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SIMULATION IN THE NEXT MILLENNIUM

Sanjay Jain

Gintic Institute of Manufacturing Technology
71 Nanyang Drive
SINGAPORE 638075

ABSTRACT

This paper looks into the future of simulation. The capabilities and features of simulation software of the future are hypothesized focusing on the major aspects of their use. The features addressed include model building, visualization, output analysis and optimization, integration and the Internet. The discussion of simulation software in the future is closely related to the vision of future applications of simulation. Applications of simulation in the near term future are proposed using examples of advanced applications that are in conceptual stages at present. Applications of simulation in the long term future are also proposed, bordering on science fiction.

1 INTRODUCTION

Simulation technology has rapidly grown since its early pioneering days in the 1960's. Many fields now rely on extensive use of simulation to test new ideas and options. The gaming industry is exploding with virtual reality and interactive simulation based futuristic games. The degree to which the players can immerse themselves into the virtual environment is continuing to grow. Interactive simulators have been in use for pilot training for years and are increasingly being used for training on advanced equipment. War games and other military applications have become well accepted and are growing rapidly supported by the High Level Architecture (HLA) initiative. A wide range of simulation applications are available to users in the manufacturing industry. Users can focus on the system level using discrete event simulations and drop down to modeling the physics of the manufacturing process using continuous process engineering simulations. At each of these levels, particularly in the system level discrete event simulation field a large number of tools exist with features suitable for many discerning users. Initial sales and marketing applications are appearing, particularly in the automotive industry where a potential customer can experience simulated rides in vehicles with different option content.

The field of simulation will continue to grow. The technology will move out from the domain of more expensive and complex industrial, defense, and gaming systems to many aspects of our lives. The growth will be met by the increasing availability of easy to use simulation software tailored for the range of simulations mentioned above. Section 2 puts forward the features and capabilities of simulation software of the future. In the third section, the applications of simulation in the near term future are discussed. Virtual factory, an example simulation application is discussed in more detail to highlight the integrated nature of simulation models in future. Section 4 makes an attempt to visualize futuristic systems that will be supported by simulation. Concluding remarks are made in Section 5.

2 SIMULATION SOFTWARE OF FUTURE

In the future the simulation software will no longer be divided clearly among discrete event and continuous process simulations. Currently continuous happenings in real-life are modeled as discrete events to reduce the computation load. In the future, with much higher computing power available, modelers will have the luxury of modeling the events with more realism. The discrete event capabilities may be used for an initial stage similar to how queuing models are used now. As the system details become clearer the model will start including more detailed continuous process representations. For example, a transport event may be modeled as a travel time from point A to point B initially, but it will rapidly be replaced by a simulation of the vehicle moving through the defined route with delays and interruption due to other traffic, obstructions, and the resultant braking, stoppages and accelerations. The level of detail will depend on the application, but analysts will probably err on the more detailed side given the expected features for easy addition of details and the negligible penalty on execution time. For transportation through a city it would be just a matter of linking to the available city model with traffic and signal pattern models off the Internet.

2.1 Development Technologies

Simulation software will follow the trend of other commercial software in increasing the use of object oriented technologies as the development platform. The trend will be further motivated by the use of object oriented databases by companies to store their data. The object orientation in simulation software will help in accessing the data from object oriented databases.

Simulation software will also become very open to allow integration with other related applications and embedding into other superset applications. The object orientation of the simulation software will further promote such integration.

2.2 Execution Technologies

The availability of greater computational power will continuously lead to more and more CPU and memory intensive simulations. The increase in computational power in individual machines will also motivate transparent networking mechanisms that will allow harnessing the power together. We are already seeing applications that tie up available computing power across the Internet for distributed calculations. This trend will continue and will lead to providing these capabilities with simple authorization activation mechanisms. These two trends, increasing computing power and increasing integration of distributed computing power, will lead to the development of simulation software that will employ parallel and distributed simulation techniques to execute the data, computation, and graphics intensive simulations.

The Internet will continue its penetration to almost all computers. Service bureaus will provide the advanced simulation capabilities that any user can access through the Internet, for a charge of course, and employ vast computing resources across the net to execute the runs. Such services will be targeted to small and medium-sized enterprises that are not able to afford powerful computing resources.

2.3 Auto Model Builders

There has been a huge leap in model building capabilities of commercial software solutions. Industry specific solution are already available that are completely data driven and minimize the model building exercise. While availability of such solutions has helped the users in starting simulation based projects, the users still find it too time consuming to provide all the data. Even when most of the data is available in other systems, writing interfaces to compute and provide the data required by simulators is a major effort. Of course, beyond the data the users still need to find the policies and procedures followed that are not necessarily captured in any systems.

Future simulation software will provide model building features that will minimize users' efforts in this phase. The following capabilities will help in this phase:

Data capture through systems: As companies are moving into the information age, more and more data is available in some system or the other. Simulation software will be able to obtain all the data from such systems minimizing the effort on data collection. This exercise will be further helped through the use of object oriented databases that will allow format independent data access.

Standards: The interfacing effort will be minimized by industry standards on data organization, allowing simulation software to read the data using standard interfaces. At present there are some standardization efforts in progress, such as an effort for developing and modeling data standard for semiconductor manufacturing simulation under the auspices of Semiconductor Equipment and Materials International (SEMI). While this effort specifically deals with data standards for simulation, it is expected that in future industry specific standards will be developed and used for storing all company data.

Input distribution fitting: Many simulation software already provide a feature allowing the user to enter the raw data and generate the appropriate distribution for use in the model. In the future, more intelligent features will be included for this task. For example, for an airline industry application based on history of reservation requests, the system can generate the input distributions for the request arrivals.

Case Based Reasoning for modeling decision making: In the future, the overall business and work flows are expected to be well captured in business process models. However, the decisions made in different circumstances and the proportion of time of their occurrences can only be retrieved through history files. It is expected that the smart model building systems will have case based reasoning features for extracting the pattern of decision making practiced over the past periods.

Human element capturing through observer modules: Observer modules will be available that will track the humans' actions over time to capture the needed information. Depending on the type of work and decisions to be captured, these "observers" may range from video cameras and sensors at manufacturing workstations, to user friendly applications for periodically entering information and reasoning with minimum interruption to the regular duties.

Identification of performance measures and detail: An important part of the modeling exercise is to determine the right level of detail for the model. Once the user has identified the performance measures, the system can assist in determining the level of detail using the embedded knowledge in the software.

Libraries: Users will have access to a number of model libraries on the Internet, maintained by professional organizations, industrial consortiums, simulation software vendors, machine and equipment vendors etc. that allow selection of past models, templates and constructs for quickly putting models together. These library offerings will be based on industry specific standards allowing quick reuse. Such libraries will be particularly useful for models of new systems for which current data and history files are not available. The user can use the concept of the proposed system and select whole models or sub-modules from library models to quickly put together models of the proposed system. These can be further edited to model the proposed concept.

Verification and Validation: This important aspect of model building will get more support in the simulation software of the future. For existing systems, the software will provide features for comparison of performance measures generated by the model and by the real system. This will be facilitated through the use of interfaces to information systems for access to data on historical and current performance.

2.4 Visualization Technologies

The area of simulation seeing the most dramatic change will be the visualization capability. This rapidly evolving area has already seen a number of advanced capabilities ranging from 3D visualization in commercial manufacturing simulation software to immersive Virtual Reality (VR) at research institutes. The use of immersive VR environments will become commonplace in the future. The user will be able to go inside the model and experience the simulated system complete with sounds. More detailed models will allow the user to delve into more and more detail.

Visualization development will perhaps gain the most from the availability of libraries and standards. Some of the visualization software, such as CASUS from Fraunhofer IGD in Germany (Luckas and Dorner 1998), already provides users with object libraries on the Internet. The user can download the objects of humans, machines, and material handling devices to quickly put together an animation scene. Each of the visualization objects takes substantial effort to develop, but once they are made available in the library, all users can access them to rapidly develop 3D scenes. In the future, such practice will be widely prevalent with 3D representations available in a standard graphic, a format that can be used with any simulation software. The effort to put together 3D visualizations will be much reduced promoting wider use.

The generation of 3D animation scenes using object and background libraries will be used for new and proposed systems. For existing systems, it is expected that the users can simply import video clips of the operation and quickly link the entities and resources to their logical counterparts in the model. Features for automatically converting the real life scenes to virtual scenes will be available. These will include capabilities such as replacing the real life machine with the closest virtual machine object available in the library with kinematic and process modeling capabilities. Similarly, human operators will be replaced with appropriately sized human object models from the library. Skill levels for human objects will be easily selected with defined cognitive capabilities for modeling of human aspects. Such mechanisms will be closely tied to the model building capabilities mentioned in the previous section.

Visualization will, of course, have its primary use in communicating the model results to the users and decision makers. The software will provide features for automatically identifying the unusual circumstances during the model run and capture the proceedings during such occurrences. This will reduce the user trouble of identifying the appropriate break points for capturing the animations. Many features will be available to use visualization along with other means of presentations.

2.5 Output Analysis and Optimization

The availability of advanced model building capabilities will be matched by the advanced model output presentation and analysis features listed below.

Statistical validity: The user friendly model building capabilities will help promote the widespread use of simulation. Such ease of use by people with little background in simulation and statistics increase the possibility of misuse. The simulation systems of the future will provide automatic modes to carry out multiple runs and provide statistically valid results at a desired level of confidence. The high execution speeds of the future will further facilitate the use of multiple runs for arriving at the results.

Performance improvements based on statistical approaches: The statistical capabilities of the software will also include capabilities for guiding the users to improve system performance. This will include techniques such as design of experiments (DOE) and response surface methodologies.

Performance improvements based on expert suggestions: The simulation software will have advanced guidance capabilities for the user to determine the changes required for improving the performance of the modeled system. Such capabilities will be based on analysis and improvement techniques used by experienced simulation analysts and built into the software. The system will also have learning capabilities that will allow it to learn the techniques from core simulation groups at a company's research and development center for later use by line personnel.

Performance Improvement through formal optimization techniques: A related capability is optimization, many of the current commercial simulation software packages already provide some means for optimization. These capabilities range from numerical search techniques to advanced features based on genetic algorithm. These capabilities will advance to provide a wider range of optimization techniques to the user with emphasis on robustness of solutions.

2.6 System Integration and Internet

Simulation systems in the future will often be used as part of larger decision support systems. At present simulation software are already being embedded into manufacturing planning and scheduling systems. The simulation software of the future will be very open to enable such integrations. The integration may be application to application, application to database or embedded in a larger application. More often than not these integrations will occur across the Internet.

Different mechanisms for simulation across the web are already being investigated and put to use (Whitman et al. 1998). The increasing use of modeling and simulation and the increasing reach of the Internet will come together. Simulation across the Internet will include models running in a distributed mode at multiple servers/clients, models accessing data across the Internet, models running at a server being accessed by users, and combinations of these modes.

2.7 User Support

The user support features will grow to provide more on-line help, tutorials and courses. These are in addition to all the user support features for model building, visualization, analysis and integration discussed earlier. The user education features will be tied to vendor servers through the Internet to provide the latest information and training programs. Users will be able to go through on-line courses to learn about software features at their convenience and on a need basis. User groups and vendor support across the Internet will get more organized to provide needed information and discussions among users.

3 SIMULATION APPLICATIONS IN THE NEAR TERM FUTURE

Simulation will become the way to do business in the future. All major decisions will be evaluated using simulations in all aspects of operations. The use of simulation modeling will extend from traditional applications in manufacturing and logistics aspects to business processes to interactive simulation applications in training and sales. At present the use of interactive simulations is limited to applications such as flight simulators. Some sales applications such as in the automobile industry are beginning to appear with limited features. Simulation will pervade all aspects of the corporate world and many aspects of personal lives.

In the corporate world, the models will grow in scope to include all aspects of an organization, and they will be integrated together to closely model reality. At present, different modeling and simulation tools are used for modeling different aspects. For example, tools such as IDEF and ARIS are used for modeling business processes, while tools such as AutoMod Simulator or ProModel are used for modeling manufacturing processes. Typically in each of these models, assumptions are made about other aspects of operations. In the future, the simulation field will be dominated by tools that model all aspects of the operation and with tools that model specific aspects that can be integrated with other tools that model other aspects of the operation.

Simulation models will be widely used across all stages of development and operation of an organization. In the area of manufacturing, use of simulation has grown widely from design applications to operation support application. The use of simulation models from design to operation stages will also lead to a lifecycle for simulation model parallel to the real system lifecycle. The value of such use has already been realized though it is not practiced widely. In many cases, simulation models used at the design stage turn in to shelfware as the real life system goes into operation. In the future, simulation models will be developed as the concept of a system develops, grow as the design grows in detail, support system integration validation activity as the real life system is built and installed, and support decision making during the real system operation stage. As the real life system is modified, the corresponding simulation models will be updated.

The scope of models will also grow from modeling a location to modeling multiple locations for a company, multiple locations belonging to different companies, industry wide and cross industry wide models. Such growth will be enabled by simulation software and applications and by higher execution speeds.

The trend towards the growing role of modeling is beginning to take place now. An example of such a trend is the virtual factory modeling in the area of manufacturing. Virtual factory modeling is discussed in more detail in the next sub-sections as an example of future simulation applications.

3.1 Virtual Factory – An Example of Future Simulation Applications

A virtual factory is an integrated simulation model of major subsystems in a factory that considers the factory as a whole and provides an advanced decision support capability (Jain et al. 1998). It mimicks the real life operations of the factory. Realistic 3D visualization of the factory can be built in the virtual factory, if needed for example for visualizing a future green field facility.

The virtual factory goes beyond the typical modeling of one sub-system at a time, such as, the manufacturing model, the business process model and/or the communication network model developed individually and in isolation. In real life, the factory performance is a result of the functioning of the whole system and not just the capacities and policies on the production floor. Performance is effected by related business processes, external and internal logistics, communication network performance, etc. With advancements in computing technology it is feasible to create a virtual factory, that models the major aspects of the factory in an integrated way. The virtual factory will represent the real life factory much more closely and will lead to more accurate predictions of factory performance under different configurations and policies. It is envisaged as a major capability that can support rapid development and efficient operation of manufacturing systems throughout the lifecycle.

At the design stage, the virtual factory can be used to ensure that the manufacturing system and sub-system designs when implemented will meet the requirements. Figure 1 illustrates some of the desired functionality that a virtual factory should provide at the design and installation stages of manufacturing system development. Each tier of the figure illustrates the integration of the models at different levels of the manufacturing system hierarchy allowing validation of integration of functions at that level. The models will also be integrated across the tiers to allow validation of integration across the manufacturing system hierarchical levels.

At the highest level represented by the topmost tier in the figure, the integrated models will allow validation of integration of different functions inside a factory. The functions are grouped into three major subsystems – the primary subsystem of manufacturing, the business process sub-system and the communication network sub-system. The manufacturing function as defined here encompasses all the processes for physical transformation of material including assembly leading to generation of final packed products. A number of business processes have been shown as examples in the figure. The actual departments and processes may vary from factory to factory and need to be modeled accordingly. The communication network model may need to be included explicitly in highly automated factories with complex and populated networks. In other cases the flow of information may be modeled within the business process sub-system simulation. The integration module will ensure that simulations of

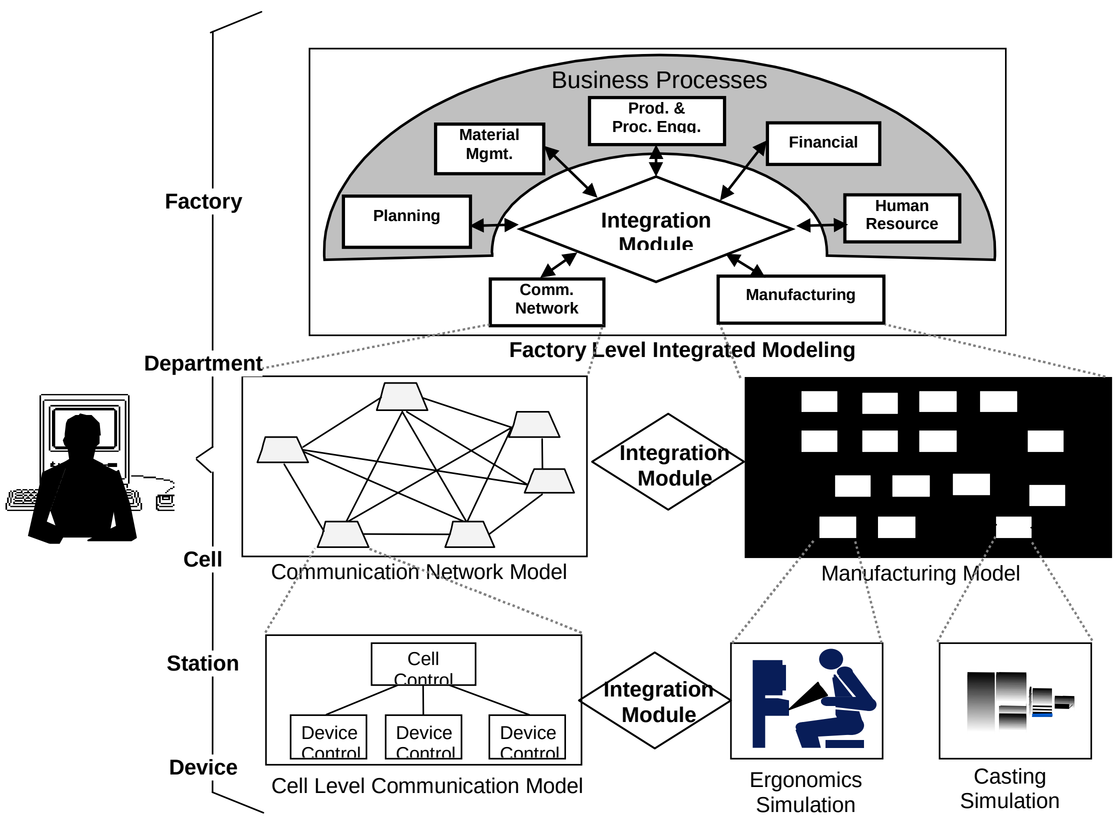

Figure 1: Proposed Functionality of Virtual Factory

individual functions mimic the real life synchronized execution of these sub-systems. The integration links across hierarchical levels will allow the validation of such integration and provide the option of studying any one of the sub-systems at successively lower levels.

At the installation stage, a virtual factory will be used to ensure that the equipment as built, installed and integrated meets the design and, in turn, the requirements. It is expected that virtual factory component models used for design stage validation will also be used to conduct installation stage validation through stepwise replacement of simulated components with physical components.

The role of a virtual factory during operations becomes threefold. First, it can serve to ensure that a validated manufacturing system continues to meet its requirements over prolonged periods of time. Second, the virtual factory can be used to support continuous improvement changes, which will go through a concept-design-installation cycle of their own. Third, the virtual factory can be used as an application itself. For example, simulation based planning and scheduling solutions can be built using the virtual factory models.

3.2 Supply Chain Modeling Using Virtual Factory Building Blocks

Supply chain models at present model individual links in the chain at a very coarse level of detail (for example, see Hieta 1998). In the future, supply chain models will include models of individual links at a fine level of detail. The supply chain models will be built by integrating other models such as virtual factory models for the manufacturing links and virtual warehouse and virtual transportation models for the logistics links. The models will be very useful for corporations and partners to make the whole chain efficient and reap the financial benefits. In addition, they can be used for exploring new partnerships for the formation of agile enterprises. Each partner can offer controlled access to its virtual factory model across the Internet to determine the cycle times for the agile enterprise. Decisions for strategic locations of inventory can be explored and agreed on for the efficient operation of the enterprise. Similarly, expected new product development times can be estimated by linking the business process models of the partner companies. Some companies may provide open access to certain parts of their virtual factory models to attract global partners for agile enterprises.

4 SIMULATION APPLICATIONS IN THE LONG TERM FUTURE

In the long term future, simulation will extend to design, evaluation and operation support of systems needed at the time. The future systems will be more automated and will be linked into a complex chain of events interacting with a number of other systems. Many of the routine tasks will become automated with little human involvement. The advance information and communication technologies will result in any event triggering a number of events for the convenience of human beings. At present, some of the luxury cars are equipped with intelligence to send signals to monitoring centers for needed service. An impending failure will initiate location of the nearest service facility and guide the driver there, triggering a request for reserving service facilities, trigger a part inventory check and orders as needed, and generate delay messages to be sent to the driver's destination. Similar complex event chains will be created for all aspects of life and commercial activities. Every entity will be part of several of these complex event chains. Plans for each entity will have to be designed using simulation to incorporate the interaction of these chains.

The possibilities of futuristic systems are only limited by our imaginations and require us to delve into science fiction. A few examples are listed below:

Automated Manufacturing Facilities: Manufacturing facilities will become highly automated and the ones generating hazardous effluents may be located at remote sites around the world and on nearby planets. Products will go through whole supply chains from mines and raw material sources to customers without much human involvement in between. The orders will be triggered globally from various demand points and the whole system will respond accordingly. Simulation will continue to be the main technique for supporting the entire supply chain through its life cycle.

Elevator networks in high rises: High rise building will fill the skyline in metropolises of the future. These tall buildings with hundreds of floors will be served by a network of elevator systems. Simulations will be extensively used for designing the capacities and control policies of these networks.

Spatial simulations for city air traffic: The metropolis of the future will use multiple modes of transportation with increasing reliance on individual flying vehicles. The traffic patterns in the air will be much harder to control compared to the streets and tracks on the ground. Spatial simulations will be used to model the traffic patterns and control policies in defined flying corridors. Similar simulations will be used for undersea facilities and transportation of individual submarine units among the facilities.

Gridlock simulations for city tunnel systems: In addition to the flying vehicles, a large amount of travel will be through underground tunnel systems for track and road vehicles. With large populations, these will be prone to gridlocks. Simulations will be used to study the formation of gridlocks and explorations of controls to avoid their occurrence. In cases of gridlock, real time simulations will be used to help redirect traffic. Individuals will be able to run real-time simulations to help find the fastest routes to their destinations.

Air wave frequency allocation and interference simulations: Currently the skies are filled with radiowaves for different kinds of transmissions – radio stations, TV stations, telecommunications signals, cell phone signals, etc. This will continue its exponential growth with multiple users sharing the same frequency bands. Simulations will be used to study the assignment time slots of frequency bands and the potential for interference.

Space flight simulations: Simulations are already used for modeling space flights by agencies such as NASA. These applications will grow with the expected growth in space flight.

Water supply: Pure drinking water will be in short supply and its supply chains across the world will be carefully monitored. Simulations will support the design and control of the water supply chain.

5 CONCLUSION

Simulation software of the future will provide a number of enhancements covering all aspects from model building, input data analysis, output data analysis and decision making. It will be available for specific applications but with integration features for use as building blocks for modeling larger systems. It has been said that simulation will become as common a tool as Microsoft Excel (Profozich 1997). However, it is expected that the nature of the simulation tools will be quite different from the generic nature of Excel. People will be using simulation widely but they will be using simulators specifically designed for their business rather than a generic tool. People involved in designing products will be using simulations of the product design to validate its functionality. Process engineers will be using process simulations to help develop the process plan. Manufacturing engineers will be using factory simulations for manufacturing cycle times. Business managers and decision makers will be using higher level business process models to explore alternatives for responding to changing markets and demographics. In the long term future, transportation engineers will use simulators specifically for applications such as elevator networks in buildings, city tunnel system, etc. Manufacturing engineers will use simulators for automated manufacturing facilities. Most of the time multi-disciplinary teams will use integrated sets of simulators to model the system of interest. Simulation will indeed be pervasive in future.

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AUTHOR BIOGRAPHY

SANJAY JAIN is a Senior Research Fellow and the Manager of the Manufacturing Planning & Scheduling group at the Gintic Institute of Manufacturing Technology, Singapore. His research interests are in the area of using modeling and analysis techniques in the development and operation of manufacturing systems, and in improving the performance of simulation systems through parallel and distributed execution. Prior to joining Gintic, he worked for several years as a Senior Project Engineer with General Motors North American Operations Technical Center in Warren, MI, U.S.A. He received a Bachelors of Engineering from the University of Roorkee, India in 1982, a Post Graduate Diploma from National Institute for Training in Industrial Engineering, Bombay, India in 1984, and a Ph.D. in Engineering Science from Rensselaer Polytechnic Institute, Troy, New York in 1988.

Sanjay has about 15 years of experience in the area of manufacturing scheduling and simulation. He has made several presentations at international conferences such as the Winter Simulation Conference, the INRIA/IEEE Symposium on Emerging Technologies and Factory Automation, Rensselaer's Conference on Agile, Integrated and Computer Integrated Manufacturing. He also has published works in the *Communications of the ACM.* He is a member of the Institute of Industrial Engineers and of the editorial board of the *International Journal of Industrial Engineering.*