIM Research Center, Arizona State University.

Ozdemirel, N. E., Mackulak, G. T., and Cochran, J. K. (1991). "A Generic Simulation Model Building System Based on Group Technology Classification of Models." In preparation.

Sargent, R. G. (1984a). "A Tutorial on Verification and Validation of Simulation Models." Proceedings of the 1984 Winter Simulation Conference, 115-121.

Sargent, R. G. (1984b). "Simulation Model Validation." *Simulation and Model Based Technologies: An Integrative View* (T.I. Oren, B.P. Zeigler and M.S. Elsaz, eds.), 537-555. Berlin, Germany: Springer-Verlag.

Shannon, R. E. (1981). "Tests for the Verification and Validation of Computer Simulation Models." Proceedings of the 1981 Winter Simulation Conference, 573-577.

de Swaan Arons, H. (1983). "Expert Systems in the Simulation Domain." *Mathematics and Computers in Simulation*, 25:1, 10-16.

Zeigler, B. P. (1976). *Theory of Modeling and Simulation*. New York, NY: John Wiley and Sons.