Enablers and Barriers for Introduction of Robotics as an AMT in the Indian Industries (Case of SME's)

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ABSTRACT
In today's economic environment, enterprises that solely rely on traditional technologies cannot meet dynamic customer demands. Several studies confirm that a nation's growth is dictated, to a large extent, by the performance of small businesses. However, the reality is that SMEs are constantly struggling to survive and maintain their schedule of activities. This is evident in the track record of the majority of SMEs in the developing countries: they have been unable to reap the benefits of globalization. This unfortunate predicament may be attributed to the fact that many developing countries face major challenges in suitably developing and using modern technologies. Hence, Introduction of Robotics as an Advanced Manufacturing Technology (AMT) represents an opportunity for manufacturing firms to improve their competitiveness in order to meet the customer's demands and be the winners in the competitive market

This paper involves review of literature of the enablers and the barriers on introduction of Robotics as an Advanced Manufacturing Technology (AMT) and the identification of key issues and strategic risks involved in this.

Keywords
Robotics, SMEs, Advanced Manufacturing Technology (AMT), enablers, barriers.

1. INTRODUCTION
Despite the idea of robots being part of human culture, the robotics industry in India is still at an early phase of development. [1-9]. The term 'robot' has been in use in English since 1923, when the Czech writer Karel Čapek's play R.U.R. was first translated. R.U.R. is an abbreviation of Rossum's Universal Robots, and the word 'robot' comes from the Czech robota, meaning 'servitude, forced labour', from rab, 'slave'.There is no definition of a robot or robotics that satisfies everyone.[6]

The International Organization for Standardization defines a robot as "an automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes".

The definition of a robot should include some or all of the following attributes: [6]

- Computing hardware and software, sensors and actuators, usually with more than three degrees of freedom, giving the ability to move in a three- or two-dimensional space with at least three joints.
- Autonomy with some degree of intelligence for decision-making, as set by the necessary degree of human intervention – adaptability for changed circumstances in operating environment. Today, we have limited autonomy and limited tolerance of change. Though automation in unstructured environments is limited today, in the future it will be possible in increasingly unstructured contexts with high degrees of change, for which decisions are required.
- The capacity to be reconfigured, usually when the robot is not in operational mode – and usually via software – for a new task or environment.
- The ability to cooperate with humans – this is increasingly important, as is co-operation with other machines (including robots), to tend, service or direct them.

The structure of a classic robot today is a kinematic chain of mechanical parts with a function near to that of a bodily skeleton. It consists of links to actuators (equivalent of muscles) with joints for multiple degrees of freedom of movement. At the end of a 'limb' is a tool, or "end effector", that carries out the robot's task, such as welding.

2. THE STATE OF THE ART IN ROBOTICS
2.1 Overview of technologies
Essentially robots carry out three functions – they 'sense', 'think', and 'act' – which form the basis of their autonomy. They 'sense' environmental stimuli and 'think' in terms of preset algorithms for planning and then, on the basis of these algorithms which define the reactions and overall behaviour, 'act'. This three-function process drives actions such: increasing pneumatic power to orient a picking limb to pick and place a part in a circuit board, or lowering a tray on to a patient's side table. These three functions define the major technologies used in robotics, as shown in Fig. 1. [6]

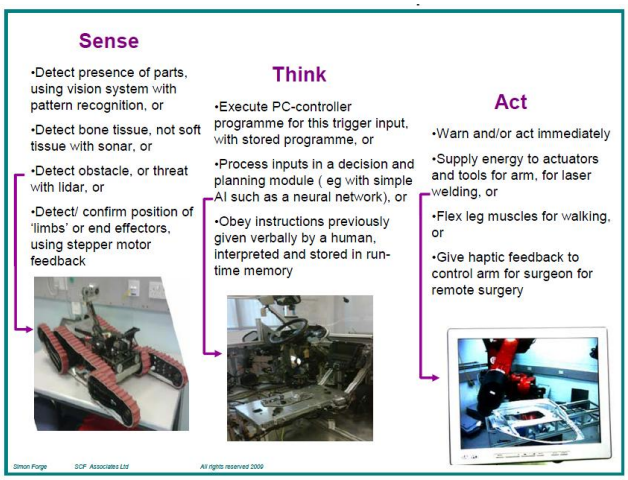

Fig. 1: Basic robotic functions and actions with examples [6] [8]

3. THE OPPORTUNITY FOR ROBOTICS IN SMES

This paper deals with a segment of industry – the Small and Medium Enterprise (SME) – which so far has not adopted robotics widely nor received real encouragement to do so. Robotics technology has generally been developed for capital-intensive, large-volume industrial manufacturing. The result is costly and complex systems, usually mono-function, which often cannot be used in the context of an SME. The volume scale is often a key part of the economic justification for robot use, usually for rapid movement with high precision in repetitive working. [5]

SMEs are sometimes caught in a trap: they must either opt for current and inappropriate solutions that do not meet their needs for small runs and low costs, or else compete on the basis of lower wages.

SMEs are one example of how, why and where robots may be used in new segments to form the next phase of the robotics market's development. SMEs cover a wide spectrum of industries and play an important role in both developed and developing economies. India is no exception and SMEs occupy a prominent position in planned development of Indian economy. The SME sector account for 40 percent of the industrial production, 35 percent of the total export and provides about 80 percent of employment in the industrial sector in the country. Over the years, SMEs have shown a consistent growth rate, both during protected economy and open economy. [3] [7]

The world of business is changing rapidly. The winds of globalization have pushed SMEs to grapple with the changing needs of their customers. Large enterprises view SMEs as satellites that would rotate around them seeking revenue and possible profit. [12] In the present era of globalization SMEs should possess the ability to get the organization to innovate quickly and produce an acceptable product and service to capture upcoming business opportunity.

SMEs are of major importance to the future economic growth of the Indian community. To sustain this role, they need support in defining their specific technological and organizational needs and in finding the right approach to respond to these needs. The definition of SMEs varies from country to country (Table 1). All over the world, numbers of employees or capital investment or both have been used as basis for defining SMEs. [7] In India, a capital investment in plant and machinery has been used as the criteria for definition. As per prevailing definition, small scale industry (SSI) in India is defined as an industrial undertaking in which the investment in fixed assets in plant and machinery, whether held on ownership term or lease or on hire purchase does not exceed Rs10 million (US$0.21 million).

Table 1:Definition of SMEs [5]

Category	Country	Category of industry	Criteria
Developed economies	Australia	Manufacturing services	< 100 employees < 20 employees
	Germany	SME	< 500 employees
	France	SME	10-499 employees
	Japan	Manufacturing	< 200 employees
	Canada	Manufacturing	< 200 employees
	USA	Very small	< 20 employees
		Small	20-99 employees
		Medium	100-499 employees
Developing economies	China	SME	Depends on product group. Usually 100 employees; Investment ceiling US$8 million
	Indonesia	SME	< 100 employees
	Malaysia	SMEs	< 175 full time workers. Investment US$1 million
	Thailand	Labor intensive	< 200 employees
		Capital intensive	< 100 employees
	India	SME	Up to Rs10.00 million in plant and machinery

The growth process of SMEs follows four basic stages: the pre start-up, the start-up, the pre maturity and the maturity. These stages are based on the time that the firm has been in existence as well as the firm's level of development. For the pre start-up, the company seeks out information on how to get the business started. What products and services does the market that the firm proposes to target require? What resources would the firm need in order to operate the business successfully?

From where will the firm obtain these resources? In the second stage the company gathers all the information that is required in order to start a business. In the pre maturity stage the company gets to know the business that it is in, e.g. based on the business it learns how to use its resources effectively, how to manage staff, how to manage money and generally how to manage the business. At the fourth stage the management has a very good understanding of the firm's market, its customers and the many other areas of the firm that are critical to its overall successful operations.

SMEs have shown their presence in nearly all sectors in India. As per an estimate, approximately 7,500 different products are manufactured by SMEs in this country. Some of the SMEs are producing directly for customer market while others are serving as suppliers to bigger industries. Based on products, SMEs in India can be broadly classified into following groups by National Small Industries Corporation [10], which are categorized in four major sectors i.e. Automobile, Electronics, Machinery, and Process (Table 2).

Table 2: products distribution in SMEs of various sectors [5]

S. no.	Industry sector	Item/product
1.	Automobile	Automobile spares parts Repair services
2.	Electronics	Small electrical item Semi conductor devices
3.	Machinery	Electrical machinery and parts Machinery and parts except electrical goods Wood products Transport equipment and parts
4.	Process	Food products Chemical and chemical products Basic metal industry Rubber and plastic products Hosiery and garments Non-metallic mineral products Paper products and printing Leather and leather products Beverages, tobacco and tobacco products Cotton textiles Wool, silk, synthetic fiber textiles

The SMEs have tended to concentrate in the vicinity of large industries or big cities. Availability of ready market, social and infrastructural facilities and skilled labour contribute to such development. Indian SMEs have been fortunate to build on a local heritage of enterprises, dynamism and renewal. Despite two centuries of colonial rule and a total lack of external support, the SMEs have re-established themselves and consolidated over the last 50 years. From about 80,000 units in the late 1940s to over 3.2 million units today, this sector has been proving its mettle time again. The last decade of the twentieth century has seen this sector maintain its steady growth. [13]

The role of SMEs has been defined as critical to the future economic growth and job creation within India. AMT provides benefits and advantages in areas that would enable SMEs to maintain quality, operational, organizational and financial performances. AMTs are a source of strategic competitive benefits, such as improved quality, greater flexibility, and cost reduction. To achieve those benefits, SMEs must carefully manage the implementation of these technologies.

Evaluating capital investments for the installation of AMTs is a critical task faced by manufacturing management due to the high capital investment and the high degree of uncertainty involved in these investments. [5]

4. ADVANCED MANUFACTURING TECHNOLOGY (AMT)

AMT appeared to represent a perfect marriage between technological potential and the manufacturing challenges. AMT refers to manufacturing process technologies that use computers to store and manipulate data.[4] [14] AMTs are a term that covers a broad spectrum of computer-controlled automated process technologies. AMT is an umbrella term used to describe a wide range of automation and related technologies, which have emerged during the past two decades as a consequence of developments in information technology.[2] More specifically, AMT can be described as a group of computer-based technologies, including computer-aided design (CAD), computer numerical control (CNC) machines, direct numerical control (DNC) machines, robotics (RO), flexible manufacturing systems (FMS), automated storage and retrieval system (AS/RS), automated material handling systems (AMHS), automated guided vehicles (AGV), bar coding (BC), rapid prototyping (RP), material requirement planning (MRP), statistical process control (SPC), manufacturing resource planning (MRP II), enterprise resource planning (ERP), activity-based costing (ABC), and office automation (OA) .[1]

Through Table 3 one can observe that each AMT is sometimes classified into different categories, or even into the sub-categories with a particular category. To assess which classification is more consistent than the other is not an easy or simple task: it depends on the purpose of the classification. [11]

Table 3: AMT classification [11]

AUTHOR	level of integration			functional application										nature of the apparatus			level of organisational integration			imbedded information processing capabilities				
	stand alone	intermediate	integrated	design and engineering	fabric. / machining & assembly	logistic related	automated material handling	autom. inspection and testing	flexible manufacturing tech.	computer integrated manufac.	manag. / information tech.	communications and control		computer hardware	computer software	plant & equipment	stand alone amt	functionally orientated amt	CIM	product design technologies	inform. exchange and plan. tech.	high-volume automation tech.	low-volume automation tech.	
US depart. Of commerce (1989)				✓	✓		✓	✓				✓												
ADLER (1988)				✓	✓						✓													
SOHAL (1997)														✓	✓	✓								
MEREDITH and SURESH (1986)	✓	✓	✓																					
SMALL and YASIN (1997)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓													
BRANDYBERRY *et al.* (1999)																	✓	✓	✓					
KOTHA and SWAMIDASS (2000)																				✓	✓	✓	✓	
CLASSIFICATION																								

NC – numerically control	√			√								√	√				√
CNC – comput. numerical control	√			√								√	√				√
DNC – direct numerical control	√			√													
CAD – computer aided design	√			√							√		√		√	√	
CAE – computer aided engineering				√											√	√	
CAM – computer aided manufac.				√							√			√			√
CAPP – comp.aided process planning	√			√													
MRP – material requirement planning	√					√					√					√	
MRP II – manufacturing resources planning		√	√						√		√					√	
AGV/AGVS – autom. guided vehicle system							√					√	√				
Robots (general)	√			√								√	√				√
Pick and Place Robots	√			√													√
AS/RS – autom.storage/retriev.syst.		√				√	√					√	√				
AMHS – autom.mat. handling syst.		√				√											
FAS – flexible assembly systems					√							√					
AITS - Automatic inspection and testing syst.		√					√					√					√
Automated shop-floor data collections systems											√						
FMC – flexible manufacturing cells			√	√			√					√					
FMS – flexible manuf. systems			√	√			√					√		√			√
CIM – computer int. manufacturing			√					√							√		
PLC – program. logic controllers	√								√								
LAN – local area network – digital I/O									√	√						√	
LAN – local area network - messages									√	√						√	
WAN – wide area network										√						√	
Data base management system											√						
TECHNOLOGY																	

5. BENEFITS OF ROBOTS TO SMES

By using robots, productivity gains can be manifested in diverse ways to give a competitive edge: [6]

- Extending the range and complexity of tasks that the SME can perform cost effectively and so extending the competitive scope of the firm.

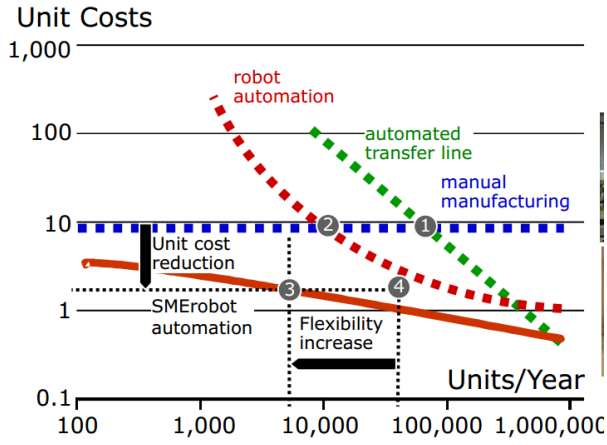

Fig 2: showing the benefits of robots in SMEs [8]

- Leveraging the strength of robots – especially in goods handling and logistics, manipulation of heavy production parts, etc – to provide greater capability.
- Leveraging robot productivity to perform some tasks faster (especially repetitive types).
- Leveraging robot productivity as a third hand, as a helper having some limited capability for co-operation, if possible in a closely shared workspace with the human workforce.
- Enabling the SME to cope with rapid changes in demand – higher or lower production.

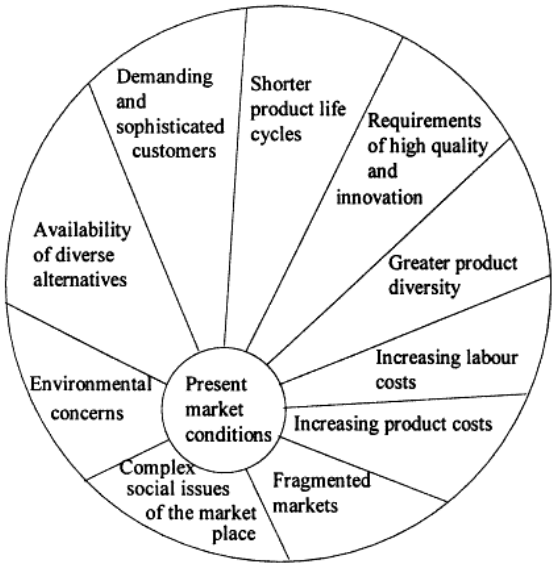

Fig. 3: Present market conditions [9]

Coping with hazardous environments, and/or long-term health risks, e.g. chemical sprays.

6. THE DIFFICULTIES FACED BY SMES IN ADOPTING ROBOTS

6.1 There are systemic economic problems in the SME segment

SMEs find that adopting robots is not a simple process. Typically the SME segment suffers from:

Low capitalisation and reducing access to capital in the current financial turmoil.

- Low awareness of technological improvements.
- Low technical competence outside core business.
- Generally less-technical competence and possibly low standards of education.
- Low capability for long term investment, with returns of a progressive nature.

Few SMEs are able to invest if they cannot see short-term returns. This means that they look to relatively rapid solutions to take effect (i.e. less than a year) and which have significant levels of returns to offset the risk of investing (i.e. at least 20% to 50% cost reduction or capability/flexibility increase). Moreover awareness of the use of robotics is highly dependent on the sector of activity. Industrial manufacturing SMEs are more inclined to understand robotics, although they may be doubtful of their real value in their particular field. Moreover the service sector SMEs are much further behind the industrial manufacturing firms, as is also perhaps the robotics industry itself – it is still exploring their specific needs and their market potential. [6]

6.2 The Barriers of SME's ignorance about robotics can hold back wider use [6]

The most commonly encountered barriers are three-fold and are closely linked:

- Ignorance about robots and what they may offer the SME. This implies that more education of the SME market is required on how robotics can be used in the specific vertical sector that the SME competes in. There may be a lack of understanding of where robotics could fit into the business and how productivity could be augmented.
- Barriers for the SME segment thus revolve around education of the market – Understanding, what can be done and then knowledge of how to do it. SMEs need to have confidence in robots delivering productivity – the barrier is education and confidence.
- Lack of skills inside SMEs for supporting robots, especially for programming them. Skill levels are highly variable but an SME is unlikely to know enough about robots to plan their integration perform the installation and then do regular changes as the working tasks change, which usually implies reprogramming plus routine maintenance. Current technology, which implies the traditional models of industrial robot, are often a step too far in complexity. Thus small businesses face special challenges and needs when deciding to invest in robotics. One fundamental challenge is how to operate every day after buying and installing the robot system. With conventional robotics technology, SMEs face the challenge of attracting and retaining a robot 'champion' who can reprogram the robot cell for new tasks and address technical issues as they arise, or of forming a close reliance on a local systems integrator with that ongoing cost.
- The lack of willingness to invest in robotics – this is linked to the factors above but also aggravated by the current economic crisis, making access to funding for a new venture more difficult. And also there is fear of unemployment by the workforce, if robots are introduced,

At a more detailed level for the industrial manufacturing SME, major rejection factors are shown in the Fig. below:

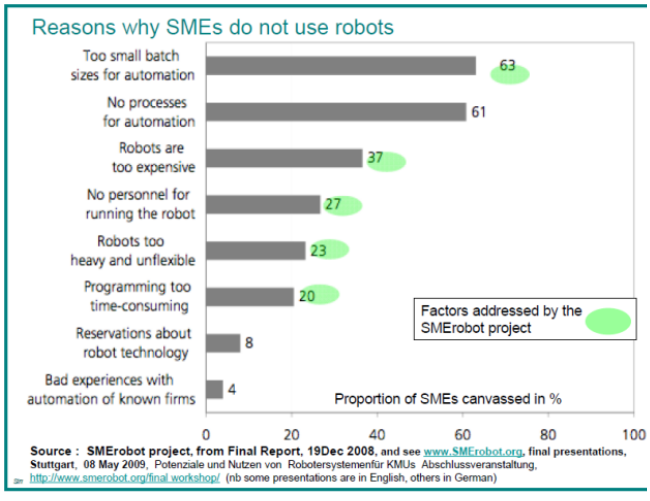

Fig. 4: various rejection factors [8]

7. CONCLUSION

Although there is an opportunity for the Indian robotics industry in the SME segment, it is distinctly different to the traditional robot market and has critical barriers to be overcome.

The major difference is the higher level of dependence on an ecosystem, which goes beyond the main robot suppliers. The first crucial market catalyst is the level of support available for SME end-users. Support is needed to educate the SME and then help to find the right solution, with system integration and training.

Thus, success lies in a co-ordinated micro-scaled SME network, putting together SME end-users with a robotics demonstration, supply and integration eco-system. It requires an active marketing and public relations campaign to build momentum for successful dissemination, with an SME focused campaign of robotics information, with events for SMEs and SME interest groups, as well as media communications (special interest group websites, TV, papers, journals, videos, radio all forms of publications, etc). The step-by-step market building process could be seen as:

1. Locate and encourage SME 'early adopters' as demonstrators
2. Use local and national SME campaigns with the SME industry organisations and interest groups as a dissemination mechanism
3. Through all these and other publicity channels build a campaign, with a series of SME robot demonstrator showcases to co-develop technical solutions for typical SME end-user problems, in order to convince SMEs beyond the 'early adopters'.

The second crucial catalyst is a technical one – to change the form of robot to towards what the SME needs: one that is cheaper, easy to integrate and reprogram, that can interwork with humans and that has reduced external safety requirements due to its internal safety features.

Thus attitudes of the SMEs to robots are a crucial factor in market success. The issue is whether recent advances in robotics engineering meet their special needs adequately. Overall, resolving the problems for SME customers will require addressing:

- The general attitude towards robots and SME levels of education of a robot's capability.
- The core reasons and barriers for rejection of robots in Indian SMEs.
- Actual uses of today's robots in SMEs – and the future demands in the SME segment.
- Numbers of robots in use in SMEs, which varies across the Indian Industries – and why it varies.
- SME plans to invest in robot technologies - and kinds of applications contemplated.
- Potential levels of interest in robots following market education.

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