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Proceedings of the Academy of Information and Management Sciences

Table of Contents

PUTTING YOUR LECTURES ON THE WEB A WORKSHOP ON USING REALAUDIO®, REALMEDIA® AND MS CAMCORDER®

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ABSTRACT

The explosive impact of the World Wide Web (www) can have a significant impact on delivery of academic lectures. For the past two years, I have been recording my lectures and putting them on the web. For the first year, the lectures were audio only (using RealAudio®). This past year, I have been doing my lectures in PowerPoint® and have been posting on the web both the PowerPoint® slides and the audio, synchronized together, in RealMedia®. The latest addition to my tool set has been MS Camcorder, which allows me to create presentations that give full screen captures with complete motion and narration. I can record a demonstration of using Excel® and show the mouse movements and describe the steps in real time.

The workshop will demonstrate how to record the lectures, convert them into RealAudio®, RealMedia® and MS Camcorder®, post them on the web and make the links for their use. I will share hints and tricks that I have learned over the past two years.

AN EMPIRICAL STUDY OF THE IMPACT OF THE INTERNET ON CONSUMER PURCHASING

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ABSTRACT

The primary purpose of this paper is to investigate the use of the Internet among college students for consumer purchasing. One hundred and nineteen students from two universities in two different states were surveyed. Research indicates that most students use the Internet to check company or product information rather than directly purchasing products. One of the major reason not to use the Internet on-line purchasing is security. The results of this study, however, suggests that seventeen percent of students purchase products from the Internet. Therefore, the Internet may change the way we do business in the future.

INTRODUCTION

Today millions of people have become aware of the usefulness of e-mail and the Internet for accessing information through PC-modem and telephone lines. The Internet is a computer network connecting more than one hundred thousand individual networks all over the world (Laudon & Laudon, 1996; 1997). Using the Internet, people communicate through e-mail, Usenet Newsgroup, chatting, FTP, Telnet, and World Wide Web (WWW). Millions of web sites have been created for commercial and educational purposes (Lee, Osborne, & Chen, 1996).

The Internet has been used in defense and academic research for many years. The commercial use of the Internet, also referred to as electronic commerce or e-commerce, was not permitted until the early '90s because the government subsidized the Internet (McKeown & Watson; 1997). Forrester Research in Cambridge, Massachusetts expects online sales to increase from $4.8 billion in 1998 to $17 billion in the year 2001 (Furger, 1998). Why is the Internet becoming a powerful tool for marketing and communication? There are many reasons, the main one being that the Internet connects more than 40 million people from 100 countries. Consumers can access information from a remote location through the Internet if they are connected to a telephone line or a network. Another reason that the Internet is becoming a powerful tool for marketing and communication is that it provides a variety of services. For example, e-mail provides communication between consumers and companies, and through electronic data interchange (EDI), buyers and sellers can exchange standard business transaction documents such as invoices or purchase orders. Finally, the ability to combine video clips into the Internet is a significant step in establishing Internet marketing as a powerful communication forum.

The purpose of this research paper is to investigate the perceptions of college students on the uses and successes/failures of Internet purchasing and communications. College students represent individuals who are more knowledgeable in technology than individuals in previous generations. This study provides information related to the following research questions:

1. What are the primary functions of college students in using the Internet for purchasing products or services?
2. What are the obstacles to consumer purchasing on the Internet?
3. Is security a primary concern as suggested in the literature? Can different payments be used to avoid the security problems?

LITERATURE REVIEW

Numerous studies have been written about the Internet. Many of these studies focus on technical topics, case studies, and the use of the Internet for educational purposes (Carroll, 1994; Kanuk, 1996; Vernon, 1996; Ullman, William, & Emal, 1996; Mahmoon & Hirt, 1995). Knowledge about the Internet, however, is still in the early stages simply because the Internet has become popular only in the last few years. While a fair amount of case studies in e-commerce (e.g., Amazon.com) have been discussed, (Hitt, Ireland, & Hoskisson, 1998), few empirical studies have concentrated on the theoretical construction of using the Internet for consumer purchasing.

Jannet (1996) suggests that the Internet, as an interactive marketing tool, has the following three functions: 1) informing consumers about products, services, discounts; 2) creating brand awareness and preferences; and 3) selling products through on-line purchasing. Jannet further indicates that inter-activity is the one of the key characteristics why Internet is so powerful in marketing. To purchase a product, customers need to get information regarding the product, the price of competitors, and so on. The Internet does provide a low-cost, no-hassle, and convenient way to search for this type of information. Most Internet sites provide a full time service (24 hours and seven days a week) for consumers to purchase a product or service.

Obstacles of Internet Marketing

Previous literature has discussed the barriers and disadvantages to Internet marketing. There remain some barriers and disadvantages that may lead managers to decide against the use of Internet marketing. The first barrier identified is the relatively small number of consumers reached over the Internet in comparison to other advertising media. The number of businesses and homes equipped for interactive marketing is still small. The second barrier is the impersonality of Internet business. Brand name recognition among consumers demands that the relationship between businesses and consumers exists long before and after the sale.

The third barrier is that security and privacy is a major concern. There are two security weaknesses inherent in the current infrastructure of the Internet (Everett, 1988). First, the Internet network of high-speed telecommunication lines (Internet backbone) may have problems with one or more of its telecommunication lines breaking, thus, Internet services can be disrupted. Second, because messages and information pass from host to host, they are susceptible to interception and being recorded. There is virtually no laws that prevent any Internet service provider (ISPs) from observing, recording, selling, or giving away any information that passes through host computers.

To protect the consumer's financial and security information, the way of payment can be varied. Today, there are three ways a customer can make a payment after purchasing a product from the Internet. First, a customer can check product information and then enter the credit card information on the Internet. Although this is a simple and easy way to purchase products, many people hesitate to use this method for security reasons. Second, a consumer can check product information and then call the company directly and charge the product to a credit card. Third, a consumer can check product information on the Internet and then mail the company a check.

METHODOLOGY

The primary purpose of this paper is to investigate the use of the Internet for consumer purchasing and communications. To answer research questions one and three, two null hypotheses have been derived:

H1: Students spend the same amount of time in a) purchasing products; b) checking product information, or c) checking a company's general information (such as company service information, warranty, or discounts) (H_0: m1 = m2 = m3).

This hypothesis is used to answer research question one: what are the primary functions of college students in using Internet for purchasing products or services? Jannet (1996) suggests that Internet marketing has three different functions. Hypothesis one attempts to determine which function is the most influential to students in purchasing on the Internet.

H2: There is no difference in the type of payment method used by students when ordering products from the Internet (H_0: p1 = p2 = p3). The three ways for consumers to purchase products on the Internet are: a) a customer can check product information and then enter the credit card information on the Internet; b) a consumer can check product information and then call the company directly and charge the product to a credit card; or c) a consumer can check product information on the Internet and then mail the company a check.

Hypothesis two answers the research questions: Is security a primary concern as suggested in the literature? Can different payments be used to avoid the security problems?

A survey questionnaire was administered to test hypotheses H1 and H2. The survey was administered in various business classes. The Friedman test, a nonparametric test procedure was used for hypothesis H1 because ordinary data was collected from the survey. The chi-square (χ 2) test also was used to test hypothesis H2 for equal proportion. The data was coded and analyzed using SPSS/PC+.

RESULTS AND DATA ANALYSIS

Procedures

The subjects are business undergraduate students from two different universities in two different states. From July to September 1998, one hundred and nineteen students in five different classes, from freshman to senior level, were randomly chosen for the survey. Sixty-four percent of the students are from age 18 to 25. Thirty-five percent of the students are above age 25. Twenty-eight percent of incomes are between $10,000 to $17,500, 19% of incomes are between $17,500 to $35,000, and 16% of incomes are above $35,000. The income levels are fairly distributed. When asked about the knowledge level of computers, 60% of the participants ranked themselves 3 on a scale of 1 to 5. The remaining participant are evenly distributed throughout the (1-5) Likert scale.

Results

Research Question One

Various questions are asked concerning the purposes of using the Internet for purchasing products or services. Table 1 shows the percentage of students using the Internet for purchasing, checking product information, or company information.

Table 1
The Frequency Information for the Use of Internet
in Consumer Purchasing or Information

	Never	Rarely	Sometimes	Often	Very Often	Total
Check the Product Information	28 23.5%	35 29.4%	37 31.1%	18 15.1%	1 .8%	119 100%
Check General Information of the Company	31 26.1%	28 23.5%	39 15.1%	18 15.1%	3 2.5%	119 100%
Purchase a Product	86 72.3%	13 10.9%	17 14.3%	2 1.7%	1 .8%	119 100%

The Friedman test was used to test the Hypothesis 1 which states that students spend the same amount of time in a) purchasing products; b) checking product information, or c) checking a company's general information (H_0: m1 = m2 = m3), The assigned values 1, 2, 3, 4, 5 were used to code the data for never, rarely, sometimes, often, and very often, respectively. The Friedman test is used to compare two or more related samples. In Table 2, the mean ranks for the functions of the Internet are calculated and compared, resulting in a test statistic with an approximate chi-square distribution of 84.564. The critical value of chi-square table at the probability level of .05 with 2 degree of freedom is 5.991. Thus, the null hypothesis is rejected because 84.564 is much greater than 5.991.

Table 2
Friedman Test in Comparison of Different Functions of Internet

Use of the Internet	Mean Rank	N = 119
Check the Product Information	2.29	Chi-Square = 84.564 df = 2
Check General Information	2.25	Asymp. Sig. = 0.00
Purchase a product	1.46	

Research Question Two

Table 3 shows the major reasons people will not buy from the Internet. These findings support the literature which suggests that security is a major concern when purchasing products or services on the Internet. The findings also suggests that if security were improved on the Internet, 18.1% say they would definitely buy from the Internet, 31% say they probably would buy from the Internet, and 37% would either buy or not buy from the Internet.

Table 3
The Major Reasons People Will
Not Buy From The Internet

Reasons	**Frequency**	**Percentage**
Lack of security	**80**	**67.2%**
Inability to judge product	**48**	**40.3%**
Can't see or feel product	**43**	**36.1%**
Expensive	**12**	**10.1%**
Do not have an Internet connection	**9**	**7.6%**
Knocked/kicked off line	**4**	**3.4%**
Frequent interrupt of communications	**2**	**1.7%**
The speed of Internet is too slow	**1**	**0.8%**

Research Question Three

Table 4 indicates that consumers (students) prefer to check the product information and then mail a check to the company. Table 4 also shows the chi-square test results for different payment method. To test the Hypothesis 2 which states that there is no difference in the type of payment method used by students when ordering products from the Internet (H_0: p1 = p2 = p3), we have used the chi square test for proportion. In the chi-square test, the observed frequency and expected frequency are compared. In Table 4, the chi-square is 6.175. The critical value of chi-square table at the probability level of .05 with 2 degree of freedom is 5.991. Thus, the null hypothesis is rejected because 6.175 is greater than 5.991.

Table 4
Chi-Square for the Preferred Payment Method for
Purchasing from the Internet

Method	Observed Frequency	Expected Frequency	N = 80
Check product information, then call them to charge it to a credit card	28	26.7	Chi-Square = 6.175 df = 2 Asymp. Sig. = 0.046
Check product information, then mail them a check	35	26.7	
Check product information, then enter credit card information on the Internet	17	26.7	
Total	80	80.1	

CONCLUSIONS

College students tend to use the Internet to check product information and check general information on a company more than to actually purchase a product. When purchasing a product, however, the students indicated that they prefer to check the product information and then mail a check to the company as opposed to using a credit card. This indicates that students are still concerned about giving their credit card number on the Internet. In fact, students indicated that they will not buy from the Internet because of a lack of security. Moreover, they do not buy from the Internet because of the inability to judge the product, and the inability to see or feel the product.

The main limitation in this study is that the subjects are students who may have limited income. Students, however, may spend more time on the Internet than other types of respondents. For future research, a study could be conducted on alumni, faculty or business men and women to see if there responses are similar to the sample used in this study.

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QA/QC SOFTWARE SELECTION: A RATIONAL APPROACH

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ABSTRACT

Rapid change in computer technology an the environment requires that business and industry continually update quality assurance/quality control (QA/QC) software. Recent surveys indicate that the potential software alternative set is extremely large making optimal selection of software challenging. This paper outlines a rational decision-making approach to QA/QC software selection in a project management framework.

INTRODUCTION

Quality Assurance/Quality Control (QA/QC) software is integral to the operation of practically all successful businesses in today's competitive environment. From SPC to TQM to ISO, businesses are using computers and software to support the quality initiatives necessary to remain viable.

Organizations also face rapid changes in computer technology (e.g. hardware, and operating systems) that often necessitate the purchase of new software. Granted, the selection of operation systems, hardware, and office software (word-processing, spreadsheet and database) is always challenging. But, the alternatives are somewhat limited (e.g. Apple or Microsoft, Microsoft's Office or Office Suite). QA/QC software selection is a different matter. The set of alternatives that could meet an organization's needs is large. In fact, the 1998 *Quality Progress* software survey (Daniels, 1998) listed 242 vendors offering different software packages for QA/QC application. In addition to the sheer volume of alternatives available, the wide variation of user needs within an organization, makes the selection of QA/QC software a very challenging project indeed.

The purpose of this paper is to offer a framework to help ensure the rational selection of software for quality applications. This paper does not discuss the alternative of hiring a consultant to guide an organization through the selection process. This is an alternative that in some cases would provide good results.

THE RATIONAL QA/QC SOFTWARE SELECTION PROCESS

The rational QA/QC software selection process (Table 1) outlined in this paper was developed from elements of: the rational decision making model (Griffin 1993); the consumer decision process (Mowen, 1990), and multiattribute choice theory (Oral and Kettani, 1989) in a project management framework to ensure timely completion and adequate documentation.

TABLE 1: Rational QA/QC Software Selection Process	
1	Establish Need for Software Acquisition
2	Select A Project Manager
3	Select Team to Make Selection
4	Establish Objectives, Goals and Time Frame
5	Determine Attributes and Attribute Scales
6	Determine Feasible Set of Alternatives
7	Evaluate and Rank Alternatives
8	Choose Best Alternative
9	Evaluation of Selection Process

STEP 1: ESTABLISH NEED FOR SOFTWARE ACQUISITION

The first step in any consumer decision making process is the recognition that there is a need for a product (Mowen, 1989: 285). In the case of QA/QC software the need for the product could be driven by changes in the firm's internal or external environments. Internal prompts might include continuous improvement efforts leading to different requirements from the QA/QC software, or changes in computer hardware and software that render current software impractical for future use. External prompts for change might include customer requirements, and competitive pressures such as attaining ISO certification.

STEP 2: SELECT A PROJECT MANAGER

Since QA/QC software selection requires that a series of related activities be completed in order to arrive at "the best" software for the organization, the selection of QA/QC software is a project by definition (Chase & Aquilano, 1995: 484), and must be managed as such. The selection of an individual to be responsible for the software selection process is essential for the successful completion of the project. The project manager should possess a diverse set of skills, or attributes (Table 2) as outlined by Badiru (1996: 66).

Quality professionals are excellent candidates for the QA/QC software selection project manager due to their technical knowledge, desire to make an optimal solution, and experience with TQM tools to solve problems in a group setting. In addition, quality professionals usually occupy a staff position thus reducing the likelihood of encountering political problems in the selection process.

TABLE 2: Desirable Attributes of Project Manager	
?	Inquisitiveness
?	Good labor relations
?	Good motivational skills
?	Availability and accessibility
?	Versatility with company operations
?	Good rapport with senior executives
?	Good analytical and technical background
?	Technical and administrative credibility
?	Perseverance toward project goals
?	Excellent communication skills
?	Receptive ears for suggestions
?	Good leadership qualities
?	Good diplomatic skills
?	Congenial personality

STEP 3: SELECT TEAM TO MAKE SELECTION

The software selection team is a problem-solving team (Rao, 1996: 477), and should include members form all areas within the organization that are affected by the software change. This includes direct users of the product and individuals that use information obtained indirectly from the system (e.g. customer service, upper management, etc.). Computer professionals must also be included to ensure that the selection is consistent with long-term information system strategies.

Team members must be willing to serve on the selection team and should possess, or receive training in, the TQM tools necessary to generate ideas in a group setting, and reach group consensus. Any necessary training should be conducted prior to the beginning of the project to keep from delaying the project’s completion. Team members should also be provided with the incentive necessary to ensure that they will contribute to the project's successful and timely completion.

In addition to making a good organization-wide selection, the use of an inclusive cross-functional team approach should help mitigate some of the adverse reactions that are bound to occur as QA/QC software change is implemented. Participation in the selection process along with the education and communication inherent in the software selection process should allow a reduction in the resistance accompanying the change (Lawrence, 1969).

STEP 4: ESTABLISH OBJECTIVES, GOALS AND TIME FRAME

The project manager and his superiors must first establish overall guidelines for the software selected and the software selection process. To avoid confusion, lets begin by defining *objective* and *goal*. “An *objective* generally indicates the direction in which we should strive to do better” (Keeney and Raiffa, 1976: 34). For example, “selecting the best QA/QC software for the organization” should be the overall objective of those involved in the software selection process. “A *goal* is different than an objective in that it is achieved or not” (Keeney and Raiffa, 1976: 34). Therefore, completing the selection process in six months or less is a goal. Realize that while goals are useful in the practical implementation of the selection project, they are not as important as objectives in the context of complex decisions (Keeney and Raiffa, 1976) such as the selection of QA/QC software.

The generation of objectives for the selection of QA/QC software can be approached in several ways (Keeney and Raiffa, 1976) . Library research regarding the selection of software (e.g. Anderson, 1986; Rocheleau, 1994; Wardlow, 1995) can provide very helpful information. In-house surveys of probable users and others affected by the software selected would not only help the team establish objectives, but might help alleviate problems associated with the change by allowing individuals not on the selection team to participate in the process. Organizations might also consider assembling a panel of experts to generate objectives.

At this point the selection team is faced with perhaps a large pool of objectives. It is necessary to reduce and structure the objectives in a manner that allows them to be of practical use to the team (Keeney and Raiffa, 1976).

The team should employ a formal methodology in this effort. Commercially available decision aids, such as Expert Choice are available to provide assistance with the structuring of multiple objectives and can also be used through as well as the remainder of the multiattribute choice problem. TQM tools can also be used to help generate and structure the objectives, and may prove easiest for most organizations to use effectively.

Once objectives have been determined the selection team must set goals to help ensure that the objectives are met. After goals are determined, a detailed project plan can be developed. This plan must include all activities necessary to complete the project. Target dates for activity completion must be set as they are key to the successful completion of the project.

Project management tools (e.g. PERT/CPM) should be used to determine activities critical to the timely completion of the project. Commercially available software such as Microsoft Project or Time Line makes the management of complex projects much easier. In addition to assisting in the determination of critical activities, project management software provides excellent documentation for continuous improvement and bench-marking efforts, allows for easy modification of the project plan, and has other features that assist the project manager in guiding the project to successful completion. However, realize that the goal is to select the best QA/QC software - not to learn how to use project management software.

STEP 5: DETERMINE ATTRIBUTES AND ATTRIBUTE SCALES

After a hierarchy of objectives is developed, the selection team must determine attributes that indicate the degree to which a software alternative meets an objective (Keeney and Raiffa, 1976: 32).

For example, one objective might be to minimize the time needed to train personnel to use the new QA/QA software. This attribute would logically be measured in time units of days or hours.

Logically, attributes should be measurable, and many (e.g. purchase cost of software, and training time) have commonly understood scales. Others, such as "feel", are more difficult to assess because no objective scale exists. In this instance the team must find or develop a subjective index (Keeney and Raiffa, 1976). Quality and marketing literature are good places to find scales with empirically supported validity. It is desirable that the team has defensible measures for all attributes. In the event that scales cannot be found or developed, the team might simple consider dropping the attribute from consideration, or finding a proxy for the attribute. In the event that this is not practical, the team should consider using a more sophisticated decision analysis technique (e.g. Expert Choice, DECAID, etc.) in the evaluation and selection stage of the selection process.

STEP 6: DETERMINE FEASIBLE SET OF ALTERNATIVES

Quality Progress' 15th Annual Quality Software Directory (Daniels, 1998) lists 242 companies offering software products with capabilities falling into 33 general categories for application in six industry classifications. Obviously, it would be very time consuming to evaluate every product offered by these vendors in great depth. Therefore, the selection team must devise a plan that reduces the size of the set of alternatives to be carefully examined.

The selection team should first compile a list of potential alternatives and their basic capabilities. The *Quality Progress* survey is a good place to start. The team may also wish to search the INTERNET or other sources to supplement *Quality Progress'* survey. Vendors that do not have products that meet the requirements of the organization can be eliminated before any additional analysis is performed. There is no need to complicate this process - a pencil and a sheet of paper will suffice.

Vendors offering potentially feasible alternatives should be contacted for more detailed product information. This information should be entered into a database that: (1) allows the team to have a record of all packages considered; and (2) allows the team to search by attributes. This allows the team to investigate how changes in objectives and goals affect the feasible set of alternatives. For example, changing cost goals may drastically alter the feasible set. The selection team may elect to modify objectives, goals, and attributes at this point. Realize that it is possible to have requirements such that the feasible set contains no alternatives. In this case the selection team might have to consider purchasing multiple packages, or develop specialized software.

The selection team should strive to have a feasible set that is not empty, but is small enough to allow serious evaluation. Vendors should be contacted for evaluation software. Unresponsive vendors or those not willing to offer a full-blown package for evaluation should be eliminated from consideration. It is essential to test the software in near real-world situations. Cut-down packages can make this difficult especially when using large data sets.

STEP 7: EVALUATE AND RANK ALTERNATIVES

The team must now perform a hands-on evaluation of each feasible software alternative. This evaluation should be consistent with the objectives and goals of the project. Operationally, this requires that each feasible software alternative be evaluated using the attribute scales developed in Step 4. Every effort should be made to ensure that each alternative is evaluated exactly like the others. The team should also strive to consider each attribute independent of the others. Attribute scores should be entered into the database.

Software packages can then be ranked according to attribute scores. In some cases packages are likely to have the same or similar scores on some attributes. This presents a challenging decision situation. If the team is using decision analysis aids in the analysis, there should be a mechanism, usually pair-wise comparisons, to arrive at a clear preference with respect to an attribute. If such tools are not used, the team may elect to use TQM tools to reach a conclusion regarding ranking of alternatives with respect to the attribute. The extent of effort expended should be consistent with the importance of the attribute in the overall selection process.

STEP 8: CHOOSE BEST ALTERNATIVE

In a perfect world one software alternative would be superior on all attributes considered. In this case the selection of the best alternative would be simple - select the package that is dominant on all of the attributes. However, it is often the case that no clearly dominant alternative exists (Keeney and Raiffa, 1976) leading to a more complex decision situation. To further complicate matters, decision objectives often conflict (e.g. minimizing cost of the software and increasing capabilities) leading to difficult tradeoff decisions.

In the event that no software alternative is dominant on all attributes, the software selection team must determine a method to assign a comprehensive score to each software alternative evaluated. As mentioned, this is sometimes difficult to accomplish in practice in large part due to conflicting objectives and differing attribute units. Many different methods have been proposed to combine attribute scores in an effort to arrive at an optimal selection. These methods have been discussed at great length in the decision analysis literature (e.g. Keeney and Raiffa, 1996; Larichev, Olson, Moshkovich, & Mechitov, 1995; Larichev & Moshkovich, 1995; Moynihan & Jethi, 1995), and can provide very good results. However, selection teams must guard against losing sight of their overall objective - to select the best software alternative for the organization *within the allotted time frame*. If a small set of software alternatives are considered almost equally preferable, inviting vendors to demonstrate these packages on site (Wardlow, 1995) might allow the team to reach consensus in a timely manner.

STEP 9: EVALUATION OF SELECTION PROCESS

After the software has been purchased and implemented, the selection team should go through a thorough post-mortem examination. Members of the selection team should be surveyed to determine the strengths and weakness of the process used to make the selection. This information should be included in the selection process documentation that should provide a benchmark for continuous improvement in software selection projects, or similar decision situations.

DISCUSSION

Inappropriate software leads to inefficiency and cost to organizations. This failure is often due to the selection process (Oliver, 1994). The software selection approach outlined in this paper is intended to provide needed structure to a problem commonly faced by quality professionals and other managers.

Several issues surrounding the selection of QA/QC software need to be investigated further to gain a greater understanding of the problem, and its ramifications. Research investigating how organizations currently approach the QA/QC software selection problem would be great interest. Questions such as, “Who is involved in the selection process?” “How are the alternatives generated?” and “How are alternatives evaluated?” need to be explored. In addition, research focused on the economic ramifications of QA/QC software on the success of organizations is also of interest so managers can determine the appropriate emphasis to place on the selection process, and its improvement.

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REDUCTION OF SHOP LOCKING IN FLEXIBLE MANUFACTURING SYSTEMS

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ABSTRACT

In this research, the problem of shop-locking (deadlock) in flexible manufacturing systems is considered. Much of the past work in the shop-locking concentrates on avoiding shop-locking during the real-time operation of a given system. However, these models usually make several simplifying assumptions about the manufacturing system. This paper focuses on identifying the system parameters and operational control strategies which contribute to shop-locking during the real-time operation of the system, without making simplifying assumptions about the system.

To that effect a new procedure is developed for the minimization of shop-locking. The proposed method combines the inferential statistics and discrete-event simulation techniques. The implementation of the procedure is illustrated with the help of a numerical example. It is shown that this method can be an effective tool in the selection of system parameters to minimize shop-locking without simplifying assumptions about real-life manufacturing systems.

INTRODUCTION

Flexible Manufacturing Systems (FMSs) represent the advent of a new era of discrete part manufacturing throughout the industrialized world. An FMS is an automated small-batch manufacturing system consisting of a number of numerically controlled and computerized numerically controlled workstations linked together via a programmable material handling system (MHS). Real-time control of workstations and MHS is accomplished by computers and data transmitting links.

FMSs possess enormous potential for increasing the overall productivity of manufacturing systems. At the same time, the task of planning and controlling an FMS is more complex compared to traditional systems. Therefore, effective planning and controlling of an FMS is required to ensure efficient utilization of the resources--workstations, MHS, pallets, etc. In a typical FMS environment, planning and operational control problems are addressed at two different levels.

During the production planning of an FMS, small batches of parts are selected for simultaneous production in a manufacturing cycle. Several planning decisions such as part production ratio, tool loading, machine grouping, and resource allocation (Stecke, 1983) are to be considered at this stage.

At the operational control level, real-time flow of parts is controlled. Several raw parts of various types are released into the system at discrete points in time. The number of concurrent parts in the system is limited by the fixed number of pallets (Nof, Barash, and Solberg, 1979; and Carrie and Petsopoulos, 1985). These parts are processed concurrently, sharing the resources such as workstations, buffer spaces, and MHS in the FMS. However, limited buffer size and resource-sharing could lead to shop-locking. (In computer network literature, shop-locking is referred to as deadlock.) (Banaszak and Krogh, 1990; and Viswanadham, Narahari, and Johnson, 1990). Shop-locking is an undesirable state of the system which can cripple the automated operations of the system. Clearing of shop-locking may require manual interference and result in production loss and added labor cost (Viswanadham, et al., 1990) as well as in larger throughput time. However, shop-locking can be minimized if a system is properly designed and if appropriate real-time control policies are employed.

In this paper, a procedure for system design is developed using the discrete event simulation technique. This procedure facilitates the identification of operational control strategies which would minimize shop-locking, without simplifying assumptions for modeling of the manufacturing system. The remainder of the paper is organized as follows. The next section describes the phenomenon of shop-locking. This is followed by an explanation of the motivation for this research. Section 4 explains the procedure for shop-lock reduction, and the subsequent section illustrates implementation of this procedure. Finally, brief results obtained from the numerical problems are presented with analysis.

SHOP-LOCKING

The phenomenon of shop-locking is defined as the state of a system when parts or vehicles are allocated to the shared resources (a buffer space, a workstation, a section of the guide-path, a robot) such that any further flow of parts is not feasible (adopted from Wysk, Yang and Joshi, 1991). In other words, a part or a vehicle, while holding a shared resource, is waiting for another shared resource which is currently held by another part or vehicle. Both of these parts or vehicles will wait until some external action is taken to clear shop-locking. This situation could arise due to the fact that the buffer at a workstation is full and parts are waiting to be moved to the other workstations.

To illustrate an example of shop-locking, consider an FMS as shown in Figure 1. This system has four workstations, a load/unload (L/U) station, two automated guided vehicles with a one-way guide path and a common input-output buffer. Parts are carried on a pallet from the L/U station to a workstation for processing on an AGV. Parts are transported between workstations according to the part assignment. An AGV carries one part at a time. Upon completion of all the operations of the part, it is returned to the L/U station. Whenever a pallet becomes available, a new part is released into the system. Therefore, the number of concurrent parts in the system remains constant and is equal to the number of pallets. Consider the following state of the system in order to visualize shop-locking. All parts in the buffer of workstation 2 are waiting for workstation 3 and vice versa. If the buffers at both workstation 2 and workstation 3 are full, then no part movement can take place between these two workstations. This will ultimately lock the whole system as workstations 2 and 3 cannot process any part until shop-locking is resolved.

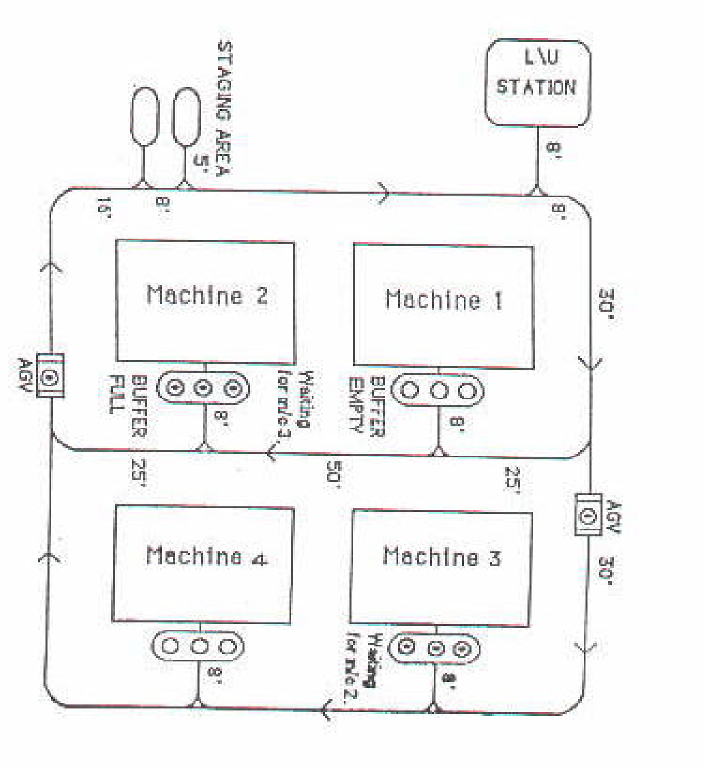

Figure 1. Flexible Manufacturing System

Shop-locking may occur due to several factors, including operational control strategies, number of pallets and buffer size. Operational control strategies include part and vehicle flow control rules. These control strategies have significant impact on the performance of an FMS (Stecke and Solberg, 1981; and Egbelu and Tanchoco, 1985). Similarly, the number of pallets and buffer size are critical factors for shop-locking.

Shop-locking is also dependent on other factors such as design of guide path for AGVs--uni-directional or bi-directional; and type of buffer--central or local and common or independent input-output buffer. For an FMS with the above described characteristics (see Figure 1) such as common input-output buffer at each workstation and uni-directional guide path AGVs with spur links, the following three states lead to shop-locking:

1. Buffers at two workstations are full and parts at one workstation are waiting to be transported to the other workstation (see Figure 1).
2. An AGV is waiting to deliver a part to a workstation with full buffer, and the workstation is either processing a part or all parts in this buffer are waiting for transportation (Figure 2a).
3. A buffer is full with parts awaiting processing at the workstation and does not have space to hold a part which has undergone processing at this workstation (Figure 2b).

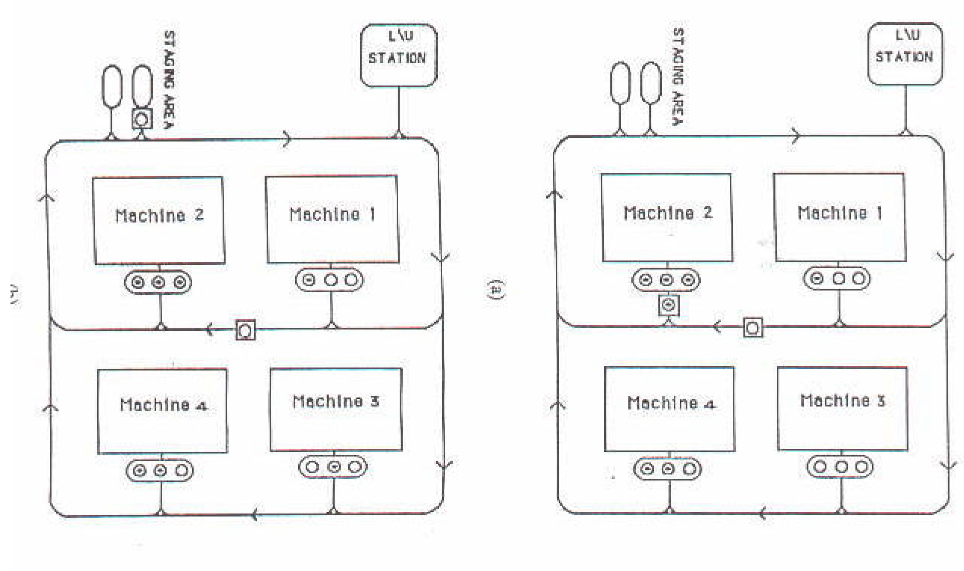

Figure 2. Shop-Locking in Flexible Manufacturing System

It is clear that the finite size of buffer space is one of the factors which causes shop-locking. If the buffer size at each workstation is infinite, then shop-locking would be restricted. But, it will result in higher work-in-process inventory. Similarly, the number of circulating pallets also contributes to shop-locking. If the number of pallets is reduced to one, then shop-locking would never occur. Hence, shop-locking is a function of these two factors--buffer size and number of the pallets.

However, size of buffers cannot be infinite in an FMS. Large buffer size results in the growth of immobilized resources (fixture, area, etc.) as well as an increase in the indirect cost of production (Zavanella, Agliari and Diligenti, 1992). Likewise, the number of pallets has an impact on the indirect production cost as well as the throughput of the system (Maheshwari, 1992). Therefore, a correct combination of these two system parameters must be determined.

Following are the two main objectives of this study:

1. To identify the operational control strategies which significantly contribute to shop-locking, and
2. To establish the ratio of buffer size to number of pallets circulating in the system so that shop-locking can be reduced.

MOTIVATION

In general, the modeling tools involved in shop-lock detection and avoidance are evaluative in nature with the exception of queueing theory models. However, most integrated manufacturing systems are too complex to be represented by a queueing model. It is, therefore, not frequently used as tool for this purpose.

The Petri-net and graph theory approaches have the potential to be used as real-time controllers in FMS. The research has shown that Petri-net and graph theory controllers are capable of detecting and avoiding shop-locking in simple systems (see Banaszak and Krogh, 1990; and Wysk, Yang and Joshi 1991). However, as systems become complex (most real life integrated manufacturing systems are very complex) both Petri-net and graph theory models become very large and complicated. These models must be decomposed, and several simplifying assumptions about the system must be made in order to reach a solution under real-life situations. Consequently, these modeling techniques have to demonstrate their usefulness in highly integrated manufacturing systems.

Unlike the Petri-net models, discrete event simulation models do not have a mathematical basis and can't be directly used as the real-time controller in a manufacturing system. However, discrete event simulation models can easily represent a complex manufacturing system. This makes simulation models a robust performance evaluation tool. This performance evaluative capability of simulation can be utilized to identify the factors which contribute to shop-locking. This research demonstrates that the simulation along with statistical inference can be utilized to identify the factors which cause shop-locking without making any major simplifying assumption about the manufacturing system. A procedure to this effect is described below.

PROCEDURE FOR MINIMIZATION OF SHOP-LOCK

The procedure for minimization of shop-locking is presented in Figure 3. This could be used to design an FMS environment with a minimal amount of shop-locking. This procedure is capable of selecting operational control strategies as well as system parameters such as buffer size and number of pallets in an FMS. This approach consists of the following steps:

Step 1. Randomly select a set of sample test cases consisting of a range of parts and their relative ratios to be processed in a manufacturing cycle. This range of parts is randomly drawn from the family of parts for which the FMS is designed.

Step 2. Perform part assignment and tool allocation using a loading model or heuristic.

Step 3. Select a set of operational control strategies. These strategies include control rules for part and vehicle flow. A combination of these may be required to control the system.

Step 4. Select other system parameters such as buffer size to pallet ratio. (The number of pallets may represent the number of concurrent parts in the system.)

Step 5. Design the simulation model.

Step 6. Experimental design. Statistically validate the design so that combinations of the operational control strategies can be tested.

Step 7. Conduct simulation experiments.

Step 8. Test the hypotheses related to the significance of shop-locking.

Step 9a. Select the operational control strategies which result in the statistically insignificant number of shop-locking occurrences.

b. Select a ratio of buffer size to pallets which results in a statistically insignificant number of shop-locking cases.

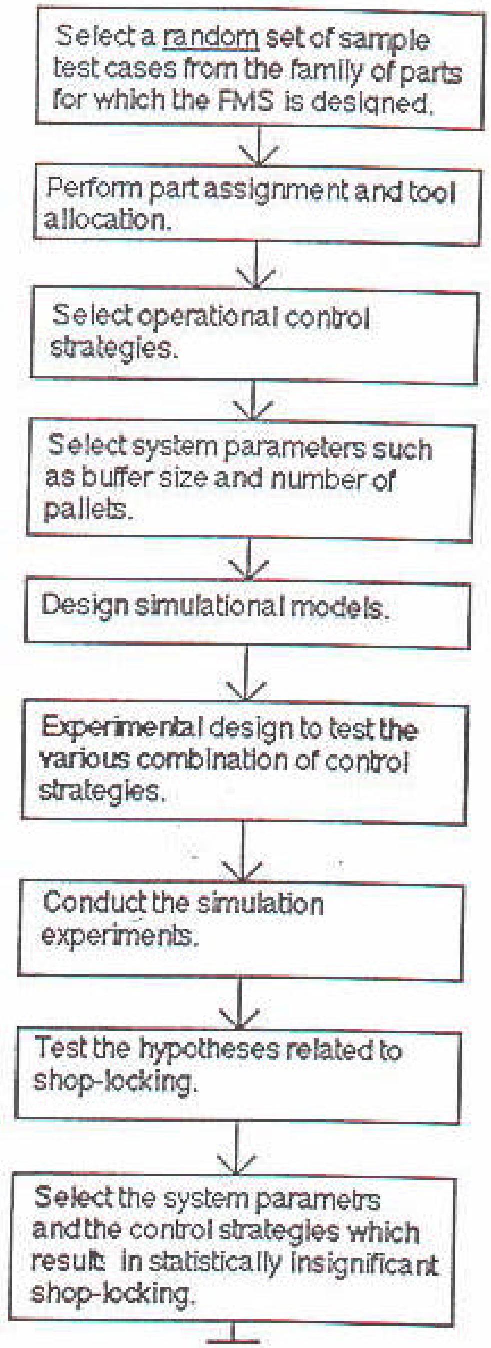

Figure 3. Procedure for Shop-Locking Minimization in Flexible Manufacturing System

There are several hypotheses which could be tested for the part dispatching rules, the vehicle dispatching rules and the ratio of buffer size to pallets, etc. The selection of dispatching rules or buffer size to pallet ratio will depend upon the statistical significance of strategies or their interactions.

IMPLEMENTATION

TEST PROBLEM GENERATION

FMSs are designed to manufacture a range of part types (Whitney and Suri, 1985). The range or family of these parts is decided before the installation of an FMS (Browne, Chan and Rathmill, 1985). In a manufacturing cycle, the FMS may be required to process any random combination of the parts from the family for which it is designed. Similarly, the ratio of the parts and the demand size may vary randomly in each manufacturing cycle. Consequently, during any given cycle, an FMS is required to manufacture a random combination of the part types, demand sizes, and relative part ratios.

Figure 4 illustrates the step-wise algorithm for the random sampling for test cases. A test case is sampled randomly by selecting a number of parts, between three and eight, from a predefined data set. This data set is created on the basis of the part families for which an FMS is designed. The information stored in this set includes workstation-cutting tool compatibility matrix, tool inventory matrix, part-operation-workstation-cutting tool-processing time matrix, part-tool material matrix and tool life matrix. After selection of the part types, the relative part-ratio is randomly sampled as 1, 1.5, 2, 2.5, or 3. Twenty different test cases are sampled.

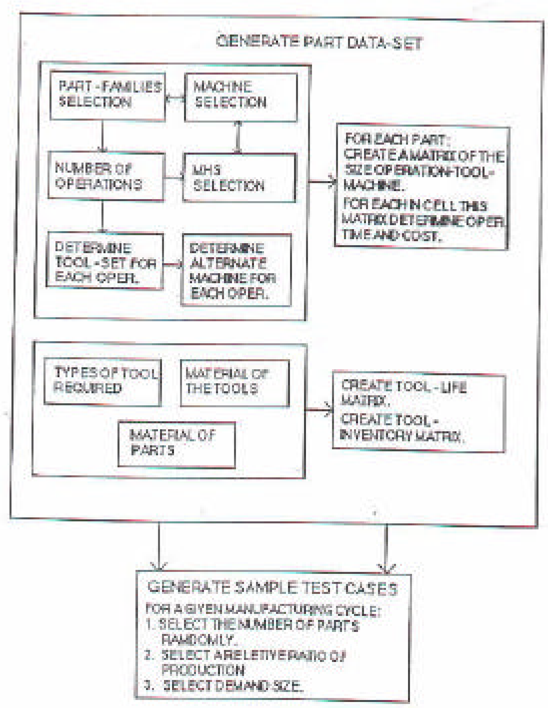

Figure 4. Generation of Random Part Sets

PLANNING MODEL

The planning model is an integer programming model which solves part assignment and tool allocation (Leung, Maheshwari, and Miller, 1993). The planning model is solved for each of these twenty test cases. The characteristics of the model are briefly described below.

Decision Variables - There are two sets of decision variables: part assignment and tool allocation. Part assignment variables represent the quantity of each part type whose specific operation is to be performed on a workstation using a particular tool type after visiting a given workstation for a preceding operation. Tool allocation variables depict the number of tools of a given type allocated to a workstation.

Objective Function - Four different objective functions are formulated. The objective functions are: minimization of total processing and material handling times; minimization of total processing; tool use and transportation cost; minimization of total cost and penalty cost for unused tool-life; and balancing of machine workload.

Constraints - The constraint set includes tool life constraint, tool availability constraint, magazine size constraint, machine capacity constraint and material handling capacity constraint. A set of logical constraints is designed to ensure that when a part is routed to a specific workstation for a specific operation, the corresponding tool type will be loaded onto the workstation. The parts and tools are allocated to the workstation according to demand, capacity and resource constraints.

OPERATIONAL CONTROL STRATEGIES

Part Releasing Rules - These rules assign priority to the parts awaiting release into the system. There is a finite number of parts circulating concurrently into the system. A part remains on a pallet while in the system. As a result, the number of parts in the system is controlled by the number of circulating pallets. Several part releasing rules are reported in the literature (Nof, Barash and Solberg, 1979; and Carrie and Petsopoulos, 1985). Four part releasing rules, which have been used in the study, are Least Production Ratio (LPR), Least Number of Visits (LNV), Shortest Total Processing Time (STPT) and Random (RAN). LPR releases a part according to the production ratio of the part. This rule aims at maintaining a constant production ratio during the operation of system. The LNV rule releases parts according to least number of workstation visits a part has to make to complete all of its operations, whereas STPT releases parts according to shortest processing load. Both of these rules maintain a cyclic order. The cyclic order is used to avoid the releasing of only one type of part (e.g., the part with minimum total processing time) in the system. The RAN rule releases parts in random order. This rule is included as a bench mark rule.

Part Sequencing Rules - The part sequencing rules deal with sequencing of parts waiting at a workstation for processing. An operation processing priority is assigned to a part waiting to be processed at a workstation. These priority rules are applicable only if more than one part is waiting at that workstation. Several part sequencing rules have been investigated in the job-shop environment (see Panwalkar, and Iskander, 1977, for a review of the job-shop scheduling rules). Similar rules are examined in an FMS environment as well (Stecke and Solberg, 1982; and Montazeri and Van Wassenhove, 1990). This study utilizes FIFO, SPT, SPT/TPT (Smallest Ratio imminent of Processing Time/Total Processing Time), and SRPT (Shortest Remaining Processing Time). FIFO is a bench mark rule whereas SPT, SPT/TPT, and SRPT assign priority on the basis of processing time.

<u>Vehicle Dispatching Rules</u> - The vehicle dispatching rules are required when a part is to be transported from one workstation to another workstation or to the load/unload station. Priority is assigned for selecting the part if more than one part is waiting to be transported when a vehicle becomes idle. Such priority schemes are called vehicle initiated rules. Several of these rules are investigated in an FMS environment (Egbelu and Tanchoco, 1984; and Bozer, 1989). Four different rules are considered in this study for vehicle dispatching. FIFO is a bench mark rule to prioritize the waiting parts. Minimum Remaining outgoing Queue Space (MRQS) assigns transportation priority to the parts according to the state of the buffer in the outgoing queue. The larger the size of the buffer queue of a part, the higher is the transportation priority. Minimum Work in Input Queue (MWIQ) determines transportation priority according to the work content in the destination queue of the part. Highest priority is allocated to the part which has minimum work content in its destination queue. Minimum Remaining Visits (MRV) transports the parts on the basis of the number of remaining machine visits a part has to make to complete its processing.

Table 1
Operational Control Strategies

Control Strategy	Description
a. Part Releasing Rules (PRR)	Priority of releasing a part when a pallet becomes free. 1. Least Part Ratio (R) (LPR), where $R = \frac{\text{Number of parts of a type released}}{\text{Total production requirement of this type}}$ 2. Least Number of Visits (LNV). 3. Shortest Total Processing Time (STPT). 4. Random Order (RAN).
b. Part Sequencing Rules (PSR)	Priority of processing a part at the workstation. 1. First In First Out (FIFO). 2. Shortest Processing Time (SPT). 3. Smallest ratio of imminent Processing Time to Total Processing Time (SPT/TPT). 4. Shortest Remaining Processing Time (SRPT).
c. Vehicle Dispatching Rules (VDR)	Priority of transporting a part waiting for an AGV. 1. First In First Out (FIFO). 2. Minimum Remaining Queue Space (MRQS). 3. Minimum Work Input Queue (MWIQ). 4. Minimum Remaining Visits (MRV).
d. Vehicle Selection Rule	Idle vehicle located at shortest distance from the requesting workstation.

SYSTEM PARAMETERS

The size of buffers and the number of pallets have a direct impact on the shop-locking of a system. The number of circulating pallets in the system must be less than the total number of workstations plus the number of buffer spaces, otherwise, all of the workstations will be blocked. In this research, it is assumed that the same buffer area is used for both input and output of the parts at a workstation. Four different buffer capacities, 3, 4, 5 and 6 are considered. Equal size buffers are available at each workstation. The number of pallets should not be less than the number of workstations. This would result in a low system utilization, because at any given time at least one workstation would be starving. Four different capacities of pallets 6, 8, 10 and 12 are considered. These capacities are 1.5, 2, 2.5 and 3 times the number of workstations.

SIMULATION MODEL

The simulation model (Figure 5) is developed using the educational version of the SIMAN 4.11 package (Pegden, Shanon, and Sadowski, 1990). The model is built for the FMS shown in Figure 1. The input parameters to the model include number of pallets in the system, number of buffer spaces at a workstation and production requirements of different part types for a given manufacturing cycle. Two AGVs are present in the system to transport the parts between the workstations. Each part is assigned the sequence of workstation visits for its different operations based on the part assignment from the planning model. Once a part is released into the system, the sequence of visits of the part to the workstations is not altered.

The simulation starts with an empty and idle system. Initially, the number of parts released into the system is equal to the number of pallets. Subsequently, parts are released as pallets become available. A simulation run is not completed until all the parts required in this manufacturing cycle are produced. Therefore, the length of the simulation run is a variable and is equal to the makespan.

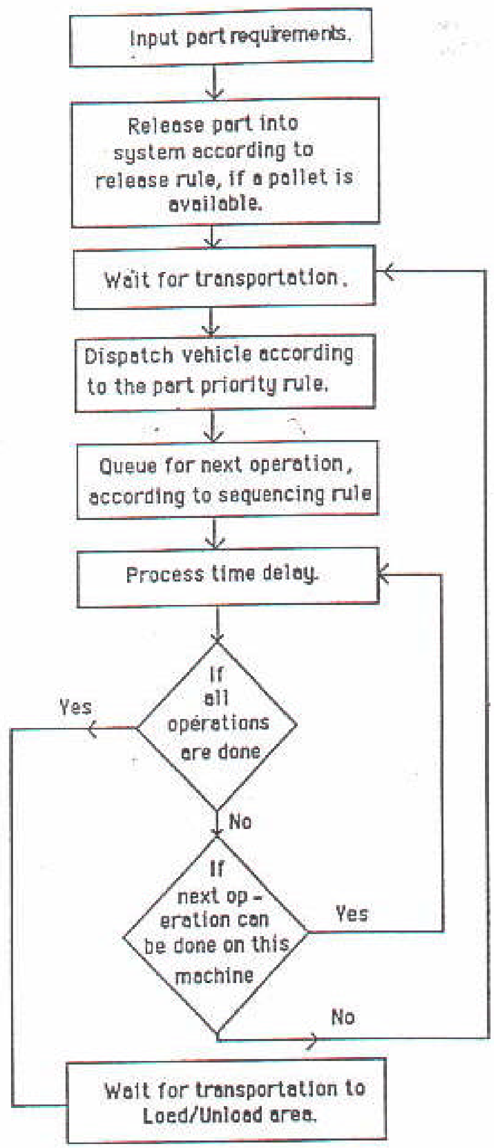

Figure 5. Simulation Flow Chart

EXPERIMENTAL DESIGN

In the above described simulation experiment, there are six main factors of interest: loading strategies, part releasing rules, part sequencing rules, vehicle dispatching rules, number of pallets and number of buffer spaces. Each of these factors has four different levels. All combinations of six factors will generate 4^6 (4096) experiments. To reduce the number of experiments, Taguchi's $L_{64}(4^{21})$ orthogonal array is utilized (see Logothetis, and Wynn, 1989, for further details on the orthogonal arrays).

RESULTS AND ANALYSIS

Results from the simulation experiments are shown in Table 2 (Maheshwari, 1992). There are 92 cases of shop-locking in the simulation experiments of 20 test cases. The total number of experiments is 1280.

The ratio (p = 92/1280) of the shop-lock experiments is statistically significant at $\alpha = .01$. Shop-locking is not significant while different loading objectives are used.

Table 2
Sample Simulation Results

TC	OF	PRR	VDR	PSR	PAL	BUF	MS
1	1	1	1	1	6	3	2476
1	1	1	2	2	8	4	2488
1	1	1	3	3	10	5	2390
1	1	1	4	4	12	6	2395
1	1	1	1	2	10	6	2470
1	1	1	2	1	12	5	2375
1	1	1	3	4	6	4	2571
1	1	1	4	3	8	3	2772
1	1	2	1	3	12	4	2576
1	1	2	2	4	10	3	2545
1	1	2	3	1	8	6	2516
1	1	2	4	2	6	5	2663
1	1	2	1	4	8	5	2578
1	1	2	2	3	6	6	2601
1	1	2	3	2	12	3	Shop-Lock
1	1	2	4	1	10	4	2678
1	2	3	1	2	10	6	2659
1	2	3	2	1	12	5	2610
1	2	3	3	4	6	4	2770
1	2	3	4	3	8	3	2669
1	2	3	1	1	6	3	2773
1	2	3	2	2	8	4	2712
1	2	3	3	3	10	5	2646
1	2	3	4	4	12	6	2604
1	2	4	1	4	8	5	2684
1	2	4	2	3	6	6	2712
1	2	4	3	2	12	3	2675
1	2	4	4	1	10	4	2499
1	2	4	1	3	12	4	2814
1	2	4	2	4	10	3	2475
1	2	4	3	1	8	6	2499
1	2	4	4	2	6	5	2764

TC: Test Case Number.
OF: Objective Function: 1 - Time Min, 2 - Cost Min, 3 - Penalty Cost Min and 4 - Machine Workload Bal.
PRR: Part Releasing Rules: 1 - LPR, 2 - LNV, 3 - STPT and 4 - RAN.
VDR: Vehicle Dispatching Rules: 1 - FIFO, 2 - MRQS, 3 - MWIQ and 4 - MRV.
PSR: Part Sequencing Rules: 1 - FIFO, 2 - SPT, 3 - SPT/TPT and 4 - SRPT.

PAL: Number of Pallets.
BUF: Buffer Spaces.
MS: Makespan in Minutes.

Table 2
Sample Simulation Results (Cont.)

TC	OF	PRR	VDR	PSR	PAL	BUF	MS
1	3	1	1	3	12	4	2263
1	3	1	2	4	10	3	Shop-Lock
1	3	1	3	1	8	6	2265
1	3	1	4	2	6	5	2450
1	3	1	1	4	8	5	2273
1	3	1	2	3	6	6	2419
1	3	1	3	2	12	3	2304
1	3	1	4	1	10	4	2265
1	3	2	1	1	6	3	2513
1	3	2	2	2	8	4	2335
1	3	2	3	3	10	5	2267
1	3	2	4	4	12	6	2225
1	3	2	1	2	10	6	2304
1	3	2	2	1	12	5	2222
1	3	2	3	4	6	4	2440
1	3	2	4	3	8	3	2429
1	4	3	1	4	8	5	2368
1	4	3	2	3	6	6	2583
1	4	3	3	2	12	3	Shop-Lock
1	4	3	4	1	10	4	2290
1	4	3	1	3	12	4	2659
1	4	3	2	4	10	3	2902
1	4	3	3	1	8	6	2282
1	4	3	4	2	6	5	2549
1	4	4	1	2	10	6	2578
1	4	4	2	1	12	5	2401
1	4	4	3	4	6	4	2759
1	4	4	4	3	8	3	2922
1	4	4	1	1	6	3	3013
1	4	4	2	2	8	4	2982
1	4	4	3	3	10	5	2483
1	4	4	4	4	12	6	2681

TC: Test Case Number.
OF: Objective Function: 1 - Time Min, 2 - Cost Min, 3 - Penalty Cost Min and 4 - Machine Workload Bal.
PRR: Part Releasing Rules: 1 - LPR, 2 - LNV, 3 - STPT and 4 - RAN.
VDR: Vehicle Dispatching Rules: 1 - FIFO, 2 - MRQS, 3 - MWIQ and 4 - MRV.
PSR: Part Sequencing Rules: 1 - FIFO, 2 - SPT, 3 - SPT/TPT and 4 - SRPT.
PAL: Number of Pallets.
BUF: Buffer Spaces.
MS: Makespan in Minutes.

The proportion of shop-lock experiments is statistically significant when small buffer size 3 or 4 is used with higher number of pallets. The following could be concluded:

a. Significant shop-locking occurs, if

$$\frac{\text{Total number of buffer spaces}}{\text{Number of Pallets}} \leq 1.6$$

b. Insignificant or zero shop-locking occurs, if

$$\frac{\text{Total number of buffer spaces}}{\text{Number of Pallets}} \geq 1.7$$

CONCLUSIONS

The operational performance of an FMS can be seriously affected by shop-locking. Shop-locking can occur due to a large number of factors including control strategies, buffer size, number of pallets, etc. In this paper, we have demonstrated that discrete event simulation can effectively be used as a tool for selecting system parameters and control strategies for the minimization of shop-locking (deadlock). To this effect, a procedure is developed by incorporating discrete event simulation and inferential statistics techniques.

The implementation of the procedure is illustrated with the help of a numerical example. The results from this example were able to identify the critical factors responsible for shop-locking in the system. For the FMS under study, a ratio of the buffer size to number of circulating pallets (1.7 or greater) was found which can minimize shop-locking. Similarly, this ratio can be established for several different types of FMSs and can be utilized as guideline in designing an FMS. Operational control strategies, which reduce shop-locking, were also identified for the given FMS. The results show that the part sequencing rules have significant impact on the shop-locking of this system.

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IMPROVING CUSTOMER SERVICE: A METRICS PROGRAM BASED ON ENTERPRISE RESOURCE PLANNING

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ABSTRACT

This paper discusses the criteria for selecting and presenting metrics to the shop floor employee, the work center manager and the general manager in a large scale manufacturing company. Areas discussed are: the importance of metrics at each level for specific decision support; the importance of the form of presentation; the update process; and the continuous use of metrics to improve delivery dates and reduce costs and flow times.

DESIGN OF GROUP DECISION SUPPORT SYSTEMS FOR MANAGEMENT OF HOLONIC NETWORKS

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ABSTRACT

This paper will address the issues of management of a functional holonic network utilising a Group Decision Support System (GDSS). It is assumed that this network is formed from a group of manufacturing companies, producing a real world product, and having a profit motive. The management issues surrounding formation, planning, control, communications, and decision making for this network and its resident nodes are numerous, and will determine its ability to become a viable enterprise. Discussion of the fundamentals of Decision Support Systems (DSS), Executive Information Systems (EIS) and the design criteria for Group DSS is provided.