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Manufacturing Technology and Operations in China:: A Survey of State-owned Enterprises, Private Firms, Joint Ventures and Wholly-owned Foreign Subsidiaries

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Abstract

The government of China has decided to privatize many state-owned enterprises (SOEs). Is it wise to consider investing in these SOEs? What is the level of installed technology, from traditional production planning systems, like MRP, to robotics? How different are SOEs from privately owned firms, joint ventures, and wholly owned foreign subsidiaries? This paper attempts to answer these questions based on a survey of 120 manufacturing firms in the Shanghai area. We report on the status of, and future plans for, manufacturing technology implementation; and we discuss other improvement initiatives. We report on significant differences among ownership types, and yet we discover that the differences among the ownership types are often insignificant.

1. Introduction and Literature Review

China continues to capture the imagination. In spite of the Asian financial crisis of the late 1990s, changing policies toward state-owned enterprises, and the presence of a global slowdown, business in China has not taken the beating that many expected. Global firms have maintained their strong interest in China, both as a source of products and components, and as a strategic location for operations. Yet the distance between the West and China, both geographically and culturally, is huge. Managers in the West do not, as a rule, understand the intricacies of doing business in China. And the business press can only be of limited help.

This research is designed to help managers and researchers understand several important dimensions of Chinese manufacturing firms. In particular, we are interested in discovering how advanced these firms are with regard to manufacturing technologies, labour relations, and other key improvement actions. We address the issue of ownership structure to find out whether foreign participation is a significant determinant of financial performance or of technology implementation. We also examine whether firm size is a better explanatory variable than ownership structure. Our findings have implications for researchers in that we discover little explanatory power due to firm size, and in fact, we find many issues for which the differences among ownership types are insignificant. However, we do discover some significant differences, which may provide useful insights for managers seeking to expand business into China, either by acquisition, partnership or subcontracting.

In a previous paper, Pyke, Robb, & Farley (2000), we reviewed much of the relevant literature on manufacturing and supply chain management in China. Here, we discuss other research specifically relevant to the issues addressed in this paper, and we highlight new research since our last paper was written.

Ownership Structure the Chinese Economy

Clarke & Du (1998) describe the various ownerships structures of Chinese firms. They provide data on output, numbers of firms, and other important factors, for state owned enterprises (SOEs), collectively owned enterprises (COEs), privately owned firms (POEs), and others. They also outline a brief history of these ownership structures. Kynge (2000) notes that about half of all firms that call themselves collectives should be relabeled as private.

Transition (2001) summarizes key data on state-owned enterprises and those from the nonstate sector, including private firms. SOEs accounted for 77.6 percent of industrial output in 1978, but only 26.5 percent in 1998. Privately held firms accounted for only 1.9 percent in 1985, but increased to 16.0 percent in 1998. At the same time, employment in SOEs fell from 112.6 million in 1996 to an estimated 81.2 million in 1999. Researchers estimate that many laid off workers from SOEs found jobs in the private sector – as many as 4,000 workers per day in 1999. Employment in the private sector rose from 4.5 million in 1985 to an estimated 81.3 million in 1999.

Along the same lines, Koretz (2001) reports that China's private sector accounts for over 75% of the country's output, and these private companies' earnings have been growing rapidly since July 2000. The cause? At least in part, this growth is due to foreign direct investment. Also, the private sector is now more reliant on stock offerings than on bank debt as a source of capital. In addition, observers note a surge in mergers and acquisitions (Roberts & Webb (2001)). In some cases, SOEs are taking over other SOEs; but in general there is a large upswing in M&A activity of all sorts. Roberts & Webb (2001) note that the number of M&As was expected to grow by 40% in 2001, to a total deal flow of $40 billion. Earlier, Kynge (2000) reported on a study by the International Finance Corp., an arm of the World Bank, that private firms in China generated 33% of GDP in 1998 compared to 37% from SOEs. The growth due to private firms appears to be phenomenal.

The vast majority of the growth in manufacturing enterprises and employment is in urban areas, causing what some term the "great migration" from the countryside to cities. As a result, social problems abound (Roberts (2000)). A survey on China by *The Economist*, "China: Now comes the hard part" (2000), highlights some of these issues and discusses the issues related to transforming China to a market economy. Ngai (1999) focuses on a particular dimension of the great migration – that of the working girls who have left farm lands for urban jobs. Manhua (2001) provides recommendations for improving the situation in rural areas. These include increasing urbanization so that more people can find jobs in manufacturing and other enterprises. A further problem that may drive considerable social unrest in the future is increasing inequality within each city. Private firms could play a central role in mitigating such problems.

Fulin (2001) addresses the challenge that WTO membership will present to China. In addition to discussion of social policy reform and agriculture reform, the article recommends separating government from enterprises by converting large and medium-sized manufacturing enterprises into joint stock companies. Furthermore, Fulin recommends eliminating institutional barriers and increasing legal protection for private enterprises, including for private property, as well as increasing financial support of private enterprises.

Kouvelis, Axaraloglou, & Sinha (2001) examine exchange rates and the choice of ownership structure using both an analytical model and empirical data of firms from many countries. They demonstrate how exchange rates and switching costs would lead a firm to choose a JV or wholly owned foreign subsidiary (WOFS) over an exporting strategy, and to specify choice of either a JV or a WOFS. For instance, depreciated real exchange rates (i.e. a weak home currency) tend to favor a JV over a WOFS, and an exporting strategy over both a WOFS and a JV. Our own observations – of the increasing popularity of WOFSs and of China's maintenance (even against most pundits) of the RMB/USD rate – confirm these results.

Child & Yan (2001) study joint ventures (JVs) in China and discuss the "nationality" and "transnationality" effects on management. They discover a very limited nationality effect; in other words, there are few differences in strategic orientation, training, management controls, and other management dimensions among the multiple countries from which the JV partners originate. However, they do find several significant transnational effects, where a transnational firm is defined as one that has manufacturing in two or more continents and worldwide sourcing or distribution. Examining the differences between transnational firms and non-transnational firms, the authors find differences on a number of dimensions. The implication is that JVs with transnational firms, as opposed to national firms, are more likely to lead to transfer of management practices into China. We should note, however, that Child & Yan (2001) assert that ownership is only one of many methods of measuring foreign involvement. Others include, for example, management and board appointments.

Robb & Xie (2001) survey foreign-invested and Chinese-owned enterprises in the Beijing-Tianjin area. They examine current manufacturing practices, differences between the two ownership structures, and the relationship between practices, structures and performance.

Advanced Manufacturing Technologies in China

There is little research on advanced manufacturing technologies in China. Anon (2000) notes that China plans to initiate computer aided design (CAD) or computer integrated manufacturing (CIM) technology in more than 90 percent of its large- and medium-sized state-owned manufacturing firms by the end of 2010. And Jiang, Wang, & Sun (1993) note that in a seven-year period, 1986-1993, only about ten flexible manufacturing systems were established in China.

De Meyer (2001) argues that overcapacity, a persistent problem in China today, means that China needs technology that leads to innovation and improvement, not the traditional turnkey factories employed by foreign firms.

The case study of Tseng, Ip, & Ng (1999) shows the benefit and appropriateness of a socio-technical approach (i.e., integrated manufacturing) in China, rather than the traditional labour intensive or high-tech, automated approaches.

Empirical Research on Quality Management

Li (2000) surveys 72 companies in China regarding marketing, product innovation, manufacturing, and human resource development. He develops regression models to test the relationship between managers' emphasis on competence in each of these areas with firm performance. Human resource development had the strongest relationship with performance, although other areas, such as quality management (a subtopic under manufacturing), scored high as well.

Lihong & Goffin (1999) interviewed six joint venture manufacturing firms in China and found that the main problem areas were recruiting and training employees, supplier management (especially delivery problems), quality output, and an effective business culture.

Pu (1991) comments on the importance of Quality Control Circles, during the 1980s, in promoting product quality in China. Later, a study of 212 manufacturers in Liaoning Province by Zhang, Waszink, & Wijngaard (2000) revealed that little empirical research had been conducted on implementation of total quality management (TQM) in Chinese manufacturing companies. This study then concluded that most Chinese companies are trying to implement ISO 9000 in order to improve their quality systems.

A 1998 Survey of 71 Shanghai Manufacturers by Hua (2000) found that 62% of respondents had registered for ISO (9001-9002-9003); 23% had not registered for any ISO 9000 certificate but were planning to register in next two years. Interestingly, the study found ISO 9000 certification did not correlate with quality management practice or performance, but that TQM practices were highly related to business performance (as measured by market share growth, profitability, lower costs, etc.).

Chen & Fu (2001) show that adoption of information technology (PCs, for example) is not clearly connected with economic performance or with innovation. However, they find that the size of the firm plays an important role in the IT adoption process. As we shall see below, we find little evidence that size of firm is an important explanatory variable for manufacturing technology adoption.

Finally, we note that our previous paper, Pyke et al. (2000), studied SOEs, COEs and POEs in the Shanghai area with a focus on supply chain management and operations strategy. The current paper builds on this survey to include wholly owned foreign subsidiaries (WOFSs) and joint ventures (JVs). Because of some confusion regarding the identification of collectively owned enterprises (specifically privately owned firms may identify themselves as collectively owned), we have dropped them from the analysis in this paper. Our focus is on advanced manufacturing technologies and other results not reported in the earlier paper.

2. Data Collection

The questionnaire, sampling and interviewing procedures, measurement and development of summary scales were the same as those used in Pyke et al. (2000), except for 50 new interviews with joint ventures and wholly-owned foreign subsidiaries located in Shanghai.

Questionnaire: The basis of the questionnaire was the framework for manufacturing strategy in Wheelwright (1984) and Pyke (1997). The questionnaire used by Robb & Xie (2001), was complemented with questions from Hum & Leow (1996), Deshpande & Farley (1999a) and McDermott, Greis, & Fischer (1997). The translated new items were added to the draft questionnaire. Back-translations to English were used to assess translation accuracy and pre-tests were done with senior manufacturing managers. No problems – lack of clarity, sensitivity of the answers, etc. – were encountered in the earlier study.

Sampling: The sample of firms was drawn from registers of businesses in Shanghai maintained by market research firms for their business-to-business projects. Interviewers reported that 85 percent of the original sample was contacted and that 75 percent of these contacts produced useful interviews, yielding 50 new firms to add to the 100 firms interviewed in the earlier study. As noted above, some collectives were dropped from the sample, yielding a sample of 50 State-owned enterprises, 20 Privately owned enterprises, 24 JVs, and 26 WOFSs. Industry representation is given in Table 1.

Interviewing: In-office personal interviews with senior manufacturing executives were conducted in Chinese by the staff of an international market research firm who specialize in research in business-to-business settings, based on prior appointments made by telephone.

Measurement: All items on the questionnaire were closed-ended. They included three, five and seven-point scales as well as nominal qualitative measures and metric measures, such as number of employees.

Construction of Summary Scales: A set of summary scales composed of multiple 7-point items measure both degree of emphasis on, and recent improvement in, the competitive objectives of cost, quality, delivery, flexibility in the new product development process, and flexibility in the production process. The content and reliability of these ten scales are shown in Table 2. In all but one case the reliability of the scales as measured by the Chronbach ∝ is above the minimum exploratory level of 0.6 (Nunally (1967). The three elements of the performance scale, shown to be reliable in a wide variety of settings Deshpande & Farley (1999b), produced a reliability measure of 0.83.

3. Some General Results

We asked about 160 questions on many dimensions of manufacturing strategy, operations performance, manufacturing structural and infrastructural decisions, improvement actions currently and planned for the future, and new technologies. The bulk of this paper will discuss technologies and improvement actions. However, we begin with some comments on operations objectives, manufacturing strategy, manufacturing structural and infrastructural decisions, and supply chain issues.

Perhaps the most striking observation is the *lack* of significant difference among ownership types. None of the summary scales measuring the degree of emphasis on the competitive objectives were significantly different among firms. Only one of the five scales that measured the degree of improvement on these objectives in the last year (improvement in cost performance) was significantly different among firms. WOFSs and JVs scored higher than POEs and SOEs, with JVs being the highest and POEs the lowest. Average scores on the seven point scale for JVs, WOFSs, SOEs and POEs were 5.54, 5.50, 4.76 and 4.20, respectively.

One set of eight questions examined the strategic role of manufacturing in the firm, asking, for instance, whether competitive advantage is sought by having manufacturing participate in making marketing, engineering and business strategy decisions. There was no significant difference among ownership types for *any* of these questions.

Another set of 37 questions examined manufacturing structural and infrastructural decisions, including worker training, production equipment developed in house, level of work-in-process inventory, supply chain management, and many others. Only 7 of the 37 questions showed a significant difference, and four of these pertained to technologies. We will discuss these results in the context of advanced manufacturing technologies in Section 4. Two of the remaining three questions had to do with worker skill and responsibilities, a topic we address in Section 5. The final significant result pertained to supplier involvement in new product development.

Therefore, we can conclude that on most dimensions the expected differences among ownership types are simply not evident in the data. The Western business press has continually reported that SOEs are in fact very different (see Roberts & Webb (2001), Roberts, Prasso, & Clifford (1999), *The Economist* "Infatuation's end" (1999), Broadman (1999), and Steinfeld (1998) for example), and that the vast majority of SOEs are being required to survive without government assistance or face new ownership structures. Our data do not support the first part of that statement. On the other hand, we do see a clear and consistent pattern of differences on new technologies, both in terms of the firms' current status and their future plans. And we see differences in financial performance. This latter result has been widely reported, and our results support it.

3.1 Other general results

Statistics regarding size of workforce are interesting. We measured the number of operators currently, the number of total employees currently, and the number of total employees five years ago. SOEs are by far the largest and *were* the largest five years ago. This is of course not surprising. POEs, on average, have not changed in size. (All SOEs and POEs surveyed were in existence five years ago.) JVs and WOFSs, most of which existed five years ago, have gotten much larger, while SOEs have cut more than 700 workers on average. The average number of operators currently for SOEs, POEs, JVs, and WOFSs, are 799.94, 138.65, 312.08, and 285.62, respectively. These numbers are significantly different at the 0.008 level. The results for the total number of employees currently are 1322.10, 249.85, 608.50, and 564.42, respectively, (significantly different at the 0.006 level). Total employees five years ago: 2094.80, 248.30, 320.04, and 335.88, respectively, (significantly different at the 0.000 level). The current averages for JVs change very slightly if we remove firms that didn't exist five years ago, while those for WOFSs are about 20% larger.

3.2 Financial Performance

Looking at the financial measures of improvement in market share, profitability, and return on sales, we find no significant difference among the ownership types on market share. However, WOFSs reported significantly higher improvement in profitability. We measured the difference between the mean of each ownership type and the overall mean. WOFSs scored 0.283, which is significant at the 0.002 level. POEs and SOEs were significantly lower, with scores (significance level) of –0.181 (0.048) and –0.217 (0.017), respectively. JVs were 0.143 higher than the mean, but only at the 0.118 level. Results for improvement in return on sales were significant for all four ownership structures, with WOFSs and JVs again higher than the mean, and POEs and SOEs lower (0.256 (0.005), 0.217 (0.017), –0.202 (0.027), and –0.237 (0.009), respectively).

We also created a summary scale using the three financial performance measures. For this summary scale, the values were significantly different by ownership type, and WOFSs were significantly higher than the others at the 0.002 level. JVs were also higher than the mean, but not significantly so. Likewise, SOEs and POEs were lower than the overall mean, but not significantly so.

Regarding all the financial measures, we should note that privately owned firms might have an incentive to bias their responses on these financial questions. SOEs, JVs and WOFSs are more closely monitored by the government, which would, one might hope, reduce the likelihood that they will misrepresent their financial results. Privately owned firms, however, may be a different story. In general, reliable revenue and profit figures are known to be unavailable for Chinese firms. The May 23, 2001 edition of *China Reform New*s reported that 92 percent of surveyed companies falsified certain financial data. Are our financial measures to be trusted? We think so for two reasons. First, the *relative* results for the non-private firms are consistent with what one would expect, providing face value to the measurements. Second, the survey on falsified data showed that the firms uniformly biased the data in one direction. Since our conclusions are based on relative values, such a bias would not cause problems for between-group comparisons based on order.

4. Results on Advanced Manufacturing Technologies

One set of questions, which we designated by the shorthand "G", asked about current status on sixteen manufacturing technologies, from quality circles and just-in-time (JIT) to automated assembly and robotics. We asked respondents to score each technology with 1 if not implemented, 2 if implementation was in progress, and 3 if fully implemented. See Table 3 for the full list of questions and results by ownership structure.

In marked contrast to the results reported above, thirteen of the sixteen questions showed at least one ownership type significant at the 0.05 level. In every case in which there was a significant result, the WOFS and JV firms had higher scores than the POE and SOE firms. In fact, in thirteen of sixteen cases, the *minimum* of the WOFS and JV average scores was higher than the *maximum* of the POE and SOE average scores. It would thus appear that foreign participation has a powerful impact on new technology implementation. In fact, for this set of measures, the values were significantly different as a set for the different ownership types.

What about the differences between SOEs and POEs, and between WOFSs and JVs? Looking at the average scores for each of these questions, we find that POEs were lower than SOEs in the majority of cases (11 of 16), the same on some (3 of 16), and higher on the remainder (2 of 16). Apparently, SOEs are more advanced than POEs in their implementation of new technologies. Now comparing WOFSs and JVs using Table 3, note that WOFSs were higher than JVs for 7 of 16 cases and lower in the remainder, indicating that neither ownership structure is clearly ahead.

One question in this set is Automation in Production (G2 in Table 3). Average scores for SOEs, POEs, JVs and WOFSs were 1.76, 1.55, 2.08 and 2.27, respectively. These are significantly different at the 0.000 level, with JVs and WOFSs clearly more advanced. A question in another set asked about the proportion of automated manufacturing equipment in the factory. Specifically, the question asked respondents to circle a number from 1 to 7 that reflects their firm's current position, *relative to competitors*, with 7 being very high and 1 being very low. The results for SOEs, POEs, JVs and WOFSs, were 3.82, 3.05, 5.21, and 5.08, respectively. These results are consistent with the current status question described here, but the differences are even more striking when the question is phrased this way. These results are also significant at the 0.000 level. A related question on the 7-point scale was the degree of specialization of production equipment. The results for SOEs, POEs, JVs and WOFSs, were 5.32, 4.35, 5.83, and 5.88, respectively. These results are a bit more mixed, although the ownership structures are significantly different at the 0.001 level. The reason for the slightly different ordering is that specialized production equipment may or may not be particularly high tech. Finally, we asked the average number of years that production equipment has been used. Not surprisingly, the results for SOEs, POEs, JVs and WOFSs, were 13.06, 8.55, 6.46, and 3.96 years, respectively.

SOEs are clearly using older, less high tech equipment; and as we shall see, they have less aggressive plans to replace this equipment with available, but expensive, new equipment.

We asked a set of questions about future plans for advanced manufacturing technologies that directly parallels the "current status" ones. Specifically, we asked respondents to score each technology with 1 if they have no plans for future investment, 2 if they are considering investment, and 3 if they have decided to make a future investment in the given technology. See Table 4 for results. Our shorthand for this set is "H".

For the H (future plans) questions, we find that far fewer items showed significant differences among ownership types than the G (current status) questions – only five of sixteen as opposed to thirteen of sixteen. However, the values for the H measures were significantly different as a set for the different ownership types. As with the G questions, for each significant individual item, WOFSs and JVs were above average, and POEs and SOEs were below average. In fact, just as in the G questions, in thirteen of sixteen questions, the minimum of the WOFS and JV average scores is higher than the maximum of the POE and SOE average scores, though not all significantly. It would appear that, not only are WOFS and JV firms currently ahead, they also have more plans to implement these technologies in the future. The sole exception is for plans for implementing ISO 9000 (H13).

ISO 9000 Results

For the ISO 9000 question, SOEs were significantly higher than the overall average while POEs were significantly lower. These results are significant at the 0.028 level. Average scores for SOE, POE, JV and WOFS are 2.64, 2.15, 2.33, and 2.58. These differences are not great, but they do suggest that more POEs and JVs are simply "considering" future investment toward ISO certification, while more SOEs and WOFSs have decided to pursue it. To put these results in context, the "current status" averages were 2.02, 1.55, 2.04, 2.00, respectively.

One possible explanation for the ISO 9000 differences is the amount of production that is exported. Many U.S. firms pursued ISO certification when the European Community announced that any firm selling to businesses in the EC must be ISO certified. On the question regarding the percentage of production is exported, the averages were 21.08, 20.40, 41.08, and 57.23, for SOEs, POEs, JVs and WOFSs, respectively. Not surprisingly, JVs and WOFSs export a significantly (at the 0.000 level) larger percentage of their output. In the past decade or so, some SOEs obtained permission to retain a portion of the foreign currency earned. Pyke (1998) notes that by 1992 Guangzhou Machine Tool Company's segment of the machine tool market in China had been nearing the saturation point, so that exports had picked up a larger share of sales, reaching 50-60% of output. The SOE average in our survey is 21%, but our results suggest that this number will increase significantly in the future, and that managers are preparing for that situation. In addition, if only one large customer requires ISO certification, the firm must achieve it or give up that customer.

These results may also suggest that, although SOEs and POEs currently have similar export percentages, SOEs may expect to export more in the future, and therefore are more aggressive in pursuing ISO certification. Because the current export percentages are so close for SOEs and POEs, it is not correlated with ISO certification, either current status or future plans. Unfortunately, we do not know their future plans for export percentage. One additional comment on these results: SOEs are clearly not lagging behind POEs in exports even though they have not achieved the export percentage found in JVs and WOFSs.

Finally, we were curious about the relationship between ISO certification and whether the firms design products for foreign markets. (The design issue is captured in a 7-point scale question, where 7 is strongly agree with the statement: "We design products for foreign markets as well as domestic markets.") The results indicate that this question is significantly correlated with G13, ISO certification current status (0.182 at the 0.047 level), but not with H13, future plans, or with the percent of production exported.

Quality Circles

For the current status questions, WOFSs were higher than the overall mean on every question except G1 (Quality circles); and for G1 the means were very close to one another (2.37, 2.40, 2.42, 2.38, for SOEs, POEs, JVs, and WOFSs, respectively). Clearly, most firms have implemented quality circles, or are in the process of doing so, and there were no measurable differences among ownership types. There were also no significant differences on future plans for quality circles, but the means all increased over the current status, to 2.52, 2.80, 2.63, 2.77, respectively. These results indicate that most of those firms that have yet to implement quality circles have decided to invest resources on them in the future. Interestingly, SOEs, which were lowest on current status, show the smallest average increase, although the magnitude of this increase is not significant. We can conclude that SOE investment funds for new technologies in manufacturing, restricted as they are, will be spent on other initiatives and technologies.

Current Status/Future Plans

To further investigate the differences between current status and future plans, we looked at the differences on each technology, H1 – G1, and so on. We denote these differences as HDIF values. All sixteen values were positive, indicating that the future plans were on average larger than the corresponding current status. For instance, a response of "2" on G5 means that implementation of computer driven production planning system was in progress, while a "3" on H5 says that the firm had decided on future investment. Positive differences are intuitive in the sense that future investment would finish the implementation, or in the sense that the firm was planning on adding to the implementation with more features, more complete rollout, and so on. Positive values are certainly to be expected; Chinese firms are not standing still.

The lowest number of the HDIF values was question 10, robotics. However, raw scores suggest that almost no firms had implemented robotics and almost no firms were planning to. The next lowest score was question 1, quality circles. Here, the opposite is true: most firms had already implemented, or were currently implementing, as noted above.

The highest score on HDIF was question 5, computer driven production planning system. The results are significant as seen in Table 5. Average scores on the G question were 1.60, 1.60, 2.08, and 1.96 for SOEs, POEs, JVs and WOFSs, respectively, while the H average scores were (from Table 4) 2.42, 2.00, 2.46, and 2.62, respectively. POEs' future plans are significantly lower than the others, but future plan averages are much larger than current status averages across the board. Manufacturing Resources Planning (MRP II) systems are common examples of computer driven planning systems, and these are widely available on personal computers for reasonably sized applications. Data requirements are not trivial, and implementation requires some real work, but the cost of the technology (hardware and software) is quite low. It is not surprising that most firms are moving ahead with these systems. An interesting supplement to these results is found in a question (C1) on the degree of computerization involved in production planning. Specifically, the question asked respondents to circle a number from 1 to 7 that reflects their company's current position, *relative to competitors*, with 7 being very high and 1 being very low. The results for SOE, POE, JV and WOFS, respectively, were 3.50, 3.20, 5.21, and 5.04 (significant at the 0.000 level). These are clearly consistent with the G question results.

The second highest HDIF score is question 4, computer driven materials planning system. The G and H averages are quite similar to those of question 5, which is not surprising as the most common application of materials planning systems is MRPII, which generally comes bundled with production planning systems. The key difference is that the materials planning modules in MRP systems can be used without problem in most factories, whereas the production planning modules apply best in only certain types of production processes. A common mistake in implementing MRP systems is to apply the production planning and scheduling tools in, say, a job shop environment where queue times are quite long and variable. MRP requires an input of the fixed lead time for a component at a given work center. Variable queue times suggest that *any* choice of a lead time will be wrong, and therefore the MRP plan will often be in error. On the other hand, the materials procurement module of the MRP system is quite robust. It simply computes the number of parts and components necessary to assemble a given product and reports that number to the purchasing decision maker. For both questions 4 and 5 on the HDIF scores, SOEs show a significantly larger increase (difference of H – G) than the group as a whole, while JVs show a significantly smaller increase (Table 5).

Results on Electronic Data Interchange (EDI) are also interesting (question 15). G scores were 1.30, 1.05, 1.38, and 1.50, for SOEs, POEs, JVs, and WOFSs, respectively, indicating that there is little use of EDI currently. H scores were still low – 1.74, 1.60, 1,83, 1.88, respectively, indicating that, at most, firms are considering investment. These results are not surprising given the cost and hassle of implementing EDI, both of which are magnified by the presence of the Internet where the same objectives can be accomplished with less cost, time and aggravation.

Scores for the questions on Statistical Process Control (SPC) were 1.74, 1.40, 2.08 and 2.15 for current status for SOEs, POEs, JVs and WOFSs, respectively, and for future plans were 2.10, 1.85, 2.21 and 2.42, respectively (Tables 3 and 4). Apparently, implementation of SPC is ongoing at many companies, but future plans are not firm. Rather, most companies are simply *considering* future investment. Of course, these are averages, and the differences (H – G) are positive, but one does not get a sense of aggressive pursuit of SPC. The one exception is WOFSs with a mean of 2.42. Why are most firms hesitant about their plans for SPC? Looking at the ISO 9000 scores for future plans, which are higher across the board than the SPC scores, we can infer that their efforts on quality management are more directed toward becoming ISO certified than implementing SPC. ISO 9000 is a much more broad quality initiative, whereas SPC is a specific tool for product quality. Perhaps the broader goal takes precedence, particularly given that foreign customers may require it. They may implement SPC after ISO certification. Another possibility is that they are in progress with implementation, and SPC really does not require further work after the current programs are completed.

Low Scores

There are a number of current status results (Table 3) where the averages for all firms were below 2.00, and two questions where three ownership types were below 2.00 and the fourth was barely above 2.00. The technologies for which all were below 2.00 are group technology (GT, question G6), just-in-time (JIT, question G8), computer aided manufacturing (CAM, question G9), robotics (G10), flexible manufacturing systems (FMS, question G11), computer integrated manufacturing (CIM, question G14), EDI (G15), and automated assembly (G16). We have discussed EDI previously, so we will not add to those comments. The questions where all but one ownership type were below 2.00 are computer driven production planning (G5) and computer aided design (CAD, question G7). Some comments about these results follow.

Group technology is a cellular manufacturing initiative that clusters products and components according to similarity of processing, thereby allowing a smaller set of machines to focus on similar components. GT reduces setup times, often significantly. These initiatives are not necessarily expensive in terms of hardware or software, but they do require substantial data gathering and analysis. Furthermore, they require that the products and components produced by the firm be somewhat stable over time, or at least that the processing steps be somewhat stable. These comments suggest that perhaps GT should not be a key initiative for Chinese manufacturing firms at this time, and our results indicate that it is not.

Just-in-time scores for current status were 1.77, 1.60, 1.75 and 1.92 for SOEs, POEs, JVs and WOFSs, respectively. Scores for future plans were 1.98, 2.00, 2.21, and 2.38, respectively. Low scores on this question are consistent with observations from Pyke et al. (2000) that the firms surveyed are somewhat behind the U.S. on supply chain issues. However, compared with the other technologies for which current status means were below 2.00, the average scores on future plans for JIT were higher. There are several possibilities for why this is true. One is the presence of Japanese partners or other customers who often require JIT implementation. Another is the fact that although JIT requires substantial time and effort, it does not require large capital investments. Yet by most accounts the return on the investment is clear.

Current status mean scores for robotics were extremely low (1.00, 1.00, 1.21, and 1.19, for SOEs, POEs, JVs and WOFSs, respectively) indicating essentially no activity in this area. These results are certainly consistent with common knowledge and our own observations. Robotics are primarily used for two purposes – to save costs by replacing human labor in high volume production environments, and to improve quality in repetitive manufacturing tasks. Labor costs are very low in China, and there is often pressure *not* to lay off employees. Therefore, the cost reduction motivation is rarely justified. Furthermore, the skill level required to install and maintain robotics, and the capital investment necessary, is quite high. Future plans mean scores on this question were also quite low (1.18, 1.20, 1.38 and 1.31 for SOEs, POEs, JVs and WOFSs, respectively), indicating that these firms do not plan to pursue robotics in the future. These results lend face validity to our study.

Similar comments can be made about flexible manufacturing systems (FMS). Scores on both current status and future plans were quite low, although not as low as for robotics. One difference is that JVs and WOFSs were at least considering investing in FMS (average scores of 2.08 for both on question H11). Foreign participation may facilitate the potentially huge investment, although on average these firms were at most considering investment. FMS have seen limited application, and limited success, in the U.S., although Japanese firms have generally been much more successful with them. Hardware and software costs are extremely high, and the systems require highly skilled labor. Very similar results are evident for CAM (G9), CIM (G14), and automated assembly (G16). Likewise, the future plans numbers (H9, H14, and H16) reveal similar patterns. See Tables 3 and 4. The intuition behind the numbers follows the same logic as that for FMS. Furthermore, some of these technologies build on others. For instance, computer aided manufacturing (CAM) is typically implemented with or after computer aided design (CAD), and CIM is commonly considered to be the combination of CAD, CAM and automated materials handling. It would clearly be unusual for firms to indicate an aggressive posture toward CIM without first, or concurrently, implementing CAD and CAM.

Now consider the results for computer aided design (CAD, G7 and H7). Average scores indicate that many firms were in the process of implementing CAD, but not many had fully implemented it. Average scores were 1.90, 1.45, 2.08 and 1.96, respectively, for current status, and were 2.31, 2.05, 2.33, and 2.46, respectively, for future plans. These results reflect a much more aggressive posture toward future investment, in spite of the fact that current implementation is either non-existent or in progress. Our own observations of machine tool and other manufacturing firms support these results. We have seen CAD in operation at some firms and not at others. CAD requires both software and hardware investment, to be sure; but the costs are coming down rapidly. And the benefits, for quality improvement, cost reduction and new product introduction time, are quite clear. Engineering graduates, particularly from top universities such as Tsinghua University in Beijing, may be trained on these systems. Furthermore, the systems are stand-alone in the sense that implementing CAD simply requires design engineers to be trained on a specific system. The output is a design that will be passed on to manufacturing personnel who then produce to that design. In contrast, implementing FMS or automated assembly requires a much larger investment in hardware and software and actually changes the tasks performed by a large number of production floor workers, engineers, maintenance personnel, quality inspectors, and so on.

Size versus Ownership Structure

As we analyzed these results, we debated whether the key issue in new technology adoption is company size rather than ownership structure. Therefore, we tested the correlation between total number of employees and both sets of technology questions (G and H). Of the 16 current status technology (G) questions, only three were significantly correlated with size: quality circles, robotics and ISO 9000. And, of the 16 future plans technology questions, only one was correlated with size: computer driven production planning system. We have seen that the means across ownership types for quality circles and for ISO 9000 were very similar and that most firms were in the process of implementing, or had decided to implement. The means for robotics were very similar, and quite low, for all firms on both sets of questions. For computer driven production planning, the means were similar, but the difference between future plans and current status was much larger. For all four cases, it would appear that, in spite of the explanatory power of ownership structure for many technology questions, size is a better independent variable. Otherwise, ownership structure dominates as the explanatory variable.

Ownership Structure, Technology Adoption and Financial Performance

To summarize our results thus far, there are far fewer differences among ownership types than the popular and business press would have us believe. However, financial performance measures do reveal several significant differences. Furthermore, current technology adoption, and plans for the future, are significantly different in many cases. As noted in Section 3, WOFSs perform better financially, with JVs also above the mean. POEs and SOEs perform much worse. Similarly, WOFSs and JVs are much more advanced implementing many of the new technologies we surveyed than are POEs and SOEs. These comments would suggest that financial performance is closely correlated with technology adoption. Table 6 shows that this is indeed the case. Ten of the sixteen current status technology questions are significantly positively correlated with the financial performance summary scale, and all sixteen signs are positive. Fifteen of the sixteen future plans questions are significantly correlated with this summary scale. All sixteen signs are positive, a pattern significant in a Sign Test at $p < 0.01$. Can we conclude that WOFSs perform better financially *and* they are more advanced technologically, or can we conclude that more technologically advanced firms perform better financially? To sort this out, we created a single summary index, TECH2, which is the sum of all the technology questions, including current status and future plans. We also created a summary measure, WFS, that scores a 1 if the firm is a WOFS and a 0 otherwise. Looking at the correlations between these two summary indices and financial performance, the partial correlation of the technology index is about twice as high as that of the ownership index (0.368 at the 0.000 level for TECH2, and 0.164 at the 0.075 level for WFS). Clearly, the technology index has greater explanatory power and is significant, while the ownership index is significant only at the 0.10 level. In sum, WOFSs do in fact perform better financially, WOFSs are more advanced with new technology, and firms that are more advanced with new technology perform better financially.

5. Results on Improvement Actions

Two sets of questions asked respondents about a number of improvement actions, again divided by current status (denoted the "E" set in our shorthand) and future plans ("F"). As in the technology questions, we asked respondents to score each action with 1 if not implemented, 2 if implementation was in progress, and 3 if fully implemented, for the current status set. Likewise, for future plans, 1 means they have no plans for future investment, 2 means they are considering investment, and 3 means they have decided to make a future investment in the given action. See Tables 7 and 8 for the full list of questions and results by ownership structure. Eight actions listed pertain to labour issues, two to supply chain, four to production cost and processes, one to delivery, one to quality, and three to flexibility. For both the E and F sets of measures, the values were significantly different as a set for the different ownership types.

We now discuss the difference between the mean by ownership structure and the overall mean for specific questions where we observe significant differences. First, for "Give workers a broader range of tasks" (E1), POEs were significantly lower than the overall mean (-0.206, at the 0.024 level). SOEs and WOFSs were higher than the mean, while JVs were lower, but none of these latter three are significant at the 0.10 level. The fact that SOEs were higher is consistent with their well-known strategy of reducing the number of workers. In fact, for the question on reducing the workforce size (E15), SOEs were significantly higher than the mean (0.346, at the 0.000 level). The average score for SOEs on these two questions was 2.08 and 2.34, respectively. In other words, SOEs are currently reducing workforce size and at the same time are giving the remaining workers more tasks. As might be expected SOEs are decidedly planning on continuing these two trends. The means for future plans for giving workers a broader range of tasks and reducing workforce size (F1 and F15) for SOEs were 2.70 and 2.76, respectively. These results again show the face validity of the overall results, and they confirm widely reported workforce reductions in SOEs.

The above results are consistent with the summary scales pertaining to the operations objectives. Several of the questions asked about factory flexibility, both "emphasis during the past year" and "degree of improvement in the past year." SOEs were higher than the other firms on both of these, although the results were significant only at the 0.134 and 0.120 levels respectively. A desire to increase flexibility may be driving SOEs to broader worker tasks.

To fill out this discussion, consider the SOE scores on all the operations objectives summary scales. SOEs seem to place strong emphasis on all the objectives – cost, quality, delivery and flexibility. However, the highest scores for "past year emphasis" were for quality, delivery and cost, in that order. Factory flexibility, while higher than the other firms, was still lower than the other three. SOEs lowest score for "degree of improvement" was for the cost summary scale, revealing perhaps that cost reduction measures, such as workforce reduction, have not proceeded at the desired pace. Furthermore, a strong emphasis on all objectives might suggest a lack of focus, which itself might be a key driver of poor financial performance.

Like SOEs, WOFSs are currently working on giving workers a broader range of tasks (E1) as evidenced by the mean score of 2.12. However, unlike SOEs, in this case the motivation is *not* a reduction in workforce size. The WOFS score on E15 (reduce workforce size) was 1.50. In other words, most of these firms are not reducing the number of workers at all. Regarding plans for the future, WOFSs plan to continue broadening worker activities (the mean on F1 was 2.50), and they do not plan to reduce the number of workers (1.92 on F15). Clearly these firms are not burdened with the holdover from the iron rice bowl.

Table 9 contains results by ownership structure for all the questions from the survey that pertain to workforce issues. There is no clear pattern across all these results, and some of the results appear mixed. For instance, one might conclude from C11, C12 and C13 that POEs give more responsibility to their workers. POEs appear to assign more improvement responsibility to workers (C11), cross train them (C12), and consult them in deciding production schedules (C13). However, this conclusion is not supported by their low scores on E1 and F1 (broader range of tasks), E3 and F3 (changing the labour/management relationship), E4 and F4 (motivate workers), or even on E10 and F10 (increase supervisor training). In other words, they do not appear to have invested in giving more responsibility, or in training or motivating workers or supervisors; and they appear to have less aggressive plans for the future than other firms. Yet, they have provided some cross training and do consult their workers more than others on production scheduling issues. Similar comments can be made about JVs. Responses for JVs on C3 (level of training given to workers), C8 (worker skill) and G1 (quality circles) suggest more training and skill. Yet JVs scored lowest on F2 (giving workers more planning responsibility), F3 (changing the labour/management relationship) and F4 (motivating workers). One final comment: the future plans (F) scores on workforce issues (Table 9) were fairly high across the board, indicating that worker responsibility and motivation are important areas of interest for all firms.

A fascinating result pertains to shifting manufacturing operations to lower cost regions (E6 and F6). SOEs, POEs and JVs all had means around 2.00 (implementation in progress). The mean for WOFSs was 1.65, indicating less current emphasis on this shift. One might wonder why these firms would consider shifting to lower cost regions when they already operate in a low cost country. Are they thinking of moving offshore? Probably not, although Vietnam, Thailand and Indonesia could offer lower cost opportunities. It is more likely that they are considering taking advantage of tax incentives to move further into the interior regions of China. WOFSs are relatively new and are more likely to be comfortable with their choice of location and the associated wage rates, having made the location decision more recently. Also, it is unlikely that they will find expatriates who will be interested in moving away from the Shanghai area, particularly to the interior of China. Differences among ownership types on *future plans* to shift production to low cost regions are, however, significant. Mean scores for SOEs, POEs, JVs and WOFSs were 2.62 , 2.60, 2.50, and 2.00, respectively. The SOE mean score is significantly higher than the overall mean, while the WOFS mean score is significantly lower (0.187 (0.040 level), and –0.331 (0.000 level), respectively). In general, it seems clear that SOEs and POEs are more likely to move operations than JVs or WOFSs.

One further result on technology and improvement actions is found in a question on developing new processes for old products (E7 and F7). Results for current status for SOEs, POEs, JVs and WOFSs, were 2.04, 2.00, 1.58, and 1.73, respectively. These numbers are not particularly surprising because JVs and WOFSs are generally newer enterprises without the burden of old processes. However, they do indicate that SOEs are in the process of improving production processes. The mean values for the same question with regard to plans for the future were 2.46, 2.60, 2.17, and 2.38, respectively. Plans for the future, across ownership types, are more aggressive than current implementation, with some significant proportion of firms having decided to pursue new processes. However, JVs and WOFSs show less inclination for this initiative.

Improvement Actions and Financial Performance

We now examine the relationship between the improvement actions (E & F) and the financial summary scale. For the current status questions (E), eighteen of the nineteen questions have positive signs, and eleven are significant. See Table 10 for results. Six of the questions pertain to assigning more responsibility to workers, training workers and supervisors, and increasing motivation (questions 1,2, 3, 4, 10 and13). For the current status version of these six questions, five are significantly correlated with the financial summary scale. Workforce issues are clearly critical, even in a country with relatively low-cost labour.

The other items that are significant on the current status set are “Introduce new products,” “Reduce production lead time,” “Reduce time to adjust machines in response to producing different customer orders,” “Modify the functions of existing products,” “Increase production capacity,” and “Reduce production cost.” It would be difficult to draw firm conclusions from the significant result on these five questions. However, it is interesting to note that several pertain to *flexibility* for new product introduction and for existing products and customers, several pertain to *delivery* lead times (including the one on increasing production capacity), and at least one pertains to production *cost*. (The question on production capacity may relate to production cost, depending on the rationale for increasing capacity). What is striking about these results is that three of the four operations objectives (cost, delivery and flexibility) are significantly correlated with financial performance, and the fourth, quality, was represented explicitly by only one item in this set of questions. In other words, it is not possible to conclude that firms pursuing a particular objective are more likely to perform better financially. Rather, one observes support for the notion of "equifinality" – that there are multiple strategies that can lead to superior performance in a given industry or market niche. In addition, there is some evidence that fit and consistency may be more important than direction (Smith & Reece (1999) and Boyer & McDermott (1999)).

For the future plans questions (F), six of nineteen are significant at the 0.05 level (eight at the 0.10 level), and seventeen signs are positive. The questions with significant correlations are 3, 4, 5, 10, 11 and 13. All of these but question 11 relate to workforce issues. The question about worker safety (F5) is significant for future plans, but not for current status. However, questions F1 and F2 (broader range of tasks and more planning responsibility) are not significant for future plans, but are for current status. While the results are not completely consistent, we can conclude in general that high scores on current status and future plans for worker relationship, motivation and training are positively correlated with financial performance. Interestingly two correlations, F6 and F15 ("shift operations to low cost regions," and "reduce workforce size"), are negative. Because SOEs score significantly higher on these questions, however, it seems clear that it is *not* the fact of planning to shift operations or reduce workforce size that reduces financial performance. Rather, SOEs perform worse financially, and these are the very firms that score high on these questions.

Finally, we address the same question of the improvement actions that we did of the technology questions: is the key driver size, rather than ownership structure? As it happens, the answer is very similar. *None* of the current status questions are correlated with size (number of total employees), and only one of the future plans questions is. The one significant result was F6 – shifting operations to low cost regions. Again, it seems clear that ownership structure is a much more important explanatory variable than size for these improvement action questions.

6. Conclusions and Discussion

We have analyzed results from a survey of 120 manufacturing firms in the Shanghai region. Focusing on four ownership structures – state-owned enterprises (SOEs), privately owned enterprises (POEs), joint ventures (JVs) and wholly owned foreign subsidiaries (WOFSs) – we discovered that for the majority of questions, there are few significant differences. For manufacturing technologies, however, we found otherwise. In particular, WOFSs and JVs are clearly more advanced, and are planning further investment, while SOEs and POEs are lagging behind. WOFSs show significantly more improvement in financial performance, while JVs are above average and SOEs and POEs below average. We also examined whether firm size is a more powerful explanatory variable than ownership structure and discovered that it is not. Finally, broadly speaking we determined that firms that emphasize workforce training, responsibility and motivation show better improvement in profitability.

Our results confirm many commonly held insights about state-owned enterprises, but they also reveal that the many assumed differences among ownership types might not be as great as the business press would suggest. A further study on these issues would be interesting, particularly given the many changes that are happening in China. Are SOEs progressing more rapidly now? Have they been able to pursue some of the new technologies? What sort of survivorship bias can we detect? What about other ownership structures? These and other questions could form the basis of fascinating research.

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Product Line/Industry	Number of Firms in the Sample
Consumer goods	
Durable consumer goods	17
Non-durable consumer goods	44
Goods for industrial / commercial / government uses	
Manufacturing equipment (capital goods)	15
Raw materials or half-finished products	10
Parts / components for assembling	24
Supplies and other consumption goods	10

Table 1: Industry representation

Scale	Number of Items	Scale Content	Reliability (Cronbach ∝)
Competitive Quality Objectives	3	Emphasis on improving product reliability, improving quality consistency, good after-sale service	0.63
Improvement in Quality Performance	4	Improved product reliability, improving quality consistency, good after-sale service, increasing product durability	0.75
Competitive Delivery Objectives	3	Emphasis on time for completion, delivery and meeting due dates	0.64
Improvement in Delivery	3	Improved time for completion, delivery and meeting due dates	0.86
Competitive New Product Flexibility Objectives	3	Emphasis on reducing time to introduction, adding functions, introducing more products	0.65
Improvement in New Product Flexibility	3	Improvement in time to introduction, adding functions and new product introductions	0.72
Competitive Factory Flexibility Objectives	2	Emphasis on ability to change product volume and product mix	0.28
Improvement in Factory Flexibility	2	Improvement in ability to change product volume and product mix	0.61
Improvement in Performance	3	Improved market share, profitability and return on sales	0.83

Table 2: Scales and reliabilities

		SOE		POE		JV		WOFS		Total	
Item	Question	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
G1	Quality circles	2.37	0.60	2.40	0.75	2.42	0.65	2.38	0.64	2.39	0.64
G2	Automation in production	1.76	0.52	1.55*	0.76	2.08	0.65	2.27*	0.67	1.90	0.67
G3	Computerization in administration (office automation)	1.82*	0.52	1.70*	0.66	2.33*	0.64	2.38*	0.57	2.03	0.64
G4	Computer driven materials planning system	1.60*	0.64	1.70	0.66	2.13*	0.74	1.92	0.69	1.79	0.70
G5	Computer driven production planning system	1.60*	0.61	1.60	0.68	2.08*	0.78	1.96	0.72	1.78	0.70
G6	Group technology	1.52	0.68	1.45	0.69	1.71	0.75	1.73	0.83	1.59	0.73
G7	CAD (Computer aided design)	1.90	0.68	1.45*	0.69	2.08	0.78	1.96	0.87	1.88	0.76
G8	JIT (Producing parts only when products are needed)	1.77	0.78	1.60	0.68	1.75	0.68	1.92	0.80	1.77	0.74
G9	CAM (Computer aided manufacturing)	1.46	0.65	1.20*	0.52	1.63	0.82	1.73*	0.78	1.51	0.71
G10	Robotics	1.00*	0.00	1.00	0.00	1.21	0.51	1.19	0.57	1.08	0.36
G11	FMS (Flexible manufacturing systems)	1.40	0.61	1.40	0.60	1.79*	0.78	1.65	0.80	1.53	0.70
G12	Statistical Process Control (SPC)	1.74	0.72	1.40*	0.50	2.08	0.78	2.15*	0.83	1.84	0.77
G13	ISO 9000	2.02	0.82	1.55*	0.60	2.04	0.81	2.00	0.94	1.94	0.82
G14	Computer Integrated Manufacturing (CIM)	1.36	0.63	1.10*	0.31	1.58	0.65	1.54	0.71	1.40	0.63
G15	Electronic Data Interchange (EDI)	1.30	0.58	1.05*	0.22	1.38	0.49	1.50	0.71	1.32	0.56
G16	Automated assembly	1.27	0.49	1.20	0.41	1.58*	0.78	1.46	0.76	1.36	0.62

Table 3: Current Status on Manufacturing Technologies (*$p = 0.05$)

		SOE		POE		JV		WOFS		Total	
Item	Question	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
H1	Quality circles	2.52	0.71	2.80	0.52	2.63	0.58	2.77	0.59	2.64	0.63
H2	Automation in production	2.14	0.67	2.00	0.73	2.42	0.78	2.54*	0.76	2.26	0.74
H3	Computerization in administration (office automation)	2.36*	0.69	2.35	0.67	2.67	0.64	2.85*	0.46	2.53	0.66
H4	Computer driven materials planning system	2.42	0.70	2.10	0.72	2.29	0.86	2.54	0.71	2.37	0.74
H5	Computer driven production planning system	2.42	0.64	2.00*	0.73	2.46	0.78	2.62	0.70	2.40	0.71
H6	Group technology	1.92	0.78	1.70	0.86	2.04	0.91	1.96	0.87	1.92	0.84
H7	CAD (Computer aided design)	2.31	0.80	2.05	0.83	2.33	0.87	2.46	0.76	2.30	0.81
H8	JIT (Producing parts only when products are needed)	1.98	0.82	2.00	0.79	2.21	0.83	2.38	0.80	2.12	0.82
H9	CAM (Computer aided manufacturing)	1.80	0.73	1.79	0.71	1.88	0.90	2.15	0.92	1.89	0.81
H10	Robotics	1.18	0.52	1.20	0.41	1.38	0.71	1.31	0.68	1.25	0.58
H11	FMS (Flexible manufacturing systems)	1.72	0.73	1.70	0.80	2.08	0.88	2.08	0.84	1.87	0.81
H12	Statistical Process Control (SPC)	2.10	0.76	1.85	0.81	2.21	0.88	2.42	0.76	2.15	0.81
H13	ISO 9000	2.64*	0.53	2.15*	0.67	2.33	0.82	2.58	0.76	2.48	0.69
H14	Computer Integrated Manufacturing (CIM)	1.65*	0.72	1.65	0.67	2.17*	0.92	2.04	0.87	1.84	0.81
H15	Electronic Data Interchange (EDI)	1.74	0.80	1.60	0.60	1.83	0.87	1.88	0.86	1.77	0.80
H16	Automated assembly	1.53	0.74	1.60	0.75	1.96	0.81	1.81	0.90	1.69	0.80

Table 4: Future Plans Regarding Manufacturing Technologies (*$p = 0.05$)

Item	Question		SOE	POE	JV	WOFS
1	Quality circles	Pearson Correlation	-0.11	0.08	-0.03	0.09
		Sig. (2-tailed)	0.25	0.37	0.71	0.35
2	Automation in production	Pearson Correlation	0.03	0.06	-0.02	-0.07
		Sig. (2-tailed)	0.77	0.51	0.84	0.45
3	Computerization in administration (office automation)	Pearson Correlation	0.05	0.10	-0.13	-0.03
		Sig. (2-tailed)	0.57	0.26	0.16	0.73
4	Computer driven materials planning system	Pearson Correlation	0.29*	-0.11	-0.29*	0.03
		Sig. (2-tailed)	0.00	0.23	0.00	0.74
5	Computer driven production planning system	Pearson Correlation	0.23*	-0.14	-0.18*	0.02
		Sig. (2-tailed)	0.01	0.12	0.05	0.82
6	Group technology	Pearson Correlation	0.09	-0.05	0.01	-0.07
		Sig. (2-tailed)	0.33	0.61	0.95	0.45
7	CAD (Computer aided design)	Pearson Correlation	-0.04	0.12	-0.12	0.06
		Sig. (2-tailed)	0.67	0.21	0.18	0.51
8	JIT (Producing parts only when products are needed)	Pearson Correlation	-0.17	0.03	0.08	0.09
		Sig. (2-tailed)	0.08	0.72	0.39	0.35
9	CAM (Computer aided manufacturing)	Pearson Correlation	-0.05	0.14	-0.10	0.04
		Sig. (2-tailed)	0.59	0.14	0.28	0.69
10	Robotics	Pearson Correlation	0.02	0.03	0.00	-0.06
		Sig. (2-tailed)	0.80	0.73	1.00	0.53
11	FMS (Flexible manufacturing systems)	Pearson Correlation	-0.02	-0.03	-0.04	0.09
		Sig. (2-tailed)	0.81	0.76	0.67	0.33
12	Statistical Process Control (SPC)	Pearson Correlation	0.07	0.09	-0.14	-0.03
		Sig. (2-tailed)	0.48	0.30	0.14	0.74
13	ISO 9000	Pearson Correlation	0.08	0.03	-0.16	0.02
		Sig. (2-tailed)	0.36	0.72	0.08	0.80
14	Computer Integrated Manufacturing (CIM)	Pearson Correlation	-0.18	0.07	0.10	0.05
		Sig. (2-tailed)	0.06	0.44	0.27	0.62
15	Electronic Data Interchange (EDI)	Pearson Correlation	-0.01	0.07	0.01	-0.06
		Sig. (2-tailed)	0.88	0.42	0.94	0.54
16	Automated assembly	Pearson Correlation	-0.09	0.05	0.04	0.02
		Sig. (2-tailed)	0.34	0.56	0.67	0.86

Table 5: Differences between Future Technology Plans and Current Status: Difference of (H – G) values from the mean H – G value (*$p = 0.05$)

Item	Question		Current Status	Future Plans
1	Quality circles	Pearson Correlation	0.03	0.18*
		Sig. (2-tailed)	0.74	0.04
2	Automation in production	Pearson Correlation	0.09	0.22*
		Sig. (2-tailed)	0.32	0.02
3	Computerization in administration (office automation)	Pearson Correlation	0.34*	0.36*
		Sig. (2-tailed)	0.00	0.00
4	Computer driven materials planning system	Pearson Correlation	0.34*	0.33*
		Sig. (2-tailed)	0.00	0.00
5	Computer driven production planning system	Pearson Correlation	0.33*	0.31*
		Sig. (2-tailed)	0.00	0.00
6	Group technology	Pearson Correlation	0.22*	0.24*
		Sig. (2-tailed)	0.01	0.01
7	CAD (Computer aided design)	Pearson Correlation	0.20*	0.26*
		Sig. (2-tailed)	0.03	0.00
8	JIT (Producing parts only when products are needed)	Pearson Correlation	0.14	0.27*
		Sig. (2-tailed)	0.12	0.00
9	CAM (Computer aided manufacturing)	Pearson Correlation	0.22*	0.27*
		Sig. (2-tailed)	0.02	0.00
10	Robotics	Pearson Correlation	0.19*	0.22*
		Sig. (2-tailed)	0.04	0.01
11	FMS (Flexible manufacturing systems)	Pearson Correlation	0.13	0.18*
		Sig. (2-tailed)	0.15	0.05
12	Statistical Process Control (SPC)	Pearson Correlation	0.29*	0.31*
		Sig. (2-tailed)	0.00	0.00
13	ISO 9000	Pearson Correlation	0.29*	0.22*
		Sig. (2-tailed)	0.00	0.02
14	Computer Integrated Manufacturing (CIM)	Pearson Correlation	0.24*	0.30*
		Sig. (2-tailed)	0.01	0.00
15	Electronic Data Interchange (EDI)	Pearson Correlation	0.14	0.19*
		Sig. (2-tailed)	0.12	0.04
16	Automated assembly	Pearson Correlation	0.06	0.10
		Sig. (2-tailed)	0.54	0.28

Table 6: Correlations between Technology Questions and the Financial Performance Summary Scale (*p = 0.05)

		SOE		POE		JV		WOFS		Total	
Item	Question	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
E1	Give workers a broader range of tasks	2.08	0.53	1.70*	0.47	1.83	0.76	2.12	0.59	1.98	0.60
E2	Give workers more planning responsibility	1.60	0.57	1.65	0.49	1.67	0.64	1.65	0.69	1.63	0.59
E3	Changing the labour/management relationship	2.18	0.60	2.10	0.72	2.17	0.64	2.31	0.62	2.19	0.63
E4	Motivate workers	2.16	0.65	2.00	0.73	2.08	0.65	2.23	0.65	2.13	0.66
E5	Improve worker safety	2.60	0.53	2.55	0.60	2.54	0.66	2.65	0.56	2.59	0.57
E6	Shift manufacturing operations to low cost regions	2.06	0.71	2.05	0.51	1.96	0.69	1.65*	0.80	1.95	0.71
E7	Develop new processes for old products	2.04	0.60	2.00	0.65	1.58*	0.65	1.73	0.72	1.88	0.67
E8	Introduce more new products	2.14	0.57	2.05	0.60	1.92	0.65	2.27	0.67	2.11	0.62
E9	Reduce production lead time	2.34	0.63	2.30	0.57	2.29	0.62	2.42	0.58	2.34	0.60
E10	Increase supervisor training	2.10*	0.74	2.30	0.57	2.58*	0.58	2.27	0.72	2.27	0.69
E11	Monitor the quality of materials from suppliers	2.38	0.64	2.55	0.60	2.58	0.65	2.42	0.58	2.46	0.62
E12	Reduce the time to adjust machines in response to producing different customer orders	2.12	0.66	2.35	0.67	2.33	0.64	2.15	0.67	2.21	0.66
E13	Introduce more worker training	1.92	0.63	1.90	0.64	2.00	0.66	2.23*	0.59	2.00	0.64
E14	Modify the functions of existing products	1.88	0.59	1.90	0.79	1.88	0.54	1.65	0.75	1.83	0.65
E15	Reduce workforce size	2.34*	0.59	2.00	0.73	1.96	0.86	1.50*	0.76	2.03	0.77
E16	Increase production capacity	2.38	0.49	2.15	0.59	2.33	0.48	2.15	0.46	2.28	0.51
E17	Reduce production cost	2.16	0.42	2.20	0.62	2.33	0.56	2.15	0.46	2.20	0.50
E18	Improve relationships with suppliers	2.28	0.50	2.50	0.61	2.33	0.64	2.27	0.60	2.33	0.57
E19	Improve relationships with customers	2.40	0.49	2.45	0.51	2.54	0.51	2.38	0.50	2.43	0.50

Table 7: Current Status on Improvement Actions (*$p = 0.05$)

		SOE		POE		JV		WOFS		Total	
Item	Question	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
F1	Give workers a broader range of tasks	2.70*	0.51	2.05*	0.69	2.29	0.75	2.50	0.76	2.47	0.69
F2	Give workers more planning responsibility	2.24	0.69	2.10	0.79	1.96	0.81	2.35	0.75	2.18	0.74
F3	Changing the labour/management relationship	2.82	0.39	2.70	0.57	2.46*	0.72	2.85	0.46	2.73	0.53
F4	Motivate workers	2.80	0.40	2.70	0.47	2.67	0.64	2.92	0.27	2.78	0.45
F5	Improve worker safety	2.82	0.39	2.90	0.31	2.79	0.51	2.77	0.51	2.82	0.43
F6	Shift manufacturing operations to low cost regions	2.62*	0.64	2.60	0.60	2.50	0.72	2.00*	0.85	2.46	0.73
F7	Develop new processes for old products	2.46	0.71	2.60	0.50	2.17	0.82	2.38	0.80	2.41	0.73
F8	Introduce more new products	2.86	0.35	2.70	0.47	2.71	0.55	2.88	0.43	2.81	0.44
F9	Reduce production lead time	2.76	0.48	2.80	0.41	2.75	0.53	2.85	0.46	2.78	0.47
F10	Increase supervisor training	2.82	0.39	2.80	0.41	2.88	0.34	2.81	0.40	2.83	0.38
F11	Monitor the quality of materials from suppliers	2.84	0.42	2.85	0.49	2.92	0.28	2.96	0.20	2.88	0.37
F12	Reduce the time to adjust machines in response to producing different customer orders	2.70	0.54	2.70	0.47	2.83	0.38	2.69	0.68	2.73	0.53
F13	Introduce more worker training	2.82	0.39	2.50	0.61	2.46*	0.72	2.81	0.40	2.69	0.53
F14	Modify the functions of existing products	2.54	0.61	2.20	0.62	2.50	0.66	2.35	0.80	2.43	0.67
F15	Reduce workforce size	2.76*	0.48	2.45	0.60	2.50	0.72	1.92*	0.80	2.48	0.70
F16	Increase production capacity	2.94*	0.24	2.85	0.37	2.75	0.44	2.81	0.49	2.86	0.37
F17	Reduce production cost	2.94	0.24	2.90	0.31	2.88	0.34	2.92	0.27	2.92	0.28
F18	Improve relationships with suppliers	2.82	0.44	2.75	0.44	2.79	0.41	2.88	0.43	2.82	0.43
F19	Improve relationships with customers	2.94	0.24	2.85	0.37	2.96	0.20	2.96	0.20	2.93	0.25

Table 8: Future Plans Regarding Improvement Actions (*$p = 0.05$)

Item / Question	SOE	POE	JV	WOFS	Scale	Signif.
C3 Level of training given to workers	4.26	3.95	5.00	4.50	7 = high	No
C8 The workers' skills at doing their jobs	5.38	4.85	5.75	5.54	7 = high	0.04
C11 Our workers have no role in helping to improve the manufacturing process	2.42	2.25	2.83	2.31	7 = strongly agree	No
C12 Our workers are trained to manage different stages of the production process	5.82	6.05	5.12	6.46	7 = strongly agree	0.01
C13 Our workers are consulted in deciding the production schedule	3.74	5.00	3.42	3.88	7 = strongly agree	No 0.054
J6 Degree to which Supervisors understand the objectives and plans of the manufacturing strategy of your company	4.58	4.95	4.75	5.31	7 = fully understand	No
J7 Degree to which Leading Hands understand the objectives and plans of the manufacturing strategy of your company	3.80	3.80	3.96	4.08	7 = fully understand	No
J7 Degree to which Workers/Operators understand the objectives and plans of the manufacturing strategy of your company	3.48	3.40	3.63	3.54	7 = fully understand	No
E1 Give workers a broader range of tasks	2.08	1.70	1.83	2.12	See Table 6	0.04
E2 Give workers more planning responsibility	1.60	1.65	1.67	1.65		No
E3 Changing the labour/management relationship	2.18	2.10	2.17	2.31		No
E4 Motivate workers	2.16	2.00	2.08	2.23		No
E5 Improve worker safety	2.60	2.55	2.54	2.65		No
E10 Increase supervisor training	2.10	2.30	2.58	2.27		0.05
E15 Reduce workforce size	2.34	2.00	1.96	1.50		0.00
F1 Give workers a broader range of tasks	2.70	2.05	2.29	2.50	See Table 7	0.00
F2 Give workers more planning responsibility	2.24	2.10	1.96	2.35		No
F3 Changing the labour/management relationship	2.82	2.70	2.46	2.85		0.03
F4 Motivate workers	2.80	2.70	2.67	2.92		No
F5 Improve worker safety	2.82	2.90	2.79	2.77		No
F10 Increase supervisor training	2.82	2.80	2.88	2.81		No
F15 Reduce workforce size	2.76	2.45	2.50	1.92		0.00
G1 Quality circles	2.37	2.40	2.42	2.38	See Table 2	No
H1 Quality circles	2.52	2.80	2.63	2.77	See Table 3	No
K12 Number of operators/workers currently	799.94	138.65	312.08	285.62		0.01
K13 Number of total employees currently	1322.10	249.85	608.50	564.42		0.01
K14 Number of total employees five years ago	2094.80	248.30	320.04	335.88		0.00

Table 9: Workforce Issues

Item	Question		Current Status	Future Plans
1	Give workers a broader range of tasks	Pearson Correlation	0.12	0.11
		Sig. (2-tailed)	0.21	0.23
2	Give workers more planning responsibility	Pearson Correlation	0.21*	0.13
		Sig. (2-tailed)	0.02	0.15
3	Changing the labour/management relationship	Pearson Correlation	0.21*	0.23*
		Sig. (2-tailed)	0.02	0.01
4	Motivate workers	Pearson Correlation	0.43*	0.25*
		Sig. (2-tailed)	0.00	0.01
5	Improve worker safety	Pearson Correlation	0.13	0.20*
		Sig. (2-tailed)	0.15	0.03
6	Shift manufacturing operations to low cost regions	Pearson Correlation	0.01	-0.13
		Sig. (2-tailed)	0.87	0.15
7	Develop new processes for old products	Pearson Correlation	0.04	0.03
		Sig. (2-tailed)	0.69	0.72
8	Introduce more new products	Pearson Correlation	0.25*	0.11
		Sig. (2-tailed)	0.01	0.24
9	Reduce production lead time	Pearson Correlation	0.19*	0.12
		Sig. (2-tailed)	0.04	0.20
10	Increase supervisor training	Pearson Correlation	0.23*	0.24*
		Sig. (2-tailed)	0.01	0.01
11	Monitor the quality of materials from suppliers	Pearson Correlation	0.11	0.25*
		Sig. (2-tailed)	0.25	0.01
12	Reduce the time to adjust machines in response to producing different customer orders	Pearson Correlation	0.22*	0.14
		Sig. (2-tailed)	0.02	0.12
13	Introduce more worker training	Pearson Correlation	0.31*	0.23*
		Sig. (2-tailed)	0.00	0.01
14	Modify the functions of existing products	Pearson Correlation	0.21*	0.17
		Sig. (2-tailed)	0.02	0.06
15	Reduce workforce size	Pearson Correlation	-0.11	-0.06
		Sig. (2-tailed)	0.24	0.55
16	Increase production capacity	Pearson Correlation	0.19*	0.08
		Sig. (2-tailed)	0.03	0.39
17	Reduce production cost	Pearson Correlation	0.25*	0.17
		Sig. (2-tailed)	0.01	0.07
18	Improve relationships with suppliers	Pearson Correlation	0.09	0.10
		Sig. (2-tailed)	0.32	0.30
19	Improve relationships with customers	Pearson Correlation	0.08	0.09
		Sig. (2-tailed)	0.37	0.33

Table 10: Correlations between Improvement Action Questions and the Financial Performance Summary Scale (*$p = 0.05$)