Human resources development and integrated manufacturing systems

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Abstract
This paper records the research on human resources development associated with integrated manufacturing. The research is based on a survey in 18 countries. It is found that only parts of the human resources factors are significantly related to the level of computerised integration. It is also found that the level of integration and the development of human resources vary from country to country. However, the difference in human resources development is bigger than the differences in the level of integration. The country context may be another source for explaining the development of human resources. Future research on revealing the forces driving human resources development is suggested.

1. Introduction

This paper records the research on human resource development versus the level of computerised integration and automation. Academically, it concerns the relationship between technology and organisation/human resources, which has been a research topic as far back as the 1960s (e.g. Woodward, 1965; Chadwick-Jones, 1969). Research on this topic has been given fresh impetus by the advent of computer-integrated manufacturing (CIM).

CIM is the term used to describe the modern approach of manufacturing (Groover, 1987; Haywood, 1990; Singh, 1996; Kotha and Swamidass, 1998). The main feature of CIM is the integration of all manufacturing functions, including design, engineering, planning, control, fabrication, and assembly through the use of computer-aided technologies. According to the CIM wheel model of the Society of Manufacturing Engineer (SME), there are one business and four technical components of a CIM system (Goetsch, 1990). The four technical components are "planning and controlling", "information resources management", "product and process definition", and "factory automation".

AMTs are the technical components of a CIM system. AMT refers to computer-aided technologies used in the whole manufacturing process. Corresponding to the four technical components of the CIM wheel model, AMT can be divided into four types as well. The first type includes material requirement planning (MRP) and manufacturing resources requirement (MRP II) for planning and controlling. The second type includes shared databases (Shared DB), wide area network (WAN), and local area network (LAN) for information resources management. The third type includes computer-aided design (CAD) and computer-aided engineering (CAE) for product design and development. The last type includes numerical control/computer/direct (NC/CNC/DNC), computer-aided inspection/testing/tracking (CAI/T/T), computer-aided manufacturing like flexible manufacturing cell or systems (FMC/FMS), automated parts loading/unloading (APL/U), automated tool changes (ATC), robotics (Robot), automated storage/retrieval systems (AS/AR), and automated guided vehicles (AGV) for factory automation.

AMT and CIM have been regarded as competitive weapons to improve manufacturing and business performance. Although AMTs have been widely implemented in the past 10-20 years, failures have been widely reported. Many companies have not been able to obtain the full potential of AMT. For example, US firms experienced an estimated 50-70 per cent failure rate when implementing AMT (Argote *et al.*, 1986; Cornfield, 1987 etc.), and studies in the UK found the similar failure rate of implementing AMT in the UK. Bessant (1990, pp. 354-7) reviewed several studies reporting failures of AMT technologies. In one study, managers were asked to rate their investment in terms of their (subjective) view of the return to the firm. Their responses suggest that nearly 50 per cent of CAD users were dissatisfied, whilst 70 per cent of the users of FMS and nearly 80 per cent of robot users felt their investments had given them "Zero low payoff". And in a study of 33 firms using computer-aided production management (CAPM) systems, nearly a third were considered by the users to have been failures. The study concludes "even advanced users are not getting the full benefits from their systems".

It appears that there has been an imbalance between the relative importance of system design and people/implementation issues (Samson *et al.*, 1993). Many researchers believe that the failure of AMT is

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mainly due to the neglect of human resources and organisational factors (Voss, 1988; Kochan, 1988; Gerwin and Kolodny, 1992; Saraph and Sebastian, 1992; Zammuto and Edward, 1992; Sun and Gertsen, 1995 etc.). This research aims to empirically investigate whether human resources are developed in balance with the level of computerised integration and, in addition, will also empirically compare the level of integration versus the human resources development in 18 countries.

2. Literature review and hypotheses

Plenty of previous research was found on the changes in human resources in association with single AMTs. Lee and Leonard (1990) discovered that the automated guided vehicle (AGV) in a small batch-manufacturing environment altered the nature of human work. Saraph and Sebastian (1992) reviewed many previous studies and concluded that the failure of AMT is mainly due to the implicit or explicit neglect of critical human resource factors. Gerwin and Kolodny (1992, p. 215) said that AMT invites a wide range of changes in human resources management and practices. They further suggested that human resources development should be integrated with the design of new technologies in the manufacturing environment. Samson *et al.* (1993) argue that human resources issues such as commitment, involvement, acceptance of changes, culture, work and skills should be considered for the successful implementation of AMT. According to these previous studies, the human resources suitable for AMT are characterised by lower division of labour, frequent job rotation, stable employment, active employees' participation, loose first-line supervision, more training, team-based work organisation, group-based incentive system etc. as summarised in Table I. (The operational measure in the last column will be discussed in the next section.) In this research, human resources development refers in particular to the moving from old to new forms of human resources.

Although the general direct of human resources development associated with single AMT has been pointed by previous research, empirical research which investigates the relationship between the human resources development and the level of integration as the consequences of applying AMT is limited. Different types and different amounts of AMTs used will lead to differences in the levels of integration in a manufacturing system. Bessant and Haywood (1988) suggested four levels of integration. They are standalone, islands of automation, archipelago of automation (i.e. partially integrated) and fully integrated systems. Standalone AMT refers to single machines or equipment that are not directly connected with other machines or systems by computers. NC machine is a typical example of standalone AMT in fabrication and a single CAD is a standalone AMT in design process. An island of automation refers to a special group of automated machines that work together but have no direct communication with other machines and systems outside their group. FMS is a typical island of automation in manufacturing. Island of automation exists also in the design, engineering and process planning processes. Integration refers to the connection of at least two different functions by computer. For example A CAPP can link design and engineering processes by converting design parameters into manufacturing plan and codes. MRP II system can link design, manufacturing and finance functions to dynamically update the changes of raw materials or components. Integration varies from partially integrated to fully integrated.

The research reported here will focus on the relationship between human resources development and the level of integration,

Table I
Two types of human resources and their operational measures

Human factors	Old form	New form	Operational measure
Division of labour	High	Low	Number of job classification
Employment period	Short term	Long term	Percentage of short-term employees
Worker participation	Inactive	Active	Suggestions per employee per year
Skills	Single	Multiple	Percentage of multi-skilled operators
Job rotation	Rare	Frequent	Frequency of job rotation
Supervision	Tight	Loose	Span of control
Training	Less	More	Hours of training per employee per year
Work organisation	Individual	Team	Percentage of workforce in teams
Incentive system	Individual	Group	Percentage of individual-based incentive systems

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which is achieved from using various AMTs in and between design, plan and manufacturing functions. The research intention will be reflected by the following hypotheses, which are formulated based on case studies (Sun and Gertsen, 1995) and previous research.

Division of labour reflects the degree of specialisation and is measured by the number of job classifications. The more the numbers of job classifications, the narrower the division of labour, and vice versa. Adoption of AMT will trigger changes in job design, which in turn introduced changes in job classification (Saraph and Sebastian, 1992). When automation level is high, jobs are likely to be both horizontally and vertically loaded. Operators do not only perform tasks like loading and unloading but also are given equal authority and responsibility for shop-floor level administration. For example, all the seven operators in an FMS plant in Denmark take care of the weekly schedule, communications with the material department, and interviewing new members (Sun and Gertsen, 1995). The foreman in the plant is nearly equal to the other six operators, except he keeps records of the performance of the plant. The plant is supervised by every operator. So a high integration production environment will have relatively fewer job classifications and fewer vertical levels. Butera (1984) also supports this point. Based on this case and previous research, the following two hypotheses are formulated about division of labour and supervision.

H1: The higher the level of integration, the fewer will be the number of job classifications.

H2: The higher the level of integration, the less will be the span of control and supervision.

Literature on the length of employment around automation and integration is sparse. Stuart (1997) reports that many Japanese, Singapore, and Korean companies with automated and integrated technologies have a commitment to lifelong employment. In a Danish FMS plant (Sun and Gertsen, 1995), all seven members of the plant are employed for a longer term than those workers working around conventional equipment. They are also paid monthly salaries instead of hourly wages. If there are not enough orders, other workers may have to stay at home with discounted payment. However, the workers in the FMS plant still get their full monthly salaries. Considering the different sizes of companies, a percentage, instead of numbers, of short-term employees is used to measure the employment period. Based on this case study, a hypothesis is formulated.

H3: The higher the level of integration, the smaller will be the percentage of short-term employees.

Participation is another feature of human resources in the integrated manufacturing environment. Resistance from labour against automation and integration is mainly due to insufficient communication and participation. Employee participation is an effective way of communicating as well as training. By participating employees can identify problems and derive their own solutions. In Japanese companies with automated and integrated technologies, operators are encouraged to suggest and implement their own ideas (Stuart, 1997). Suggestions given by employees are an indication of the extent of their participation in the improvement process. The hypothesis regarding the relationship between level of integration and the participation of employees is formulated below:

H4: The higher the level of integration, the more the number of suggestions per employee per year.

Although traditional skills like controlling the machining process are not required, new skills like programming control and other administrative skills are required in the automated and integrated manufacturing environment. In the CNC and FMS systems in Danish companies, the majority are skilled workers (Sun and Gertsen, 1995). It is also customary to deploy skilled workers on CNC machines in Germany (Hartmut, 1993). To be a skilled worker, more training is needed. Traditional training is mainly based on on-the-job training. However, the automated manufacturing environment will first depend on structured off-the-job class training and then followed by unstructured on-the-job training. That means, of course, that training time will be longer. Due to multi-skills, equality and fewer job classifications, job rotation can be accomplished between operators. For example, in the Danish FMS plant, the seven operators can fully rotate their tasks (Sun and Gertsen, 1995). Job rotation is used to transfer understanding and facilitate the implementation of AMT (Stuart, 1997). Based on the above discussions, the following three hypotheses are formulated about skills and training.

H5: The higher the level of integration, the higher will be the percentage of multi-skilled operators.

H6: The higher the level of integration, the more hours will be needed for training per employee per year.

H7: The higher the level of integration, the more frequent will be job rotation between workers.

In the early days, integrated manufacturing allowed little or no scope for alternatives in organising work (Hartmut, 1993). Programming control etc. is designed to take place in the office and away from the shop floor. Operators are organised individually as they were around traditional machines. However, in the early 1980s, new forms such as group-based work organisation (Horte, 1989; Bengtsson, 1992; Steudel and Desruelle, 1992) were proposed and implemented. The group-based work organisation can be reflected by the percentage of employees working in teams. To reflect the relationship between integration and the way that workers are organised, the following hypothesis is formulated.

H8: The higher the level of integration, the larger will be the percentage of workers working in teams.

In the traditional manufacturing environment, workers are paid mainly according to their individual working hours. However, the automated manufacturing environment requires increased teamwork and co-ordination. The differentiation between workers and supervisors is smaller. Team performance is more important than that of individuals. Group performance and group incentive are emphasised and individual-based incentive is reduced. So the following hypothesis is formulated.

H9: The higher the level of integration, the smaller will be the percentage of companies which adopt individual-based incentive systems.

In addition to the hypotheses on the relationship between automation level and individual human resources factors, the relationship between integration level and human resources development as a whole will also be studied. Previous research revealed that the success rates of AMT/CIM vary from country to country. Haywood and Bessant (1987) had made a comparison of economic performance between Swedish and British small and medium sized (less than 1,000 employees) manufacturing companies with FMS/FMC. They found that, although company size and adopted AMT technologies are more or less the same, the level of economic efficiency in the Swedish companies was double that of their British counterparts – £69,000 to £34,000. The technologies were more or less the same, and did not explain the differences in performance. However, many organisational and human dimensions between the two countries' manufacturers are really different, and may account for the differences in efficiency. For example, employees in Swedish companies have both better education and skills. About 75 per cent of school leavers went on to higher education in one form or another, while the percentage in the UK is only about 30 per cent. Jaikumar (1986) carried out a study of 35 FMS systems in the USA and 60 in Japan, which produced comparable products. These systems required similar metal cutting times, numbers of tools, and the precision of parts. However, their performances in terms of flexibility are different. The average number of parts made by an FMS was ten in the USA, and 93 in Japan, almost ten times greater. Seven of the US FMSs produced just three parts. For every new part introduced into a US FMS, 22 new parts were introduced in its Japanese counterpart. Jaikumar concluded that the USA was not using AMT effectively, and used FMS incorrectly. Kochan (1988) compared the US and Japanese car companies and had found that the Japanese companies have more advanced human resources systems, while the US companies had more advanced technologies. He also found that high quality and high productivity in Japanese companies were correlated with human resources development. Based on these previous studies, the following hypothesis is formulated.

H10: Human resources developments are different in the 18 countries.

In addition to investigating the differences in individual human resources factors, the overall human resources status will also be compared. The intention of the comparison is to provide benchmarks so that countries know what is their position in technological development versus human resources development in comparison with other countries, so that future areas for improvement can be identified, and learning from companies in other countries can be initiated.

3. Method and empirical data

The research reported in this paper is based on data from the International Manufacturing Strategy Survey (IMSS). IMSS was initiated by the London Business School and Chalmers University of Technology and is being co-ordinated by the Instituto de Empresa in Spain. Researchers in more than 20 countries carried out the survey, which has been conducted twice. The first time was in 1992/1993 and the second in

1997/1998. This research is based on data collected in 1998. At the time of writing, 18 countries have reported data to the project co-ordinator. The countries and the sample sizes are shown in Table IV, in which *N* stands for the sample sizes of each of the participating countries.

The companies participating in the survey are in the metal and electronics industries, i.e. the International Standard Industry Classification (ISIC) 38, which adopted more AMT than other industries. For details of the data and the IMSS project, please refer to the book by Lindberg *et al.* (1998).

The questionnaires were sent to companies in individual countries, separately, in the period from 1997 to 1998. The methods of data collection vary from country to country: in some countries, post surveys were used, while in others, on-site interviews were adopted. All the data were sent to the co-ordinator in Spain, then distributed to all the participants.

The sizes of the 556 sampled companies vary. Since the standard for small, medium and large size companies varies from country to country and this project includes 18 countries, I divided the sampled companies into five classes. The class benchmarks and the percentage of sampled companies in each class are <100 (14 per cent), 101-500 (40 per cent), 505-1,500 (26 per cent), 1,001-3,500 (11 per cent), and > 3,500 (6 per cent) employees. Missing data occupies 3 per cent. The survey covers a wide range of companies in terms of their sizes. The questionnaire in this survey contains around 300 variables about strategies, practices, programmes, and performances. The research reported here focuses on the integration/automation level and human resources factors.

3.1 Integration level

In previous research, integration was measured by Likert scales based on subjective opinions of the amount of AMT implemented (e.g. Snell and Dean, 1992; Sargent and Matthews, 1997). However, although the integration level reflects the amount of AMT used, the amount of AMT may not necessarily reflect the level of integration. AMTs may not be integrated in a company. The questions about integration level in this research are illustrated in Table II. The level of integration refers to the extent of computerised machine automation and computerised control of information and materials in the manufacturing process. The level of integration is determined by the extent of utilising AMT in engineering, process, administration, and the computerised integration of information and materials. In the IMSS survey, integration is measured at a ten-level scale of utilising different types and amounts of AMT. Each category is clearly defined in terms of the type of AMT involved. For the convenience of statistic analysis (ANOVA, e.g.), the ten levels are simplified into five levels of integration suggested by Bessant and Haywood (1988), ranging from "none at all", islands of automation, archipelagos of automation (i.e. partial integration), up to full integration. Informants were asked to select the general level of integration in their companies.

3.2 Human resource factors

The questions on human resources in the IMSS survey include percentage of temporary employees, span of first-line supervision, payment system, number of job classifications, suggestions by each employee per year, percentage of employees working in teams, training hours, job rotation, and percentage of multi-skilled workers, etc. These factors are objectively measured as follows.

- How many different job classifications (or pay grades) do you have in your manufacturing plant? __________
- How many employees are under the responsibility of one of your line supervisors (on average)? ___________
- How many of your operators are temporary (i.e. not permanent) ? __________ %
- How many suggestions do you have per employee per year (on average)? ______
- How many of your operators do you consider as being multi-skilled? ______ % of total number of operators.
- How many hours of training are given to regular production workers? __________
- How frequently do your employees rotate between jobs? 1 = never, 2, 3, 4, 5 = frequent.
- What proportion of your total work force work in teams? ________%
- What is the design of the payment system for the direct employees? (Please select all relevant alternatives): group ( ) individual ( ) company ( ) fixed salary ( )

In most previous studies, especially those conducted by researchers in pure human resources and organisational theory fields, human resources factors are measured by subjective opinions. An example is to ask to what extent a company developed the skills of its employees. In this research, except for job rotation, all other human resources factors are measured by relevant objective figures. For example, the percentage of

Table II
The levels of integration (5-level and 10-level respectively) and basic statistics

5-level characters	10 level	Span of computerised control	Description of computerised control and AMT involved	Percentage
I: None	1	None	Computer not used in manufacturing	12
II: Stand alone	2	Stand alone NC	Instructions for computer control	46
	3	Machining centre	Level 2 + instructions for changing tools	
III: Islands of automation	4	Machining cell	Level 3 + multiple machining control	29
	5	FMS – type I	Level 4 + scheduling	
	6	FMS – type II	Level 5 + loading/unloading, storage	
	7	FMS – type II	Level 6 + sorting	
IV: Archipelago of automation	8	Automated factory I	Level 7 + computerisation of functional modules, e.g. MIS, MRP, CAD, CAM and CAPP	11.4
	9	Automated factory II	Level 8 + linkage of MIS, MRP, order processing, sceduling and cost analysis	
V: Fully integrated	10	Automated factory II	Level 9 + linkage of CAD, CAPP, CAE and CAM	1.6

skilled operators is used to measure the consequence of skill development. The theoretical constructs and operational measures are shown in Table I.

4. The results

The integration level follows a normal distribution as illustrated in Table II (the last column percentage). On the one hand, there are few companies (12 per cent) that have not computerised automation. On the other hand, very few companies (1.6 per cent) achieved full integration. Among the 556 sampled companies, only seven companies claim that their production is fully integrated by computerised control. The majority has invested in computerised integration and automation to certain extents. The average integration level is 3.7 by the ten-level measure. The integration levels of most sampled companies are somewhere in the middle, characterised by standalone or islands of automation, with some companies reaching the level of partial integration (11.4 per cent). In brief, not all of the manufacturing processes are integrated. Fully integrated manufacturing systems are perhaps still future issues.

Since the level of integration is measured by a scale, Analysis of Variance (ANOVA), instead of correlation analysis, is used to investigate the relationship. The reason is if the ordinal data are treated as interval data in correlation analysis, the probability of rejecting a true hypothesis is comparatively large (Seigel, 1956). The five-level measure of integration is used in the ANOVA, because, in the ten-level measure, there are not enough data in each group. In the five-level measure, the fifth group is omitted since few companies are identified as belonging to this group. The ANOVA tests between integration level and each human resources factor are shown in Table III. Each of the dimensions will be discussed below.

According to the ANOVA test in Table IV, about half of the factors of human resources are significantly different in relation to the level of integration. These dimensions include the percentage of temporary employees, the span of first-line supervision, the number of employees working in teams, the use of grouped-based incentive systems and the frequency of job rotation, etc. *H2*, *H3*, *H7*, *H8*, and *H9* are accepted. It has to be pointed out that the relationship is not exactly linear from 1 to 4. In these hypotheses the differences between non-integrated at all (level 1), level 2, level 3 are obvious and nearly linear. However, the differences between level 3 and 4 are not very obvious. The relationship between managerial variables is complicated and should not always be simple linear.

However, the other human resources factors are not significantly positive related to the level of integration. These dimensions include the number of job classifications, suggestions per employee per year, training hours, and the percentage of multi-skilled operators. This implies that these human resources factors may not automatically change towards the new form after the integration level increases. *H1*, *H4*, *H5*, and *H6* are rejected.

5. An international comparison

In this section, the level of integration versus human resources development in 18 countries is investigated. First, the level of

Table III
The relationship between automation and work organisation

		Automation level					F-test	
H	**Human resource factors**	**1**	**2**	**3**	**4**	**5**	***F***	***P***
H1	Number of job classifications	15.22	13.53	10.26	10.31	n/a^	1.04	0.38
H2	Span of first line supervision	28.05	26.19	35.26	38.76	n/a	2.60	0.05*
H3	Percentage of temporary employees	11.74	6.440	8.560	7.360	n/a	2.88	0.04*
H4	Suggestions per employee per year	7.980	10.28	23.47	10.96	n/a	0.81	0.49
H5	Percentage of multi-skilled operators	39.46	46.10	50.19	50.80	n/a	1.81	0.14
H6	Training hours per employee per year	52.60	69.65	73.02	62.15	n/a	0.17	0.91
H7	The frequency of job rotation	2.890	2.950	3.160	3.210	n/a	2.26	0.08*
H8	Per cent of work force in teams	35.23	45.83	54.63	48.90	n/a	2.52	0.06*
H9	Per cent of individual-based incentive systems	0.41	0.46	0.41	0.17	n/a	4.67	0.00**

Notes: ^n/a: date are not available; *: Significant at 0.09 level; **: Significant at 0.01 level

Table IV
Countries, country codes, sample size (*N*), integration level index (ILI) and rank, the ranks of nine human resource factors and human resource index (HRI)

		Integration			Human resource factors (ranked by country)									
Country	**Code**	***N***	**ILI**	**Rank**	**H1b**	**H2b**	**H3b**	**H4b**	**H5b**	**H6b**	**H7b**	**H8b**	**H9b***	**HRI**
Argentina	ARG	31	3.26	12	3	16	1	17	18	2	8	18	8	9.15
Brazil	BR	27	3.05	14	11	3	10	14	8	10	14	3	6	8.31
China	CHN	30	3.67	7	16	1	12	12	15	1	15	15	18	9.85
Denmark	DK	27	2.96	15	6	4	3	13	1	11	9	16	2	8.62
Finland	FL	14	2.93	16	5	8	14	18	4	7	12	6	14	10.00
Hungary	HGR	38	1.83	18	18	7	4	16	16	15	7	5	16	10.92
Italy	IT	71	3.44	9	7	6	5	11	13	16	10	17	13	11.08
Japan	JP	29	3.67	8	9	15	11	1	7	12	4	1	15	7.69
Mexico	MEX	29	3.08	13	2	14	17	3	14	5	17	14	10	11.46
The Netherlands	NL	29	3.32	11	10	9	16	2	10	17	5	4	7	9.46
New Zealand	NZ	32	4.00	5	1	18	8	15	2	18	3	9	17	9.92
Norway	NW	13	3.40	10	8	10	2	7	9	4	11	10	1	8.23
Peru	PR	8	2.83	17	4	17	18	8	12	8	16	8	11	13.00
South Korea	SK	50	4.98	2	15	11	9	9	17	6	18	12	4	10.08
Spain	SP	33	4.50	3	12	12	15	4	11	3	13	13	9	10.69
Sweden	SW	27	4.30	4	17	5	13	6	3	13	1	2	12	7.08
UK	UK	24	3.80	6	13	13	7	10	6	9	2	7	5	8.31
USA	USA	41	5.56	1	14	2	6	5	5	14	6	11	3	7.15
***F*-value**			4.00		2.30	3.7	3.71	4.66	16.69	2.28	2.50	6.32	8.89	
P			0.001		0.002	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.000	

Note: The incentive system is a multiple-choice question. Countries are ranked according to the percentage of companies that are based on individual based salary system. **: *F*-test is based on the original means instead of the ranks in the table

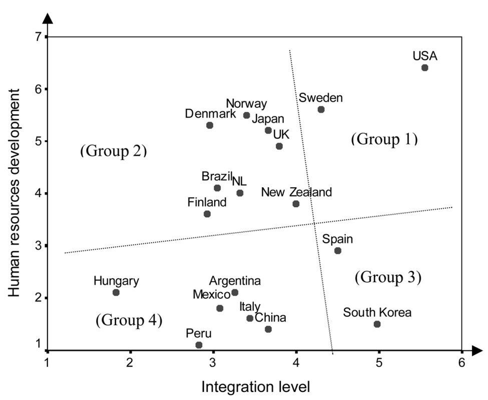
integration varies from country to country, as shown in Table IV, column "ILI and rank". Statistically, the difference in automation level among the 18 countries is significant at $F = 4.00$ and $p < 0.001$. The sequence from high to low is US, South Korea, Spain, Sweden, New Zealand, UK, China, Japan, Italy, Norway, The Netherlands, Argentina, Mexico, Brazil, Denmark, Finland, Peru, and Hungary. On average, US companies are somewhere around islands of automation. South Korea is in the second place. Japan is somewhere in the middle, characterised as standalone and islands of automation. Developing countries including Argentina, Mexico, Brazil, Peru, and Hungary are at the bottom.

To test *H10*, the differences in the nine human resource factors among the 18 countries are investigated, as shown in the last two rows in Table IV. Hypotheses from *H1b* to *H19* are accepted. The *F*-value and confidential probability *p*s are shown in Table IV. That means all nine human resources factors are significantly different among the 18 countries. That means that *H10* is accepted. This provides another source of explanation for differences in human resources development in addition to integration levels.

For the purpose of comparing the participating countries in terms of integration level versus the development of human resources, a human resources integration map (Sun, 1994; Kochan, 1988) is used. The map is a two-dimensional co-ordinate diagram. In this research, the level of integration measures the technological dimension. It is the average integration level index (ILI) of the 18 countries at the ten-level scale (see Table II). The human resources dimension is reflected by the average ranks of the countries. The average rank is defined as human resource index (HRI). According to their ILI and HRI, the 18 countries are plotted in the map as shown in Figure 1. It can be visually found that the positions of the countries are rather scattered. Cluster analysis (k-means) classifies the countries into four groups.

The first group includes the USA and Sweden. It is suggested that both the integration and human resources development should be taken into consideration. According to the current theory about technology innovation and human resource development, the two countries are the best models. In many previous studies in the 1980s (Jaikumar, 1986; Kochan, 1988), US companies had more advanced technology but less advanced human resources, especially compared with Japanese companies. It is probably the first research in which US companies lead both in technological development and human resource development. The reasons for this may be three-fold. First, most previous research studied only the auto industry, while this research looks at other mechanical

Figure 1
The average positions of 18 countries in the co-ordinate diagram of integration level versus human resources development



and electronic industries. Second, previous research is based on case studies while this research is based on survey. Finally, US companies may have actually improved their human resources in the past decade.

Most other developed countries (Denmark, Norway, Japan, UK, Finland, and New Zealand) plus a developing country (Brazil) are grouped into the second group and they are quite balanced in automation level and human resources development. Scandinavian countries including Denmark, Norway and Sweden are all higher in human resource development. They are on the right path towards the future.

South Korea and Spain are special and are grouped into the third group. They are quite high in integration level. However, their human resources ranks are rather lower. As mentioned in the introduction section, neglecting human resources development will lead to failure in AMT. In a similar research (Sun, 1994), companies which are located in the technology-overwhelming positions tend to fail. It is suggested that these countries should shift towards human resources development.

All other developing countries, plus Italy, are in the fourth group. Except Hungary, countries in this group are not lagging much behind in the level of integration and automation compared with the developed countries in the second group. However, they are lagging behind in human resources. The variance of the four groups in automation level ($F = 9$, $p < 0.009$) is less significant than in human resources development (F = 34, $p < 0.001$). The main difference, therefore, is in human resource development. If these developing countries do not develop their human resources, they will find themselves on a level with Spain and South Korea. What these countries need to learn from developed countries is not just their technologies but also human resources.

6. Discussions

This paper records research on integration level versus human resources development. The levels of integration are significantly different among the 550 sampled companies. Very few companies reached full integration. Most of the sampled companies are between standalone and island of automation stages. It would appear that the "the fully integrated factory for the future", proposed and widely discussed in the 1970s and the beginning of the 1980s, is still in the future.

Some human resources factors are related to the level of integration. It is widely suggested that human resources in the integrated manufacturing environment should be characterised by team basing, employee participation, multi-skills, more training and frequent job rotation etc. However, not all the human resources factors are significantly related to the level of integration. That means the integration level explains only part of human resources development and will not guarantee the development of all human resources factors. Thus, there must be other factors that influence these human resources factors.

It was found that both the integration levels and the human resources development are significantly different among the 18 countries. The main difference among the four groups lies in the development of human resources. The country contexts provide another source of explanation of difference in human resources development. What the developing countries should learn includes not only the hardware technologies, but also human resources development.

The contributions of this paper include the following.

- This research reveals the current status of computerised integrated manufacturing and highlights the fact that fully integrated manufacturing is still a future issue.
- This research reveals the statistical relationship between integration and human resource development and suggests that full integration may not guarantee the development of human resource development.
- This research discovers the differences in integration level versus human resources development in different countries and provides an international benchmarking map.

The result of this research triggered the following discussions and ideas for future research.

The cause-effect relationship between integration level and human resources development has triggered intensive debate. The debate ended with a “chicken or egg first?” question. Although it is found that the development of some human resources factors are significantly related to the level of integration, it is very difficult to conclude which is the first in this research. However, it appears that in the past few years, technical integration has been emphasised over the development of human resources. Schroer and Ziemke (1994) found that US apparel manufacturers counted on increased integration to counteract a decreasing market share. When this did not work, apparel manufacturers turned their attention to human resource issues as a means to improve worker retention, productivity, and product quality. Sun and Frick (1995) found that companies would like to implement AMT first and then shift to the development of human resources and organisations, mainly because of the failures and problems caused by AMT. So future research should look at:

- on the one hand, how to use the implemented AMT as a vehicle to develop human resources; and
- on the other, how to develop human resources in advance of implementing AMT.

The country context is clearly another source of explanation of the differences in human resources development. Future research should look into country contexts that influence the development of human resources. Other influential factors may include traditional organisation form, management style, and co-operation with labour union etc.

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