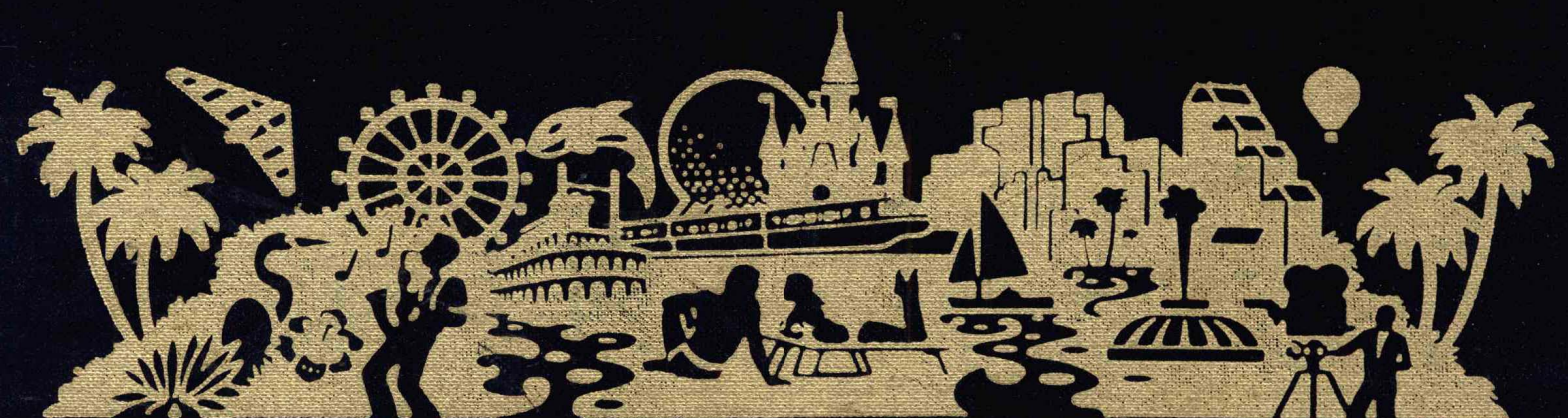# WSC '94

1994 Winter Simulation Conference

Conference Proceedings

Edited by:
Jeffrey D. Tew
S. Manivannan
Deborah A. Sadowski
Andrew F. Seila

December 11 — 14, 1994   ~ ~ ~   Walt Disney World Swan Hotel

1994
WINTER SIMULATION CONFERENCE
PROCEEDINGS

Edited By

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About the Conference

From the Editors

A conference called "Conference on the Applications of Simulation Using GPSS," sponsored by ACM, SHARE, and IEEE, was held in 1967. In 1971 the name of the conference was changed to the "1971 Winter Simulation Conference," and it has been held annually with the exception of 1972 and 1975. As the conference proceeds into its second quarter-century, we have occasion to reflect upon the development of the conference as well as the changes we have seen in the field of simulation. The evolution of the conference has reflected the development of the field of discrete event and combined continuous-discrete event simulation. In looking back, three patterns emerge.

First, the number of participants has grown in parallel with the growth in the number of professionals in the field of simulation. Attendance at the 1993 conference was very strong, and based upon the number of program submissions and inquiries this year, attendance is expected to continue this upward trend. Clearly, research in and application of simulation are in a period of strong, steady growth.

Second, the field has seen an integration of methodology and application. As you will see in the program this year, many software products utilize the latest modeling and analysis methodology. Similarly, much of the current research in analysis and modeling methodology is directed toward solving applied problems. Like the first conference in the series, applications are the driving force.

Third, the Winter Simulation Conference has become more international in scope. In the early conferences, virtually all participants were from the U. S. However, over the past decade, the number of participants from Europe and the Far East has increased dramatically. This year, the program includes presenters from such far-flung places as New Zealand, Japan, Germany and Croatia. Many simulation modeling ideas, such as activity cycle diagrams and Petri nets, have developed in Europe quite separately from modeling approaches developed in the U. S. In this year's conference, we see a merging of these approaches. It truly can be said that we now have a global simulation community.

One of the primary purposes of the Winter Simulation Conference is to provide a meeting place for people from academia, industry and government to exchange knowledge and technology concerning discrete and discrete-continuous simulation. We hope all conferees will take advantage of all the opportunities for professional advancement at this conference.

The theme of this year's conference is "Simulation... Beyond Imagination." The program certainly echoes this theme. This program is arguably the largest yet at a Winter Simulation Conference. The number of contributed papers was so overwhelming that the Conference Committee decided to expand the program to 11 tracks. The final program consists of 214 presentations in 101 sessions. There are 171 full-length technical papers, 25 software/modelware tutorials and 6 panel discussions. In the 11 parallel tracks there are 78 invited papers and 136 contributed papers. Altogether, 286 contributed papers were received and the acceptance rate was 48

The program can be divided into three broad areas: education, methodology and applications. In the area of education, tracks on introductory tutorials, advanced tutorials and state-of-the-art reviews increasingly advance surveys of current practice in all areas of simulation methodology and application. Every attendee should find a tutorial or review that is of interest. Two additional tracks containing software/modelware tutorials are also provided to introduce attendees to various simulation software products. Next, three tracks are devoted to

simulation methodology: the analysis methodology track presents papers and issues related to the statistical and mathematical aspects of simulation, while the modeling methodology track, which includes the parallel and discrete event simulation mini-track, has papers and panels concerned with issues in model development and representation. Finally, there are three tracks involving applications in the entire spectrum of potential application areas. Applications are presented in such areas as military, health care, manufacturing, restaurants and entertainment, computer performance analysis and others.

This volume and indeed the entire conference is the joint creation of the persons serving on the Conference Committee and the Program Committee. In addition to ourselves, The Conference Committee includes David Goldsman, Daniel Muller, Bill Lilegdon, M. Eric Johnson, David Sturrock, Thomas McGuigan, and Christine Watson. The Program Committee includes Laurie Travis, Sheldon Jacobson, Jim Wilson, John Miller, Richard Fujimoto, Keebom Kang, John Fowler, Paul Auclair, Julie Lowery, Mark Roberts, Kevin Healy and Jim Swain. These track coordinators were empowered to invite presentations and review and accept contributed papers. They were assisted in the performance of their duties by the generous efforts of session chairs and referees. Referees are acknowledged by name on page *xxviii* of this volume. We are all indebted to them for their highly competent and dedicated work.

A number of other persons have contributed significantly. Special thanks go to David Goldsman for his efforts as Associate Program Chair. We also wish to thank Pam Dwight for her help in maintaining the program database and to Sheila King for providing secretarial support. Also, thanks go to the Terry College of Business at the University of Georgia for the use of their services and facilities. In addition, on behalf of the Proceedings Editors, special thanks go to Phil Seeley, Jerry Bowdle, and Thoi Truong, all of Consolidated Freightways, Inc., for their support in the development of this Proceedings.

The host location for this year's conference is the Walt Disney World Swan Hotel, adjacent to EPCOT in Lake Buena Vista, Florida. WSC 94's general committee worked to capitalize on the informal atmosphere to present an environment encouraging free exchange of information among a wide variety of participants. We would like to thank Dave Sturrock, Eric Johnson, Dan Muller, Christine Watson, and Tom McGuigan for their care in ensuring a successful conference and a very positive experience for attendees, presenters, and exhibitors. Also, thanks to Caroline Zenkevich and Lynn Barrett of Systems Modeling for donating behind-the-scenes time and effort that were well "above and beyond the call" to put together high-quality publications for WSC. Finally, many thanks to Shelly Richardson of EPIC Management, the conference's professional services organization, for tirelessly attending to details, making suggestions, and managing the conference preparations throughout the year.

We thank all attendees for their participation in the 1994 Winter Simulation Conference. We hope that you find the conference to be a rewarding and enriching experience.

Jeffrey D. Tew   Mani S. Manivannan   Deborah A. Sadowski   Andrew F. Seila
Proceedings Co-Editor   *Proceedings* Co-Editor   General Chair   Program Chair

About the Editors

JEFFREY D. TEW is a Senior Systems Analyst with Consolidated Freightways, Inc. and an Adjunct Associate Professor of computer simulation at the Oregon Graduate Institute. He received a B.S. in Mathematics from Purdue University in 1979, a M.S. in Statistics from Purdue University in 1981, and a Ph.D. in Operations Research from Purdue University in 1986. From 1987 to 1993 he was a faculty member in the Industrial and Systems Engineering Department at Virginia Tech. He has published in such archival journals as *European Journal of Operational Research, IIE Transactions, IMACS, Journal of Statistical Computation and Simulation, Management Science, Operations Research,* and *SCS Transactions.* From 1992 to 1994 he served as the Newsletter Editor for the TIMS College on Simulation and currently is the Vice President/President Elect of that organization. He has participated in the Winter Simulation Conference since 1985 and served as its Publicity Chairman for 1992. His research interests are in applied statistics, design of simulation experiments, variance reduction techniques, and statistical linear models theory. He currently serves as *Proceedings* Co-Editor for WSC '94.

MANI S. MANIVANNAN is a Senior Systems Engineer in the Intelligent Systems Engineering Group at Consolidated Freightways, Inc. and an Adjunct Associate Professor in the Engineering Management Department of the Portland State University. His research interests lie in the areas of knowledge-based systems and simulation for modeling and analysis of complex, large scale transportation and manufacturing systems. He is a member of IEEE, ACM, SCS, ASEE, ORSA/TIMS and SME. He is a *Proceedings* Co-Editor for WSC '94.

DEBORAH A. SADOWSKI is Vice President of Software Development at Systems Modeling Corporation. She received B.S. and M.S. degrees in Industrial Engineering and Operations Research from The Pennsylvania State University in 1984 and 1988, respectively. She joined Systems Modeling in 1983 where she has had responsibilities in a variety of areas related to simulation application, sales and marketing, research, customer support and training, and development. Since taking her current position in 1990, she led in the conceptualization and design of Systems Modeling's Arena product line. She is a member of IEEE/CS, ACM, IIE, and ORSA. She previously served as Exhibits Chair for WSC '90 and Business Chair for WSC '91; she currently serves as General Chair of WSC '94.

ANDREW F. SEILA is an Associate Professor in the Terry College of Business at the University of Georgia. He received a B.S. in Physics and a Ph.D. in Operations Research and Systems Analysis, both from the University of North Carolina at Chapel Hill. Prior to coming to the University of Georgia, he worked for Bell Laboratories in Holmdel, New Jersey. His research interests are in all areas of simulation methodology, especially the application of probability and statistical methods to problems in simulation. He is a member of ORSA, TIMS, and ASA and is an Associate Editor for *IIE Transactions.* He has been a member of the Program Committee for WSC '92 and WSC '93, and is the Program Chair for WSC '94.

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Institute of Electrical and Electronics Engineers/Computer Society (IEEE/CS)

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Operations Research Society of America (ORSA)

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The Board of Directors is responsible for the year-to-year continuity and organization of the WSC. It also selects the members of the Conference Committee for each WSC. The Board consists of one member from each of the nine sponsoring organizations, and has four rotating officers: Chair, Vice Chair, Secretary, and Liaison to each WSC.

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WSC '94 Conference Committee

A Conference Committee organizes and runs each WSC. It is headed by the General Chair, who is the chief overseer of the conference. The Program Chair is responsible for the program of presentations, including the selection of Track Coordinators. The *Proceedings* Editor is charged with producing the document containing the papers submitted by the WSC's presenters. Other Conference Committee positions include the Associate Program Chair, the Associate *Proceedings* Editor, as well as Business, Registration, Exhibits, and Publicity Chairs. The WSC Board Liaison serves as a link between the Conference Committee and the WSC Board of Directors.

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Referees

The high quality of the contributed papers appearing in this volume is a direct result of the joint efforts of the authors, the Program Committee, and the following referees.

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Christopher Carothers	Georgia Tech
Martha A. Centeno	Florida International University
Daren Dance	SEMATECH
Samir Das	University of Texas at San Antonio
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Taieb F. Znati	University of Pittsburgh

The Winter Simulation Conferences

For the periods 1967–1968 and 1974–1991, the attendance figures given below represent total paid attendance including students, but excluding exhibits-only registrants. For the period 1969–1973, no surviving records of WSC attendance are held by any of the sponsoring societies; consequently attendance estimates were obtained by discussions with the Program Chairs and General Chairs for this period—namely, Harold Hixson, Julian Reitman, Arnold Ockene, Philip Kiviat, Michael Araten, Joseph Sussman, Austin Hoggatt, and Michael Morris. Although the figures for the years 1969–1973 are subject to uncertainty, there is little doubt that in the period 1970–1971, attendance at WSC was substantially higher than in all other years. In the following table, the abbreviations GC, PC, APC, PE, and APE denote General Chair, Program Chair, Associate Program Chair, *Proceedings* Editor, and Associate *Proceedings* Editor, respectively.

	Conference	Conference Leaders	Attendance
1	Conference on the Applications of Simulation Using GPSS 13–14 November 1967 Hilton Hotel, New York, NY	Harold G. Hixson (GC) Julian Reitman (PC)	401
2	Second Conference on the Applications of Simulation 2–4 December 1968 Hotel Roosevelt, New York, NY	Julian Reitman (GC) Arnold Ockene (PC)	856
3	Third Conference on the Applications of Simulation 8–10 December 1969 International Hotel, Los Angeles, CA	Arnold Ockene (GC) Philip J. Kiviat (PC)	400
4	Fourth Conference on the Applications of Simulation 9–11 December 1970 Waldorf-Astoria Hotel, New York, NY	Philip J. Kiviat (GC) Michael Araten (PC)	1100
5	The 1971 Winter Simulation Conference 8–10 December 1971 Waldorf-Astoria Hotel, New York, NY	Michel Araten (GC) Joseph Sussman (PC)	1200
6	The 1973 Winter Simulation Conference 17–19 January 1973 St. Francis Hotel, San Francisco, CA	Joseph Sussman (GC) Austin C. Hoggatt (PC)	600
7	The 1974 Winter Simulation Conference 14–16 January 1974 The Washington Hilton Hotel, Washington, DC	Michael F. Morris (GC) Harold Steinberg (PC) Harold J. Highland (PE)	463

	Conference	Conference Leaders	Attendance
8	The 1976 Bicentennial Winter Simulation Conference 6–8 December 1976 National Bureau of Standards, Gaithersburg, MD	Harold J. Highland (GC) Thomas J. Schriber (PC) Robert G. Sargent (APC)	306
9	The 1977 Winter Simulation Conference 5–7 December 1977 National Bureau of Standards, Gaithersburg, MD	Robert G. Sargent (GC) J. William Schmidt (PC) Harold J. Highland (PE)	465
10	The 1978 Winter Simulation Conference 4–6 December 1978 The Deauville Hotel, Miami Beach, FL	Larry G. Hull (GC) Norman R. Nielsen (PC) Harold J. Highland (PE)	388
11	The 1979 Winter Simulation Conference 3–5 December 1979 Holiday Inn Embarcadero, San Diego, CA	Mitchell G. Spiegel (GC) Robert Shannon (PC) Harold J. Highland (PE)	375
12	The 1980 Winter Simulation Conference 3–5 December 1980 Orlando Marriott, Orlando, FL	Paul Roth (GC) Tuncer I. Ören (PC,PE) Charles M. Shub (APC)	205
13	The 1981 Winter Simulation Conference 9–11 December 1981 Peachtree Plaza Hotel, Atlanta, GA	Claude M. Delfosse (GC) Charles M. Shub (PC) Tuncer I. Ören (PE)	267
14	The 1982 Winter Simulation Conference 6–8 December 1982 Holiday Inn Embarcadero, San Diego, CA	Yen W. Chao (GC) Orlando Madrigal (PC) Harold J. Highland (PE)	274
15	The 1983 Winter Simulation Conference 12–14 December 1983 Crystal Gateway Marriott Hotel, Arlington, VA	Jerry Banks (GC) Bruce Schmeiser (PC) Stephen D. Roberts (PE)	416
16	The 1984 Winter Simulation Conference 28–30 November 1984 Sheraton Dallas Hotel, Dallas, TX	Udo W. Pooch (GC) C. Dennis Pegden (PC) Sallie Sheppard (PE)	350
17	The 1985 Winter Simulation Conference 11–13 December 1985 San Francisco Hilton and Tower, San Francisco, CA	Gerard C. Blais (GC) Susan L. Solomon (PC) Donald T. Gantz (PE)	369

	Conference	Conference Leaders	Attendance
18	The 1986 Winter Simulation Conference 8–10 December 1986 Radisson Mark Plaza Hotel, Washington, DC	James O. Henriksen (GC) Stephen D. Roberts (PC) James R. Wilson (PE)	531
19	The 1987 Winter Simulation Conference 14–16 December 1987 The Ritz Carlton, Buckhead, Atlanta, GA	Hank Grant (GC) W. David Kelton (PC) Arne Thesen (PE)	475
20	The 1988 Winter Simulation Conference 12–14 December 1988 The San Diego Marriott, San Diego, CA	Peter L. Haigh (GC) John C. Comfort (PC) Michael A. Abrams (PE)	535
21	The 1989 Winter Simulation Conference 4–6 December 1989 The Capital Hilton Hotel, Washington, DC	Kenneth J. Musselman (GC) Philip Heidelberger (PC) Edward A. MacNair (PE)	619
22	The 1990 Winter Simulation Conference 9–12 December 1990 The Fairmont Hotel, New Orleans, LA	Randall P. Sadowski (GC) Richard E. Nance (PC) Osman Balci (PE)	517
23	The 1991 Winter Simulation Conference 8–11 December 1991 The Arizona Biltmore, Phoenix, AZ	W. David Kelton (GC) Gordon M. Clark (PC) Barry L. Nelson (PE)	540
24	The 1992 Winter Simulation Conference 13–16 December 1992 Crystal Gateway Marriott Hotel, Arlington, VA	Robert C. Crain (GC) James R. Wilson (PC) James J. Swain (PE) David Goldsman (APE)	734
25	The 1993 Winter Simulation Conference 12–15 December 1993 The Biltmore Hotel, Los Angeles, CA	Edward C. Russell (GC) William E. Biles (PC) Gerald W. Evans (PE) Mansooreh Molleghasemi (APE)	584
26	The 1994 Winter Simulation Conference 11–14 December 1994 The Walt Disney World Swan Hotel Lake Buena Vista, FL	Deborah A. Sadowski (GC) Andrew F. Seila (PC) Jeffrey D. Tew (CPE) S. Manivannan (CPE)	

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