# Perceptions and Problems Related to the Use of Manufacturing Automation in a Small, Geographically Isolated Economy

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***ABSTRACT***

*In small, geographically isolated economies, it is possible to find a lack of appropriate support for the implementation of state-of-the-art technologies and methodologies for manufacturing automation, thus compromising the efficiency and competitiveness of the manufacturing sector in the global marketplace. In this work, we carry out a critical investigation of the use of automation within the manufacturing sector of such an economy, using the island nation of Malta as a case study. We focus mainly on high value-added manufacturing, characterized by the need for high product variety and relatively low product quantities, and triggering the need for versatility in production facilities, potentially in the form of reconfigurable production systems. We have developed a set of detailed questions, in the form of a survey questionnaire, which we pose to a sample of companies from various sub-sectors, and of various sizes, within the Maltese manufacturing sector. Respondents answer the questions in the setting of a semi-structured interview, following an extensive familiarization tour of the company facilities by the interviewers. We present the results, as well as their analysis and interpretation, from our first sample of thirty manufacturing firms, ranging in size from micro to large, and taken mainly from the electronics, medical, pharmaceuticals, plastics, food and beverage, chemicals, and furniture industries.*

## 1. INTRODUCTION

In the past decade, various authors have discussed the emerging challenges related to the continuous struggle faced by manufacturing companies to improve efficiency and effectiveness [1]-[5]. These challenges affect different manufacturing sectors to varying extents, however in general they continue to become more stringent, for a number of reasons. Firstly, customers are expecting a much larger amount of product variants and increased quality. Secondly, as time passes, there is continuous progress in technology, and as a result, products are constantly evolving so as to incorporate new technologies. Manufacturing systems and processes are also being directly affected with this advancement of technology due to the development of new techniques, processes and equipment. The introduction of regulations is also having an effect on the manufacturing industry, both due to regulations affecting the product, as well due to regulations that require a particular change in a manufacturing process. Another existing challenge concerns the shift to an ever-expanding globalised market, with manufacturing companies no longer having to compete only against local companies, but nowadays having to compete against distant and/or foreign companies as well.

However, such studies have generally been based on relatively large countries and economies, or else been based on very general overall situations. The specific aim of our work is to carry out a critical investigation of the manufacturing situation within a small and geographically isolated economy, with a focus on the implementation of industrial automation, and to identify and address problems that exist. Solutions to identified problems will be developed with a focus along the new paradigm of reconfigurable manufacturing automation systems. This paradigm was developed in the early 1990s and early 21st century, and various authors have discussed Reconfigurable Manufacturing Systems (RMSs) [2], [3], [5], Reconfigurable Equipment [6], and Reconfigurable Machine Tools [7]-[9]. Such systems bridge the gap between Dedicated Manufacturing Systems and Flexible Manufacturing Systems, and combine the advantages of both approaches. RMSs are built around a part family, or part families, allowing product variants within the respective part family/families to be manufactured through a

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rapid and relatively simple reconfiguration of the equipment. Reconfigurable equipment has the potential of substituting, exchanging, adding, removing, and/or modifying specific modules to change an existing RMS configuration into a new configuration with different capabilities.

This paper focuses on the first part of our overall project. The primary targets of this specific study are to investigate the perceptions and problems relating to manufacturing, with a focus on automation, that are experienced specifically by companies operating within a small and geographically isolated economy. As a case study, the current situation in the Maltese Islands has been taken.

Malta is an island nation, and European Union (EU) member state, in the middle of the Mediterranean Sea. It has a population of 400,000 and a gross domestic product (GDP) of about €5.7 billion ($7.4 billion) [10]. The manufacturing sector accounts for about one fifth of the GDP. The Maltese economy has experienced a transition in the last decades whereby the traditional low technology mainstream manufacturing sector experienced difficulties due to its heavy reliance on manual labour. Therefore, Malta's focus has been directed towards high value-added manufacturing, in an attempt to enable industry to achieve productivity growth to engender prosperity and wealth. Analysis has shown that the European manufacturing industry consists in large majority of SMEs (Small and Medium Enterprises), with over 99% of companies and 58% of manufacturing employment falling within this group. In fact these SMEs generate the majority of new and innovative products, providing some three-quarters of EU exports. Malta's economy as in the case of other EU countries is characterized by a predominance of SMEs. These businesses are not only fundamental for the on-going internal economic activity, but are also a complementing arm of industry in general since these would supply the larger companies making up the industry.

This study therefore has two objectives with respect to the Maltese manufacturing sector: an information gathering objective, and a problem identification objective, with the particular focus being automation in high value-added product manufacturing. The results of this study, although specific to the Maltese manufacturing environment, may also be widely relevant to other pocket economies within the EU, as well as within the rest of the industrialized world.

## 2. PRELIMINARY GUIDELINES

To thoroughly achieve the two primary objectives of this study it is required to carry out an extensive investigation of the local scenario through the gathering of information about various issues relating to manufacturing and industrial automation. The companies that have been investigated so far have been chosen at random from an exhaustive list of manufacturing companies compiled from databases taken from various sources.

Table 1: Sectors listed according to Priority

| Sectors with Priority 1 | Sectors with Priority 2 | Sectors with Priority 3 | Sectors with Priority 4 |
|---|---|---|---|
| Electronics | Beverages | Meat Processing | Construction |
| Medical | Chemicals | Paper | Explosives |
| Pharmaceuticals | Food | Printing | Metal-work |
| Plastic-ware | Furniture | Tobacco | Mineral |
| | Glass | Wax | Recycling |
| | Textiles | | Shipping |

The companies within this list were categorized according to the nature of the products produced within each company, e.g. medical, pharmaceutical, furniture, chemical, etc. Twenty-one manufacturing sub-sectors were outlined. These sub-sectors were put in a priority list as outlined in Table 1 in terms of the nature of the products manufactured. Perceived high-volume discrete product manufacture and consumer product manufacture were given a high priority (in this case level 1 and level 2), whilst products that tend to be one-offs, such as infrastructure, and high-volume production of the same product, such as paper manufacture, were given lower priorities (in this case level 3 and level 4). This study aims to investigate the high priority manufacturing sectors.

Apart from the manufacturing sector within which a particular company operates, another important factor that may lead to characteristic problems is the actual size of the company in terms of the total number of employees. Each category has thus been further subdivided into four sub-categories according to the number of employees within each manufacturing company, namely: micro-sized companies, having less than 10 employees and with a turnover less than €2 million; small-sized companies, having less than 50 employees and with a turnover less than

€10 million; medium-sized companies, having less than 250 employees and with a turnover less than €50 million; and large companies, having more than 250 employees, as per the definitions in [11].

## 3. SURVEY DEVELOPMENT

### *3.1 SURVEY FORMULATION*

As mentioned in the previous section, this study has two main objectives; a critical investigation, and a problem identification objective. The gathering of information is mainly through a detailed survey, consisting of two main sections. The first section contains general questions relating to the company and the manufacturing approaches and means implemented. This first section is intended to be answered by all respondents. The second section focuses on automated manufacturing, and is therefore intended for respondents that already implement automated machinery.

The first section of the survey starts off with general questions related to the company being investigated, such as a description of the manufactured products, company size, as well as the number of employees. As mentioned above, certain characteristics may arise that can be correlated to each of these separate factors. Therefore, such questions were required to position the company in the right categories, mainly with respect to sector and size, so as to be able to analyse trends of these separate categories.

As indicated above product lifetimes are constantly decreasing, that is the time between the initial stages of production to the time when the product is not manufactured any more. This being a very important driver for the subsequent manufacturing approach implemented within a company, there was a need for a question related to the lifetime of the products being produced by the company being interviewed.

The next questions tackle specifically the manufacturing approach and processes currently being made use of within the production facility of the company being interviewed. In this specific study, the broad categorising of manufacturing approaches has been taken to be manual, semi-automated and fully automated. Manual processes are processes made up of mostly manual labour. A semi-automated manufacturing approach refers to operations being split between manual and automated, whilst fully automated processes refer to processes run fully autonomously or with minimal human intervention. Respondents could choose any of these approaches; or multiple approaches if different approaches are undertaken for different manufacturing processes. The reasons given by the respondents for their choice of manufacturing approaches) were also requested. Some potential reasons that were identified beforehand, and given to the correspondents to choose from, include product variety, production volumes, and product/process complexity. In addition, correspondents were also questioned about specific production processes implemented on their shop-floors, and whether such processes are fully manual, semi-automated or fully automated.

In order to determine the use, or the lack of use, of automation equipment, it was considered necessary to inquire about any perceived problems towards the implementation of automation equipment and industrial stand-alone robot arms. Together with this information, other questions that tackle issues relating to the willingness to invest in automation in relation to customer pressure and/or to competitor facilities were also included in the survey.

The second section of the survey is more focused on automation and its implementation, and as mentioned, is reserved only for respondents that currently already employ some level of automation. The first question in this section relates to the identification of equipment that generally is implemented for automated manufacturing. Respondents are given a list of such automated equipment from which they have to tick any already implemented equipment. The list includes Computer Aided Design (CAD), dedicated automation equipment, specialised automation equipment, Computer Numerically Controlled (CNC) machining equipment, pneumatic/hydraulic devices, flexible or reconfigurable automation, and machine vision. This is required so as to determine what facilities are currently being used the most in automation. In addition, it was deemed useful to understand where the design and manufacture of such automation equipment is undertaken. Common approaches include companies designing and manufacturing their equipment in-house, with others subcontracting it both to local as well as to foreign mainland equipment manufacturers. In the case of certain subsidiary companies, the technology, processes, and even any required equipment may be directly adopted from the respective mother/sister companies. As a result, all these options were included from beforehand in the survey. For each option chosen, the respondents were also required to give the reasons for their choice. Some possible reasons that were included from beforehand in the survey include quality and available expertise; however respondents were encouraged to add to the list.

The next set of questions, relate to how the companies react with respect to the implementation of automation equipment when a completely new product is to be introduced to the existent product portfolio. This would be useful to determine whether a new system would be opted for straightaway or whether the existent system would be considered for the manufacturing of the new product thus resulting in reconfigurability of the automation equipment.

Besides reconfigurability of automation equipment, this study is also interested in flexible automation and whether this specific philosophy of manufacturing is actually implemented or not. A number of questions were introduced in order to determine whether equipment with extra in-built capabilities would be considered even though at that point in time, there would be no use for all its capabilities. Also, it was deemed useful to determine whether if this is opted for, the equipment would actually later be used to its full potential or not.

The next questions address the utilization of specific equipment for various different products, with a focus on reconfigurability and modularity. First, the issue of whether the current production equipment is to a particular extent modular or not was tackled. Following this, respondents were asked whether the equipment utilized for the manufacturing of a particular product is re-used or reconfigured when the lifetime of the respective product reaches an end. Subsequently, the frequency of "engineering changes" on an existing production system was requested, with the term "engineering changes" being used in this particular study referring only to changes that require a certain degree of new engineering input, and hence not including work order changes. This was followed by the reasons causing these changes, and a list was again made available to the respondents. The list included regulations and/or customer requests, quality requirements, capacity requirements among others. Finally, the typical extent of changes and the time taken to carry out the changes were asked. These questions would be required to determine the degree of changes and thus the requirement to adapt quickly to new set-ups.

The final question of the survey focuses on the relationship between the product design and product manufacture, focusing on the extent to which the product design may be affected by the manufacturing set-up itself. Product design is one of the initial stages of the product life time, with manufacturing following at a later stage. This question would give an indication on how the product design may affect the modularity or reconfigurability of the production facilities used and the extent to which the product design may be affected in order to automate the process on which the product will be manufactured.

Table 2: Number of companies interviewed for each sub-sector

| *Categories* | *Micro* | *Small* | *Medium* | *Large* | *TOTAL* |
|---|---|---|---|---|---|
| *Beverages* | ***0*** | ***0*** | ***0*** | ***1*** | ***1*** |
| *Chemical* | ***0*** | ***1*** | ***2*** | ***0*** | ***3*** |
| *Electronics* | ***1*** | ***2*** | ***3*** | ***1*** | ***7*** |
| *Food* | ***0*** | ***0*** | ***1*** | ***0*** | ***1*** |
| *Glass* | ***0*** | ***1*** | ***0*** | ***0*** | ***1*** |
| *Medical* | ***1*** | ***0*** | ***2*** | ***1*** | ***4*** |
| *Pharmaceuticals* | ***1*** | ***3*** | ***1*** | ***1*** | ***6*** |
| *Plastic-ware* | ***2*** | ***2*** | ***0*** | ***1*** | ***5*** |
| *Textiles* | ***0*** | ***0*** | ***0*** | ***1*** | ***1*** |
| *Woodworks* | ***0*** | ***0*** | ***1*** | ***0*** | ***1*** |
| *TOTAL* | ***5*** | ***9*** | ***10*** | ***6*** | ***30*** |

### *3.2 SURVEY IMPLEMENTATION*

Following a number of test runs, it was decided that the methodology adopted for the gathering of information through the survey would consist of conducting a semi-structured interview with an appropriate company representative(s). This company representative(s) ideally had to be very familiar with the production activities within the company, such as the head of manufacturing department or operations manager. The semi-structured interview included a physical tour within the manufacturing facility of the company and subsequently a discussion on the survey questions. The discussion as well as the tour proved to be a valuable source of information towards the completion of the survey questions. In fact, this was confirmed during the test runs that were conducted. Even though lengthy, this methodology improved consistency in the answers given by different respondents due to the fact that, the replies to the questions asked were always recorded by the same person. To date, thirty interviews have been conducted from the sub-sectors with priority weighting 1 and 2. The breakdown of the companies interviewed by sector and size can be seen in table 2.

## 4. PRELIMINARY RESULTS

This section discusses the results obtained from the preliminary analysis of the first sample of thirty surveys performed. However, it is pointed out that this analysis is still a general one due to the relatively small number of surveys performed within each sub-sector. The trends within each particular sub-sector and size category require more surveys to be performed.

### *4.1. PRODUCT LIFETIME*

It was interesting to note that approximately half of the companies answered that their product has a lifetime of more than 5 years as illustrated in Figure 1. Another twenty per cent produce products with a lifetime between two and five years. The rest of the respondents have products with lifetime of up to 24 months. Thus a trend can already be seen, with the majority of cases being companies having quite lengthy product lifetimes, which contrasts with some descriptions of current trends found in literature. Through the various discussions with manufacturing personnel from such companies, a common reason for this behaviour was that the companies are subsidiaries having foreign mother companies, with the trend being that the mother companies move those products that have already reached their maturity stage to the plant in the small country. Newer products are possibly manufactured nearer to the customers, since they would still be under development. Since products that have already reached their maturity stage, in general, tend to start decreasing in volume, the companies in the small countries would end up producing an increasing variety of batches/types of products, with each of these having a relatively small volume. This would result in having a good number of products with relatively low volumes to be produced for a considerable length of time.

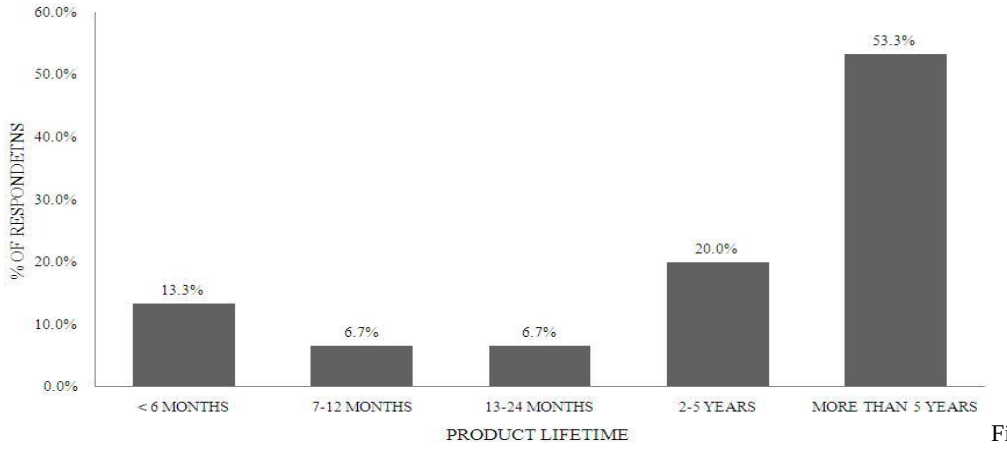


Figure 1 - Product lifetimes against percentage number of respondents

### *4.2. MANUFACTURING PROCESSES*

Having a large variety but low volume products portfolio was given as one of the main reasons why fully manual manufacturing processes are still adopted by many of the companies, totalling forty per cent of the survey respondents. These respondents commented that the utilization of manual processes is due to requiring various changeovers in the production setup, and therefore necessitating a high degree of flexibility in their processes so as to be able to quickly adapt the process to all the product variations required. However, another primary reason for the adoption of manual labour is the complexity of mechanical assembly, with the most common manual processes being material transfer, packaging, and inspection.

Semi-automated processes were implemented when the requirements of quality and efficiency were deemed to be the primary manufacturing issues. In fact, this was the case in forty per cent of the interviewed companies. In such cases, many mechanized processes such as injection moulding are also included. Other techniques include printing and cleaning processes. The semi-automated processes are also characterized by higher volumes. However, it is important to note that the respondents noted that their clients do not generally impose the requirement of automating the processes.

Fully automated processes are only employed by about one fifth of the interviewed companies. The reason given for implementing fully automated processes is mainly due to high production volumes. The most common fully

automated manufacturing processes include soldering processes, especially in the electronics industry, as well as printing processes.

### *4.3. Implementation of Automated Equipment*

With the implementation of automation being relatively limited, it is important to investigate whether there are some perceived problems for the implementation of automation. A common and significant problem that has been encountered in practically all companies is the lack of time to study opportunities. A reason for this may be that in small and geographically isolated countries, most often all companies are relatively small. Even companies that are regarded locally to be large, in fact are still relatively small when compared to mainland companies. This results in these small companies having to compete with larger competitors while seeing to everyday routine non-manufacturing tasks as well, such as maintenance works. These everyday non-manufacturing tasks would make it difficult for them to study opportunities to enhance their productivity. In addition, the exposure to newly developed technologies through relevant industrial shows, exhibitions, and fairs is minimal, due to the relative isolation of the economy.

Besides the above discussed reasons, there are other perceptions that hinder the use of automation equipment. Continuing from the lack of exposure to manufacturing technologies, these include the perception that such equipment is not appropriate for the products or for the volumes being produced. This was especially identified when automation equipment such as stand-alone industrial robot arms were discussed. Another high rating perception is that the equipment and its relevant required implementation are too expensive. Such respondents argue that it all depends on the volumes being produced. With the already identified low productions volumes, such investments are regarded as not being justifiable.

### *4.4. Design and Manufacture of Manufacturing Automation Equipment*

When automation equipment is actually implemented, the most common approaches include making use of dedicated and specialized automation equipment, flexible and reconfigurable equipment, as well as machine vision. The common approach is for the design of such equipment to be outsourced to specialized manufacturers outside of the country; however modifications and adaptations are usually done in-house. This is due to the fact that for such complex manufacturing equipment the knowledge of complex processes and technologies is considered to be in the hands of developers who are specialized within that particular manufacturing field, and thus are readily equipped with the knowledge and technologies required. Therefore, local manufacturers outsource the design of such manufacturing equipment with the perception of obtaining high quality equipment. The manufacturing of such equipment is also mostly left in the hands of these foreign based industrial equipment manufacturers. However, when it comes to the development of relatively simple equipment or a slight modification to equipment, the common approach is to outsource such tasks to local manufacturers or else they are performed in-house, with both these approaches opted for due to financial reasons.

### *4.5. Nature of the Products and Industrial Manufacturing Equipment*

It was observed that many of the investigated companies specialize in the production of part families, with the products that they manufacture being to a certain extent similar to each other in nature. In fact, in most cases, even new products that would be added to the current product portfolio would also be similar in nature to those already existing or to past products. Therefore, it would be possible to include them in already existing setups without major changes. In fact, when discussing this issue, most of the survey respondents said that when new products are to be introduced, these are in fact added on to the already existing production lines. In fact, when investing in industrial manufacturing equipment, the common approach is to invest in equipment having extra in-built capabilities. The approach taken is to utilize this equipment to manufacture the product portfolio, which as has been mentioned, within each manufacturing company can be regarded to be a broad product family. Still, respondents pointed out that many times, the extra in-built capabilities invested in when buying the equipment are still not all made use of. When it comes to the end-of-life of a current product, these trends are reflected on the approaches taken with regards the manufacturing equipment that was being utilized for that particular product. This is illustrated in Figure 2, which illustrates the most common actions taken for the manufacturing equipment for new products.

### *4.6. Changes to Equipment*

It has already been established that the lifetime of the products manufactured by the companies interviewed, is, in general, relatively long. This together with the fact that the products would be past their development stage, would mean that not a lot of “engineering changes” would be required in the processing facilities. In fact as opposed to work order changes which occur on a daily basis due to the various different products manufactured, the

survey showed that such engineering changes occur very rarely, with these changes occurring every few years. The main reasons for these changes when they occur include requirements for quality improvements, new implemented regulations, new products adaptation, as well as capacity changes that are beyond what was catered for initially. The

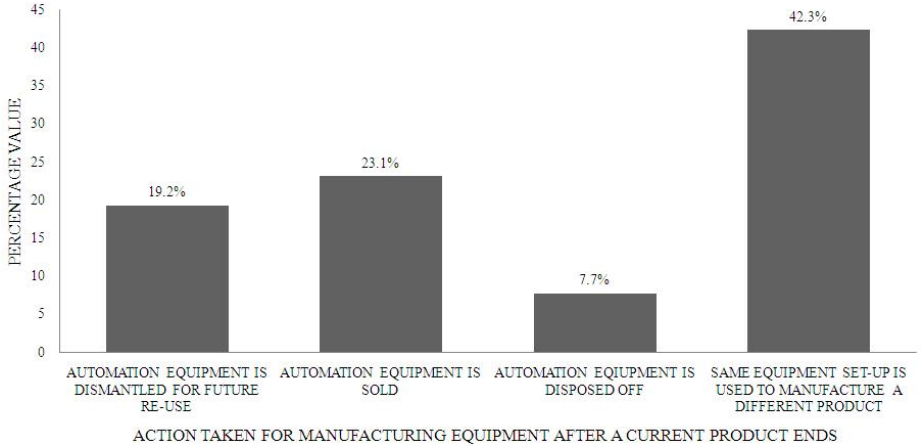


Figure 2 – Most common actions taken for manufacturing equipment after the end-of-life of a current product

typical extents of these changes are minimal hardware and/or software changes; with the time to carry out such changes ranging from only a few hours to a few weeks.

### *4.7. PRODUCT DESIGN*

Another interesting point that arose from this study is that no product design activities are present in most of the investigated companies, with the main reason being that the majority of respondents are subsidiaries to larger companies. In these cases the trend is that the mother company develops the product design, with this design being handed over to the local companies. These local subsidiaries would therefore have to manufacture the already designed products. As was discussed in a previous section, these products tend to also have already reached their maturity stage, and therefore would be well past their developmental process. This further limits any possible changes to the product design.

## 5. DISCUSSION

Many of the key characteristics of manufacturing companies that were identified in this study, with regards to manufacturing and industrial automation equipment, may be relevant to other small and/or geographically isolated economies. One of the key points is that most of the thirty companies investigated have a product portfolio composed out of broad product families, each of these having a large amount of products which despite having differences amongst themselves, can still be categorized and grouped together due to a high percentage of similarities. During the investigation, this was mostly encountered in micro-sized companies. The end result would be that such companies opt for fully manual manufacturing processes with the perceptions that there is no other feasible way. The lack of industrial fairs and locally based industrial equipment manufacturers continue to reinforce this perception. It is clear that manufacturing companies operating within such a pocket economy cannot stay competitive for long without the exposure to new and improved manufacturing approaches, ways, and means. The survey has revealed that companies that do attend industrial fairs tend to be much more open to innovative and advanced manufacturing methods. This implies that such exposure may be of great importance to local companies, to enable them to be competitive with mainland companies, which in today's globalised markets have become direct competitors.

It was also noted that in companies where the products have been around for a significant amount of time (several years), such companies are less willing to take up new products and try to achieve a larger market share. This is especially the case for subsidiary companies. In such cases, it is not unusual for the mother company to decide and impose the products that the company in question should manufacture, with these products potentially even being those that the mother company deems not worth marketing anymore, but is forced to continue producing for example for past users. Therefore, the common approach is for no investment to be considered in such

production lines. Further to this, some local companies were identified to be less willing to invest in new manufacturing approaches, with the mentality of "if we have managed during the past decade, we will manage during the coming decade as well". Such a mentality exists especially in those companies that have very limited exposure to new and innovative ideas from outside the company.

During the discussions with manufacturing personnel, other factors not directly mentioned in the survey were also brought up. In more than one instance it appeared that the potential enlargement of the physical factory size was an issue. Companies seem to find it difficult to enlarge the physical size of the factories, with the main reason being attributed to the documentation and bureaucracy necessary for such a move. Another recurring issue in these discussions with several manufacturing organisations relates to the lack of networking between the local factories themselves especially in the case of micro and small companies. This is unfortunate for multiple reasons, including the consequent absence of sharing of potential solutions and of the identification of possible customers through subcontracting. Lack of networking also affects the already existing local automation service providers. Due to this lack of communication and networking, many of these service providers are still relatively obscure, with only a few being known by the majority of companies.

In concluding this preliminary investigation of the data obtained from the survey, one can note that for a survey of this nature, it is essential that a company tour be taken prior to the actual interview. The survey itself is at times too general and thus not capable of capturing all the information that is being obtained through the tour and the discussions being taken up with the respondent.

## 6. Conclusion and Future Work

Further surveys will be performed with more companies from the various outlined manufacturing sub-sectors. This will give the possibility to analyse the various sub-sectors, together with the company size categories, on their own. Following this, the perceptions and problems related to manufacturing currently existing within particular sub-sectors could be determined. After an-depth analysis of the identified manufacturing perceptions and problems, the project will then proceed to address these specific manufacturing issues that emerge from this study.

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