A Study on Integrated Manufacturing Technologies in the Caribbean Manufacturing Firms

B.V. Chowdary

Manufacturing today is the most critical and dynamic sector, with the capacity to provide more jobs, stabilise communities and drive nation's growth. There remains an urgent need in Trinidad and Tobago (TT) to research and assess opportunities to strengthen the manufacturing sector that is expected to provide a stable economy in the absence of the energy sector. Manufacturing technology users and researchers of the Caribbean region must work together to configure the critical technologies for the future development of the local manufacturing sector. This paper presents an industrial survey to study the current status/usage of integrated manufacturing technologies (IMT) in the TT manufacturing firms. From the results of the survey, it can be seen that considerable scope exists for the introduction of IMT in the local manufacturing industries.

Keywords: *Integrated manufacturing technologies, Caribbean region**,** Industrial survey*

1. Introduction

Throughout history, a nation's wealth, standard of living, and status in the international community have directly benefited from its manufacturing activity. Energy generation and distribution, health care, construction, education, banking, transportation systems, and virtually every aspect of the modern way of life depend on the quality and affordability of manufactured products.

With current advances in computer technology, computer aided design (CAD), computer aided manufacturing (CAM) and flexible manufacturing systems (FMS) have attracted organisations to undertake significant investments in these systems. Next generation manufacturers need to effectively integrate these systems to gain a competitive advantage, reduce risks and improve productivity. The real challenge for today's manufacturers will be transforming the whole of their businesses into a digital enterprise, in which e-commerce is deeply integrated with e-production.

By implementing computer-integrated manufacturing (CIM), manufacturing enterprises have achieved significant performance enhancements in several areas, e.g. improved quality, responsiveness, effective sales and marketing information, increased operational productivity, lower overhead costs, reduced WIP inventory, reduced lead time, less floor space, and reduced setups (Rehg and Kraebber, 2001). Reduction in WIP and lead times is a result of lean manufacturing (Albert, 2005), which includes JIT. Improvement in shop floor operation is a hindrance in some of the SMEs (Marri et al., 2000). Various surveys conducted in the past indicated (Chowdary and Rao, 2004) the benefits (refer Table 1) due to implementation of CIM.

In this paper, the term 'Integrated Manufacturing Technologies (IMT)' is defined as the integration of the total manufacturing enterprise through the use of several technologies including CAD, CAM, FMS, CNC, robotics, MRP I, MRP II and JIT production and data communication networks coupled with new managerial philosophies that improve organizational and personnel efficiency. IMT show a new way to do business that includes use of a single computer database for all product

Department of Mechanical & Manufacturing Engineering, Faculty of Engineering, The University of the West Indies, St Augustine, Trinidad.
Email: boppana.chowdary@sta.uwi.edu

design and development information that is the basis for manufacturing and production decisions in every department, and the integration of various enterprise resources (Ulrich and Eppinger, 2003).

TABLE 1: CIM Implementation Benefits

Study	Benefits
National Research Council, Washington, D.C.	30-60% reduction in WIP inventory 200-500% increased yield in acceptable parts and products 30-60% reduction in total lead time 15-30% reduction in product design-engineering costs
Arthur Andersen's Clients	90% reduction in manufacturing lead time 25% reduction in costs of direct and indirect labour 75% reduction in machine setup time

There remains an urgent need in all developing nations to research and assess opportunities to strengthen the manufacturing sector that is expected to provide a stable economy. The rationale for IMT is compelling. All manufacturing industries of the Caribbean region must be enabled to meet the grand challenges of tomorrow posed by a wide spectrum of advanced technologies. The focus of this paper is to study the current usage/status of IMT in TT manufacturing sector.

2. Need for Industrial Survey

The main contributor to the gross domestic product (GDP) in TT is the energy/ oil and gas sector. Others include the agriculture, services and manufacturing industries. The energy sector provided approximately 31.4 per cent of the GDP in 2003 while the manufacturing sector provided only 6.8 per cent (Trinidad and Tobago At A Glance, 2003). Hence an urgent need exists in TT to research and assess opportunities for development in the manufacturing sector that is expected to provide a more stable economy and offer sustainable development in the absence of the energy sector. Presently, the manufacturing sector in TT caters primarily to the regional markets as well exporting to the North and South Americas and European markets. The steel industry is also quite prominent in Trinidad and Tobago, but it is still small in comparison to other industries. Also, there are plans to build an aluminium smelter in the country. It can be seen that manufacturing sector in TT is a major contributor to employment opportunities while petroleum and gas is the smallest contributor (Trinidad and Tobago At A Glance, 2003). Hence, development of such a sector is of great importance.

There are initiatives to develop the manufacturing sector in TT but on a small scale. The manufacturing sector mainly supports the petroleum sector since the latter relies on the former to provide maintenance items for example. The extent to which manufacturing industry is being developed is limited at present. Metal Industries Company (MIC) for example is performing some mould design work and making a limited number of plastic products, which is an indication of the diversification of the sector. To speed up the development and ensure that companies are better equipped for global challenges, an industrial survey such as this is needed to ascertain the needs of the local manufacturers. The objective of this paper is to study the current status of manufacturing technologies in TT and to provide some guidelines for its implementation with a view to improve their operations and be competitive to manufacture better quality products.

3. Development of Questionnaires

To conduct the proposed survey in TT manufacturing firms, two types of questionnaires were developed. The questionnaire labelled as the "Preliminary Questionnaire" gathered general information from the companies, pertaining to their current usage of IMT and the level of assistance they expected from the outside agencies in terms of design and development of IMT within their firms. The questionnaire labelled as the "Main Questionnaire" gathered technology-specific information from the companies. This questionnaire includes much more detailed questions pertaining to IMT and a few questions on the organizational structure of the company. The responses from the preliminary questionnaire played a major role in the development of the main questionnaire since from the responses we are able to pinpoint those firms that are:

- using some form of IMT.
- have plans of using IMT in the future.
- have no intentions of using IMT.
- the line of study does not fit their company objectives.

This survey targeted on the manufacturing firms that are currently involved in design, fabricate and manufacture of products for both the local and global markets. The main questionnaire sought to gather information regarding the status of IMT especially on:

- how much TT manufacturers know about it?
- how many are currently in use and the degree to which they are employed?
- what plans or expectations does the management of such companies have for their organizations?

3.1 Preliminary questionnaire design

This questionnaire was designed to be as short as possible in order to obtain immediate response from the participants the estimated completion time for the preliminary questionnaire is in the range of 5-10 minutes. The questionnaire contained two sections: Section 1 covered various questions on the usage of IMT and their plans of implementing them or not. Section 2 focused on various questions pertaining to the type of information or training that the firm might need for implementation of some IMT components within their company.

3.2 Grouping criteria

Based on the outcome of the preliminary questionnaire, we were able to construct and fine-tune the main questionnaire according to the general trends and tendencies within the manufacturing industry. The information from the preliminary questionnaire also allowed us to streamline our onsite interviews. Also, it enabled us to eliminate questions based on technology that is not currently being used by the company or have no plans on using it in the near future. This method was chosen based on its efficiency though it may look a bit redundant at first, since some of the questions from the preliminary reoccurs in the main questionnaire but at the end it saves both time and resources on both sides of the study. The following criteria are used to group various components of IMT:

a) Technology interaction and similarity
b) Trends in usage amongst the manufacturing industry
c) Uniqueness of technology (age, philosophy, etc.).

Using the above criteria and based on the information gathered from the preliminary questionnaire, we have divided IMT into four groups. These groups are as follows:

1. CAD, CAM, CAPP and CNC (based on criteria a and b)
2. MRP II and JIT (based on criterion a)
3. FMS, FLA (flow line automation) and Robotics (based on criteria b and c)
4. IT in Manufacture (ITM) (based on criteria c and b)

3.3 Main questionnaire design

The main questionnaire comprised four sections and thirty-two questions. These sections labelled in the following manner:

a. General questions on IMT: implementation issues and evaluation of currently used technologies
b. Detailed questions on the individual technologies: perceived/expected outcomes of implementing IMT tools and also experiences gained from these technologies.
c. Organization related questions: like the product range and company type.
d. Feedback: recommendations made and assistance needed by the firms in order to improve or implement IMT.

4. Data Collection

To conduct this survey six distinct firm types were selected (refer Table 2). These six categories represent the various types of manufacturing firms one can find in TT. The job titles of the individuals responsible for filling in and returning the questionnaires ranged from

CEO, middle level managers and engineers to shop floor technicians. Three methods were used to deliver the questionnaires: e-mail, personal delivery and onsite interviews. The majority of the preliminary questionnaires were delivered by e-mail but most of the main questionnaires were performed through onsite interviews.

TABLE 2: Categorization of the firms

Firm Type	Number of Firms Participated	Description
Assembly	7	Seafood containers; insulation materials walk-in freezers; die design and mould development; plastic products; circuit breaker panels; lighting fixtures; metal structures; ornamental iron works; manhole covers; metallic windows/doors and bottling
Chemical and non-metallic	5	Automotive batteries; tyres; glassware
Construction	4	Air-conditioners; refrigerator coils; metal structures
Personal care and food	3	Personal care and food (milk, juice and cereals) products
Energy	4	Petroleum products
Engineering	8	Metal component design; metal refurbishments; gears and shafts
Total	31	

The questionnaires were targeted at manufacturers that were using or had potential for using IMT. A search at the TT Manufacturers' Association (TTMA)'s website provided the names of such companies. Both the questionnaires were sent to 70 different organizations. Here, the sample chosen was based on the selective criteria or at times, just on consideration of availability. Forty two questionnaires were returned. Of those returned, 11 of them were considered not relevant to the study. This resulted in 31 usable responses. The overall response rate was therefore 60 per cent (42/70), and the effective response rate was calculated to be 44.29 per cent (31/70). The categorization in terms of various manufacturing firm types which have contributed to the study are shown in Table 2.

5. Data Analysis and Results

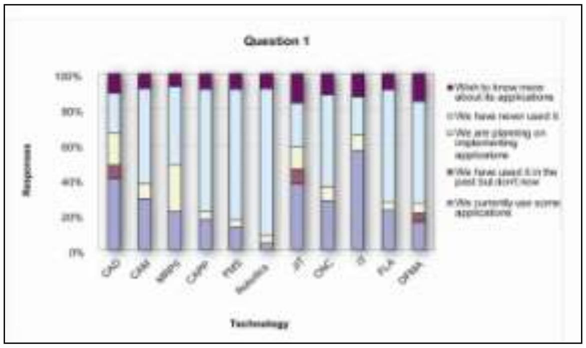
5.1 Validity of the survey instrument

In this study, importance is given primarily to internal validity in validating the survey instrument used for the research. Two measures of internal validity considered were content validity, and criterion related validity.

The content validity was established based on the subjective judgments of researchers and practitioners (Nunnally, 1988). The constructs of the IMT system were based mainly on the literature and local manufacturing practices. The draft instruments were however vetted for content of each IMT construct by small groups of practicing managers and academicians. The criterion validity was also conducted by using the procedure presented in Nunnally (1988). For analysis of the collected data, various graphic representation tools were used to give straightforward views on the status of IMT in TT. Group-wise analysis of the data for various technologies is presented below:

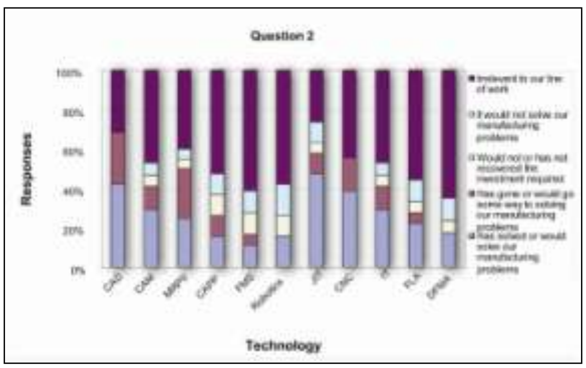
5.2 Group 1 technologies: CAD, CAM, CAPP and CNC

From the analysis it was found that 40% of the survey population uses CAD in their day-to-day operations (refer Figures 1 and 2). Also, the companies that have used CAD generally have a positive perception of the technology with a majority of participants stating that it has improved the quality of design in terms of accuracy (Figure 2). Largely, the response shows that CAD not only reduces design time but also saves labour costs. What is surprising is when asked on "the flow of information provided with the use of CAD applications", many firms disagreed on it since CAD improves the flow of information being shared amongst departments. But when asked on how it has performed within their firms, they said it has improved the flow of information, which is a 26.32% increase based on the expectation score of 2.92 (refer Table 3).



Legend: Question 1 – What is your current situation with respect to these technologies?

FIGURE 1: Current situation with respect to various technologies



Legend: Question 2 – How would you evaluate the use of these technologies?

FIGURE 2: Evaluation of the use of various technologies

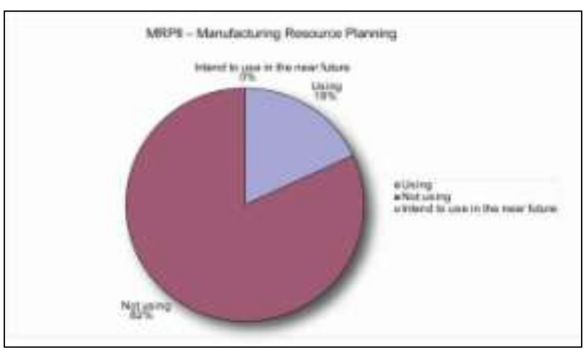


FIGURE 3: MRP II Usage

CAD and CAM are mutual technologies. CAM cannot function without CAD hence from the pool of CAD users we found that a certain percent that also uses CAM. The information from Figures 1 and 2 indicates that 29% of the survey respondents are currently using CAM. The low number of CAM users in the region is due to several reasons ranging from lack of capital to inadequate skills and training within the firm. From Table 4 it is clear that the expectation scores are not encouraging since the values presented under "Average Expectation" lies between "disagree and neither" (based on rating scale: 1-5). These values reflect the lack of knowledge when it comes to the aspect involving the benefits of CAM. This becomes evident when we look at the responses made under the outcomes, where a drastic increase ranging from 32 per cent to 50 per cent was found. This indicates that shortening lead-time and reduction in engineering costs were widely agreed upon being a key benefit in using CAM.

CAPP is also another component of IMT that works closely with CAD and CAM hence we expect that the users of CAPP are also users of CAD and in some cases CAM. The information from Figures 1 and 2 indicates that 17% of the survey respondents are currently using CAPP. Here it can be seen that CAPP expectations in Trinidad is quite low. We also found from our on-site interviews that the CAPP will increase the legibility of a process sheet. What is strange is that they do not perceive CAPP as being a time saver, based on the facts that it reduces lead times or that it will incorporate higher levels of standardization. The summary of the responses on CAPP is presented in Table 5.

The responses to the questions pertaining to CNC technology based on the firm's expectations were quite mixed, overall, most questions were above neutral, lying between neutral and agree (refer Table 6). The opinion titled "we hope CNC will reduce non-productive time" was the only one with a negative score. Based on our interviews, many firms had a hard time in understanding the principles under which CNC can reduce non-productive time even when we demonstrated examples that supported the claim, hence the reason for such a low score. On comparing the outcomes to the expectations of CAPP, we can see a general increase in the scores given to each opinion, where the reduction in tooling and the accommodation of engineering design changes on the work piece both had strong responses (3.75 and 4.00 respectively). The only decrease in scores was the response based on "reduction in human error", here a 4.55 per cent decrease was noted.

TABLE 3: Perception of CAD in TT Manufacturing Firms

Perception of CAD	Average Expectation Score (1-5)	% Difference from Outcomes	Standard Deviation Based on Expectation	Standard Deviation Based on Outcomes
a. We hoped CAD would improve designs	3.79	9.18	1.53	0.74
b. We hoped CAD would enhance productivity of the designer	3.64	7.97	1.60	0.80
c. We hoped CAD would help us to design or response faster	3.50	12.38	1.61	0.80
d. We hoped CAD would Improve the quality of designs (accuracy)	3.86	7.41	1.66	0.86
e. We hoped CAD would help to save labour	3.64	7.97	1.55	0.80
f. We hoped CAD would Improve flow of information to manufacture (to create a manufacturing data base)	2.92	26.32	1.50	0.85
g. Using CAD would reduce lead time by less time to produce drawing	3.43	10.83	1.45	0.77
h. Applying CAD can improve design documentation	3.50	12.38	1.65	0.80

TABLE 4: Perception of CAM in TT Manufacturing Firm

Perception of CAM	Average Expectation Score (1-5)	% Difference from Outcomes	Standard Deviation Based on Expectation	Standard Deviation Based on Outcomes
a. We hoped CAM would improve quality	2.36	48.07692	1.68954	0.759555
b. We hoped CAM would reduce the engineering costs	2.27	50.85714	1.678744	0.851631
c. We hoped CAM would help to reduce inventories	2.27	44.57143	1.678744	0.726273
d. We hoped CAM would shorten lead time to manufacturing	2.64	32.75862	1.911687	0.759555
e. We hoped CAM would improve flexibility greatly	2.45	42.59259	1.75292	0.759555

TABLE 5: Perception of CAPP in TT Manufacturing Firms

Perception of CAPP	Average Expectation Score (1-5)	% Difference from Outcomes	Standard Deviation Based on Expectation	Standard Deviation Based on Outcomes
a. We hoped CAPP would help process rationalization and standardization	1.90	63.16	0.99	0.32
b. We hoped CAPP would help to increase productivity of process planners	2.20	40.91	1.48	0.32
c. We hoped CAPP would help to reduce lead time for process planning	2.20	40.91	1.23	0.32
d. We hoped CAPP would improve legibility (Since computer-prepared route sheets are neater and easier to read than the manual ones.)	2.30	39.13	1.49	0.63
e. We hoped CAPP would incorporate other application programs	2.00	55	1.33	0.32

TABLE 6: Perception of CNC in TT Manufacturing Firms

Perception of CNC	Average Expectation Score (1-5)	% Difference from Outcomes	Standard Deviation Based on Expectation	Standard Deviation Based on Outcomes
a. We hoped CNC would reduce non-production time	2.55	28.57	1.21	0.65
b. We hoped CNC would help to improve reliability	3.09	17.65	1.51	0.81
c. We hoped CNC would help to reduce fixturing	3.00	24.24	1.55	0.90
d. We hoped CNC would reduce lead time	3.09	14.71	1.30	0.82
e. We hoped CNC would give greater manufacturing flexibility	3.27	13.89	1.56	0.90
f. We hoped CNC would make it easier to accommodate engineering design changes on the work piece	3.45	13.16	1.29	0.70
g. We hoped CNC would improve accuracy and reduce human error	4.00	- 4.55	1.25	0.87

5.3 Group 2 technologies: MRP II and JIT

The perceptions of MRP II amongst the firms in Trinidad are presented in Figure 3. Also from Figure 1 it is clear that only 18 per cent of the population has plans to put MRP II into practice. Based on our observation the general perception of MRP II is neutral, where the scores lie between 2.14 and 2.29. Here the lowest score of 2.14 was given to the opinion that MRP II will control changes in the shop floor orders. Also we found that most firms have benefited from the use of MRP II when it comes to long-term planning tool for manufacturers of complex goods and to pinpoint progress and inventory within the firms.

Figure 4 illustrates the perceptions of JIT amongst the firms in Trinidad. From Figure 1 it is clear that only 37% of the population has plans to put JIT into practice. Many of the firms have expressed negative views on the performance of JIT within their institutions. They claim that JIT does not complement the general attitude towards material distribution and procurement methods being displayed in Trinidad. Several firms govern their inventory by the "buffer" stock method in other words over stocking hence resulting in waste. This simplistic approach to inventory and material management can be a result of ignorance when it comes to properly implementing JIT.

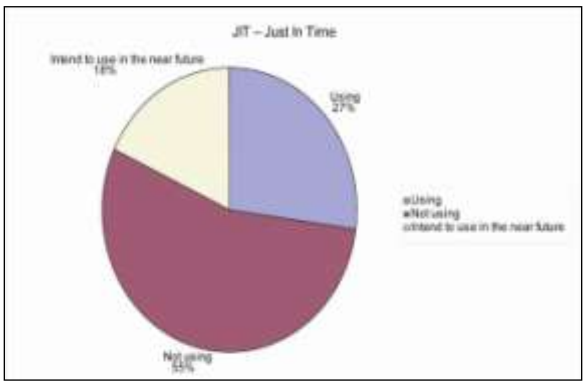


FIGURE 4: JIT Usage

5.4 Group 3 technologies: FMS and FLA

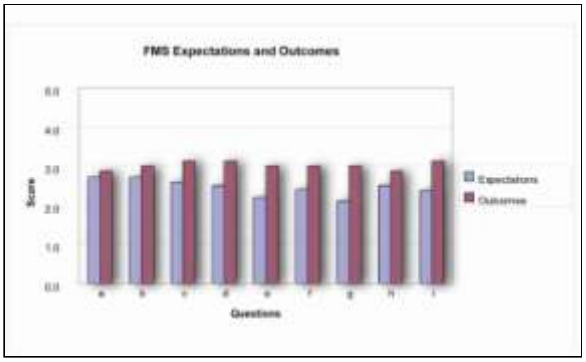
Figure 1 illustrates the perception of FMS in Trinidad, which represents nearly 15% of the research sample. On looking at the average expectation score one will notice that all the scores are negative, lying between disagree and neutral (refer Figure 5). Such low scores are as a result of the low usage of FMS in Trinidad. This technology is quite new to the region since many of the respondents were puzzled when questioned about FMS. The most positive response was made with regard to the option that FMS would reduce WIP and lower manufacturing lead times. Where as many firms disagreed that FMS would provide higher machine utilization. The respondents agreed that FMS would increase flexibility and provide higher labour productivity.

The perception of FLA in Trinidad can be seen in Figure 1, which represents 22 per cent of the survey population. On examining the average expectation score, we can say that the results are mixed (refer Figure 6), where the scores lie in the region of "disagree and agree". The opinion that FLA would provide an increase in capacity production was strongly agreed upon by most of the firms. Also we noticed through our field interviews that FLA would provide higher machine utilization and help to decrease inventory.

5.5 Group 4 technologies: ITM

From the Figure 1, it can be seen that 52% of respondents used ITM. Also through the field visits, it was observed that many firms who responded in the negative manner, however, are using some of the other individual IT tools. Questions were also asked on areas where help might be required by the respondents in order to facilitate the use of various IT tools. From the results, we can see that the majority of respondents require assistance in the training of professionals for use of various IT related software (refer Figure 7).

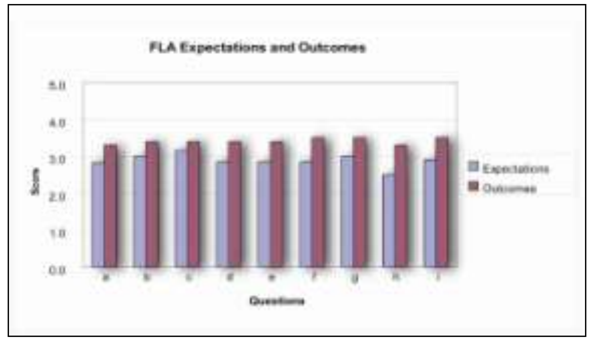
The graph of the usage of IT shows some interesting statistics, which is depicted in Figure 8. The graph showing the use of IT for distance learning is of particular importance. It appears that less than 40 per cent either using or plans to use distance learning for the training of employees. Some of the respondents suggested the need for a consultant in their field to gain hands-on experience and the ability to get assistance in real-time.



Legend:

- *a.* *We hoped FMS would help to reduce work-in-progress*
- *b.* *We hoped FMS would help to lower manufacturing lead times (faster customer deliveries)*
- *c.* *We hoped FMS would give greater flexibility in production scheduling (Improve product variety)*
- *d.* *We hoped FMS would provide higher labour productivity*
- *e.* *We hoped FMS would produce lower cost*
- *f.* *We hoped FMS would help to reduce labour*
- *g.* *We hoped FMS would provide higher machine utilization*
- *h.* *We hoped FMS would help to decrease inventory*
- *i.* *We hoped FMS would help to improve operational control*

FIGURE 5: FMS Expectations and Outcomes



Legend:

a. We hoped FLA would help to reduce work-in-progress
b. We hoped FLA would help to lower manufacturing lead times (faster customer deliveries)
c. We hoped FLA would give increase capacity of production
d. We hoped FLA would provide higher labour productivity
e. We hoped FLA would produce lower cost
f. We hoped FLA would help to reduce labour
g. We hoped FLA would provide higher machine utilization
h. We hoped FLA would help to decrease inventory
i. We hoped FLA would help to improve operational control

FIGURE 6: FLA Expectations and Outcomes

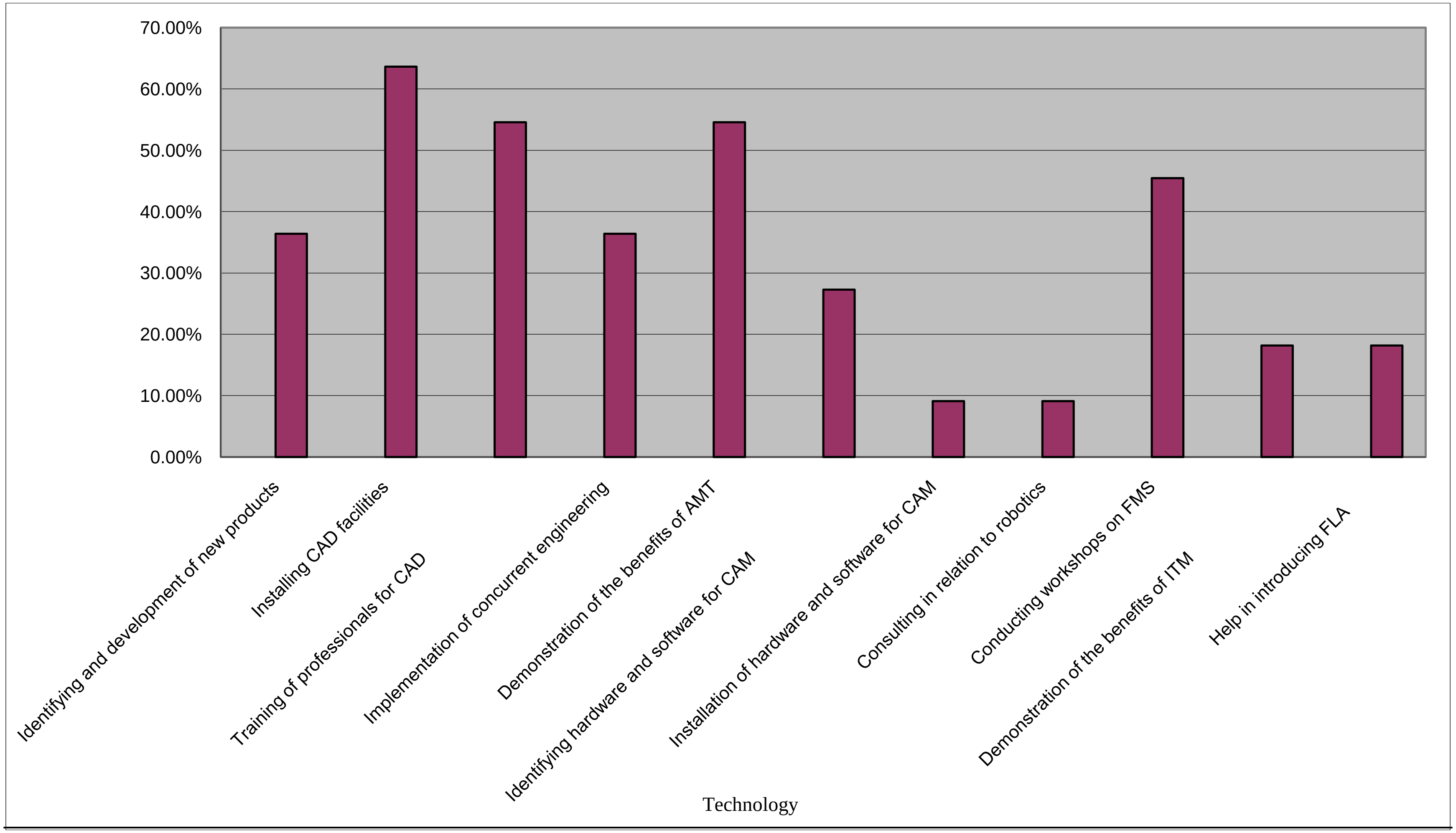


FIGURE 7: Assistance required in implementation of IT related tools in TT Manufacturing Firms

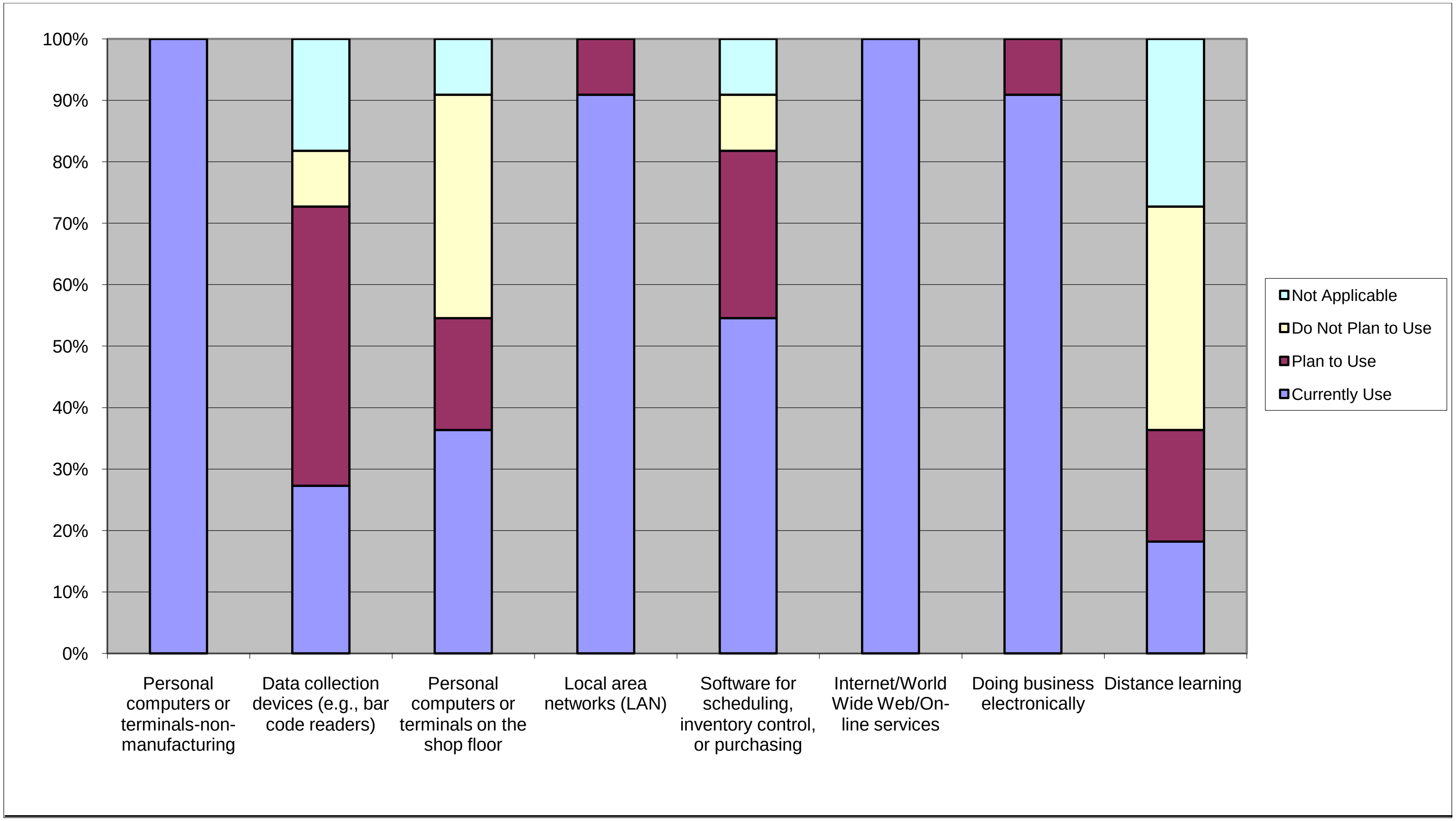


FIGURE 8: Summary of IT usage in TT Manufacturing Firms

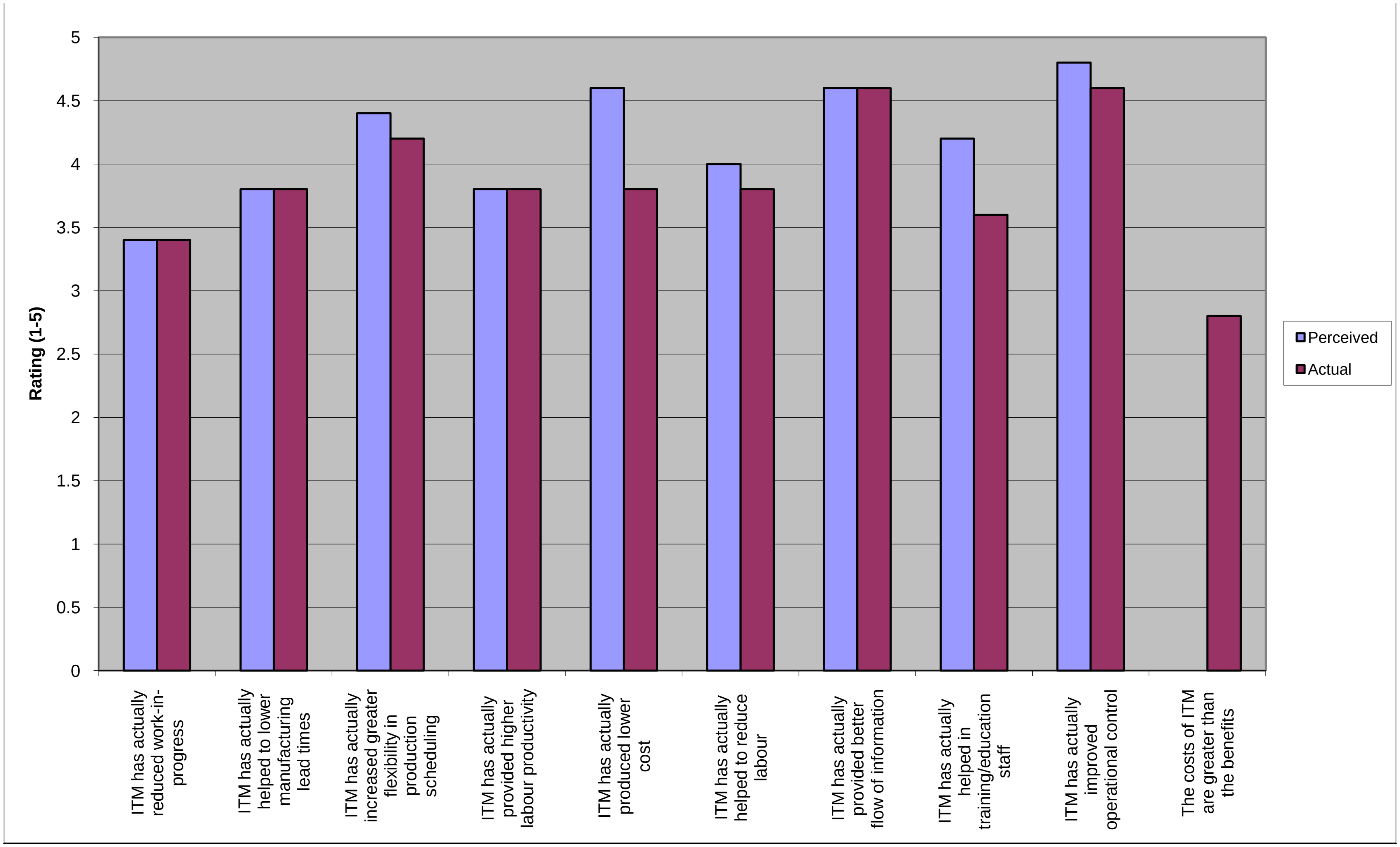


FIGURE 9: Benefits of ITM

However, there is evidence on high usage of personal computers and the Internet facilities, while over 90% of respondents agreed to use LAN and do electronic business. This is shown in Figure 8. It is also seen that approximately half of the respondents indicated the use of software for scheduling, inventory control and purchasing. Figure 9 shows that manufacturers in TT believe the actual benefits of ITM are very close to the perceived benefits.

6. Data Validation

For validation of the data, Box and Whisker plot was used since it is invaluable for gaining a quick overview of the extent of a numeric data set. It takes the form of a box that spans the distance between two quantiles surrounding the median, typically the 25% quantile to the 75% quantile. Commonly, "whiskers," lines that extend to span either the full data set or the data set excluding outliers, are added. Outliers are defined as points beyond 3/2 the interquantile range from the edge of the box; far outliers are points beyond three times the interquantile range. In this paper, the data validation is limited to only Group 1 (CAD, CAM, CAPP and CNC) technologies.

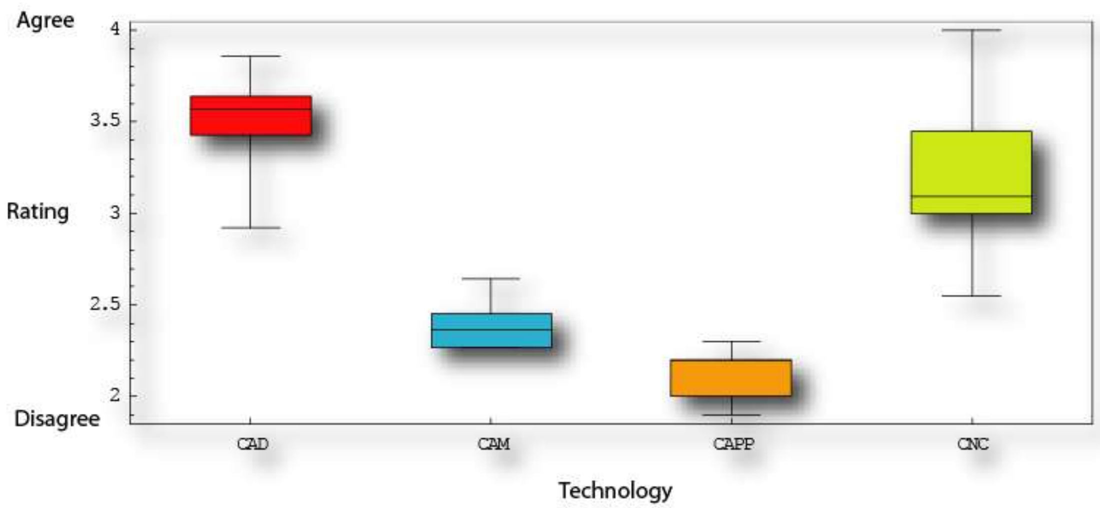


FIGURE 10: Box and Whisker Plots for Group 1 Technologies Based on Expectations

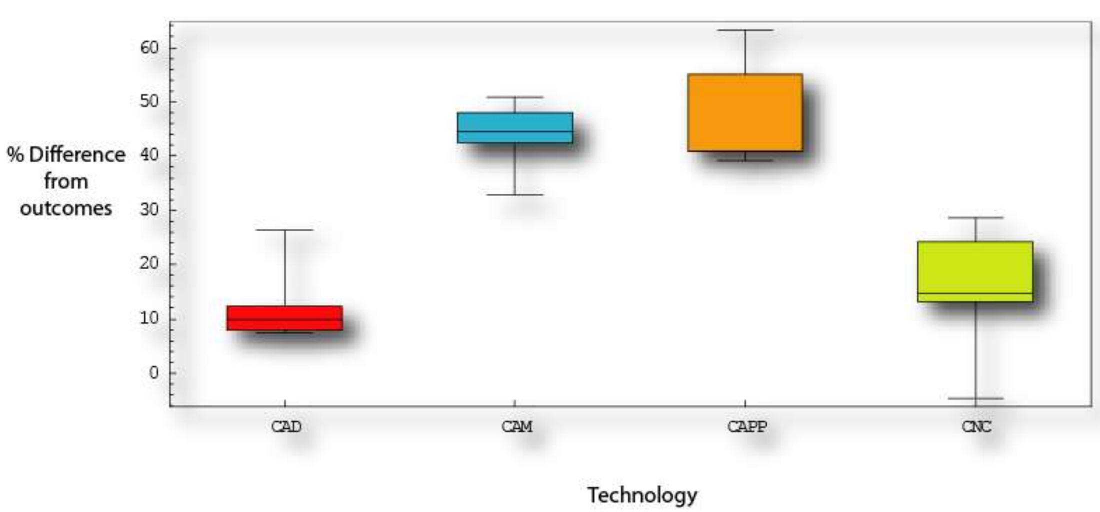


FIGURE 11: Box and Whisker Plots for Group 1 Technologies Based on Outcomes

Figure 10 shows Box and Whisker plots for the Group 1 technologies, the y-axis is the average expectation score given to the various technologies, which is represented on the x-axis. These diagrams are plotted based on the average expectation scores as presented in Tables 3 to 6. On examining Figure 10, CAD shows a more positive result where all the scores are above 3 except the option “CAD improves the flow of information to manufactures”, while CAM and CAPP all show negative responses since they all fall below 3. CNC shows a wide spread ranging from high (4) to a low (2.55), where the median is skewed towards negative side.

If we take a closer look at the individual Box and Whiskers for the various technologies, we see that option “CAD improves the flow of information to manufactures” is a negative outlier, which means that it stays away from the rest of the opinions. For CAM, we see that the 25% quartile corresponds with the tail of the distribution and the median negatively skewed, generally showing a poor agreement with the CAM technology. On examining CAPP, we see a highly positive skewed median with no outliers and a low spread, but still a generally poor agreement with the technology. For CNC, option “CNC improves accuracy and reduces human error” is a positive outlier and also the median is skewed negatively with a wide spread.

Switching the attention to the “outcomes” (refer Figure 11), we see a general increase in the rank for all the technologies except for CNC, where one of the views relating to CNC technology displayed a decreased in rank by - 4.55 per cent. This was the view that CNC would improve the accuracy and reduce human error. Although there was a decrease, it did not take the general perception into the negative region (disagree). If we look at CAM, one will notice a fairly high increase in the rank (from 32.7% to 50.8%), which pushes all the opinions into the positive region and the spread is slightly skewed to the negative. For CAPP, we see the largest increase amongst the other technologies. This increase takes all the views held for CAPP out of the disagree region and into the neutral region. Looking at CNC, we also see an increase in spread and the median is negatively skewed, when compared with the other technologies. This indicates the general view that CNC would improve the accuracy and reduce human error.

7. Proposed Guidelines

Serious thoughts should be given to the implementation of IMT in the local manufacturing firms. Identifying the gaps for the introduction of IMT in the Caribbean region could help to minimize product design and manufacturing risks and to promote the success of manufacturing organizations. From the current study, we have gained some valuable insights on the status of IMT. A selective list of the findings is as given below:

- CAD generally improves the quality of design in terms of accuracy
- CAD not only reduces design time but also saves labour costs
- Reduction in lead-time and engineering costs are widely agreed as key benefits in using CAM
- CAPP increases the process legibility
- Manufacturing firms in TT requires manpower training specifically in the area of IT, which will facilitate the local industry to become a competitive sector
- A need exists to establish a forum to share IMT information for a greater degree of collaboration and co-operation amongst the Caribbean institutions.

Based on the knowledge gained from the survey we are now able to formulate some guidelines regarding what could be done to encourage the implementation of the IMT in the local firms. The proposed guidelines are:

(i) *Providing a checklist for integration of CAD/CAM and Product Design and Development with the other functional areas of the system*

Here, the checklist can be used as a general template to configure the firms for implementation of IMT. The checklist could take into consideration of the local economical and employment factors. With this, managers will now be able to make decisions concerning software and hardware requirements. An implementation task force is needed to evaluate necessary steps to be taken in advancing the level of technology at which firms conduct their day-to-day manufacturing activities.

(ii) *Identifying new products and to provide support for its design and development*
Based on the survey findings, it is evident that most companies have expressed the need for identifying new products and to provide assistance for its design and development. Hence manufacturing companies must increasingly exploit various product design and development systems such as CAD/CAM, if they want to manufacture products competitively.

(iii) *Providing a base for coordinated future development*
The goal here is to install systems that facilitate a shared network of knowledge among various industries. This coordinated information can be used for the endeavours of the manufacturing industry. Such collective efforts are further useful to monitor the developments within the industry and pose as a forum for troubleshooting and technical support.

(iv) Moving towards e-manufacturing
The role of IT in the Caribbean manufacturing firms can be categorized under four broad headings. These are: (a) knowledge management (b) e-business (c) enterprise resource planning and (d) enterprise maintenance and asset management. From the study, it is clear that TT firms' employed one or a combination of the IT tools for addressing the areas mentioned above. Some routine IT tools employed in the firms are: (1) E-mail (2) Internet (3) Intranet (4) collaboration through web based applications. Further, from the survey it is clear that employing IT tools would reduce the lead-time and improve the quality and productivity of manufacturing operations to a considerable extent.

Hence the challenge for TT manufacturers' will be the transforming the whole of their businesses into a digital enterprise, in which e-commerce is deeply integrated with e-manufacturing.

8. Conclusions

8.1 Outcome of the survey

The survey has produced valuable information. Many of the companies are concerned with upgrading their manufacturing facilities. Most importantly, with the free trade area of the Americas (FTAA) negotiations taking place, most of the small and medium industries are concerned about their survival and ways of competing amongst the global market. As it stands, the general situation of IMT with in Trinidad is not heartening since most of the philosophies being used in the industry today are outdated and hence there is an urgent need to upgrade these technologies on par with industrial nations worldwide.

From the survey findings, we have seen little usage of what is perceived to be critical manufacturing tools and philosophies. Tools such as CAD and MRP software and philosophies such as JIT are key tools and are quite common amongst leading manufacturers' world wide. For example, many companies claimed that JIT will never work and does not suit the manufacturing environment here in Trinidad. Such a statement does not reflect proper appreciation of the potential of JIT since JIT can be incorporated into variety situations of the product being produced or the service being provided. To begin an upgrade in this sector will require manpower training, which will facilitate the industry to grow into a globally competitive sector providing high quality products.

8.2 Further research and development issues

Some of the issues that will affect the survival of many SMEs in Trinidad are:

- The need for government policies specifically to promote the development and growth of the manufacturing sector by providing incentives, tax breaks on machinery and other investments.

- The need to put mechanisms in place to encourage the importance for development of CIM area.
- The need to establish a forum on IMT.
- The need to establish a symbiotic mechanism between SMEs and the higher learning institutions where information can be freely shared and a greater degree of collaboration and co-operation is displayed amongst these organizations.

The results of this study will serve as the basis for further research into specific IMT needs and applications in the region. The challenge for the future is to identify appropriate IMT modules and application strategies that help to build more flexible, reconfigurable and proactive manufacturing systems with capabilities for managing the change and innovation to be able to adapt to market evolution and prosper, in the face of global competition.

Acknowledgement
This research was supported in part by the School of Graduate Studies & Research of the University of the West Indies, St. Augustine Campus under grant CRP.3FJ.

References

[1] Albert, M. (2005), "Setup reduction: at the heart of lean manufacturing", Modern Machine Shop Feature Article (Retrieved on December 9, 2005 from http://www.mmsonline.com).

[2] Chowdary, B.V. and Rao, U.R.K. (2004), "Integrated manufacturing technologies in the Caribbean firms", APETT's 17th Annual Technical Conference, Faculty of Engineering, The University of the West Indies, St. Augustine, Trinidad, March 11-12, pp.4-11.

[3] Marri, H. B., Gunasekaran, A. and Grieve, R. J. (2000), "Performance measurements in the implementation of CIM in small and medium enterprises: an empirical analysis", International Journal of Production Research, Vol. 38, No. 17, pp.4403 – 4411.

[4] Nunnally, J. C. (1988), Psychometric Theory, Englewood Cliffs, McGraw-Hill, NJ.

[5] Rehg, J.A. and Kraebber, H.W. (2001), Computer Integrated Manufacturing, 2nd edition, Prentice Hall, New Jersey.

[6] Trinidad &Tobago Manufacturing Association (TTMA) (Retrieved on December 9, 2005 from http://www.ttma.com)

[7] Trinidad and Tobago at a Glance, 2003, Tourism and Industrial Development Company of Trinidad and Tobago (TIDCO) Publications, Phillips Street, Port of Spain, Trinidad, West Indies.

[8] Ulrich, K. T. and Eppinger, S. D. (2003), Product Design and Development, 3rd edition, McGraw Hill, Irwin.

[9] Visionary Manufacturing Challenges for 2020 (Retrieved on December 9, 2005 from http://www.books.nap.edu./catalog/6314.html)