The effect of social factors on the implementation of automation: an empirical study in Taiwan

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Abstract
In a highly competitive global economy, automation has been an important approach to improve productivity, quality, and customer satisfaction. The literature reveals that when introducing automation systems, social influences are usually neglected. This study cross-organizationally examines the impact of social factors on the success of automation. We analyzed data obtained from the questionnaires of 105 companies and supplementary interviews of six firms in Taiwan. Statistical analyses show that a greater extent of automation tends to be accompanied by a higher level of social activities; companies with matching social and technical stages are not necessarily more successful in automation; social factors significantly predict the degree of success of automation. In addition, we observed that technically related improvements are of greater concern in the interviewed companies. Furthermore, support from employees, a competent project leader, and a proper alignment between technical and social factors are highly valued for the implementation of automation. Some managerial implications are also discussed.

Keywords: Automation; Sociotechnical system; Taiwan

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1. Introduction

Growing competition in the market place has exerted a strong pressure on firms to adopt various approaches to retain their competitiveness. The application of automation is perhaps one of the most prevalent methods employed to enhance a firm's productivity. For example, the installation of computerized production facilities, material handling equipment, and automatic storage and retrieval systems typifies the practices of factory automation. Management believes that these types of equipment will reduce lead time, in-process inventory, and space requirements, and improve quality control and productivity. Similarly, automation in service systems is supplied by information technologies such as electric data interchange, electric fund transfer, and the like. The benefits of automation may result in improved quality, efficiency, and flexibility.

The effective implementation of automation has been widely discussed and documented. Unfortunately, the failure rate of automation is surprisingly high. Statistics show that an estimated 50–75% of programs involving advanced manufacturing technologies in the US fail to realize their planned goals (Majchrzak, 1988, p. 11.) Many scholars have investigated the factors that influence the success or failure of automation. A common contention is that social factors should not be ignored in the implementation of automation programs. For example, Majchrzak (1988) commented that the primary cause of failure is due to human factors rather than to any deficiencies of any particular technologies. Larsen et al. (1991) advocated that it is crucial to contemplate automation programs from both social and technical perspectives, i.e., from the sociotechnical system (STS) approach.

The STS approach has a history dating back approximately 40 years to the early work of Trist and Emery at the Tavistock Institute in London (Fox, 1990; Pasmore, 1992). Their first application of STS theory involved the coal-mining industry in England. The use of self-managed work teams in the coal-mining industry improved both the performance and morale of the miners. Since most STS interventions have been associated with the development of high-performance organizational systems, and have been marked by improved employee morale and quality of working life (Kiggundu, 1986), STS has been widely discussed and studied in manufacturing and service settings. Among others, Susman and Chase (1986) advocated that it is crucial to manage the automation of factories from both social and technical perspectives and Taylor (1986) examined a case of organizational change and concluded that STS analysis is also appropriate for white-collar service settings. With the advancement of new technologies and a rapidly changing environment, the interaction between technical and social systems becomes more and more complex. STS theorists propose that effective organizations are those which can achieve the ‘joint optimization’ of these two interdependent systems (Purser, 1992).

However, Maton (1988) pointed out that despite its clear attraction for both workers and managers as a humane way to increase efficiency, acceptance of STS in firms has been quite limited. He argued that this is mainly due to the conflict between the requirements of technological efficiency and the needs of workers. Therefore, an investigation of the compatibility between social and technical systems is helpful for the successful implementation of STS. Furthermore, although it has been deemed that the STS approach may facilitate the success of a given automation program, research has provided little empirical evidence concerning the effectiveness of STS (Shani and Elliott, 1989). Klein and Sorra (1996) reported a similar observation. Examining the effective implementation of innovation, they noted that although cross-organizational studies of the determinants of innovation adoption are abundant, cross-organizational studies of innovation implementation are extremely rare. Common empirical literature on the implementation of workplace innovations is dominated by single-site qualitative case studies. As a result, a cross-organizational examination of the effects of social factors may provide valuable information to enrich the STS theory.

The objective of this empirical study is to cross-organizationally investigate the effects of social factors on the implementation of automation. In so doing, we attempt to answer the following questions: (1) Do the relationships between the social and technical systems exert any effect on the success of automation? (2) Do managerial practices exert any effect on the success of automation? (3) Does a company’s characteristics influence the success of automation? In what follows, firstly, we review the relevant literature and propose three hypotheses to address our research questions. Secondly, we describe the research method. Thirdly, research results were presented. Finally, we conclude this paper with the discussions of our major observations, managerial implications, and suggestions for future research.

2. Related literature and research hypotheses

In examining the implementation of automation, we mainly adopted the concept of STS theory, which advocates the joint consideration of social and technical factors when introducing new technologies into an organization. The theory explicitly considers organizations as consisting of two interdependent systems: a technical system and a social system. The technical system focuses on equipment and processes, while the social system emphasizes people and relationships (Shani et al., 1992).

2.1. The technical system

The technical system of an organization consists of the tools, techniques, devices, artifacts, methods, configurations, procedures and special knowledge used by organizational members to acquire input and to transform input into output (Persico and McLean, 1994). The extent of automation of a given technical system is crucial to the productivity of an organization. A typical quantitative measure of the extent of automation is the percentage of automated equipment among the total number of machine tools (Nieva et al., 1982). A larger percentage indicates a higher extent of automation. The extent of an automated system can also be described qualitatively. Wall et al. (1987, p. 6) noted that the advanced manufacturing technology has evolved from the automation of individual machine tools, through integration among these machine tools, towards much higher level of integration involving large-scale monitoring and controlling systems(e.g., flexible manufacturing system(FMS) , computer-integrated manufacturing(CIM)). In the same vein, Cohen and Apte(1997, p. 20) proposed a hierarchical pyramid approach to CIM planning as described below:

> At the bottom level, the firm must select individual machines and processes. The next highest level combines these pieces of equipment into automated workstations. Workstations, in turn, can be combined to form functionally oriented cells. Such cells require a high degree of coordination among multiple stations. Managerial issues concerning production scheduling and factor information management are prominent at the next level, which consists of groups of cells

organized into divisions or departments. Finally, at the peak of the pyramid, we have factory level view of the automated enterprise.

1 ‘‘Success’’ is a generic term in this context. It refers to the completion of an automation project on time and within the budget. It may also suggest that the performance of an automated system meets the expected standards and is accepted by the individuals concerned.

Based on the degree of complexity of technology, Lawrence(1984)proposed that there is a four-tier classification of automation for production processors. Similarly, Meredith and Hill(1987)proposed that an operations system could be classified into the following four levels to determine the extent of integration of automatic equipment: (1) stand-alone, e.g., independent machine tools; (2) cells, e.g., FMS; (3) linked islands, e.g., material requirement planning II(MRPII)and computer-aided design/computer-aided manufacturing(CAD/CAM); and (4) full integration, e.g., CIM. We noted that this classification, although being oriented to manufacturing systems, is also applicable to service systems. For example, stand-alone equipment may indicate word processors or printers that are running independently, linked islands may indicate point-of-sales system, which links inventory and sales systems. Given the nature of this classification, we note that stand-alone automatic equipment may have a local impact and leave the structure of the technical system largely intact. On the other end, the introduction of fully integrated automatic equipment may involve a complete transformation of the technical structure. The classification is helpful in investigating the effects of automation on the organization and will be used in this study.

2.2. The social system

The social system of an organization comprises ‘‘the individuals who work in the organization and the total of their individual and social attributes’’ (Shani et al., 1992). Specifically, a social system encompasses individuals’ characteristics and relationships within and between groups. Individuals’ characteristics are related to employees’ aptitudes, skills, education, attitudes and beliefs. Relationships include lateral and vertical relationships between supervisors and subordinates.

Gerwin and Kolodny(1992, p. 157)noted that ‘‘Early STS implementation concentrated on the shop floor work organization areas. Design issues have become more dominant in recent years as organizational issues have moved up and out from the shop floor units to encompass managerial and support areas and customers and suppliers’’. Shani et al.(1992)reported that ‘‘STS analysis emphasized the merits of multi-skill requirements, autonomous work groups, group-based reward systems, minimal critical specifications, increased interactions with customers, self-inspection of quality, information-sharing mechanisms, performance feedback loops, pay for knowledge, flexible response, and parallel learning structures.’’

The foregoing description suggests that the effective management of people and people’s relationships are crucial for the successful implementation of STS organizational redesign. In addition, the application of STS analysis to organizational redesign involves the employment of process technologies. In the light of these clarifications and within the context of organizational redesign due to technological change, we would define a social system to include such items as skill requirements, job assignments, task design, structure, work integration, information flow, decision-making processes, and reward systems. It should be noted that all these items are categorized by Shani et al. (1992) as both social system and work design. These eight items serve as the basis to investigate the effect of social factors on the success of automation. In a study of advanced manufacturing systems, Shani et al.(1992)described four stages of these eight items. Comparable to the four levels of automation in the technical system described above, the classification of social stage suggested by Shani et al. is mainly based on the degree of complexity and flexibility of the relevant factors. For example, multiple-skills requirements and flexible job assignments characterized the highest social stage, while the lowest stage for work design involves a mechanistic structure and individual-based rewards. In this work, the four-stage classification will serve as a vehicle to identify the characteristics of a social system.

2.3. Hypotheses

In line with the idea of stages for automated systems, Grant et al.(1991)argued that, for most established firms, an incremental approach will more successfully deliver the promises of a new technology. Persico and McLean (1994) noted that how well the social and technical systems are designed with respect to one another determines to a large extent how effective the organization will be. We mentioned earlier that a higher stage of a technical system utilized by a company represents a greater extent of integration. A highly integrated factory may require a flexible application of a wide range of engineering and programming skills. As a consequence, a higher extent of integration may be conducive to broader and less specific job assignments. Shani et al. (1992) argued that a higher extent of automation (higher stage of technical system) required a more complex mix of skills (higher stage of social system)because tasks tend to become non-routine. A similar prediction may be applied to structure, information, and the like. Furthermore, STS theory holds that a high-performing system results from finding, through comprehensive analysis and design, the 'best match' or most mutually enhancing 'fit' between the technical and social systems of an organization (Mohr, 1989; Shani et al., 1992). We therefore come to the following hypotheses.

H1a. The greater the extent of automation is, the more developed the social system is likely to be.
H1b. Those companies that have matching social and technical stages are more likely to be successful in implementing automation.

Successful automated organizations change their structure in a series of stages (Persico and McLean, 1994). Changes must allow individuals who work together to share information and make decisions in a coordinated way (Purser, 1992). In promoting self-regulated work teams, tasks need to be redesigned and jobs reassigned (Susman and Chase, 1986; Shani et al., 1992). Multiple skills are also required to facilitate a flexible task rearrangement (Larsen et al., 1991; Purser, 1991). It has been reported that STS-designed organizations enhance the quality of the work environment, improve product quality and increase productivity (Purser, 1992). From another perspective, the reward system should be redesigned to recognize the contributions of teamwork in an automated organization (Susman and Chase, 1986; Hu, 1989, p. 89). Clearly, STS represents a desirable approach to the effective implementation of automation. Therefore, we suggest the following hypothesis.

H2. Social factors can significantly account for the success of automation.

The introduction of automation usually involves multi-functional efforts at all operational levels and requires a comprehensive organizational transformation. In this regard, management support may be expected to play a significant role in the success of automation. Taylor (1986) observed that STS management must permit flexibility to change and adapt to changes in the workforce and external environment. Cohen and Apte (1997, p. 19) advocated that the first step to implement a CIM is to simplify processes and to eliminate wastes. For automation to be successful, a leadership that solicits employees' consensus through participation and communication is essential (Hu, 1989; Larsen et al., 1991). In addition, appropriate personnel training and providing sufficient financial support facilitate systems success. Therefore, we propose the following hypothesis.

H3. Management support can significantly affect the success of automation.

3. Research method and data collection

This work empirically examines the effect of social factors on the success of automation. A questionnaire survey consisting of three parts was administrated to obtain a large pool of data for statistical analyses. An in-depth interview was also conducted to collect supplementary data for further confirmation of the statistical results.

3.1. Design of the questionnaire

Based on the study of Shani et al. (1992), we include eight questions concerning social items (readers can refer to the Research results section for item descriptions) in the first part of the questionnaire. Each social item is literally described in four stages to reflect its increased complexity and flexibility. For example, complexity of skill requirements can be classified into the stages of (1) single and highly specialized skill, (2) two skills, (3) more than two skills, and (4) multiple skills and the ability to integrate all of them. For each of the eight social items, respondents were requested to select a particular stage (from among the four stages) that best fit the characteristics of their automated systems. In other words, social items are measured on a four-point scale in an increasing order of the extent of complexity and flexibility of the relevant issues.

The second part of the questionnaire contains 11 questions that served to evaluate the managerial practices in the companies. The questions were developed mainly from the report of Gupta et al. (1993). Readers can refer to the Research results section for item descriptions. Respondents were requested to rate the situation in their organization as they perceived it on a seven-point scale (1 for strongly disagree, 7 for strongly agree). In order to avoid a monotonous reaction from respondents, one of the 11 questions is described in a reverse manner.

The third part of the questionnaire consists of the demographic data of respondents and information related to their automation programs. Demographic data include the age of company, total number of employees, and job position of the respondents. Data related to automation include the focus of the automated system (production, office operations, or both), the extent of automation (stand-alone, cells, linked islands, or full Integration), the amount of capital invested in automation, the number of persons involved in planning automation implementation, current percentage of completed automation vs. projected, and the general evaluation of the success of automation. In this exploratory research, we asked the respondents to give a score (from 0 to 100) to measure the overall satisfaction from his or her viewpoint in order to reflect the success of an automated system.

Prior to the distribution of the questionnaire, we solicited advice from a consulting firm that specializes in business process automation to improve the questionnaire. In addition, the questionnaire was pilot-tested on three of their customers to ensure the adequacy and clarity of the questions.

3.2. Respondents

Automation has been adopted by large and small Taiwanese firms. However, our target companies represent the top 300 manufacturers, the top 150 service firms (CommonWealth Magazine, 1995), and 133 corporate customers of two consulting firms specializing in office and factory automation. The selection was based on the following considerations: (1) the top 300 manufacturers and top 150 service firms usually serve as model companies, and their business practices may provide more valuable managerial implications; (2) small firms are unlikely to undertake systematic automation initiatives and we would not be able to draw meaningful information from them; and (3) those firms that seek consulting assistance regarding automation are likely to have a more profound understanding of the questions being examined.

All the questionnaires were addressed to either production managers (in manufacturing companies) or administrative managers (in service firms. of the target companies. The survey was administrated between December 1996 and January 1997. Among the 113 questionnaires returned, 105 copies (a response rate of 18%.were usable. Sixty-eight copies were returned from the top 300 manufacturers, 30 copies were returned from top 150 service firms, and only seven copies were returned from the customers of the two consulting firms. In Taiwan, a low response rate is anticipated for a direct mail survey without special arrangements being made. The main reason is that companies receive overwhelming number of survey forms from business schools, consulting firms, information service centers, government agencies, etc. In our case, the low response rate for the customers of two consulting firms may be partially due to the constrained time of the surveyed targets since the majority of them are chief executive officers of small firms. To test the representativeness of the responding companies, the distributions of employee number of responding companies and target companies were compared. The result shows that, excluding the two extreme ends, the deviation between means of employee number is 3.6%. The small deviation suggests that the returned questionnaire should be valid for analysis. To compensate for the expected low response rate, an open question was included in the questionnaire and supplementary interviews were conducted to solicit a greater amount of insightful information.

4. Research results

4.1. Sample profile of the questionnaire survey

The profile of surveyed companies is shown in Table 1. It is worth noting that 80.6% of the respondents participated in the planning and implementing of automation. This fact enhances the value of the data because majority of the respondents were apparently knowledgeable about their automation programs and were able to provide us with valuable information. On the other hand, we should cautiously interpret the data related to performance evaluation as Hiltz and Johnson (1990) mentioned that expectations and prior experience of a new facility are strong predictors of subsequent satisfaction. In this work, our in-depth interview facilitates further validation of the statistical findings.

Table 1
Profile of the sample companies
Missing values were excluded from the table.

Characteristics	Grouping	Number	Percentage (%)
Industry	Manufacturing	75	71.4
	Service	30	28.6
Age of company	10−	19	18.5
	11−20	24	23.3
	21−30	30	29.1
	31+	30	29.1
Total number of employees	300−	35	33.3
	301−1000	35	33.3
	1001+	35	33.3
Position of respondent	Top level	30	29.4
	Middle level	45	44.1
	Low level	22	21.6
	Non-supervisor	5	4.9
Respondent participates in the planning of automation	Yes	83	80.6
	No	20	19.4

Table 2 shows the automation-related characteristics of the surveyed firms. Among 105 firms, 45 identified their automated systems as production-focused, 20 as service oriented, and 18 as related to both production and service. About 80% of the firms had a history of automation below 5 years. As for the extent of automation, 35.6% of the surveyed firms were in the second stage, i.e., automated cells; and 26.5% claimed that they were in the final stage of full integration. Regarding the number of persons participating in the planning of automation, while the average number was 10, more than half (52.4%) of the firms involved less than five persons. A majority of firms (63.9%) invested fewer than US$400,000[2] in their automated systems. The average investment amount was US$14,434 with a variance of US$21,560. The substantial variance was mainly due to the relatively small capital investment in service systems. As for the current degree of completion of automation against expectancy, more than half (54.3%) of the firms rated lower than 60%, with an average of 62.1%. The average score of the overall success of automation was 70.2 in a scale of 100. Among 105 firms, 65.7% enjoyed a rating higher than 60.

[2] US$1 was approximately equivalent to NT$28 in 1996.

Table 2
Characteristics related to automation of the responding companies
Missing values were excluded from the table.

Characteristics	Grouping	Number	Percentage (%) (Total = 100%)	Mean	S.D.
Type of automation system	Production-focused	45	54.2		
	Service-focused	20	24.1		
	Both	18	21.7		
Years of automation	Less than 5 years	81	77.1		
	More than 5 years	24	22.9		
Extent of automation	Stand-alone	19	21.8		
	Cells	31	35.6		
	Linked islands	14	16.1		
	Full integration	23	26.5		
Number of persons participating in the planning of automation	5–	55	52.4	10	9.3
	6–10	32	30.5		
	11–20	12	11.4		
	21–30	3	2.9		
	30+	3	2.9		
Total investment in automation	US$400K–	53	63.9	US$14,434	US$21,560
	US$400–800K	–	–		
	US$800–20,000K	17	20.5		
	US$20,000K+	13	15.7		
Percentage of automation completed vs. expected	Under 20%	18	17.1	62.1%	17.4%
	21–40%	11	10.5		
	41–60%	28	26.7		
	61–80%	43	41.0		
	Over 80%	5	4.8		
Overall score of automation success	Under 20	12	11.4	70.2	15.8
	21–40	5	4.8		
	41–60	19	18.1		
	61–80	52	49.5		
	Over 80	17	16.2		

4.2. Factor analysis of raw data

Before going ahead with data analyses, factor analyses were conducted to summarize the information contained in the original questionnaire items. First, we inspect whether the data set has sufficient correlation to justify the application of factor analysis. In order to assess the factorability of the correlation matrix, we conducted the Bartlett test of sphericity and calculated the Kaiser–Meyer–Olkin measure of sampling adequacy (Hair et al., 1998, pp. 99–122). After the appropriateness of factor analysis is determined, principal components analysis with the criterion of eigenvalue greater than one is applied to extract the factors. In addition, varimax rotation method was used to interpret the factors. Finally, internal consistency of each factor is examined to ensure the reliability of the scale.

Factor analysis of the eight social items proposed by Shani et al. (1992) yielded two factors with eigenvalue greater than 1. Table 3 shows the factor loading of the eight items. Based on the contents of the factors, we named the two factors as *control system (*items S1, S5, S6, and S8) and *work design (*items S2, S3, S4, and S7). In this study, Cronbach's alpha is calculated to assess the consistency of the scale. The values of a for factors control system and work design are 0.70 and 0.63, respectively, which are higher than the limit of acceptability for this exploratory research (Hair et al., 1998, p.118). These two factors serve as the variables of social system in the latter analyses. Each of them is represented by the mean of its factored items.

Similar approach was applied to the 11 questionnaire items relating to managerial practices. Factor analysis of these items with varimax rotation yielded two factors with eigenvalue greater than 1. However, factor loadings of items 5 and 9 on both factors are too close to have distinctiveness. In addition, loading 0.384 of item 10 is not high enough to be assigned to a factor. Therefore, items 5, 9 and 10 were discarded. Table 4 shows the factor loading of the remaining eight items. We named the two factors as *support (*items m1, m2, m3, m4) and *preparation (*items m6, m7, m8, and m11) to reflect their contents, respectively. The values of Cronbach's alpha for factors support and preparation are 0.89 and 0.82, respectively. The mean value of the factored items is used as the measure of that factor.

Table 3
Results of rotated factor analyses on eight social items

Social items	Factor 1 control system	Factor 2 work design
Eigenvalue	2.938	1.175
	Factor loading	
s1 Skill requirement (specialized single skill vs. integrated multiple skills)	0.77	0.09
s2 Job assignment (relatively specialized vs. flexible)	0.00	0.72
s3 Task design (individual vs. Autonomous work groups)	0.19	0.62
s4 Structure (rigid/mechanistic vs. organic/networked)	0.23	0.73
s5 Work integration (limited local vs. total system integration)	0.62	0.31
s6 Information flow (manual vs. automatic)	0.72	0.07
s7 Decision-making process (bureaucratic vs. self-regulated)	0.20	0.63
s8 Rewards systems (individual vs. system-based)	0.70	0.22

4.3. Hypotheses testing

Hypothesis H1a proposed that a greater extent of automation should be associated with a higher stage of social system. For example, a fully integrated automatic system may require a low specialization of job design with multi-skilled workers. On the other hand, a stand-alone automated system tends to be suitable for routine and repetitive tasks. We performed a correlation analysis to test this hypothesis. The data in Table 5 support the hypothesis that the extent of automation is positively correlated (at as $\alpha=0.01$) with the stage of social factors — control system and work design. To further verify this observation, we conducted analyses of variance (ANOVA) to examine the relationship between the extent of automation (independent variable) and the four stages of the two social factors (dependent variables). The results (detailed data are omitted for brevity) have suggested that different degree of automation may result in significant difference in the mean values of the two social factors. This is consistent with the conclusion obtained from Table 5 that the extent of automation is positively correlated with the stages of social factors. Therefore, H1a is accepted.

Table 4
Results of rotated factor analyses on 11 managerial items
Items with '–' were discarded, as explained in the Factor analysis of raw data section.

Management items	Factor 1 (support)	Factor 2 (preparation)
Eigenvalue	4.303	1.357
	Factor loading	
m1 Leadership style of top management is suited for system automation	0.820	0.246
m2 Top management supports automation	0.832	0.244
m3 Managers provide necessary support and assistance in implementing automation	0.833	0.358
m4 Company provides sufficient budget and equipment for system automation	0.836	0.107
m5 Job description and job design are suitable for automation	–	–
m6 Relevant employees participate in the designing and planning of automation	0.196	0.805
m7 Training is provided to relevant employees to facilitate smooth implementation of automation	0.221	0.835
m8 The purpose of automation is communicated to employees to reduce the feeling of insecurity	0.145	0.838
m9 Internal information flow facilitates automation	–	–
m10 Administration is modified to fit the implementation of automation	–	–
m11 Reward system is not modified to fit the implementation of automation	0.346	0.607

Table 5
Pearson correlation of automation stage, control systems, and work design
The values in the parentheses are the number of observations.

	Automation	Control system	Work design
Automation	1.00 (91)		
Control	0.58** (91)	1.00 (105)	
Work	0.25** (91)	0.46** (105)	1.00 (105)

$^{**}p < 0.01$.

Hypothesis H1b proposed that a closer match between the extent of automation and the stages of social factors would lead to a more successful transformation to automation. In order to test this hypothesis, we first created two variables to represent the degree of correspondence between the extent of automation and the mean values of the two social factors (control system and work design). These variables, denoted as gap1 and gap2, are the gaps (i.e., the absolute value of difference) between the technical stage and factors of control system and work design, respectively. Smaller values in gap1 and gap2 represent, respectively, closer matches between technical stage and control system, and between technical stage and work design. Based on Hypothesis H1b, we would expect that smaller values of gap1 and gap2 would result in higher score of success. In other words, gap1 and gap2 should be negatively correlated with the score of success. However, the result of correlation analysis does not support this hypothesis. Another approach to testing Hypothesis H1b is to investigate the effect of interactions between the extent of automation and the social factors on the score of success. This is based on the presumption that automation is more likely to be successful when the extent of automation and social factors are both high. Again, the result of a regression analysis (criterion: score of success, predictors: two social factors, interaction terms of social factors and technical stage) does not support this hypothesis. Therefore, we reject Hypothesis H1b and come to the conclusion that a closer match between the technical and social systems does not necessarily lead to a more successful implementation of an automated system.

Hypothesis H2 proposes that social factors in an organization will account for the success of automation. A regression analysis was performed to investigate the relationship between predictors (the measures of the control system and work design) and the criterion (*oVerall success score)*. The data in Table 6 reveal that the whole model explains 18.2% of the variance of the success of automation. The measure of the control system significantly account for the success of automation (at as0.014). As for the stages of work design, it exhibits a significant effect at as0.056. Overall, we conclude that Hypothesis H2 has been accepted.

Table 6
Regression analysis: social factors vs. success of automation
$R^2 = 0.182$, Adjusted $R^2 = 0.164$, $F = 10.113$. Degree of freedom: regression = 2, residual = 91, total = 93.

Model	Coefficient	Standard error	Beta	t value	p value
Intercept	37.99	7.34		5.174	0.000
Control system	7.14	2.86	0.26	2.500	0.014
Work design	5.83	3.01	0.214	1.937	0.056

Hypothesis H3 proposes that managerial practices affect the success of automation. We also performed a regression analysis to examine the effect of the two managerial factors (support and preparation) on the success of automation. Table 7 indicates that the R_2 of the total regression model is 0.241. The result reveals that factor support significantly explain the success of automation at as0.001 level, whereas preparation does not. Therefore, *management support*, which connotes leadership style, top management support, budget support, matching job descriptions, and matching information flow is a variable that should be of primary concern in facilitating a successful automation.

We further perform a regression analysis to examine the combined effect of managerial factors and social factors on the success of automation. Table 8 shows that R_2 of the combined effect is 0.353. Interestingly, among the four predictors (support, preparation, control system, and work design), support is the only variable exerting significant effect on the success of automation.

4.4. Other observations

To answer the research question whether a given company's characteristics have an effect on the success of automation, ANOVA were conducted. Seven company characteristics were examined, namely, industry, years of automation, age of company, total member of employees, number, extent of automation, number of persons involved, and total investment in automation (please see Tables 3 and 4). Data analyses reveal that 'age of company' has a significant effect on the success of automation. The Scheff test and mean values indicate that newer companies (those operating for 10 years or less, with a mean of 77.38) demonstrate a higher degree of success of automation than more established companies (more than 31 years, with a mean of 63.65.. The results suggest that newer companies may be more amenable to change.

We also observe that a longer history of automation does not necessarily result in better automation performance. In addition, the number of persons involved in the planning of automation and the overall amount invested in automation did not positively correlate to a successful implementation of automation. Another interesting finding is that the extent of automation has nothing to do with the success of automation. In other words, the success of automation does not depend on the extent of automation.

Table 7
Regression analysis: management practices vs. success of automation
$R^2 = 0.241$, Adjusted $R^2 = 0.224$, $F = 14.256$. Degree of freedom: regression = 2, residual = 90, total = 92.

Model	Coefficient	Standard error	Beta	t value	p value
Intercept	23.37	8.975		2.604	0.011
Preparation	3.23	1.74	0.20	1.86	0.066
Support	5.30	1.61	0.35	3.28	0.001

Table 8
Regression analysis: social and managerial factors combined vs. success of automation
$R^2 = 0.353$, Adjusted $R^2 = 0.323$, $F = 11.862$. Degree of freedom: regression = 4, residual = 87, total = 91.

Model	Coefficient	Standard error	Beta	t value	p value
Intercept	10.593	8.854		1.196	0.235
Work design	2.90	2.74	0.109	1.06	0.292
Control	4.43	2.64	0.176	1.68	0.096
Preparation	3.19	1.67	0.200	1.92	0.058
Support	4.43	1.51	0.303	2.94	0.004

4.5. Summary of open question

At the end of the questionnaire, an open-ended question was added. The major purpose of the open question was to solicit further comments on the automation process. Specifically, we asked respondents to identify the areas and the approaches to further improve or refine their automated systems. Table 9 summarizes the 25 comments obtained from 21 respondents.

Although 25 comments are not sufficient to draw any assertion, these comments suggest that the major concerns of system improvement are technology-oriented. Social factors account for only a small part(16%.of total comments. This observation is rather consistent with the results of statistical analysis reported in Table 6 that social factors are responsible for only 18.2% of the success of automation.

4.6. Results of interview

The purpose of conducting interviews was to collect further information from sources other than the structured questionnaire. The profile of six companies from which representatives were interviewed is shown in Table 10. The interviews were conducted either as on-site visits or over the telephone. The interviewees all occupied a high managerial level and were well informed about the entire operations of their firms.

Table 9
Summary of further improvement on automation

Description	Frequency
Integration of software and hardware	7 (28%)
Automation of material flow	6 (24%)
Automation of quality control	4 (16%)
Office/service operation automation	3 (12%)
Training and downsizing*	3 (12%)
Robotization of machining	1 (4%)
Communication between management and employee*	1 (4%)
Total	25 (100%)

* Represents the social-system-oriented issue.

Table 10
Profile of the companies interviewed
The companies' names have been replaced by letters of the alphabet to preserve anonymity.

Company	A	B	C	D	E	F
Industry	Manufacturing	Manufacturing	Service	Manufacturing	Manufacturing	Manufacturing
Product or service	Machine tools	Printing machine	Electrical appliance	Machinery	Computer and communication	Mother board
Employee number	540	100	170	300	1200	600
Company age	17	9	10	45	17	24
Sale revenue (million US$)	100	10	86	30	120	72
Extent of automation (%)	–	–	70	80	100	–

The interviews revealed that automation has consistently been regarded as a necessary measure to retain their firms' competitiveness. The five manufacturers interviewed have long been devoted to factory automation as a major means to improve their product quality, production efficiency, and their employees' working environment. For example, an automated system in Company F has successfully replaced 90% of operators of one of its production lines. Automation in the service firm appeared more oriented to business process computerization in order to enhance internal and external communication, and the accuracy and speed of business transactions. In what follows, we summarize three major findings commonly observed in these firms.

4.6.1. Employees' support

The automation or computerization of operational processes have been clearly recognized as an inevitable trend. All of the interviewees asserted that automation has improved employees' morale and increased satisfaction. In contrast to employees' personal resistance to newly implemented technology commonly reported in literature (for example, Bamane, 1994; Orr, 1994), the firms interviewed seem to have enjoyed the full support from their employees. We suspect that this observation may be due to the following reasons: (1) the shortage of labor in manufacturing makes the relocation of employee from their original position less problematic; (2) firms' long-term commitment to automation and their effective communication with employees form a culture of adaptation to change; and (3) the school and social education in Taiwan have delivered the message that the mastery of computers is a prerequisite in applying for a job.

4.6.2. Competent project leaders

All the automation projects were implemented under the leadership of technicians. In addition to the operational soundness of the automated systems from the users' perspective, the interviewees explicitly mentioned that the project leader of an automation program should be competent to integrate the social and technical factors of the entire system. Other than a sound technical training, several other crucial characteristics of project managers highlighted by the interviewees included good communication skills, adaptability to change, and strong leadership skills. These factors are regarded as even more important than technical skill. This is consistent with the suggestions of Meredith and Mantel (1995, pp. 129–132) that a project manager should be (1) technically and administratively credible, (2) politically sensitive, (3) strong in leadership, and (4) capable of handling stress.

4.6.3. Aligning technical and social factors

In addition to the general observations mentioned above, the following specific issues of the individual companies are related to the alignment between technical and social factors.

Company A has introduced many product and process technologies through technical cooperation with its well-established Japanese, European, and American counterparts. The firm is aware that technology is usually embedded within a context of culture, belief, and work habits. A lesson the firm learned is that a sound understanding of these intrinsic social components is required to fully appreciate and exploit new technologies.

Company B has inculcated into its employees the notion that continuous improvement in productivity is the key to the firm's survival. The firm believes that the proper attitude is crucial to the introduction of factory automation. Company C attributes their success to its project leader's familiarity with the firm's entire business processes. It explicitly described the importance of a systematic view of the automation designer.

Company D launched a FMS program in the late 1980s to enhance the firm's productivity. Although its FMS is perceived industry-wide as a success, the firm suffered a setback with the functioning of its new control procedure before the system commission. The primary cause was due to the idealistic design of the system operating procedures over the objections of production personnel. The lesson learned is that the advice of system users is crucial to the success of an automation program.

Company E had implemented a fully automated assembly line and gained a full return of its investment within a year. The automated line not only solved the firm's problem of labor shortage but also significantly boosted the product quality. The automation project had been highly dependent on mechanical and industrial engineers to configure and implement the entire system. However, the chief executive who was interviewed by the authors asserted that cooperation from the production line is crucial to the success of the project. He attributed the limited resistance and lack of conflict to the early involvement of the concerned parties and to the necessary adjustment of related work. He estimated that the social factors could take as high as one third of the credit for the success of automation.

The automation of Company F is being carried out by a project group staffed mainly by engineers. The automation program is aimed at not only enhancing production efficiency but also at improving the work environment. The firm has envisioned completing the project by year 2000, a goal set in 1996. A consensus throughout the company's organizational echelons has been proven to be helpful for the smooth implementation of automation. Furthermore, the production director interviewed noted that the frequent interaction between the project group and responsible individuals in production, R&D, process engineering, and maintenance has significantly reduced the number of potential conflicts among the parties concerned. It may be noted that the firm's practice is consistent with the suggestions of Bamane (1994). Bamane noted that resistance could be reduced by effective information-sharing, open communication, and appropriate training.

5. Discussion and conclusions

5.1. Summary

Automation has become increasingly important in the pursuit of productivity in both manufacturing and service industries. This empirical study investigates cross-organizationally the effects of social factors on the implementation of automation. The major findings from our questionnaire survey suggest that (1) a technical system with a high extent of automation is associated with an increased extent of complexity and flexibility of social factors; (2) companies with matching social and technical stages are not necessarily more successful in implementing automation; (3) the extent of complexity and flexibility of social factors(control system and work design) can explain about 18.2% of the variance of the success of automation; (4) management practices explain about 24.1% of the success of automation; (5) combining the two social factors and the two managerial factors, management support is the only factor that exhibits significant effect on the success of automation; (6) newer companies tend to be more successful than more established firms in automation. Furthermore, qualitative data collected from the open question in the questionnaire as well as from our in-depth interviews with six companies reveal that (1) continuous technology-related improvements are more at-tended(see Table 9), and (2) employees' support, competent project leaders, and alignment between technical and social factors are essential to a successful automation.

Some observations with managerial implications are further discussed in the following section.

5.2. Discussion and future research

Social considerations should be an integral part of an automation program. Research results indicate that a technical system that is highly automated tends to go with a high stage of social factors. However, this result does not imply that a company with a lower extent of automation need not concern itself with social factors. On the contrary, the success of automation can be predicted by social factors (work design and control systems). Furthermore, the success of automation is independent of the extent of automation(a finding of ANOVA). These two observations combined suggest that social factors are crucial for the effectiveness of technical system in any stage. Grant et al. (1991) noted that, for most established firms, incremental approach to applying manufacturing technology tends to successfully deliver the promises of new technology. This observation prompts us to further suggest that social issues such as skill requirements, information flow, degree of autonomy, and rewards should be integrated into a firm's automation program from the very beginning in order to achieve an optimal result. The conventional wisdom of appointing an engineer as project leader in implementing a technical program still prevails. However, we would strongly suggest that such engineers should be open-minded and invite managerial staff for advice. An ideal approach would be that both parties work as a team and contribute their own expertise to deal with both technical and social changes simultaneously.

Results of statistical analyses show that social factors and managerial factors combined can explain 35.3% of the variance of success of automation (see Tables 3 and 4). Clearly, these two sets of factors are important, yet they are by no means the dominant factors in determining the success of automation. The remaining factors are presumably mainly related to technical issues. Although automation has been regarded as a prerequisite for enhanced productivity and quality, our statistical analyses reveal that a higher extent of automation does not necessarily render more satisfactory results. These findings suggest that not all companies require a fully automated system. The extent of automation should be compatible with product requirements, financial capability, a given firm's strategies, and employees' expectations. This assertion is supported by the responses to the open question and the comments of interviewees. The summary of the open question in Table 9 reveals the nature of the technical issues concerned. Interestingly, the comments (Table 9) are little concerned with the functional performance of an individual workstation. Instead, they seem oriented to peripheral operations and the integration of hardware and software. As a consequence, we suggest that management would seriously review and adopt an effective automation strategy appropriately covering the social and technical factors.

It is evident that social factors (in this context, i.e., control system and work design) is important for the successful implementation of automation. However, their effects are not so significant (see Table 8) as the effect of management support covering appropriate leadership style, support from top management, managers' assistance in implementing automation, sufficient budget, and good internal information flow. This result suggests a justification why Hypothesis H1b, i.e., an organization with matching social and technical stages is more likely to be successful in implementing automation, has been rejected. The rejection of this hypothesis prompts us to suspect that the effect of matching between the two systems may be overshadowed by the effect of managerial factors. In addition, our observation about Hypothesis H1b is in some sense in concert with a key principle of STS design — equifinality — the concept that there are different ways of achieving the same purpose (Majchrzak, 1997). Majchrzak (1997) noted that, ''not all organizations need to be designed according to an ideal profile. Instead, compensatory efforts among sociotechnical variables help the organization to overcome constraints and an inability to meet all the characteristics of an ideal profile.'' Furthermore, the comments on the use of advanced technology by DeSanctis and Poole (1994) are worth noting. They concluded that, ''there is no doubt that technology properties and contextual contingencies can play critical roles in the outcomes of advanced information technology use. The difficulty is that there are not clear-cut patterns indicating that some technology properties or contingencies consistently lead to either positive or negative outcomes''. All of these suggest that further research is needed on the effectiveness of the matching between social and technical systems.

We recognize that the success of an automated system may be involved in multi-dimensional conceptualization of acceptance. For future research, indicators of success could be expanded to include the performance against the expected technical standards and users' satisfaction in various dimensions (Hiltz and Johnson, 1990). Finally, although this study has limited itself to firms in Taiwan; we believe that the results of this research have cast some light on the effective implementation of automation. Future studies may repeat the method employed to compare and contrast the effects in different cultural settings.

5.3. Concluding remarks

STS theorists and practitioners advocate the idea that social factors exert a significant influence on the success of automation programs. Our statistical analyses also provide empirical assertions that the implementation of automation should not be solely a technical task. Supplementary data from the interviews of six companies further support this observation. The results of the interviews suggest that, although users may be psychologically ready to accept technical changes, system designers should familiarize themselves with the entire business process in order to implement a successful automation program. In an era of hyper-competition, automation is a process en route to high productivity for manufacturing and the service industry alike. We believe that concurrent change in both technical and social systems is crucial to the effective exploitation of the performance potential of new technologies.

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