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Simulation in Japan: State-of-the-Art Update

Shigeki Umeda
Musashi University, Tokyo, Japan

and

Albert Jones
U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
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Abstract

Computer hardware continues to decrease in cost and increase in power. Simulation vendors have hypothesized that this trend, together with new requirements for system integration, have produced a new business environment for discrete-event simulation all over the world. This paper, which provides an update to an earlier report, describes current trends in Japanese industry regarding the use of discrete-event simulation. The information contained in the paper was dervided from interviews with many representatives of Japanese industry. It shows that, in general, this hypothesis is true in Japan.

* Guest Researcher from Musashi University, Tokyo, Japan

1. Introduction

The recent advances in various technologies has provided industrial users with high performance computer hardware and powerful Graphical User Interfaces. This, in turn, has led to significant advances in computer performance and visualization. The result is a collection of very powerful software tools for solving problems across the manufacturing enterprise [1-4]. Part designers, manufacturing engineers, and production managers can now compute and visualize the impact of their individual decisions right at their desktop. They can assess, to a limited degree, the impact of their decisions on both product and process performance and company profitability. To compute the real impact of those decisions, however, they must work together. That is, their decisions must be made in a coordinated way. This requires communication between the people, and the integration of the software tools that they use to make those decisions [5-8].

One of those tools is simulation. Recently, many simulation tools (both continuous and discrete-event simulation tools) have become available on the market. [9-15]. The advances mentioned above have made it possible to run these tools on desktop computers. This, in addition to improvements in the tools themselves, are the main reasons that simulation is used heavily in manufacturing plants around the world.

Nowhere is this more evident than in Japan, where simulation use is on the rise. This paper, which extends our earlier work [16-18], summarizes the current use of simulation in Japanese industry. It also discusses some of the criteria used to make purchasing decisions. Finally, it presents some preliminary views of Japanese industry toward future uses of simulation in systems integration's and virtual manufacturing environments.

2. Simulation practices in Japanese industries

2.1 Software Introduction

Figure 1 displays the evolution of simulation use in Japanese industry. It shows the number of new manufacturing firms using simulation in their company. As shown, there was very little interest after its introduction into Japan more than 25 years ago. Starting in 1985, a gradual increase occurred.

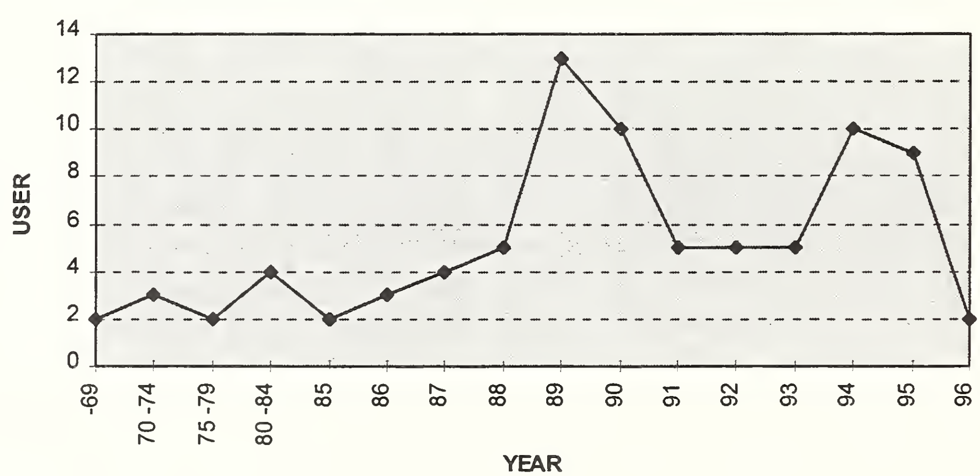

Figure 1. New Users of Simulation Software

Around 1989 or 1990, a dramatic expansion occurred when many manufacturing enterprises made major investments in computer technologies and manufacturing equipment. Following this, a sharp reduction took place. The number of new users declined to pre-89 levels and remained relatively constant for a few years. The main reason for this, we believe, was the downturn in the Japanese economy. Then, remarkably, another dramatic increase took place in 1994 or 1995. We think that the principal cause for this was the rapid changes in computing technologies. These changes included a decrease in price, growth in processing power, and more robust operating systems. Many vendors took advantage of these changes to release desktop simulation packages with graphical user interfaces that were integrated with existing windows-based operating systems (Table. 1). This was very attractive to simulation users.

Table 1. Computing Environments

Computers	PC	WS
OS	DOS/WINDOWS	UNIX
CPU	DX-4, P-90, P-100	various (R4000,MIPS, SPARK)
RAM	16 MB or 32 MB	64 MB or 128 MB
Disk	500 MB over	2 GB

2.2 Target applications of simulation analysis

The two main users of simulation tools are communications companies and manufacturing enterprises, with the latter being the most popular. The target applications within these companies which are the subject of simulation studies are shown in Figure 2.

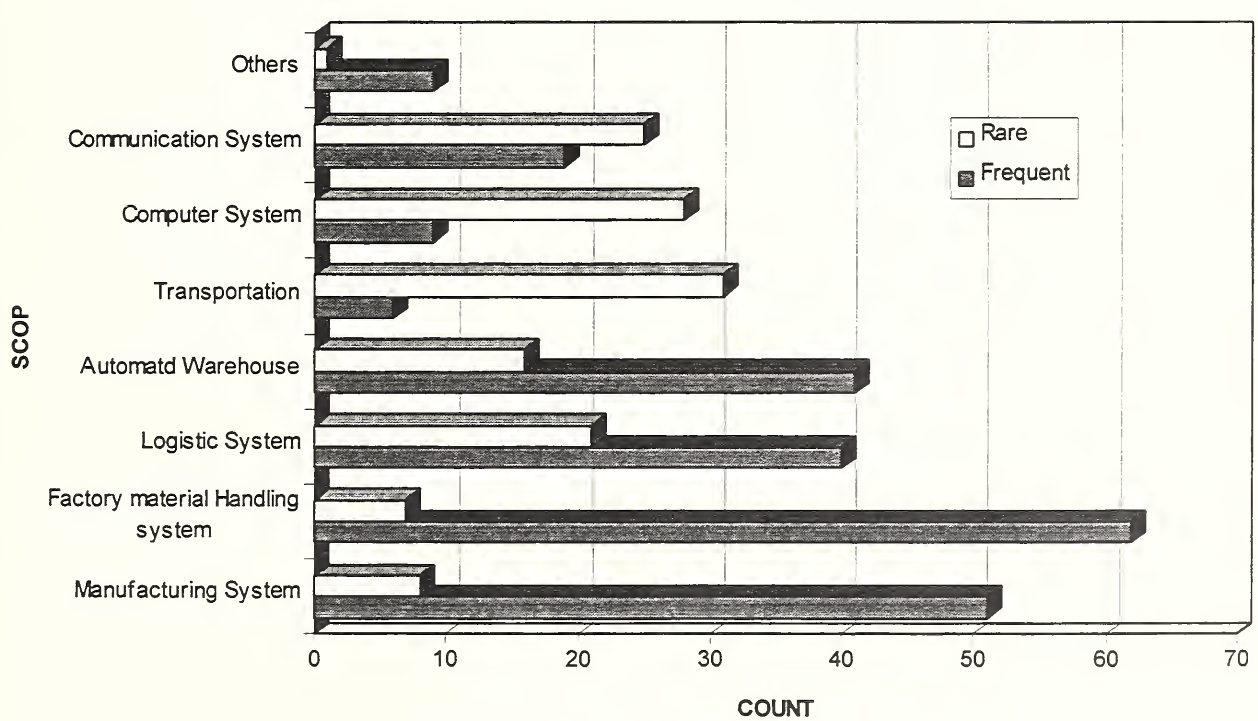

Figure 2. Target application systems

The most popular applications deal with the movement of raw materials and finished goods. These include factory material handling systems, logistics systems including automated warehousing, and transportation to and from those warehouses.

To date, the least popular applications areas are computer and communication systems. However, we believe that this is likely to change since many companies have introduced Local Area Networks which are connected to the INTERNET. As these systems grow in complexity and importance, industrial users will require tools to analyze various design alternatives and to predict performance.

2.3 Simulation project characteristics

Figure 3 shows simulation projects organized by department. The people who actually carry out the project can be classified into two groups: a developers group and a users group. The people from the developer's group analyze potential problems, design general purpose simulation models to solve those problems, and implement those models on target computing environments. People from the user's group run the developed models to give a solution to specific instantiations of those problems. That is, they provide the actual data to run the models. For example, suppose the plant manager decided that a new simulation-based scheduler was needed. The developer's group would develop the model with parameters for all of the required variables. Each time a new schedule was required, a user would input that data, run the simulation, and get a new schedule.

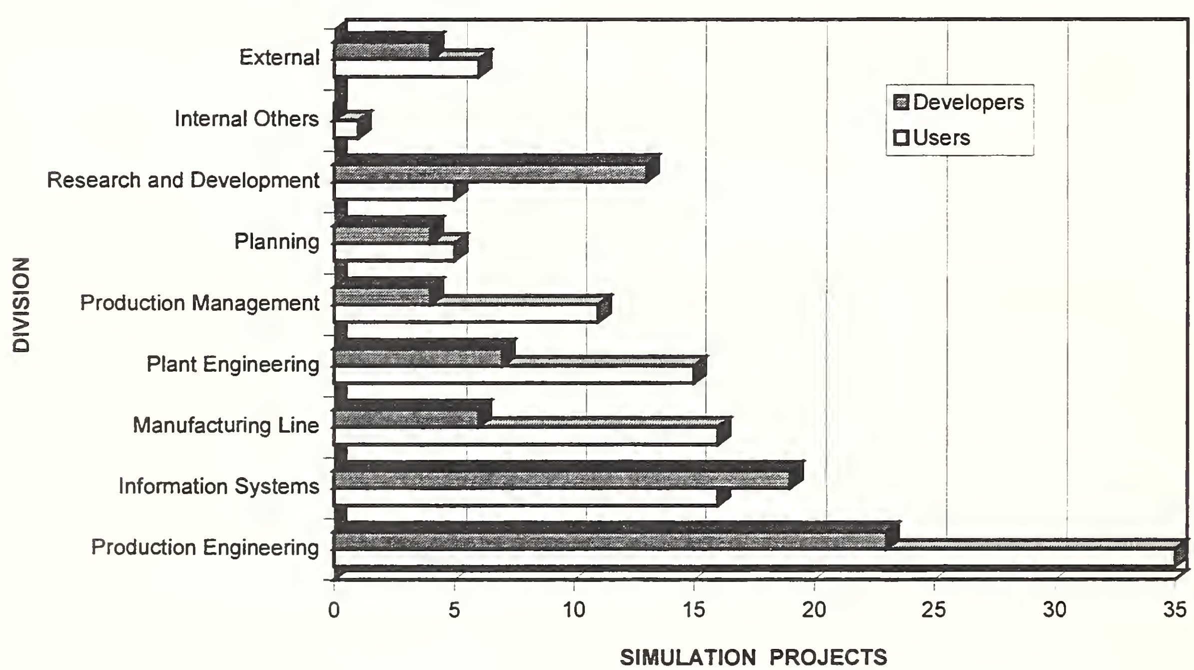

Figure 3. Simulation developers and users

The level of effort required to complete a simulation project varies between 0.2 worker-months and 24 worker-months, with an average of about 2 worker-months (Fig. 4). This is difficult to estimate because 1) the work-load changes as the project evolves, and 2) larger projects require more effort than smaller projects. In general, as shown in Table 2, approximately 60% of the effort is expended in the model development and data collection phases of the project. The remaining 40% is split equally among the other phases. Table 2 also shows the range for the various phases.

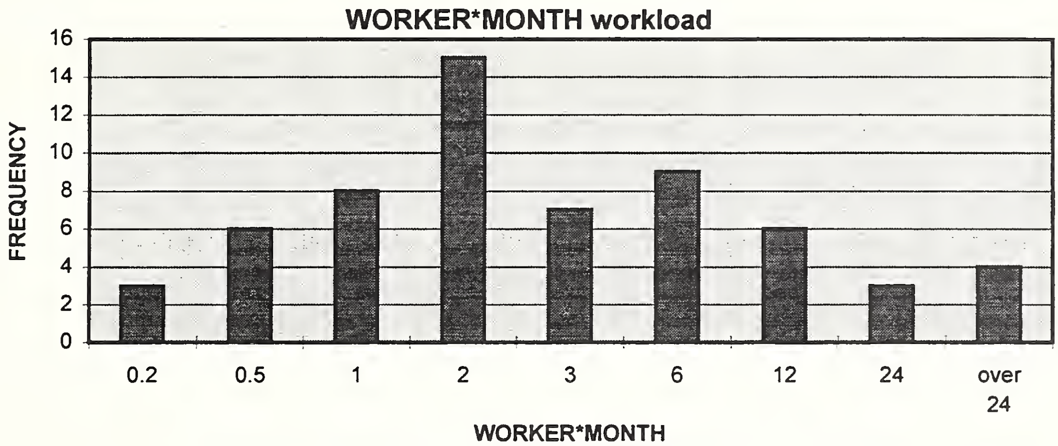

Figure 4. The work-load of simulation projects

Table 2. Typical work breakdown of projects

Work	Work load Ratio (%) [Range]
Data Collection / Gathering	20 [15 -25]
Model design	40 [30 -60]
Animation	10 [5 -15]
Model modification	10 [5 -15]
Simulation experiments	10 [5 - 20]
Summary of result	10 [5 -10]

2.4 Experimental design and output analysis

Depending on the complexity of the project, a statistical design might be required to determine how many simulation experiments to run, what kind of data to collect, how to vary the inputs parameters to minimize the overall variance in that data. Experimental design methods like orthogonal arrays and Taguchi methods [19], for example, are very popular and powerful methodologies used in Japan. These methodologies can support multiple views into an enterprise including financial, accounting, sales, marketing, management, information, and manufacturing. Table 3 provides some summary information on the use of experimental design in simulation projects today. Clearly, there is no widespread use of these techniques in industry at this time. These results have not changed substantially from those reported in our earlier work.

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Table 3. Practice of experimental design methods

Use experimental design method	15	utilize orthogonal array methods do not use orthogonal array methods	9 6
Do not use experimental design	68		

The final step in a simulation project is the analysis of the output data [20-23] . In general, this will include statistical calculations to compute estimates of performance measures, compare one set of measures against another, or both. The knowledge required to carry out these calculations is very specialized. Since most users do not have this knowledge, it is important that simulation software packages support a variety of statistical data analysis routines. These routines should allow users to generate the required results easily and with confidence. Table 4 summarizes the use of statistical analysis routines.

Table 4. Practice of statistical output data analysis

Do statistical analysis	36	implement own analysis routines use supported analysis routines use statistical data analysis packages	6 24 8
Not do statistical analysis	45		

The users gave the following reasons for not using statistical analysis.

- Statistical analysis output is not required.
- The merits are too small in accordance with its work load.
- The replication of simulation runs is impossible, because the calculation time is very huge.

The implication of this is that most users still perform deterministic simulations which include no probabilistic parameters. User explanations include:

- We use deterministic simulation for model validation.
- We use deterministic simulation to validate production plan and schedules.
- Animation is always done with deterministic simulation.
- We only evaluate the maximum performance of the target system.
- We do not have enough data to implement probabilistic models.
- We get only a simplified estimation of manufacturing lead-time.
- We validate schedules using deterministic simulation.

Many of these are what is commonly called "what if" simulations, because they show what happens in the system if particular plans and schedules are executed. It will identify problems with workload, lead-time, bottleneck process, bottleneck queues and others. They will also provide some insight as to why these things happen. The interactive parameter setting function will help such studies. More than half of users owns such function (Table. 5).

Table 5. Interactive parameter setting functions on simulation execution

Interactive parameter setting functions	Users	Usage	Users
Support the functions	51	Frequent use	15
		Occasionally	20
		None	16
Not support the functions	41		

2.5 Modeling maintenance

About 40 % of simulation models are reused (Fig. 5). Some of them are copied into new modeling code as is, and some of them are modified and used into new simulation models.

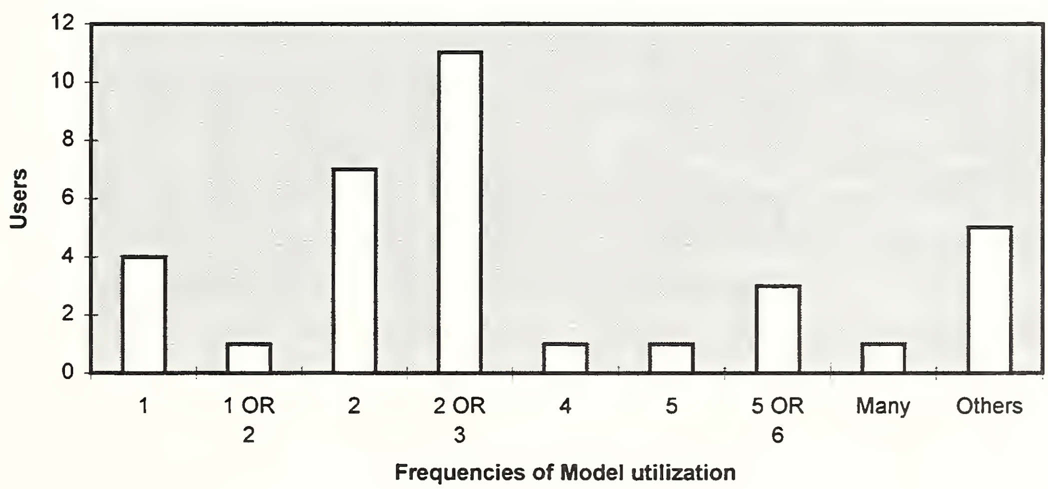

Figure 5. Frequency of model re-utilization

Figure 6 shows the various methods that are used to accomplish this reuse. By far, the most effective of these methods is a model library. By using a model library, model builders can use previously-built and tested models to address the current problem. The ability to do this reduces the time and cost associated with the development of the new model. The goal is to have models of each component in the enterprise system [24] . This way, models of different systems can be developed quickly and easily. The model library can also include development tools which will support the integration of simulation with other management tools.

Other problems associated with model reuse, and possible methods for addressing those problems are described below:

- **Input of simulation parameters**: Automatic generation of input parameters; Standardization of parameter design; External database of simulation input data.
- **Block modules of simulation models**: Continued maintenance of models libraries in; Basic building blocks of simulation models; Object-oriented modeling environment.
- **Re-utilization of old version models**: User implements generic models; Modify the old version of the model to suit current need.
- **Documentation and comments**: Include in source code for model.

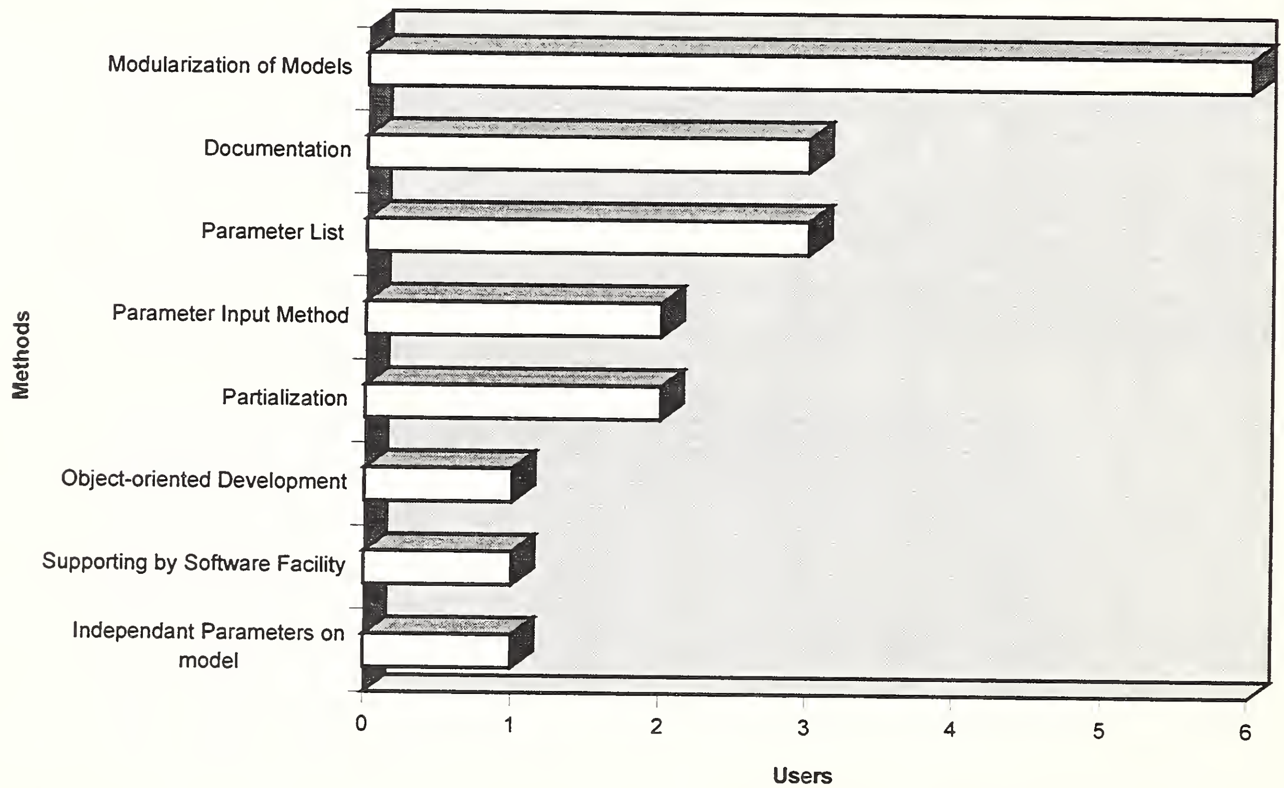

Figure 6. The methods of model re-utilization

3. Reasons For Buying Particular Software Packages

3.1 Current Market shares

As noted above, there are a large number of simulation software packages on the market today. During the last five years, the vendors of many of these packages have developed relationships with Japanese firms who sell their products and consulting services. Even though the simulation software market in Japan is not as mature as in the United States, Figure 7 shows that these efforts are beginning to pay off. The number of different simulation products in use in Japan has increased sharply since our earlier reports [16-18]. Even so, there is still a requirement to implement models in packages based on general programming languages. This can be seen from the relatively large usage of packages like SLAMSYSTEM and WITNESS. Graphics-based packages such as AUTOMOD, FACTOR/AIM, and ARENA are, however, becoming increasingly popular.

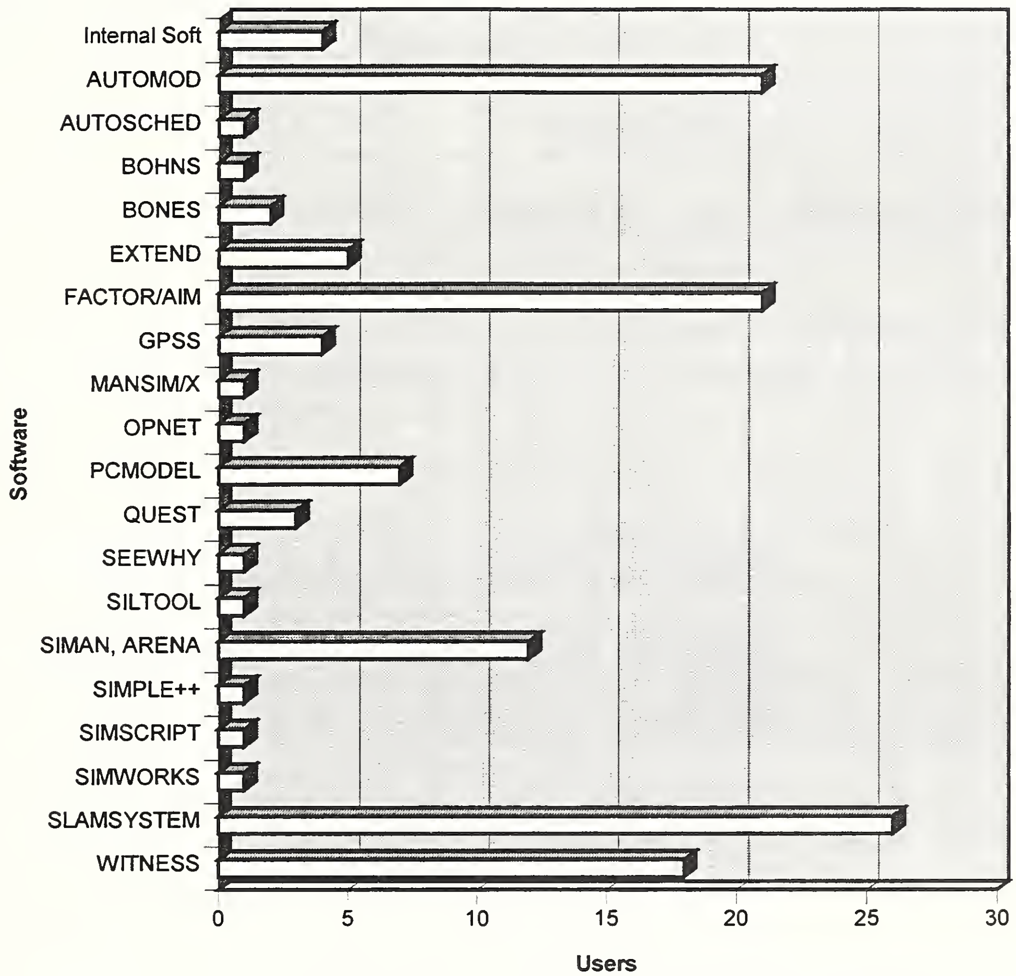

Figure 7. Simulation Software Packages in Japan

3.2 User Interface Capabilities

Table 6 shows some of the user interface factors which users consider when they purchase simulation software. The top two, modeling support and output analysis tools, have remained unchanged from our earlier reports. In those reports, we combined graphical displays and animation into a single factor. In this report, they constitute two separate categories. Since, in our opinion, animation is considered very important in the U.S., it is perhaps surprising, that it is rated fourth. We believe that both of these tendencies will continue in near future. This depends on the decision making style of the top management in Japanese firms. It is very rare that the important decision is made by the business review and presentation. While, Japanese business style has dynamically changed in these several years. The role of animation will become gradually important factor in future.

Table 6. Important user interface facilities

Important interface facilities for simulation users	Positive	Negative
Modeling support tool	77	6
Statistical simulation output analysis	75	8
Graphical display routine for simulation output	74	10
Animation facility	68	9
Interactive parameter handling facility in simulation execution	61	14
Others	-	-

3.3 Modeling Capabilities

Figure 8 summarizes users' views on the different capabilities offered by various packages.

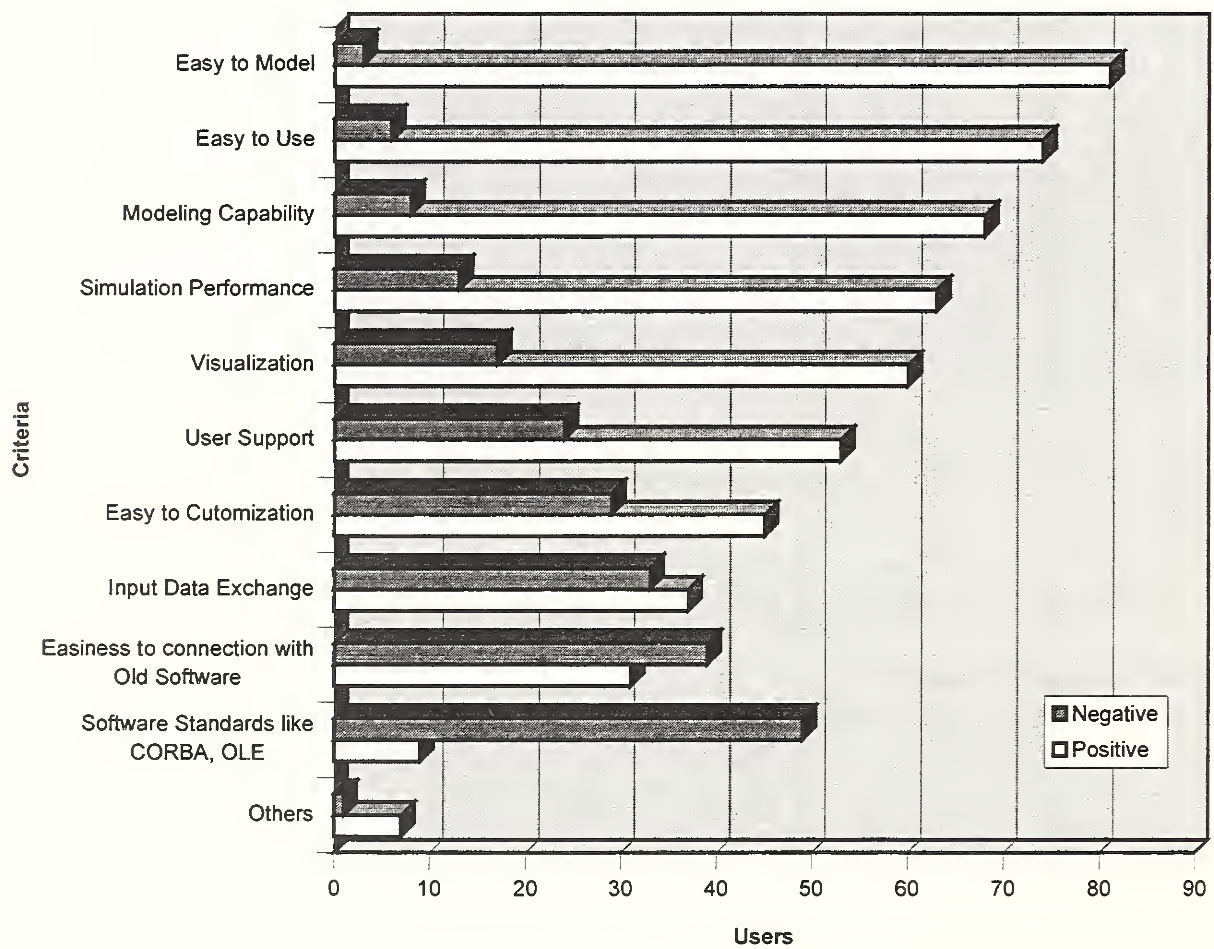

Figure 8. Capabilities of simulation software

Modeling support tools are considered most important when choosing simulation software for particular applications. User-friendly, icon-based modeling tools reduce the time and cost associated with building and maintaining simulation models. Some of these tools are aimed at specific application domains only, like manufacturing or communications. Others provide a collection of templates for various domains. The system definition language for these tools is contained in the domain expertise of the user. This is accomplished by providing:

- An external view that contains modeling elements which are targeted to the specific domain;
- A hidden abstraction layer which maps those elements to the proper internal simulation concepts;
- A dynamic modeling layer which can link operational models of those concepts into a coherent simulation of the user's system; and,
- A pragmatic modeling environment.

As a result, these tools can generate the simulation model directly from system configuration data. This gives the user the ability to automatically model changes in dynamic systems at various levels of complexity and detail.

3.4 Animation Capabilities

Animation facilities enable the user to visualize the results of simulation directly. Users can see which process is the bottleneck or which process is not synchronized with other ones. Many users indicated the importance of animation capabilities of simulation software. Currently, only 60% of users run animation programs every time; while 20% say that they run them often. Users have summarized their reasons for not using animation more frequently. They are given below:

- Users are not required presentation results to management.
- Users only interact with people having intimate knowledge of simulation technology.
- Physical models are 3-dimensional, which is difficult to represent in 2 dimensional animation.
- Models are too large to understand using animation.
- Models are simple enough to understand without animation.
- The objective of simulation is performance evaluation based on statistical calculations.
- The objective of simulation is a schedule which is easier to visualize using a Gantt-chart.
- The users do not have enough time to implement animation programs for system analysis.

As we said earlier, this is a little surprising, but we expect this number to grow in the coming years.

3.5 Other reasons

Several other reasons were given for selecting particular packages including: must address problems in a specific target domain; must be able to handle models of a particular scale; must provide a particular level of accuracy; must be suited to user's modeling skills; and, must be able to finish the project on time. Some examples are given below:

- use SIMTOOL for complex and large-scale simulation models.
- use FACTOR/AIM to mode manufacturing line or when rapid solution is required.

- use AUTOMOD when an exact layout or 3 dimensional simulation is required.
- use WITNESS when designer use simulation or when rapid solution is required.
- use AUTOMOD or EXTEND when the target system is material handling or AS/RS.
- use SIMSCRIPT when the target system is traffic flow simulation, and use AUTOMOD.
- use SIMAN when the target system is a lot-based production system.

4. Simulation and System Integration

The requirements for the integration of simulation with other manufacturing software applications and manufacturing databases are increasing. The subsequent comments from simulation users provide support for this view:

- It is necessary to integrate simulation software with production planning software so that we can provide accurate estimates of delivery times to our customers.
- It is important to link simulation with real time control systems.
- We want to integrate simulation and scheduling.
- We need to link simulation with cost estimating.
- Distributed, autonomous simulation will be required in the near future.

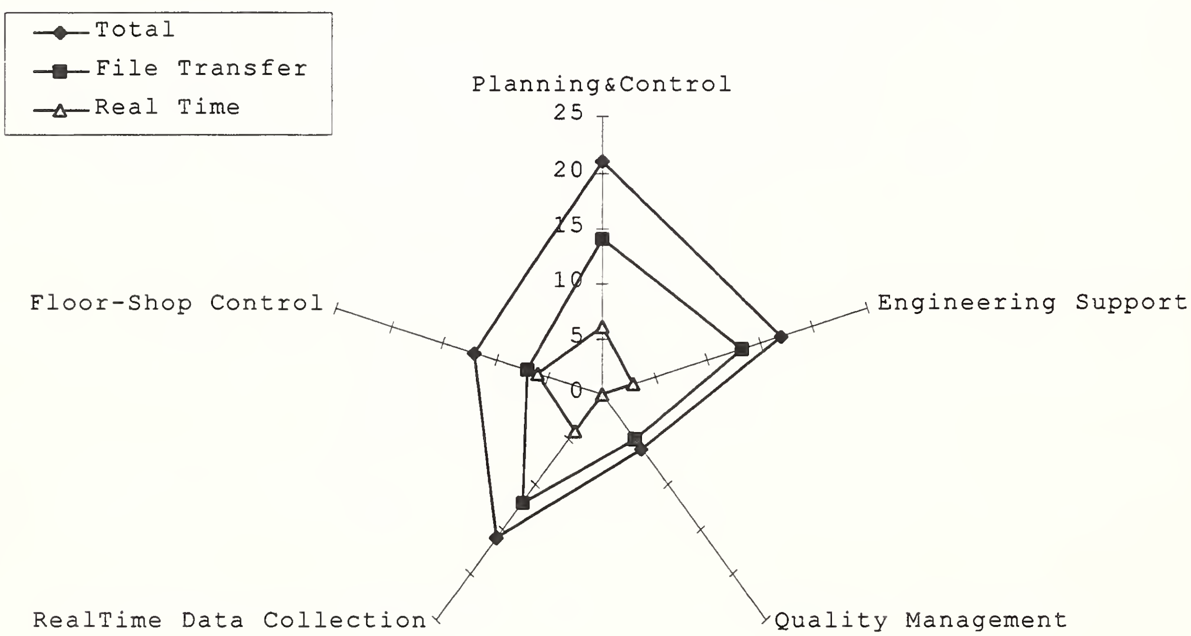

Figure 9. Current supporting system interfaces

Fig. 9 shows the current implementation of system interfaces with simulation. About 30% of the cases connect simulation with other application systems. Most of these cases combine simulation with production planning & control systems, floor-shop control systems , and engineering support systems. Implementations are currently realized by using file transfer mechanisms, but the majority of them are moving toward real-time data exchange using some sort of messaging protocol or database access. Some examples are:

- Data transfer from production management database to simulation system
- Data transfer from shop floor control database to simulation system
- Data transfer from simulation system on WS to spread sheet applications on PC
- Data transfer from spread sheet applications on PC to simulation system on WS
- Data transfer from CAD input data file to simulation system

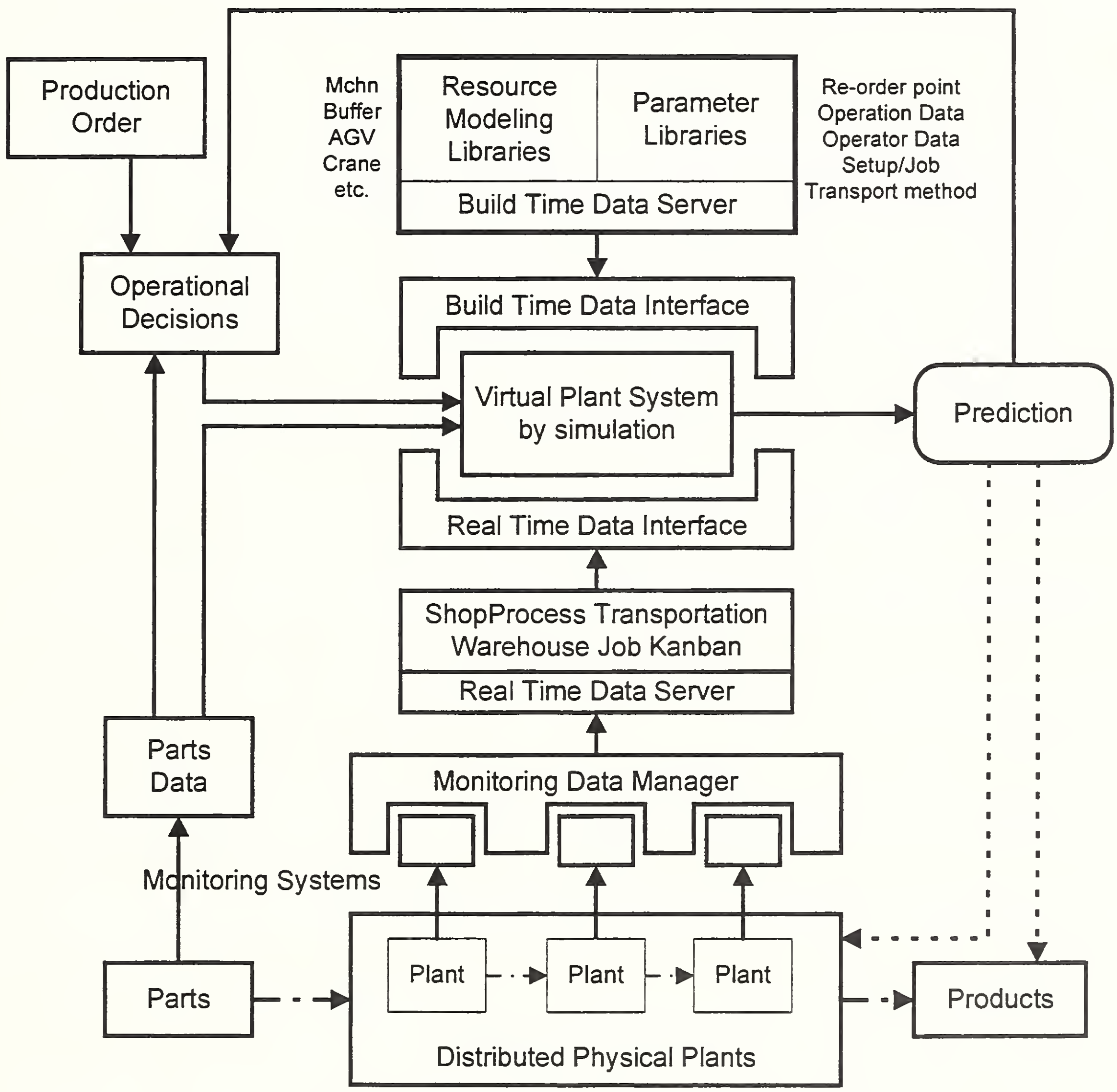

Figure 10. System concept of "Virtual Plant"

We asked users to comment on application systems they planned to integrate with simulation in the near future. They included :

- Shop floor monitoring systems,
- Distributed simulation across a LAN,

- Business Process Re-engineering,
- Production Management,
- Large scale logistics, and
- Virtual Production systems

Virtual Production Systems are by far the most ambitious of these plans. The objective is the synchronization of material-flow with information-flow across all factory operations. This is achieved through the integration of manufacturing automation processes, business processes, and data management systems (Fig 10). The implementation will require both advances in optimization technologies [25-29] and distributed simulation techniques [30-32].

5. Conclusions

The use of simulation in Japanese industry is still modest compared to the U.S, but it is on the rise. With the growing emphasis in Japan on virtual manufacturing, particularly through the Intelligent Manufacturing System program [33], we expect this trend to continue. Some of the most important areas of future interest among Japanese users are:

- Real time planning, scheduling, and control using simulation,
- Distributed simulation,
- Gaming simulation,
- Object-oriented simulation, and
- Integration of simulation with other applications.

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animation; computer environments; simulation; statistics; system integration; virtual manufacturing

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