PERGAMON

Available online at www.sciencedirect.com
SCIENCE DIRECT®

Omega 31 (2003) 189–204

omega
The International Journal of Management Science

www.elsevier.com/locate/dsw

The relationship between technology and performance: a meta-analysis of technology models

Michelle Lane Heine[a], Varun Grover[b,*], Manoj K. Malhotra[c]

[a] *Department of Management, College of Business Administration, Bowling Green, OH 43403, USA*
[b] *Department of Management, Sirrine Hall, Clemson University, Clemson, SC 29631, USA*
[c] *The Moore School of Business, Department of Management Science, University of South Carolina, Columbia, SC 29212, USA*

Received 2 July 2001; accepted 29 January 2003

Abstract

The effective deployment of technology within an organizational context is of integral concern to fields associated with the management sciences. While there has been significant study of technology effectiveness, it is often piece-meal as diverse models are hypothesized and empirically tested. This paper attempts to examine the models purporting to study the fundamental question of effective use of technology. Models examining the technology-performance relationship are summarized and meta-analyzed in an attempt to provide a more integrated perspective of technology and the factors that interact with it to enhance performance at the individual, process, or organizational level. The models are evaluated on their common dimensions, and insights for further research are identified. A research plan, along with a research model, is proposed with the hope of facilitating future work in this area of imminent and growing importance.

Keywords: Technology effectiveness; Empirical; Organizational implementation; Technology fit; Meta-analysis

1. Introduction

General trends by manufacturing firms are to employ increasingly advanced, computerized technologies. This trend is driven by the hypothesis that utilization of the technology will result in improvements in some measures of performance such as reducing costs or manpower or improving quality or flexibility. Unfortunately, in many cases, these investments have been criticized for not yielding the desired results. This is because the link between technology and performance is influenced by a number of factors, some controllable, and some uncontrollable. Both are important in order for us to understand technology's role. In order to *effectively* leverage technology, it is critical that the interactions between technology and its context are well understood. Technology functions within the broader context of the organization structure and management, the defined work task, and the people that interface with it [1,2]. Many researchers have proposed and tested models of technology effectiveness, but for the most part these models tend to be isolated representations rather than cumulative studies that systematically build upon each other. This meta-analytic review of technology research is simply a first, but necessary step in the process of developing a theory of effective technology deployment.

This study reviews 16 models of the impact of technology on performance. These models have been presented in major operations management, information systems, management, and other cross-disciplinary journals. Cumulatively they represent the current viewpoints in the academic arena on technology's role within the firm.

First, a general framework for understanding the role of technology within the firm will be presented. Propositions based on this model will then be drawn. Specific technology

* Corresponding author. Tel.: +1-864-656-3773; fax: +1-864-656-6768.

E-mail addresses: mlheine@cba.bgsu.edu (M.L. Heine), vgrover@clemson.edu (V. Grover), malhotra@darla.badm.sc.edu (M.K. Malhotra).

0305-0483/03/$ - see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0305-0483(03)00026-4

models will then be reviewed individually, and the pertinent parameters of the research presented. Then the existing research will be reviewed across these parameters in order to evaluate its comprehensiveness as a whole. Finally, insights gained by comparing the models that motivate need for further work will be explored, and a model for further research presented.

2. The MIT framework for technology and organizational change

In the 1991 book *The Corporation of the 1990's* Michael Scott-Morton presented the MIT 90s framework that is shown in Fig. 1. This general model of technology's role within the firm reflects his basic theory that there are five elements within the firm that need to be in balance. The model focused specifically on the role of information technology (IT) within the firm, and a major conclusion of Scott–Morton's research was that successful use of IT depends upon the adaptation of four other areas within the firm. The strategy of the firm influences, and is influenced by IT through the organization structure, management processes, and the individuals and their roles within the firm. All five elements need to be in balance in order to effectively transform an organization for full utilization of IT. The *strategy* provides a vision and view of where the firm is heading. None of the potentially enabling aspects of IT can take place without clarity of business purpose and an emphasis on technology exploitation. This must then be aligned with the 'people management' approach that is put into place. People need to understand the goals for the firm, and be empowered to work toward them. The *organization structure* should be designed to allow people this autonomy. A highly decentralized and less formal organization structure allows the workforce opportunities to explore different means of accomplishing work and multiple ways of accomplishing goals. The *management processes* that define how work is done should also be transformed. For example, narrow job tasks that do not allow the employee to explore and leverage the technology they work with will not permit flexibility in fitting the job to the abilities of the equipment. *Individuals* and their relationship within the firm can be influenced by use of training, teamwork, use of incentives, and communication.

Thus, keeping all of these elements in balance with the technology selected by the firm will allow the firm to leverage technology's potential. It is useful to note that this model is a recursive one, where the five elements all impact one another and decisions should be made collaboratively on these issues in order to maintain alignment. This implies that they should 'fit' each other. Performance, which is implicit in this model is a function of that fit.

Our study focuses on the interrelationships of technology with structure, management processes, and individuals and roles. The influences of the organizational strategy on

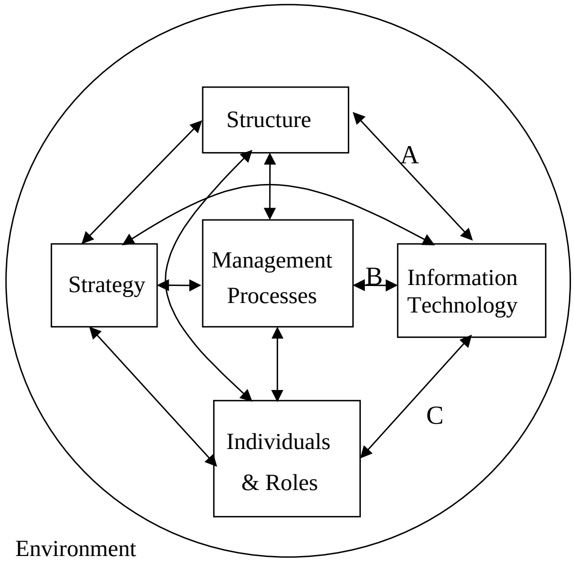

Fig. 1. MIT framework for information technology and organizational change. *Source*: Ref. [1].

technology are less relevant when reviewing the effectiveness of technology in its operational context, and therefore will not be reviewed here. However, the role of operations strategy may be more pertinent since the firm's operations strategy would establish the purpose for which the technology was acquired, the capabilities expected from its acquisition (low cost per unit, high quality, quick changeovers, etc.), and the performance criteria selected to measure how well the technological system is achieving its objectives. Implementation of the selected operations strategy will be constrained and guided by the existing structure, management processes, and individual task and roles. Thus the impact of operations strategy is subsumed within the other elements and is neither shown nor discussed here as a separate entity by itself. The other three interrelationships then define the environment in which the technology must operate, and are represented by the arrows labeled 'A', 'B', and 'C' in Fig. 1. Based on this work of Scott-Morton, the following propositions are presented:

Proposition 1. *There will be certain conditions of structure, process and people that might enhance individual and organizational performance of technology.*

Proposition 2. *A 'fit' between attributes of technology and its contextual contingencies is necessary for improved performance.*

These propositions are based on the thesis that a technology can be best leveraged if it is carefully aligned with its contingent context. Hence, Propositions 1 and 2 are critical if we are to develop a 'theory of technology effectiveness'.

In addition, these propositions must be evaluated in the context of prior published literature within the domain of technology effectiveness. Towards this end, a meta-analysis of major journals yielded 16 technology related models that are relevant to this discussion. They are reviewed in the following section.

3. Overview of models of technology

Eight prominent journals were reviewed for research on the technology-performance relationship, since 1988. The journals included two in operations management, *Journal of Operations Management and Production and Operations Management*, two in MIS including *Management Information Systems Quarterly* and *Information Systems Research*, two in management, *Academy of Management Journal and the Organization Science*, and two cross-disciplinary, *Management Science* and *Decision Sciences*.[1] The 16 models that focused on technology deployment and its effectiveness provide a reasonable representation of the theoretical and empirical research on effective technology deployment.

A review of the models revealed three distinct levels of analysis: individual, process, and organizational. Table 1 provides a general summary of the models, which are discussed below in chronological order. A brief synopsis of these models is presented, along with proposed structures of the technology relationships within the firm, and general findings regarding these relationships. Figs. 2–16 present a depiction of the causal relationships. It should be noted that in some cases the model depictions represent our interpretations of how the models were proposed or tested.

3.1. Technology acceptance model

Introduced by Davis et al. [3] this model predicts individual attitudes and behavior (use) of software products. The primary focus of this model is on how perceptions of usefulness and ease of use of information technology affect the operator's intention to use it. The intention to use is proposed to be a significant indication of actual use (Fig. 2).

The underlying assumption of this model is that when technology is available but *not required* for use, its utilization is a measure of its perceived effectiveness. It is assumed that increased utilization is a desirable behavior and implies better performance. It is in Davis' study and subsequent studies on the model that perceived usefulness of the technology has been most important in predicting intent to use, with ease of use being secondary. It should be noted however, that the independent variables, ease of use and usefulness, are really perceptions by the user, and are also influenced by other contextual variables. These perceptions are dependent upon the attributes of the technology and the manner in which they are presented to the user, as well as the preconceived attitudes of the user, and their skills. This research started a considerable stream of empirical studies on the utilization of information technology, where utilization is by choice [4,5].

The generalizability of this research to all technologies must be tempered by the assumption that technology use is elective and performance measures are strictly based on utilization. But the model could also be useful in situations where technology use is mandated and certain features of the technology are underutilized. The major constructs of perceived usefulness and ease of use reflect the concept of technology fit with the context, which in turn predicts usage behavior.

3.2. Technological change model

This model depicts the implementation of new technology and measures its impact on performance objectives (shown in Fig. 3). The impact of technology is mediated by the method with which the firm handles the implementation, referred to as organizational response in the model [6]. The level of analysis is the technology-process, with emphasis on pervasive types of technology. The model predicts that certain technological attributes create uncertainty and organizations need to respond to this uncertainty before the benefits of the technology can be observed. The technology attributes examined included scale, sophistication, and systemic shift (shifts away from current norms and practices). Scale was defined as the size of the investment in technology (dollars) and was proven to be a significant measure of technological impact. Three organization responses were presented for aiding the implementation process: preparatory search, joint search, and functional overlap. These represented pre-installation organization changes, the use of outside experts and cross-functional teams, respectively. Results of the study indicated that the attributes of the technological change had a significant impact on the difficulties encountered in implementation. For instance, the higher the novelty of the change (systemic shift), the greater is the reliance on outside help for success. Performance was measured by the ability of the technology to meet its intended objectives. Implementation success was measured by the length of time for startup of the technology.

An important conclusion from this research was that different technological changes require different organizational responses in order to achieve operating benefits associated with the technology. This research reinforces the proposition regarding the fit between technology and organizational responses (individual roles and management processes) for enhanced performance.

[1] Other significant journals like the *Journal of Strategic Management*, *IEEE Transactions on Engineering Management*, the *Journal of MIS*, and *Omega* were also reviewed. While these journals contained empirical studies based upon some of the models described (secondary studies), we did not find any primary application at the time of conducting this research.

Table 1
An overview of the technology models

Model	Basic premise	Exogenous variables	Endogenous variables	Findings
Technology acceptance model, Davis et al. [3]	Perceived use and usefulness of technology impact the intention to use it.	Intention to use Percent of time using	Perceived usefulness Ease of use	Longitudinal study of 107 users, hierarchical regression analysis found perceived usefulness strongly predicted intentions to use. Ease of Use also a weaker predictor.
Technological change model, Tyre and Hauptman [6]	Technology-process change causes operating benefits, moderated by methods to reduce uncertainty.	Startup time Operating improvement compared to goals.	Project size Sophistication Systemic shift Organization response	Process change improvements in 48 plants, using regression showed technology change characteristics impact operating benefits. Improvements occur if use intervention to reduce uncertainty.
Independent effects model, Georganstaz and Shapiro [7]	Synchronize administrative and technology innovations for best impact on performance.	Overall performance	Production innovation Administrative innovation	Small sample showed this independent effects model to best explain impact on performance.
Impact of IT on productivity, Pinsonneault and Kraemer [8]	To examine how the acquisition of IT influences the number of middle managers and ultimate productivity of IT.	No. of middle managers	Centralization Decentralization	Examination of six previous studies plus a new case study found support for higher levels of decentralization improving the performance by reducing No. of managers.
IT productivity model, Kelley [9]	Information technology impact on performance of machining process will be moderated by experience, batch sizes, and labor policies.	Production hours Programming time Machine hours	Product type Technology Labor policies	Study of 584 machining plants found: Labor Management committees lower performance, advantages of programmable automation increase with experience, more efficient if workers help with programming, union plants more efficient.
Task-technology fit model, Goodhue and Thompson [4]	IT-task fit study of the impact on utilization and performance	Utilization Quality Efficiency Effectiveness	Task characteristics Technology characteristics	Results showed that task-technology fit impacted performance
FMC, infrastructure, performance model, Maffei and Meredith [10]	Exploration of the operational infrastructure required to benefit from the routine use of FMT	Quality Response Productivity Inventory On-time delivery Marketing	Operator conditions Operation infrastructure	Study of 6 cases for theory building: Human involvement in the monitoring, problem solving and prove-out improves quality, productivity and long-term responsiveness.
AMT, infrastructure, performance model, Boyer et al. [11]	Examines impact of AMT investment on performance depending on fit with infrastructural elements.	Growth Profit Flexibility	Training Autonomy Responsibility Communication	Empirical study of 202 plants found that infrastructural investments enhanced the relationship between AMTs and performance, while AMT employment alone does not.

Technology's impact on process output & quality model, Mukhopadhyay et al. [12]	Examines the impact of technology levels—manual, mechanical and automated on the output level, timeliness and quality of output.	Timeliness Quality Output level	Supervision level Absenteeism Level of automation	Empirical study of 36 mail processing centers showed a definite improvement in output levels with increased automation of technology. Also found more supervision and less absenteeism improves quality. Quality improvements also improved output levels.
AMT type-performance model, Swamidass and Kotha [13]	Examines the relationship between four types of AMTs, firm size and performance.	Profitability Growth	Business unit size AMT use & type—high volume, flexible, product design, information exchange	Empirical study of 110 manufacturing firms show product design use not influenced by firm size and no relationship between AMT use and performance, but size has strong influence on performance.
Performance impacts of AMT systems, Brandyberry et al. [14]	Study's AMTs impact on organizational processes.	Organization integration of production processes Market flexibility of production Administrative intensity	Usage of AMTs of three classes: Stand-alone Functionally oriented CIM	Found that organizations that move along the technology scale from stand alone toward CIM have more integrated production processes. Also found that market flexibility of the processes and administrative intensity do not change.
AMT adaptation performance model, Frohlich and Dixon [15]	Examines first and second generation AMT performance coupled with direct and indirect effects of process, human resource and information systems adaptation.	Cost Yield Productivity WIP turnover Product defects	Human resource adaptation Operational structure adaptation Technical adaptation IS adaptation	Findings indicate that IS adaptation was the most important for improved performance. HR and process adaptation linked to decreased performance. Overemphasis found on shop floor adaptation and under emphasis on IS adaptation.
Technology use and performance: a field study of Broker Workstations, Lucas and Spitler [16]	Extends the Technology Acceptance Model to include social norms and perceived system quality; looks at system performance.	Average monthly commission revenue Use Intended use	Perceived usefulness Ease of use Perceived quality Norms	Use was not found to be a significant predictor of commission revenues. Social norms and the design of the task important to performance results, while ease of use, perceived usefulness and intentions to use were weakly related if at all.
Effects of employee skills on AMT performance, Pagell et al. [17]	Examines how the skill level of employees impacts the successfulness of AMT use, both directly and when there is 'fit ' with the environment.	Level of goal achievement with respect to Quality Cost Delivery Flexibility Innovation	Level of training required Management discertion Product process change	No direct relationship between employee skills and AMT performance. But, 'fit' of employee skills with environmental characteristics yields significant relationship to AMT performance.

Table 1 (*continued*)

Model	Basic premise	Exogenous variables	Endogenous variables	Findings
Relationship between management practices and CAD, Malhotra et al. [2]	Examines how organizational structure, teams, training, & incentives moderate the influence of CAD on design performance	Level of goal achievement with respect to Quality Flexibility Overall Process Performance	Training Decentralization Formalization Team use Equity of incentives	Findings indicate CAD sophistication and functionality impact performance. The moderating impact of training also improved performance. The management levers were needed to influence performance of more sophisticated CAD systems, but not less sophisticated systems.
Process-technology fit & its impact on manufacturing performance, Das and Narasimhan [18]	Examines how the alignment of the process with technology impacts the performance of AMTs	Level of goal achievement & relative to competition with respect to Cost reduction Quality New product introduction time Delivery Customization	Decentralization Teams Task design Cross-training Process type-assembly line or job shop	The concept of the ideal profile or fit of technology with process design is supported in this fit research. It was found that human resource management practices help rigid process assembly lines become more flexible. The research also supports the use of traditional processes in the markets they were designed for, with firms rarely extending into other areas.

3.3. Independent effects model

The innovation area is one where some research has been done on the impact of technological change on the organization. Georgantzas and Shapiro [7] performed an empirical study on the impact of implementing administrative innovations (such as task designs, compensation schemes, work group empowerment) and technological innovations (such as robots, flexible manufacturing systems or any information technology use) on performance. In this research they tested many combinations of administrative and technology change relationships, recognizing that their ultimate effectiveness is related to their interdependencies. Moderating, intervening and interaction effects were all examined but the direct effects model shown in Fig. 4 had the most significant results. There was also some support for an interaction effects model that reflects the interdependence of changes to structure and procedures along with the technology.

Their most significant model showed that direct effects of administration and technology independently influence performance. While this finding does not fully capture the relationships in the MIT model, the moderate support for interaction effects is promising. Even though the sample is small and the research is exploratory, in general it supports the need for establishing the complementary role of organizational forces on technology effectiveness.

3.4. IT's impact on performance, impact on middle managers

This research looks at an organizational perspective on technology effectiveness, by studying the relationship between investments in Information Technology (IT) and their impact on the productivity of the firm as measured by the number of middle managers employed [8]. Existing IT research showed mixed results in this area, with eight studies showing decreases in the middle managers employed and nine studies showing increased employment. Interestingly, the additional case study supplied by the authors also reflected these contradictions, with IT investments having negative and positive impacts on the number of middle managers. However, further analysis supported the theory that it is the *fit* between investment in IT and the level of decentralization that is consistently related with reductions in the numbers of middle managers. Higher levels of centralization resulted in more middle managers. This study therefore also lends support to the importance of the relationship between structure and technology in influencing performance.

3.5. The impact of programmable automation on productivity

In this study by Maryellen Kelley [9], her proposed hypothesis is that information technology will enhance production efficiency in a specific manufacturing process.

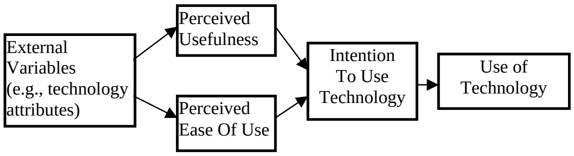

Fig. 2. Technology acceptance model. *Source*: Ref. [3].

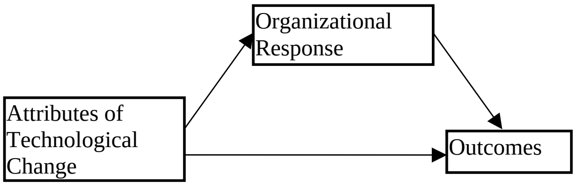

Fig. 3. Technological change model. *Source*: Ref. [6].

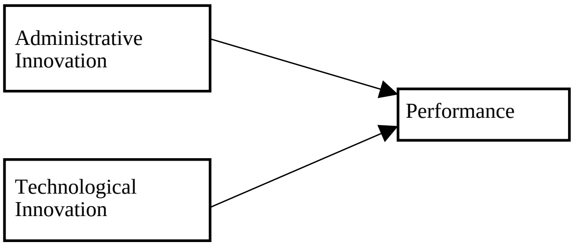

Fig. 4. Independent effects model. *Source*: Ref. [7].

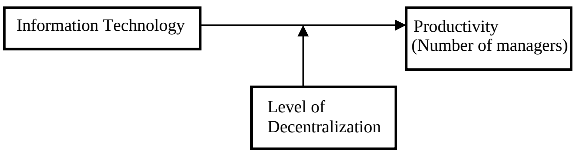

Fig. 5. Impact of IT on productivity. *Source*: Ref. [8].

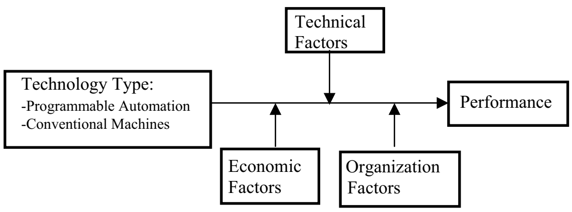

Fig. 6. Use of programmable automation and its impact on productivity. *Source*: Ref. [9].

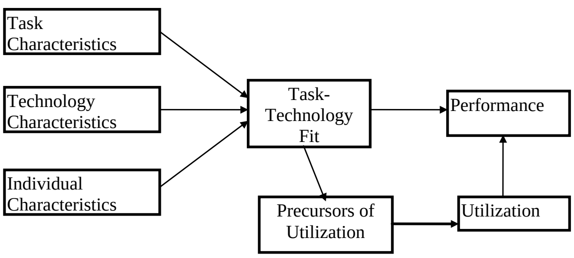

Fig. 7. Task-technology fit model. *Source*: Ref. [4].

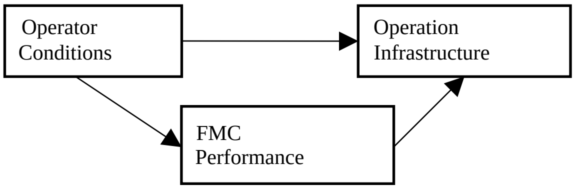

Fig. 8. FMCs impact on performance. *Source*: Ref. [10].

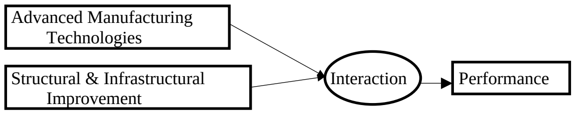

Fig. 9. AMTs impact on performance. *Source*: Ref. [11].

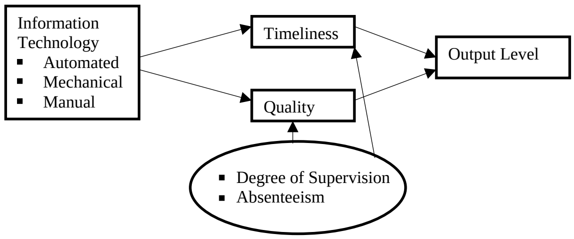

Fig. 10. Technology's impact on process output and quality. *Source*: Ref. [12].

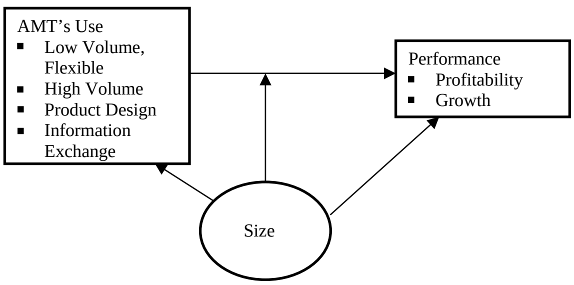

Fig. 11. AMTs type and size's impact on performance. *Source*: Ref. [13].

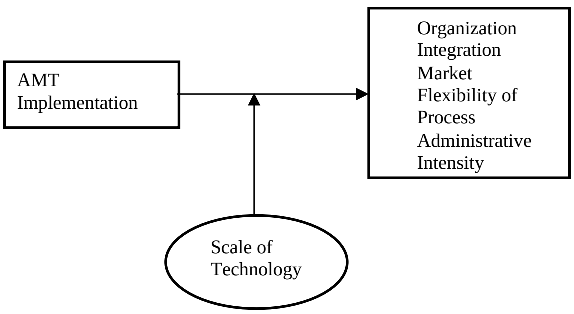

Fig. 12. Performance impacts of AMT systems. *Source*: Ref. [14].

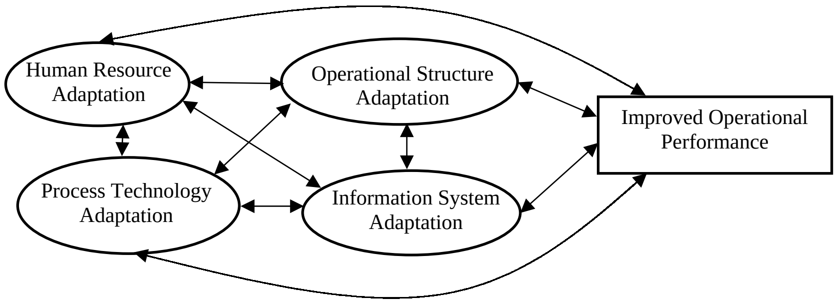

Fig. 13. AMTs, human resources & process adaptation. *Source*: Ref. [15].

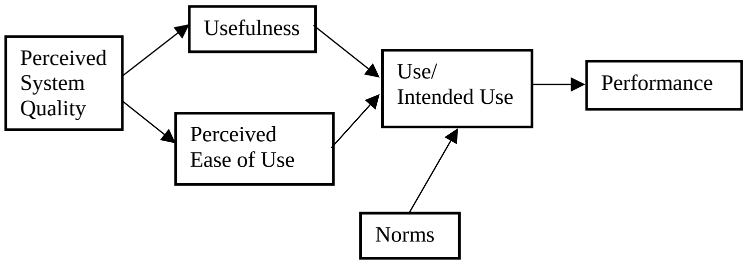

Fig. 14. Technology deployment and effectiveness. *Source*: Ref. [16].

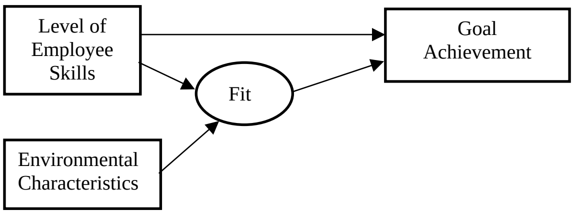

Fig. 15. Effects of employee skills on AMT performance. *Source*: Ref. [17].

Programmable automation (PA) is the technology studied, and is defined as machines controlled by computer software and electronic devices (often referred to as CNC machines). This extensive study considered the level of PA within a plant, as a percentage of metal-cutting machines and their impact on productivity. She presented three types of factors, technical, economic, and organizational, proposed to mediate the impact of PA on performance (see Fig. 6). Technical factors included the percentage of PA machines, the ratio of machines per worker and the percentage of new equipment. This gave an idea of the progressiveness of the facility. The economic factors represent the size of the firm in volume of output and number of employees, and the average batch sizes produced. The organizational factors include the average wage, which is used as a proxy for operator skill level, the amount of training provided on an ongoing basis, the presence of a union, level of decentralization and worker autonomy and whether labor-management committees are used. Her results provide support for less bureaucratic designs in firms employing more PA. Firms employing high levels of PA had greater efficiencies if these used more autonomy and decentralization. The use of teams, in particular the labor-management committees, seemed to perform poorly and these teams did not help with productivity.

This study also provides support for the proposition that technology is an important factor in deciding the type of structures and management processes employed. Older, more traditional technologies may require a different type of organization structure and management than newer, more computer-based technologies, thereby supporting both Propositions 1 and 2.

3.6. *Task-technology fit (TTF) model*

This model represents fit research in the information technology area that links technology to performance. The authors, Goodhue and Thompson [4] have acknowledged that the individual and the task must be matched with the technology to achieve the best performance results (see Fig. 7). This study was performed at the technology-process level, but focused on smaller technologies with impact on individual level processes. They also include utilization as a moderator of performance, recognizing that there can be no improvement if the technology is not used. It is not

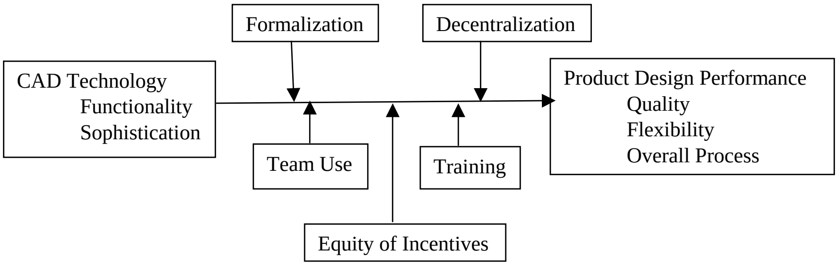

Fig. 16. Relationship between management practices and CAD. *Source*: Ref. [2].

a study of technology change and implementation but of technology use. The conclusions of this research imply that both utilization and task-technology fit impact performance, thus providing support for Proposition 2.

3.7. Flexible manufacturing cells impact on performance

This study provides an in depth case analysis of six firms utilizing flexible manufacturing cells (FMCs) [10]. Their proposal is that operational infrastructure must be designed to harness the potential benefits from this technology. The authors point out that there is little research on the type of organization infrastructure needed to fully exploit advanced manufacturing technologies. They also comment that the routine use of technology should be studied rather than just its adoption and implementation. This rigorous case study analysis yielded three models and corresponding propositions for further research were presented. The operator infrastructure model (shown in Fig. 8) is the relevant model for this review, as it deals with technology performance and organizational management to enhance it. This case analysis theorizes that the operator conditions influence FMC performance directly and dictate the operation infrastructure that will then also impact performance. They propose that these factors will impact the performance as measured by productivity, inventory levels, delivery reliability, and quality. Another finding proposes that upstream and downstream communication in manufacturing is an important contributor to better performance. The findings here suggest that both individual roles and management processes strongly influence the outcomes of the technology.

3.8. Effectiveness of AMT's, influence of manufacturing infrastructure

This study by Boyer et al. [11] does not use a specific technology, but rather has respondents indicate their level of usage of many available manufacturing technologies, referred to as advanced manufacturing technologies (AMTs). The importance of this study is that it is examining the direct influence of structural and infrastructural programs on performance in manufacturing firms, and their interactive effects with the level of AMT usage (see Fig. 9). The structural measures deal with the individual role of the worker, their autonomy in performing their task, and management's level of control and encouragement. Extensiveness of the use of training, teams, and communication are other exogenous variables that also influence the fit. These influences are measured collectively through the use of two constructs. The first, defined as soft integration, represents the use of linkage mechanisms to coordinate functional areas and 'worker empowerment'. A second construct measures the level of plant emphasis on programs such as training, team-building, role expansion and autonomy. The results show that firms that adopt AMTs and invest in soft integration and worker empowerment have better performance than firms who invest solely in the technology. The correlations between technology growth and flexibility performance measures, when not considering context were insignificant. But the influences of these individual role changes and management processes interacted significantly with technology for significant improvements in performance. Although individual effects of various management levers are not specifically examined, the data supports the proposition that the fit of individual roles and management processes with technology influences the relationship between technology and performance.

3.9. Technology's impact on process output model

This research by Mukhopadhyay et al. [12], studies the use of three types of mail sorting technology, automated, mechanical and the alternative, manually sorting, for their influences on the output levels, quality and timeliness of the sorting process (see Fig. 10). It is a process level study performed on 46 mail processing centers over a three year time period. The influences of the level of supervision, and the disruptive impact of absenteeism were also examined. The findings reflect that higher levels of technology, moving from manual to mechanical to automated significantly improve the output level (volume of mail sorted) of the process. Production functions were designed for precise prediction of the influences of technology. Higher quality output was not a deterrent to output volumes, with better technology leading to higher quality output and higher output levels. Increased absenteeism was found to decrease both quality and output level, while increased supervision improved quality. This research therefore also provides support for the notion of fit between individual roles and technology.

3.10. Manufacturing technology use, size and performance

The empirical study by Swamidass and Kotha [13], examined advanced manufacturing technology (AMT) use, their interaction with firm size, and the impact on firm performance (see Fig. 11). This study of 160 manufacturing firms resulted in a classification of four types of AMTs—low volume flexible technologies, high volume manufacturing technologies, product design technologies, and information exchange technologies. The examination of their interrelationship with firm size showed that as firm size increases logarithmically, the use of three of the four types of AMTs increased linearly (product design excluded). In this organization level research, it was found that technology use for each of the four types was not a predictor of improved firm performance, but that with size as a moderator, larger firms seemed to use technology more effectively. The basic premise that technology adoption alone is not a means of improving performance is supported by these findings. If it can be presumed that size represents changing organizational structures and processes, then the study suggests that these factors interact with technology for improved performance.

3.11. Performance impacts of AMT systems

This research by Brandyberry et al. [14] makes a unique contribution to AMT research by classifying all AMTs into one of three groups; stand-alone technology such as CNC machines, functionally oriented technologies such as FMSs, or fully integrated CIM systems. The performance variables measure the level of integration of the production process with the organization, the resulting market flexibility, and the administrative intensity (ratio of number of employees per manager) that evolves as a result of the technology. The model tested is shown in Fig. 12. The findings suggest that different performance results occur with each of the three technology configurations. For instance, firms with fully integrated CIM systems did not achieve increased flexibility, in comparison with firms with functionally integrated systems. It appears that CIM constrains flexibility to some extent through requiring organizational integration. No significant impact to flexibility was found by implementing stand-alone systems either, indicating that one technology alone will not improve process flexibility. No significance was found for the relationship between administrative intensity and technology type, indicating technology adoption had no influence on supervisory levels. The integration of the technology with the organization is shown to increase with technology level, providing support for the notion that a firm achieves competitive advantage by adapting processes and people to technology. This research provides additional support for the integration issues proposed in Proposition 2.

3.12. AMT, human resources, process adaptation and performance

In contrast to more general technology research, the research by Frohlich and Dixon [15] focuses on a specific AMT, surface mount technology (SMT), for applying integrated circuits to boards, and examines the ‘fit’ of the SMT technology with human resources, information systems, and operations structure. The findings of this research strongly suggest that ‘fit’ of technology with other aspects of the process are key to its success (refer to Fig. 13). The strongest influence on performance for SMTs was the fit with the information systems of the firm. Surprisingly, Human Resource adaptation had a negative impact on performance. This (as suggested by Frohlich and Dixon [15]) is indicative of the fact that skilled workers do not adapt well to advanced technologies, and that automation calls for elimination of skilled jobs rather than adaptation by the workers. There was also a negative influence of process adaptation, suggesting that if the technology does not ‘fit’ the process needs, attempts to make it fit with process change will not be successful. These findings, while not generalizable to all technologies, provide strong support for the ‘fit’ concept proposed in Proposition 2.

3.13. Technology deployment and effectiveness

This research by Lucas and Spitler [16] was a field study of predicted use of broker workstations in a field setting using an extension of the technology acceptance model presented by Davis et al. [3]. The expanded model is shown in Fig. 14. This model uses social norms and perceived systems quality as precursors to intended system use, and ultimately performance of the broker workstation. The model is tested among groups with different job profiles. Limited support was found for the technology effectiveness model, but social norms and the design of the job tasks themselves were more important in predicting technology use than user perceptions. This research therefore, reinforces the importance of task design in examining the link between revolutionary technology and performance.

3.14. Effects of employee skills on AMT performance

This study by Pagell et al. [17] is a rigorous field study of human resource decisions and their impact on AMT performance. The ‘fit’ between employee skills and their work environment, as depicted in Fig. 15 is examined in the study to determine the impact directly, and when considering

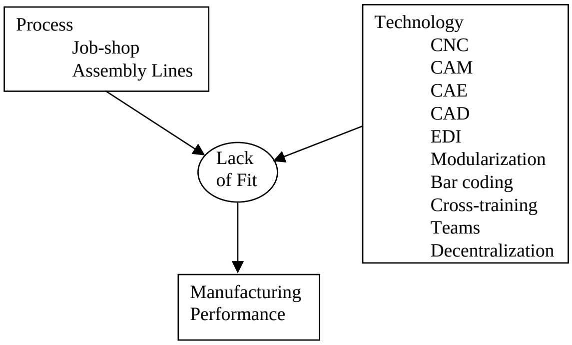

Fig. 17. Process-technology fit, implications for performance. *Source*: Ref. [18].

fit, on the performance of the AMT. When 'fit' was not considered, employee skills did not influence the performance of the AMT. When employee skills were fit to the skills needed, and fit to the complexity of the process, there was a significant improvement in performance. So general skill level increases did not influence performance, but their match with the technology demands did. These results, while being very preliminary, provide more support for the notion of fit.

3.15. The relationship between management practices and CAD

This study, by Malhotra et al. [2] examines the moderating influence of five management levers on computer-aided-design (CAD) technology performance (see Fig. 16). The CAD technology was defined in terms of its level of sophistication and number of functions. This empirical study found that while the level of functionality and sophistication of the CAD technology influenced product design performance, results were mixed with respect to the moderating variables. Training improved performance, but the use of formalization and teams was only helpful for more sophisticated technology.

3.16. Process-technology fit and manufacturing performance

Fit is addressed in this study where the type of manufacturing process is proposed to be more effective if the technology employed fits the process (see Fig. 17). In this study by Das and Narasimhan [18], AMTs are defined as multi-dimensional including manufacturing technology, human resource management, manufacturing design and manufacturing infrastructure. The study compares combinations of these items by ideal expected profile types. This research allowed for examination of the product process matrix. The findings indicate that firms are using advanced manufacturing technologies to effectively support off-diagonal positions. This research supports profile descriptions of best-in-class technology performers and the influence of human resources and organization structure to adapting physical technology to the process needs.

4. Categorization of the models

The focus in the following discourse will be to compare and contrast the models with respect to several important issues. Table 2 summarizes the scope of the model definitions and their empirical validity.

The level of analysis for the examination of technology can encompass individuals, processes or groups, or the entire organization. As shown in Table 2, there were five organization level studies [6,8,11,13,14]. In general, these studies had weaker results for the impact of technology on performance. Since technology needs to be defined widely in these studies for its impact to be discerned by corporate performance measures, the significance of specific types of technology, as well as the means of managing it, cannot be easily evaluated. Brandyberry et al. [14] contribution divided AMTs into groups, providing more insight into technology integration issues. But, there are many other organizational influences that will dilute the findings in studies at this level.

The eight process level studies shown in Table 2, generally speaking, showed a significant performance impact due to technology used. Since technology is applied to a specific process, it can be evaluated with regard to the group of people involved in the process, and the process outcomes. The significance of findings here demonstrated the importance of this level of analysis for examination of the relationships between structure, management processes, individual roles, and technology. Two individual level studies were also included in this review examining how the performance of each person is impacted within the process group.

The technology definitions used by authors varied significantly, from examining the impact of *a specific technology* [2,9,10,15–17], to a more general examination of technology involving not just equipment, but also people and processes [6,7,18]. It is, of course, of primary interest to acquirers of technology, to learn how the technology will impact the performance of the people and process, and ultimately, the firm. There were instances where cross-sectional subjective evaluations of performance were used, as well as more unbiased, objective measures such as production rates and time.

The three individual level studies [3,4,16], contributed to the understanding of the technology-performance relationship in a simpler setting. The findings of these three studies also provided support for fit between the user and the technology. Overall, the studies at all levels provided general support for the concept of 'fit'.

Table 2
Review of model applicability

Model	Level of analysis	Technology applicability	Performance measures	Construct validity	Empirical validity	MIT model relationships studied
Davis et al. [3]	Individual	Medium—information technology	Subjective Objective	Validated Subjective Cr alpha=0.91–0.97	Mediated regression $p < 0.001$ $N = 107$	C
Tyre and Hauptman [6]	Organization	Wide—any size & complexity	Subjective Objective	Subjective Newly validated Cr alpha 0.67–0.90	Mediated & moderated regression $p < 0.01$ $N = 8$	B,C
Pinsonneault and Kraemer [8]	Organization	Medium—information technology	Objective	Subjective Semi-structured interviews	None-cases	B
Georganstaz and Shapiro [7]	Process	Wide—any devices, systems & procedures	Subjective	Subjective Validated Cr alpha 0.52–0.97	Regression-moderated, mediated & direct effects $p < 0.0001$ $N = 35$	A, B
Kelley [9]	Process	Narrow—programmable automation	Objective	Objective	Moderated regression $p < 0.001$ $N = 1612$	A, B, C
Goodhue and Thompson [4]	Individual	Medium—25 IT applications	Subjective Objective	Subjective Validated Cr alpha's 0.6–0.88	Mediating fit regression most areas $p < 0.001$ $N = 662$	C
Maffei and Meredith [10]	Process	Narrow—flexible manufacturing systems	Subjective Objective	Conceptual Starting construct development	None-theory building, 6 cases	B, C
Boyer et al. [11]	Organization	Wide—any advanced manufacturing technology	Objective	Subjective Validated	Mediating regression p values < 0.05 and 0.01 $N = 202$	B, C
Mukhopadhyay et al. [12]	Process	Narrow—mail sorting equipment	Objective	Objective	Production function $p < 0.01$ $N = 46$	C
Swamidass and Kotha [13]	Organization-SBU	Wide-AMTs—high volume, flexible, product design, information exchange	Objective	Objective Validated Factor analyzed	Moderated regression $p < 0.05$ and 0.001 $N = 110$	A

Brandyberry et al. [14]	Organization	Wide-AMT's	Subjective	Validated Factor analyzed	Bivariate regression MANOVA $p < 0.05$ $N = 92$	A, B
Frohlich and Dixon [15]	Process	Narrow—surface mount technology	Objective	Objective Validated Factor analyzed	Regression Factor analysis $p < 0.1$–0.001 $N = 104$	A, B, C
Lucas and Spitler [16]	Individual	Narrow—broker workstations	Objective Subjective	Validated Factor analyzed	Regression $p < 0.10$–0.01 $N = 107$	B, C
Pagell et al. [17]	Process-AMT	Narrow—FMS & CNC	Subjective	Structured interviews Multiple respondents Validated measures	Regression $N = 30$	C
Malhotra et al. [2]	Process	Narrow-CAD	Subjective	Validated Factor analyzed	Regression $N = 143$	A, B, C
Das and Narasimhan [18]	Process-job shop and assembly lines	Wide—manufacturing technologies	Subjective	Validated Factor analyzed	Regression $N = 322$	A, B, C

5. Research comparison to the MIT framework

This research provides significant support for the proposed framework presented by Scott-Morton. As stated in Proposition 1, there are certain conditions of structure, process and people that enhance technology performance (labeled as A, B and C in Fig. 1). The constructs present in this empirical research fall under Scott-Morton's definitions of Structure, Management Processes, and Individual Roles. According to Scott-Morton, *Structure* deals with the organizational forms and ways of working that will need to be adjusted for technology. Types of organization structures such as organic and bureaucratic, as well as the organization's levels of formalization and centralization represent this concept. *Management Processes* represent the firm's method of planning and control. This parameter includes supervisory power and the empowerment that employees gain with more knowledge and control of their workplace. Constructs such as supervisory levels and types, communication levels, the use of cross-functional teams, performance evaluations and compensation methods, all fall under the management processes realm. The *Individual and Roles* are defined by the influences on individual employees in their work environment. Constructs such as training, information access, autonomy, responsibility, task characteristics, and job predictability define the individual and their work roles.

The areas in the MIT framework that are addressed in each of the studies with regard to these three interrelationships with technology are shown in the last column of Table 2. It can be observed that all three of the interrelationships have been equally represented in this body of research, indicating that the need for studying the influences of technology and structure, roles, and management processes has been recognized. This research provides support for Proposition 1. There were significant findings in every study on the influences of various structural and management variables with respect to enhancing the performance of technology. The evidence of 'fit' between the variables as proposed in Proposition 2 also found limited support in the research. The model tested by Goodhue and Thompson [4] proposed a level of fit between technology and its management. The research by Boyer et al. [11] also support the 'fit' notion because of the significant interaction effects between the exogenous variables. The study by Georganstaz and Shapiro [7] also found one interaction model to be significant. The Das and Narasimhan study [18] examined fit more specifically with ideal profiles of combinations of management and technology types. The study by Pagell et al. [17] defines a fit variable and examines it empirically, further confirming the trend towards more rigorous examination of fit between technology and other variables. This stream of work will help us to understand what levels of the structure, individual roles, and management process variables enhance different levels and types of technologies. In the next section, we will discuss the insights gained from this research and from the study of these models.

6. Important insights from the technology models research

The technology models presented here are representative of the major work on technology effectiveness. Providing a synopsis of this research within the context of a broader framework alerts us to areas of further research and possible gaps in the current technology research. While not all gaps are necessarily in need of being filled, summarizing research allows us to determine where further efforts should be focused in order to advance knowledge. In reviewing these models, there are several inconsistencies that suggest a need for further research. Five major insights from this research that are in need of further examination are presented here:

1. *There are very few fit models in technology research.* Of the models presented here, only four specifically and directly address the concept of 'fit' between technology and the other dimensions [4,7,17,18]. Most models address technology's role in terms of moderating or mediating relationships. Fit is important because the premise of fit is that certain levels of each variable give the best match to specific levels of the other. For instance, the level of training, not just a yes—no dichotomization of training, must be fit with the technology attribute. A fully automated technology may require some training, but not at the levels required by a technology with less automation and more functionality. Matching the best level for the management levers with the technology attributes will yield the most effective process. This supports the need for more extensive research on the 'fit' notion specifically.

2. *The combining of all business technologies into one group dilutes the impact of individual management techniques.* Advanced manufacturing technologies (AMTs), flexible automation, factory automation and flexible manufacturing automation are terms that have been used for studying manufacturing technology groups [10,11,13,18,19] among others. There have been primarily inconsistent findings on the influences of these groups on performance. The research by Boyer et al. [11] examined the influence of AMTs as a whole, finding insignificant results for many relationships, while Swamidass and Kotha [13] took the same AMT group and further refined the definition into four categories, noting differences in findings between groups. This lends support to the premise that grouping technologies together masks their impact on performance and does not allow their individual attributes (which may differ considerably) to be examined properly. This is recognized and supported by the research by Brandyberry et al. [14] and Malhotra et al. [2]. An important contribution to technology research would be to identify categories and attributes of technologies that tend to have similar impacts on performance under different management styles.

3. *Results are not comparable since studies lack external validity.* Generalizability of results is often limited since studies either lump all technologies together or only look at a specific technology. Intrafirm studies or industry specific studies and case study formats are common. But, how can the management of these specific technologies be compared and conclusions drawn about general technology types [2,9,10,12,15,17]? Research that focuses on technologies represented by specific attributes, would allow comparisons across technologies, and allow researchers to determine management techniques that are most effective for certain technology attributes.

4. *Process level research needs a framework for organizing and understanding findings.* Process level research is very often focused on a specific technology and results cannot be used cumulatively to make conclusions about technology management in general. The results of Kelley's study of programmable automation show that the use of teams is not always effective in enhancing performance. On the other hand, team use in the Georganstaz and Shapiro [7] research on innovative technology was shown to be effective. The premise was presented by Maffei and Meredith [10] that more human involvement and less management intervention is better with increased technology. The opposite was found with the examination of mail sorting technology, where increased supervision improved performance [12]. Pagell et al. [17] found administrative intensity was not a significant factor influencing performance for manufacturing FMS and CNC technologies. Malhotra et al. [2] had similar findings where only sophisticated CAD technology was impacted by management levers. Again, in order to be able to compare process level technology research, frameworks describing the attributes of technologies should be developed to compare across technologies, so that, the relevance of various interventions can be properly determined.

5. *Construct definitions are inconsistent and therefore not comparable*. Researchers in the use of technology use a variety of definitions for variables. Technology itself is defined in many ways, from tangible equipment itself [2,20], to a combination of people, processes and material [6,7,18]. Administrative innovation, labor policies and adaptive management represent classifications of groups of management styles that differ between researchers. Similarly, there is a lack of uniformity with respect to performance measurement constructs. Performance measures at the process level may include productivity, quality, utilization, throughput time, delivery speed, as well as many others. Organization level research measures performance with a variety of measures for profit, sales growth, return on investment, and so on. There appears to be no set standards for construct measurement in technology research, leading to difficulties in building upon the work of others. This calls for a paradigm of the technological system to be defined, thereby allowing researchers to position their work according to its location along the technological system continuum [14].

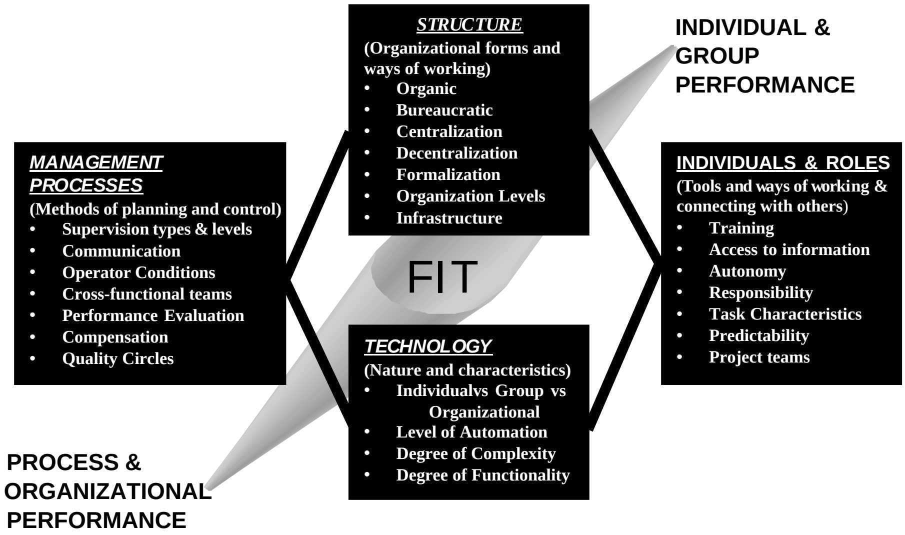

Fig. 18. General model of technology and performance.

7. Recommendations

Recommendations for further research to build upon our findings involve three steps.

- A general framework of technology and its context must be fully defined using current theory. Using the MIT framework as a model, the paradigm could include four dimensions: the technology itself as defined by certain attributes (e.g., level of use, level of automation, complexity), the individual and their roles as defined by their way of working and connecting with others (e.g., training, information access, autonomy, task), the structure of the organization as it relates to the technological processes (e.g., organic, formalization), and the management processes that facilitate planning and control (e.g., supervision, compensation, cross-functional teams). An illustrative model is depicted in Fig. 18. We would hasten to add that this model is illustrative only and draws its variables mainly from the studies reviewed. As such, it needs to be fleshed out in greater detail and better grounded in theory.
- The four dimensions of the proposed paradigm will need to be examined empirically, through interviews and case study work that allows exploration of new concepts. Once these dimensions are developed more fully and accurately defined, measurement instruments for the dimension attributes will need to be developed and validated through field-testing.
- The notion of fit between the dimensions across numerous technologies and contexts can then be examined in a consistent and cumulative manner.

The culmination of this stream of research would be to further a theory of technology management that would be valuable to practitioners and academics alike.

8. Conclusions

Technology effectiveness is critical in contemporary environments that promote increasing deployment of technological initiatives. Unfortunately, mere existence of technology is not sufficient. It has to be imbibed into its contingent context in order to be effective. While there has been substantial research on technology effectiveness, it has not been reviewed in a single article. This article takes the modest step of presenting a synopsis of technological effectiveness research that has been published in major journals associated with the management sciences. This research is interpreted in light of a broad MIT based framework that espouses notions of "fit" between various organizational entities. Sixteen models are reviewed and it is argued that these models provide a foundation upon which further technology research can be positioned. In general, there seems to be support for the validity of the interactions between structure, management processes, individuals, and technology. Therefore, it is apparent from this review that technology is not and cannot be implemented independent of its environment.

There was a major amount of support for the interrelationships presented in the MIT model, providing strong validation for it as presented in Proposition 1. The findings consistently support management, task design, and structure as important parameters for technology performance. However, while the 'fit' notion is also partially supported, the limitations in the conduct of this research make it difficult to compare the models and their empirical results. Therefore, Proposition 2 needs more extensive empirical examination through a general technology paradigm.

A framework for examining technology in its context will lead to better theory building that can allow us to examine results across technologies. For instance, a researcher studying the influence of cross-functional teams on flexible manufacturing cells may find that these teams are helpful in improving the quality of the cell output. How would this apply to a manufacturing setting involving assembly line rather than cells? Placement of both technologies regarding their context could enable researchers to make generalizations about management techniques across technologies. The use of fit models for exploring the balancing of the various management levers with the technology will then allow researchers to develop a 'theory of managing technology'. The research summarized here has created a foundation for such a theory. We believe that the field will better progress with development of such a paradigm for technology management, and empirical examination of many technologies and their level of 'fit' with their context will further advance research in this realm.

References

[1] Scott-Morton M. The corporation of the 1990's, information technology and organizational transformation. New York: Oxford University Press, 1991.
[2] Malhotra MK, Heine ML, Grover V. An evaluation of the relationship between management practices and computer aided design technology. Journal of Operations Management 2001;19:307–33.
[3] Davis F, Bagozzi R, Warshaw P. User acceptance of computer technology: a comparison of two theoretical models. Management Science 1989;35(8):982–1003.
[4] Goodhue D, Thompson R. Task-technology fit and individual performance. Management Information Systems Quarterly 1995;19(2):214–36.
[5] Taylor S, Todd PA. Understanding information technology usage: a test of competing models. Information Systems Research 1995;6(2):144–76.
[6] Tyre M, Hauptman O. Effectiveness of organizational responses to technological change in the production process. Organization Science 1992;3(3):301–20.
[7] Georgantzas N, Shapiro HJ. Viable forms of synchronous production innovation. Journal of Operations Management 1993;11:161–83.
[8] Pinsonneault A, Kraemer KL. The impact of information technology on middle managers. Management Information Systems Quarterly 1993;17:271–92.
[9] Kelley M. Productivity and information technology: the elusive connection. Management Science 1994;40(4):1406–25.
[10] Maffei MJ, Meredith J. Infrastructure and flexible manufacturing technology: theory development. Journal of Operations management 1995;13:273–98.
[11] Boyer K, Leong K, Ward P, Krajewski L. Unlocking the potential of advanced manufacturing technologies. Journal of Operations Management 1997;15:331–47.
[12] Mukhopadhyay T, Rajiv S, Srinivasan K. Information technology impact on process output and quality. Management Science 1997;43(12):1645–59.
[13] Swamidass PM, Kotha S. Explaining manufacturing technology use, firm size and performance using a multidimensional view of technology. Journal of Operations Management 1998;17:23–37.
[14] Brandyberry A, Rai A, White GP. Intermediate performance impacts of advanced manufacturing technology systems: an empirical investigation. Decision Sciences 1999;30(4):993–1020.
[15] Frohlich MT, Dixon JR. Information systems adptation and the successful implementation of advanced manufacturing technologies. Decision Sciences 1999;30(4):921–57.
[16] Lucas HC, Spitler VK. Technology use and performance: a field study of Broker Workstations. Decision Sciences 1999;30(2):291–311.
[17] Pagell M, Handfield RB, Barber AE. Effects of operational employee skills on advanced manufacturing technology performance. Production and Operations Management 2000;19(3):222–38.
[18] Das A, Naramsimhan R. Process-technology fit and its implications for manufacturing performance. Journal of Operations Management 2001;19:521–40.
[19] Pathasarthy R, Sethi S. The impact of flexible automation on business strategy and organization structure. Academy of Management Review 1992;17(1):86–111.
[20] Orlikowski W. The duality of technology: rethinking the concept of technology in organizations. Organization Science 1992;3(3):398–427.