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Simulation Modeling: Obstacles Faced by Small and Medium Manufacturing Enterprises

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Abstract

Simulation modeling has been acknowledged as one of the key engineering tools of the 21st century and many large enterprises, such as automotive and aerospace, have taken advantage of its benefits. Unfortunately, these benefits have not generally been available to Small and Medium Enterprises (SMEs) due to various barriers. An example of one of these key barriers is the time and level of expertise it takes to build a valid simulation model of even a relatively simple manufacturing operation. This is particularly true for SMEs which are often engaged in "low volume, high variety" manufacturing environments, which are complex to model adequately. This paper provides an overview of the importance of SMEs to the nation's manufacturing base and develops a prioritized list of obstacles that SMEs face in terms of tapping into the power of simulation modeling. In addition, recommendations are developed regarding how these obstacles can best be overcome and a research agenda is defined that targets both the issue of preparing a SME's maturity level and readiness for the technology, as well as technical simulation modeling issues that need to be resolved in order to make the technology more accessible.

Keywords
Simulation, small and medium enterprises, manufacturing

1. Introduction

Small and medium size manufacturing enterprises (SME) play an important role in the nation's economy. The U.S. Department of Commerce defines SMEs as plant sites that employ less than 500 people. Economic data provide ample evidence regarding an SME's importance to the American economy. SMEs are responsible for about 7% of the country's GDP and employ 7 million workers. In addition, SMEs account for 95% of all manufacturing establishments, responsible for over 50% of the 'value add' in manufacturing, and comprise over 1/3 of the total value of exported products [1].

In today's environment, manufacturing firms face a myriad of challenges in order to be successful. This task is particularly difficult for the nation's smaller manufacturers. These firms often do not have sufficient understanding of, or access to, the resources, technologies, and management practices needed to meet these challenges. Data analyzed several years ago, and available from the U.S. Census Bureau, indicate a pronounced gap in productivity between large and small manufacturers [1]. While this data is admittedly dated, nevertheless a clear gap can be observed between large and small manufacturers. According to a recent report published by the Department of Commerce, "small manufacturing firms face huge challenges in this transforming world. Pressures to rapidly introduce new products and technology, reduce costs, and increase quality leave many small firms struggling to survive [1]". This report also noted that that, while these challenges are daunting, small manufacturers have a great opportunity to increase their performance.

According to the National Academy of Engineering, two key technological breakthroughs – "innovative submicron manufacturing and enterprise modeling and simulation – would have a profound impact on manufacturing of the future [2]." "Simulation modeling holds tremendous promise for reducing costs, improving quality, and shortening the time-to-market for manufactured goods. Unfortunately, this technology still remains largely underutilized by industry. A number of factors currently inhibit the deployment of simulation technology in industry today [3]." This paper describes several obstacles to SMEs, which prevent them from fully utilizing simulation modeling to help make decisions and improve performance. In addition, recommendations for addressing these obstacles are presented.

2. Simulation Modeling

Simulation is a modeling technique in which the key cause-and-effect relationships of a system are captured in a computer model that is capable of generating behavior similar to that which would occur in the actual system. The simulation produces a historical log and statistical summary of the events that took place in the model over a designated period of time.

A simulation model is a tool that takes in a set of inputs, which are comprised of uncontrollable factors and controllable factors, and after applying logic and policies that represent the true system, return a set of outputs or measures of system performance. Uncontrollable factors are things such as variation in processing times, reliability, quality, etc. Controllable factors (also known as decision variables) are things such as product mix, production schedule, and sometimes product flow. A simulation model is an abstraction of reality in which only those components relevant to the system being analyzed are included. A model uses statistical distributions and multiple replications to accurately depict a system over time. The outputs are analyzed by comparing key system performance measures to assess changes in decision variables. The concept of how a simulation model works is shown in Figure 1.

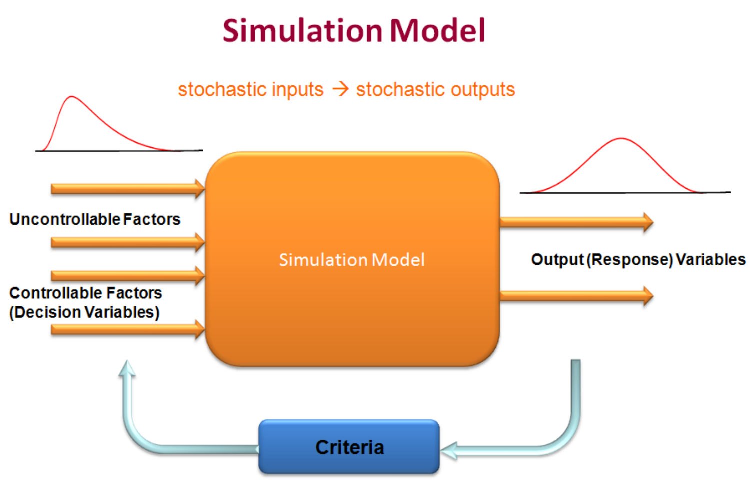

Figure 1: Simulation Model Description

Modeling and simulation are emerging as key technologies … and no other technology offers more than a fraction of the potential for improving products, perfecting processes, reducing design-to-manufacturing cycle time, and reducing product realization costs [4]. This is extremely important for SMEs, who need every advantage in order to compete. The use of simulation models helps the SMEs in many ways. The building and design of a simulation model forces attention to detail and improves the understanding of the current system. In addition, the use of models is less costly and less disruptive than experimenting with the real system, while still being able to identify bottlenecks early in the process and helping to evaluate the effectiveness of different strategies. It also can help justify the need for capital investment in new equipment or technology. This allows the SME to achieve substantial improvement in manufacturing performance (e.g., reduced operating cost, lower inventory, increased throughput, improved delivery performance) in an extremely competitive and dynamic environment.

3. Barriers to Implementation

Pegden [3] states, "(a)lthough we celebrate the progress and application successes, many also view simulation modeling as a disappointment. In reality simulation is used in a very few situations where it could be applied. There are many important decisions made by enterprises without the benefit of a simulation model." Obstacles to the use of simulation in SMEs can be broken into two main categories: business and technology. Business obstacles are those that are rooted in the management of simulation tools, resources and projects; they include timeliness, costs, management, and technical skills. Technology obstacles are those that are inherent in the software implementations themselves; they include lifespan, interoperability, verification and validation, and data acquisition.

3.1. Business Barriers

Business barriers fall into a four minor categories. These categories include timeliness, cost, management, and technical skills.

The first type of business obstacle is timeliness, in terms of the lengthy, or a perceived lengthy, development process. Pegden [3] supports this with the following statement: "(t)he simulation model development process is labor intensive. … Each industrial user must build his or her models of manufacturing systems, processes, and resources. This is true even if the models represent current off the shelf manufacturing equipment. …. The models developed for one simulation system are of little or no use to another [3]." SME's have limited resources and are driven to move quickly in order to succeed. Although some complex simulation projects may take months to complete, many questions can be answered in a relatively short period and with little effort. Given a mission critical project, allowing a small amount of extra time can save a company lots of money or even save them from closing their doors. In addition, much information can be obtained during the construction of a simulation that may prove useful.

The second type of business obstacle is associated with the cost of simulation modeling and analysis. These costs include the cost of the software itself, the cost of the required hardware to execute the simulation models, and the cost of the labor resources or external consultant needed to develop simulation models. Many of these simulation packages cost tens of thousands of dollars for a single license and require high-end computer hardware. Although all of this is expensive, ultimately the choice comes down to an ROI analysis as to whether to purchase the software or use external consultants. No matter what the decision, the goal should be to make simulation a true part of the SME's culture. The company needs someone trained in simulation, not necessarily specific software, to effectively manage simulation projects. This individual may or may not actually build simulation models, but they must be able communicate and manage any external consultants.

The third major type of business obstacles are those that focus on the management of the simulation projects. These issues usually arise from a lack of trust or understanding with the technology. Senior management might distrust simulation modeling due to a general distrust of new methods and technologies. This distrust could rise from past experiences with new technologies or projects that utilized simulation modeling that failed or did not give desired results for some reason. Senior management could also have a general misunderstanding of what simulation can and cannot do. This usually falls into two extremes: from simulation cannot at all to the notion that simulation is a "golden bullet." The former view shows a lack of knowledge of what can be modeled and what questions can be answered through simulation. The latter indicates the misperception that simulation can answer any question; this leads to the notion that everything should be modeled.

Of course, many systems can be modeled and many questions can be answered using simulation models. A fundamental question that must be answered is whether or not a system *should* be modeled. This depends on what questions need to be answered. Another issue is the expected longevity of the simulation model; i.e., will it be used for a single project or continue to be used as an aid in continuous process improvement?

The final type of business obstacle results from access to technical skills and expertise. It can easily cost more to develop the technical skills required to execute a simulation project correctly and efficiently, than the cost of acquiring the software. "The simulation development process is very much an ad-hoc process. Texts provide high-level guidance, but model development is more of an art than a science. Unfortunately, this often leaves considerable work and possibly too much creative responsibility to the simulation analyst [3]." Learning simulation methodologies and a piece of simulation software is only part of the technical skills required to be an effective modeler. It is not just about building a simulation model it is about solving problems. Simulation modelers must be able to build a model, and analyze and interpret the results. They must be able to troubleshoot problems both in the model and on the shop floor to understand what is truly going on. The software can be taught be the vendor and university courses can teach the methodologies, but the experience, the problem solving and troubleshooting skills take time to hone.

3.2. Technology Barriers

Technology barriers fall into a four minor categories. These categories include model lifespan, interoperability, verification and validation, and data acquisition.

Most simulation models are developed to answer a specific question or look at a specific scenario and are then discarded. This is often a side effect of the timeliness obstacle discussed above. How the models are developed can determine their effective lifespan. For SMEs, spending extra time and money to develop or adapt a model of long-term use, such as schedule analysis and optimization, is often not an option. However, building a simulation model to be flexible can result in much greater rewards. Although this is possible to achieve in most current simulation packages, it usually takes custom code to make a model flexible enough for long-term use. In addition, spending a little extra time on a model or component of a model could yield benefits in terms of reuse. Quality components could be incorporated into new models reducing develop time. Merging existing models can provide a test bed for additional analysis and ultimately help understand the global impact of decisions.

Interoperability is the ability of multiple uncommon systems to communicate with each other. "Interoperability between other manufacturing software applications and simulation is currently limited. Other applications include design, manufacturing engineering, and production management. The simulation software used to model and predict the behavior of manufacturing systems do not use the same data formats as the systems used to design products, engineer production systems, and manage production operations [3]." As with many software packages, simulation packages do not usually communicate with other simulation packages, nor is there a common format that simulation packages can use to transfer models between each other. Interoperability is important because it would allow SMEs to have their models communicate with other internal, supplier, and customer simulation models to improve an entire plant or the entire supply chain. In addition, being able to transfer models between packages allows a company not to be locked into a specific simulation package.

Arguably, the most important steps in simulation model building are verification and validation (V&V). Verification is the process of ensuring that a simulation model performs as expected. This process includes analyzing key behaviors in the model to make sure they represent what would happen in the real world (e.g., when a downtime occurs, do the resources respond just as they do in the real system). Verification is the process of ensuring that a model gives accurate results. Often this is accomplished by replicating a scenario that occurred in the real system (i.e. by giving the model a set of known inputs, executing the model and comparing the results of the model to what actually happen in the real world). Unfortunately, new modelers can often overlook this step. This is due partly to training classes that often focus on software specific topics. In addition, it usually takes a large amount of time and data to recreate a scenario from the real world.

The final technology obstacle is the lack of access or availability to obtain data. This obstacle can be broken into two aspects: collection of data to support a simulation model and the inability of simulation packages to link to key data sources. Data collection becomes an issue when collecting data that is not routinely collected. Data that may be required to answer a given question using a simulation may not be collected and in order to get the data a SME may have to parse months of data not normally analyzed, spend time to manually collect the data, or make some simplifying assumptions that could impact the results.

Linking a simulation model to key data sources reduces the need of manual data collection and manipulation. This would allow simulation models to be developed that can adapt to changing conditions on the shop floor. This also increases their lifespan. Currently, data is usually exported from systems, such as ERP or CAD systems, manipulated, and then imported into a simulation model where custom code has to be written to handle it. This is a very time consuming process for any company, but especially for SME's.

4. Overcoming the Barriers

In this section, we offer some preliminary means to overcome the barriers to implementation that were defined in the previous section. Similarly, the solutions are described in terms of business and technical barriers.

Many of the business barriers, especially in terms of timeliness and cost, can be addressed and overcome through advanced technology solutions. However, management of simulation projects and access to technical skills and expertise are best addressed through non-technical means. In fact, the primary means to break these barriers is through education.

Information about simulation modeling and analysis is often limited to a relatively few individuals in an organization and is especially limited in SMEs. It is mostly industrial engineers and management scientists who understand the value that simulation can bring to effective decision making and improving organizational performance. This is because these individuals have a solid understanding of the technology from their undergraduate or graduate curricula. However, it is very difficult for those individuals to effectively introduce the use of models and simulation into the organizational culture, especially from a grassroots level.

Modeling and simulation education needs to expand beyond the technical courses offered in most curricula or those offered by simulation software providers. There needs to be more general education of the value of simulation and the basic process for conducting a successful simulation project within enterprises. The focus needs to be non-technical; it needs to be about appreciation and awareness not detailed modeling and analysis methodologies. This notion is put forth in Beaverstock, et al. [5]. They organize their new textbook around three levels of simulation users – occasional, intermediate, and advanced. Material from their occasional user section could be further developed to provide the foundation for a short course on simulation modeling and analysis.

In a similar manner, materials need to be developed to effectively make the case to senior managers that simulation can improve their decision making and improve their organization's performance. Research is needed on how to effectively make this case, in terms of content and format, and materials need to be developed and made available for broad dissemination.

It needs to be understood that simulation does not only support design, or once-of type, decisions and analyses. "The classic application is to help in the design of a new manufacturing line, or analyzed proposed changes to a supply-chain. This design-only view is to limiting and does not begin to tap the real potential of simulation in the enterprise. Models should be used as an enabler for all types of decisions from design through system execution. For example, in manufacturing, a simulation model can serve multiple purposes including real-time visualization, design simulation, MES emulation/testing, factory scheduling, and real-time factory execution [3]."

Another way to break the implementation barrier is to better align the use of simulation with improvement methodologies, such as Lean Manufacturing. Again, this is mostly a matter of education, developing the approach and materials for making simulation an integral part of the application of these methodologies. It also involves providing means to raise awareness of how simulation supports process improvement activities and analyses; e.g. the article by Babin and Greenwood [6].

While somewhat of a technology issue, simulation models need to be embedded within work systems so that those who are not experts in simulation and modeling use their power on a day-to-day basis. This is most often achieved through embedding simulation models in custom-developed decision support systems. The models could also be embedded in Manufacturing Execution systems or MRP systems. Currently, this requires significantly more development time and expertise than just developing the underlying model. Changes in technology are needed so that an interface layer can easily be added between the technical model and the non-technical end user.

There are a variety of ways that changes in technology can help overcome implementation barriers in SMEs. For example, simulation modeling and analysis software packages can incorporate facilities that encourage model, or at least object, reuse. This would involve support for the creation and sharing of custom model or analysis objects, such as object libraries that enable common model components to be used in a variety of models.

A similar reuse concept would be to develop object templates that are common within an industry. McLean [3] notes "simulation analysts typically code their models from scratch and build custom data translators to import required data. A better solution would be to simplify the process through modularization, i.e., the creation of reusable simulation model blocks. Simulations would be constructed by assembling, or configuring, modular building blocks." For example, seamers are common fabrication equipment used in shipbuilding. We have developed a seamer, and other common equipment objects, that can be quickly incorporated into a model; only parameter data have to be modified to reflect the specific operating conditions.

Pegden [3] indicates "(o)ne of the promising ideas for expanding simulation into a broader set of users is the concept of having pre-built models or model components from a library that can be plugged together to form a model of a system. The idea is that we simply select these models from a library and use them directly. For example, we might build a model of our entire supply chain by simply connecting pre-built, generic models or four plants, distribution centers, and transportation centers. The goal is to build the model once, verify its operation, and then make it available in a library to be used in many different applications." He also notes that this is not a new idea and that simulation software vendors have pursued this concept over the last decade; however, substantial obstacles remain to making this a reality. According to Pegden [3], progress in this area is "key to broadening the use of simulation."

Much research is being conducted in the field of interoperability in order to allow uncommon simulation packages to dynamically communicate with each other. Most of the focus is on utilizing third party frameworks such as the High Level Architecture (HLA). There is also research in neutral interface specifications to transfer simulation models between packages. Neutral interface specifications that permit quick and easy integration of commercial off the shelf software do not exist [3]."

Similarly, evolving computer and Internet technologies may foster collaborative model building and, thus, make simulation experts outside of the SME more accessible for help and guidance. The technologies could also be used to execute models and provide analyses remotely or offsite from the SME. This would involve a pay-for-use type of arrangement where the SME only pays for the benefits obtained from the software when it is used and, thus, avoid large front–end capital costs for hardware, software, and training.

Another means to expand the application of simulation in SMEs is through improvements in how models access data sources. Simulations are obviously data driven and, oftentimes, data that exist for one purpose in the enterprise is not accessible to a simulation without significant development efforts. As Pegden notes, "neutral interface formats for transferring data between simulation and other manufacturing applications are also needed. Data would ultimately be imported directly into the simulators without translation using standard data input formats [3]."

5. Research Needs

The barriers identified above and the posited means to overcome those barriers provide a good starting point for research into how small- and medium-sized manufacturing enterprises can improve performance through simulation. Both the particular needs of SMEs and the means to address those needs require further investigation.

It is certain that as computing technology improves, simulation technology will continue to improve in many dimensions. However, research that explicitly focuses on the needs of SMEs can enhance and accelerate the development efforts. Expanding simulation applications to SMEs provides a huge market opportunity for the simulation community.

As we indicate above, education is a key means to overcome SME barriers. Thus, this leads to a variety of research questions, such as what content needs to be delivered to whom and in what manner. Obviously, there is not just one answer or approach; in fact, a portfolio of offerings is needed. The simulation community needs to move beyond its relatively small sphere of experts to raise awareness of the value of simulation and the basic concepts that are involved. We need to identify ways and means to move from an environment where modelers and analysts try to push simulation on organizations to an environment where organizations pull analysts and modelers into their problem domains. Even more interesting and challenging is to explore how simulation can become an integral part of the work environment – where experimentation prevails and ideas and options are tested virtually before decisions and changes are made.

6. Conclusion

In today's environment, SME's must strive to utilize advanced engineering tools such as simulation to ensure they stay competitive. This paper has outlined some of the major obstacles to the wide spread adopt of simulation including business obstacles such as timeliness, costs, management, and technical skills and technology obstacles such as lifespan, interoperability, verification and validation, and data acquisition. In addition, recommendations for eliminating or reducing these barriers are proposed. Research in these business and technology obstacles needs to continue to aid these SMEs in making better, faster decisions to improvement their performance in the global market.

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