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A SURVEY ON COMPUTER INTEGRATED MANUFACTURING (CIM) IN MALAYSIAN INSTITUTES OF HIGHER EDUCATION

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RINGKASAN : *Kertas ini ditulis berdasarkan satu kajiselidik yang telah dijalankan pada tahun 2001 di institusi pengajian tinggi di Malaysia mengenai Pembuatan Bersepadu Komputer (CIM). Objektif utama kertas ini ialah menyediakan bukti empirikal terhadap keperluan kepakaran sumber manusia dan kelengkapan dalam CIM kini dan di masa depan. Untuk mencapai objektif ini, penulis telah membangunkan satu set soalan kajiselidik yang terdiri daripada 17 soalan utama. Analisis yang dibuat berdasarkan maklumbalas 28 institusi menunjukkan bahawa institusi pengajian tinggi tempatan mengalami kekurangan yang serius dari segi bilangan dan kepakaran dalam teknologi CIM. Tambahan pula, kajiselidik itu juga menunjukkan bahawa majoriti sistem dan peralatan CIM diimpot daripada seberang laut dan hanya sebilangan kecil sahaja yang diperbuat di dalam negara. Kertas ini juga membincangkan kepentingan CIM dalam mempertingkatkan daya saing syarikat Malaysia di dalam industri pembuatan. Akhirnya, kertas ini membuat kesimpulan dengan memberikan cadangan dan syor bagaimana untuk mempertingkatkan penggunaan CIM di institusi pengajian tinggi tempatan dan seterusnya membantu Malaysia mencapai status negara maju pada tahun 2020.*

ABSTRACT : This paper is based on a survey carried out in 2001 on Computer Integrated Manufacturing (CIM) conducted at Malaysian institutes of higher education. The main objective of this paper is to provide empirical evidence of the institutions current and future needs on CIM manpower expertise and facilities required. To achieve this objective, the authors developed a questionnaire comprising of 17 main questions. The analyses from 28 institutions showed that there is a serious shortage in terms of number and expertise in CIM technology in these institutions. In addition, the survey found that most of the CIM systems and equipment were imported from overseas and very few were locally manufactured. The paper also discusses the importance of CIM in enhancing Malaysian companies competitiveness in the manufacturing industry. Finally, the paper concludes with some suggestions and recommendations on how to improve the adoption of CIM in

INTRODUCTION

Harrington (1973) was the pioneer in introducing the concept of Computer Inte Manufacturing (CIM). Since then, CIM has received a lot of attention from industrial mar companies' top management and government officials who are responsible f manufacturing industry. CIM technology concerns the developing field of auto manufacturing and materials handling, which involves the extensive use of computer ha and software, knowledge-based information exchange. It links all aspects of a manufa enterprise from order entry to shipping for real-time planning, scheduling, and contr technology can be applied to design, machining, and manufacturing of products as emphasises on quality and process control. In short, CIM represents a set of techniqu are making fundamental changes to the manufacturing industry. CIM is a multi-disc subject and is a complex, multi-layer system designed to minimise waste and creates in the broadest sense (Gunasekaran *et al.*, 2000). In today's business environmer manufacturing organisation to survive and remain competitive, it must deliver the best product or service, at the lowest possible cost, and in the minimum lead time, startir product conceptual stage to final delivery to customers. In short, the ultimate aim of C produce the correct number of parts/components of acceptable quality at the right ti every time (Gunasekaran *et al.*, 2000). In a fully integrated CIM environment, in wh factory is totally automated, a manufacturer can respond rapidly to changes in product quantity or product mix according to customers' request (Gunasekaran *et al.*, 1994). words, fully integrated CIM production system can effectively serve both small and large requiring many different types of components/parts. Furthermore, the mix can be ma consistent quality and with minimum waste. However, the high investment required implementation is becoming a major hurdle especially for small and mediur manufacturing companies.

WHAT IS CIM?

Currently, there are numerous definitions of CIM by different authors and researchers. H they all agreed on the basic principle that CIM is associated with automati computerisation (Zhou and Chuah, 1999). For example, Ranky (1986) interprets C system, which provides computer assistance, control and high level of integrated aut at all levels of the manufacturing industries by linking islands of automation into a dis processing system. Lefebvre *et al.* (1996) interprets CIM as a system, which concerns p

(CAPP), Automated Storage and Retrieval System (ASRS) and robotics into a distributed processing system. Majchrzak (1988) defines CIM as a system, which involves the integration of information, software, hardware and people. Thurwacher, as quoted by Zhou and Chuah (1999) interprets CIM as the logical organisation of engineering, production, marketing and supporting functions into a computer integrated system. In other words, functional areas (e.g. product design, analysis, production planning, purchasing, cost accounting, production and inventory control, production processes and distribution) are integrated with all the factory functions through the use of computer software and hardware. In short, CIM can be viewed as a strategic operating philosophy and methodology. Its main objective is to achieve higher business efficiencies across the whole cycle of product design, manufacturing, and marketing.

THE NEED OF CIM IN MALAYSIAN INDUSTRIES

The adoption of CIM system in Malaysian manufacturing industries especially the Small and Medium enterprises (SMEs) is very important in order to be more efficient and competitive in the marketplace. Great emphasis must be placed on reducing costs, improving productivity and product quality as well as reliability. To achieve these goals, Malaysian manufacturers have to apply new production concepts such as Just-In-Time (JIT), Flexible Manufacturing System (FMS), Total Quality Management (TQM), and Business Process Re-engineering (BPR), which require the application of different computer-aided technologies such as Computer-Aided Design and Computer-Aided Engineering (CAD/CAE) and Computer-Aided Manufacturing (CAM).

Referring to the Industrial Master Plan (IMP2) (1996-2005), one of the five critical elements of economic foundation is technology development based on re-engineering of the production systems, the shift from labour-intensive structure to capital-intensive structure, enhancing indigenous Research and Development (R&D) efforts, technology diffusion, knowledge-based and information-based manufacturing and international production networks. The introduction of CIM is expected to fulfil the above requirements. In addition, the participation of institute of higher education including universities and colleges are important to provide highly skilled and trained manpower for the industries. This is also one of the critical elements mentioned in IMP2 report on information intensive and knowledge-based processes. Some of the issues addressed in the IMP2 report are greater flexibility and autonomy in the management of public training institutes, increasing and upgrading training of trainers, synchronising private-public sector and responsibilities for education and training.

In this case, the universities and colleges in Malaysia will have to focus their efforts to produce skilled and trained manpower on a continuous basis and enhance their research and development (R&D) in CIM. The primary goal of the CIM program is to provide all graduates with the solid technical foundation necessary to ensure their success in a wide variety of

employment opportunities. This is important because the graduates that choose a career in CIM are expected to have a lifelong occupation. They are expected to automate and integrate the hardware and software systems in their manufacturing plants. These can only be done with technically competent employees that are able to install, operate, programme, interface, service, troubleshoot, and maintain the advance computer controlled equipment.

RESEARCH METHODOLOGY

Survey Instrument Development

Bethlehem (1999) and Mangione (1995) provide a summary of the history, overview of various techniques and steps to carry out a survey, which was considered by the authors. A prerequisite in designing a good questionnaire is to decide what to measure. This step seems simple and self-evident but if overlooked may result in producing low quality questionnaires (Fowler, 1984). The survey questionnaire in this study was developed based on previous empirical studies found in the literature and using the general rules as provided by Fowler (1998) on questions and answers of the basic characteristics, which are fundamental to a good measurement process.

The final form of the postal survey questionnaire consisted of 17 main questions. In this survey, respondents were asked to select the name of courses they offered, list of equipment, software and hardware facilities currently available and what they are planning to buy in future, planned budget for future equipment procurement, equipment brand name and country of origin, the factors they consider before buying, availability of manpower and expertise in CIM and number

Population and Sampling Procedure for the Study

In order to ensure a high representative number of responses, a total of 45 survey questionnaires were sent to the Malaysian institutes of higher education. These 45 institutes comprise of four different types, namely, all public universities, private universities, technical institutes or polytechnics and private colleges. These institutions were chosen for the study because it offered courses or programmes directly related to CIM education. A reply-paid self-addressed envelope was included. A total of 28 institutes of higher education responded to the questionnaire, giving a response rate of about 62%. Given the low response associated with mail surveys, this response rate was considered very satisfactory and indicates the cooperative attitude of Malaysian institutes of higher education towards survey questionnaire.

SURVEY RESULTS AND FINDINGS

The results from the survey are plotted and shown in Figures 1 to 10. On overall, 90% of the responses were from the institutions of higher education, which are offering CIM related courses. Figure 1 shows the distribution of various courses on CIM available in the institutions.

The most common courses are manufacturing, machining, CNC and PLC. These courses are considered as the fundamental subjects that provide an understanding on advanced manufacturing technology. In addition, majority of institutions are offering courses on mechatronics, automation, robotics and machine tools. These courses are considered as the more advanced topics in manufacturing technology. However, for example courses that are very important with regards to Computer Integrated Manufacturing (CIM) such as sensor control and computer control are still very few. These components represent the latest development in CIM and are still in the early stage of research and development in the Malaysian industry.

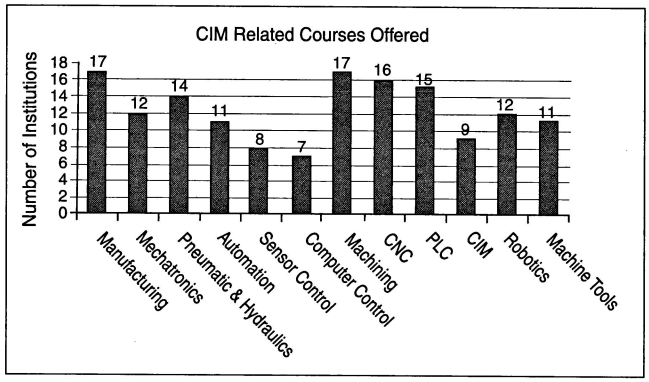

Figure 1. *Number of institutions versus list of course offering on CIM related courses*

Figure 2 shows the list of hardware, which is relevant to CIM technology. The survey results shows that a large majority of the local institutions of higher education have already procured the basic equipment for automation technology, for example : PLC (85%), CNC lathe (78%), CNC milling (75%) and EDM (61%). These equipment are most probably purchased to support the courses in manufacturing, machining and PLC as mentioned above. Meanwhile, about half (50%) of the institutions own equipment such as microprocessors and pick & place robots. On the other hand, in terms of advanced equipment 30% of the institutions owns CMM and 10% rapid prototyping.

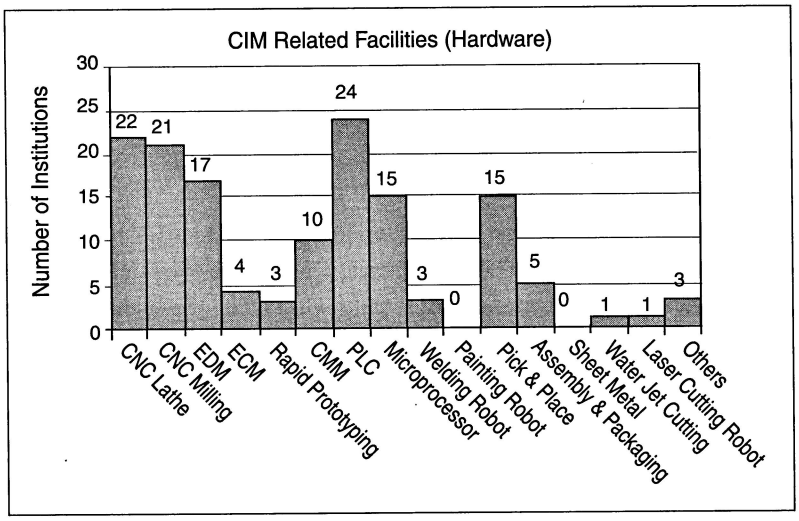

Figure 2. *CIM related facilities (hardware) owned by local institutions*

As shown in Figure 2, only a few institutions own the latest equipment in CIM technology such as rapid prototyping, computerised measuring machine (CMM), non-conventional cutting technologies and various types of robots. With regard to painting and sheet metal handling robots, none of the local institutions had this equipment. This may probably be due to their minimal application in the local industry. The results from Figure 2 are actually in tandem with Figure 1, where the appropriate equipment was used in conducting the courses offered by the institutions.

With reference to Figure 3, a large majority (86%) of the institutions are using CAD systems. There are many reasons attributed to these trends including their widespread use not only for tertiary education but also in the industry. Another factor that could contribute to this is the price of CAD systems that are affordable to most institutions, both on the software and hardware as the platform. However, as expected the institutions are yet to implement the full capability of CAD system because most of the current CAD installations remain confined to drafting only. This is due to the fact that very few institutions have the complete CAD package including solid or surface modelling.

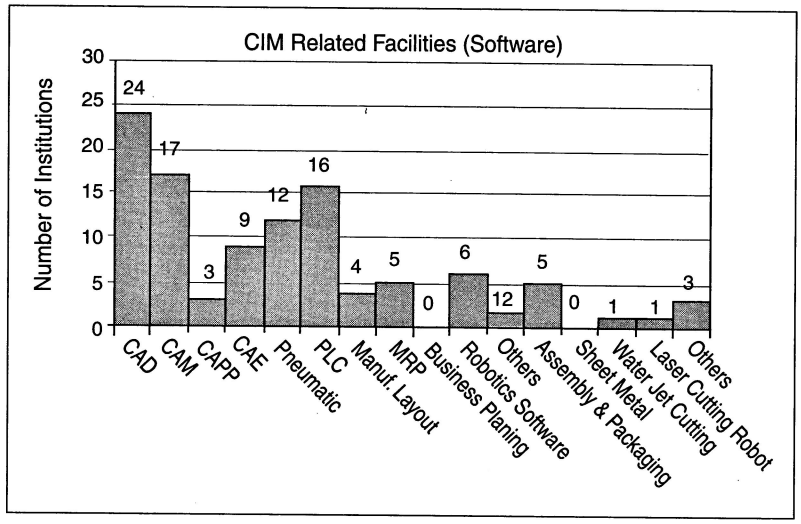

Figure 3. *CIM Related Facilities (Software) Owned by Local Institutions*

Computer Aided Manufacturing (CAM), Programmable Logic Controller (PLC) and pneumatic software achieved relatively widespread use with 61%, 57% and 43% levels respectively. It is expected that the majority of CAD users in the institutions would link their part geometry to CAM software to generate the NC program. The tool path could be optimised and verified before the actual process is fed to the Computerised Numerical Control (CNC) machine. The usage of PLC and pneumatic software proves the awareness among the institutions on the importance of preliminary design work for the semi/full-automation systems. However, if we compare the results from Figure 2 and 3, it seems that the usage of software to transfer the data to the hardware is still minimum. Only 17 institutions might use the CAM software to programme their CNC lathe, milling and EDM machine. On the other hand, others might still be using the conventional methods to generate the NC programme. In addition, only 16 institutions use the PLC software to design their initial design.

Referring to Figure 3, CAE software with 32% usage provides a good indication that some institutions are keen to further analyse their design features such as automatic mesh generation for finite elements, stress and strain analysis, thermal analysis, and kinematics studies. Whilst, a very small percentage of the institutions owned a more advanced software on CAPP, manufacturing layout, MRP, robotic software and other software which is related to robotic application. Figure 3 clearly indicates that most of the institutions concentrate more on the technical aspects of CIM, which involve machine tools. Meanwhile, the usage of management aspects of CIM software is still insufficient.

However, when asked about the equipment they intend to buy in the near future, many institutions have indicated that they are planning to buy the basic equipment for CIM system.

With reference to Figure 4, about 30% of the Malaysian institutions of higher learning are planning to buy CNC milling, rapid prototyping, PLC and CMM. On the other hand, 25% of them are considering purchasing the CNC lathe, microprocessor, welding robot, ECM and EDM for conducting research and training purposes in their respective institutions.

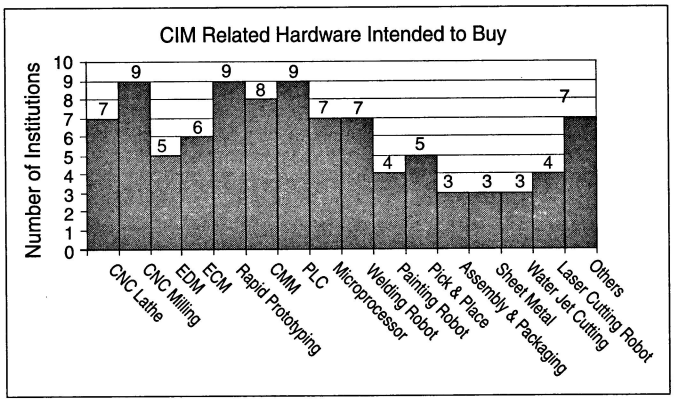

Figure 4. *List of CIM facilities to be purchased by local institutions of higher education*

Figure 5 shows that 36% of the institutions have already allocated more than RM1 million for the purchase of CIM related equipment. This indicates that more than one-third (33%) of the institutions are very serious in investing their money in CIM technology and equipment. This figure also suggests that the institutions allocated bigger amount of money probably for buying more advanced CIM equipment. This could be seen from Figure 4. Meanwhile, about three-quarter (75%) of the institutions that participated in the survey had allocated their budget in buying CIM equipment. This trend indicates that there is a great improvement on the awareness among top management on the importance of CIM technology in the educational institutions.

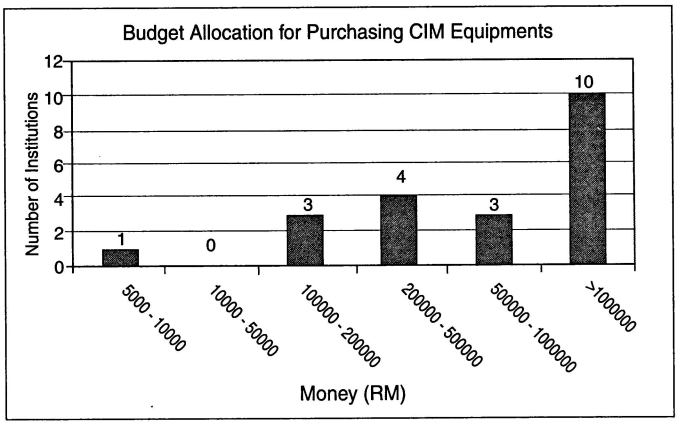

Figure 5. *Budget allocated for purchasing CIM equipments*

When asked about their preference on imported or locally manufactured CIM equipment, 75% of the local institutions of higher education have indicated their interest to buy the CIM equipment produced locally in Malaysia (see Figure 6). This trend is in-line with the government efforts to develop locally advanced technology equipment and hence less dependent on foreign technology. This indicates that the end users have confidence in locally produced or manufactured CIM equipment. This could reduce foreign exchange and more saving as the locally produced equipment are cheaper than imported ones. On the other hand, CIM equipment imported from Europe, USA and Japan are still the popular choice among the institutions surveyed.

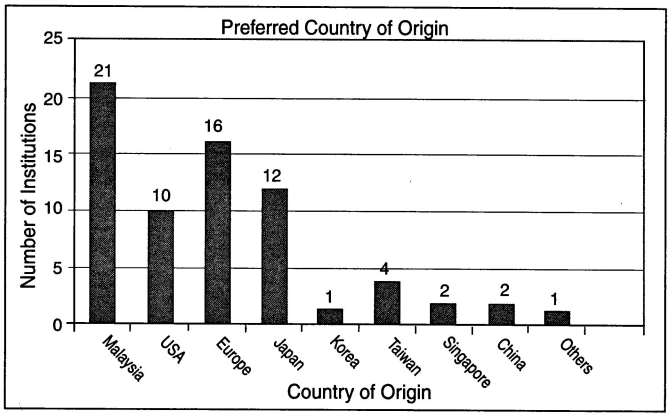

Figure 6. *The preferred country of origin for CIM facility*

As shown in Figure 7, the survey had indicated that there are two types of staff (i.e. academic and technical) who are currently involved in CIM related courses. The survey result shows that 60% of the institutions have at least one technical staff trained in CIM related technology. It also shows that 82% of the institutions surveyed have more than one academic staff with an expertise in CIM systems and technology. However, in the authors' opinion, the total number of academic and technical staff that are currently involved in CIM is still very small to cater for the educational and training needs in CIM. This could be due to the lack of interest or awareness in CIM by the top management of the institutions. It may also be due to their failure to realise the important role played by CIM in the transfer of technology and competitiveness of Malaysian companies involved in the manufacturing industry.

Figure 8 shows that 78% of the institutions are currently sending more academic and technical staff to undergo training in CIM related courses. This shows that educational institutions are realising that they need more academic and technical staff, who are well-trained and knowledgeable in CIM. They are expected to train students and industrial personnel in CIM systems and technology. This is essential to contribute to further enhancement of the competitiveness of the Malaysian manufacturing industries.

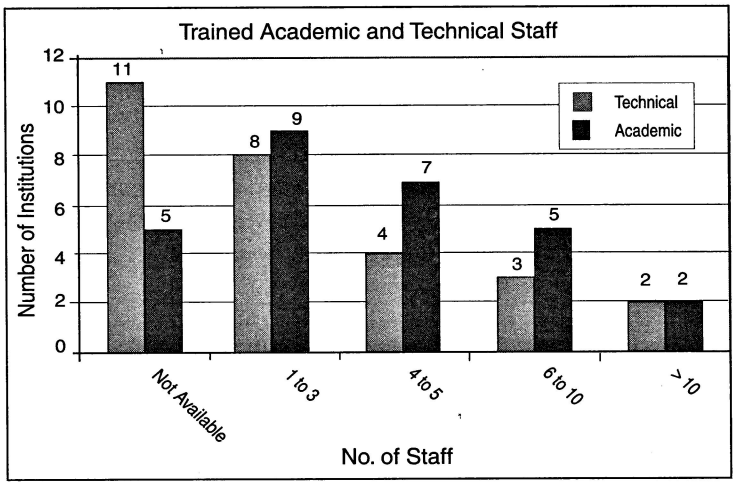

Figure 7. *Trained academic and technical staff available in local institutions*

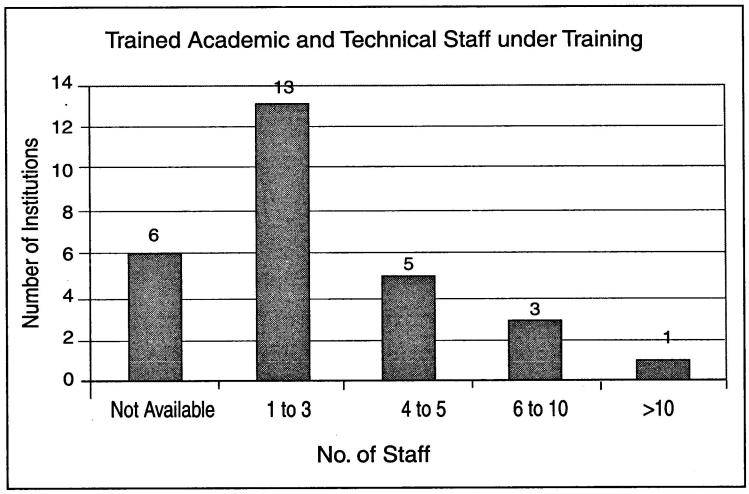

Figure 8. *Academic and technical staff currently undergoing CIM related training*

Referring to Figure 9, 79 % of the institutions have students studying CIM related courses. However, only 48% of the institutions have student enrolment higher than 40 and 26% of the institutions did not have any student at all. This finding matches the result shown in Figure 7 whereby about 20% of the institutions did not have trained academic staff in CIM.

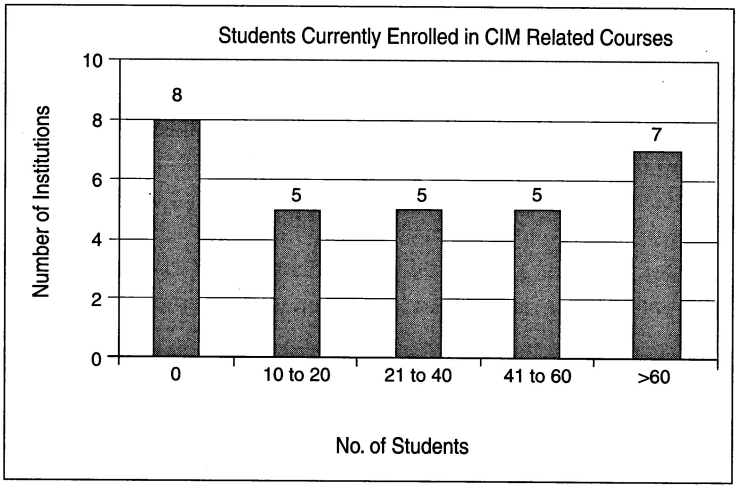

Figure 9. *Number of students currently enrolled in CIM related courses*

Referring to Figure 10, more than 78% of the institutions expected an enrolment of more than 30 students in their future academic year. This is an increment of about 10% in the number of students compared to 48% in the current enrolment as shown in Figure 9. Figure 10 clearly indicates that a bigger number of students are expected to enrol in CIM related courses. This indicates that more institutions will be offering CIM related courses in the future.

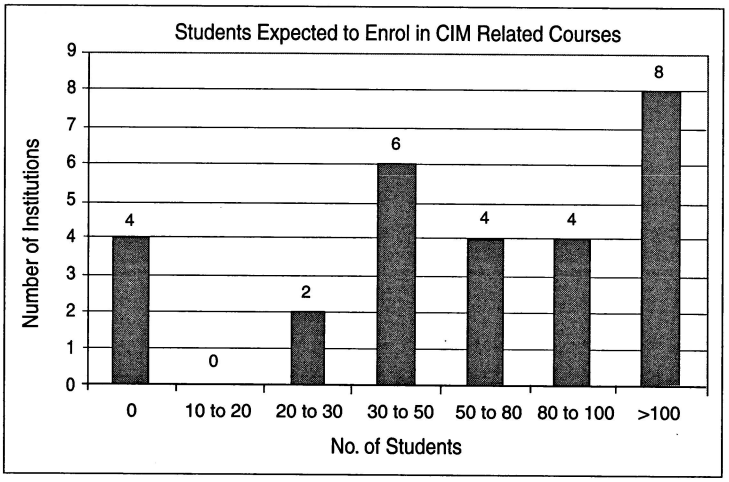

Figure 10. *Number of students expected to be enrolled in CIM related courses*

DISCUSSION AND RECOMMENDATIONS

The survey conducted in this research provides an overview of CIM implementation in Malaysian institutes of higher education. The survey could be used to evaluate to what extent the institutes of higher education could participate in providing skilled manpower in CIM for Malaysian industries. The success of CIM depends largely not only on the investment of expensive facilities and technology but also on highly skilled and educated employees in the CIM technology. However, in order to train skilled graduates, the institutes of higher education must be equipped with proper facilities and well-trained instructors or lecturers.

At present, the level of implementation and educational programme in CIM technology at Malaysian institutes of higher education is considered low. Reasons may include the high cost of capital investment, lack of skilled academic personnel and lack of technical support service (Figure 7). The survey shows that the number of CIM related courses currently being offered or conducted are still insufficient to meet the manufacturing sector demand on trained workers. These phenomena could be attributed to the following main factors such as : cost of CIM systems hardware and software, lack of skilled manpower availability of institutes of higher education and lack of awareness (Figure 7).

The cost of CIM systems hardware and software varies, depending on the function of the hardware and software capabilities and applications. For example, simple CIM equipment can easily cost RM100,000 while more advanced equipment such as Rapid Prototyping machine can cost as high as RM500,000 or more. At present, a majority of the CIM systems hardware and software are imported (Figure 6), as there are no local manufacturers. The depreciation of Ringgit against the US Dollar from RM2.50 per US Dollar to RM3.80 per US Dollar has further aggravated the situation, making the imported CIM systems 46% more expensive.

The supply of trained lecturers or instructors is not enough to offer CIM related courses. Hence only few educational institutions are able to offer such courses. At present, only a few public universities, technical institutes, polytechnics and colleges are well equipped with CIM facilities (software and hardware). On the other hand, most private universities and colleges are not well equipped with CIM facilities; this may be due to higher capital cost required to purchase such equipment. The number of trained staff in CIM related courses are low as shown in Figure 7. This could be due to awareness level among top management on the advantages of CIM systems is low.

The number of academic and technical staffs who are trained in CIM systems and technology should be increased by at least 50 times if Malaysia is to be transformed to a fully industrialised country by the year 2020. According to the survey results and authors' opinion, there may be insufficient promotional campaigns being carried out to enhance industry awareness on the

advantages of using CIM system. This lack of awareness includes the knowledge on the types, applications and the usefulness of the CIM systems. The authors suggest that the government establish a referral centre in order to provide the following services to the general public and increase their awareness towards CIM systems. This referral centre should provide free advisory services; provide up-to-date information on CIM technologies; expose CIM to the local manufacturing industries personnel; plan, guide and assist the manufacturing industry to adopt and use CIM systems in their manufacturing operations and co-ordinate research activities in local research institutions and universities, and manufacturing industry in order to facilitate better understanding and interaction between technology resource centres and the manufacturing community.

Currently, there are only a few universities and technical training colleges that offer CIM related courses. The number of experts involved in the CIM technology is still very small. Therefore, the government should provide more funds to the local universities; colleges and technical training institutions to acquire CIM related software and hardware systems, to provide more training for their staff to become experts in CIM systems. They shall later conduct courses in CIM hardware and software to increase the number of knowledge workers in the CIM system for the manufacturing industry.

As the level of technology advances, the cost of CIM systems will eventually increase. In order to encourage the use of CIM hardware and software, the cost of these systems should be low and affordable to most SMEs operating in Malaysia. The Malaysian government should provide assistance to local integrators and inventors to undertake the design and development of locally manufactured CIM hardware and software systems that suit the local manufacturing environment. This assistance could be in the form of grants and tax relief to facilitate these Universities, R&D institutions and also manufacturing companies to develop the CIM systems.

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