Industry 4.0 and Urban Development
The Case of India

Bernhard Müller/Otthein Herzog

acatech MATERIALIEN

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> THE acatech MATERIALS SERIES

This series publishes discussion papers, presentations and preliminary studies arising in connection with acatech's project work. Responsibility for the content of the volumes published as part of this series lies with their respective editors and authors.

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FOREWORD

Industry 4.0 and Advanced Manufacturing are topics of a high international relevance. They are currently intensively discussed both in the academic literature, and in practice within the framework of Industry 4.0 which refers to the so-called 4th industrial revolution. They depend to a high degree on the availability of adequate digital infrastructures and well-functioning logistics systems, and they have a number of repercussions on cities and regions.

As there has not been much work done yet regarding the interrelations between Industry 4.0 ("Advanced Manufacturing") and urban development, the report by the Deutsche Akademie der Technikwissenschaften (acatech) presented here is dealing with a new field of academic and practical interest, especially as it also takes up an international development cooperation perspective.

The acatech project reported here on "Advanced Manufacturing/Industry 4.0 and Urban Development – Connected, sustainable and urban economic activities in the industrial sector in the context of local, regional and global ICT-based value and logistic chains using the example of selected Indian metropolises" was commissioned by the Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) on behalf of the Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ). The study was conducted in close cooperation with the Indian National Academy of Engineering (INAE).

The report is based on a number of expert studies on Advanced Manufacturing, logistics and urban development, as well as on own research by the authors, for example in India. Furthermore, the results of a symposium held in India together with GIZ and INAE have been reflected in the report.

In the report, reference is made to the German Digital Agenda 2014 – 2017, the GIZ "Quality of Growth" concept, the GIZ/ICLEI[1] discussion paper on "Green Urban Economy", and the BMZ document on "Managing urbanization – towards sustainable cities". The ongoing discussion on the National Platform City of the Future (Nationale Plattform Zukunftsstadt NPZ) in Germany was taken into consideration, too. On the Indian side, among others, the National Manufacturing Plan, the 12th 5 Year Plan 2012–2017, and the 100 Cities Program of the National Government were subjects of discussion.

The following project results can be highlighted:

- Industry 4.0 is a relevant topic for the German international development cooperation. It has the potential to support all dimensions of qualitative growth as defined by the German international development cooperation. Furthermore, it is apt to promote a green urban economy and to make an essential contribution to sustainable urban development.
- The potential of Industry 4.0 regarding the implementation of the new international development agenda beyond 2015, based on the Sustainable Development Goals (SDGs) defined by the United Nations, should be carefully explored and introduced into the international debate.
- Industry 4.0 has a high potential to positively impact economic development and to contribute to the sustainable development of cities of developing countries and emerging economies. However, it is also dependent on appropriate economic and urban framework conditions in order to make its potential benefits work. These framework conditions should be especially addressed by BMZ and the German international development cooperation.
- India is a very suitable partner for further action, especially for generating good practice examples regarding Industry 4.0 and urban development, and to work on the improvement of the framework conditions for successfully preparing the country for further development.

The opinions expressed here are those of the authors. They are neither binding BMZ or GIZ nor acatech or INAE.

Dresden, Bremen, March 2015

Bernhard Müller Otthein Herzog

[1] Local Governments for Sustainability

1 POTENTIAL OF INFORMATION AND COMMUNICATION TECHNOLOGY AND ITS IMPACT ON ADVANCED MANUFACTURING WITH SPECIAL REFERENCE TO AN INTERNATIONAL CONTEXT[2]

FRITZ KLOCKE

1.1 ENVIRONMENT

Links between classical machinery and plant engineering with information and communications technologies provide companies with new opportunities for honing their competitive edge. The Industry 4.0 Initiative encompasses not only new forms of smart production and automation technology which will have a profound effect on the value-added networks, but also incorporates smart modelling along with production, engineering and production environment design which takes account of demographic changes and achieve new forms of work organization. The Industry 4.0 Initiative focuses on new models, technologies and systems which increase collaborative productivity in the interaction between humans and technology when the right framework conditions are in place. Yet in the production industries, the mood is one of anticipation and certainty in equal measure. The answers to the following questions will define the course of future developments:

- How can detailed models use semantic web technologies to interact efficiently with production in an intercompany or interdisciplinary environment?
- How can product and production complexity be kept under control in global supply chains?
- What new services will emerge?
- How can cognitive knowledge be transferred to the digital world of production?
- Can Cyber-Physical Production Systems (CPPS) play a part in increasing competitiveness?
- What notable features will emerge from the global networking of customers, suppliers and production facilities?
- How can issues relating to data security and the protection of know-how be resolved to the satisfaction of all parties?

Many of these questions were discussed at the *Aachener Werkzeugmaschinen- Kolloquium 2014* by representatives from industry, equipment suppliers from the machine and plant construction and information technology (IT) sector, science and politics. These discussions produced tentative answers but also revealed that there are a number of issues still to be addressed. Consequently, the potential which could possibly be tapped via digital production networking will be explored in the following along with an analysis of the deficits currently affecting hardware, software and the personnel involved and what actions are needed in order to support Industry 4.0 in achieving a breakthrough within the framework of international collaboration.

1.2 FRAMEWORK

Cyber-physical production systems (CPPS):

- comprise data relating to process and machine status as well as to material and product characteristics recorded by the integrated sensors
- summarize data to provide information relevant to production
- interact with manufacturing equipment, products and people involved in the manufacturing process and with the digital world
- are connected to one another via suitable interfaces in networks

This study focuses on the manufacturing industry. CPPS form an important element in the Industry 4.0 campaign to explore new avenues in the effort to digitalize and network modern production. The concept that the potential of the Industry 4.0 Initiative can be fully exploited, provided the same information is used to plan, control and regulate the value-added process, and is consistently available at all times to each operative level, is undisputed. Automation engineering and stimuli from the field of information and communications technology are the driving forces behind developments. However, it is vital to ensure that each individual level in the value-added industry, from level one to level n, is actively involved. Engineers must be empowered to think holistically in the digital world of Industry 4.0 and to

[2] This study is based largely on insights gained in the course of a broadly-based discussion among experts in the run-up to the Aachener Werkzeugmaschinenkolloquium 2014 and on the contributions published in the conference proceedings as well as on relevant specialist literature and research results from the Laboratory for Machine Tools and Production Engineering and the Fraunhofer Institute for Production Technology IPT.

develop IT-based products and services. Skilled workers must likewise be given training to enable them to deal with these innovative products and systems as naturally as they already do in their private lives. Interdisciplinary, target-oriented, high-quality education and training are, therefore, vital.

The production environment is characterized by significant changes to the product range. The range of materials used is increasing sharply, various functions are being integrated within components and geometrical variations are being tailored in terms of both macro-geometry and micro-geometry to meet the requirements of the case in hand. The outcomes are high levels of product variability and smaller batch sizes. Additionally, each manufacturing operation is hampered by variability. This variability is described by the scatter of the material characteristics, variations in tool quality and by distributions arising from the interaction between tool, workpiece and machine. The production department must therefore be in a position to cope with uncertainties. The challenge facing decision-making processes within the field of production is: to make appropriate decisions having given due consideration to the outcome of all responsibility-based risk assessments within an unstable production environment.

What constitutes a responsibility-based risk assessment depends on the finished product and on the production environment. Risk assessments conducted by or on behalf of the aircraft industry will differ from those carried out in relation to products which are not directly involved in ensuring that the user does not come to any harm. In such cases, digitalization can be a help to pave the way for the decision-making process or even make decisions independently in self-optimizing systems. Given these boundary conditions, the overriding target in any production process remains to work productively and economically efficient. Everything must be quantifiable in economic terms; otherwise industrial acceptance is rapidly eroded. This becomes all the more important when production takes place at a number of sites worldwide.

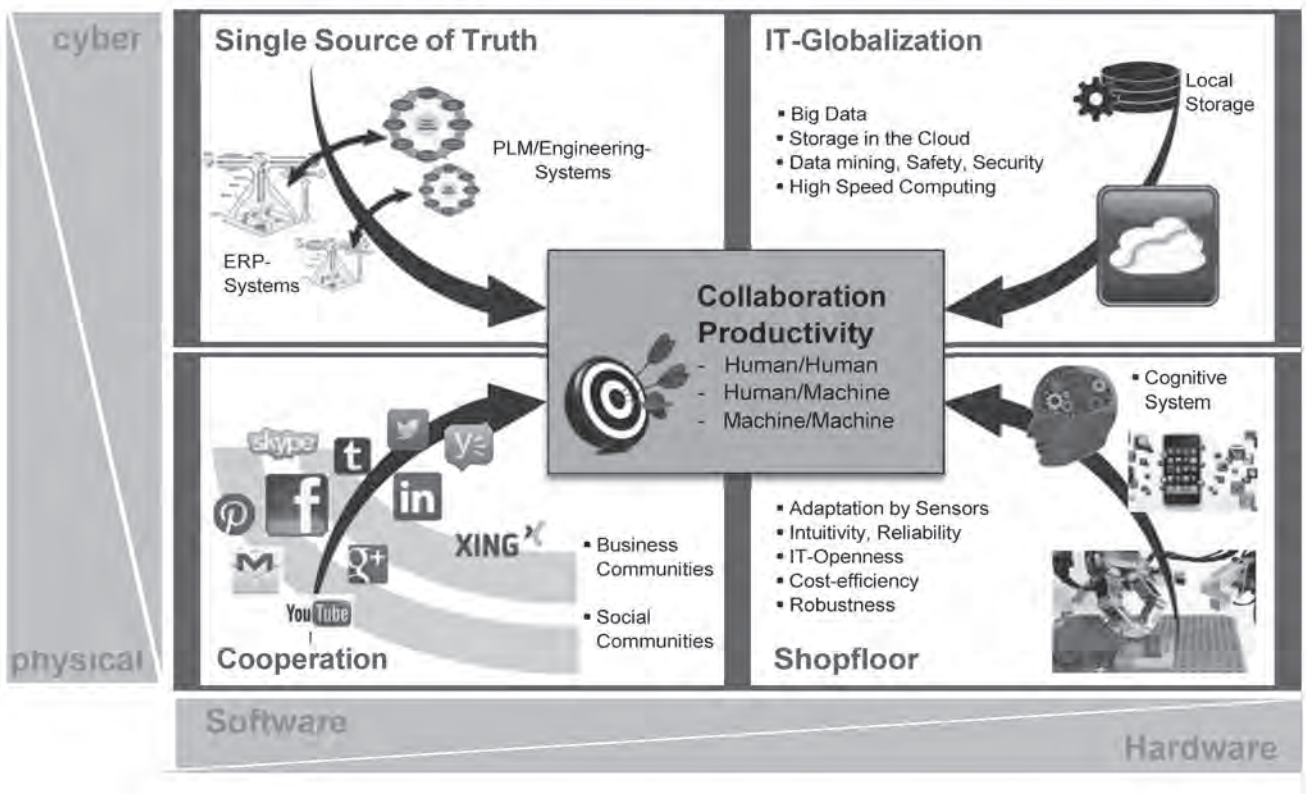
The production of goods is a decisive sector which still holds considerable as yet untapped potential in relation to developments in the field of digitalized production.

There are a number of reasons for this which will be investigated in detail in the following. However, one thing is clear: the potential offered by networking can be increased only when all industrial sectors in the supply chain are networked and when there is cooperation simultaneously at various levels. Isolated solutions result in incremental improvements. Disruptive change is possible only where there is total networking, although even then it is far from certain. In an international context, the greatest challenge is perhaps to achieve complete consistency of the data flows and the active involvement of people with different cultural backgrounds. The overall design framework for CPP systems is illustrated in Fig. 1.

In this context, questions will be examined and suggestions as to how digitalization and networking can rise to the challenges facing manufacturing today will be -assessed. One key element is the provision of relevant and consistent data followed by further purposeful manipulation and development of this data at process, machine and factory level. When modelling the production process, it is vital to ensure that on one hand the model meets the fundamental production requirements and on the other hand it must have a sufficiently extensive data base to enable modelling results to be adapted to actual production conditions. Models must adapt automatically to modified boundary conditions. The quantitative modelling outcomes which can be used for process management purposes can only be as good as the database from which they were derived and the decision-making algorithms and tools used.

Sensors, which already play an important part in the development of a consistent and representative database, will assume much greater significance in the future. It should be noted at this point that in the following reference will be made more to data from the machine-workpiece-part environment than to the movement data related to material flow. Further developments in sensor technology such as wireless data transfer along with entirely new solutions will enable sensors to be used much more extensively than at present. The reasons for this are the increased functionality and falling prices of mass sensors resulting from the application of micro-electronics and semi-conductor technology. Sensor networks, piezo-electric film and lab-on-a- chip solutions for production applications all contribute to functional integration. More extensive use of sensors will permit data to be acquired from the main and secondary processors which will then be coupled into process models and process chain models. This increases the predictive quality of the models. Coupled multi-physics models are operated on a server in close proximity to the production process or in a higher-level cloud. Real time process data can provide the

Figure 1: Framework for designing CPPS[3]

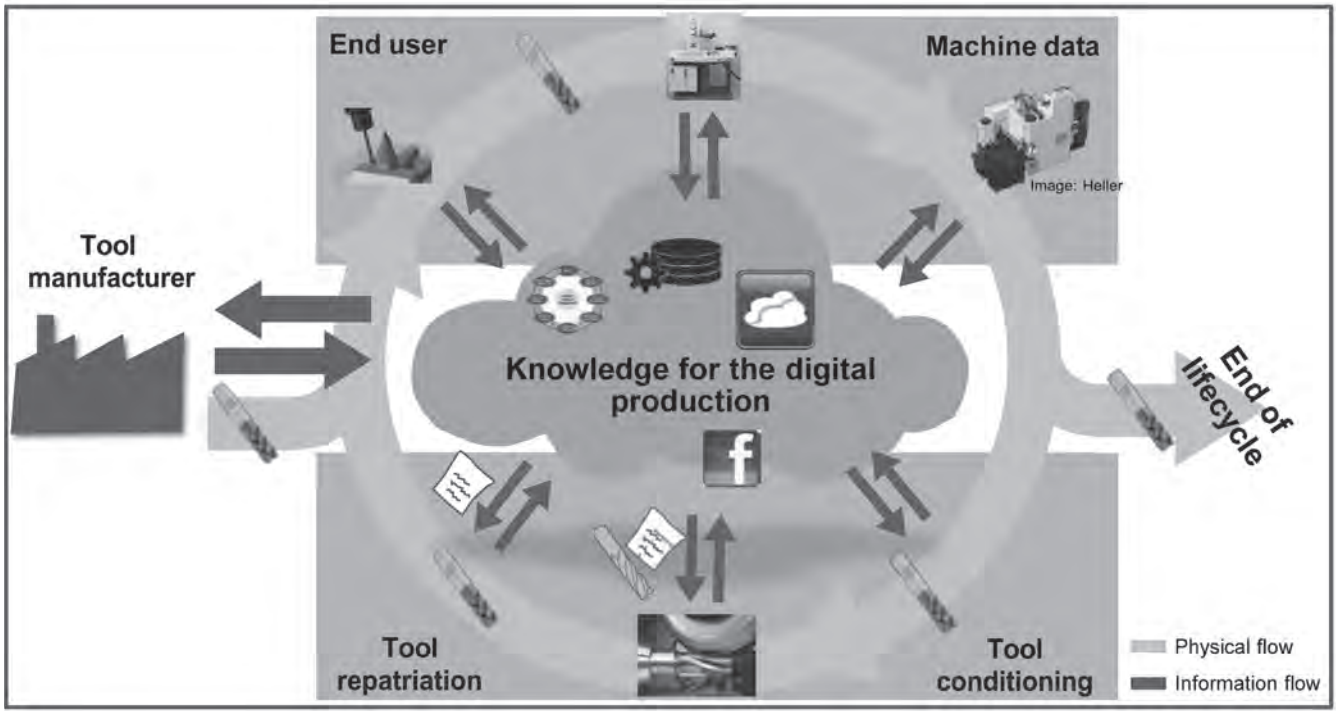


boundary conditions for model solutions in real time and calibrate the models. These model results have a number of uses in the production environment. On one hand, they can be coupled directly to Product Lifecycle Management (PLM)-systems and provide basic layout parameters for process flow. They can also be coupled with Enterprise Resource Planning (ERP) systems to plan manufacturing processes and, at shop floor level, it is even possible to display the information to the operator via the Manufacturing Execution System in order to facilitate the decision-making process.

In principle, there are a number of reasons for conducting extensive modelling, statistically secured analyses and analyzing scenarios in a cloud. The main obstacles relate to questions as to the security of data in the face of external attack and safeguarding company know-how. In addition to cloud-based modelling, smart agents are assuming new significance. These are smart interface devices and production-based servers which are used on the production area by those responsible for the process to intervene in the process where necessary. The information needed to make a decision is faded in optically or displayed on interactive touchscreens. The development of these devices specifically for the production environment is in progress as the operator interfaces, operator prompts and symbols have to be adapted to suit production conditions and must be designed so as to ensure that decisions can be made swiftly and intuitively. Straightforward process applications (tech-apps), which use the sensor data recorded to generate and display suggestions relating to the decision-making process, can be programmed on smart interface devices. The development of tech-apps stores permits these devices to be used to address a wide range of issues affecting production. These range from adjusting energy consumption levels in production sequences to fine-tuning control variables in the manufacturing process or evaluating performance data. An example of the conceptual development of a network structure, which links tool manufacturers, machine manufacturers and end users as well as physical material flows and data flows, is shown in Fig. 2.

[3] Klocke 2014.

Figure 2: Material, data and information flows[4]



It is essential to network all company levels shown in Fig. 1. It is in the 4th quadrant in Fig. 1, on shop floor level, that the need to catch up is greatest. However, this is also where approximately 80% of the value added element takes place. Reliable links between production information and the Manufacturing Execution System (MES) are crucial. The design and organization of this interface present a particular challenge in terms of cooperation with other companies. Collaboration in digital networks increases the economic efficiency of a company only when all areas have comparable network densities, when interfaces are standardized and when there is one uniform database to serve all areas (Single Source of Truth, Fig. 1).

To summarize, the following has been established up to this point:

- Digital production knowledge is wholly reliant on the sensor equipment used.
- Technology data acquired from processes and equipment as well as from the production area form the basis on which models are generated.
- High Speed Computing enables technology data to be expanded using mathematical models (Big Data), thus creating a basis for holistic forecasting models.
- Standardized interfaces enable human-machine-workpiece-network communications to control value-added processes online.
- Human-network communication can be used to facilitate continuous learning by specialist staff and for training purposes.
- Cognitive knowledge is used to control processes and to develop cognitive databases.
- New, marketable products are being manufactured via networked demonstration factories and pilot production runs, while at the same time research focusing on exploring issues related to the real-time capability of logistics systems is already well under way.
- The development of sensors to record movement data is one of the elements in this research work. New, marketable products are being manufactured via networked demonstration factories and pilot production runs while at the same time research focusing on issues related to the use of sensors in processes, machines and products is already well under way.

4 Veselovac, 2013.

– The need for shorter development and production cycles gives rise to the question: How can models and model information communicate and interact with production equipment?
– How can the technology transfer required for networked production be achieved in the case of new products?
– Can CPPS facilitate the organization and operation of mass production activities regardless of the site concerned?

1.3 SMART MANUFACTURING

1.3.1 General

The purpose of this section is to examine the topic of Industry 4.0 (Fig. 1) from the perspective of the manufacturing technologies, production machines and automation involved. The current state-of-the-art will be explored on the basis of various examples, which will highlight current deficits. In conclusion, the research and development issues which need to be addressed urgently will be set out within the context of international networking.

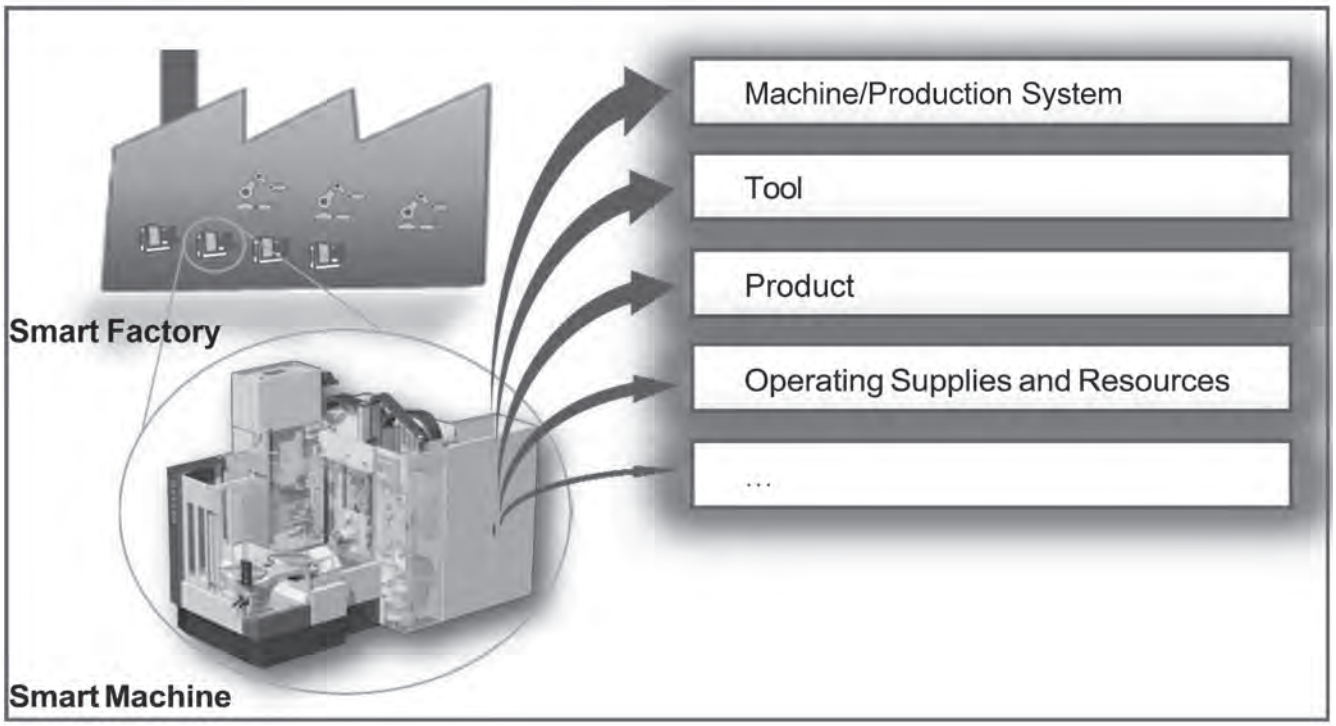
1.3.2 Sources of technological expertise

The scope of the areas from which to extrapolate technological expertise from system information encompasses the categories shown in Fig. 3:

– machines as smart units, which are networked with other machines and systems within the production environment,
– tools incorporating monitoring functions and information technology which enable them to recognize conditions, generate tool information and recommend process settings,
– smart products containing information about their own quality and part functionality,
– efficient, optimized use of consumables and resources in manufacturing processes and machine tools.

Examples of the four categories listed above will be presented in the following. These examples will illustrate how technological information will be used as a basis from which to expand technological know-how. In order to achieve the goal of collaborative productivity in a manufacturing technology environment, it will be essential to ensure that data is generated during the

Figure 3: Frame of reference in production[5]



5 Klocke 2014.

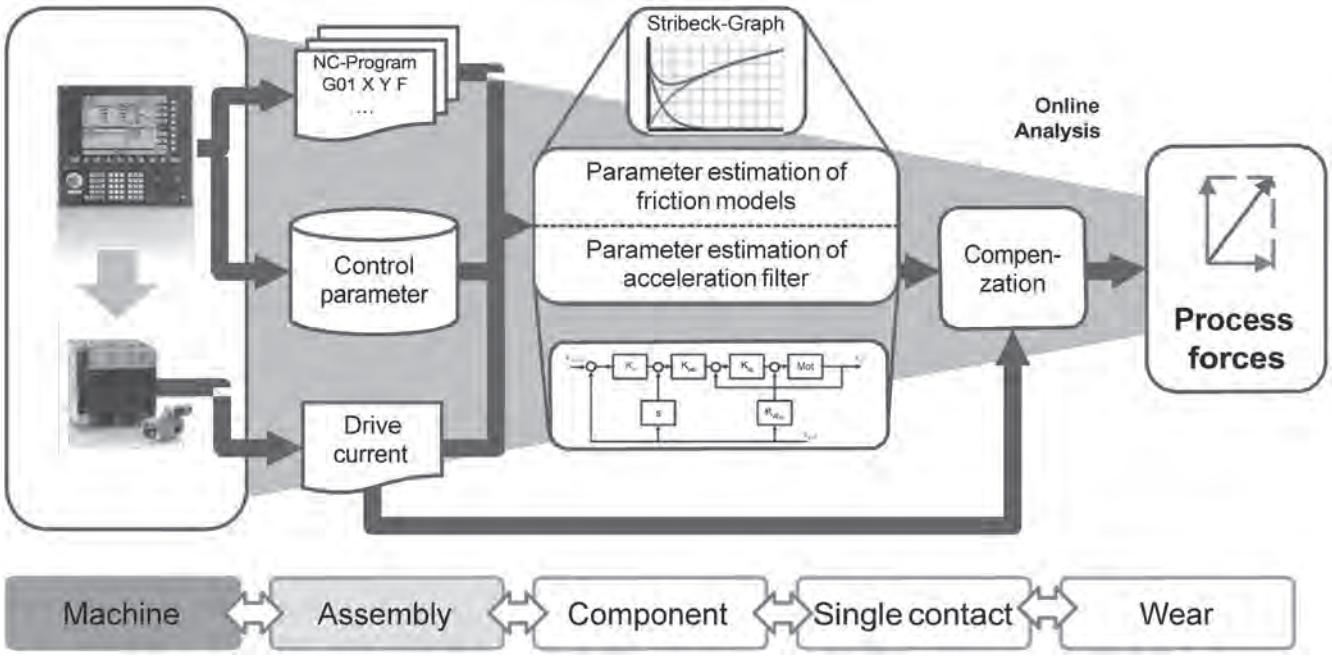
production process in a form that can be used to create digital production models. The information obtained from these data will be further processed in hard and software systems. This means on one hand that technological models must be reached and made available. On the other hand, these models must be constructed in such a way as to allow for expansion via the generation of additional product related data and, at the same time, they must be machine-readable.

In production, the smallest unit of production in the manufacture of a product is a machine tool or a work station. As a result of developments in the field of machine tools and their control units, data either available within the machine tool or generated by it, can provide precise information about the manufacturing process and the condition of the machine tool as well as process status and conditions. This information represents an excellent database for the analysis of processes and machine components. Consequently, technological knowledge within a machine tool and its control unit is obtainable and can make a major contribution to digital production[6].

In smart machine tools, data relating to the process forces can be obtained from measurements of the current power consumption of the motors powering the drive axes. One of the most important research issues to be addressed is whether information, which could be used in order to optimize methods of monitoring tool wear and collision avoidance, can be obtained from the control signals. Research is under way to establish which signal sources within the control unit and information lend themselves to supplying a cluster of machine-independent signals. Parameter models to compensate for friction and acceleration effects will subsequently be implemented. The parameters typical of each machine will be generated autonomously in a routine operation. All insights gained and methods developed on this basis must be designed to be applicable to a range of machine systems, Fig. 4.

Any requirement for farther-reaching research will emerge from these studies because the systems must be coupled to higher-level CAD/CAM systems and material databases. Communication between these systems and databases must run fully automatically in future.

Figure 4: Determining process forces from data within the control unit[7]



6 Klocke 2014.
7 Uhlmann et al. 2012, Rudolph 2014.

In the tool technology sector, wear models such as those used in broaching operations can exploit considerable potential for increasing efficiency, converting it into productivity when expensive special-purpose tools are used. In the manufacture of safety-critical parts for aircraft turbines, for example, tools are frequently replaced long before their performance capacity has been reached simply because their current state of wear is not known. One of the outcomes of this is that tool costs and set- up times are much higher than necessary. The development of a suitable wear model analytically formulated on the basis of empirical knowledge and correlating current tool temperature with process forces and state of wear can provide direct feedback from the process via in-process temperature measurement[8]. As a result, the tools can remain in operation for longer and each one can be used until the end of its own, individual tool life. If necessary, the cutting speed can be varied specifically either to increase productivity or to prolong tool life in order to ensure that an entire turbine blade is machined using the same tool, for example.

Abstraction of the complex hobbing operation in an analogy experiment enables the contact conditions to be analyzed in greater detail. The load to which the tool is exposed is determined via sensors. In a gear-cutting operation conducted in the course of an analogy experiment, the machining forces and the local temperatures are measured. At the same time, chip formation is recorded using a high-speed camera.

In addition to the practical experiments, numerical calculations are carried out in order to simulate the load to which the cutting edge is exposed. A process model[9], which predicts tool life at the specific level of load involved, has been developed on the basis of the calculation and the investigation. These results have been used to develop a process model based on a geometrical penetration calculation, which has achieved a considerable reduction in the calculation time required[10]. Further development is required before the process model can be transferred to a monitoring system.

It is vital to ensure that workpiece-oriented process monitoring is in place prior to the manufacture of smart products. This is illustrated using the example of the manufacture of rotating, safety-critical aero-engine parts. These are particularly demanding for two reasons: firstly, they are manufactured from materials which are difficult to machine, therefore making the highest demands on each of the production operations involved in the manufacture. Secondly, these components must meet the highest safety requirements in order to rule out any failure of these safety critical parts when they are in operation. The current best practice is to screen part characteristics using Low-Cycle-Fatigue (LCF), High-Cycle-Fatigue (HCF) and Thermo-Mechanical-Fatigue (TMF) test methods. These tests are conducted after manufacture and involve the destruction of the components. The primary goal of in- process testing is to provide indicators as to the part characteristics from significant process information. This encompasses in-process evaluation of the finished surface as well as an assessment of peripheral rim damage. When faults or critical conditions are identified at this point, there are two options: either conduct a subsequent machining operation or manufacture the part again from scratch.

The need for continuous data generation throughout the course of all manufacturing processes in order to facilitate the assessment of the condition of the product becomes apparent at this point. It is crucial that the manufactured part can be assessed in terms of its quality and operational reliability. Only when this has been achieved in the case of safety-critical engine components can the manufacturing process and the products be described as digitalized. In a digital production environment, the product would thus become a smart product as a result of coupling manufacturing and product data to the part[11].

Consumables include water-mixed cooling lubricants, oils in cutting and forming operations, dielectrics in electrical discharge machining and electrolytes in electro- chemical machining operations conducted on metallic materials. The consumables are usually characterized in laboratories and are tested manually at irregular intervals. Although there is ample evidence of the influence exerted by the condition of these consumables on the quality of the manufactured product and on the productivity of the manufacturing processes, characterization is seldom carried out online. Status data are not available for direct processing in models. There is one development in chemical diagnostics which may present a solution. Miniaturized analysis systems, lab-on-a-chip sensors which

8 Rudolph 2014.
9 Klocke et al. 2013b.
10 Herzhofff, 2013.
11 Hardjosuwito 2013.

permit consumables to be characterized in terms of age, chemical composition or contamination, are currently under development. Systems of this nature will enable the condition of consumables and, therefore, the influence they exert on manufacturing quality and productivity to be measured directly.

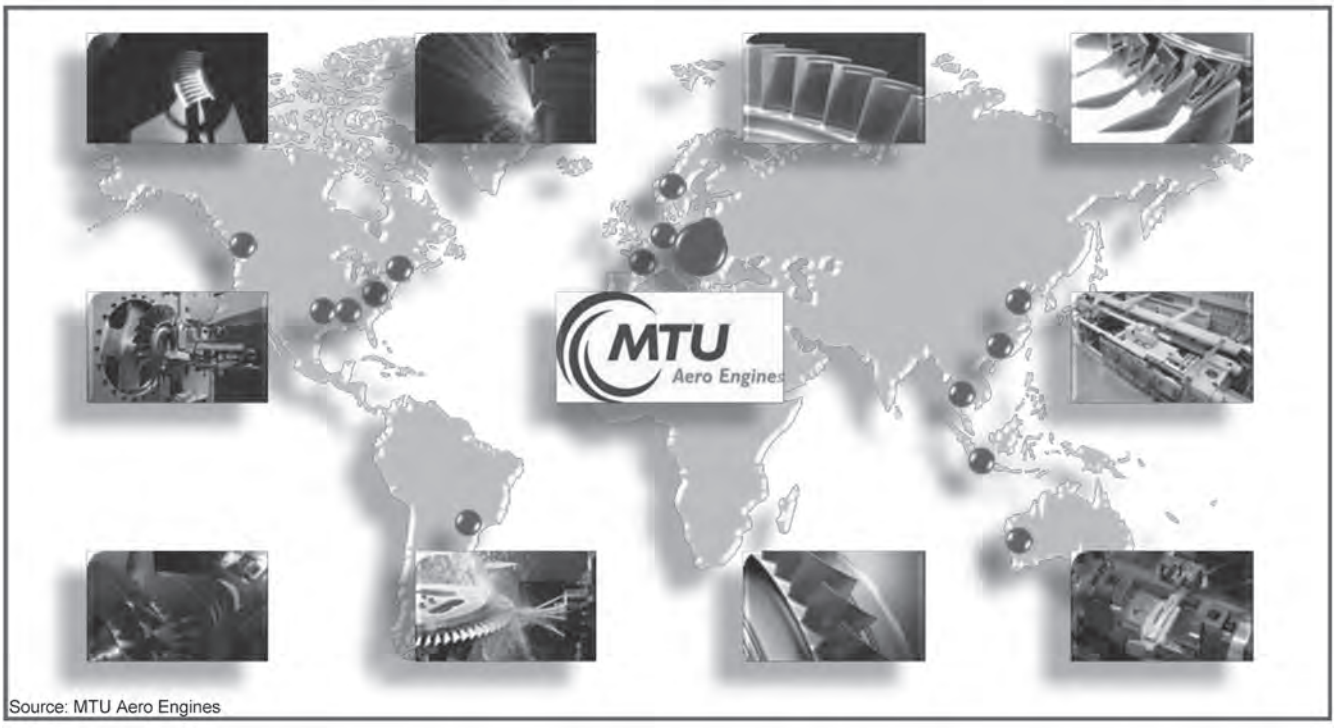
Internationalized production networks

Products are increasingly being manufactured in global manufacturing networks. The manufacture of components for turbomachinery at the company MTU is an example of this (Fig. 5). The distribution of different steps in the process among various sites has a number of advantages. The individual sites can focus on their core areas of expertise for specific steps in the process, thereby achieving higher levels of process reliability and manufacturing quality. Decentralized manufacture in the country which is the target market also reduces delivery periods, particularly in the case of service parts. This decentralized organization of the manufacturing process presents the supply chain management among others, with an enormous challenge which is being met via software solutions such as "myOpenFactory"[12]. Interfaces must be defined and new communication tools introduced in order to ensure that technology know- how is available in equal measure at all sites and is applied uniformly.

The prerequisite for successful implementation of global manufacturing within global manufacturing networks is an exchange of information regarding process status and targets. The entire production system must be fully equipped with sensors supplying data from the processes. One of the major advantages of extensive data recording is that statistical analysis methods can be used to differentiate between systematic and random influencing factors (Fig. 6).

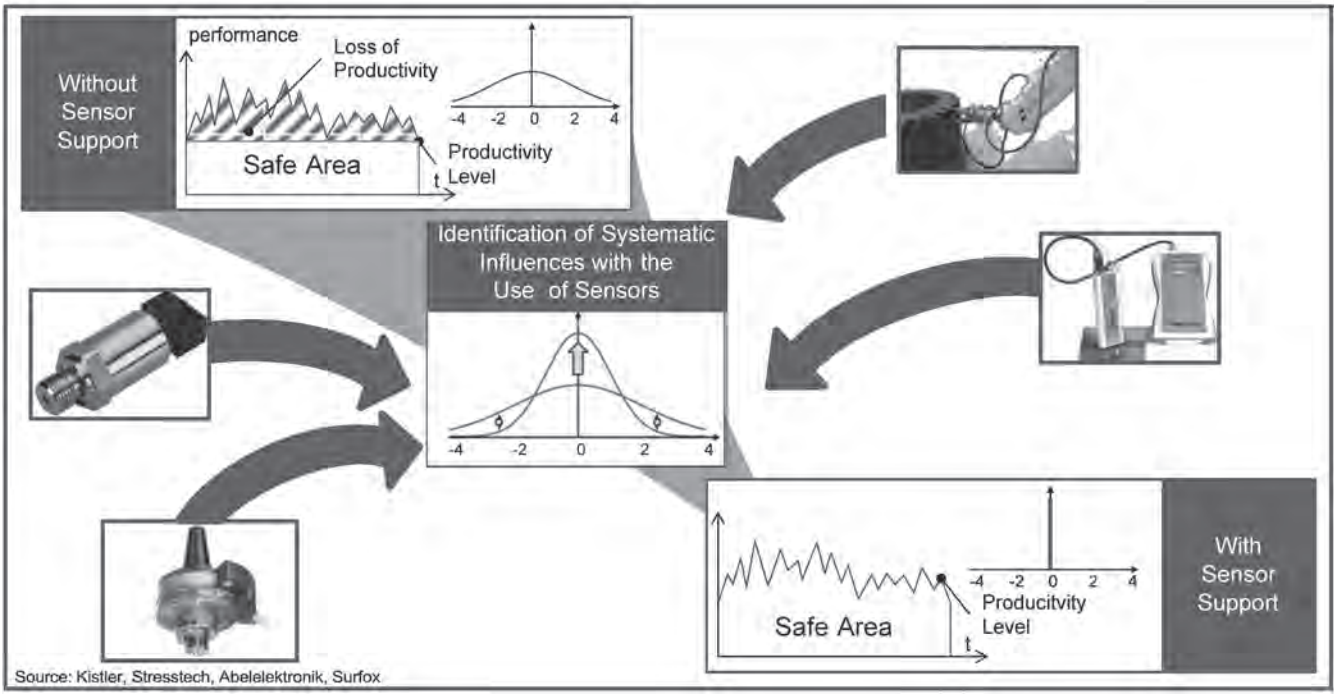
Additional technology is required before the sensors can be integrated in the global IT infrastructure. The sensors must be integrated directly into the IT network online as embedded systems. It will then be possible to evaluate process information even retrospectively in order to learn. At the product quality testing stage, the information from previous steps in the process will be

Figure 5: Global manufacturing networks[13]



[12] Schuh 2008.
[13] Klocke 2014 (MTU Aero Engines).

Figure 6: Using sensor systems to reduce systematic influences[14]



evaluated in conjunction with the outcome of the part testing operation. In the case of global manufacturing networks, this traceability of data requires infrastructural support. Despite the number of sensors in the field, baseline investigations and research using process models remain a necessity.

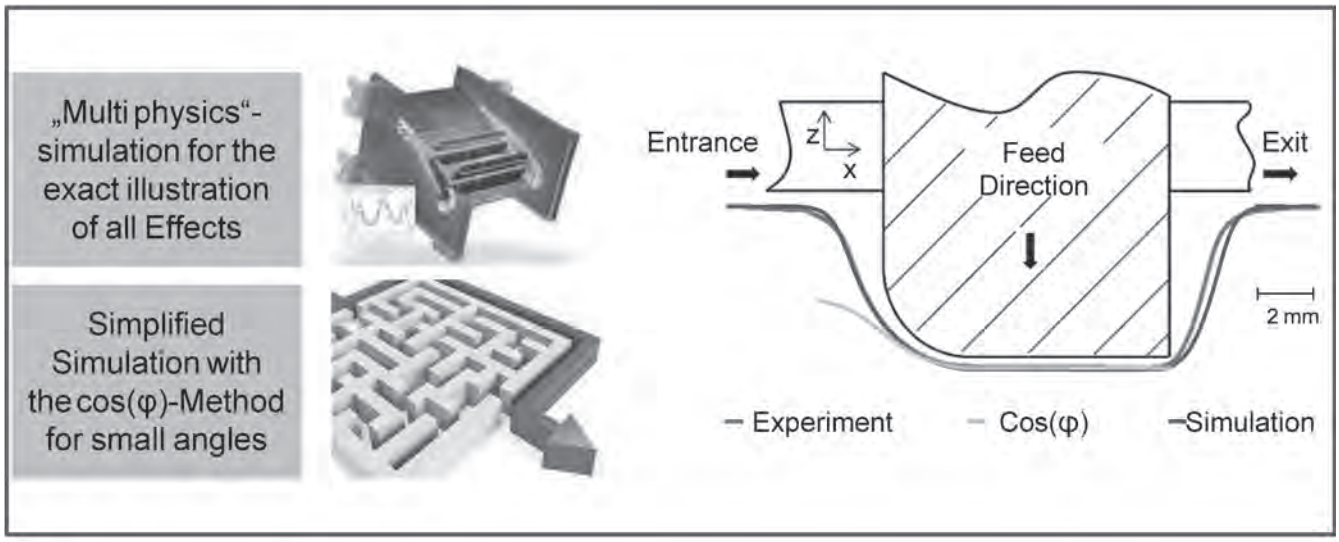
Analytical/numerical calculation models with various degrees of detail will be available[15] to describe complex, non-linear processes such as electro-chemical machining (ECM). Depending on the specific issue in question, simulation approaches which have been optimized in terms of cost-effectiveness can be pursued individually for each specific application. Multiphysics simulations draw on all physical and chemical phenomena in modelling and are therefore capable of describing the relevant effects over the entire geometry in precise terms. Fluid dynamics, the electric field, the actual electro-chemical material removal and process-related modifications to the properties of the electrolytes can thereby be taken into account. These approaches, however, require considerable computer capacity and long calculation times.

Alternatively, simplified modelling approaches such as the cos(φ)-method, which has been applied extensively in industry for a number of years, enable process behavior to be modelled efficiently for certain sub-sections of the geometry, Fig. 7. This method can be used to predict EC machining behavior for small angle deviations φ from the feed direction only (area of flat contours) with a sufficient degree of accuracy by simply projecting Faraday´s law in a significantly shorter calculation time.

Parallel to this, in future it will be possible to reduce the calculation times for more detailed models using global IT resources, thus permitting large numbers of process data evaluations to be carried out. Distributed calculations in the cloud will be able to draw on computer resources, enabling them to optimize processes swiftly and individually for specific machining tasks. In the age of global integration even of private individuals and their hardware, projects such as "Seti@home" or "World Community Grid" can also act as prototypes of distributed computing. However, in the case of industry and company specific

[14] Klocke 2014 (Kistler, Stresstech, Abelelektronik, Surfox).
[15] Hinduja/Kunieda 2013.

Figure 7: Modelling concepts for reducing calculation times[16]



implementation of application-oriented products in the field of manufacturing technology, confidentiality and security aspects along with the regulation of rights and obligations of all parties involved and whose interests may vary, are essential. The example outlined reveals how it will be possible to file fundamental technological understanding on in-company and global IT structures. There is still a need for technology experts to research and implement complex modelling approaches. However, it is vital to ensure that these models are available at the production planning stage and can be used at all levels in a modern production environment facility.

Planning and scheduling

Process planning is associated with uncertainty. Planning certainty diminishes with increasing numbers of variants in conjunction with falling lot sizes. Surveys conducted in the Aachen cluster of excellence "Integrative Production Engineering for High Wage Economies" reveal that planned manufacturing time can deviate from actual manufacturing time by as much as 100%. Clearly, there is a need for further research in this area[17]. The objective in planning activities is to exploit all production capacity to the full. The outcome is maximum productivity and associated minimum investment of resources. The majority of modern production processes are already so complex that efficient planning is possible only when optimization models are used (Fig. 8).

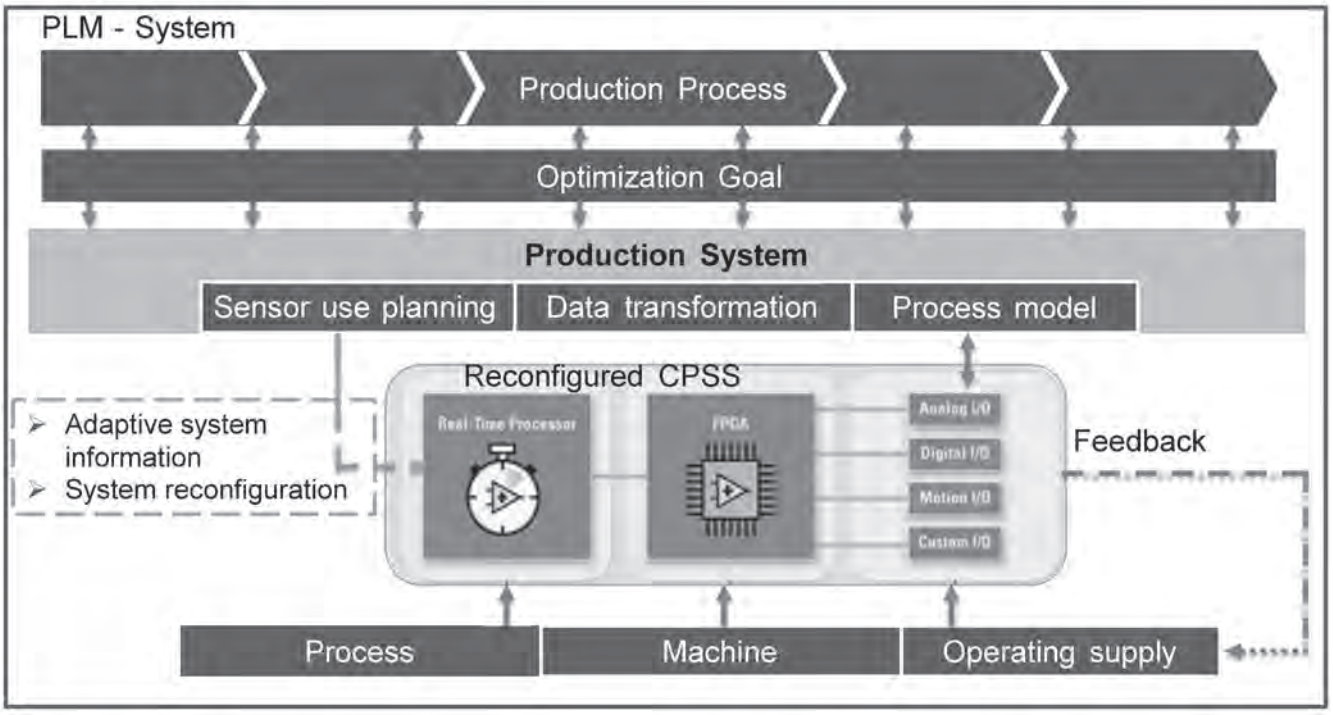
The real factory is equipped with sensors and records status data from the production process. The virtual factory consists of information systems and software components. The real factory is modelled to enable it to be optimized via scenario analysis.

The production process is tweaked in virtual production runs, moving ever closer to the optimization target in order to ensure that the CPPS can be used to plan production sequences directly. Critical process steps are detected and the information required for production control is specified. This supplies the basis on which to plan the deployment of sensors and to develop the communication structures needed.

One of the optimization problems in manufacturing relates to 5-axis milling operations conducted on complex structures. When complex products are machined in a 5-axis milling operation, it is important to take a holistic view of the production system in use. This encompasses the machine tool, the material to be machined and, most importantly, the tools. It is also vital to ensure that there is complete data consistency throughout the CAD-CAM chain. The optimization of tool macro and micro-geometry is just one example in the development of 5-axis milling processes. The development of barrel shaped milling tools for deployment in 5-axis milling operations is an important element in the chain described above. Fig. 9 shows the influence exerted by the geometry of the milling tool on

[16] Klocke 2014.
[17] Brecher 2011.

Figure 8: Total system overview[18]



the time required to machine a structural component. The machining time is determined for each point on the surface. A different area of the barrel shaped milling tool is used to machine the part depending on the curvature of the surface. Because there are different contact radii, productivity fluctuates to the degree that the time required to machine points on the surface with small radii of curvature is comparable with the time taken by a ball-end mill. When the radius of curvature is larger, the part can be machined using the shaft of the barrel shaped milling tool, which results in considerably higher productivity of this tool than in operations conducted using a ball end mill.

Alongside productivity, surface topography is a major factor in the manufacture of complex products such as impellers or blisks (Blisk – Blade Integrated Disk). In order to safeguard the aerodynamic properties, it is crucial to ensure that the surface roughness specified in the design is not exceeded. The development and optimization of one element in the production process must not be at the expense of any other part. In this case, care must be taken to ensure that the deployment of a barrel shaped milling tool which would be useful from the point of view of productivity, does not result in a situation in which the required level of surface quality cannot be achieved.

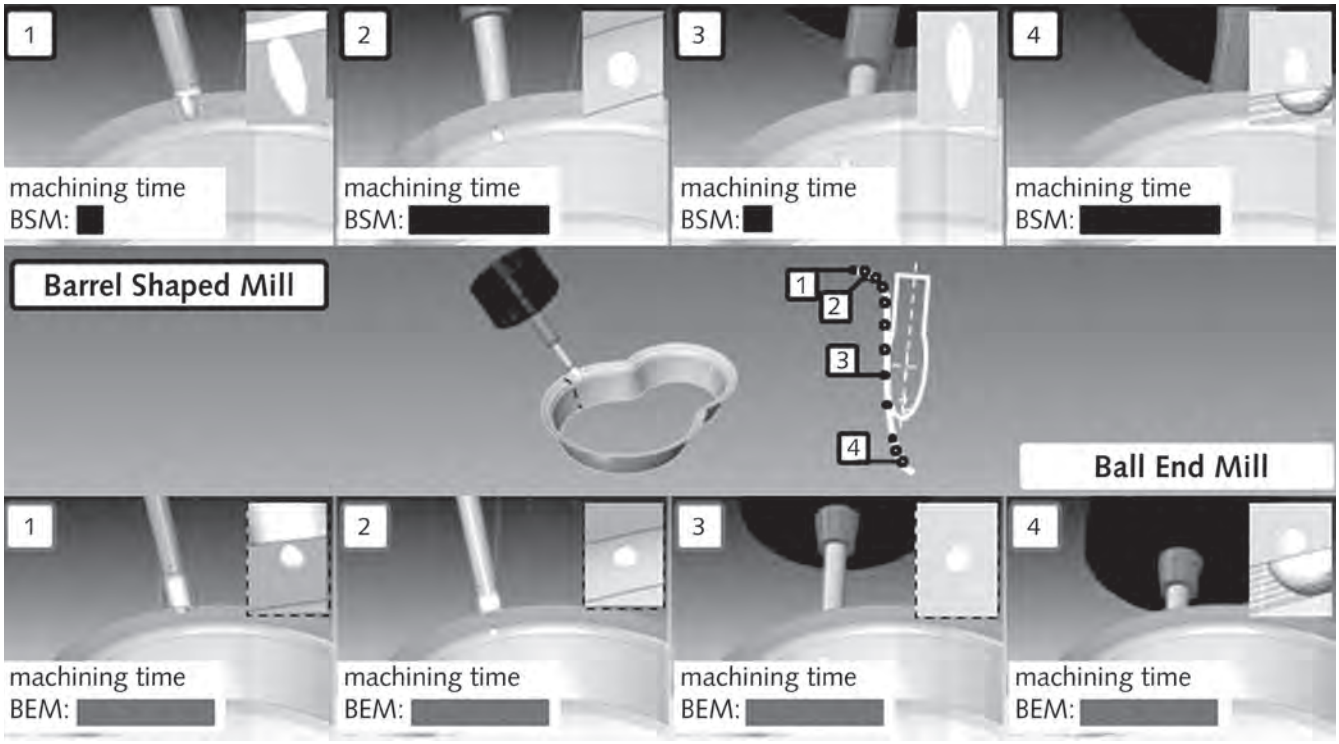
This section has illustrated how manufacturing and manufacturing processes will have to be networked in future to permit global manufacturing to take place under the prevailing boundary conditions. In an international context, the need to standardize and to put in place interfaces for the exchange of relevant data along with the requirement for standardized descriptions of products and product characteristics presents a challenge. To achieve this, it is essential to incorporate the option of applying cognitive expertise within the systems. Humans, as the decision-makers at all levels of production, must always be able to add their own technological expertise and experience to the production process. This will require the development of output and input systems capable of presenting complex manufacturing and production correlations in a straightforward manner.

Assistance systems in the digitized production of tomorrow

The term app (application software) is used to refer to application programs de- signed to provide useful functionalities on

[18] Klocke 2014.

Figure 9: Comparison of the productivity of barrel shaped and ball end milling tools[19]



a system. Most apps are aimed at end users and are used for mobile devices such as tablet PCs or smart phones. The functionality of an app is limited and provides the user with a defined service. Their operation is intuitive and no expert knowledge is required to install an app. One consequence of this is that consumers frequently use apps for only a limited period before switching to a different one. This trend is boosted by the intuitive operability of such apps. The availability of a wide range of apps in the web-store means that customers can decide spontaneously to install an additional functionality on their device.

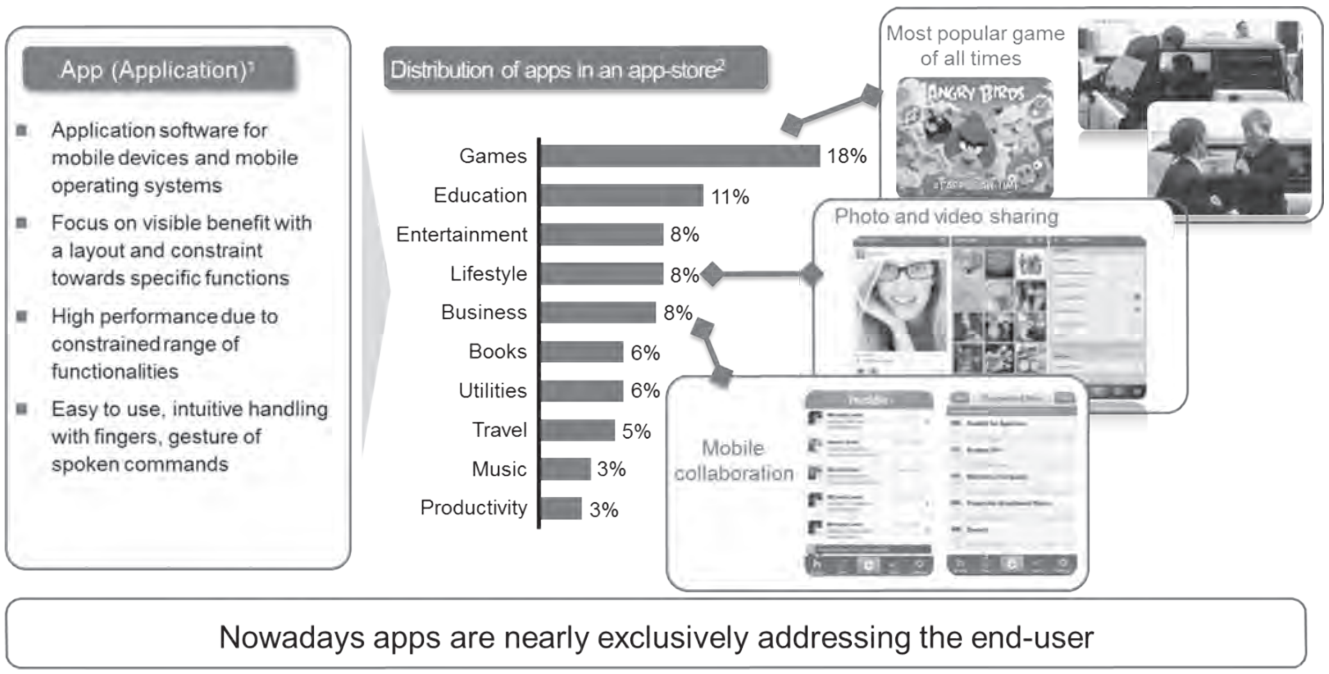
It is a logical progression to develop these tools for production environments too. We are still in the early stages of this process; there is enormous scope for collaborative research and implementation in an international context.

Mobile devices are so ubiquitous in society that virtually all employees are accustomed to using apps. This in itself provides enormous potential for improving communication in a digital production environment. The use of new IT options in the production environment will facilitate the exchange and distribution of information. In order to ensure that applications for digital production are as intuitive as apps for mobile devices for private individuals, it is advisable to develop apps to address specific technological issues and to restrict the scope of their functionality. Apps which perform technical functions or which involve technological expertise are referred to in this report as tech-apps.

The purpose of tech-apps will be to contribute to the drive to pool globally distributed technological know-how and thus to make it generally available. One of the requirements of tech-apps is that these applications are capable of providing the operator with clear feedback about the process. It is just as important that contextual support is available to the operator in cases where there is a high level of variance. It is anticipated that where there is a need for additional information, the tech-app will have access to IT infrastructure in the cloud and will use the process models available there. However, real time diagnosis of process status relies on a high-performance IT infrastructure. The interaction between humans and machines with support from tech-apps is presented in Fig. 11.

[19] Klocke 2014.

Figure 10: Apps in mobile communications[20]



The requirements to be met by tech-apps are more demanding than those to be met by apps for general every-day use. In addition to meeting the demands of society, tech-apps must present an industry-specific solution, which in turn also meets the requirements of the company concerned. Depending on the context in which they are used, there may also be a need for in-company as well as external communications.

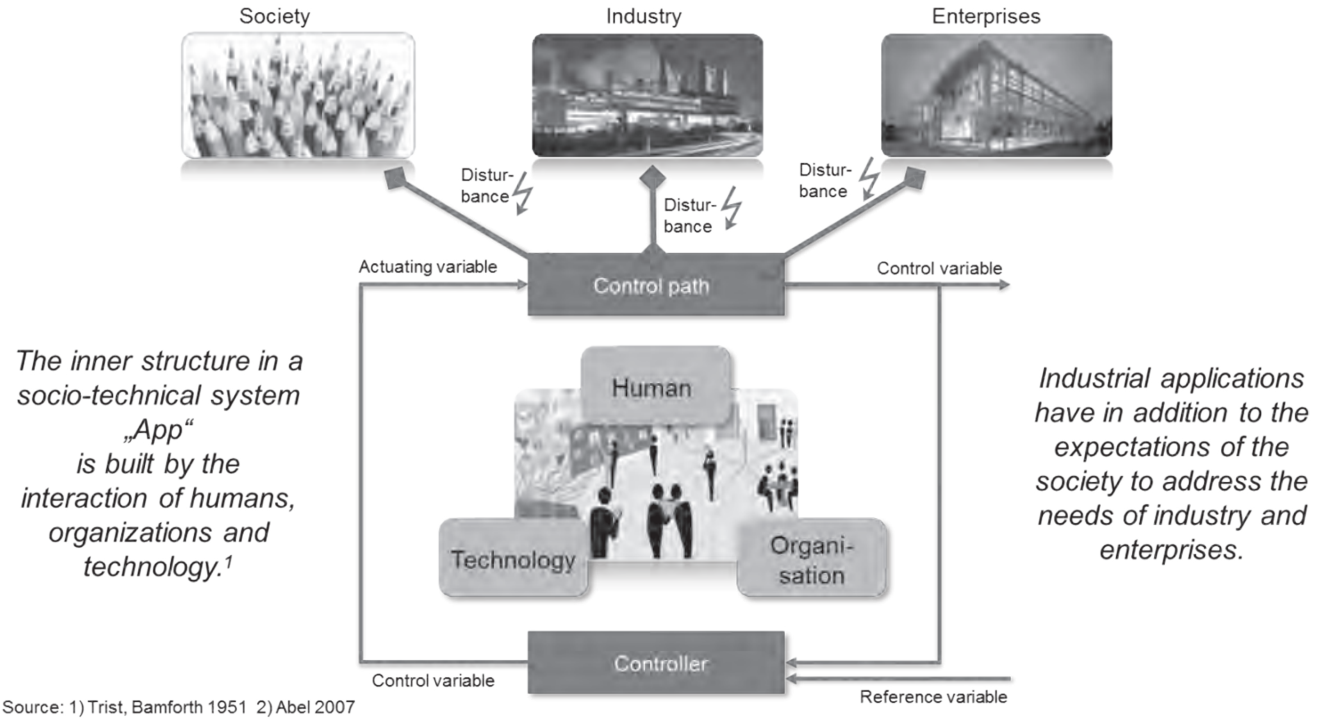
In future, operators faced with process analysis tasks or with machine tool operation will be able to access support based on technological models coupled with an understanding of the cause and effect relationships between tool, workpiece and machine tool. Some machine manufacturers are now initiating a shift towards introducing systems which permit remote communication with the machine. Status messages can be sent to smart phones, certain machine functions can be controlled remotely via iPad and on-going machining operations can be optimized by an experienced operator who is not on-site. Process models will require further development until they reach greater technological maturity before this remote control becomes an industrial reality. The machine tool must achieve a high level of process reliability independently and without active control on the part of the operator. A virtual, digital production must run alongside the actual production process to permit online comparison between the target and the actual status of the process.

Thorough, technological understanding is thus the most important requirement for digitized production. A process can be performed independently only when it is in an environment of thorough and extensive understanding of the process. Technological know-how must be implemented in tech-apps and in more complex simulation models for the cloud so that production systems can access and use this expertise.

A possible example for an application of this nature is presented in Fig. 12. There are various models for calculating the cutting force in machining operations conducted using geometrically defined cutting edges. One feature shared by all models is that they calculate cutting force on the basis of the cutting parameters selected the contact conditions and the material to be machined. These calculations are based on a comprehensive collection of cutting force measurements recorded in several series of experiments and filed in databases. However, complex processes cannot be reproduced using simple tools and machine operators certainly cannot be expected to work out which process boundary conditions prevail at a given time before using

[20] Pitsch 2014 (Heitkötter et al. 2012; 148apps biz 2014).

Figure 11: Straightforward interaction between humans and machines via tech-apps[21]



suitable models to draw conclusions as to the cutting force or the moment required without software support.

At this point, a tech-app could generate enormous added value by drawing on complex models stored in a database or a cloud. These could then be compared with the data supplied by the sensors integrated within the production system and projected directly onto mobile devices using a suitable visualization app. This would permit the machine operator or other entities involved in production to determine whether the manufacturing system was currently operating within the required tolerances or to its full capacity. In addition to providing direct representations of complex production and manufacturing processes, tech apps like these could be used to feed relevant results and new characteristic values generated in a specific application into networks. These networks might represent in-company communities which form global networks used to exchange empirical values and machining results with one another. It is also conceivable that companies could share independent networks of technology experts in this way, thus contributing to technological development in a diverse range of areas of production technology.

1.3.3 Sensors in manufacturing

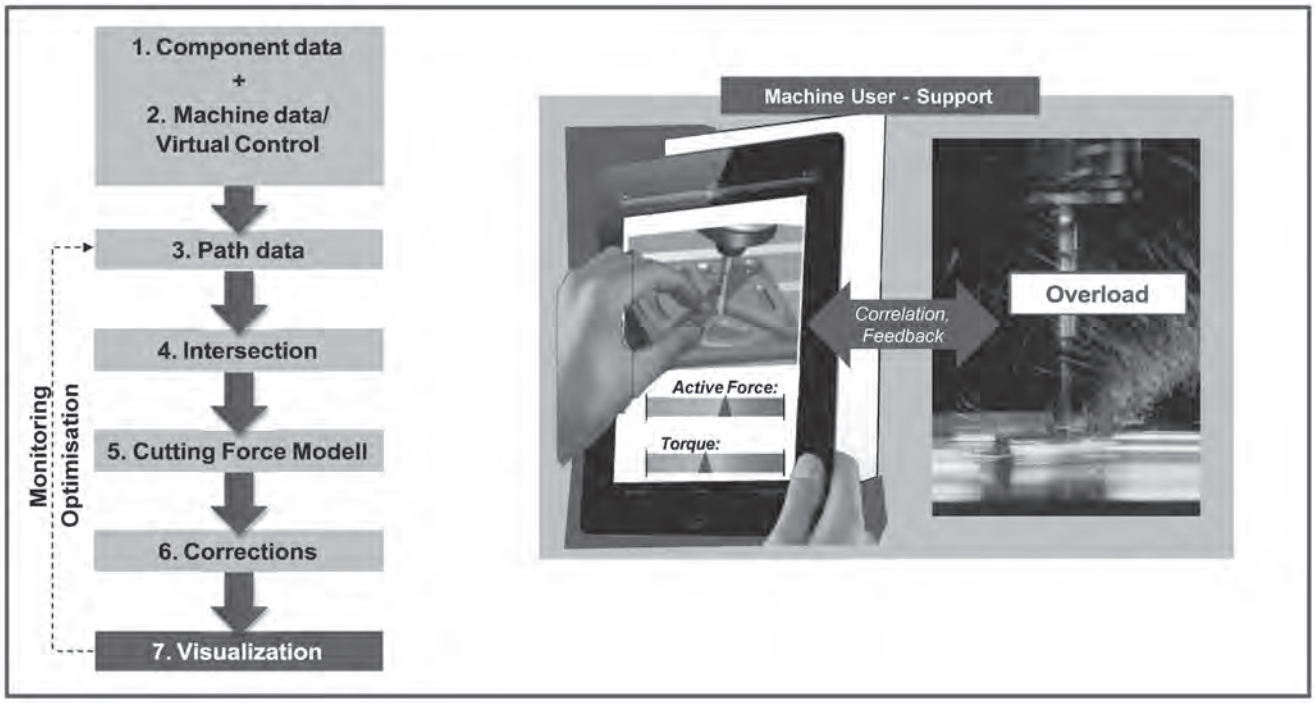
Established sensors and their application in production technology

A diverse range of external sensors is used in any production environment. Various sensors are shown in Fig. 13, arranged according to their measuring principles and their use in assessing workpiece, tool and active medium with the manufacturing process.

The sensors use various measuring principles in order to record condition or process variables. The operating principles of the sensors can be divided into six main categories: mechanical, thermal, electrical, magnetic, radiating and chemical. In many cases, the external sensors provide an electrical signal which represents the measurand. The widely-used standards of analog metrology are a voltage signal between 0 and +/- 10 V or a current signal between 4 and 20 mA. Ideally, the correlation between the measurand and the electrical signal is proportional and given by a constant factor. The overview suggests that there is a technical sensor solution for each field in the matrix. However, the fact that many of the sensors shown can either record

[21] Klocke 2014 (Trist, Bamforth 1951; Abel 2007).

Figure 12: Application in the production environment – Determining the theoretical cutting force[22]



only one measure or are extremely costly and are therefore suitable only for laboratory use is a fundamental problem. Any sensor used in everyday production has to be suitable for online operation – i.e. fully integrated in the process – which does not apply to a number of the examples shown. In the future, lab-on-a-chip developments and thin film sensors will provide further options of recording large volumes of process and machine-relevant information. As a result, it will become possible to perform statistical evaluations and to draw conclusions relating to process stability and process anomalies by analyzing trends.

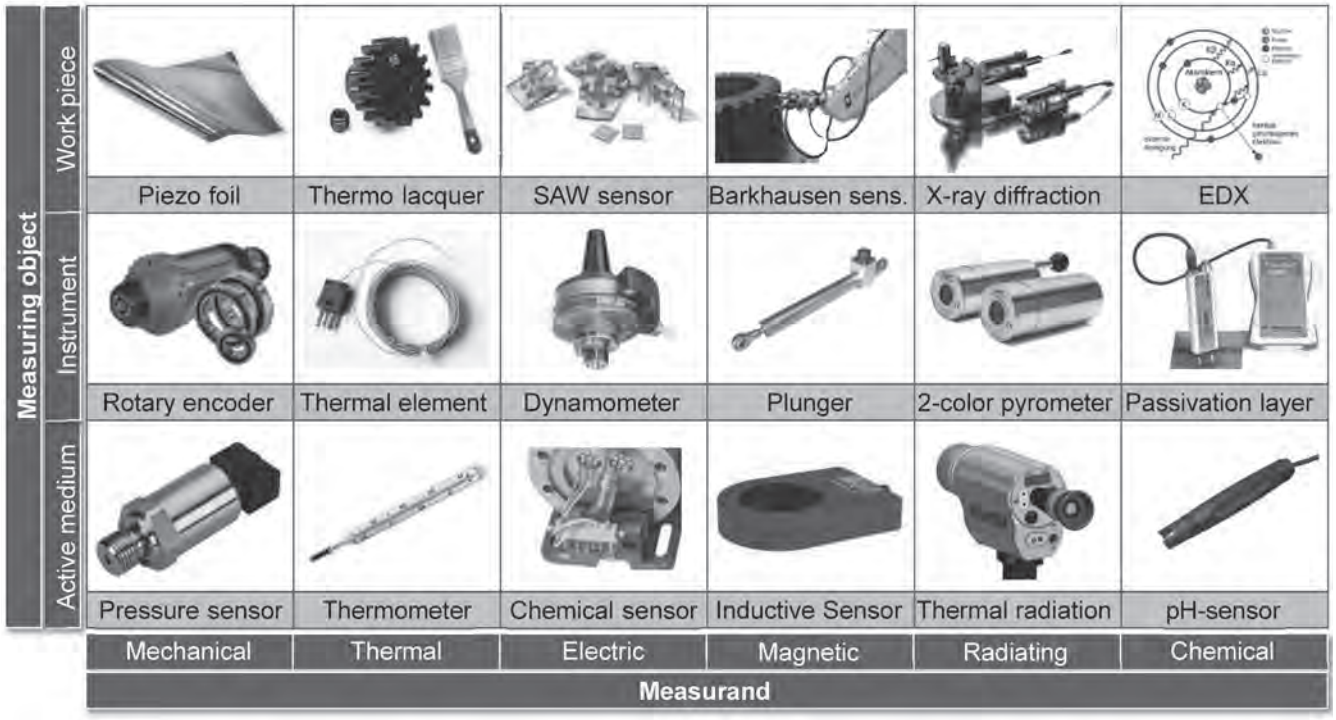
Internal signal processing and multi-sensor systems

The sensors described up to this point are used in the real world of modern manufacturing. They have only limited online capability. The examples outlined in the following demonstrate that the measuring signals recorded by sensors are frequently not unambiguous. Without information as to the position of the workpiece and tool, any attempt to evaluate the signals emitted by a force sensor with a view to measuring process forces ends in misinterpretation. In addition to this, individual sensors may measure process variables and send signals to assist in process monitoring but extended signal processing is always required in order to permit model-based interpretation of the quality produced or of the condition of tools, machines and auxiliary devices. Consequently, two strategic directions are being pursued in research in a drive to close these gaps, Fig. 14. Fundamentally there are two development trends: on one hand, integrated sensors which will be capable of supplying a higher volume of information are under development. These will be sensors which already permit evaluation of the data which has been recorded and which, in conjunction with suitable models, already supply information instead of simply passing on signals to the next level – e.g. machine control, the operator or to the process planning level. On the other hand, multi-sensor systems capable of measuring several quantities in the system are currently being developed. These are actually networks of sensors or integrated solutions which permit several measurands to be measured via one sensor system.

The combination of these two strategic directions is driving sensor fusion, a term which describes combined smart signal processing by a multi-sensor system of several measured variables[23].

[22] Klocke 2014.
[23] Klocke 2014.

Figure 13: Examples of the application of sensors in production technology[24]



In machining operations, the measurement of process forces is essential for process analysis and process optimization. Alongside temperature models, force models are the approaches most frequently applied in order to optimize cutting operations and to achieve the required level of quality in complex products. In most cases, piezoelectric force measurement is used to determine process forces. This is achieved by pre-tensioning individual quartz disks and connecting them to a sensor with high linearity. Additional information can be achieved by interconnecting several sensors to a force measuring platform. As well as expanding the range of measurement, this permits the torque values to be calculated. Despite the linear behavior of the piezoelectric sensors, external environmental influences such as the operating temperature can necessitate a correction of the sensor signals. The operating temperature causes change in the correlation between force and the charge given off by the sensor. It is therefore essential to characterize this behavior and to calibrate it accordingly prior to the manufacturing operation. In addition to mechanical compensation via a construction which largely balances out the thermal expansions, the target is to correct measured values frequently by exploiting further sensor signals. Thermal effects are often corrected with a view to increasing measuring accuracy. If, in addition to the actual test signal, information relating to the operating temperature is available, a model-based correction can be carried out, thus further increasing the accuracy of the measurement. Compensation methods like this are used both to measure the cutting force and within the machine tool itself.

In machine tools, measured temperature values are used to compensate for thermal expansion in the machine structure. Temperature is a pivotal variable in the cutting zone and can impact directly on both tool wear and product quality. Process input variables such as the material to be machined and the cutting material or process parameters like cutting edge geometry, feed rates and cutting speeds exert considerable influence on the temperature in the machining zone. Essentially, the temperatures which prevail when productivity is low, i.e. low rates of material removal, are not very high and there is no risk to the quality of the surfaces being produced. Depending on the optimization target, the ideal window within which the process should be performed may involve various cutting zone temperature ranges.

In the example outlined here, which relates to broaching operations conducted on materials which are difficult to machine, the

[24] Klocke et al. 2014a.

response to the challenge was the addition of complex sensors. The measurement setup equipped with the high-speed thermal imaging camera was supplemented by a 2-color pyrometer. By referencing measurement signals internally from two neighboring wavelength areas, the 2-color pyrometer provides a means of eliminating the influence exerted by the emission ratio and, thus serving as an optical, absolute temperature measuring device. The inclusion of the pyrometer signal allows the thermographic measurements to undergo a dynamic, temperature-dependent calibration. Fig. 15 shows how a calibration function is generated via temporal synchronization for the work area overlapping the two systems.

The differences in sampling rates of the measurement signals coming from the systems present one of the main challenges to be overcome when processing the measurement data recorded during the operation. Whereas measurements take place at selected points in the case of the 2-color pyrometer, in the case

Figure 15: Concept for the calibration of infrared camera data[26]

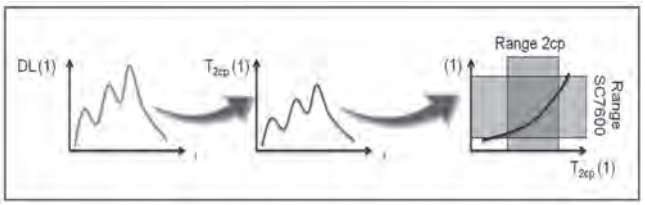


Figure 16: Reducing calibration variance via location-referenced measurements[27]

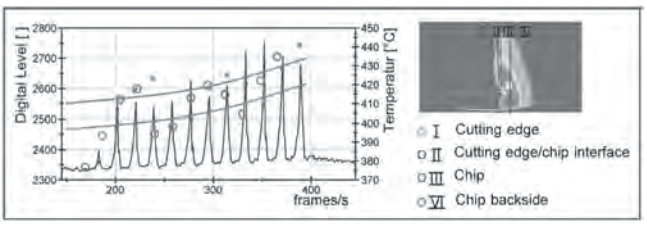
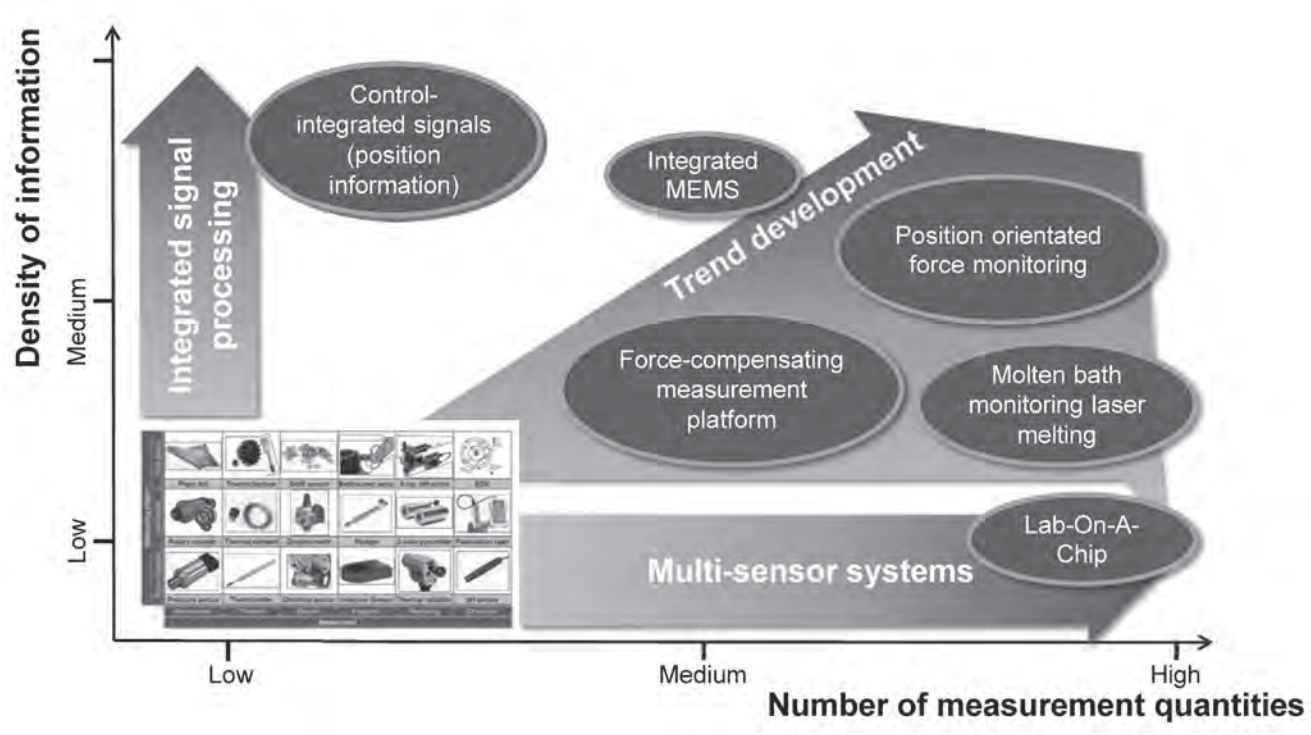


Figure 14: Trends in sensor development[25]



[25] Klocke et al. 2014a.
[26] Klocke et al. 2014a.
[27] Klocke et al. 2014a.

of thermography heat radiation is recorded over a relatively extensive image section. Additionally, the measuring range is considerably more extensive, beginning with ambient temperature. Consequently, the integration times are longer and the sampling rate diminishes at the same rate. The result is a disparity in the timeintervals between individually measured points. It is therefore essential to include the position of the pyrometer when process data are used, in order to identify a suitable calibration function. The four different options arising from the combination of the two signals are shown in Fig. 16.

As the calibration curve on the left of the diagram shows, the result was significantly improved by adding information referencing the location. All of the measurements can be calibrated using the method presented here. The temperature distributions over the process are absolute, providing all of the data required for further process modelling operations.

Two measuring systems, both of which record temperature, are required in order to determine the absolute temperature distribution in broaching operations. The systems differ in terms of their temporal and spatial resolution capacity. It is conceivable that there will be other production engineering applications which will require sensor fusion in order to create an innovative sensor with completely new capabilities by combining temporal or localized resolution capacity.

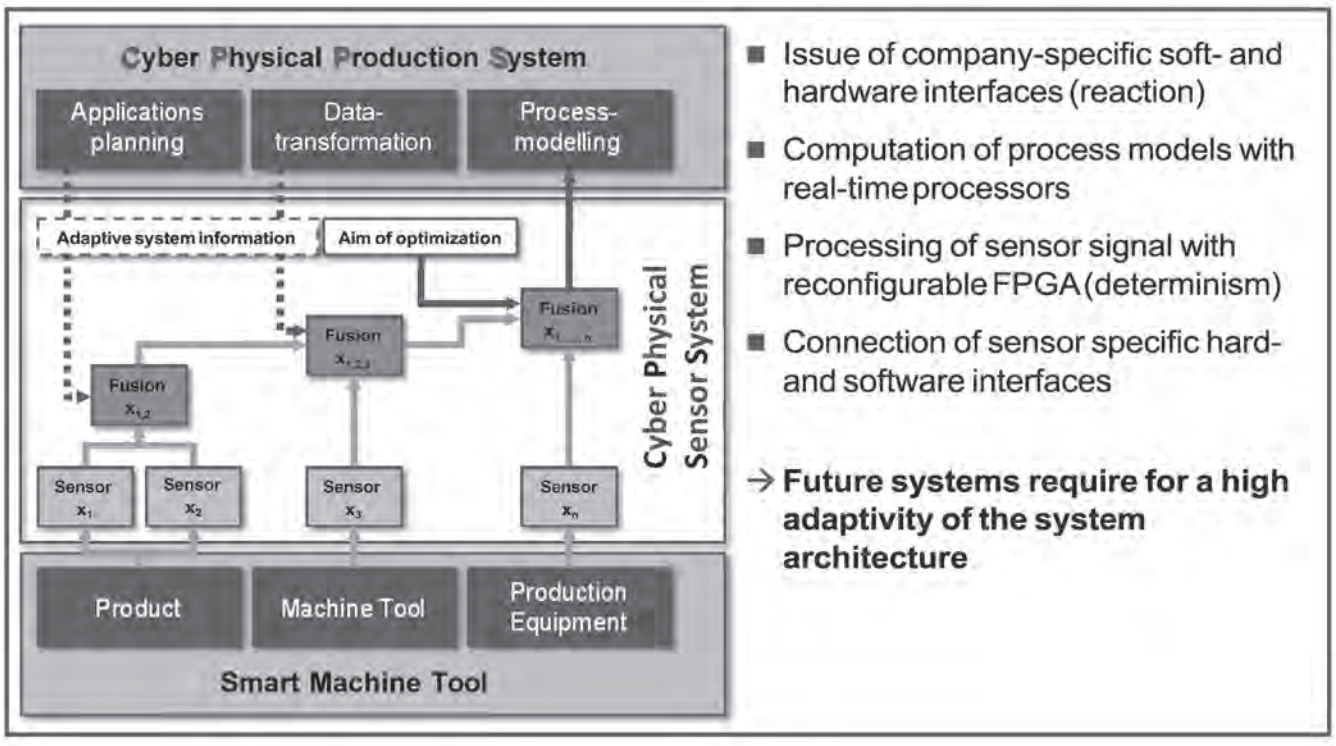
Cyber-Physical Sensor System – CPSS

The Cyber-Physical Sensor System (CPSS) describes a system of networked sensors based on independent fusion, c.f. Fig. 17.

The network relies on adaptive system information passed by the CPPS to the sensor system. The Cyber-Physical Sensor System takes account of the optimization goals and supplies the process information required for the development of suitable process models to the CPPS.

Information has to be extracted from the raw data before the process or individual part characteristics can be monitored independently. The algorithms required for this must be adapted dynamically in the CPPS to meet the requirements of the part feature concerned. Information which can be provided by PLM

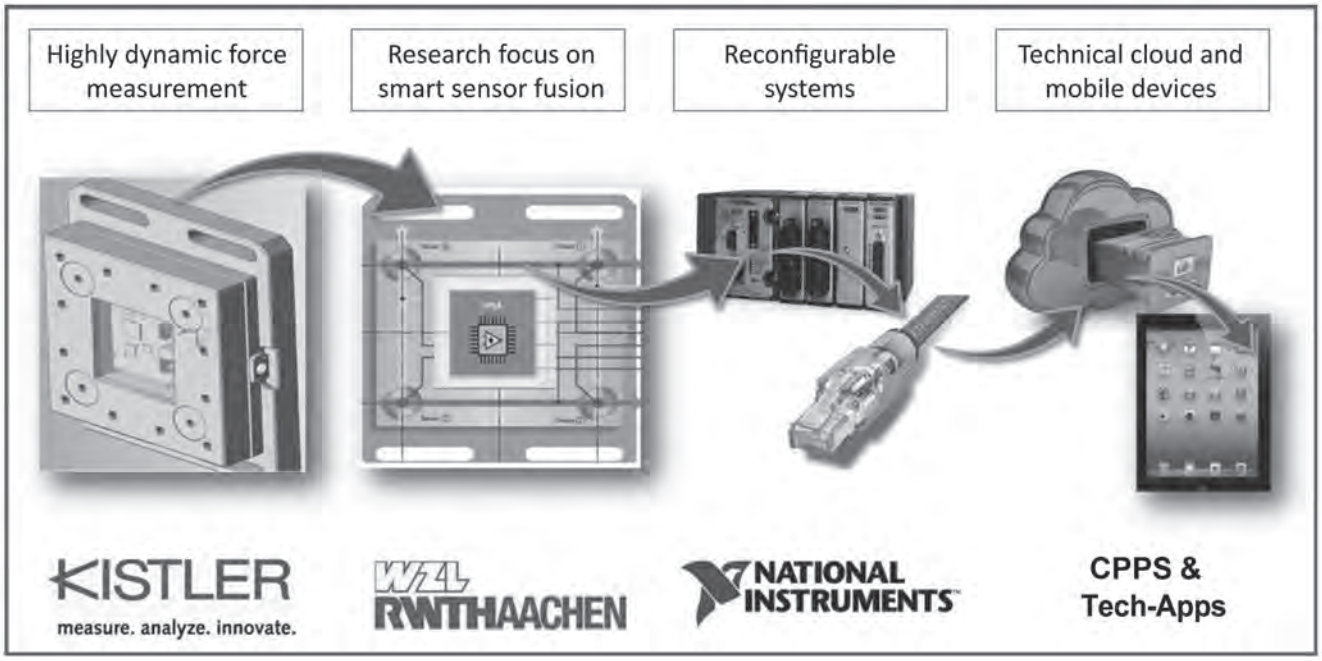
Figure 17: Cyber-Physical Sensor System[28]



[28] Klocke et al. 2014a.

systems must be obtained from the planning level in order to achieve this degree of adaptivity. Future process monitoring systems will be configured via production planning. The optimization criteria, i.e. neither excessively high nor low boundary condition (stability parameters, minimum chip thickness etc.) can either be filed via characteristic values or they can be determined via modelling in CAx systems. Where it is possible to work on the basis of characteristic values, which is an important option particularly for SMEs, both the volume of data involved and the required computer performance are reduced. In extreme cases, characteristic values can be described simply via attributes such as "good" or "bad". It is important that the entity concerned receives only the data essential to its work. Otherwise, there is a danger that volumes of "dead" data will accumulate as they are simply filed to server systems but are never used. The customer of a manufacturer will require information only as to whether a certain part ticks all the relevant quality attribute boxes. However, this does not mean that attributive evaluation and documentation are sufficient within the manufacturing process. From the point of view of product liability and certification in particular, it is vital to file quantified documentation of important process parameters within the company. This, in turn, necessitates the development of strategies to manage and archive measurement data. The increasing measuring accuracy of sensors coupled with higher temporal resolution presents a challenge to data processing operations. The limiting factors are the transfer rate and the latency of modern bus systems in machine tools. Due to the provision of information at various execution levels, the demand for real-time processing is growing. The next generation of sensor systems will have to be capable of processing data autonomously. The information supplied can then be made available to actuator components or to a higher level system of targets for further processing. In the case of non-time-critical applications, the parameters which have been calculated can be transferred via standard network protocols to database systems. A CPPS sensor without a host could process even a direct stream of data to a decentralized data storage device. In order to maintain a degree of flexibility as high as possible, it will therefore be essential to deploy more reconfigurable and scalable systems based on real time processors and FPGA technology. Manufacturers of sensors and actuators can provide only one hardware platform in terms of CPPS as customer requirements can vary enormously. The objective should therefore be to develop open, embedded sensor platforms which are easy to integrate.

Figure 18: From simple sensors to mobile use of information[29]



[29] Klocke et al. 2014a.

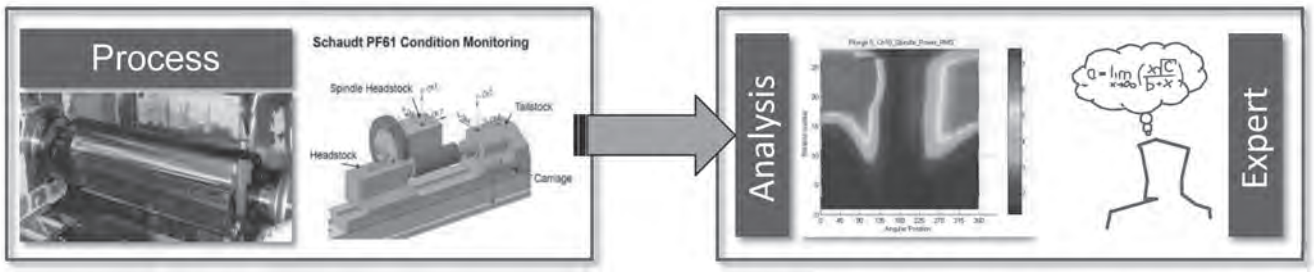
This would permit users to use their own algorithms to add new functions to measuring devices and actuators. Customer demand for smart products which can be expanded as required is already emerging in many areas of the entertainment industry. These smart devices can be adapted via "tech-apps" to meet the requirements of individual customers. Many of these platforms permit the apps to be programmed by the user. These apps can then either be sold or made available to the community free of charge. Future terminals are open, reconfigurable platforms which can be adapted by the customer and used to form communities. Through the development of apps, these user communities generate new areas of applications and functions for the manufacturer.

The greatest challenge in relation to networking is how to manage the data and information generated. To ensure that the information can be found quickly and that the documentation is reliable, it is essential to file additional, descriptive information along with the measurement data. Some standardized data formats provide an ideal data structure which permits data management systems to be developed swiftly and cost effectively using commercially available systems, without sacrificing the classical functionalities of a database. Since it must be possible in the future to access measurement data, information and parameters from outside the company, the development of a technical data cloud is under way. Cloud Computing is the term used to describe the approach of providing dynamic IT infrastructures, calculation capacity, data storage, network capacities or services on demand[30]. The advantage for companies is that resources which are required for only a short time do not come hand in hand with irreversible, costly expansion of the IT infrastructure. Fig. 18 shows direct transfer of data to the cloud or to mobile devices.

Remote monitoring with cognitive intelligence

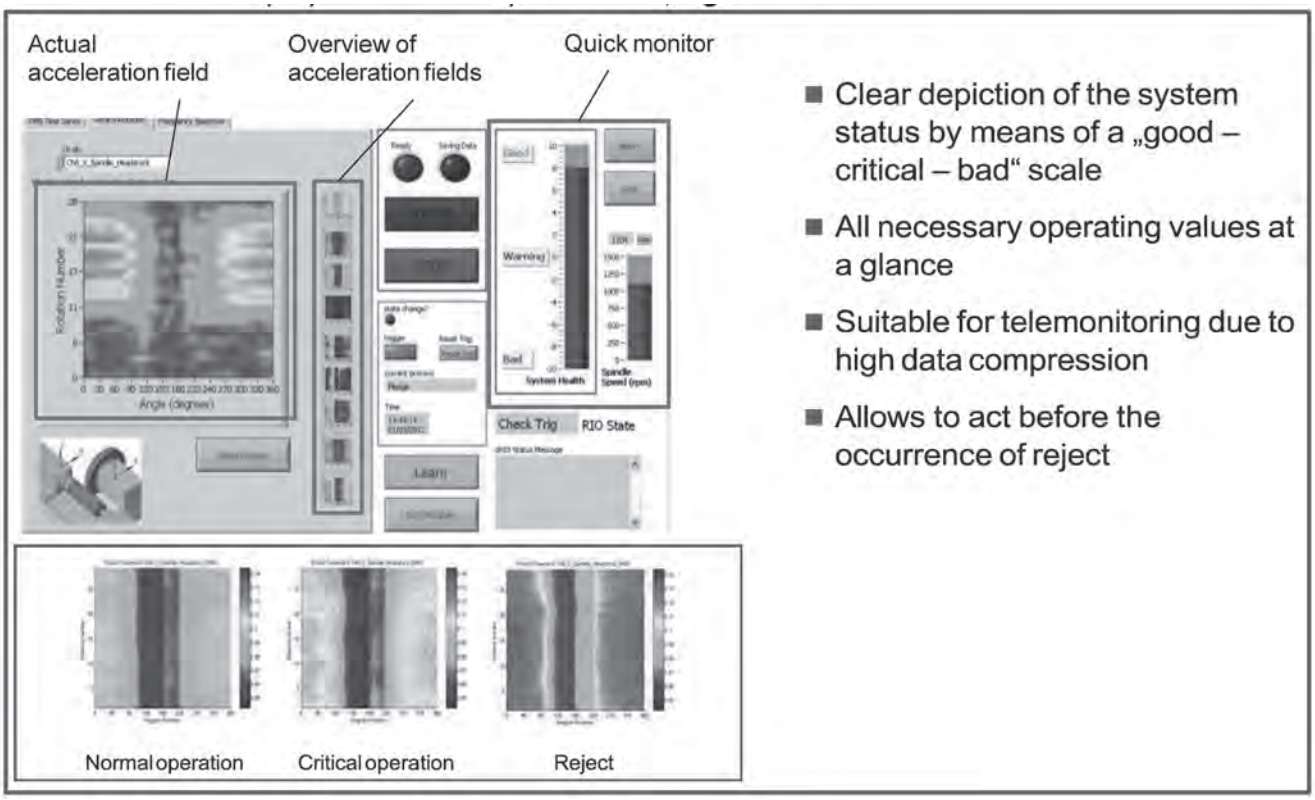
The evaluation of extensive field information, e.g. thermo-camera images is a fundamental problem. In such cases, the ability of humans to recognize significant information quickly without additional evaluation algorithms and to give due consideration to it in decisions relating to the process can be helpful. Given digital networks, these technology experts can be based anywhere in the world. An example of remote monitoring based on a technical cloud system set up by the globally operating manufacturer of printing machinery Heidelberg, is outlined in the following. One of the major factors in determining the success of printing equipment is the precise manufacture of print rollers. The grinding operation conducted as a final manufacturing step on the cylinder surface represents an enormous challenge because in addition to the usual requirements relating to form and dimensional accuracy, the optical requirements to be met by the surface also determine whether or not the part will be accepted for the subsequent coating and assembly stage. The 100%-testing of optical surface quality is currently carried out in a downstream process step outside the machines and under special lighting. Consequently, there is a time lag before changes to the overall workpiece, grinding wheel, or machine tool process become apparent. In addition to this, changes to the process often happen gradually over time with the result that although it is possible to trace retrospectively the starting point of the change or the point at which the boundary value was overstepped, by the time it is noticed, it may be necessary to rework several print rollers. Chatter marks – barely discernible waviness on the surface - represent one of the main criteria in the optical assessment of the cylinder surface. In addition to the direct machining parameters such as cutting speed, feed and grinding wheel diameter, the cause of these marks is often to be found in one of the machine components. The occurrence of chatter marks and, more particularly, what causes them

Figure 19: Global use of information via technical cloud systems[31]



[30] Klocke et al. 2013, pp. 090-095.
[31] Klocke et al. 2014a.

Figure 20: Monitoring tool for the machine tool user[32]



is not predictable without appropriate monitoring. When they do occur, however, it is vital to react immediately in order to isolate the fault and minimize reworking or to eliminate the source of the cause and to remedy the fault. Within the framework of an EU-funded project, a steel cylinder grinding process performed on a Schaudt Polygon grinding machine was analyzed by a team of experts comprising research engineers, maintenance engineers and operators using a process monitoring system which records and evaluates changes in the overall system during actual machining, thus facilitating early intervention. The sensors used to evaluate the condition of the machine components and of the process are acceleration sensors. Since the point of origin of the vibrations which cause the chatter marks is not known in advance, three-axis sensors were mounted on the headstock, the workpiece spindle and the tailstock and a one-axis sensor was mounted on the carriage. The machine coordinates were also recorded in order to permit spatial resolution of the vibration. At a sampling rate of 12.5 kHz and a 16 bit resolution for the acceleration sensors, approx. 1 gigabyte of raw data is thus collected per hour of machining on one machine. Storing and transferring the raw data to an expert who can analyze the data but who is located elsewhere would be inefficient and time-consuming. The machine examined in the EU project was installed in a manufacturing facility in Germany whilst the expert responsible for data analysis was based in Ireland[33]. The concept of remote monitoring by an expert working a long distance from the manufacturing site is based on the data preprocessing facility already implemented in the machine which converts data into information thus reducing it to a size suitable for the network, c.f. Fig. 19.

This was achieved by installing a Compact Rio System with a FPGA chip within the grinding machine, to which the expert outside the manufacturing facility had access. This made it possible for the expert to adapt the data analysis. The information obtained via the analysis was filed by the system onto an FTP server and displayed on an analysis monitor, Fig. 20.

[32] Klocke et al. 2014a.
[33] Morgan et al. 2012.

To expand the options for application of the system to include shop floor level, the display shown above was installed in the machine. This allows the expert to view selected information in real time, which is then directly available to the machine operator.

Model-based process control
The need to meet the increasingly demanding requirements relating to products manufactured nowadays frequently confronts the manufacturers of metallic parts with a challenge. The problem which occurs most often is the demand for reproducible manufacture of geometric forms. Form deviations can arise as a result of variations in the properties of the semi-finished product or of tool wear.

Normally, the process parameters are adjusted manually on the basis of production scenarios or of previous deviations revealed during the target and actual comparisons. The selection of new parameters then depends mainly on the experience of the machine operator. This results in a protracted and expensive process which occurs at each phase in the process life cycle. Additionally, process requirements are becoming increasingly demanding due to the general trend towards miniaturization and to reduced tolerances coupled with increasing material strength. In an effort to reduce the reject rate and the tooling times, a model-based approach was selected for an adaptive control strategy. This involved first modelling the production process, for example a bending process. The bending process is initially analyzed by varying the process variables which exert the greatest influence on the process. This is achieved via corresponding simulations. The correlation between the significant variables and the geometrical deviation is determined and various self-optimizing control strategies are developed and tested. A special-purpose tool was developed in order to validate the simulation and to test the quality of the self-optimizing control strategy. This tool has an additional measuring device and can be used on standard test machines. When the self-optimizing control strategy was tested under real production conditions, the process parameters of interest in this case, the initial dimensions of the product to be bent were kept completely within the tolerances, thereby achieving a reject rate of 0 percent[34].

1.3.4 Monitoring the condition of production machines

Potential benefits
The introduction of methods of analyzing the condition of a machine tool incurs considerable costs. The aim of the developments is, therefore, to allow a simplified application of machine condition analysis methods. The vision of a self-monitoring machine tool is shown schematically in Fig. 21.

Considerable potential, which can be split into three higher-level areas, arises from the efficiency of the self-monitoring machine, cf. Fig. 22.

The current developments on the way to a self-monitoring machine tool are in progress at various levels, cf. Fig. 23.

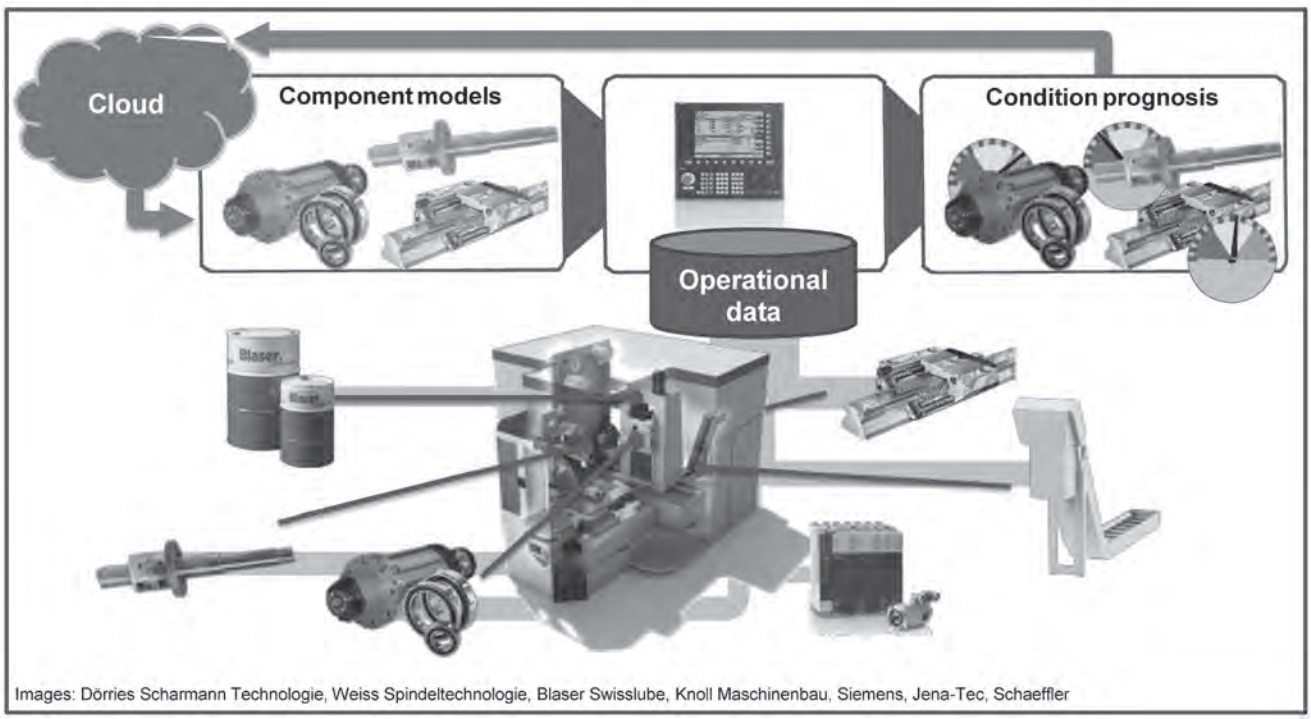
In addition to protecting the machine, protection of the part to be machined, which may already have undergone previous processing steps and therefore has a value-added element, is important.

Integration within the production landscape
There are server interfaces for the integration of planning and production data from well-known ERP and MES systems. Not only does this permit the actual production process to be completely reproduced; it also facilitates suggestions regarding alternative production parameters to be suggested. When the order situation is known (from the ERP system, for example), and when the correlation between operating parameters and power consumption has been analyzed, it is possible to optimize the parameters in terms of energy consumption.

The administration and analysis of large amounts of heterogeneous data present a challenge. Existing, relational databases cannot scale automatically. This, however, is essential where large volumes of data are concerned. Non-relational (No-SQL) database technologies provide an alternative. Due to the non-existent relations, these permit automatic scaling, i.e. splitting of the data over several servers, thereby providing the basis for parallel data processing. Algorithms which can be parallelized are used in order to permit distributed information to be evaluated decentrally on various different servers. The Apache HBase is an example of a database of this nature. This is based on the Big Table developed by Google Inc. and is used by this company to run data-intensive applications with a large number of users, such as Gmail. Large volumes of heterogeneous data ("Big

[34] Pitsch 2014

Figure 21: The self-monitoring machine tool[35]



Data") can be analyzed and utilized. Complex correlations can then be scrutinized in terms of their causality on the basis of this technology. The models obtained can subsequently be used to develop user-specific applications such as forecasting systems. These customized applications can, in turn, be distributed to the individually connected devices via the ISB server. In addition to developing specific applications, potential for optimization in production can also be unveiled.

1.3.5 Resource-efficient manufacturing

Challenges arising from national and European targets

Resource efficiency must also be considered from economic and social points of view. The term sustainability, which combines ecological, economic and social factors in one single concept, has established itself in this context. Legislative instruments which demand sustainability and are intended to provide further incentives for companies have been used for a number of years to implement European and national objectives. Companies are being confronted with demands to incorporate energy management systems and with carbon dioxide emissions certificate trading. At European level, the flagship initiative for "A resource-efficient Europe" under the Europe 2020 strategy has been set up[36]. This initiative sets guidelines for the member states, as to the degree to which sustainability targets are to be pursued and, most importantly, the overall orientation of efforts in the field of resource efficiency is focused and standardized. One of the main goals is to achieve a reduction in the emission of greenhouse gases within the EU by 80–95% by the year 2050. This headline target is reflected in many approaches initiated by the EU[37, 38, 39].

A Product Environmental Footprint (PEF) as an instrument for standardization and creation of a shared understanding of the environmental impact of products is under development and has been defined for selected sectors. This PEF specifies and quantifies the ecological impact of a product over its entire life cycle. The equivalent carbon dioxide emissions during manufacture, use, recycling or disposal can contribute to the

[35] Brecher et al. 2014.
[36] Kaiser 2013.
[37] Krüger/Denkena 2013.
[38] Schuh 2008.
[39] Hinduja/Kunieda 2013.

Figure 22: Benefits of the self-monitoring machine tool[40]

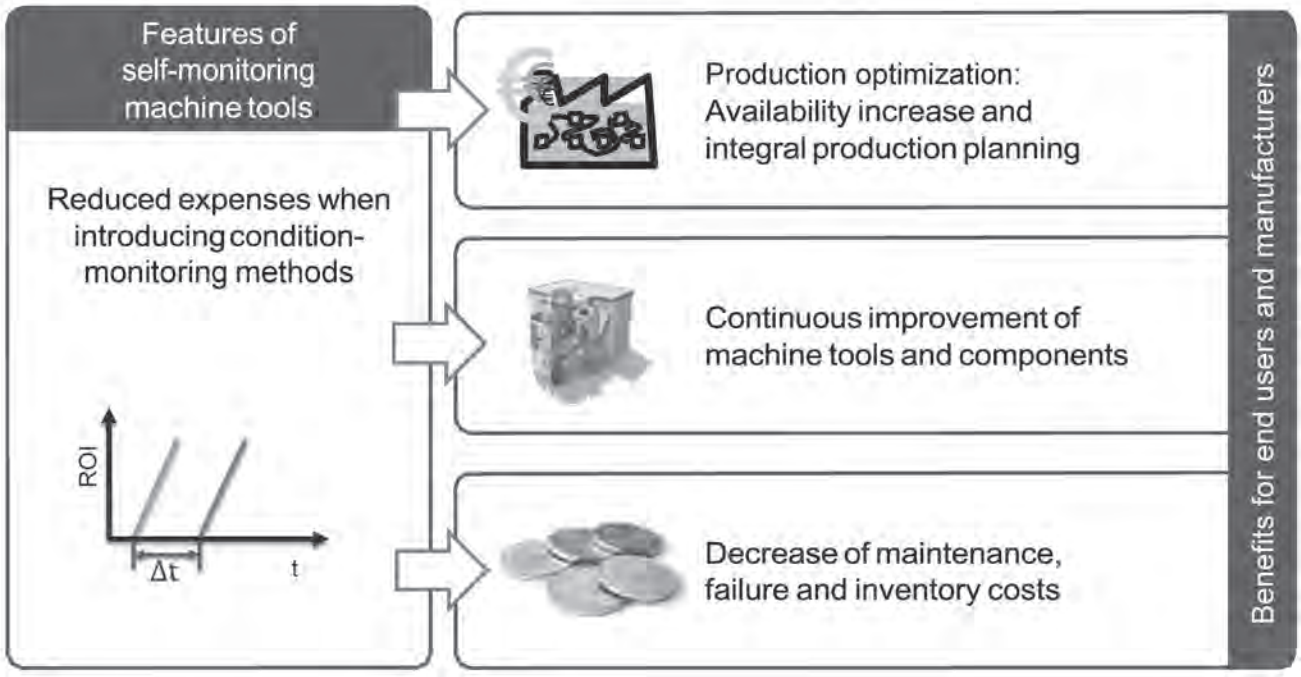
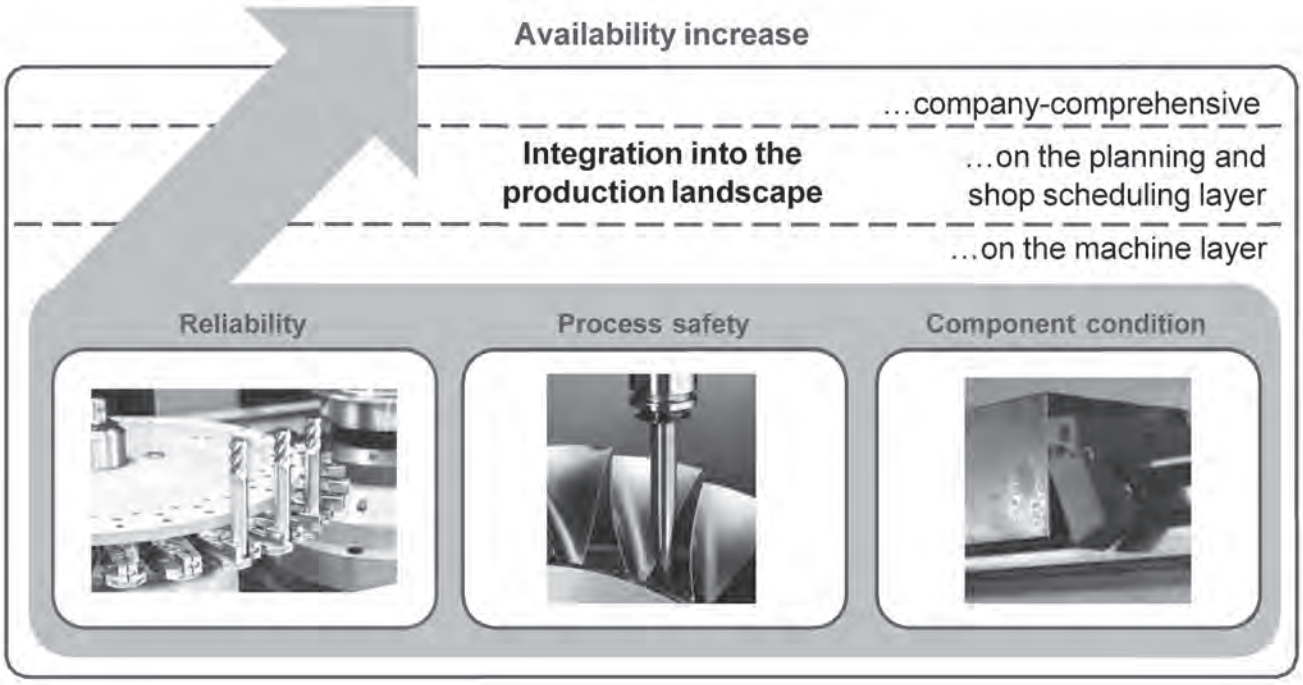


Figure 23: Areas for measures to increase availability[41]



[40] Brecher et al. 2014.
[41] Brecher 2011.

PEF assessment regarding environmental impact. The European Commission is currently funding pilot projects aimed at defining benchmarks and meaningful, product-specific characteristics in a range of sectors for the Product Environmental Footprint. The aim behind the entire development of this footprint is to facilitate comparisons between different products using standardized methods and tools, whose application must be verified. In future, the PEF will be extended to cover additional sectors. The PEF for the metal sheets product group will become relevant to the metal-working industry in future years; the first constitutive meetings have already taken place[42]. Germany´s targets for the year 2020 have been set within the framework of the sustainability strategy, which is reviewed regularly in a progress report. A total of 38 indicators for sustainability in the key areas of Quality of Life, Intergenerational Justice, Social Cohesion and International Responsibility quantify progress. In the meantime, this perspective has also been brought into line with a vision for the year 2050. In this context, the switch to renewable energy for electricity generation is one of the key targets[43, 44].

In the industrial environment, major challenges arise simply from the fact that considerable expertise and willingness to invest are essential if energy and resource efficiency measures are to be implemented. The evaluation of measures, particularly of their payback period and long-term impact is frequently no simple matter and previous knowledge is essential. Small and medium-sized organizations in particular can afford to assign staff to this function alone only in situations where very considerable savings stand to be made. Measures which can be implemented swiftly and effectively are often to be found in reports in specialist journals highlighting quick wins and recognized measures for dealing with particular applications. Additionally, however, more thorough, specialist knowledge is essential in order to identify and subsequently exploit potential means of increasing efficiency in addition to performing all of the activities required for manufacturing. Software solutions such as Umberto or GaBi can be used to evaluate industrial consumption in ecological and economic terms at the same time[45, 46]. In the majority of cases, these methods call for experienced staff. Consequently, tools which are easy to use and which are customized to tackle the daily work in the company and whose purpose is to make it easier to carry out ecological evaluations, are continuously establishing themselves. The ProBAS database used by the Department of the Environment is an example of data which can be accessed by the public. The barriers described have been verified on the basis of surveys[47]. Far-reaching strategies, firmly embedded within the company, will be required in order to tackle the challenges.

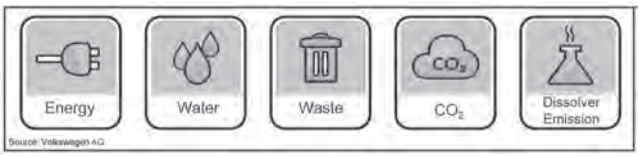
Previous approaches to the implementation of measures aimed at increasing resource efficiency frequently relied on extensive data collection via sensors integrated in machines and equipment. These sources churn out immense volumes of data which, of course, all have to be processed in order to generate actual information in the form of key performance indicators (KPI), for example. These KPIs can then be used downstream as control information. The hardware-based application of this approach is complex, requiring that consideration be given to numerous different elements. Information must be obtained from the measurement data and aggregated to form KPIs, ensuring that no important information is lost. One single key indicator such as greenhouse gas emissions per vehicle can be tracked over a number of years, for example, but specific elements with potential for improvement can be identified only when the indicator can be divided into sub- indicators. A precise level per vehicle, module or site would be meaningful but, given the current IT structure, is not universally achievable. Not all types of machine and equipment consumption can currently be measured due to a lack of sensor technology.

Resource-efficiency in the company

In view of the challenges outlined above facing manufacturing companies in Germany, it is vital to embed resource-efficiency within business processes in order to meet the demands of both energy management systems and energy conservation targets. It is important to note that not only technological factors but organizational and social aspects in particular exert considerable influence on any such effort. Simple measures, such as switching off electrical devices when leaving the room for example, which are part of everyday domestic life, can be transferred to the work environment and, in close cooperation with employees, become part of the daily routine there. To achieve this, it is important to create a framework which, with the support of staff, will permit energy-efficiency measures to be implemented on organizational

42 Klocke et al. 2013a.
43 Brecher 2011.
44 Pitsch 2014.
45 Denkena et al. 2013.
46 Klocke et al. 2013c.
47 Morgan et al. 2012.

Figure 24: Goals of the Think Blue Factory. Initiative[48]



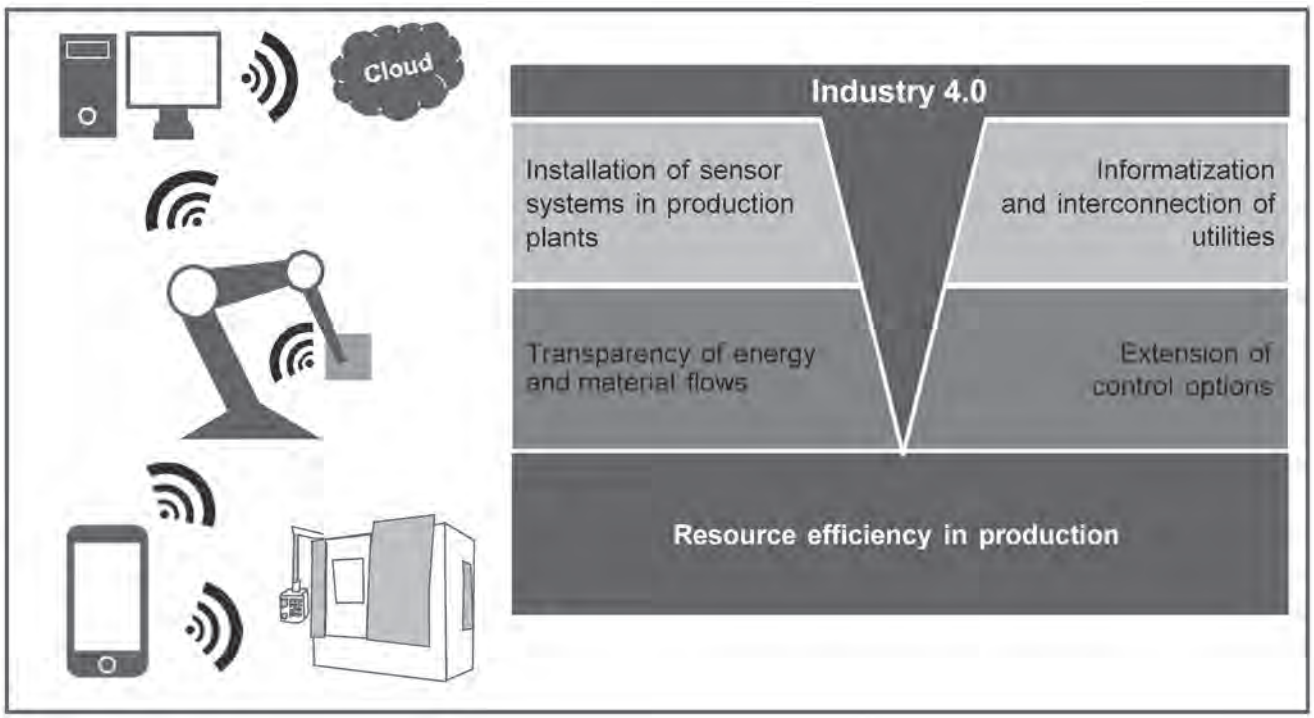
and technological levels. In addition to this, research will be conducted with a view to developing highly complex technological measures aimed at increasing resource efficiency.

It is evident that there is a broad spectrum of organizational and technological measures which can be implemented in order to increase resource efficiency. One example of this is the "Think Blue" initiative launched by Volkswagen AG[49]. The Volkswagen group has committed itself internally to causing twenty-five percent less energy, water, waste, CO_2 and solvent emissions per vehicle as against the 2010 levels, c.f. Fig. 24. The pursuit of these aims and developments in recent years in relation to sustainability will be embedded and published in sustainability reports as is the case with other companies[50, 51, 52].

The combination of higher transparency and controllability of value-added networks can increase resource efficiency (Fig. 25).

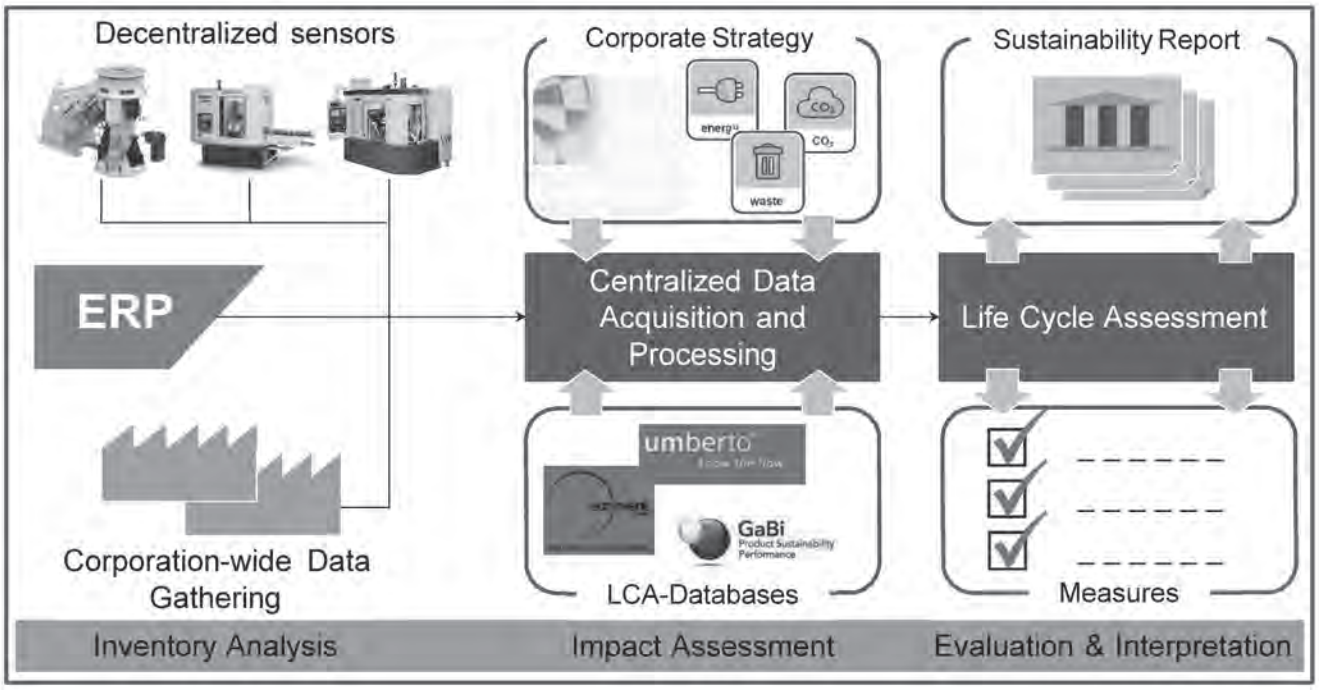
Concepts and statements regarding the significance of Industry 4.0 in terms of resource efficiency have so far been vague and expressed only in general terms[53, 54]. It stands to reason that the increasing use of sensor systems and the associated rise in the volume of information available coupled with flexible and

Figure 25: Resource-efficiency in the context of Industry 4.0[55]



48 Volkswagen AG 2012.
49 Volkswagen AG 2012.
50 Rudolf 2014.
51 Klocke et al. 2014b.
52 European Commission 2011.
53 Volkswagen AG 2012.
54 Daimler AG 2012.
55 Klocke et al. 2014b.

Figure 26: Lifecycle assessment within the context of Industry 4.0[56]



intelligent control concepts will result in a more efficient use of manufacturing resources in general. However, there is still a need for a significant amount of research in order to establish how exactly resource efficiency can be improved as a result of Industry 4.0. In conjunction with the additional control facilities made possible by this development, Industry 4.0 also provides a means of controlling the manufacturing process more efficiently and thus also more resource-efficiently. Assessment methods and strategies for economizing on the consumption of resources adopt either a top-down or bottom-up approach. On one hand, it is possible to assess energy consumption on the basis of annual accounts and on what are usually rough allocations of total consumption among manufacturing sites and technological areas combined with production volumes. These assessments are then recorded in the form of target values such as energy consumption per vehicle produced. On the other hand, enormous efforts are made to equip machines with sensor systems in order to generate actual consumption data, in real-time, if possible. How best to link all of the data which has been generated with the target systems remains an issue.

Automated ecological auditing

Digital networking also offers a means of conducting life-cycle assessments automatically, without the need for much manual input in future. The conceptual framework is outlined in Fig. 26. The outcome is an ecological audit, drawn up virtually automatically and parameterized via the central control entities which can be used to extrapolate cost-saving measures, review the continuous improvement process or public relations activities.

1.4 SAFETY AND SECURITY

Tested security technologies represent a major obstacle to the introduction of global manufacturing networks, extending beyond company boundaries and using cloud technologies. Whereas early IC technologies were previously organized as service departments in manufacturing companies, modern communication and information technology is firmly integrated within the entire value-added chain (Fig. 27).

Klarke (Fig. 28) presents models and methods which can be used systematically to develop concepts for risk-conscious data networking on the basis of sensor data and process information.

[56] Klocke et al. 2014b.

Figure 27: Ubiquitous IT Critical for Success – and Increased Threat[57]

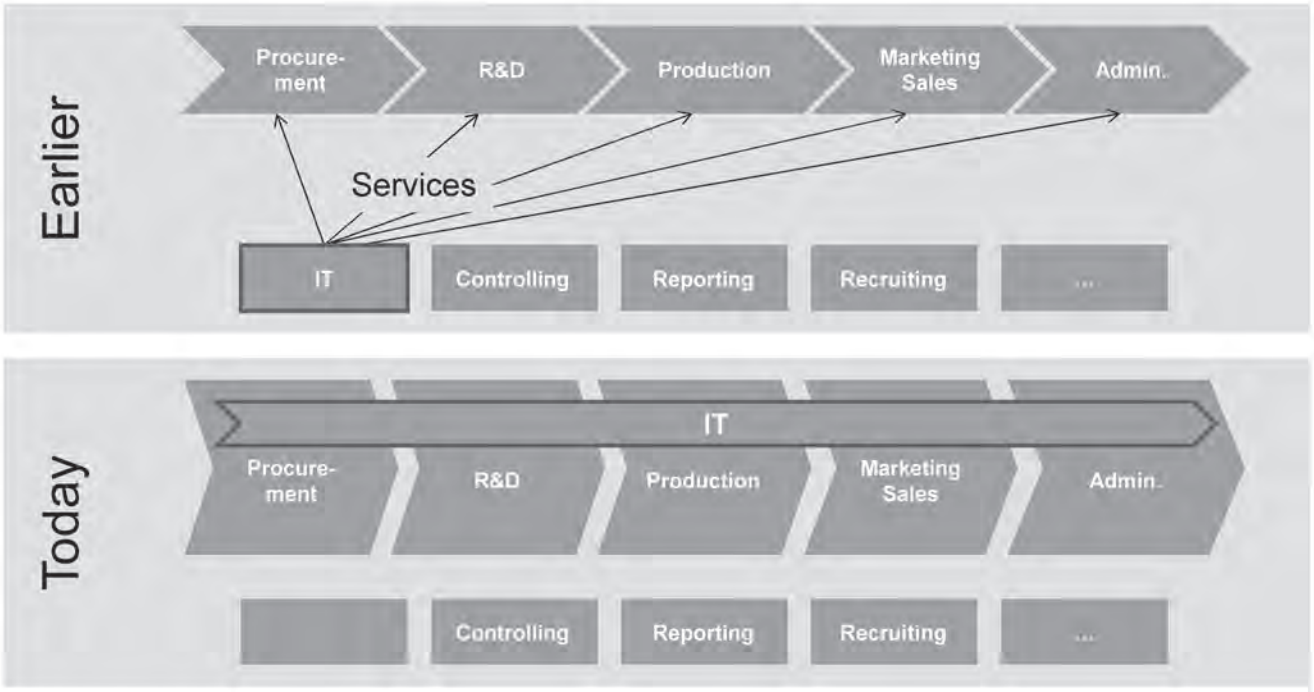
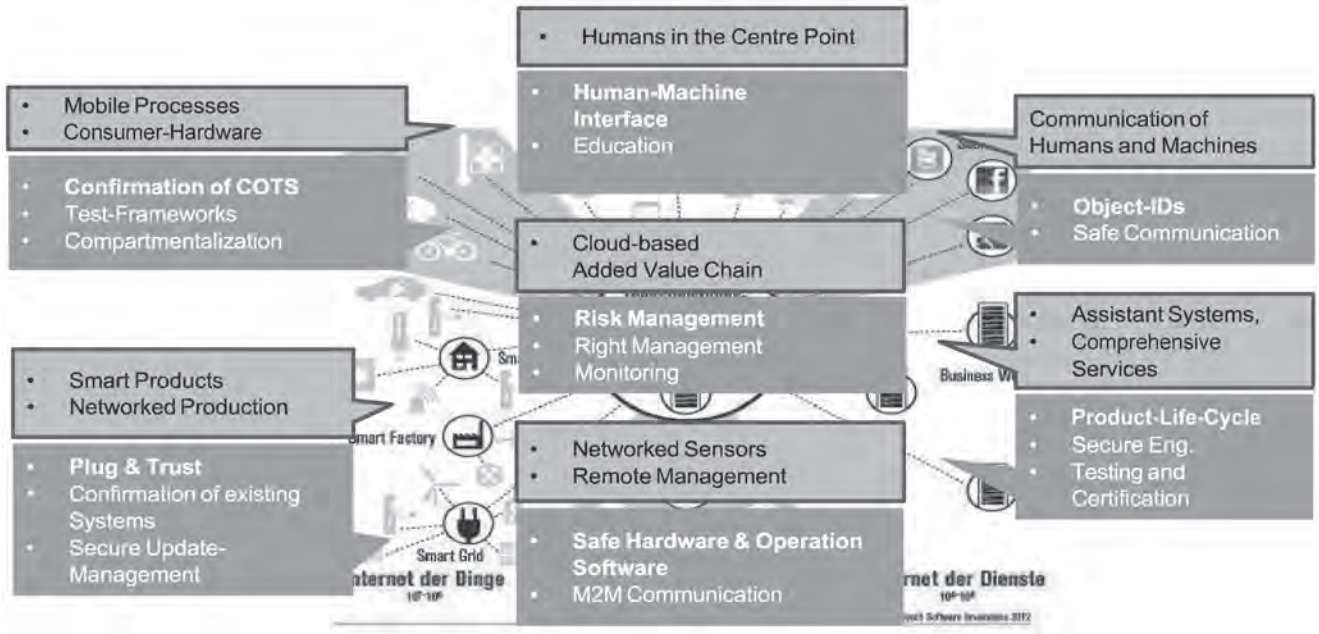


Figure 28: Concepts for risk-conscious data networking[58]



57 Jarke 2014 (Fraunhofer FKIE).
58 Jarke 2014.

1.5 DEFICITS AND ACTIONS RECOMMENDED

This research study focusses on potentials and impacts of information and communication technology on advanced manufacturing with special reference to an international context. In particular the following deficits, which call for joint target-oriented action, have become apparent.

Standards, interfaces, co-operation

- In emerging economies, standards will generally not be reached until after introduction and achievement of market maturity. In international collaborative ventures with developing markets, the definition of standards will provide their markets with an excellent opportunity to implement technologies worldwide.
- Communications protocols must be developed from scratch in terms both of form and contents for manufacturing companies.
- Specific key abilities are to be defined as required by cooperating enterprises to create value creation networks (Tier 1, 2, and 3 capabilities).
- Logistics follows production requirements. Production follows also logistics. Dependent on products to be made appropriate sensors systems have to be developed (chosen) to create smart products.
- Test procedures to check manufacturing and logistic resilience on all tier levels must be jointly designed and agreed upon.
- A total quality chain should be implemented, including a risk management system.
- All relevant standards with regard to interfaces and interconnections have to be considered. Any standards not set in intercompany and international co-operation should be listed. Proposals should be made regarding standards which are yet to be defined.
- A market study should be conducted in India on state of the art of digital manufacturing in order to identify any gaps.
- A joint risk management system is necessary.
- A show case production with fully integrated IT functions could help to conduct further development jointly on smart manufacturing.

Sustainability

- CPPS systems provide the option of implementing new forms of energy and resource efficiency in manufacturing companies. This assumes special significance where the development of new production facilities in an international context permits the introduction of new forms of resource-efficient production.

User-friendliness

- The availability of user-friendly application technologies is one of the basic requirements for a network extending beyond the company boundaries and areas of economic activity. The efficient and ergonomic design of work processes will be re-organized via human-machine interfaces.
- In the consumer area, it will be necessary to scrutinize interfaces in terms of their applicability in manufacturing companies and, where necessary, to adapt them.
- In the traditional machinery and equipment manufacturing industry, it is vital to transfer the functionalities used in younger generations to include manufacturing operations.

Recording, analyzing and modelling field data

- Sensor technologies permit field data to be comprehensively recorded. This opens up new possibilities for resource-efficient manufacturing and for resource-efficient deployment of production facilities.
- Condition monitoring of machines, equipment and tools fosters significant increases in efficiency.
- Process fluctuations as a result of unforeseeable influences (variations in material tools, attachments) must be recorded via sensor and evaluated statistically.
- In-process sensor data are used to calibrate parameterized, complex manufacturing processes.
- Resilient process chain design via order-dependent combination of manufacturing steps.
- Process fluctuations can result in uncontrolled instabilities in the process chain. Broadly-based recording of process fluctuations and real-time control return processes to stable operation.
- Suppliers of industrial information technologies must resolve the challenges associated with classical data recording and data compression concepts.
- Reservations relating to opening up interfaces and to large-scale data analysis must be dismantled.
- The implementation of new sensor concepts to record field data enables resilient production processes to be developed and run.

Material and information flow

- CPPS systems permit material flows to be controlled automatically and flexibly.
- Order allocation and lot size specification are carried out on site, taking account of the manufacturing capacities required and manufacturing systems available.
- It is vital to implement new solutions to integrate software/hardware systems (mechatronic systems).

Technological basis
- Manufacturing-related research in an international context encourages all partners to move towards designing a CPPS which, although independent of national idiosyncrasies, also reflects and models national idiosyncrasies.
- The links between dynamic technologies and industrial applications permit the efficiency of CPPS to become apparent and to be transferred over a wide area.
- CPPS will make it possible to merge the strengths of various areas of the country thereby allowing all to benefit from the synergetic effect.

Education and qualification
- The application of CPPS in the manufacturing environment functions only where there is a good balance between the integration of humans and continuous education and training.
- CPPS creates a bridge between the strategic decision-makers employed in management in any sector of business and employees working specifically in the manufacturing industry, who implement these decisions.
- CPPS offers a means of providing further training for staff who are established in the world of work and of introducing younger generations to production tasks.
- CPPS opens doors; CPPS attracts graduates from top universities who are recognized internationally and high-fliers in manufacturing industry.
- CPPS has already achieved social status. It opens the door to recruiting specialist staff.
- Reservations vis-à-vis automation are reduced.
- CPPS is becoming part of the brand in globally operating companies and strengthens their competitive position.
- The machinery and plant engineering industry will offer CPPS only when assurance has been given that it will have no adverse social impact on international sales markets.
- New CPPS business models will develop. This applies particularly to companies which are integrated in the global manufacturing network.
- In addition to manufacturing efficiency, services provided via CPPS will become a firm feature of manufacturing companies.

Corporate culture and flexibilization
- Corporate structures will become more flexible and their adaptability will increase as a result of the implementation of CPPS systems.
- CPPS permits rapid innovation cycles, particularly in technologically-oriented companies.
- Secure data processing and data protection are crucial for vertical integration and for the development of customer-supplier-manufacturer networks.

Sales and procurement markets
- The international integration of CPPS offers excellent opportunities to open up new sales markets.
- Increasing proportions of total value-added in emerging economies are driving the development of strong demand structures.
- In expanding markets, production networks will be developed which will be capable of manufacturing products of the same quality as those made in Germany.
- An established basis of production knowledge and production capacity is an excellent starting point for those with ambition to become a leading supplier of CPPS.
- Countries with highly developed knowledge societies will be the first to exploit the benefits of system networking and collaboration.
- CPPS appeals primarily to sales markets in which there is an acceptable level of broadband access to the internet.
- The demands to be met by CPPS for comprehensive and integrative deployment within the value-added sectors of engineering/production/product/service will rise sharply.
- The requirements will be particularly exacting wherever specific elements of CPPS systems are being refined alongside ongoing production processes.

Technology and safety
- System integration and the aspiration to technology leadership result in proven unique selling points. This, in turn, demands reliable and secure CPPS systems.
- Work in a cloud requires the development of systems which are securely protected from external attacks. This is a major obstacle to the broadly based setup of company and customer networks.

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2 REQUIREMENTS FOR AND IMPACTS OF ICT BASED ADVANCED MANUFACTURING WITH SPECIAL REFERENCE TO AN INDIAN CONTEXT

MANOJ KUMAR TIWARI

EXECUTIVE SUMMARY

The Micro, Small and Medium Enterprises (MSMEs) sector is the backbone of the Indian Economy and one of the prime drivers of employment as it employs approximately 101.25 million. However, the MSME sector contributes only 8.72% to the gross domestic product (GDP) of India as per the latest available records. Despite its apparent success in recent times, the Indian MSME sector is facing many challenges like a sub-optimal scale of operation, technological obsolescence, supply chain inefficiencies and International competition.

To improve the competitiveness of MSMEs, the presented report discusses several insights across a plethora of issues and concerns with respect to the Indian context. The extensive study of the data and reports available on the public domain and collection of the foresights regarding the Indian manufacturing sector from experts and executives in industry, academia and concerned regulators are the basis of this report. On application of the analytical tools to the assimilated collection of studies, this report investigates the deficits in the current state and proposes recommendations to integrate radical new technologies based on "the requirements for and impacts of ICT-based Advanced Manufacturing" to promote participation of Indian enterprises in international networks.

Increased attention has been paid to gauging the necessary abilities required to empower the Indian enterprises to deliver quality products and manufacture in accordance with global standards in the future. The integration of Information and Communication Technologies (ICT) and Cyber-Physical Systems (CPS) in Advanced Manufacturing Technologies (AMTs) has scaled up technological excellence. Increased automation in manufacturing robotics, additive manufacturing, Advanced Manufacturing systems, Big Data and advanced analytics merits a mention in the design of smart manufacturing for Industry 4.0. A description of models of technology transfer and tools to leverage data computing illustrates technology and manufacturing innovations and green manufacturing initiatives for optimization of resources utilization.

A complimentary online survey was conducted to get the opinions from executives and employees from various MSMEs throughout the country. Even feedback and case knowledge from government officials, academics experts from various walks of life have been elicited. Based on discussion and further probing into critical high growth manufacturing sectors such as the automobile and electronics sector which have reported a paradigm shift, a possible growth path was chartered for the whole range of Indian MSMEs to establish them as participants in the global manufacturing chain.

A comprehensive study of integrated efforts and initiatives by the regulators to propel the Indian manufacturing productivity is undertaken. A range of policy initiatives to weed out the shortcoming of skilled work force, infrastructural and financial constraints and to promote cooperation at both local and global level, enhance productivity and quality through standardization, and safety and sustainability concerns are critically discussed. To fortify the concerns of the prospects of the bilateral trade between both Germany and India, we deliberated on lucrative foreign investment affiliation, economic and business partnership for achieving global competency, studying the social, economic and environmental impact of participation in international networks to unleash the innovation potential, promote urbanization and enrich the human capital. An assessment of the required joint risk management strategies was undertaken to suggest necessary conducts to mitigate the vulnerabilities which accompany CPS and AMTs based systems.

Taking insights from this significant study, we conclude that ICT application in manufacturing would definitely play a paramount role in maximizing productivity and efficiency of the cooperative enterprises in the near future, if the policies and proposals are deployed efficiently and effectively. We discuss the proposition that implementation of ICT would enable the MSMEs to become internationally and globally competitive and increase their contribution towards international value creation. Moreover, the conduct of such bilateral research between Germany and India to integrate efforts from both sides and follow up with recommendations to integrate manufacturing networks of both countries is highly appreciable. Germany,

being the leader in manufacturing technology, especially in precision manufacturing, automobiles, renewable energy, and more, will open avenues of rapid growth and allow intellectual capital to flow in Indian industry, accelerating India's participation in the international value creation network. It will also accelerate the innovation potential of entrepreneurs and support the policy of government to give boost to path breaking innovations.

About the report

The report is divided into six sections. Section one presents an overview of Indian manufacturing, highlighting its importance to Indian economy and also underlining the premises for the relevance of this study. It also mentions about the key ICT enabled technologies, necessary to operate the various business functions to strengthen the Indian MSMEs. Section two describes the advanced technologies and their technicalities necessary to plan the architecture of smart factories. It encompasses a discussion about various automated machines, cloud manufacturing, its applicability in SMEs, application of Big Data for virtual manufacturing, and various other Cyber-Physical Systems, also illustrating their suitability for green manufacturing. The next section describes the present Indian manufacturing scenario; the analysis of the survey presents the current status of ICT utilization in Indian MSMEs. This section also proposes the gaps between the current scenario and enterprises with abilities to make a global impact, deliberating on various challenges and opportunities.

The government of India champions many policy initiatives and regulatory frameworks to boost Indian manufacturing MSMEs. Section 4 explains the scores of policies, schemes and initiatives, supporting the idea of strategic management through involvement of government, academia and corporates for advancing manufacturing. Section five discusses the high growth sectors of India and the relevance of international networks in propelling their growth. Section six describes the aftermaths of adoption of ICT in manufacturing and the resulting new risks and challenges. This section highlights the necessity of deployment of joint risk management and proposes recommendations for resilience in International advanced manufacturing network. It also mentions far reaching implications of adoption of ICT with regards to society, enrichment of human capital, economy, urbanization, enhancement in innovation potential and resource optimization through the best practices of energy efficient technologies.

2.1 INDIAN MANUFACTURING: SCOPE AND KEY ABILITIES

2.1.1 Introduction

The Indian union budget 2014 was recently presented on July 10, 2014. To boost the Indian economy, massive emphasis was laid on the enhancement of the Indian manufacturing sector[1]. Many significant proposals are outlined by the Government of India (GoI) to increase the productivity of the Indian Micro, Small and Medium Enterprises (MSMEs), to build effective infrastructure and propel investments[2,3] to create pro-entrepreneur sentiments, that augur well to revive the manufacturing sector. Information and Communication Technology (ICT) has proved its significance as a potential driver for advanced manufacturing across the world. Thus the timely move by the government of India[4] to commence and promote ICT adoption in Indian enterprises through its policies and international collaborations[5] is a landmark step in the right direction. The participation of experts from academia and industry also supports the government's focused approach to organize this sector for manageable targeting for its improvement. They are engaged to conduct scientific research and analysis for constructing a comprehensive roadmap to gauge the situation for implementation of ICT in Indian enterprises to make them globally competitive.

The manufacturing sector is considered to be one of the backbones of India's economy with its current annual contribution of 17% to India's GDP, comprising of approximately 53 lakhs, most of them being categorized within MSMEs[6]. They alone contribute 45% to the national manufacturing output and 40% to the total export[7]. The Indian MSMEs are dispersed across the country and are regarded as the largest job creating sector, estimated to add nearly 100 million jobs to India's economy

1 The Hindu Business Line 2014.
2 The Hindu 2014a.
3 The Hindu 2014b.
4 Annual Report 2012–13.
5 Business Standard 2014.
6 National Manufacturing Competitiveness Council 2010.
7 National manufacturing policy 2011.

by 2022[7]. Thus, these manufacturing MSMEs entail the much required government's attention owing to its contribution to the socio-economic development of the country.

In the current Indian scenario, Indian manufacturing struggles hard to gain the desired niche as its position dwindled from 2nd in 2010 to 4th in 2013[8] in the global manufacturing competitiveness index[9], where it was outdone only by China in 2010. This setback can be attributed to a lack of supporting infrastructure and improper implementation of regulatory policies, lack of skilled workers and low ICT penetration, impeding the enterprises to attain global competency. India's low threshold of ICT adoption is attested by its 121th rank out of 157[10] countries in terms of utilization of ICTs for development. In the wake of the evident global progress pertaining to the application of ICT in Advanced Manufacturing Industries, the realization of ICT adoption to strengthen Indian manufacturing is indispensable.

Adopting ICT would act as a potential multiplier for the Indian manufacturing sector, as India has several competitive advantages such as its talented demographic profile in science, technology and research, low cost skilled work force, investments in infrastructure, and comprehensive government policies like the National Manufacturing Competitive Program and others. Along these lines, this research project reports the gap in the current scenario of Indian MSMEs and the key areas abilities required to boost the manufacturing industries. In our study, the impact of ICT on technology intensive manufacturing firms and its socio-economic aspect has been undertaken. The in-depth study carried out may also support the ways to maintain international collaborations in supply chain network along with the ease of enhancing production and delivering the product at cheaper prices.

2.1.2 ICT Adoption: key areas for technology upgrading

Given the ubiquity of ICT and technological advancements in the manufacturing sector worldwide, it is high time to force the pace of Indian enterprises to acquire new technologies and support development of indigenous technologies on a par with global acquisitions. India has already witnessed deep penetration and utilization of ICT in the fast growing automotive, electronics and pharmaceutical sectors[11], possibly a cascading effect of the international collaboration and competition. The unparalleled growth of these sectors has been transferred in tier 1 and tier 2 enterprises agreeing to the vendor interface of large industries and OEMs, through cohesive ICT utilization. Adherence to ICT is beneficial in reducing the lead time in manufacturing and also in sharing the information and data across the world at nominal cost. This gives access for local enterprises to link with the global supply chain, and to practice e-commerce and e-marketing strategies through an ICT enabled comprehensive information management system. The key characteristics and advantages of ICT adoption in various business processes of the manufacturing enterprises are discussed below.

2.1.2.1 Core business processes:

a. **Production Logistics:** The adoption of ICT for management of inventory, production sequence planning and order processing through established data communication technologies have expedited the process on the shop-floor with introduction of the right product in the right time. It eventually decreases the lean time of the production. The RFID technology is used for inventory tracking and fulfills its promise of optimal price by reducing the inventory, whereas on the other hand the tracking of orders helps in planning the sequence of production.

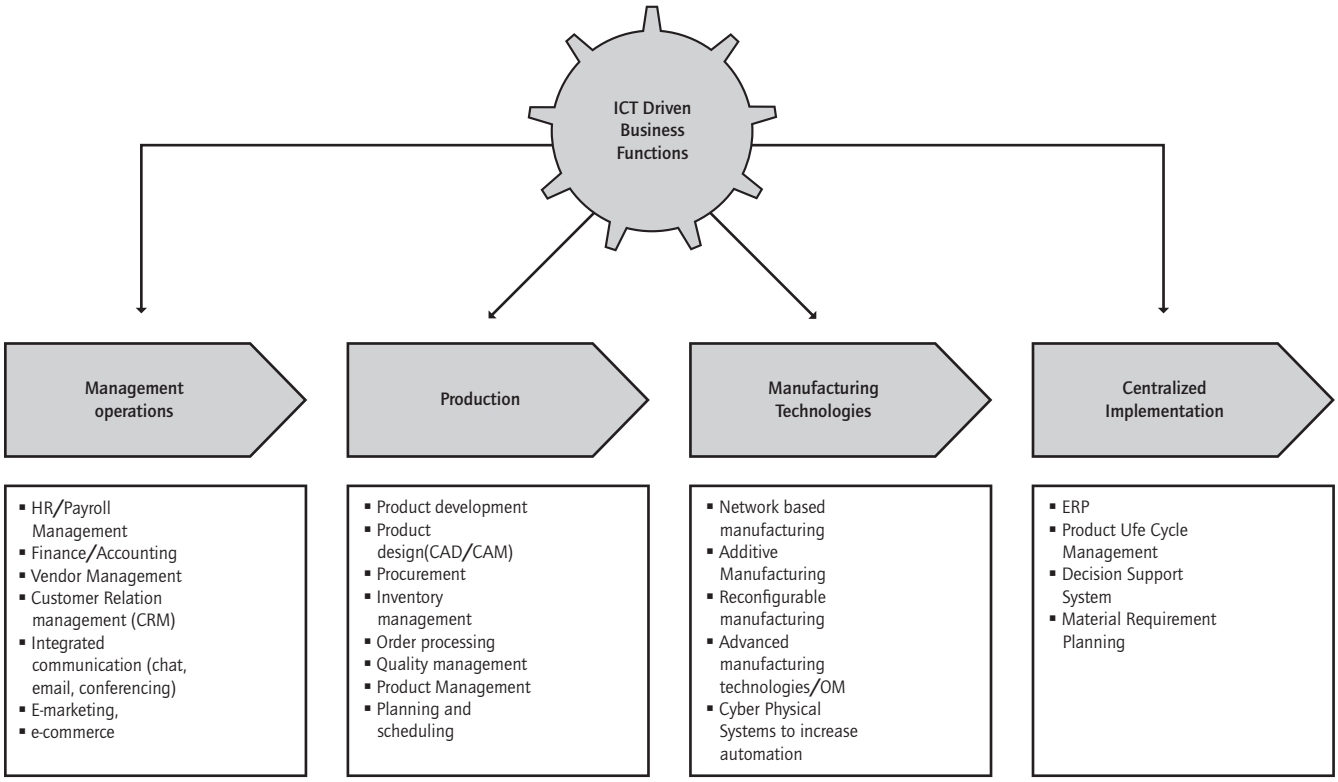
b. **Product development:** The manufacturing MSMEs could avail advantage of the ample resources available by practicing ICT tools. The local enterprises could build customized products, CAD/CAE models whose extensive libraries are available online and save time and resources on product conceptualization and designing stages. The remanufacturing process of the obsolete products could be easily conceptualized and planned using the available software and rapid prototyping technology.

c. **Manufacturing processes and flexibilities:** The range of state-of-art manufacturing technologies available could boost the core manufacturing process by reducing the processing time and enhancing the product quality. Some advanced technologies pertinent to manufacturing industry that will determine their competitiveness are:

   Network based manufacturing[12]: Being a simulation based task, this technology uses ample codes which could be made accessible easily through data sharing on the internet.

8 Deloitte 2013.
9 FICCI 2010.
10 The Hindu 2014c.
11 National manufacturing policy 2011.
12 Paquet et al. 2008.

Figure 1: Function-wise ICT applications



Network based manufacturing uses cloud computing[13] for optimizing the supply and manufacturing process. Cloud assists in operational flexibility, shares resources, and realizes virtual processing services.

Advanced manufacturing technologies[14,15]: The following technologies are crucial to the future of the manufacturing industry: Additive manufacturing, also called 3D printing, is a technology for mass production especially for the pharmaceutical and electronics industry. Virtual manufacturing for new product development, future of electronics, solar cell manufacturers, and bioinformatics could rely heavily on nano-manufacturing, while robotics in industry and automation through computer integrated manufacturing is refurbishing the manufacturing processes. Sensors and actuators, machine learning, cloud based support systems enable manufacturers to adopt the theme of intelligent manufacturing.

Advanced forming and joining technologies[14,15]: The mechanical manufacturing industry has accelerated due to the introduction of various advanced machining, joining, casting, and forging technologies. For instance, laser welding has replaced other welding techniques in ship building and aerospace industry; cold forming will be crucial for repairing and remanufacturing of products.

Reconfigurable manufacturing and product platforming: With often changing product demand, the deployment of modular manufacturing systems would provide a cost effective solution to the problem of process different products within a product family.

d. **Quality management:** Technological penetration to implement quality management strategies will provide companies with substantial resources and global competency to meet the customers demand for quality. Deployment of ICT

13 Peng Fei Wang et al. 2012.
14 Koten 2013b.
15 Koten 2013a.

enabled Quality Technology Tools (QTT) such as six-sigma, Total Quality Management, Total Productive Maintenance, Kaizen tools, 5S would enhance the performance of these companies in terms of productivity and adoption of Quality Management Standards like ISO 9000/18000/22000, etc. and would essentially boost their market value and customer relations. The inclusion of the computer aided tools for sampling, precision designing and manufacturing from the initialization phase of the product development onwards would be cost effective, decrease product lead time and add to product quality.

e. **Customer Relationship Management:** The industry has shifted from its traditional manufacturer driven market to a customer dictated market. Hence, today serving the customer is of utmost priority. The task of taking online customer feedback, providing after-sales-service, and applying innovative practices to leverage the competition information through customer data build strategies and synchronize all functions of the business is a crucial factor for the success of MSMEs.

f. **Enterprise resource planning:** The growth of a business is highly dependent on the firm's ability to consolidate the different functions of manufacturing planning and control activities through data sharing. The ERP software such as BaaN, SAP, IFS are real-time knowledge repositories which optimizes the resource utilization by concurrently interconnecting all the core and non-core business processes.

The above mentioned business functions and key technology abilities required by them are illustrated in fig. 1.

2.1.2.2 Non-core business processes

The non-core business includes functions which do not directly control the product manufacturing processes such as logistics, finance, *HR*, among others. ICT in logistics provides for sharing of information at a faster rate with the vendor and other entities, thus helping the complete supply chain to catch up with the global standards. ICT enabled accounting, marketing and management of the human resources optimizes the overall cash allocation and resource utilization across the enterprise. ICT might also be used to track the energy utilization of the firm for energy optimization.

2.2 VISION FOR TECHNOLOGY – TRENDS IN THE FACTORY OF THE FUTURE

2.2.1 Architecture design for implementation of AMT

The integration of AMT requires a visionary roadmap for international value creation. Indian enterprises exhibit the readiness to integrate these systems as they can provide Indian MSMEs with the capability to produce a wide range of cost effective and quality products. ICTs can be leveraged to enhance the manufacturing ability, production process, operations management and product life management. Essentially, the functions and modern ICT enabled technologies described in section 1.2 are the major amenities for the factory of the future. Here, we present a comprehensive illustration of the technologies of the future and their implementation protocols.

The internet revolution and later progressions such as automation and Cloud Computing have opened several opportunities to develop the next generation manufacturing systems. A whole gamut of productivity enhancing systems such as concurrent manufacturing (CM), Agile Manufacturing (AM), Computer Integrated Manufacturing (CIM), networked manufacturing (NM), application service provider (ASP), and manufacturing grid (MGrid) are viable solutions to create value products to be competitive in an international market.

These modern technologies are investment intensive; hence, a thorough risk assessment needs to be carried out to put the optimum strategic mix of significant technologies and their deployment techniques in place, concomitant with the development in the manufacturing chain. As most Indian SMEs are tier 1 and tier 2 suppliers to OEMS and larger industries, they are prominently engaged in transforming raw material into finished manufactured goods. In relation to MSMEs, some specific AMTs include advanced processing technologies like cold forming, forging, (computer numerical control) CNC lathe and milling, water jet cutting, laser welding, injection molding, vacuum forming, laser cutting and other non-conventional machining. These modern automated precision tools on integration with computer network will create a 'virtual enterprise' (VE). This would be an encouraging interface to instantaneously communicate with the distributed manufacturing resources such as designers for availing data and codes, representing and exchanging information about the processed product throughout its life cycle by utilizing a uniform electronic standard.[16]

[16] Association of Indian Forging Industry.

Thus, the Indian enterprises would be enabled to acquire vast amounts of data to enter the global manufacturing supply chain with highly efficient, cost effective and flexible manufacturing processes. These processes meet the demand of customers for high quality products in significantly compressed lead time, enabling the Indian MSMEs to create value through minimizing the scrap rate and optimizing the resources and energy utilization. The analytic reductions of the market data would drive the new sales and distribution mechanism.

Unlike the majority of SMEs, the commercial activities of a few medium enterprises are driven by some critical high growth manufacturing sectors such as the automobile industry, aerospace, electronics and pharmaceutical industries. Taking in account the automotive sector, there is a deluge of world automotive giants establishing their manufacturing units to bring new brands and their variants and outsource automotive components from India due to its distinct cost advantage. These include some big names such as Daimler, Ford, General Motors, to mention only a few. As the automotive sector involves huge investment and requires deployment of the highly advance manufacturing technologies, the competitiveness of the Indian SMEs has increased, refurbishing the whole manufacturing chain.

In the machine tool industry segment[17], India stands 13th in production and 6th in consumption[18] in the world. Apart from around 20 large industries, which account for 70% of production, most of the industry is categorized within the SME sector. Taking in account the statistics of increasing adoption of CNC in comparison to conventional tools, this sector has registered a substantial growth in export by 19% in 2012–13. Through statistical deductions, we also infer that there is discord between demand and supply as productivity for the same year decreased by 10%. The current gap in this industry needs technological intervention to speed up the production as the machine tool sector serves as the mother industry for automobiles, consumer durables, etc. Thus, this sector needs to break the glass ceiling and build capacity to cater to the demand through profit maximization by value stream mapping and incubating skill development for innovative technologies.

Some emerging technology trends[17] in this sector include high speed and dry machining to reduce machining time and to eliminate coolants, the integration of machining processes to finish the work in one setup, micro-processing for the generation of miniaturized components, and rapid prototyping aids to realize and test the new product prior to production. Other innovative technologies include laser systems for high process dynamics and added features, also for innovative welding solutions; CNC capable of increased accuracy, geometric compensation, thermal effect compensation, remote diagnosis, automatic and downloadable programs at the machine and automatic die change features which improve operations. To increase the capability of the traditional machines, they are replaced by hydraulic systems for generating complex geometries from a single work piece, improved components such as linear direct drives, electric drives, variable spindle speeds; enhanced machine capability comprising of 5-axis milling and turning, greater tool storage, incorporation for live tool station on turning centers for allowing multiple operation in a single setup. Some machines illustrating their acceptance in enterprises include near net shape forming and metal forming machines for dieless forming, hydro forming, hybrid bending, axis tube bending, other machineries include high speed presses, wire EDM machining, water jet machining, etc.

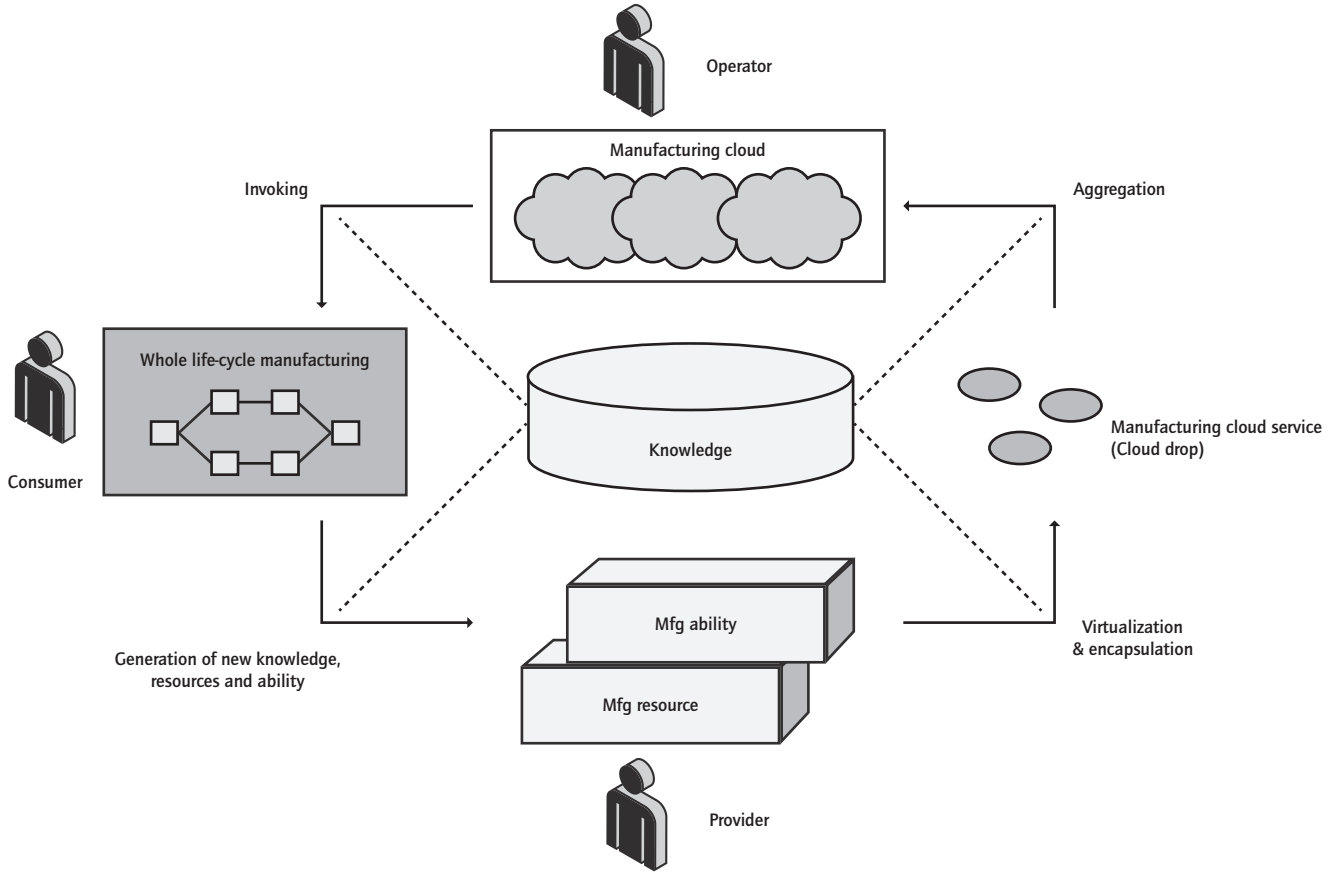
There are many manufacturing abilities used on the factory floor such as computer numerical control (CNC), direct numerical control (DNC), automated guided vehicles (AGV), robotics, Flexible Manufacturing Systems (FMS), automated material handling systems (AMHS), automated storage and retrieval systems (AS/RS), rapid prototyping, etc. The increased automation has penetrated throughout the manufacturing life cycle with Computer Aided Design (CAD) and other design software used during the product development stage to the Manufacturing Resource Planning (MRP), Statistical Process Control (SPC), Bar Coding (BC), and RFID expediting production operations.

Analogously, large manufacturing setups by global players such as Ranbaxy, Dr Reddy laboratory in pharmaceutical industries; Philips, GE, ABB, Siemens, Samsung, Du Pont in electronics; Boeing, Dynamic Limited in aerospace have compelled the enterprises to acquire the latest technologies to compete in the global manufacturing supply chain.

The trend to adopt basic automated traditional machining systems has gained pace in the current Indian manufacturing landscape. Due to analyzing and gauging the advancement in technologies and organization of the manufacturing sector around the world, it has become imperative to introduce high

[17] Technology Paper Series 2005.
[18] Indian Machine Tool Manufacturers' Association 2014.

Figure 2.1: Abstract running principle for cloud manufacturing systems[19]



end ICTs and AMTs in India. The enhanced computational power with increased automation will determine the manufacturing capabilities in the factory of the future, the brainchild of Industry 4.0. The data driven manufacturing, Big Data Analytics, and Internet of Things (IoT) and knowledge management systems (KMS) will focus on extracting valuable knowledge and insights to augment the production efficiency.

2.2.2 Cloud manufacturing as a solution

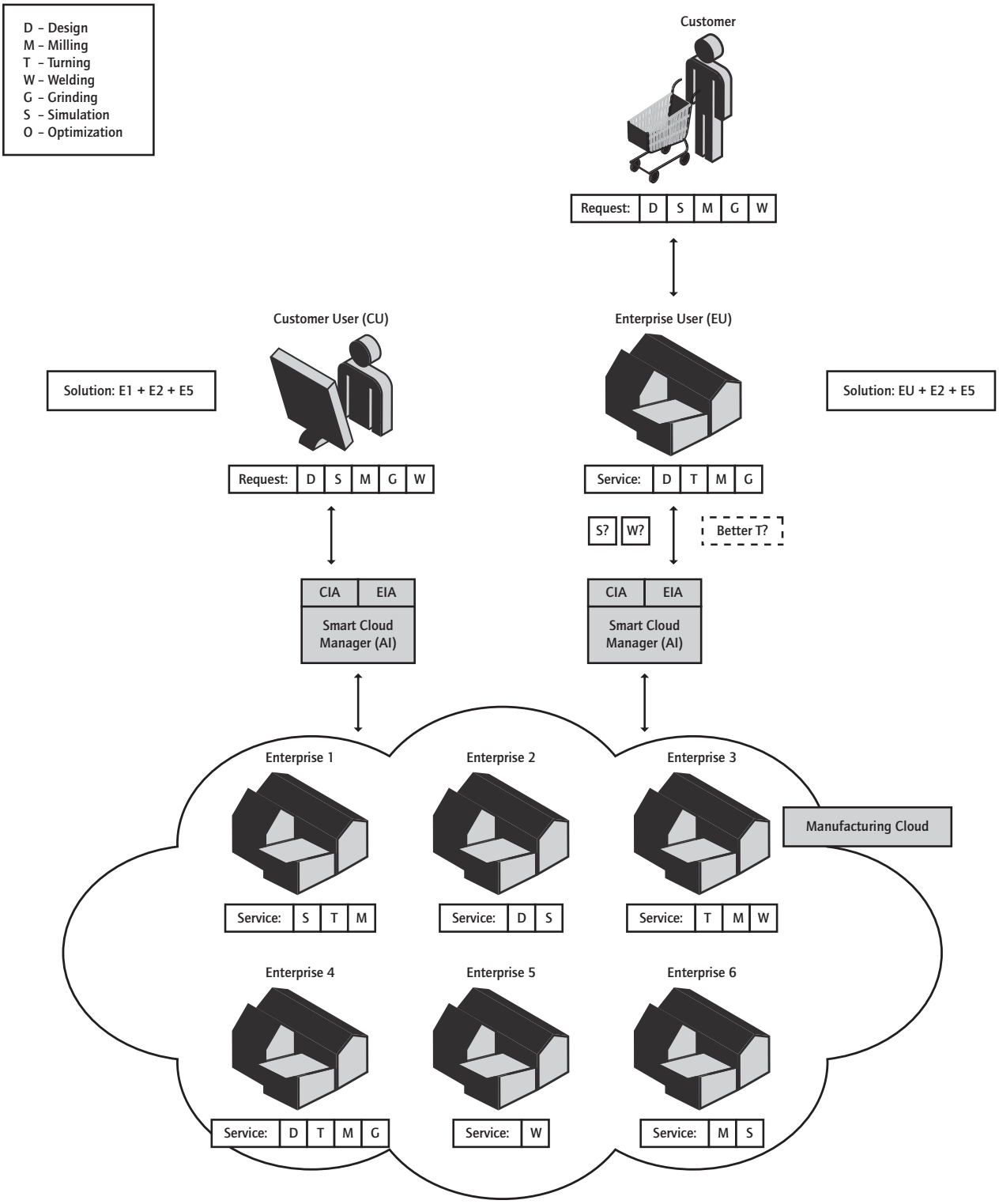
Cloud manufacturing (CMfg) is now emerging as a network based computing and service platform to enhance the different aspects of advanced manufacturing approaches and to facilitate the formation of responsive manufacturing networks. Integrated with information technology (IT) and Internet of Things (IoT), CMfg is ready to take existing manufacturing technologies such as Agile Manufacturing (AM), Network Manufacturing (NM), Lean Manufacturing to the next level by incorporating real time data, information and knowledge. A possible architecture for CMfg provided by[19] is shown in fig. 2. In this architecture, various geographically distributed manufacturing resources, platforms and abilities are connected, thus forming the provider. The operator is responsible for delivering functions and services to customers. Finally consumers are also integrated in the system to avail services provided by the CMfg platform.

2.2.2.1 Cloud manufacturing service platform for the SMEs

CMfg service platform for SMEs is a new networked manufacturing (NM) service platform. It is based on NM and ASP service platforms, combining the service mode of CMfg and the characteristics of SMEs, applying the technologies of Cloud Computing, cloud security and IoT. It can contribute to sharing and coordinating of network-based manufacturing resources of SMEs. Compared with the existing ASP and NM platforms, the CMfg service platform used by SMEs has properties such

[19] Huang et al. 2013.

Figure 2.2: Customer user and enterprise user[20]



[20] Vincent Wang/Xu 2013.

as wide separation and multi-dimension of resource, depth of manufacturing service, reliability of service transaction, convenience of the resource application and marketability of platform operation and maintenance. It can provide full-scale, reliable, on-demand, high quality and low-price manufacturing service.

2.2.2.2 Integrating product life-cycle-management with cloud manufacturing

The product life cycle is an important aspect in the entire manufacturing activity. The customers have their specific demand with different specific attributes that are to be met by the product. At the user cloud layer (as described in [20]), the CMfg has two sets of users: customer users (CU) and enterprise users (EU) (fig. 2.2). The functionality of CMfg can be extended from traditional manufacturing tasks to customer specific manufacturing through collaboration of multiple organizations. CUs are connected by the Consumer-to-Cloud platform and enterprises are connected by the Business-to-Cloud platform. A CU initiates the task by providing manufacturing requirements through the Customer Interface Agent (CIA); the manufacturing request of a CU is transferred to CMfg for analysis of requirement and potential enterprise identification, thus forming a Request-Provide service chain. Another benefit of this system is that an available manufacturing capability will be known to the users as feedback after meeting its own requirements.

Efforts to make the system autonomous will be realized by embedding many algorithms to take decisions, help in adhering to the protocols and carry out many service application tasks.

2.2.2.3 Empowering virtual enterprises with an agent-based Infrastructure to share and communicate knowledge, information and data

Small and medium sized enterprises (SME) in the manufacturing sector are increasingly forming coalitions in the form of Virtual Enterprises (VE) on an ad-hoc basis, with the aim of sharing knowledge, competencies and resources to achieve a common goal of satisfying encountered business opportunities. The increased configurability and responsiveness to business opportunities under tight constraints is one of the main advantages of such an association.

Companies in a VE identify business interests of mutual benefit and share them with appropriate partners in the network through information systems. Therefore, it is pertinent to have an effective paradigm to manage the relevant information electronically for collaborative engineering, production and logistics. A robust IT infrastructure and appropriate decision support tools/mechanisms as in fig. 2.3, thus become a key element to support effective VE integration.

A VE coordinator locates its potential manufacturing agents that can meet its specific business and/or technical goals by using the Discovery Service support and accessing the UDDI registry. Upon identification of a potential partner and obtaining all the necessary information of the agent, the VE coordinator sends a Simple Object Access Protocol (SOAP) message regarding a task request to the agent as in fig. 2.4.

A VE coordinator gathers the bidding information from agents interested in forming the collaboration for further evaluation and the selection of the best candidate. The VE Coordinator then notifies the selected manufacturing agent to start the contracting process.

2.2.2.4 Standardization of SME protocols

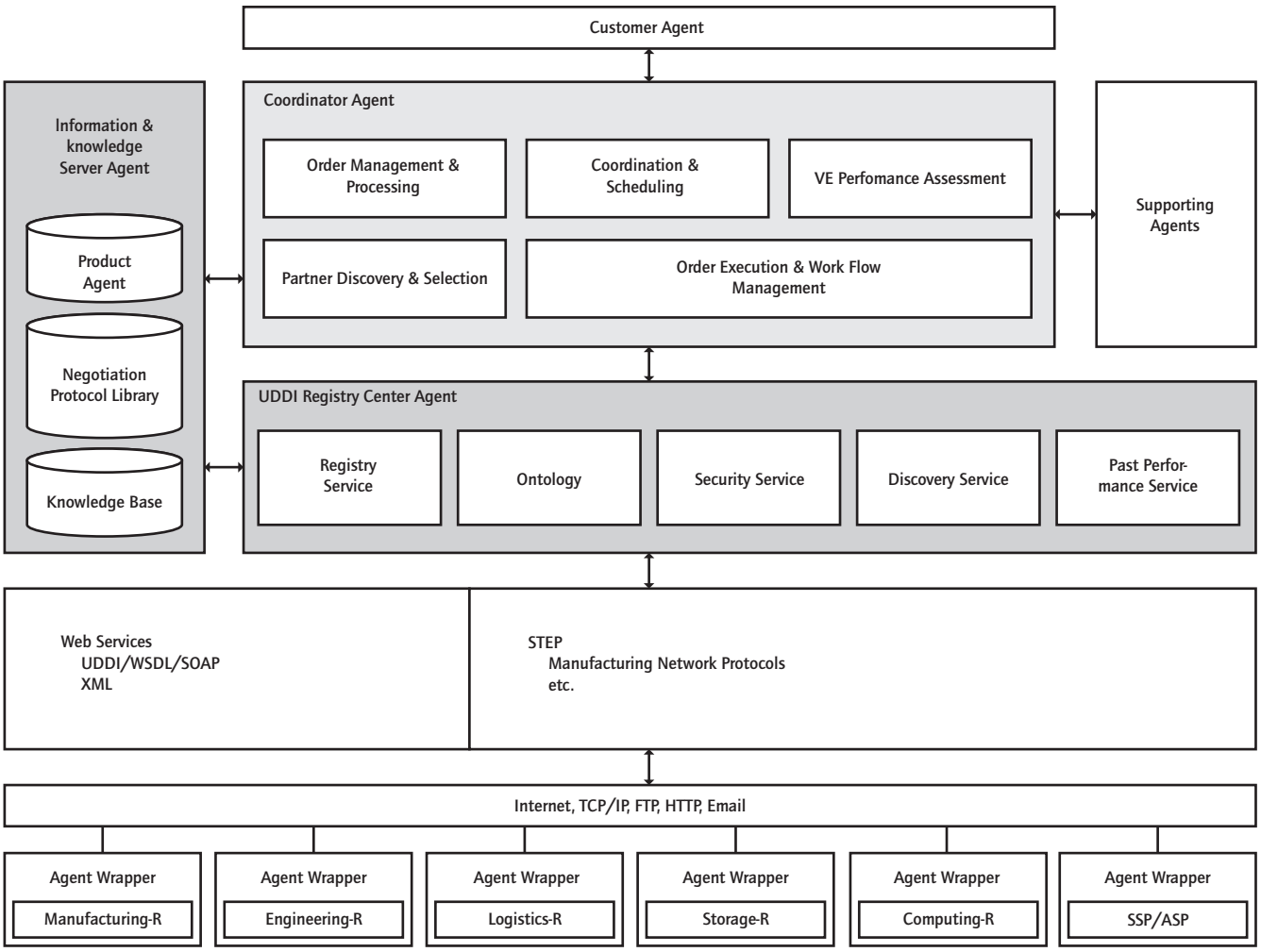
One of key roles of VM is to shorten the product development process. Thus it is imperative that the product design information such as the VM simulation model is properly disseminated with up-to-date data among the design team. Therefore, it is essential for enterprises to develop a collaborative information sharing environment.

Ironically, presently the role of IT in SMEs is limited to information searching, e-mailing and posting of company websites instead of improving the competitiveness. In addition to that, most of the manufacturing software programs are not based on the browser/server architecture, which would make it possible to overcome the financial burden on enterprises, especially SMEs.

A Collaborative Information Sharing Platform (CISP) can be used for efficiently integrating various manufacturing activities including manufacturing software license sharing. This platform will facilitate visual engineering, which refers to the visualization of geometrical models of concept design on computers and will expedite the product realization and development stage.

One of the main aspects of a virtual organization is to elucidate how its members interact with each other to fulfill a larger corporate goal. In the absence of a central control, this interaction can take place according to a protocol that is followed by each member. The choice of a protocol crucially affects the

Figure 2.3: An agent-based infrastructure for VEs using Web Services standards[21]



UDDI: Universal description, discovery and integration
SOAP: Simple object access protocol
WSDL: Web service definition language
XML: Extensible markup language
STEP: Satellite telecommunication experiment project
ASP: Application service provider
SSP: Service switching point

performance of the whole organization and its abilities to satisfy its goals. There are many possible decisions one can make to construct such protocols, with important consequences on the behavior of the whole organization.

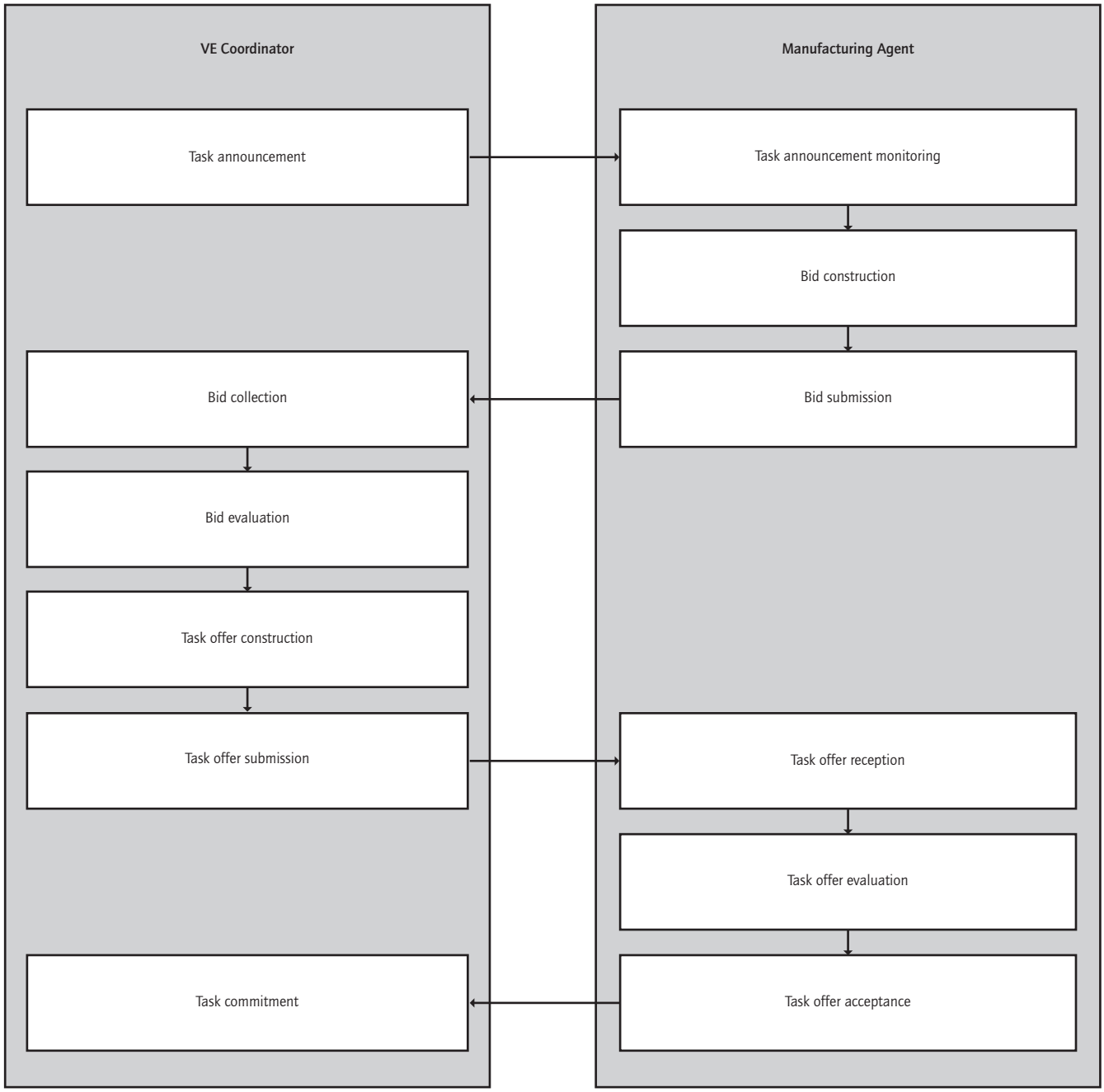
In the next section, we explore aspects of Big Data that may be integrated into the existing VE framework, to help facilitate knowledge sharing in SMEs. This is especially relevant due to emerging technologies like Cloud Computing and Internet of Things (IoT).

2.2.2.5 Application of big data in virtual manufacturing

The manufacturing sector is rapidly progressing to its next evolutionary stage of predictive manufacturing[22]. Emerging

[21] Fung et al. 2008.
[22] Lee et al. 2013.

Figure 2.4: Bidding process between VE Coordinator and its Manufacturing Agent[23]



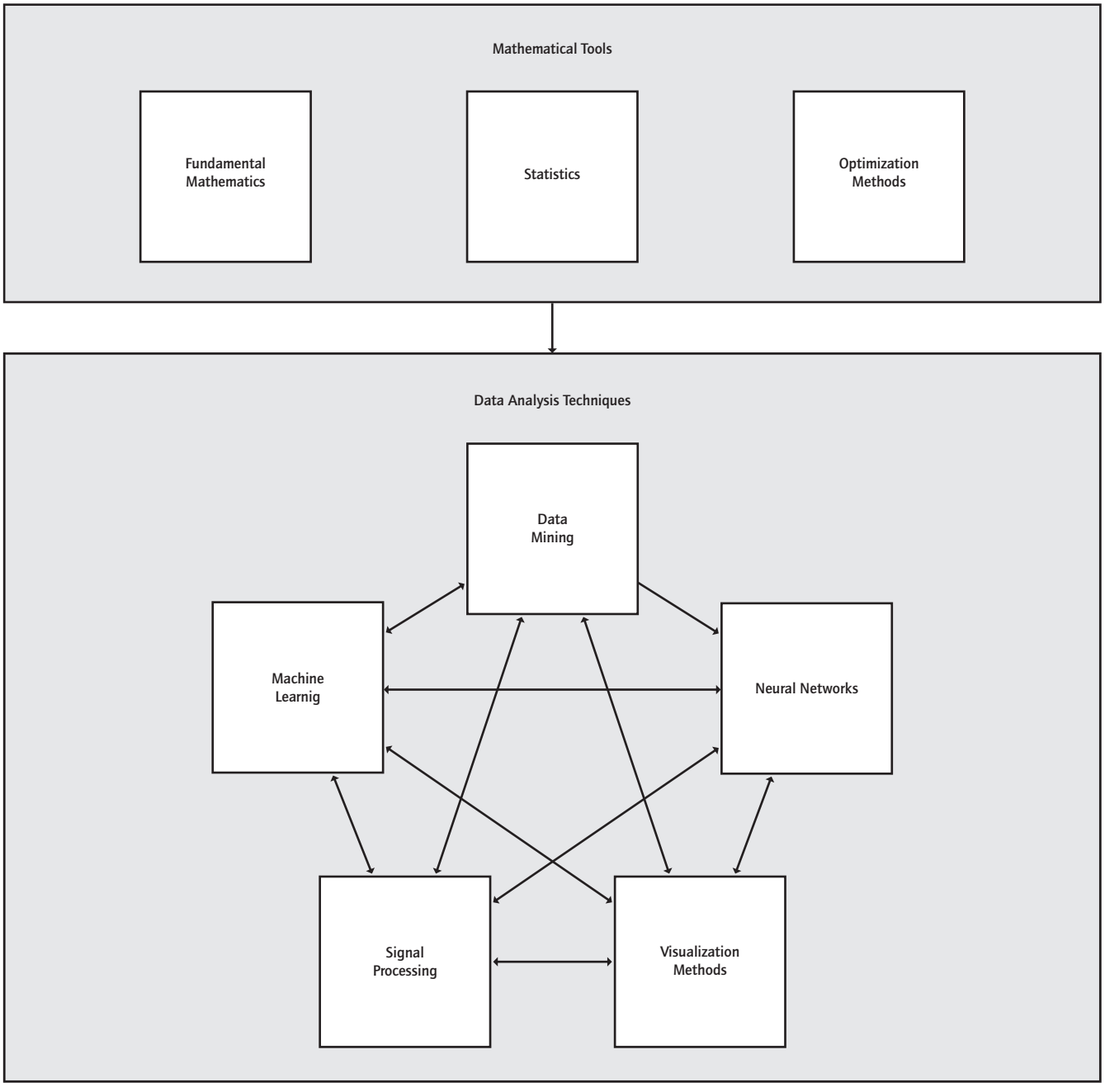
technologies, namely advanced analytics and Cyber-Physical System-based approaches, are being adopted by manufacturers due to their contribution to efficiency and productivity. With the advent of IoT, i.e., the Internet of Things, manufacturing data has become an ever present and exponentially growing entity. This calls for appropriate methods and tools to convert data into valuable information, which can be used in decision making.

Manufacturing generates and stores a behemoth amount of data - close to 2 Exabyte of new data stored in 2010. This figure

[23] Fung et al. 2008.

is the highest among all sectors. The prime sources of data generation are supply chain management systems, instrumented production machinery (process control), and performance monitoring systems (e.g., during a single cross-country flight, a Boeing 737 generates 240 terabytes of data). Manufacturers are also on the verge of consolidating data from different systems including computer-aided manufacturing, computer-aided engineering, computer-aided design, collaborative product development management and digital manufacturing and also across different tiers of the organization, as in the case

Figure 2.5: Big Data Techniques[24]



[24] Philip Chen/Zhang 2014.

of end-to-end supply chain data. Given this massive amount of data at one's disposal, it is vital that we use it effectively to enhance productivity and growth in the long run. It is important that manufacturers utilize these large data-sets to design and market higher-quality products and to drive efficiency across the extended enterprise.

In order to sustain productivity growth, it is imperative that manufacturers respond to the challenges put forth by global and fragmented manufacturing value chains. Globalization and technological growth have allowed countries to specialize in specific stages of the production process. This has led to the creation of a large number of specialized suppliers, with competencies in cost and quality in the specific components they supply to advanced manufacturers.

Some of the applications of Big Data in manufacturing are illustrated:

a. **Preventive maintenance and repairs:** These days most engineering devices are embedded with sensors and RFID that can actively transmit vital information about machines like:

   i. Machine variables (temperature, oil level, humidity...)
   ii. Production rate
   iii. Waste metrics
   iv. Life expectancy
   v. Breakdown information

   Production downtime is a potential loss of revenue for companies. This can be due to loss of production output, cost of repairs or waste generated in the process. All the machine logs can be used by companies to proactively plan a potential downtime using real-time information. They help in preventing waste, avoiding major repairs and minimizing downtime.

b. **Vehicle engineering:** Based on real-time streams of data feeds from RFID and active wireless sensor networks, vehicle engineering can significantly be improved; thus making cars safer, more efficient and cost effective.

c. **Auto-repairs:** Vehicle sensors will actively transmit relevant information from vehicles to nearby authorized dealers who will provide repair and maintenance services for your business. For large fleet companies, this will allow for proactive repair and maintenance of the vehicles. Analytics showing potential downtime, availability of parts at repair shops, probability of failure before next maintenance, and loss of business assist this process. The decision to send the vehicle to a repair shop will be automated, i.e., guided by systems, unless overridden by humans.

d. **Productivity improvement:** Real productivity can be measured and improved by applying pattern matching from Big Data Analytics.

e. **Downtown reduction:** An insight into the recovery and elimination of the reasons as to why the system is in downtime can be drawn from Big Data Analytics.

f. **Parts traceability:** Track of complex flow of parts across the manufacturing facility can be kept by using Big Data Analytics. Historical traceability records can also be built.

g. **Energy efficiency:** Efficiency of the manufacturing processes which are energy-intensive in nature can be measured and improved by Big Data Analytics.

Big Data tools and techniques

Big Data can be captured, curated, analysed, and visualised by implementing a wide variety of techniques and technologies which are inter-disciplinary (include computer science, economics, mathematics, and statistics) and overlap with one another (Fig. 2.5).

2.2.3 Cyber physical systems for clean production

The intelligent assembly of smart networked systems such as embedded sensors, actuators and processors, designed to sense and interact with the physical world, is termed Cyber-Physical Systems (CPS)[25]. These systems are designed for efficient computing, networking, controlling and sensing as illustrated in preceding sections. In the manufacturing sector, it empowers the whole system with the power of advanced computing, analytics, low-cost sensing and new levels of connectivity permitted by the internet, called the Industrial Internet. Thus, CPS systems are important for providing the technical strength for optimum management of resources, automating tasks and incorporating interoperability across discrete physical systems.

The new molecular scale processes[25] integrating information processing capabilities require sensing and smart measurement

[25] Cyber Physical Systems 2014.

technologies, advanced robotics and other intelligent production systems. Their efficient utilization in real time inspection, monitoring of product quality and process control has dynamically ramped up production, optimizing resources requirement and energy efficiencies. Advanced systems such as single setup and tool-less manufacturing, product platforming and flexible manufacturing increase the productivity and utilize fewer resources than the distributed systems. The production planning, simple tools and operations and proper layout promote the use of clean energy technologies given to efficient consumption, thus meeting challenges of high volume manufacturing and process control at reduced expenses.

2.3 ENHANCING THE INDIAN MANUFACTURING MSMES

2.3.1 Indian MSMEs: current state, key challenges and opportunities

To gauge the current scenario of technology implementation and readiness to adopt ICT enabled technologies, we conducted a survey whose analysis is presented in this section. Based on the analytical deductions, we deliberated on the barriers in the present scenario and the growth drivers and opportunities necessary to achieve the niche position in the context of Indian manufacturing.

2.3.1.1 Survey analysis: capturing the current landscape

In order to accurately describe the basic reality and to obtain authentic information we have created an online survey targeting experts and executives of MSMEs. Several telephone interviews were also conducted with executives from the automobile and electronics firms who provided valuable insights into the situation and also aided in creating the online survey. At the request of the executives who have participated in the telephone interview, the name of the firms are omitted to preserve anonymity, given the confidential nature of the data. The online survey conducted received 50 responses from executives of different firms at various levels. A summary of findings is given in the following paragraphs, while the detailed results are presented in appendix 1. Of the firms surveyed, sole proprietorship firms formed the bulk of the responses with joint ownership firms coming at a distant second. The educational qualification of the workforce was on very low with 96% of the employees having done high school or diploma certification.

The survey also highlighted that business in most of these firms (approximately 78%) is still conducted by communicating through telephones and by one to one interactions. Though there is a steady shift towards web based technologies, they are used only by a small fraction of firms and their complete potential remains untapped.

It was found from the survey that basic ICT infrastructure was in place at a majority of firms, while there was also a high number of firms with no established ICT infrastructure. This could be attributed to the affordability of mobile communication technologies which has acted as a catalyst in increasing the implementation of basic ICT infrastructure. Since most of the micro enterprises are located in rural areas, many of them still have to install basic ICT infrastructure.

Order processing and CRM related activities formed the majority of applications when ICTs were implemented. The main mode of implementation was through e-mail. Very few Micro and Small Scale Industries employed CAD while a vast majority still relied on paper based drawings. This could mainly be due to the lack of training and skills in handling CAD/CAM/PLM software and ignorance towards the benefits of using ICTs.

Although ICTs were used for costing and accounting, they were hardly used for quality control and failure analysis. Of those who have some kind of ICT infrastructure implemented (68% of the respondents), data from these sources were hardly considered while taking decisions. The skills of employees with respect to these technologies were very low, indicating a strong need for their skill upgrading.

A majority of the firms (63.5%) used electricity as a means of power and they did not openly advocate green energy sources. They also did not intend to trade carbon credits and were largely unaware of their benefits. The innovative spirit was missing in this sector as only 2.3% had filed some sort of patents; the rest of the firms seems more oriented towards job processing and manufacturing of known products using conventional manufacturing systems rather than bringing innovation.

It was also clear from the survey that the information and communication technologies presently being used by the micro-small scale firms are still primitive and are mainly dependent on a personal computer with an internet connection. Thus these firms have very little collaborative manufacturing capabilities.

2.3.2 Challenges and opportunities

India enjoys favorable conditions like flexibility, owner management, inexpensive labor, and less overhead and favored capital – output ratio[26]. Despite the competitive advantages, the low productivity level and limited ICT penetration in most of the Indian enterprises can be attributed to the limited availability of capital for business operations, high cost of modern technologies, dearth of skilled man power, infrastructural constraints, lack of awareness, and a low level of industrialization.

The current shortcomings of the Indian manufacturing sector could be weeded out through committed regulatory and executive efforts to exploit the range of competitive advantages hosted by India. Indian MSMEs sport a huge potential for value creation in international manufacturing networks. There is a gamut of opportunities presented by the Indian MSMEs which can be unleashed by integrating them with the manufacturing networks – locally and globally.

2.3.2.1 Flexible cooperation and clustering

MSMEs in India are heterogeneous and dispersed throughout India in small pockets/clusters[27]. This heterogeneity allows for a variety of products, services and levels of technology but also restricts large scale production economies[28]. The inherent strength of the MSMEs in India is that these enterprises can be set up with very small investments and have the locational flexibility to be established anywhere in the country. These characteristics can be tapped by setting up industrial clusters. The landscape of MSME has evolved from manufacturing of traditional products to hybrid products, a change that has been fuelled by the advent of industrial clusters. Bringing the rural and remote industrial clusters within the coverage of integrated networks can potentially help to reduce the technological obsolescence in MSMEs and add value to the network by manufacturing products at lower costs. This could further open the opportunity for collaboration amongst the MSMEs and their international partners[28].

MSMEs can easily adopt new innovations and methods because their cost of changing the existing system is relatively small. The possibility of owner management in Indian MSMEs allows for quick decision making while reducing red-tapism will lead to increased flexibility and adaptability of the MSMEs. Flexibility will be enhanced by the increased ability of the MSMEs to adapt to new technologies and collaborate with their partners on integration, cost and resource sharing. Collaboration or clustering of enterprises is earnestly being addressed through a government's proposal[29] for establishing National Investment and Manufacturing (NIMs) zones.

2.3.2.2 Quality enhancement

The Indian manufacturing sector needs to keep the cost of production low while achieving consistent standards of quality and safety to be competitive. This could be achieved through integrated advanced manufacturing networks. As the maturing Indian consumer base demands globally competitive products, MSMEs need to bolster growth and attain the competitive edge for profit sharing in the open market economy by adopting global standards and practices in terms of technology, quality, marketing and pricing.

With an exception of a few enterprises, most MSMEs use non-standard tools and methods, often local tools for production purposes which affect the quality standards of the manufactured products. The underdeveloped methods for quality assurance and deprived management impede the enterprises from participation in global value creation. The absence from the global supply chain and reluctance to acquire standardization or certifications must be called into question. These gaps can be diminished by rewarding and recognizing small units, motivating, incentivizing and supporting them to pursue the desirable competitive edge and access to global markets.

2.3.2.3 Skill training

India has the opportunity to tap the potential of its abundant human capital. Along with that, India hosts one of the biggest and fastest growing software industries. The skill level and efficiency to operate manufacturing operations and ICT enabled functions are usually high. The work force usually available is not trained to handle CAD/CAM, CAE software, design automation and Cloud Computing. Due to this factor, very few MSMEs use ICT to their advantage. However, India's MSMEs sector has a high inertia for adopting ICT. The basic reason observed is a lack of information on advantages of ICT in manufacturing and lack of realization of its prolonged impact. Another major reason is a lack of skill on the part of the employees to understand the applications and a bias

[26] MSME – Ministry of Micro, Small & Medium Enterprises 2012.
[27] IBEF 2013.
[28] Approach to 12th Plan.
[29] National manufacturing policy 2011.

towards traditional methods of manufacturing. The national policies must also aim to establish institutes of national importance employing consultants and trainers of international competence to provide certification, training and consultancy.

2.3.2.4 Research and development

MSMEs in particular need research and development for the introduction of new products and practices. Innovation as a key business strategy has also been proposed by the Government of India[30]. India has a large student base and recognized schools like the Indian Institute of Technology (IITs) and the National Institute of Technology (NITs) in almost all states. Involving students in research and development can facilitate the development of new technologies at lower costs. The Indian government has initiated different schemes for involving students in research and development[31]. Apart from that, schemes have also been started for individuals to participate in innovation[32]. Indian students have performed exceptionally well in foreign universities with good research infrastructure. However, due to lack of opportunities and infrastructure in Indian industries, India lags behind in claiming its innovation potential and is unable to attract a high level of talents in research and development in the manufacturing sector. The introduction of ICT would promote research and development activities within the institutes and new technological advancements in MSMEs.

2.3.2.5 Miscellaneous factors

The infrastructure in India is poor, however, the major objective in the 12th plan[33] is to augment the capacity of various modes of transport and set up high level infrastructure[34] On the other hand, the Indian MSME sector is highly unorganized[35]. This unorganized sector has us face the task of converting it into an organized structure and integrating it with the manufacturing networks in a most efficient and innovative manner by making use of labor resources in India to unleash the opportunity for low cost manufacturing.

Despite the various regulatory schemes proposed to favor manufacturing industries, top managers lack the knowledge and the will to elicit benefits for their organization and to build capacity in terms of manpower, technology and infrastructure. The indiscipline shown at the customer's end to provide feedback and maintain relations also inhibits the functioning of specific CRM units; only 10–20%[36] of enterprises in India have a CRM function. Whereas the ERP is used widely in around 60–70%[36] firms in India but the compartmentalized mindset has militated against reaping its necessary benefits.

Although faced with several challenges, India has all the necessary resources from manpower to being an IT hub, to promote efficiently adoption of ICT in MSMEs. There have been ideas and policies proposed by the Government of India (GoI), also the increased promotion to take up entrepreneurship has accelerated the exploitation of ICT. With an expansive range of web based resources and information management systems, the enhancement in awareness and skill level to leverage them for business advantages is very critical. A task force was constituted in 2009 by the prime minister of India to overhaul the stagnant manufacturing scenario in India. They proposed the concept of cooperative enterprises by clustering them into segments and staging awareness programs. A few highlights and a detailed analysis of the recommendations of the government policies[37] and other constructive methods likely to be enacted is carried out in the subsequent section. It includes policies concerning implementation of awareness campaigns, cluster based integration of MSMEs, skill training programs and infrastructural requirement.

2.4 THE STRATEGIC PATHWAY FOR ADVANCEMENT IN MANUFACTURING

With the liberalization of the Indian economy in 1991, the Indian manufacturing industry inter-alia with the IT sector was open for international competition. Even though the IT sector reported an exponential growth, the advantages of the IT revolution were not translated into the manufacturing sector. While the global manufacturing industry has been was advancing at a tremendous rate, the Indian counterpart has remained stagnant contributing approximately 16% to the GDP since 1980[38]. The government of India has recently focused their attention

30 Joseph 2014.
31 Development Commissioner.
32 Department of Scientific and Industrial Research.
33 Press Information Bureau 2012.
34 Government of India.
35 SME.
36 Figures from conducted survey.
37 Joseph 2014.
38 I crore is equal to 10 million and 1 Euro is equal to 77.38 Indian rupees.

towards this sector and is committed to provide the resources to boost the pervasive Indian manufacturing industry, particularly the MSMEs. The government's policies are aimed at increasing the share of this sector from 17% to 25% by 2025.

2.4.1. Government policies

A comprehensive study of the proposed government and regulatory policies as mentioned below is carried out in liaison with the determination to integrate ICT and CPS functions for advanced manufacturing industry. There have been committed efforts by the government to map the deficits in the current state and propose timely remedial policies to strengthen the Indian manufacturing. Some of them are:

1. National Manufacturing Competitive Programme (NMCP), 2010[39]
2. National Manufacturing Policy, 2011[40]
3. Working Group on Micro, Small & Medium Enterprises (MSMEs) Growth for12th Five Year Plan (2012–2017)[41]
4. Institutes of National Importance for skill training and consultancy[42]

The agendas and proposals of the indigenous program to upgrade manufacturing are in compliance with the aspirations of the MSME associations to attain competency. NMCP with a corpus of INR 1000 crore[43] aims to strengthen and provide assistance to integrate application of lean manufacturing, with a fair share devoted towards promoting ICT and setting up of mini tool rooms by the Ministry of Small Scale Industries. Technology and Quality upgrading are chartered as top priority along with supporting entrepreneurial and management development. A high amount of emphasis is laid towards raising awareness for investment in intellectual property; it was often overlooked in yesteryears and has become an area of concern with the advent of global MNCs in India.

Most of the MSMEs are not concerned about getting their innovations patented which prevents India to claim its innovation potential. The global MNCs have setup their R&D units in India, carry out research utilizing the intellectual capacity of Indian minds often benefiting through patent commercialization at premium prices. A holistic framework of IPR in collaboration with international authorities is indispensable in today's competitive manufacturing to empower the technology base of our country. Among a myriad of government policies, a few schemes[44] for technology development in MSMEs are mentioned below:

- Lean Manufacturing Competitiveness Scheme: the project aims to reduce manufacturing waste and enhance technology competence under the Public-Private Partnership (PPP) mode.
- Design Clinic Scheme: The scheme focuses on the adequate consultancy service to MSMEs with expert advice and cost effective solutions to real-time design issues. It includes two projects, they are – Design Awareness and Design Project Funding.
- Marketing Assistance and Technology Upgrading: To upgrade marketing, the project is specific to providing technology assistance to MSMEs. It enables them to promote packaging, competition studies, and development of marketing techniques.
- Technology and Quality Upgrading: Adopting a global standard would enhance promotion of MSMEs globally in reference to their quality of products and competitiveness. The scheme aims to achieve the objective mentioned above.

2.4.2 Implementation

With potential benefits from international associations and abundant investments in technology initiative, the primal focus of the regulatory policies is to make the Indian environment ready to gain a maximum advantage from technology adoption. The possible future growth of the Indian enterprises with the potential to contribute to the international manufacturing chain by creating value heavily depends on proper implementation of the policies with greater emphasis on providing adequate quality training and building pertinent infrastructure. This section prominently highlights the current drivers of change and recommends possible solutions which will determine the future of Indian enterprises to take part in the international value creation network.

India is foreseen as one of the youngest countries in the world by the year 2025. The human resource is readily available and

[39] National Manufacturing Competitiveness Council 2010.
[40] Ministry of Commerce & Industry 2011.
[41] Press Information Bureau 2012.
[42] Ficci 2010.
[43] General Knowledge Today 2013.
[44] India Brand Equity Foundation.

requires being equipped with skills demanded by the next generation manufacturing. While the combined enrolment in higher education and vocational training is about 15.3 million, the composition of technically sound and skilled work force makes a small share of around 3.4 million which comprises of ITI/ITC (1 million), BE (1.7 million), polytechnics (0.7 million). Moreover, the prospects to meet the ambitious target of creating 100 million jobs in the manufacturing sector opens up more challenges. Even after creating opportunities, the difficulty faced by the employers in India to fill up the jobs is 48%, considerably high above the global standards of 34% in 2012. The facts and figures demand for formulation of stringent policies and close cooperation between regulators, industry and academia.

There have been several government schemes and initiatives, with allocation of huge investments to meet the desired objectives e.g. the promulgation of the National Skills Development Policy, Modular Employable Schemes and the formation of Public-Private Partnerships to upgrade the training institutes apart from funding from the World Bank and GoI. There are plans to establish 50.000 skill development centres across India with combined efforts and investments with several ministries and state government bodies. The union budget 2014–2015 proclaims a range of initiatives such as to suitably amend the apprenticeship act to make it more responsive to industry and youth, launch Skill India Programmes to emphasize on employability and entrepreneurial skills. It was also announced to increase the total corpus of the National Skill Development Fund (NSDF) to INR 25 billion from INR 10 billion in 2012–13. In order to establish career centres and technology centre networks, budget fund allocation of INR 100 crore and INR 200 crore has been made to transform employment exchanges.

Other major impediments in advancement of the manufacturing sector and adoption of ICT enabled technologies are the non-availability of a conducive infrastructure and financial constraints. Thus, in order to provide the necessary impetus to the manufacturing sector and increment the employability index, there have been several regulatory and international proposals regarding infrastructure development. In the Union Budget 2014–15, the following proposals were made:

- A framework is to be proposed to formulate new rules and structures, extricate the bottlenecks and deliver concrete suggestions and examine a financial architecture for the MSME sector, also reviewing their current higher capital ceiling.
- A corpus of INR 7060 crore is supported in the current fiscal year to realize the development of hundred smart cities. This would catalyze the growth in manufacturing and accelerate urbanization, backing the development of industrial corridors.
- Export promotion mission is proposed to observe collaboration among all stakeholders to propel export.
- To encourage entrepreneurship and eliminate financial constraints, funds of INR 10.000 crore are allocated for providing equity through venture capital funds, quasi equity, soft loans and other risk capital. An ample number of schemes and funds are proposed to encourage entrepreneurship at all levels such as District Level Incubation and Accelerator Program, and a legal bankruptcy framework will be developed for SMEs to enable easy exit.
- An allocation of INR 100 crore is granted to set up a National Industrial Corridor Authority with plans for 20 new industrial clusters advancing Public-Private Partnership and foreign investments.
- A National Rural Internet and Technology Mission is proposed and a corpus of INR 500 crore is allocated to provide internet and technology skills in villages[45].

German Skill development program

VET is regarded as the pillar of the educational system in Germany. Two-thirds of young people undergo vocational training in the dual system. This training would ideally last two to three and a half years, depending on one's occupation. It is described as a 'dual system' as training is carried out in two places of learning: at the workplace and in a vocational school. The aim of training in the dual system is to provide a broad-based basic to advanced vocational training and impart the skills and knowledge necessary to practice a skilled occupation within a structured course of training. Those completing the training are entitled to undertake skilled work in one of about 355 recognized occupations requiring formal training. The only requisite is that the student should have completed full-time schooling before commencing vocational training. The key success factor for the German system is the added focus on apprenticeship.

[45] live mint 2014.

Figure 2.6: Skill pyramid

2.4.3 Recommendation

In order to disperse the program widely and quickly, the enlisted solutions could be conducive to meet the objectives:

- The institutes must aim to impart skills at all levels of work force as shown in fig.2.6.
- The targeted training stressing on imparting skills pertinent to specific industry.
- Quality training is more important than mere reporting of increment in numbers.
- Provision of expert consultancies and international exposure
- Exposure to high end technologies
- Focus on R&D to develop indigenous technologies customised for India matching international excellence.
- Quality deliverance of training packages.
- Regular assessment and revision of training modules, learning from vocational education training (VET) of other countries[46]
- Internet technology and smart class rooms in rural areas
- Networking and marketing targeting skills for increasing export and trades.

Some recommendations in support of drivers of industrial growth, highlighting the pervasive micro enterprises:

- Finance and credits: Availability of easy credits, nominal taxation policies, setup of branches of the banks near clusters for operational convenience and trust building, awareness about fund raising through equity, angel funds and venture capitals. All this will support the micro enterprises, majorly based in rural areas to connect with larger enterprises.

46 Ficci 2010.

- Marketing and procurement: marketing being the driver of all the business functions in enterprises and promotion of exports entails special concern. Since rural income is rising, the enterprises must target these markets to tap their potential. The enterprises must be trained to increase connectivity to national and international markets through B2B portals at cluster and national levels. This is necessary for dissemination of information. The procurement process must be supported by the bulk production of new materials and mass procurement at lower rates through enterprise collaborations.
- Business planning skills must be imparted and large corporations can make a key contribution to the economic development by localizing value creation through collaboration with SMEs. This reinforces their license to operate, by creating a positive local impact. Furthermore, supplier cost reduction and innovation to develop new products and reach new costumers is an added advantage.
- Efforts should be made to liberalize the labor laws and apprenticeship act. Legal frameworks must be regularly revised to support the dynamic manufacturing sector.
- Cooperation with international industrial counterparts and formation of modular industrial estates, building hi-tech clusters; should be promoted.

2.5 BECOMING GLOBALLY COMPETITIVE

India offers a lucrative domestic market for manufacturing products as India is looking to increase its share in GDP from 16% to 25% by 2020[47]. India has good connectivity with south – Asian countries which are emerging as a major market for manufacturing products. Integration with Indian MSMEs will lead to increased global economic security by enabling manufacturing businesses to manufacture products cost-effectively by producing manufacturing goods for their global markets. India is also emerging as a manufacturing export hub due to a long coastline and good international connectivity. The Government of India is keen to increase the export from MSMEs[48] by various incentives like marketing assistance, Export Promotion Schemes[49], the inclusion of differential tax regime, higher interest subsidy and enhanced budgetary support[50] and restructuring of the facilities like ports and road transportation. However, the reduced production cost will come at the price of increased transportation cost. Thus manufacturing in Indian MSMEs opens up an opportunity for lowered production costs but also needs creative thinking of improved logistics systems to facilitate this lowered cost. India presents a platform with huge potential to be tapped by integrating it with an advanced manufacturing set- up of globally competitive industries.

The future of the manufacturing sector is governed by its level play in ICT and CPS integration. The IT sector in India is has done well[51], although its services are yet to be realized by the manufacturing sector, particularly by the MSME sector. With ensuring high skill levels and efficiency, ICT adoption will improve the productivity. The software industry in India becomes significant in developing ICT which can be implemented by the manufacturing sector, too. The software industry of India holds the key to integrate the MSME sector with international networks in a cost effective manner.

India has a mega opportunity in Advanced Manufacturing Technologies through public – private partnerships. Innovative research and investments can lead to the development of low cost ICT enabled technologies to be implemented in Indian MSMEs. Global partnerships have been a huge success story in India. Many large global players in manufacturing have advanced engineering industries and R&D Centers which continue to show better results than their counterparts in other parts of the world.

It is advised to take lessons from the growth of the Indian automobile sector[52], which accounts for 22% share of manufacturing's contribution to GDP. With a current standing of seventh position in the world, the Indian automobile sector reports a total production of 17.5 million vehicles and an export share of 2.3 million vehicles. Reporting data from the Department of Industrial Policy and Promotion (DIPP), the total FDI in this sector between April 2000 and May 2014 is recorded at US$9,885.21 million. The Indian automobile industry has reaped several benefits from international cooperation in advanced manufacturing and continues to identify more potential for further growth through international cooperation. This is substantiated by some recent international investments and

47 India Brand Equity Foundation 2014.
48 India Global Summit on MSMEs 2011.
49 Development Commissioner a.
50 live mint 2013.
51 Joseph 2014.
52 India Brand Equity Foundation 2015.

their forecasted benefits like Fiat's plan to introduce 12 models in India based on three platforms, increase its work force by 100% and capacity by 80% at its Ranjangaon plant by 2018; Mercedes-Benz India inaugurated an AMG Performance Centre at Sundaram Motors in Bengaluru. This segment lures further investments from more auto giants like BMW group, Isuzu motors and others.

The sector attracts foreign investment due to multiple reasons such as the cost advantage to perform operations, and government support. The GoI allows 100% FDI in this fully delicensed industry, also permitting free import of auto components. This organized sector, concentrated in the four automobile clusters of India, is not constrained by any minimum investment criteria. The automotive plan for the period 2006–2016 aims to energize this sector and accomplish many more foreign collaborations, unleashing prospects of more investments and opportunities. Many accountable projects such as National Automotive Testing and R&D Infrastructure (NATRiP) promote and support Indian industry to match the global standard.

In the same way, electronic good production in India grew at a compound annual growth rate (CAGR) of 14.4% during 2007–2013. It is projected to grow at a CAGR of 24.4 % in a period of 2012–2020, becoming a US$ 104 billion industry by 2020. The electronic sector, also backed by the IT sector, has achieved this extensive growth due to the growing demand which attracted multinational corporations to establish low-cost plants in India. Like the automobile sector, this sector also rises high in its share of recent global investment such as DietY's investment proposal of US$ 10.9 billion, out of which a large share is allocated to build two silicon wafers foundries; Indian Electrical and Electronics Manufacturers' Association (IEEMA) has entered into a MoU with the Institute of Electrical and Electronic Engineers (IEEE) to promote the enrichment of technical knowledge which includes skill training in the electronics sector. This and Intel's US$ 120 million investment to set up a R&D centre in India are a few among many illustrations of international collaborations.

These examples illustrate how the two biggest Indian industrial sectors have evolved in relationship to their participation in international networks. The sector's readiness for foreign investment is evident. These investments and advancements ultimately cascade to their vendors (tier1, tier 2 and tier 3 suppliers), pulling the MSMEs to upgrade and determining their possible growth paths. Their determination is realized by promoting skill acquisition, involvement in R& D, and scores of advancing opportunities which this kind of growth hosts.

Some more illustrations of direct and indirect penetration of Indian MSMEs in international networks of various other leading sectors in collaboration with government, academia and public are[53]:

- Germany-based Linnhoff, which makes asphalt batching and concrete mixing plants, has set its fifth global greenfield manufacturing facility at Khed City near Pune and will look after both domestic and export needs. Furthermore, the company also plans to establish a research and development (R&D) unit there.
- KPMG Insights Labs, a virtual R&D centre launched by KPMG International in Bengaluru, is third of its kind, after centres in the USA and the UK. It aims to develop and encourage innovative data-driven business solutions for KMPG member firms' clients globally.
- Virginia Tech, an US-based University has come under a MoU with Marg group, an infrastructure development firm to promote research in sustainable technologies. They have established a research centre near Chennai which will cover broad research areas under sustainable technologies in water, energy, renewable materials and nano-scale science and engineering.
- International collaborations are being fostered to exchange information and material of interest through student exchange programs and through research and academic activities. One such example is an agreement between Bengaluru's institute of Finance and International Management (IFIM) and UK's Plymouth University.

2.6 INTEGRATED ADVANCED MANUFACTURING NETWORKS – REQUIREMENTS AND IMPACT

The successful implementation of ICT in the advanced manufacturing industry will require integrated efforts from all sections of the society and so its impact will seep into both the global and the local network. An insightful study would cover the impacts of the advanced manufacturing network with regards to human capital, education, urban infrastructure, innovation potential and energy optimization. The identification of potential risks and challenges of the adoption of ICT and its far reaching implications will be enunciated in this section.

[53] IBEF.

The installations of intelligent and Cyber-Physical Systems in the smart manufacturing industry brings along a consequential threat to the country's economy with possible lethal attacks on financial systems, databases, and e-commerce sites. Thus, a cautionary prior check is required to maintain resilience to cyber-attack and embodying robust strategies to militate against the risks and challenges which an advanced integrated network is likely to invoke. The various risks and challenges are enlisted below:

- Database management: cyber security issues
- High cost of modern technologies
- Energy optimization
- Location and Adaptability risk
- Variable global standards and trade barrier given to international conflicts
- Cost effectiveness of the products
- Financial risks as value proposition of new processes are unclear.
- Obsolescence of business models and need for new adaptable and dynamic solutions
- Technology fads and saturation
- Growth in throw away culture and changing consumer demand
- Sustainability: resource scarcity, climate change, waste disposal, energy security
- Carbon crediting and low ceiling of carbon accounts are at disadvantage for developing countries.
- Resource depletion, resource conflict and resource based political power
- Waste and pollution control
- Government regulations to keep up with new business models
- Robustness of IPR framework

2.6.1 Resilient international advanced manufacturing: joint risk management

The above risks could be mitigated by deploying joint risk management framed by cooperative enterprise and backed up by the government polices to integrate resilience in international advanced manufacturing network. The plausible strategic ways[54] to tackle the risks adherent to adopting new protocols in advanced manufacturing MSMEs are:

- The business models of the SMEs should be robust against multiple external factors, such as change in technology trends, frequent variations in customer demands, global recession resulting in low demand and others.
- Involvement of multiple stake holders from the government, academia, FDI and general public could mitigate the risk of insolvency on high investments demanding activities such as innovations and disruptive technologies and high end technology acquisitions.
- Government must ensure updating the legal framework to structure the easy exit policies for bankrupt SMEs. Regulatory bodies must work towards revising the tax regime to reduce the tax obligations on the firms undertaking R&D/ innovations and strict protocols for Intellectual Property Rights (IPR) must seek international advocacy.
- Firms must associate themselves with international and national industrial networks to facilitate adoption of forward looking mechanisms to cope with uncertainty through participation in the provision of systemic solutions.
- The treaties and policies regarding promotion of sustainability and environmental obligations, such as ceilings for carbon trading, formulation of global renewable energy policies, etc., must be optimized to provide equal opportunities for industrial development to all countries.
- Large companies and global conglomerates, who have built their risk management postures regarding cyber risks and knowledge management could adopt SMEs or collaborate to work with their supplier to improvise their structure and mitigate their vulnerabilities with the aim to grow.
- The major risk of delay of business operations could be minimized by optimizing the variables such as the choice of manufacturing location, decision on customer interaction, total business cost and target market segment.

2.6.2. Implications

The manufacturing sector is crucial to the growth of a country with regard to to its economic, social, technological, environmental and political impact on the economy. Indian manufacturing, which lags behind in its contribution to the annual GDP when compared to China's 30% and Germany's 21%, Indian regulatory bodies, private institutions and most importantly the people of the country are steadfast in wanting to take its manufacturing to reach new scales.

For instance, the cluster centric approach through development of industrial corridors and National Investment Manufacturing Zones (NIMz) to promote collaboration among the MSMEs was preceded with proper planning to touch all aspects of

[54] Foresight 2013.

development. Taking cue from Germany's model to grow and compete in manufacturing[55] through more collaboration and industrial association hopes to generate a good investment climate for India. The industrial corridors have already attracted investments from the world over and with sixteen more NIMz announced[56], the situation of future manufacturing looks promising. Recently, after Japan's commitment to invest $4.5 billion in the ambitious Delhi Mumbai Industrial Corridor (DMIC) project, Germany, the most powerful economy of the European Union, has also showed interest to invest $90 billion in this project[57], opening further opportunities to create value in the global manufacturing chain. The Bengaluru Mumbai economic corridor (BMEC) has interested the United Kingdom, and a MoU has been signed between India and U.K for its development. These foreign cooperation and industrial collaborations have manifested the farsightedness and determination to overcome the three biggest challenges of capital, technology and marketing.

The manufacturing sector is a labor intensive industry, thus its growth translates directly into employment generation. The previous sections of the report prominently highlights the technological advances required to modernize the Indian manufacturing scenario, ascribed by the various proactive policies and initiatives flagged achieve the prospected goals. In this section, we study the future prospects and implications of the abstracted development.

2.6.2.1 Social

The solution to more employment generation is like a panacea for the second most populated country. When more people are employed, this would directly impact their standard of living and consuming capability, which would directly head to their requirement of latest technologies, good education and empowerment. The pan India promotion of adoption of ICT in manufacturing would benefit the micro and small enterprises primarily located in rural and semi-urban areas. The capacity building of the micro enterprises would translate into the development of backward zones of the country, also accelerating urbanization due to industrial associations. The trend would lead to an increase in distribution of wealth throughout the country, and decrease in income disparity. The cascading effects of the development would boost the quality scenario of India. The skill development training would enrich the human capital and would make India a reservoir of such asset. When the whole world, especially the Asian countries, is facing the crisis of human capital due to ageing population, India has the demographic advantage. The setup of more skill training institutes, research and development activities and promotion of entrepreneurial ventures would raise the demand of India's human capital.

Clustering would decrease work force mobility, preventing urban agglomeration and pursuing holistic growth. Due to ICT adoption, the enhanced quality of production would be in demand both by the local and global customers. In today's throwaway culture, high productivity and compressed time to market due to AMTs would make Indian enterprises competitive. This is essential to creating value in the global supply chain. As logistic and production both are coupled to each other. The advancements in manufacturing have to be equally translated with a robust and flexible logistics system.

2.6.2.2 Innovation potential

India stands as one of the most innovative countries, being the eight largest country in terms of R&D investments. It was placed sixth in terms of most innovate countries, as per General Electric's Annual Global Innovation Barometer in 2013. With splurging investments in R&D, human capital and growing exports in IT, auto, electronics and pharmaceutical sectors projects India as a product development destination. MNCs are now completely off-shoring complete product responsibility, inducing an environment for innovation in India.

The adoption of ICT would drive such innovations. The acceptance of ICT in the Indian manufacturing scenario unlocks more opportunities to make such technologies accessible through easy availability. This opens avenues for entrepreneurial undertakings. The need and capacity of high skills and a high education level would induce intellectual capital flow within the system, and generation of creative approaches to become globally competitive. The establishment of more enterprises adoption of Cyber-Physical Systems promotes and spurs financial investments and innovation in renewable energy systems, cyber security systems to meet the key environmental and security challenges.

2.6.2.3 Economic

The adoption of ICTs would catalyze a generation of knowledge. In today's knowledge based economy utilization of technologies allows access to the vast source of data, information and knowledge and encourages connectivity with rest

[55] Maira 2014.
[56] The Economic Times 2014.
[57] Business Standard 2013.

of the world. Alliances with international giants in design, development, manufacturing, and marketing would penetrate in Indian enterprises supporting them to attain international standards and develop new business models to practice international trading. The boost in export would generate income for India and moreover escalate the value with more visibility of Indian product in the global supply chain. The intergovernmental agreements and formation of trade blocs will opens pathways for more opportunities.

The high standard of living will cascade into higher consumption rates and thus more liquidity in the market will provide opportunities for investments and trading. This would also contribute towards the Indian economy. The economic factors are closely interconnected and often get influenced by the political dynamics. High productivity would strengthen the nation and empowers its resource capacity. The strengthening of the nation would obviously influence its geo-political stand in the global governance. The effective and efficient implementation of the projects and their positive short term and long term achievements would make India an exemplary model of good governance which can later be adopted by other countries. This could bring more good will to the stature of Government's industrial policies and leadership.

2.6.2.4 Environmental and sustainability

Advanced manufacturing and CPS aims at developing technologies and systems for cost efficient and environmentally friendly production. It addresses the product throughout its lifecycle. Advanced manufacturing has a huge potential in itself to boost the environment improvement. New technologies can replace power and water intensive resources[58]. Advanced manufacturing calls for adoption of clean manufacturing technologies, renewable energy sources and environment friendly processes. The Government of India has established Compliance Assistance Centers for MSMEs to create awareness of better environment management practices and policies for better compliance of environment regulations[59]. Advanced manufacturing will emphasize on development and usage of innovative technologies with thrust on green, clean and energy efficient environmental friendly technology. Indian enterprises need assistance in deployment of clean and green technology. ICT can help through information sharing about environment friendly developments. The Government of India has strict laws aimed at the protection of environment[60] and pollution control policy[61]. Different steps need to be taken for promoting environmentally sound technologies like close cooperation between academia, industry, service providers, associations and stakeholders. Indian industries lack the fervor of sustainable and inclusive innovation which needs to be addressed through start-ups which are flexible and have high risk taking abilities. A bent towards cleaner production technologies open avenues for multiple opportunities for resource optimization:

- It will promote education for sustainability.
- Design of new models of collaborative consumption like resource sharing and encourage symbiotic partners using by-products of a company as input material for another.
- Design of business models for managing waste and recycling, adopting cleaner technologies.
- Encouragement to new industries based on energy management and renewable energy concepts.
- Encourage development of environment friendly materials.

2.6.3 Conclusion

In a nutshell, to strengthen the Indian manufacturing enterprises and boost the growth of this sector, we propose the following recommendations:

- Technology acquisition has proved to be a growth driver for the emerging manufacturing sectors. This growth needs to be swiftly translated to the other manufacturing sectors; illustrating the multiple benefits of ICT enabled manufacturing technologies for cleaner, faster and integrated production.
- Strong interconnections between academia, private persons and the government sector shall be nurtured. It is essential to promote the organization of effective skill training programs pertinent to the target sector and customized for all levels of the skill pyramid ranging from technical to business skills. New product development and growth of research and development to meet consumer demand with minimum product complexity, high quality and affordable prices through innovative production techniques must be promoted and incentivized.
- A strong campaign and institutional set-ups to promote engagement of micro enterprises existing in rural areas for participation in manufacturing value chains through capacity building shall be expedited and supported by regulatory bodies.

58 Chu 2012.
59 MSME – Ministry of Micro, Small & Medium Enterprises 2012.
60 MSME b.
61 MSME a.

- There is a strategic need to standardize the variation in global standards for quality and product benchmarking. Enterprises must be encouraged to follow up with the standards and achieve quality standards and certifications. This shall be largely promoted by bringing in the rewarding culture and allow the firms to form collaborations with their counterparts in other emerging markets.
- Such bilateral relations like German-Indian collaboration to deliberate on building the roadmap for ICT adoption in Indian manufacturing shall be fostered. Germany, being world leader in manufacturing and innovation, with a third global position in terms of exports is expedient to transform the manufacturing scenario. The advancement in manufacturing capabilities for the automobile, pharmaceutical, energy, aerospace and electronics sector in Germany has revitalized the growth of these sectors across boundaries, particularly in India. Thus, such collaboration and international associations, giving importance to formulation of risk management strategies is significant to create value in international manufacturing networks.
- To realize the objectives, the government plays a key role. Through its policies of establishing flexible cooperation networks and clusters, building suitable infrastructure, participating as a stakeholder, and developing proper legal and institutional frameworks to ensure its upgrading with changing market requirement, the government could exponentially boost the manufacturing capabilities, employment capacity, leading to increment in the gross domestic product (GDP).
- Finally, national and international policy making initiatives shall encompass a formulation of strategic marketing, procurement and export policies to extract maximum value from products and processes through its significant participation and contribution in the global supply chain. The policies shall emphasise the incorporation of resilience through inter government agreements on trade blocs, standards and resource utilization, especially energy policies.

2.6.4 Discussions & suggestions coming out of symposium

A well-organized symposium on "Advanced Manufacturing, Logistics and Urban Development: New Perspectives for International Development Cooperation" was held at India International Centre, Delhi on 3–4 September, 2014; where intense deliberations and discussions were carried out and participants raised many important concerns which may help in implementing the main theme of the workshop

(I) ICT related inputs: During the discussion, participants and experts suggested that following points should be taken into account with respect to ICT application in advanced manufacturing.

1. Cyber-Physical Infrastructure should be strengthened and suggested standards of Industry 4.0 should be supported by required specification of hardware and software components.
2. Service providers related to ICT should be given enough access to connect the villages, small towns, etc. so that SMEs and Micro enterprises should avail the maximum benefit out of these initiatives.
3. Different kinds of advancement taking place in manufacturing and many innovations emerging out of applications of ICT should be coalesced to create an eco-system which may revolutionize the customization of goods and services supporting three trinities of manufacturing:
   a. Low cost of manufactured items
   b. Best quality of manufactured products
   c. Shorter delivery window to ship the products at the customer's doorstep.

(II) Manufacturing advances: To propel the best practices of manufacturing, an intensive exercise needs to be undertaken to promote near net shape manufacturing, cleaner manufacturing, precision manufacturing and additive manufacturing. Waste removal and zero impact on the environment with minimum energy consumption should be the hallmark of our next-generation manufacturing practices.

(III) Logistics: It is the backbone of all the developmental activities and it was agreed upon by the members that ICT Industry 4.0 standards need to be quickly amalgamated with different logistics providing equipment such as vehicles, GPS, GIS, RFID, warehousing, toll-collection, licensing, penalty, packaging, pickup delivery, order-processing, vendor management, coordination among partners, customer centric logistics support, etc. This should be given top priority.

(IV) Skill Development: It's an area where immediate steps should be taken to devise short term, long term and well focussed programs to create necessary skills for various manufacturing practices, ICT services and logistics services, etc. Skill training about advances in manufacturing and re-manufacturing received greater attention from the experienced

participants. Massive training and skill development on e-services, e-governance, equipment to handle ICT, interface development, application development, information sharing and providing mechanism, etc were recommended.

(V) Urbanization: The application of the above mentioned advances would provide the necessary impetus to drive urbanization and prevent urban agglomeration and mobility for livelihood. The experts discussed that mere dissemination of such advancement is not enough; rather it has to be bolstered by the proper planning to integrate these components of logistics, advance manufacturing and skill development. A well planned clustered setup entails targeted statutory policies and coordination between institutions to incorporate modern facilities such as smart grid, manage overriding vehicle population and other infrastructural facilities.

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APPENDIX

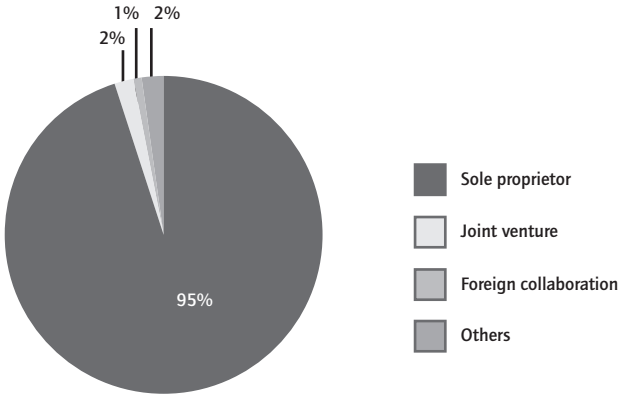
E-SURVEY RESULTS

The open ended questions in the survey were not mandatory as we did not intend to impose constraints on the respondents. This resulted in limited responses to these questions, but they were more likely to be genuine answers. A summary of responses to these questions is given below:

The investments in these information and communication technologies were rather limited and were need based rather than being strategic. Very few companies of the micro and small scale industries surveyed had access to a personal computer. The skills of most of the personnel working in these firms were gained through experience rather than through formal education. This could be the prime reason for low penetration of modern technologies among these groups.

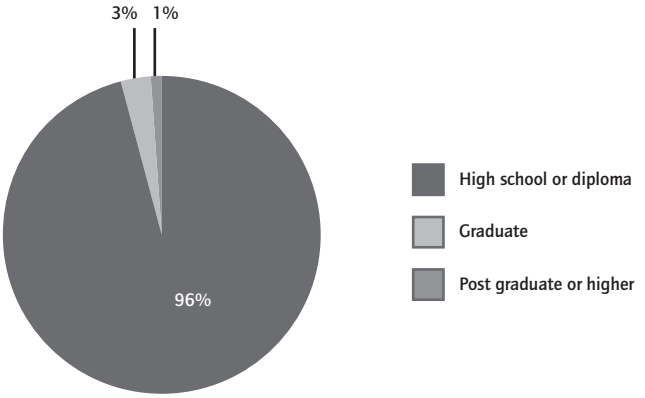
The training gained by these personnel, either one-time events and skills updating or continuous improvement, was virtually absent with very few firms organizing training programs for their employees. CNC infrastructure has been only implemented by medium scale industries but collaborative manufacturing capability was largely absent. ISO and other quality certifications were enforced by customers on firms and were rarely seen as means to gain business or improve profits. None of the respondents to the survey had filed patents of any sort, quantifying the lack of innovation in the industry.

1. What is the form of your firm's ownership?



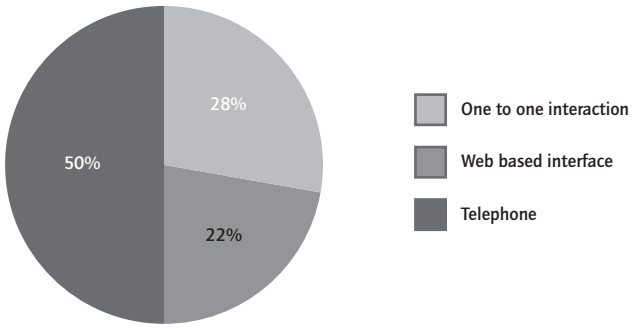
Sole proprietor	94.9
Joint venture	2.5
Foreign collaboration	0.7
Others	1.9

2. What level of qualification do you expect your employees to have?



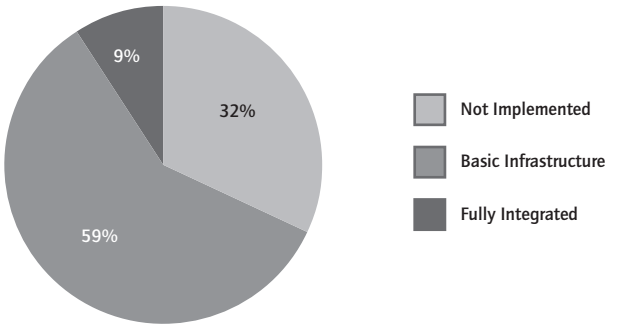
High school or diploma	96.0
Graduate	3.4
Post graduate or higher	0.6

3. How does the firm manage customer interface and vendor interface?



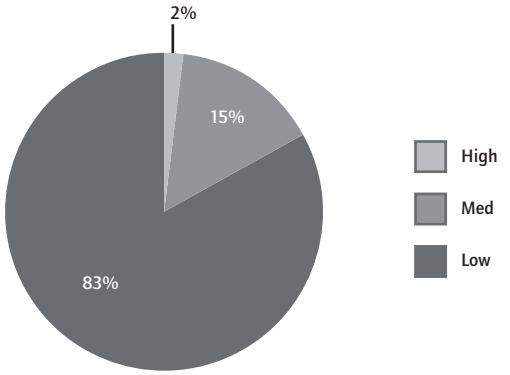
One to one interaction	28
Web based interface	22
Telephone	50

4. What is the level of ICT Implemented in the firm?



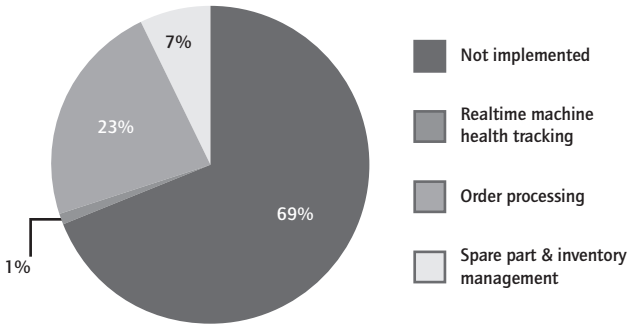
Not Implemented	32.0
Basic Infrastructure	58.9
Fully Integrated	9.1

5. What level is the requirement analysis conducted before implementing ICTs?



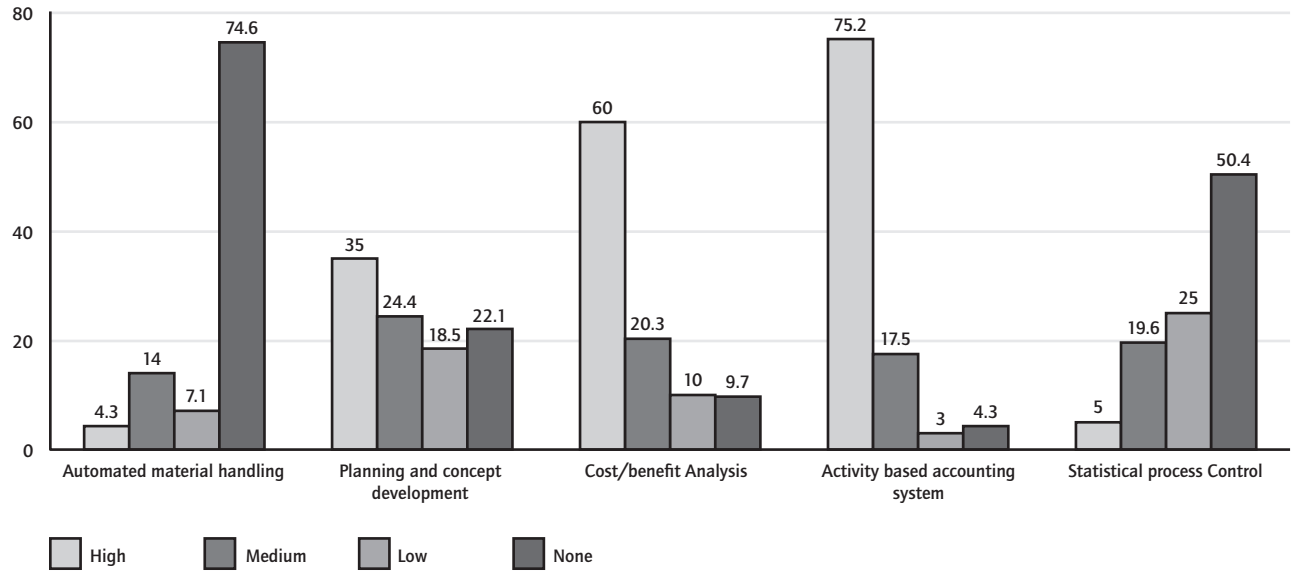
High	1.7
Med	15.4
Low	82.9

6. What is the level of use of ICT in production systems?



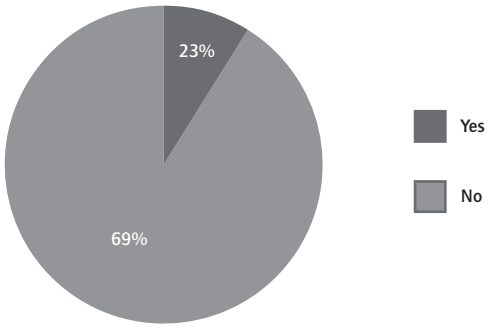
Not implemented	68.9
Realtime machine health tracking	0.8
Order processing	23.6
Spare part and inventory management	6.7

7. What is the level of ICT application in following processes?



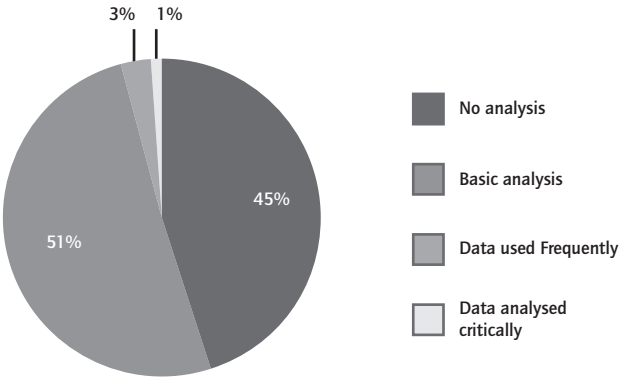
	HIGH	MEDIUM	LOW	NONE
Automated material handling	4.3	14.0	7.1	74.6
Planning and concept development	35.0	24.4	18.5	22.1
Cost/benefit Analysis	60.0	20.3	10.0	9.7
Activity based accounting system	75.2	17.5	3.0	4.3
Statistical process Control	5.0	19.6	25.0	50.4

8. Is ICT used for real time quality control and failure analysis?



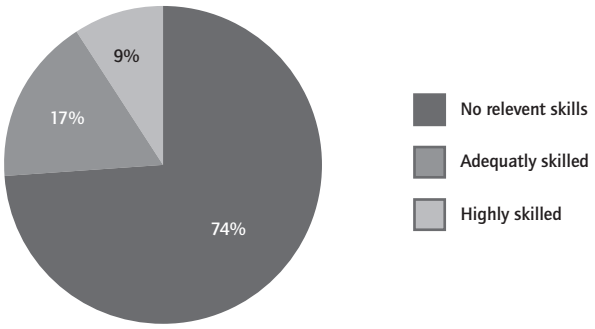
Yes	9.3
No	90.7

9. What type of analysis is done with the data obtained from ICT?



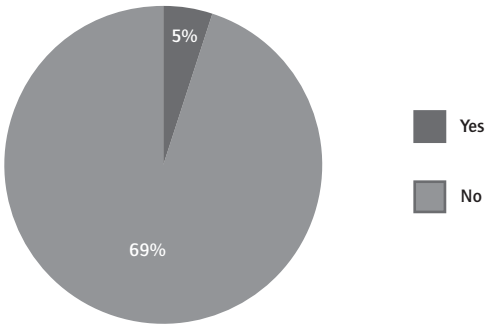
No analysis	Basic analysis	Data used Frequently	Data analysed critically
45.0	50.7	3.0	1.3

10. What is the skill level of the employees with respect to ICT application?



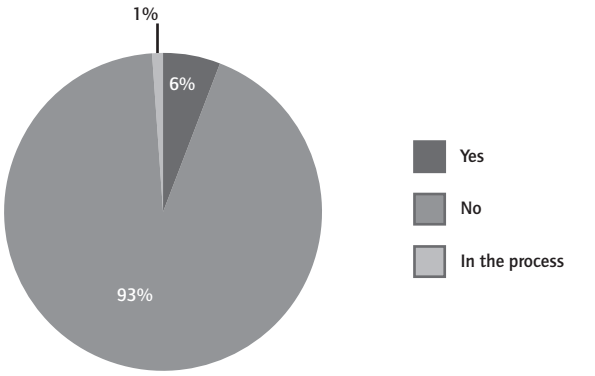
No relevent skills	73.9
Adequatly skilled	17.3
Highly skilled	8.8

11. Does the firm have a well established ERP or SAP system?



Yes	4.9
No	95.1

12. Has the firm launched a product in its operational domain, new to the local market?



Yes	5.7
No	93.0
In the process	1.3

3 LOGISTICS INTEGRATION OF SUPPLIERS FROM INDIA IN SUPPLY CHAINS OF GERMAN MANUFACTURERS – REQUIREMENTS AND KEY ACTION FIELDS UNDER AN INDUSTRY 4.0 PERSPECTIVE

AXEL KUHN, TOBIAS HEGMANNS, ANDREAS SCHMIDT

3.1 INTRODUCTION

3.1.1 Initial situation and objectives

The integration of suppliers and the creation of values in global corporate networks have a strategic importance for global manufacturing companies. For successful and efficient operations in these global networks corporate communication, organizational performance and the coordination of business processes are highly demanded. Logistics takes a central role in the coordination and organization of these tasks. Reliability of global material flow processes, the exchange of information between the companies and the corporate information processing require highly-developed logistics systems. To achieve this, customers pose specific requirements towards the logistics operations of suppliers to realize high delivery quality, in terms of on-time, in-full (complete order, complete documentation) and damage-free deliveries, at low costs. Potential suppliers must fulfill these requirements in order to enter into a strategic partnership and long-term cooperation.

In this study, the variety of organizational and technical requirements related to this is brought together. The examination area of the study covers supply logistics and distribution logistics in global automotive value chains. Subject of the analysis undertaken is the German automotive industry. The automotive industry can be seen as role model for German manufacturers, as the logistical systems in this industry are of a very high standard and very well documented. The automotive industry takes a pioneering role in the field of efficient high-tech logistics processes and the field of operational supplier management respectively.

To determine relevant indicators, three steps are realized:

- Consolidation of requirements in corporate practice by screening recommendations of VDA (German Association of the Automotive Industry), quality and environmental standards according to ISO and publically accessible documents of automotive manufacturers
- Consolidation of findings in available empirical research as well as a general literature review
- Empirical analysis of logistical requirements through interviews with experts from practice and science and their qualitative analysis

In addition to existing logistical requirements, current developments in Industry 4.0 with its Cyber-Physical Systems induce new challenges and opportunities to companies. Joining the virtual world of latest information and communication technologies and internet-based business processes with the physical world of industrial operations is at the core of this development. The development of Cyber-Physical Systems sends key impulses for intensified networking between the value chain partners and a higher market-orientation of the logistics networks. To benefit from these developments, companies are challenged to build up new ICT-enabled operational competencies, to improve networkability of their processes and to establish inter-operable IT and communication systems.

The aims of this study are the compilation and empirical validation of general requirements for logistics integration of suppliers from developing countries, as India, in supply chains of German manufacturers. Building upon this, an outlook of potentials and challenges for future development in these requirements fields under an Industry 4.0 perspective is undertaken.

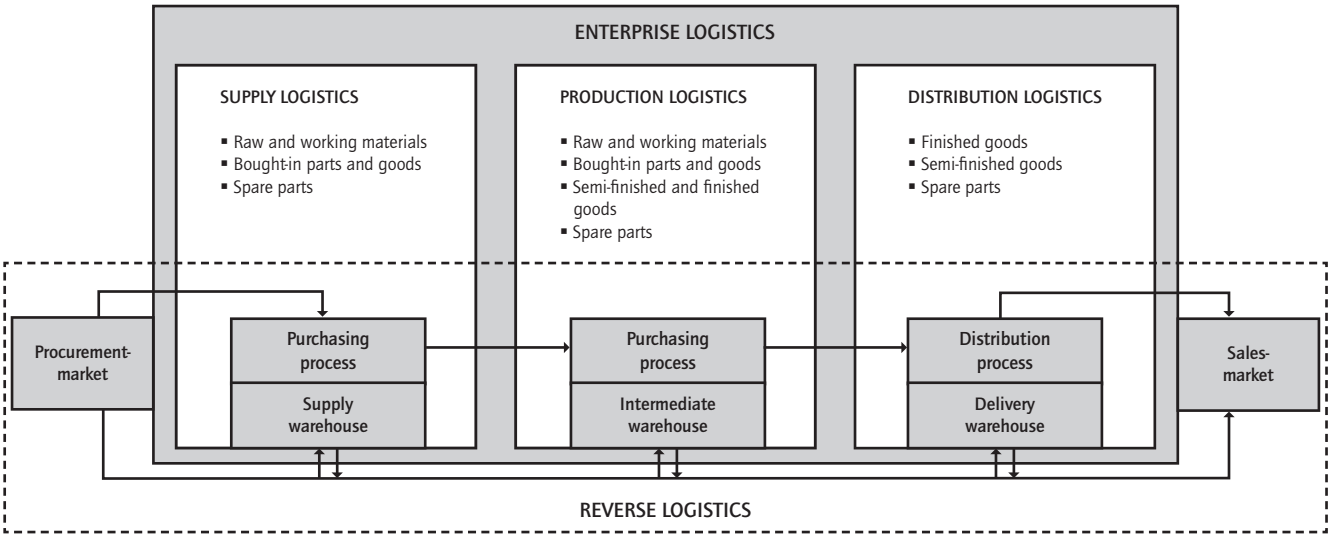
3.1.2 Terms and definitions

In this study original equipment manufacturers (OEM) as well as first tier suppliers were interviewed. The focus of this analysis remains on procurement and distribution logistics, which can be seen as the interface between the customer and supplier. For the understanding of the results the terms Logistics system, Supplier management, Requirements management and Systemic flexibility are defined:

Logistics systems

Logistics systems are networks for the distribution of goods using transformation processes, which generate a material flow through the coordinated movement of goods. In order to realize these material flows the coordination of personnel, technical resources (e.g. machinery, transportation means, load units etc.), inventory, space utilization, information and energy flows has

Figure 1: Functional distinction of logistics systems according to the phases of the material flow on the example of an industrial company



to be organized. This study concentrates on the requirements of the logistics processes. These include on the one hand transportation, handling, storage, packaging and labeling processes, which constitute and support the material flow, on the other hand, order handling and order processing and all related information flows of information management and communication. For industrial companies these processes can be summarized under the term enterprise logistics as shown in Figure 1.

Supplier management

Supplier management is defined as the planning, steering and control of individual supplier-customer-relationships as well as the entire supplier base as part of the strategic procurement management. In order to implement the supplier management processes the requirements of the business functions procurement, research & development, logistics and quality management have to be translated into operational interactions and measures with suppliers. Due to the changes in and between corporations and the technological advancements, processes and main activities of the supplier management are subject to dynamic change.

Supplier requirements is also a subject of investigation in both empirical and scientific literature. The findings range from comprehensive catalogues with evaluation criteria and weighting factors capturing the capabilities of suppliers to complex arithmetic methods for analyzing and visualizing key performance indicators. A logistics-related statement of requirements in form of a collection of theoretical and practical criteria for integrating suppliers is currently not available.

Requirements management

In the scientific literature the terms requirements management, requirements technique and requirements engineering are used synonymously. The requirements engineering includes evaluation, documentation, check and administration of the requirements of system development processes. Due to the requirements management the customer requests as well as optimization potentials are taken into account. System requirements do not only cover individual functions, but interfaces to other systems, too. Generally, requirements are provided by the customer. In the case under consideration the automobile manufacturers are the customer side and thus raise demands on the logistics systems of suppliers.

3.1.3 Structure of the study

To systematically analyze the requirements for logistics systems of suppliers, the relevant design guidelines and standards of the automotive industry will be presented in chapter 2. The consolidation of existing logistics standards and strategic components of global supplier relationship management lead to a fundamental overview on the logistics system requirements. Afterwards results of an empirical study with external experts are summarized in chapter 3. Chapter 4 compiles the requirements identified from both the analytical scan of standards, guidelines

and other available documentations and important business insights mentioned by the experts in the empirical study. Finally, the study results are summarized in chapter 5 and evaluated under an Industry 4.0 perspective.

3.2 LOGISTICS REQUIREMENTS IN GLOBAL PRODUCTION NETWORKS

3.2.1 Guidelines and standards in the automotive industry

The aim of this chapter is to provide an overview over existing and relevant standards for the automobile industry regarding logistical systems. Underlying standards are the guidelines by the German Association of the Automotive Industry (VDA) and the International Organization for Standardization (ISO). An introduction to these standards and guidelines is given in the following. It is not comprehensive though, but highlights the most relevant aspects for supplier integration and development in order to depict specific and practical actions. Specific examples for the design and planning of enterprise and distribution logistics are pointed out. In addition to the previously mentioned guidelines, a vast number of documents and directives are in practice, e.g. concerning data transmission for production-synchronous call-offs and dispatch notices via EDIFACT and XML (VDA 4984/4985/4986/4987) as well as the application of RFID (VDI 4472).

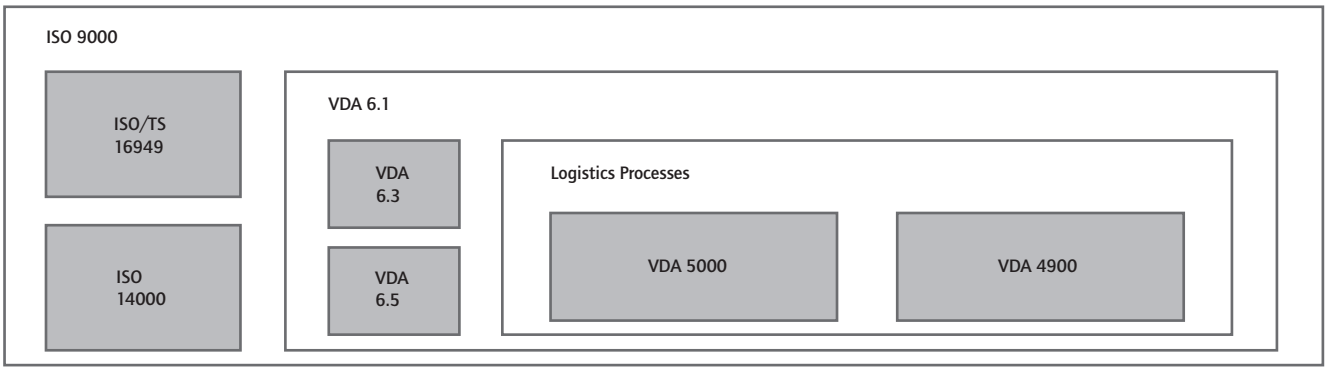
In Figure 2 the structural relations between standards are shown. The ISO 9000 standards series, broken down in industry-specific standard for the automotive industry in ISO/TS 16949 and the VDA guidelines represents the starting point and general framework for all following guidelines. Moreover, many companies require the fulfillment of general environmental management standards represented by ISO 14000 or EMAS. In the automotive industry, a globally uniform standard for quality management systems is ISO/TS 16949, developed by the International Automotive Task Force (IATF) and the Japan Automobile Manufacturers Association Inc. (JAMA).

This set of standards and guidelines can be regarded a minimum pre-requisite in order to become involved in supply chains of the German automotive industry.

A certificate according to ISO/TS 16949 is meant to establish reliability of a customer into its potential supplier's system and process quality. A supplier without valid certificate today has little chance to become 2nd-tier supplier and basically no chance to become a 1st-tier supplier for serial parts supply to almost any automotive OEM worldwide. The company's top management has to ensure that customer requirements and expectations are determined and fulfilled correctly. Intra-organizationally, the fulfillment has to be supported by a quality management unit, training, means of prevention and correction as well as product development. On the shop floor it is necessary to ensure order, cleanliness, maintenance and risk prevention for workers. As information systems are also used to communicate with the customer, there are special requirements for transmitting data in a language and format defined by the customer alone.

In terms of operating logistic systems, this translates into avoiding failures and minimizing risks in order to keep up an adequate flow of material. This requires suppliers to set up an adequate management of resources, develop sufficient staff

Figure 2: Relations of relevant standards and guidelines in the automotive industry



competence and provide suitable infrastructure and work environment. For instance, the reliable and on-time provision of materials is linked directly to the requirement of establishing an inventory management and the acquisition of inventory-related performance indicators. Further, the ISO 16949 demands the adoption of basic principles of up-to-date factory and warehouse design, i.e. arranging the resources with the aim of minimizing material handling effort, optimizing value-adding activities and space consumption.

Another part of ISO/TS 16949 deals with the identification and traceability of products, which means the covering of the identification of products along the value stream from arrival to shipping, the product-specific determination of the degree of traceability as well as guaranteeing the separation of batches and charges, e.g. through the principal of first-in first-out (FIFO). Customer-orientation is an underlying principle of IST/TS 16949. Therefore, any supplier is requested to continuously control and measure the satisfaction of their customer. According to ISO/TS 16949 any supplier is demanded to measure their own performance using data concerning

- the quality of the delivered products
- disruptions on customer side
- delivery reliability and
- customer notifications in case of quality or supply problems

Due to the high quality standards in the automotive sector, the VDA developed the 6.x document series (e.g. 6.1 for serial production). The documents of the series describe a quality management system supporting stability and reliability in the value adding processes of a company. They contain requirements regarding corporate governance, quality management, methods for the logistical supplier evaluation (VDA 5001), logistics process quality (VDA 5008), and propositions for the design of logistics processes (VDA 5000). Combined with the standards procedures of material delivery in the automotive industry (VDA 5010), they create a framework for logistics system design.

VDA 5000 contains design recommendations gathered by automobile manufacturers such as AUDI, BMW, Daimler, Ford and VW. It divides into three parts:

- part 1: general statements for designing processes
- part 2: material supply concepts
- part 3: packaging

Part 1 addresses contractual elements, e.g. agreements between supplier and OEM concerning days of inventory, recommendations for the logistics system design as well as methods for the systems response on disruptions, such as sales and demand fluctuations. Furthermore, the guideline contains central elements in a supply agreement as a check list for both customers and suppliers. This checklist indicates planning data and control parameters of information and material flows being exchanged between customer and supplier. It ensures a necessary degree of transparency.

Part 2 informs about the organization and design of industry parks. VDA 5000 understands an industry park as a regional concentration of suppliers of one customer facility, usually in an area of about 5 km. It thus represents a special form of a logistics system.

Part 3 contains requirements on used packaging. The main issues are avoiding waste and careful division of non-reusable and reusable packaging. According to VDA 5000, a logistics system uses recyclable, easy to clean and labelled packaging.

An additional important factor of VDA 5008 is process quality. To enhance process quality, data about process performance needs to be collected first. For example, the number of cases where packaging data was provided late is an indicator for low logistical process quality. Therefore, the logistics system needs to be able to gather, record and provide quality-related indicators, which are usually supported by a suitable IT system. VDA 5010 can be seen as a tool for designing one-stage supply concepts based on standardized process elements. Every supply concept, e.g. JIT, VMI, call-off, poses specific demands on logistics processes. Thus, the logistics system must be designed to meet those requirements with its operational and organizational structures. As an example, a just-in-sequence (JIS) supply is driven by the production sequence and quantity in the customer plant. As a consequence, the upstream logistic system at the supplier must bear for customer-driven call-offs and deliveries just in this customer-determined sequence. In general, the supply concepts defined in VDA 5010 can be understood as a market standard that potential suppliers should be able to handle.

With respect to tracking and tracing of supply chains and delivery processes VDA 4905, 4915, 4916 and 4913 are considered state-of-the-art and also represent the fundament for object identification, communication and intelligent control that will develop under Industry 4.0. For order and delivery management

on the short-term operational level, automated information exchange based on EDI-messages has become the standard communication process between OEMs and their suppliers. Defined message formats e.g. for different types of customer call-off, advanced shipping notice and delivery sheet are established widely. In an international context also EDIFACT messages are of importance for supplier-customer communication.

The guidelines of the VDA mirror the interests of the German automotive industry on a national and international level and thus represent the minimum requirements regarding functionality and design of customer-supplier-relationships. They are extended by individual contractual conditions. These company-specific conditions can also be retrieved from company websites and supplier portals, which are often freely accessible.

3.3 EMPIRICAL ANALYSIS OF LOGISTICAL REQUIREMENTS

3.3.1 Methodology and investigation process

The aim of empirically analyzing logistical requirements by interviewing experts is the identification of major challenges and discovering future trends and developments within the topic. Also, a snapshot of current conditions and processes can be picked up by this procedure.

The first priority was to identify potential interview partners. As selection criteria, the automotive industry and extensive knowledge of procurement, supply planning and supplier management were taken as a basis. The experts' sample is shown in Table 1.

A structured interview guide was created. Each interview started off with general questions on the company, the position of the interviewees and their working experience. Then their area of responsibility was discussed. The main part of the interview was structured by relevant topics as follows:

- criteria of supplier finding and process of supplier choice
- supplier assessment systems and performance indicators
- logistics requirements and aims
- levers of supplier development and integration
- new goals and topics of collaboration
- alterations of supplier management through industry 4.0
- specific requirements for distribution logistics (IT, warehousing, automation...)

Table 1: Interview Directory

NO.	FUNCTION	COMPANY
1	Divisional Director "Information Logistics and Logistical Assistance Systems"	Business Consultancy
2	Divisional Director "Production Logistics"	Business Consultancy
3	Divisional Director "Supply Chain Engineering"	Business Consultancy
4	Managing Director	IT service provider
5	Project Manager Production Abroad	OEM
6	Project Manager Supplier Management	OEM
7	Project Manager Supplier Management Logistics	System Supplier
8	Divisional Director "Global Supplier Management"	System Supplier
9	Head of Department "Purchasing"	System Supplier

The interview guide also allowed for open questions and a neutral positioning of the interviewer. Designing the interview guide ensured that all relevant topics were dealt with and made it possible to identify problems and solutions that have a direct influence on the conception of the requirements catalogue. Subsequent to the interviews, the conversations were analyzed and categorized according to key features and statements. This categorization led to the structure of the requirements. The results are presented in the following chapter.

3.3.2 Qualitative evaluation of the expert interviews

In this chapter, excerpts from the interviews are revealed. They can either be regarded as general statements due to multiple mentions. Or the statements are very specific and are therefore of great importance for the further investigation and for the development of the requirements catalogue. The topics conform to the theoretical dealing with supplier management, logistics systems, global customer-supplier-relationships and process organization. The following five areas of interest resp. key action fields have been deducted from the expert interviews:

3.3.2.1 Information and communication technology

When using IT in the management of logistics systems, the primary goals are transparency, reactivity and speed in decision

making. The latter focusses on the efficient design of a company's organization and structure. Transparency puts high demands on the collaboration between customer and supplier. On both sides, informational transparency concerning capacity usage is required. For the supplier this means that the data need to be provided in the appropriate format. But the partners can also use these data to plan their own capacities accordingly. This information exchange reduces planning insecurities and enables the partners to lower inventory stocks. Currently, the experts state that communication and information exchange is still limited to the bare minimum needed. On a global scale, necessary standards for developing this transparency do not exist.

Technically, inaccuracies and statistical deviations during the forecast of delivery orders and capacity demands in the production are a great challenge. Currently, these deviations are compensated for by inventory stocks and mutual flexibility agreements. These agreements are necessary in order to maintain supply security. In case that this compensation is not possible, cost intensive special processes are required. High planning and coordination efforts and the maintenance of flexibility create additional costs which can only be reduced by a deeper collaboration and integration between the partners. The collaboration process itself is characterized by a transparent data provision.

3.3.2.2 Logistical performance

From a technical perspective, for any OEM the realization of various supply concepts like VMI, JIT or consignment warehouses are of great interest. Suppliers that can demonstrate their readiness and qualification for implementing these concepts meet the requirements. In this context, the supplier needs to reveal location, scope and traceability of all necessary quality assurance measures and must be able to transform individual customer requirements. In case of a production-synchronous delivery, which puts great demands on the logistical systems, suppliers must maintain adherence to delivery dates and show high delivery quality over a long period of time. Ensuring supply security, suppliers may also be required to monitor and control the customer's inventory levels. Due to an increase in the variety of products, capacity usage and demand for space in the factories of the OEM is also increasing. This results in a general increase in the demand for production-synchronous logistical concepts.

Process synchronization and transparency require a standardized electronic data connection for delivery call-offs, advices and invoice. If they cannot be managed by an IT system supporting EDIFACT standards, suppliers will be able to manually use a web-based application on the supplier portal. The suppliers are also required to flexibly handle differently formatted and designed messages and react accordingly.

From the point of view of a German automotive expert, potential suppliers from growth markets need to adapt to internationally acknowledged data standards, before county-specific or branch-specific frameworks are developed. In this context there are often particular backlogs concerning the definition of public responsibilities and representatives such as the VDA in Germany. Suppliers need to organize themselves and create a platform for collaboratively designing these standards, which can be a huge advantage for the development of individual standards based on the model of VDA or Odette.

The most common starting points for supplier development are improving process know-how and the standardization of interfaces between customer and supplier concerning both the information and the material flow. For the material flow, standardization also concerns charge carriers, containers and packaging. In global logistics networks, a direct shipment is often impossible due to incompatible loading units and means of transport. Therefore, cost and time advantages by applying a consistent standardization and a branch-specific material flow become even more important. For capable suppliers, implementing these standards must not be considered as a barrier or disadvantage.

While purchasing contracts with global suppliers in fully industrialized countries, e.g. US, UK, etc., usually the Incoterms "free alongside ship" (FAS) or "free on board" (FOB) apply. Yet, in India transport in responsibility of the local supplier and local subcontractors is considered unreliable. Often, for this reason, "ex works" (EXW) is chosen. In this case, the German customer organizes the transport by means of one of his logistics service providers which usually is a globally operating logistics service provider.

Industrial modernisation in India is still ongoing. The development towards quality-oriented production is still underway. For this reason the material sourcing processes of the suppliers also require the customer's attention. Raw materials and manufacturing supplies should be quality-checked. In some cases, support and collaboration in identifying adequate suppliers and in implementing suitable quality-control procedures are of help.

This applies to the manufacturing process at the supplier as well. Frequent monitoring of quality aspects is recommended. Since certificates for quality and process management, such as ISO 9001 or 16949, confirm conformity of the defined corporate processes with the standardized requirements only, the actual product quality or management behaviour may still deviate. Requirements concerning the product or service therefore should be declared precisely, also requirements concerning quantity and delivery performance, in bilateral agreements.

Under total cost considerations, an advantage of about 30% on the purchasing price is required in order to trade-off inventory, risks and additional efforts in India. For identifying, selecting, and maintaining local suppliers in India increased efforts have to be calculated.

3.3.2.3 Human resources

Qualifying suppliers until a desired product and process quality is secured is a lengthy process. In the process of assessing and selecting potential suppliers, product quality is of major importance. Just in the course of the subsequent operations, collaboration and logistics requirements get into focus. Maintaining and improving product and delivery quality goes beyond operative means and demands a quality- and customer-centered corporate philosophy as well as the training of the supplier's staff. A problem can be a missing loyalty towards the company. Qualification and training can only lead to long-term success, when the people stay inside the company. Fair and transparent payment models combined with trainings can prevent fluctuation.

In case of problems in the logistical processes, quick reaction times are necessary in the context of escalation management. From the experts' point of view, time-critical processes are not recommended for implementation today with suppliers from developing countries due to cultural barriers. These barriers can be attributed to communication problems or rigid organizational structures. Language-related barriers however are seldom a problem, as often a contact person is defined locally.

3.3.2.4 Organizational requirements

Global manufacturing companies, OEMs, have a global production footprint. Therefore, they look out for global suppliers who offer the same service to them for all of their worldwide locations. So, in many cases there is also an international dimension to the selection of a local supplier. For local domestic firms, especially SMEs, this can be an insuperable entry barrier.

Logistic service providers, even international ones, focus their services on traditional warehousing and distribution services when operating in India. Still, the number of highly productive high-rack warehouses which can be considered an industry operating standard in Europe is still under-developed. Also, value-added services such as customer-specific packaging, labelling, assembling or information management are not part of the regular service portfolios of logistic companies in the Indian market. Contract logistics has a very small market share in the overall logistics market compared to the European market.

3.3.2.5 External Influences

Even if the above described topics are considered and problems are prevented accordingly, the flow of materials across national borders - which is common in today's global supply chains - is another barrier within inter-organizational value adding networks. Main sources of imponderables are legal regulations and customs formalities, with combined results in unpredictable transportation times. This can only be compensated for by inventory stock on the customer side and it leads to additional planning efforts and inventory costs. Measures to lower these efforts usually apply to activities in administration and order processing; however they might not have tremendous impact on delivery quality. Generally, a declared objective is to reduce bureaucracy and trade barriers.

Traffic congestion represents a major infrastructural bottleneck in India. Transportation times in India therefore have to be calculated with an impact factor at least five times as high as in western European countries. The radius for suppliers for local sourcing in India is therefore recommended not to exceed 300km. In general, sufficient buffer times are recommended to ensure that shipping schedules of sear freight carriers are met. Port operations, loading / unloading, is estimated to take approximately three to four times longer than in the European average. Due to the deficient infrastructure, logistic costs are relatively high compared to more industrialized sourcing markets. Often, the choice of potential service providers is limited preventing market mechanisms.

From the perspective of the customer, efforts put into infrastructure and transport should be as low as possible. Therefore, an appropriate location of the supplier factory is important. During the assessment of a potential supplier, an inappropriate infrastructure with a relatively low reliability can negatively alter an otherwise positive result. Insecurities may arise from a lack

of federal investments into the road network as well as faulty transport facilities. When a supplier is not integrated into a local industry cluster, bigger delivery distances and longer delivery times lead to greater accident rates and material damage. Then it might happen that the supply chain is disrupted and the customer cannot be delivered in the right time with the right amount. Experts are of the opinion that connecting industry clusters with trans-shipment points via railroad can make industrial transport more independent from public transport. If this is not possible, the supplier has the responsibility to consider these delays in the delivery plans.

Climate conditions, especially the Monsoon, are reported to be a risk factor to logistics operations. Several months per year are affected by Monsoon rain falls. Transportation as well as factory operations suffer from this since delivery schedules cannot be met, transportation is delayed and even factories are not accessible for the personnel. Another problem may arise from damage to stocked goods due to humidity and high temperatures. Therefore, risk and resilience management is seen as an important topic.

3.4 REQUIREMENTS CATALOGUE FOR LOGISTICAL SUPPLIER INTEGRATION

In the course of this study, a great number of logistic requirements could be collected by analyzing research papers, studies, project documentations and expert interviews. In this chapter, they are compressed into a single catalogue.

The catalogue divides the requirements into common main topics that were touched by the interviewees. The intention (goal) behind the requirement is listed as well as related measures for their implementation. The listed measures may be seen as propositions and examples. It is not a comprehensive catalogue. The purpose of the catalogue is to provide an overview on the most relevant supplier integration requirements in the automotive industry. The structure of the catalogue displaying also the main topics mentioned during the interviews is shown in Table 2.

Table 2: Structure of the requirements catalogue

TOPIC	GOAL	REQUIREMENTS	MEASURES
Resources	...	...	...
Delivery Performance	...	...	...
ICT	...	...	...
Material Handling	...	...	...
Infrastructure	...	...	...
Supplier Environment	...	...	...

Table 3: Requirements Catalogue

REQUIREMENTS / INTEGRATION CATEGORIES	TOPIC	GOAL	SYSTEM REQUIREMENTS	MEASURES
Resources	Customer orientation	Increase flexibility	The logistics system should react to changing delivery schedules.	- Implement demand-driven production planning and control - Plan spare capacities - Create inventory buffers (approx. 15%) - Manage customer orders according to delivery date and quantity
	Standardization	Meet standards on a long-term basis	The logistics system should ensure compliance to standards.	- Ensure compliance with standards through a tight documentation of processes, methods and responsibilitie - Develop trainings according to quality management systems
	People	Build up and maintain skills	The logistics system should provide qualified staff.	- Develop training and qualification guidelines - Create personnel requisition profiles - Create thorough understanding for adherence to standard procedures through training - Set up fair and transparent payment systems
	Transparency	Avoid capacity constraints	The logistics system should provide information for capacity planning.	- Define interfaces with customers for capacity data exchange - Determine indicators, implement IT systems for capacity planning - Identify customer requirements concerning capacity data
Delivery performance	Traceability	Improve process quality	The logistics system should track part numbers, batch identifiers and related process data.	- Set up IT assistance for order processing - Determine customer requirements concerning traceability - Ensure consistent product labelling through all processes - Process integration through use of auto-ID and identification systems for reliable information on delivery notes and accompanying documentation
	Flexibility	Implement established industry-specific delivery processes	The logistics system should meet customer requirements concerning established delivery processes of the automotive industry.	- Adopt established standard delivery concepts - Establish flexible IT design enabling compatibility with all required logistic standard processes of the automotive sector
	Delivery quality and service level	Track order status	The logistics system should monitor order processing.	- Implement IT assistance for order processing - Define and standardize interfaces and information flows for communication of order status information with customer - Implement an IT system for order monitoring
	Quality	Ensure damage-free and disruption-dree handling and logistic operations	The logistics system must comply with definitions for packaging and handling of goods.	- Ensure reliable implementation of packaging definitions of the customer - Analyze impact of physical conditions during transportation and logistics operations on materials and packaging - Consider legal regulations and means of transport

REQUIREMENTS / INTEGRATION CATEGORIES	TOPIC	GOAL	SYSTEM REQUIREMENTS	MEASURES
ICT	Delivery reliability	Comply with delivery times and schedules	The logistics system should use an IT system for logistical planning purposes.	- IT assistance for order processing, handle production planning data from customer side, plan delivery capacities and quantities
	Data security	Enhance information security	The logistics system should meet the information security standards of ISO 27001.	- Determine and implement requirements by ISO 27001, continuously check the security of IT systems
	Quality	Continuously improve process quality	The logistics system should gather qualitative process indicators.	- Implement an IT system for collecting, storing, processing and provision of logistical data - Determine responsibilities for process quality
	Communication	Optimize communication with customer	The logistics system should process and exchange electronic data.	- Set up IT assistance in for order processing, define and standardize interfaces, provide ICT infrastructures
Material handling	Quality	Comply with quality directives	Prior to delivery the logistics system should ensure compliance with quality agreements.	- Define responsibilities and requirements for process stability, develop quality assurance measures, define time and place for quality tests
	System design	Ensure process security	The logistics system should clearly separate restricted material stock and goods, e.g. stock blocked for quality check, due to damage or missing approval, from non-restricted materials and goods.,	- Develop IT systems and clear process definitions for handling, labeling and processing of material and goods ensuring reliable mapping of physical objects and related IT status information
	Process transparency	Minimize delivery risks for the customer	The logistics system should react to operational disruptions.	- Determine and monitor influences on logistical processes - Develop emergency plans for operational interruptions - Transmit reaction times and quantity deviations to customer
	Inventory	Guarantee security of supply	The logistics system should provide real-time inventory data.	- Set up inventory management system Determine stock coverage - Provide inventory data to customer
Infrastructure	Transport	Minimize replenishment lead time and reliability	The logistics system should bear for risks and operational deficiencies of transportation infrastructure.	- Align logistics concepts to transportation infrastructure, expected transportation lead times and reliability
	Flexibility	Optimize lead time	The logistics system's infrastructure should be compatible to all handled products and materials.	- Determine product-related requirements on buildings and workplaces, warehousing, process equipment and services
	Delivery reliability	Minimize delivery delays	The logistics system should consider transportation limitations.	- Determine and evaluate unpredictable, predictable and legal influences on the transport operations - Communicate transport restrictions to the customer, determine risks of influences and derive measures
	Communication	Improve communication with customer	The logistics system should provide an EDI connection.	- Design and implement IT assistance for managing EDIFACT messages - Determine communication with customers, provide appropriate communication infrastructure

REQUIREMENTS / INTEGRATION CATEGORIES	TOPIC	GOAL	SYSTEM REQUIREMENTS	MEASURES
Supplier environment	Environment	Increase resource efficiency	The logistics system should meet environmental management system requirements according to ISO 14001.	- Determine requirements from ISO 14001 and customer, implement system to evaluate resource efficiency
	Laws and norms	Minimize delivery delays	The logistics system should consider restrictions concerning product and packaging labelling.	- Define responsibilities for shipment labelling, ensure product labelling by information systems, determine legal regulations and customer requirements for labelling
	Laws and norms	Minimize delivery delays	The logistics system should consider import and export regulations for delivery management.	- Determine import and export regulations, ensure a constant inspection of regulations, define responsibilities
	Delivery reliability	Minimize delivery delays	The logistics system should monitor internal production and delivery schedules as well as those of their suppliers.	- Arrange delivery data exchange between supplier and customer, implement IT systems for monitoring delivery times, Set up IT assistance for order processing

3.5 SUMMARY AND OUTLOOK

The study yields various requirements for the integration of suppliers into supply chains of German manufacturers in the automobile industry. The requirements were developed on an analytical as well as on an empirical basis. Eight automobile experts on the subject of supplier management, international logistics and industry 4.0 have been interviewed to support the analysis. Relevant goals and measures within the automobile industry have been deducted from this. They point out directions for supplier development and integration and highlight trends and opportunities for the strategic orientation of customer-supplier-relationships.

3.5.1 Identified strategic key action fields

A cluster analysis of all measures compiled in chapter 4 was done. Measures were grouped due to the type and subject of actions required and based on similarities in context and motivation of the actions. The cluster analysis identified four key action fields.

- *Synchronization* refers to the material and information flow as well as related business activities required to synchronize customer/market demand with supply. From the experts' point of view, synchronizing the customer's supply processes with the supplier's distribution processes is of highest priority. Emphasis is laid on technological and organizational means to coordinate synchronization. Communication infrastructure is a key enabler to this as well is reliable and productive transportation infrastructure. Demand-driven or even production-synchronous delivery can only be achieved by making plans more flexible and the transportation of goods more reliable. This places high demands on distribution processes and order handling and all related systems. Synchronization is closely related to transparency which can be seen a pre-requisite to synchronizing demand and supply.
- *Transparency* is a key enabler for advanced planning and control of logistic networks at a global scale. There are at least two major dimensions to transparency. Organizationally, transparency describes an open system design and a clear face to the customer with documented and comprehensible processes. Open systems facilitate information exchange and deeper collaboration but also consider data security and legal restrictions. Operationally, transparency concerns planning processes based on high-frequent exchange of information. From forecast demand and handling of order data to frequent and near real-time status information from all relevant supply chain operations it is a key requirement in this action field to improve information and communication systems. Real-time information systems should support decision making and supply chain control based on latest status updates from the operations.
- *Standardization* is a key enabler to the ideas of Industry 4.0 and Cyber-Physical Systems in general. Standardization covers

the implementation of process and data standards as well as the development and utilization of standardized technical components and equipment, e.g. containers, pallets, bins, identification tags and labels. This also includes packaging and carriers. Great potential is seen in standardization of data interfaces, needed for an appropriate interoperability of systems. In the context of industry 4.0, the demand for global standards will increase and gain importance.

– *Qualification* is a key action since the above mentioned strategic actions fields can organizationally only be exploited if personnel and organizational skills are developed accordingly. The successful implementation of today's supplier integration requirements as well as future fields of development under Industry 4.0 depend on the know-how and skills of the people in charge. Future job profiles in logistics, on all levels from shop-floor to management, will evolve. Jobs in the logistics sector will experience extensive knowledge intensification, and a focus on information technology, standardization, collaboration and process management.

From the requirements analysis presented in Chapter 2 to 5 the following has been elaborated: the requirements leading to these key action fields as well as specific measures constituting the key action fields. To round off the analysis, the measures clustered in these action fields, have been evaluated under the perspective of Industry 4.0 and Cyber-Physical Systems. The results of the expertise gained on this are presented as conclusive remarks of this study in the following.

3.5.2 Future logistics and supplier integration under an Industry 4.0 perspective

Logistics sees the Internet of Things as one of the strategic lines of attack to address this challenge. Goods should organize their own route to the destinations through a network of intelligent actors and services. The internet of things has become a core principle for the 4th industrial revolution. According to Prof. Dr. Henning Kagermann, president of the National Academy for Science and Engineering acatech, "Industry 4.0 enables batch sizes of one to be produced at the same cost as a mass product, and the requirement-oriented optimization of value adding processes in real time. Active, autonomous and self-organizing production units are replacing passive, plan-oriented production systems. The intelligent product actively supports the production process. Production becomes highly flexible, highly productive, resource-preserving and compatible with urban areas. The factory of the future will run at the pace of the people."[1]

Cyber-Physical Systems form the basis for the fourth industrial revolution: informational components (cyber) and mechanical or electronic and sensory components (physical) merge with each other to form an intelligent system, a Cyber-Physical System, in short a CPS. CPSs are more than a single sensor application or stand-alone assistance device. They stand for the networking of efficient intelligent embedded systems, mobile services and worldwide data sources forming smart networked services and systems. CPSs use the internet as a business web, i.e. as a platform for business co-operations – with the objective of generating added value by means of new applications, new services and co-operations at the complex systems level.

The Internet of Things expresses a new form of control and organization for logistical systems based on individual, decentralized and autonomous decision-making designed jointly by logistics and ICT. In Cyber-Physical Systems the Internet of Things becomes alive connecting the virtual world of data with the physical world of goods and physical movements.

In logistics operations Cyber-Physical Systems will help to connect all transport, handling and storage processes with all relevant associated information. Thus, control alternatives can be identified and efficiently exploited and communicated at any time. These new systems have to be combined with new resource-efficient transport technologies such as electro-mobile transportation, especially in urban areas, in order to promote environmental-friendly and efficient services. Further approaches in this field enabled by Cyber-Physical Systems are the shared use of transport and logistics infrastructures (e.g. transshipment areas, distribution transportation, and goods transfer systems) by companies and service providers as well as new solutions for "last mile" distribution and goods transfer. Exploiting these potentials is a strategic measure to handle the continuous growth of transport volumes and traffic in line with acceptable levels of environmental emissions, particularly in cities and densely populated areas.

Vehicles, loading units, containers, pallets, all these logistical items become intelligent logistics objects in future Cyber-Physical logistics systems. This means that they recognize their environment and their situation and develop their own behavioral strategy on that basis. The exchange of information occurs decentralized and locally via the latest near field communication processes between logistic objects, machines, conveyors, storage and handling equipment. Parallel to this, information is also passed upstream to cloud-based IT infrastructures. Ambient

[1] At the presentation of the "Industry 4.0" report, Hannover, April 2013.

systems in logistics facilities, factory premises and transshipment terminals, harbors or goods transport centers can make contact with the units. Thus, they can on the one hand support the processes of these logistics objects and, on the other hand, gather information to improve the processes in the logistics facility. That also results in interactive information exchange between downstream transport systems and infrastructures (provision of information about transport flows, traffic situation, etc.) that can be passed to other actors in the supply chain to coordinate operations. This requires standardizing services, communication protocols and methods planning and control operations on this basis. Furthermore, new processes have to be deve-loped for IT security in connection with the logistics services being provided. Data security aspects are also very important particularly in distributed supply chains that go beyond company boundaries.

Bringing these developments and future innovations together with the key actions fields the following potentials and challenges for supplier integration under an Industry 4.0 perspective are seen:

		KEY ACTION FIELD: **SYNCHRONIZATION**
MEASURES (cf. chapter 4)	*Resources*	- Implement demand-driven production planning and control - Plan spare capacities, provide inventory buffers (approx. 15%) - Manage customer orders according to delivery date and quantity - Identify customer requirements concerning capacity data - Plan delivery capacities and quantities - Supply customer with inventory data
	Control	- Determine customer requirements concerning traceability - Ensure reliable implementation of packaging definitions of the customer - Handle production planning data from customer side - communicate transport restrictions to the customer - determine communication with customers
	Processes	- Determine relevant delivery concepts in the branch and set up a flexible logistics system accordingly - Develop emergency plans for operational interruptions - Transmit reaction times and quantity deviations to customer - Align logistics concepts to transportation infrastructure, expected transportation lead times and reliability - Arrange delivery data exchange between supplier and customer
	Structures	- Set up IT assistance for order processing - Define and standardize interfaces and information flows for communication of order status information with customer - Design IT systems for various delivery conditions - Secure efficient and risk minimal IT connection between supplier and customer - Provide appropriate communication infrastructure
Industry 4.0 related potentials		- Promote inter-operable IT systems - Use web-based communication services and user-friendly frontends - Collaborative order management as a service - Service-based IT infrastructures - Use of mobile devices and retrofitting solutions to speed up informational process integration. - More efficient use of transportation and logistics infrastructure will reduce transportation lead times and delays. - Achieving higher integration of the transportation sector by promoting so called Third-Party Logistics Service Provider as a business model for the logistics sector; higher degree of integration and coordination of fragmented transportation of mostly SME carriers will help to improve reliability and transit times of transports.
Other potentials		- Financial support and financial supplier development measures to ensure economic survival of SME in order to build-up competencies and expertise in long-term relationships - Lower logistics costs

		KEY ACTION FIELD: **STANDARDIZATION**
MEASURES (cf. chapter 4)	*Resources*	- Ensure compliance with standards through a tight documentation of processes, methods and responsibilities - Determine performance indicators - Ensure consistent product labelling through all processes
	Control	- Determine risks of influences on transportation and derive measures - Determine requirements from ISO 14001 and customer - Determine legal regulations and customer requirements for shipment labelling
	Processes	- Consider legal regulations and means of transport - Define time and place for quality tests - Develop means for the correction of material faults - Develop IT systems and clear process definitions for handling, labeling and processing of material and goods ensuring reliable mapping of physical objects and related IT status information
	Structures	- Define and standardize IT interfaces - Determine and implement requirements by ISO 27001 - Continuously check the security of IT systems - Determine product-related requirements on buildings and workplaces, warehousing, process equipment and services - Design and implement IT assistance for managing EDIFACT messages
Industry 4.0 related potentials		- The Internet-of-Things and Internet-of-Services will bring along standardization of physical logistic objects, e.g. containers, load units, etc., and of data formats, e.g. identification, event information, event repositories, and of information flows and processes. Early adoptions of these ideas will bring the industry forward. Early efforts of industry-wide harmonization of different standards are beneficial. - Standardization will help building up a competitive edge in the SME-dominated transportation and logistics service sector and creating improved efficiency and productivity of logistics processes. - Standardization will further help to exploit the potentials of the so called unorganized sector in India's economy; many activities in transportation of goods and people as well as in trade are organized in loose networks without coordinating authorities; this experience and openness towards the idea of networked services forms a supportive factor for Industry 4.0 implementations and can be further emphasized by means of standardization as described above, - Ensure early industry-wide harmonization of standards; examples from Germany show that conflicting or incompatible standards have established over times even within the same industry. E.g. object identifiers based on GS1, DUNS or ISO standards currently are an issue for industry wide- Auto-ID/RFID implementation between different OEMs.
Other potentials		- Promote behavioral change and understanding of the importance of standards from top management to shop-floor level - Containerization is an substantial field for standardization of hardware and physical objects; currently use of containers in India is still low compared to other nations; standardized intermodal containers for freight transport are an important issue for promoting multimodal logistics. - Establishing high-quality industrial services and industry-wide harmonization of industrial service quality, also for SMEs, in the logistics sector. Service innovation includes transshipments and cross-docking services, operated consignment warehouses, packaging and labelling, late-customization, tracking & tracing. - Establish business support services for supplier identification and integration; these parties may act as intermediaries between customers from abroad and local firms, they coordinate and organize the compliance of suppliers with the customer requirements; since many manufacturers are looking for global suppliers this could be thought of as a global service as well. - Industry working groups for elaborating important topics on an industry-wide basis support by branch associations; following the idea of steering committees and working groups at German VDA and ODETTE - Promoting modal shift from truck transport to rail and waterways comes along with greater efforts in standardization to streamline operations at truck-rail transshipments points and hinterland traffic; containerization of the rail cargo system.

		KEY ACTION FIELD: **TRANSPARENCY**
MEASURES (cf. chapter 4)	*Resources*	- Set up fair and transparent payment systems - Set up inventory management system - Determine stock coverage - Implement system to evaluate resource efficiency
	Control	- Determine and evaluate unpredictable, predictable and legal influences on the transport
	Processes	- Analyze impact of physical conditions during transportation and logistics operations on materials and packaging - Consider legal regulations and means of transport - Develop quality assurance measures - Determine and monitor influences on logistical processes - Determine import and export regulations and ensure a constant inspection of regulations - Process integration through use of auto-ID and identification systems for reliable information on delivery notes and accompanying documentation
	Structures	- Implement an IT system for order monitoring - Implement an IT system for collecting, storing, processing and provision of logistical data - Implement IT systems for monitoring delivery times
Industry 4.0 related potentials		- Improved integration of suppliers, especially on the 2nd or 3rd sub-tier level in a supply chain integration framework. Today technology is available to document every physical good movement in the outgoing goods area, hubs or during transport with so called supply chain events [e.g. GS1 EPCIS]. The intention is to create a true integration loop between informational flows and operational planning: From call-off to goods receiving at the customer, all status information on order processing and production data (e.g. batch number, revision stand, QC check data etc.) need to be communicated based on existing standards and necessary extensions. All required object events at AutoID-/sensor read points in the supply chain are captured, stored and made available to partners through the integration framework and its communication infrastructure. - Interactive information exchange between down- and upstream transport systems and infrastructures (provision of information about transport flows, traffic situation, etc.) that can be passed to other actors in the supply chain
Other potentials		- Risk management and resilience management on the corporate-level as well as on the level of authorities responsible for infrastructure management should be promoted in order to reduce the frequency and impact of disruptions to industrial processes in production and logistics.

		KEY ACTION FIELD: **QUALIFICATION**
MEASURES (cf. chapter 4)	*Resources*	- Develop trainings according to quality management systems - Develop training and qualification guidelines - Create personnel requisition profiles
	Control	- Develop trainings according to quality management systems
	Processes	- Determine responsibilities for process quality - Define responsibilities and requirements for process stability
	Structures	- Define responsibilities and requirements for process stability - Define responsibilities for shipment labelling - Ensure product labelling by information systems
Industry 4.0 related potentials		- Prepare personnel to manage a higher degree of automation in production and logistics; in future the focus of work will shift from operating machines to monitoring machining operations, maintenance and problem-solving in case of errors, break-downs or failures of complex technical systems. - Prepare personnel for increased IT usage at workplace, for operating internet-based services and mobile devices.
Other potentials		- Behavioral change in understanding the importance of adherence to standard procedures - Operational and management skills for complex processes and time-critical operations, e.g. JIT-/JIS processes

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4 PATH TO GROWTH: TECHNOLOGY ENABLED LOGISTICS IN INDIA

NUKALA VISWANADHAME

ABSTRACT

The logistics function is to ensure the availability of right product at the right place, in right quantities and right condition at the right time and right cost for the right customer. Integration and synchronization of material, information and financial flows across organizations, sharing information and destiny and process orientation and coordination are needed to achieve this objective. The logistics services are provided by the private sector and the logistics infrastructure such as roads, ports, airports etc. are provided by the Governments. The performance of the logistics sector depends on both hard and soft infrastructure, skilled manpower, Government policies, cluster locations and connectivity, service providers, insurance agents, research in educational institutions, and host of other things in addition those connected with actual goods transport and delivery.

This report's focus is on logistics in India. In sections 2–4, we define logistics and bring to focus its relevance in all three sectors of the economy and identify various types of logistics. In section 5, we define and identify the various types of logistics service providers. In section 6, we identify the recent ICT technology innovations in the inbound and retail logistics which are the way forward. In sections 7 and 8, we review the state of the Indian logistics sector and the industry clusters. We note that Indian logistics has millions of small players and one of the issues is coordinating their functions in providing efficient delivery. The retail sector in India has immense potential for technology intensive home delivery logistics. The report is concluded with recommendations for developing both hard and soft infrastructure in a coordinated fashion for making logistics in India a world class sector.

As mentioned above, the performance of the logistics sector depends on both hard and soft infrastructure such as roads, ports etc and the skilled manpower and technology sophistication. Disruptive changes are occurring due to advances in technologies such as internet of things, mobile, social media and cloud computing in the inbound logistics, manufacturing, maintenance and repair (MRO) and retail logistics sectors. Retail is changing face from buying at the retail mall to home delivery. The report develops an ecosystem framework for logistics service sector that includes all the above stake holders and new technologies and develops methods for analyzing performance and mitigating risk. The report presents ecosystem examples inbound logistics, e-retail sectors and analyzes their importance in the Indian context. The ecosystem is used for developing supply chain innovations and also mechanisms for supply chain governance using the concept of logistics mall.

4.1 INTRODUCTION

The last half Century has seen several innovative and industrial developments in automation. Various business activities were automated, starting with material flow automation in the factories, followed by automation of information and financial flows. Currently, we are witnessing automation of integrated supply chains that encompass the entire industry and the world. In particular, the B2B and B2C logistics processes are witnessing several innovations including automated fleet control and home delivery using drones.

A substantial portion of business costs in developing countries can be traced to inefficiencies in their supply chains, limitations created by logistics bottlenecks and the lack of streamlined administrative procedures for goods transfer. According to the World Bank, logistics-related expenses comprise between 15% and 30% of GDP and between 20% and 60% of the final price of food products in the region. The Inter-American Development Bank (IDB) estimates that transport costs account for up to two-thirds of the total costs of logistics operations, which in turn constitute approximately 15% of the final value of goods. Logistics facilitation will play a significant role in supporting higher rates of economic growth worldwide.

The Internet has fueled the growth of E-commerce and has revolutionized the so-called front-end systems of order placement, sales, and marketing. Fast and easy ordering of customized goods over the web raised the expectations of fast, reliable and convenient delivery among consumers. The Internet and e-commerce have matured, from the early days of pure on-line selling

focus to a more stable multi-channel network with logistics capabilities for back-end fulfillment. Companies in the future must not only be able to design and market products, they also must be able to globally source the components, build, move and store the final product and deliver to the market – on time and at a competitive price and collect the cash. Furthermore, they should guarantee to their customers of durable goods competitive after sales service levels to ensure the return of the customers for their next purchase. Thus, logistics becomes an integral and critical part of businesses. It needs to be embedded in all phases of the product life cycle from product design (design for logistics) to order fulfillment and installation (design for delivery) and after sales service (design for serviceability).

The developments in logistics across countries of the world differ widely. In countries like India, most of truck logistics is in the unorganized sector and the rail logistics is with the Government. Most of the so called supply chain best practices such as cross docking, supply hubs, supply chain visibility, etc are not often seen in the industry.

This report is about logistics in India. In sections 2–4, we define logistics and bring to focus its relevance in all three sectors of the economy and identify various types of logistics. The logistics services are provided by the private sector and the logistics infrastructure such as roads, ports, airports etc are provided by the Governments. In section 5, we discuss the types of providers. In section 6, we discuss the recent ICT technology innovations in the inbound and retail logistics which are the way forward. In sections 7 and 8, we discuss the state of the Indian logistics sector and the industry clusters. We note that Indian logistics has millions of small players and one of the issues is coordinating their functions in providing efficient delivery.

From these discussions, it is clear that the performance of the logistics sector depends on both hard and soft infrastructure, skilled manpower, Government policies, cluster locations and connectivity, service providers, insurance agents, research in educational institutions, and host of other things very remotely connected with actual goods transport and delivery. In section 9, we develop an ecosystem framework (see fig. 1) which considers the resources, institutional factors and delivery mechanisms. This can be used for identifying risks in logistics network and methods of mitigating them, possible innovations due to policies, creation of new resources, technologies and delivery modes and finally the Governing mechanism for selecting the partners, coordinating and monitoring the end to end process delivery. All these are discussed in sections 9–13. Section 14 presents a very brief account of the mathematical models that can be used for analytical studies. In sections 15 and 16, we deal with the retail sector in India which has immense potential for logistics. We conclude the report with recommendations for making logistics in India a world class sector.

4.2 LOGISTICS

Logistics is defined as the broad range of activities concerned with effective and efficient movement of semi-finished or finished goods from one business to another and from manufacturers to the end consumers via the distributors and retailers. The Council of Logistics Management (CLM) has formulated the following definition of logistics with a flow and process orientation.

"The process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information and financials from point of origin to point of consumption for the purpose of conforming to customer requirements"

The activities within the sphere of logistics include freight transportation, warehousing, material handling, packaging, inventory control; order processing, marketing, forecasting, and customer service. Thus, "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements" (Council of Logistics Management).

Logistics is important in all three sectors of the economy: agriculture, manufacturing and the service industry. The logistics market is huge. It amounts to 10–15% of every product produced and is estimated to be at US$ 4 Trillion worldwide. North America has the largest global market share for logistics services ($ 2 Trillion), India has a logistics market of about $250bn. There were several innovations such as the Suez and Panama canals to improve the trade logistics by reducing the ship travel distance by thousands of miles and also creations of transhipping hubs such as Singapore, Hong Kong, Amsterdam, etc. Modular product designs of electronic and textile products, Outsourcing to low cost

destinations have increased vertical trade and has created tremendous growth in logistics infrastructure. The highly connected and efficient logistics networks have also become prone to risks such as government protectionism, trade collapse due to financial crisis, piracy and host of other extraneous factors.

There are several new innovations happening in logistics due to developments such as Industry 4.0 and Industrial Internet. Also, the rise of social media such as face book, Twitter, Google circles etc, Mobile phones and Cloud computing have affected the logistics industry tremendously. The consumer side impact on logistics in terms of home delivery, product returns and order cancellations due to the big data analytics and e-commerce have been tremendous. Also, resource shortages are influencing logistics costs in a big way. Recycling, green houses gases reduction, carbon trading, etc. are issues that have big impact on logistics operations. The developments in Internet of things in particular, sensors for monitoring the health of equipment in critical network industries such as power and airline transport is changing the maintenance process from scheduled to predictive maintenance. The availability of 3D printing is changing the way spare part logistics is organized. While these developments increase the technology analytics contents in logistics operations, they reduce the downtime of equipment and trucks, inventory requirements and also the energy intensity in operations. We call these new trends as E-logistics and define the term below.

E-Logistics

E-Logistics is a dynamic set of Sensor (IOT), Communication (Internet, Mobile), Computing (Cloud), and Collaborative technologies that transform key logistical processes to be customer centric, by sharing data, knowledge and information with the supply chain partners and enable synchronization of events and right decision making. The ultimate objective is fulfilment which is to deliver the right products in right quantities at the right place and time to the right customers. The transformation of logistical processes through electronic means of collecting, moving, storing, and manipulating data, information and knowledge or e-logistics, will equip companies with greater agility to deliver customer-configured products and value added services faster than competition. Promises of configure to order, same day delivery of groceries, 2 day delivery of Tablets and 5 day deliveries for cars, need to be managed in a way that customer expectations are met while controlling inventory and transportation costs.

The competitiveness of the economies can be enhanced by adopting promising new technologies and next generation logistics thinking. In this report, we also underline the importance of logistics in the face of current trends in cognitive manufacturing, green consciousness, Cyber physical systems, Internet of things, on line retail, driverless trucks and home delivery using drones. Our focus here is on India logistics. For an emerging economy like India it would be difficult, given the resource limitations, to develop a globally competitive logistics infrastructure in one go. Hence, it is important to prioritize the focus of industry and government towards a phased development of selected industries and logistics sectors and regions.

4.3 ECONOMIC RELEVANCE OF LOGISTICS

The importance of logistics in the economy of a nation is established both, by the size of the logistics industry, and by its ability to transform and impact all three sectors of the economy: agricultural, manufacturing and services. In fact investments in logistics infrastructure and services have a multiplier effect on the entire economy of a nation. A good logistics network can reduce inventory levels in the industry, increase the market reach of companies and allow them to procure supplies from a larger base of suppliers, deliver products to the consumers through multiple channels including home delivery and be in constant touch with the customers through variety of e-commerce networks.

Logistics sustains all three sectors – agricultural, manufacturing and service - of the economy by providing life-supporting arteries that transport essential goods and services across the country. Furthermore, the competitiveness of the logistics sector and the three sectors of the economy are mutually reinforcing. An efficient logistics system can reduce costs for other sectors of the economy making their offerings globally competitive. In turn, increased demand for globally competitive products builds economies of scale for logistics operations.

Agriculture

The agriculture sector comprises of a number of inter-related value chains. The farm to fork supply chain starts with the farmer and ends with the retail shops. The manufacturing industry supports fertilizers, farm equipment and processed foods. Financial institutions, Insurance agents, government agencies and other organizations play important supporting roles as well. Given that these products are perishable and also subject to attacks by

pests, it is important that transport and storage of these items is undertaken with care. The Indian agricultural value chain is long and slow. Currently, the chain is full of inefficiencies introduced by various partners along the chain. There is also a lot of wastage at the interfaces in the chain. Agricultural trading and financing activities are also closely tied up with the logistics of agricultural produce.

Manufacturing

Global manufacturing is characterized by the staged production of goods by multiple companies across multiple countries and regions. Components may be sourced from several different regions, assembled in another region, and distributed to customers across the country and even across the world. Logistics plays a critical role in coordinating procurement, manufacturing and distribution in such a dispersed manufacturing environment. A well managed manufacturing logistics operation can help companies reduce the cost of transportation and minimize inventory, reducing the cost of inventory holding and freeing up capital. In fact leading companies have successfully employed logistics and integrated supply chain networks to minimize their costs and simultaneously improve and differentiate their product and service offerings to their customers. Supply hubs, Transshipment hubs, Cross docking, Clustering are some of the innovations in this arena. Currently the manufacturing logistics is undergoing sensor induced transformation.

Services sector

Logistics-enabled service chains arise in a number of different contexts. The service sector amongst others comprises of the financial, healthcare, retail and the telecommunications industry. A number of processes in these industries are closely related to logistics. For example, the goods sold through retail stores are delivered through an elaborate network of manufacturers, distributors and logistics service providers. Healthcare services involve coordination between multiple parties of doctors, hospitals, pharmacists, medical equipment manufacturers, medical consumables manufacturers, etc., all managed through systematic management of patient records. Logistics also supports after-sales repair and maintenance of goods and products. The after the sale service sector for aircrafts, automobiles, and other capital goods involves returns handling of defective goods, spare parts distribution for repair of spoilt items based on service level agreements, servicing of products over their entire life cycle and reverse logistics for disassembly and green disposal. The service logistics sector is at the cusp of big revolution.

4.4 TYPES OF LOGISTICS

We can classify logistics into three categories: Business-to-Business (B2B) logistics and Business-to-Consumer (B2C) logistics, and Service logistics. The B2B logistics is very important and forms about 80% of total logistical activity and is again divided into four distinct categories: *Manufacturing logistics*, which refers to the movement of materials from machine to machine on the factory floor, *Inbound logistics* which refers to the management of material movement and integration from component suppliers to a manufacturer/assembler, *Outbound logistics* which is the management of movement of final products from a manufacturer/assembler to the distributors and retailers and finally *Spare part logistics* which moves spare parts from the manufacturers to the service centres or dealers . B2C logistics can be divided in to two categories: *Retail logistics* which is the management of goods delivery from manufacturers/distributors/retailers to the end consumers and *Reverse logistics* which involves movement of used goods from consumer to the manufacturers for service or refurbishment. Finally, Service logistics is logistics in the service industry such as in construction industry, health care, etc. Logistics typically involves freight transportation via multiple modes, warehousing, material handling, packaging, inventory control, etc. Logistics activities are typically resource intensive and emit lot of gases and have high carbon foot print. In recent times, lots of attention is being given to improving the carbon foot print.

We thus see that logistics is product dependent and the requirements are different for each stage of the product life cycle. The logistics requirements of packaging, warehousing and transport are different for Oil and Petrochemical, Pharmaceutical, Electronics, Auto, Fruit and Vegetables, Flowers, Meat, etc. Also, for new products the inbound and out bound logistics play a significant role. For mature products reverse logistics is crucial. Spare part logistics is a big market in life critical applications such as IT servers in banking applications. The profit margins also vary, spare part logistics is more profitable than the inbound or outbound logistics. Also the profits from maintenance contracts of equipment and software far outweigh that of direct equipment or software sales.

The Logistics Function is to ensure the availability of right product at the right place, in right quantities and right condition at the right time and right cost for the right customer. To achieve this objective, integration and synchronization of material,

information and financial flows across supplier, manufacturer and logistics organizations is needed. Trading partner integration is important both at the application software and the business process levels. Logistics is a service function and countries are ranked by Logistics performance index based on their infrastructure and service levels.

4.5 LOGISTICS SERVICE PROVIDERS

Most manufacturers handle all logistics functions including trucking and warehousing through their own logistics or transportation departments. The outsourcing of logistics activities has been on increase. The second party logistics providers (2PLs) are basic transportation and storage providers such as truck owners, the rail operators, the shipping companies, the airlines, the freight forwarders, the warehousing companies, the packaging and distribution companies who have high levels of asset intensity but low barriers to entry. Airports and Seaports as capacity providers are also categorized as 2PLs. These companies are now changing their traditional business models and moving up the value chain. They now want to be "one-stop total end to end logistics solutions providers" offering multi-modal cargo carriers, trade documentation, financial support such as insurance, customs clearance and a host of other things. They are labelled as integrated third party logistics (3PL) company.

Recently a new category of logistics service providers called Lead logistics provider (LLP) or Fourth Party logistics providers (4PLs) came into existence. They orchestrate the logistics functions without owning any assets. A 4PL is a master contractor who manages an entire outsourced logistics network for a company. These LLPs are characterized by a broad scope of multi-modal services, global reach, complex management capabilities, and superior technological systems. The logistics provider's goal is to add value: engineering and consulting, transportation procurement, consolidation and aggregation of freight inventory management, customs brokerage, and tracking and order management. In countries like India, where are millions of owner-driver truck owners, family owned warehouses located in 29 states with differing regulations, 4PLs have a greater role to play and perhaps will be the model that will succeed.

Although logistics is performed mainly by private operators, its performance of the whole depends on such government interventions as infrastructure, customs and cross-border trade facilitation, etc. Supply chain reliability is a major concern for traders, logistics providers and Governments.

4.6 RECENT TECHNOLOGICAL INNOVATIONS IN LOGISTICS

Technology has brought several innovations into logistics. There are several recent technologies such as the internet of things, mobile, augmented realty, social media, cloud storage and computing which improve the efficiency of the logistics operations. They are in operation in some countries and India can easily adapt these for improving the supply chain operations. Here we consider recent technology innovation in various logistics segments.

The manufacturing factory floor logistics is fully automated using robots and guided vehicles controlled by agent based centralized software i.e. the parts that enter the factory floor are assembled as final products and are delivered as the factory output without human intervention. The factory floor is a cyber physical system using tags, sensors and embedded chips.

Several innovations are happening in the inbound logistics arena. Vehicle tracking and dispatch keeps track of the location and inventory on every vehicle. Annual traffic density figures are used to generate the most efficient routes to minimize the cost of transporting goods. Generation of routes and manifests for the trucks is dynamically based on their inventory loads and tracking and monitoring the delivery. Warehouse Operations and Cross docking use information system that dynamically coordinates trucks and the dock. Large trucking firms are adding data from new sensors-monitoring fuel levels, container location and capacity, driver behaviour, etc. to its logistical optimization algorithms. The goal is to improve the efficiency of the company's route network, to lower the cost of fuel, and to decrease the risk of accidents. Rio Tinto's driverless trucks moved 100 million tonnes in Australian mines. Driverless truck fleet is predicted to be a reality much before driverless cars. Penske logistics a US trucking company processes numerical, text, voice, past records of 5.000 trucks and equal number of drivers with the help of GENPACT, a BPO based out of Hyderabad, India.

Augmented reality (AR) can assist in loading, unloading, and handling merchandise, and inventory pick-up and allows employees to interact with animated stock. AR can achieve more effective

pick-ups. An AR-equipped collector could quickly glance at the load to check if it is complete. Currently, this requires manual counting or time-consuming barcode scanning with a handheld device. In the future, a wearable AR device could use a combination of scanners and 3D depth sensors to determine the number of pallets or single parcels (by scanning specific markers on each parcel) or their volume (using measurement devices). This measurement is compared to predefined values and the result – hopefully a match – will be displayed to the collector. This AR system could also scan items to detect any damage or faults.

In retail logistics, e-commerce is making a big come back via the mobile applications. Online retailing is on the rise driven by Amazon. In India, online retailing is making a big wave. There are a whole bunch of shopping sites in India and many are being launched on a monthly basis. People use these sites to shop for things from electronic gadgets, books to fashion apparels etc. Flipkart, Amazon, Ebay.in, Snapdeal, Shopclues, Myntra, Homeshop18, Yebhi, Tradus, Pepperfry are some of the companies doing very well. Following the lead of other e-commerce firms, online food and grocery stores such as BigBasket.com, ZopNow.com, EkStop.com and LocalBanya.com are launching their own brands for products such as fruits, vegetables, rice and pulses priced to compete with kirana stores (mom and pop stores). On the urban retail transportation side, Gogovan and Easyvan are start-ups in Hong Kong that provide a peer-to-peer app that connects van drivers with individuals or businesses who need their stuff shipped quickly. Amazon is experimenting package home delivery through drones.

There are several ICT applications that retailers are using to help attract the customers and also predict their needs and requirements. Retailers watch when shoppers come to the store, where they go, in what order, how long they stay and understand how all these map to actual sales. Recommender Systems help consumers by selecting products they will probably like to buy based on their browsing, searches, earlier purchases, and preferences. They use predictive models for discounting, advertising, and couponing.

Food companies that use IoT-connected testing equipment can confirm food quality as it leaves the factory or warehouse. Fleet managers can then leverage the IoT to make sure temperature-sensitive, perishable goods don't go bad in transit through sensor-enabled refrigeration systems. Any temperature fluctuations can trigger alerts that automatically adjust the truck's refrigeration. If the system is not able to auto-correct, an alert can be sent to the food supplier, who can replace bad goods before they arrive at the customer's dock. And by using an IoT-based fleet management solution to enable continual visibility into connected trucks, trucking managers can optimize routing and ensure on-time delivery of the new goods via an alternate vehicle. In the end, the customer receives quality goods on time and is never aware there was an issue. Plus, the sensor-enabled refrigeration system can send alerts to the manufacturer, pinpointing the exact part that broke down and facilitating faster replacement and fixes.

Service logistics has undergone revolutionary changes in recent times by shifting from the practice of maintenance being carried out on a set timetable or reactively to predictive maintenance. Using big data analytics, Aircraft will tell maintenance crews the status and which parts need replacement, maintenance engineers at GE can predict failure of gas turbines weeks' in advance using IOT information. Also 3D printing is enabling availability of service parts as per the original design as and when required.

The above innovations are supposed to be in practice soon. The technology innovations have implications in other areas such as passenger transport. **Autowale** in Pune and **mGaadi** are bringing Uber-like convenience to auto rickshaw riders in Pune and Bangalore. UberX in Bangalore, Delhi and Hyderabad, directly competes with startups such as Ola Cabs and TaxiForSure. Inrix gathers location information from millions of mobile devices and feeds information on traffic flow and optimal routes to drivers.

Social media for logistics

Social media is used as a tool to listen to, and engage customers. It can also be used as a way to share content and establish you as a thought leader in a specific market or niche. For logistics companies these benefits can run deeper that just a general improvement in brand awareness and leads. There are logistics companies already effectively using social media for a number of purposes:

a. Carriers such as FedEx and UPS are proactively dealing with customer issues and complaints through Face book and Twitter.

b. 3PL's are posting loads on Twitter to help find carriers to cover loads – and conversely trucking companies are posting the location of carriers looking for loads to haul. Many truckload owner operators are very active on Twitter.

c. A variety of logistics companies are engaging potential clients by posting educational and informative content on topics that matter to their customers which drives traffic to their website.

d. Some logistics companies are using social media to create social communities built around their core services, bringing clients and employees together into a virtual conversation

We can see more mobile apps being developed in this area in the very near future in India. The above innovations have implications in terms of future logistics industry and also for the future of the logistics service providers. In the past four decades, outsourcing has increased the logistics content in product manufacturing and delivery and this has lead to vertical trade and increased logistics infrastructure across the world. While these trends may continue at a slower pace, the technology innovations mentioned above are going to transform the logistics industry in a disruptive ways.

4.7 STATUS OF INDIAN LOGISTICS INFRASTRUCTURE

The logistics sector in India is an area of priority. One prime reason for the same stems from the reason that years of high growth in the Indian economy have resulted in a significant rise in the volume of freight traffic moved. This large volume of traffic has provided for growth opportunities in all facets of logistics including transportation, warehousing, freight forwarding, express cargo delivery, container services, shipping services etc. The strength of the logistics sector is the key determinant of the pace of future growth of the Indian economy.

Logistics processes in developed countries have been optimized and improved constantly in the past. Consequently, many transportation, handling and warehousing processes have become highly automated. In contrast, emerging countries are frequently characterized by very low labor costs and low levels of automation. Especially in the field of logistics, a large portion of processes in emerging markets are conducted manually. This practice may not be changed easily given the large number of small players in the sector.

In India nearly 61% of the cargo is moved by road, 30% by rail and rest by airway, pipelines and inland waterways. This is as compared to a 37% share of road in the USA and 22% in China. Movement of long haul bulk traffic by road is less efficient than by rail. In India, road has become the predominant mode of transportation of freight cargo because poor rail freight infrastructure such as low quality loading and unloading stations and lack of container trains on the railway network and Government policy of subsidizing and prioritizing the passenger tariff and traffic by freight tariff and traffic creating uncertain transit times. This is further compounded by Railways having a preference for customers who can provide full train load and cannot efficiently run mixed trains which can carry different types of cargo. About 89% of its freight traffic is contributed by major commodities such as coal, fertilizers, cement, petroleum products, food grain, finished steel, iron ore and raw material to steel plants. The balance 11% is other commodities moving in bulk and containers.

The Indian truck market is dominated low-cost trucks manufactured by local manufacturers. Only 10% of Indian truck operators own fleet of more than 25 trucks, and 1–2% own between 200–1.000 trucks. 80% of truck operators own less than 10 trucks. Majority of them are owner-drivers with a single truck. The Indian transport industry is organized by transport middlemen or goods booking agents. They do not own fleet and hire truck capacity from the smaller truck operators or owner-drivers.

Containerisation is the use of standardised intermodal containers for freight transport and is the single most important development in the evolution of multimodal logistics. Domestic container traffic constitutes about 20 per cent of the total container traffic. Capacity for container handling at the Major Ports is limited. The containerized freight movement by rail in India is provided by Container Corporation of India Ltd (CONCOR). Incorporated in 1998 CONCOR provides multi-modal logistics support for the country's domestic trade and commerce, with 44 out of 51 of the CONCOR terminals are linked by rail network.

Cold Chain is a critical component of the logistics chain in order to preserve perishable items and normally consists of pre-cooling facilities, cold storages, refrigerated carriers, and warehousing. A streamlined, well maintained cold chain helps to reduce costs, improve product integrity, increase customer satisfaction, reduce wastage and returns of expired stock. The total cold chain market in India is worth Rs. 21,375 million, which is equivalent to USD 475 million, of which the biggest chunks are emerging segments including ready-to-cook, ready-to-eat and ready-to-serve foods, followed by the ice-cream industry.

The third party logistics market is still in its nascent stages in India, facing issues such as lack of infrastructure (viz, warehouses and cold storage), lack of economies of scale due to unorganized private truck operators, and lack of efficient processes and automated, technologically advanced monitoring systems.

Creation of a central body to integrate and coordinate transport services of various modes will be a key strategy in development of a seamless integrated transport and logistics system. The government of India has realized the importance of infrastructure and logistics for the continued growth of the country and has been making reforms in policies and investing in building the infrastructure across rails, roads, airports and ports. The government has been giving impetus to the logistics sector by allowing 100% FDI, eliminating CST, introducing VAT, improving multi-modal transportation through projects such as dedicated freight corridor, encouraging public private partnership (PPP), and 100% income tax exemption for port development projects.

In Indian retail, Food and Groceries account for the largest share in Retail. In 2011, 'Food and Grocery' accounted for nearly 59.5% of total revenues in the retail sector in India; Clothing and Fashion followed with a share of 9.9%. In 2011, 48% of total household income in India was spent on food and groceries. Given this data, it will be prudent to improve the logistics involved in transporting and storing groceries, rice and food materials and eliminate wastage and improve the supply chain efficiencies. There are several government regulations such as minimum support price, essential commodities act and the APMC act which actually increase the inefficiency of the supply chain. With online retail an increasing trend, this sector needs attention both for deregulation as well as for logistics innovations.

As we have seen above physical infrastructure is only a third or fourth of the logistics requirement for efficiency. The IT infrastructure, connectivity, analytics, mobile applications connecting stake holders, Cloud infrastructure, SaaS, LaaS, social media, trade facilitation, integrated shipment planning from origin to destination including the transhipment ports, driverless truck fleets, cyber security and above all the talent to discover, produce and manage all these applications are the rest of the requirements. *How much of the physical infrastructure is essential and can the ICT replace or substitute some of these is a big question that needs to be answered*. For example 3D printing reduces the service logistics, Social media can improve empty truck returns or half truck loads, home delivery can reduce the retail inventories, trade facilitation and quick customs clearance can reduce the warehouse inventory, etc. This requires close examination and research.

Today, logistics faces complex challenges: International trade and urbanization are constantly increasing, while the utilization of existing infrastructure capacity is approaching its limits. Energy efficiency has become a considerable factor for global logistics, since transportation accounts for more than 60% of oil usage worldwide. Dwindling resources, unpredictable fossil fuel prices, and the growing impact of climate change are reshaping the logistics industry. Thus, current trends in logistics strive for the mitigation of resource consumption and emissions while maintaining high-performance efficiency.

We see from above, that logistics operations are influenced by government policies, regulations such as Green, Taxes, Customs, Trade facilitation, ICT Interactions between various actors, human, financial and industrial resources such as water, power and oil in addition to the infrastructure. To study further about the performance, risk and governance, we use the ecosystem framework developed in[1].

4.8 INDUSTRY CLUSTERS IN INDIA

India has several well developed industrial clusters in apparel, leather goods, auto components, biotech research and manufacturing, software technology parks. Here we are concerned about the auto clusters in India particularly in the Bombay-Pune region, National capital region (NCR) near Delhi and in Chennai. The automobile industry, because of its large backward linkages, greatly influences the pattern of economic development in almost every country and every region that produces cars. The automobile sector has grown remarkably since the 1980s, to become one of India's leading manufacturing industries. In India, auto clusters are in three regions: Chennai, NCR region near Delhi and Pune.

Chennai Auto Cluster accounts for 21% of passenger cars, 33% of commercial vehicles and 35% of the auto components produced in India. At present, over 100 medium and large auto companies are located in and around the Chennai cluster. With regard to infrastructure, Chennai has an international airport and two sea ports; the second one was recently constructed at a distance of 25 kilometers from the city. The emergence of the IT

[1] Viswanadham/Kameshwaran 2013.

industry in Chennai and Tamil Nadu and the rapid development of the internet infrastructure have helped small and medium firms to globalize and take advantage of B2B commerce. The human and physical infrastructure provided by the government and the presence of large component manufacturing firms attracted global firms like the Ford, Hyundai and Mitsubishi to set-up plants in Chennai. The arrival of these firms had a major impact on the Chennai auto cluster resulting in a radical restructuring of the industry. Till the early 1990s, Tamil Nadu was mainly producing components to the Indian market. Several Chennai-based firms, which are mostly Indian conglomerates, have played a critical role as lead firms in the development of the Chennai auto cluster, including the TVS Group, the Rane Group, and Ashok Leyland Ltd. The component manufacturers-led formation of the Chennai cluster Assembler firms started playing leading roles in cluster development only after the global players such as Hyundai, Ford, and Mitsubishi came to Chennai.

The auto cluster in the NCR was mainly created by a single assembler firm, Maruti Udyog Limited (MUL). As an anchor firm, MUL was motivated to actively develop its first-tier suppliers by various policy factors, such as the requirement to increase local content, mandated by the Indian government; high duties on imported parts; and the reservation of various items for production by the domestic small-scale firms. In both clusters, the state government actively intervened in the creation of industrial estates, which helped many small firms to locate in the clusters, and the development of infrastructure.

Pune's proximity to Mumbai, India's commercial centre with a seaport and an international airport made it a favorable destination for commercial activities. It has significant opportunities to emerge as a global player in specific sectors given focused strategic planning. Pune also offers well-qualified talent, abundant skilled IT manpower and better living standards, to name a few. Today, Pune is the seventh largest industrial metro of the country.

Pune is a major industrial centre, particularly for automobile manufacturing. It is home to one of the world's largest two-wheeler manufacturers – Bajaj. Tata also has its plant here. Mercedes Benz also has an assembly line. Whirlpool has an appliance manufacturing plant near Pune. Some of the big names in Auto Components and auto Aggregates are in Pune. Tata established a cluster called the Tata Auto Component at Pune which include companies like: Tata Yazaki, Tata Toyo, Tata Nifco Fasteners, TC Springs, and Tata Yutaka. Pune also has also a burgeoning software industry with many of India's major software players such as TCS Infosys and Wipro and global majors like SAS, Veritas Software, and BMC.

The industrial clusters have inbound logistics embedded within them. The outbound transport of the finished vehicles to the dealers in various states across India poses its own challenges of damage, theft of spare parts, customs regulations at state borders and host of other issues.

4.9 ECOSYSTEM FRAMEWORK

The ecosystem framework for any supply chain or service chain is introduced in categorizes the various entities under the following four major categories[2]:

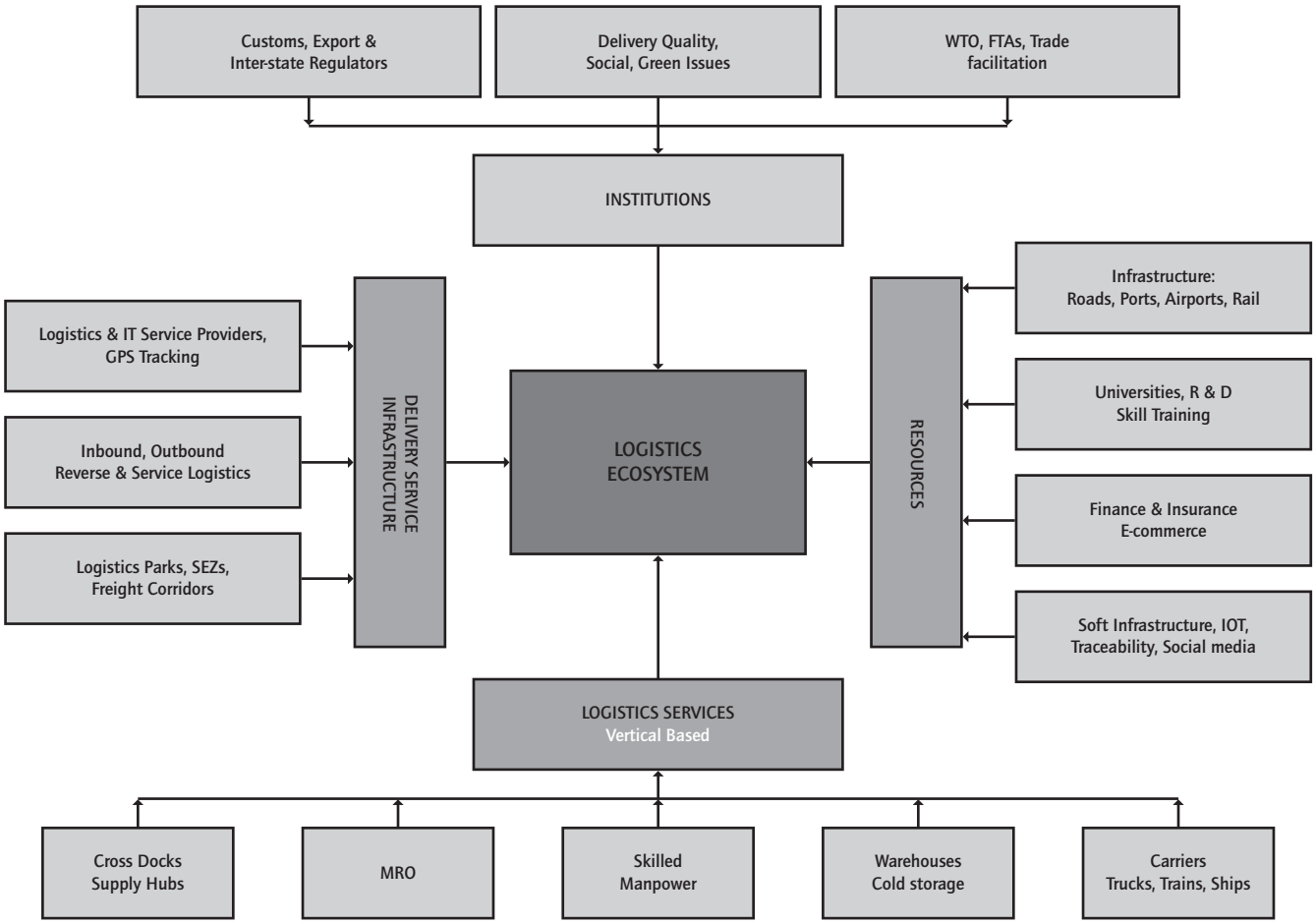
1. Logistics service chain
2. Government, Social and Business Institutions
3. Resources: including Human, Natural, Financial and Industrial
4. Delivery Service infrastructure

The items 2–4 together are termed as Investment climate and are determined by the political, economic, resources such as water, power and finance, logistical and IT infrastructure, human resources, trade regulations and industry clusters. For services growth and also to attract foreign direct investment it is important to have the proper investment climate. For example for IT services, the Indian government has given tax breaks, created SEZs and software technology parks, opened more IIITs for generating manpower, encouraged creation of IT training centers awarding certificate courses and launched NASCOM as a representative organization for the IT industry.

Studies find that differences in logistics performance are driven only in part by poor quality of physical infrastructure services such as road, rail, waterways, port services, and interfaces. Instead, the inadequacies often are caused by (non-tariff) policy and institutional constraints – such as procedural red tape, inadequate enforcement of contracts, poor definition, and enforcement of rules of engagement, delays in customs, delays at ports and border crossings, pilferage in transit, and highly restrictive protocols on movement of cargo. Figure 1 shows the ecosystem for logistics services. This is valid for any country and gives a one page view of all factors that makes the international logistics work.

2 Viswanadham/Kameshwaran 2013.

Figure 1: The Logistics services Ecosystem



In India, opportunities for investment exist in all the 29 states and 7 Union territories. Some states have more advanced infrastructure. Maharashtra, Delhi, Tamil Nadu, Karnataka, Gujarat and Andhra Pradesh are the top six attractive FDI destinations. Mumbai, Chennai, Kolkata, Cochin, Visakhapatnam and Ahmadabad are favored locations for industries requiring sea transport. Delhi has good air transport facilities. However, there are large numbers of manufacturing and service industries already in operation in those cities and they are already very congested. Crowded cities attract companies for setting up operations in the name of backward-forward linkages, human and financial resource availability. Among other states West Bengal and Orissa have recently seen some investment activity over the last few years. Nagpur is going to be a highly attractive regional multi-modal hub of the future.

However, because of the interconnected nature, global logistics and transport networks are often "reliant on thousands of independent suppliers and partners located in many countries". Consequently, they affect and are affected by risks at various stages, from the sourcing of raw materials to the destinations of goods and services, and these risks are not always within the confines of the company's control.

Logistics Network Risk

Network industries of critical infrastructures – electricity, transport or communications- have the features of connectedness, large size, and loose governance structures. These *systems of systems* are subject to systemic risks. Connectedness makes individuals and organizations accessible over distance.

Logistics Network Risk: Definition: "Any changes in the information, material and financial flows of the logistics network – deviation, disruption, disaster – due to events in its ecosystem (anywhere in its path or its network partners or in the industry vertical or in the economic environment) "

These changes affect the service quality of on time delivery, create mismatch between supply and demand or affect the logistics process functioning, efficiency and output and sometimes company closure. The financial crisis in the US in 2008 has resulted in trade collapse during last quarter of 2008 and first quarter of 2009 which in turn affected the shipping logistics. Companies doing business on an international scale must assume that disasters will occur, even if the probability of their occurrence is low. In a connected world, causality is not linear but net-like; even small risks can have unpredictable impact on the supply chain in remote areas and can cause long-lasting disruption.

The logistics risks can be classified under the four ecosystem elements. This kind of classification allows one to detect the sources of risk and help in formulating mitigation strategies appropriately. We mention the risks below. It is important to realize that risks are time dependent and also vertical dependent.

- **Logistics services risks**
  - Location risk: weather, environmental problems
  - Outsourcing risk: partner risk, breach of trust
  - Delays or bankruptcies of suppliers
  - Sudden loss of demand due to economic downturn, company bankruptcies, war
  - Delay or unavailability of either inbound and outbound transportation to move goods due to carrier breakdown or weather problems
  - Breakdown of power, water, warehouses and offices.
  - Terrorist attacks such as Somali pirates

- **Resource related risks**
  - Poor infrastructure , labor unions
  - Credit squeeze, energy , water and talent shortage
  - Social unrest, war, natural calamities
  - Raw material : price increase, diseases in live stock, contamination

- **Institutional risks**
  - Regulatory risk: foreign exchange volatility , customs delays, antidumping, taxes, protectionism
  - Trade agreements, VAT, voluntary export restrictions
  - Political: gov. changes, center -state relations, environmental issues, corruption,
  - Labor unions, NGOs, social interest groups
  - Preference to source from domestic suppliers during downturns because of trust or financing problems and protectionist policies

- **Delivery infrastructure risks**
  - Failure of IT infrastructure due to network, hardware or software failures or virus attacks, or natural disasters leading to the inability to coordinate operations
  - Cyber Security: biggest risk of connectivity
  - SC Visibility Failure
  - Inbound and outbound logistics failures
  - Lack of execution or governance mechanism
  - Piracy: Somali pirates have expanded over the years 2006–10

The above list gives us almost all possible risks that will affect the performance of the logistics network.

Risk response strategies

Design of resilient logistics networks is an important topic and should be studied for each of the industry verticals. We have discussed above that risk sources can arise from any of the four ecosystem elements. Risk transmission and amplifications are also possible. Also, in globally dispersed supply chains disruptions occur almost every day in one country or one city or other. Risk mitigation in our opinion should be a part of regular operations rather than after the event intervention as is practiced today. The operations manager is familiar with normal conditions and also how an abnormality arises and should be tasked to handle the abnormal conditions.

Strategies for a government, corporation, or individual to reduce overall risk exposure include

a. Avoid the risk whenever possible. Not sourcing from countries with possible war or weather problems or from companies with financiers who are in trouble are examples.

b. Mitigate the risk directly by improving flexibility – to attempt to reduce the impact or likelihood of the risk at source. Dual sourcing is an example.

c. Adapt to the risk by preparing for its occurrence. For instance Earth quake resistant building construction, Quick evacuation in case of floods.

d. Transfer the risk to a third party such as an insurer, or through more sophisticated hedging strategies.

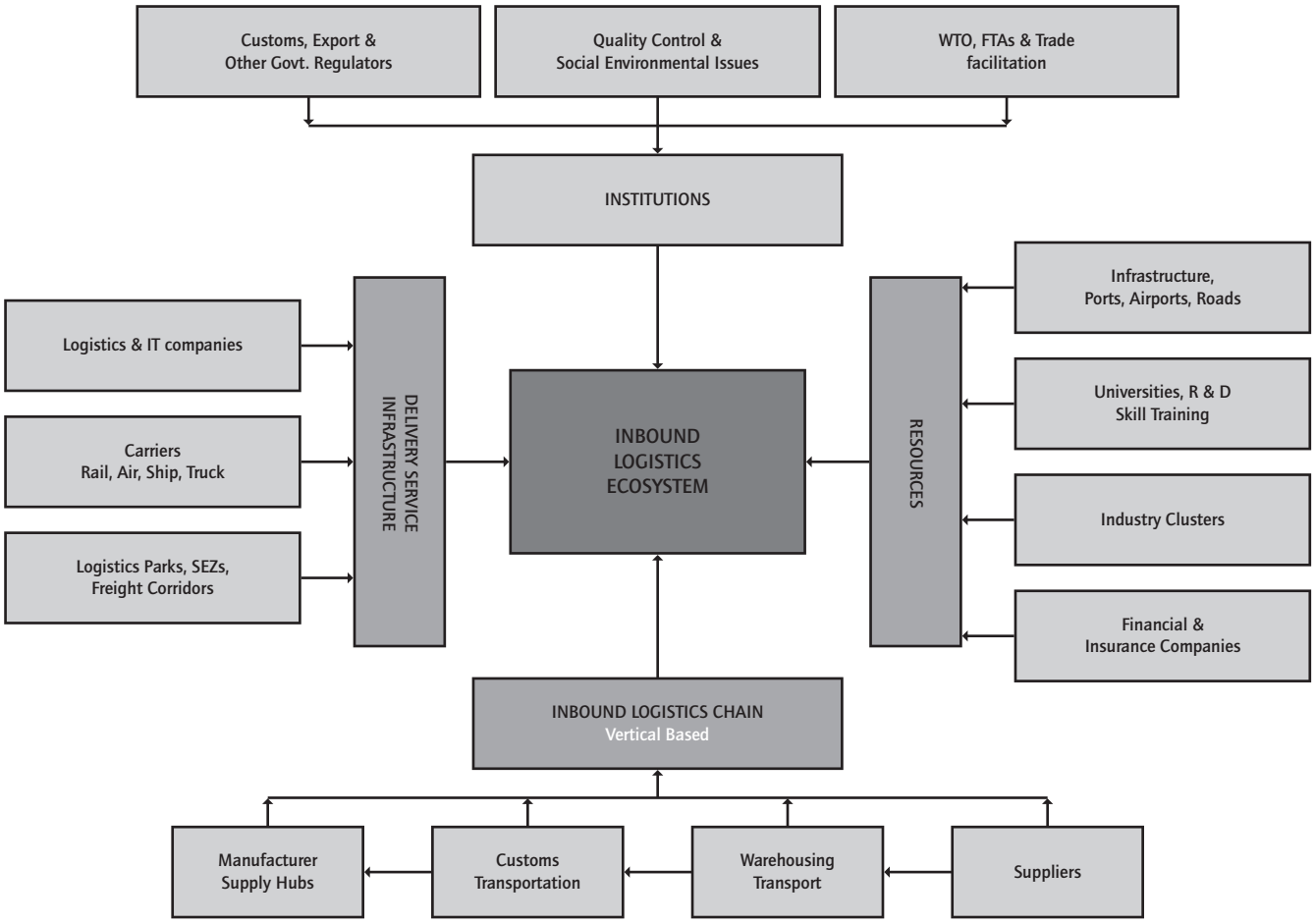
e. Mitigate the risk using order based Governance which involves: partner selection, coordination and monitoring and execution. Here, for each order, based on the state of the ecosystem elements, the 4PL selects the logistics partners for each order to minimize the risk before the order completion.

No supply chain strategy will eliminate risk, and if one tries to eliminate it the cost would be too high. The managers can and should excel, however, in identifying, quantifying, and preparing for the new realities of risk. The organization or individual should make provisions to deal with the possible consequences. Determining whether greater resilience is worth the extra cost is part of the new strategic economics. We discuss the Governance to reduce risk in section 13 in more detail.

4.10 INBOUND LOGISTICS ECOSYSTEM

Inbound logistics which refers to the management of material movement and integration from component suppliers to a manufacturer/assembler. This is a part of the procurement function which has in recent times has gone global. The inbound logistics function therefore includes warehousing at the supplier

Figure 2: Inbound Logistics Ecosystem



and manufacturer ends and also transportation from supplier to warehouse and to international transport via sea or air. It is an important function that affects the inventory held, the timeliness of the manufacturer's schedules, etc.

The Ecosystem shows all the actors influencing the effectiveness and efficiency of the inbound logistics function. The Institutions play a significant role while the freight is crossing the borders. The port and airport infrastructure the availability of the software and other logistics players also are factors for the efficient functioning of inbound logistics vertical. The logistics function is executed by the logistics players called the Third party logistics companies. Some companies have their own logistics departments. There were several innovations such as supply hubs, where the component or subassembly inventory is held by a third party at the suppliers cost nearer to the assembler site.

Globally distributed supply chains mean more facilities, infrastructure, suppliers, and product variations, numerous and fragmented sales channels, and increasing regulatory and transportation security requirements. The complex webs of interactive relationships in a global economy inevitably generate long-lasting catastrophic disruptions. Companies doing business on an international scale must assume that disasters will occur, even if the probability of their occurrence is low. In a connected world, causality is not linear but net-like; even small risks can have unpredictable impact on the supply chain in remote areas and can cause long-lasting disruption. Global uncertainty and increasing volatility require flexible asset management, reduction of fixed costs, greater scalability, increased network elasticity, capacities, and capabilities, and development of smart business networks.

Procurement involves several interrelated business processes including order management; payment processing; warehousing; transportation and delivery; and after sales services (returns, repairs, customer service). Companies need to focus on both the back-end processes as on the front-end processes. Efficient relationships among supply-chain partners create the need for companies to get deeper into each others' business processes and to connect their enterprise systems. The software systems are not isolated stand alone silos, but area part of broader solutions and integrated with transportation, logistics, supply chain management and other enterprise applications. When orders are executed, managers optimize, plan, schedule and manage goods movement domestically and internationally with the ability to re-plan and reroute orders as needed.

Because of this, most global enterprises aim to bring sourcing and production facilities closer to customers; for example, they may switch from the low-cost production capabilities of outsourcing and off shoring back to more individual strategies such as intelligent sourcing and X-shoring. This changes what's required of logistics network organization and supply management – more raw goods must be transported over long distances and finished products may have to be distributed via different channels or delivered individually to end consumers.

4.11 INNOVATIONS IN THE INDIAN LOGISTICS

Located midway between the Australian, Middle Eastern and European continents, India can play the role of a transhipment hub, a knowledge services hub, and a food hub for the oil rich Middle Eastern neighbours. Indian organizations can also leverage the geographical position and resources to gain sustainable advantage as a manufacturing hub, education hub, after-sales service hub, etc. to meet local as well as export demands. There is a tremendous opportunity for building the distribution backbone for the country connecting the various demand points along the path of goods flow which is the future railway and roadway corridors such as the golden quadrilateral, freight corridors etc. These will improve the supply chain efficiency in India.

Logistics Service Innovation: ICT enabled customs clearance, sensor networks for visibility, new canals like Suez or Panama canals to shorten distances,

Institutions: Green, VAT, customs, trade, knowledge, connections, foreign exchange, free trade agreements & trade facilitation, city logistics,

Delivery Services Infrastructure: Home delivery, IOT, GPS, orchestration, data integration and mining, remote monitoring, Service providers,

Resources: Training and other HR approaches, efficient operations with poor industry inputs, supply chain finance, innovative governance models, Logistics research, IOT technologies.

Innovation usually co evolves in a cycle. For example, the availability of smart phones allows on line ordering of groceries, this creates a boom in on line retail and a need for home delivery

of large number of small items. This process started with books and electronic items and got extended to food and groceries. Thus e-commerce is creating a boom for e-logistics and the performance of e-logistics companies determines the success of on line retailers. In the future, the traditional stores in cities or outlet centres will be lean stores which will not hold large quantities of stock of every product in every size and every colour, but will focus more and more on providing customers with experiences such as look and feel, touch and smell, and – last but not least – the thrill and emotion of shopping. Thus e-retail will transform the appearance of city centres and shopping malls in the very near future.

Another example is the Cluster development. The auto cluster in Delhi region was initiated with the policy deregulation of permitting the Maruti Ltd to collaborate with Japanese companies and providing all the land infrastructure and resources by the Government. All the suppliers were invited to set up businesses. Now Maruti is a leading car manufacturer and NCR region has a big auto industry cluster.

4.12 POSSIBLE TRENDS FOR THE INDIAN LOGISTICS INDUSTRY

Looking ahead, we see two opposite trends possible and happening. The first model is the current vision of most companies and the second one is probably the most suitable when large numbers of small players are involved and also goods have to cross several regions.

Scenario 1: Integrated logistics
Integrated logistics companies provide cost-effective solutions to manufacturers and service industries through value-added services, economies of scale and investment in IT and tracking systems. Outsourcing of logistics activities to third party logistics (3PL) players will be a key growth driver as companies feel the pressure of reducing costs. We see more and more DHLs in this scenario.

Scenario 2: Modular logistics service providers
Indian logistics consists of large number of small players who are self employed. One has to build a business model that creates efficiencies and scale using these small players. The logistics Industry should be considered as a modular cluster or stacks populated by specialist firms and infrastructure authorities. It is like a logistics mall where services can be procured and integrated as needed.

In Figure 3, the logistics industry mall divides activities into layers that are complementary to each other. Most companies specialize in one or a few layers and rely on other companies to offer complementary components by communicating through standard interfaces. The first layer consists of the infrastructure such as ports, airports, rail and road, logistics hubs and free trade zones. The second and third layers contain the carriers and warehouse and distribution channels. The fourth layer consist of software providers and the fifth the logistics service providers. Sitting on the top are OEM, lead logistics providers, Regulators etc who are making decisions and assisting in execution.

The governance structure is to be chosen to for manage the logistics operations by selecting the appropriate players for

Figure 3: The Logistics Mall

OWNERS/ REGULATORS	OEM	4PL	CONSULTANTS	SOFTWARE PROVIDERS	REGULATORS
Service providers	3PLs	Clearing agents	Customs	Trucking companies	Auditors	Call centers, BPO
Software providers	WMS	TMS	Trade facilitation	GPS	IOT Technologies
Storage	CFS	Warehouse, Distribution centers	Transshipment hubs	Supply hubs	Cross Docks
Carriers	Ships	Aircrafts	Wagons	Trucks	Cranes	Moving Equipment
Infrastructure	Ports	Airports	Rail Freight	Road Freight	Logistics hubs	Free trade zones

each order. In this way, the current logistics players could be encouraged to modernize using new technologies and integrate themselves into the country's logistics network. Also, this leads to the innovative architecture which is an efficient national and international logistics network using the existing players.

4.13 GOVERNANCE OF THE LOGISTICS NETWORK

In India there are millions of very small players with one truck and two trucks or a warehouse or a family owned distribution centre. They may not be IT enabled but the scenario is changing with wireless technologies. A few large 3PLs such as GATI, TCS, SICAL, etc make things happen in the 3 PL space. Most of the shippers do not have logistics connectivity and use private players. The train is cheaper than truck but hauls mostly the government freight such as the iron ore or the food grains.

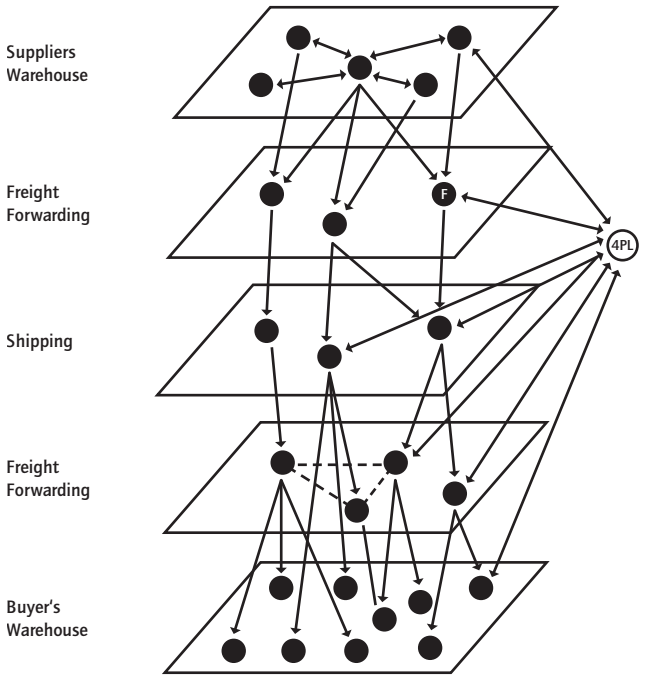
There are two general types of global logistics networks associated with production networks, the procurement-driven inbound logistics, retailer-driven outbound logistics chains and the network driven orchestrators. In inbound logistics networks and outbound logistics, the lead firm a 3PL, plays a central role in exercising relatively close control in coordinating a geographically distributed network of trucking companies, warehouse owners and suppliers. The 3 PLs own all or some of the assets and coordinate the goods flow through transhipment, cross docking, supply hubs etc. In the second model, called the orchestrator model, the orchestrators who do not own any assets connects with all the players in the logistics mall shown above and plans and executes the logistics functions. As we have seen above, in the Indian logistics scenario which consists of large number of small players who are self employed, the orchestrator model, which builds a business model that creates efficiencies and scale using these small players is well suited.

The orchestrators know their customers' supply chains in great detail. To cater for the customer need for predictive risk assessment, two things must be linked and continuously checked against each other: A model describing all elements of the supply chain topology, and monitoring of the forces that affect the performance of this supply chain. Data on local developments in politics, economy, nature, health, and more must be drawn from a plethora of sources (e.g., social media, blogs, weather forecasts, news sites, stock trackers, and many other publically available sites), and then aggregated and analyzed. Most of this information stream is unstructured and continuously updated, so Big Data analytics power the retrieval of input that is meaningful in the detection of supply chain risks.

Robust supply chains that are able to cope with unforeseen events are a vital business capability in today's rapidly changing world. In addition to a resilient and flexible supply chain infrastructure, businesses need highly accurate risk detection to keep running when disaster strikes. With Big Data tools and techniques, logistics providers can secure customer operations by performing predictive analytics on a global scale.

A generic business model diagram for in-bound logistics orchestrator is shown in Figure 4. The Orchestrator receives orders from the manufacturer for materials procurement, and then seeks information on the operational status from its execution partners namely the suppliers and the logistics companies. It uses this information to generate plans for the movement of goods in the procurement chain which are transmitted to partners. Once the goods reach the manufacturer, the manufacturer initiates payment to the orchestrator for the product or service delivered.

Figure 4: Logistics Orchestration model



Similarly, examples of orchestrator business models in outbound logistics and the service logistics can be developed as well. The competencies that are common to all orchestrator are relationship management, business analytics and decision making capabilities.

Network orchestrators are firms that does not own assets and their basic role is coordinating and integrating activities along a given value chain. Because they own fewer assets and leverage the resources of partner companies, network orchestrators generally require less capital and often generate higher revenues than traditional firms. Connecting to competencies is the core competency of the lead logistics providers or orchestrators.

4.14 MATHEMATICAL MODELS FOR DESIGN OF GOVERNANCE MECHANISMS

In the above orchestrator model, a separate logistics chain is formed for each order. This involves three functions

1. **Partner selection** based on both structural features (asset specificity, capabilities) and relational ties (with governments, social organizations, cluster managements, etc.)

2. **Coordination:** Once partners are selected, coordination involves determining who does what and when and communicating to everyone

3. **Execution:** Monitor order status so that processes work as per plan & control exceptional events

The partner selection problem can be formulated as Fuzzy AHP or MIP problem. One can rank order the suppliers for each component based on the ecosystem parameters based on the transaction costs. Coordination, scheduling problems can be formulated as mixed integer optimization problems and solved some standard packaged software. Expert systems, decision support systems, case based reasoning and hybrid control systems are useful for exception management and execution

4.15 INDIAN RETAIL INDUSTRY

The retail sector of India is now among top five fastest-growing markets globally and by 2015 it is going to touch US$637 billion. Most of it is going to be through modern retail i.e. through shopping malls, which is expected to increase by 22 per cent by 2015. By 2015. The 500 malls are going to be operational in India.

The e-commerce market in India has grown by 34% in the last seven years, was about US$ 600 million in 2011–12 and is expected to touch US$ 9 billion by 2016 and US$ 70 billion by 2020. The key factors that are driving this growth are the rise of Internet usage (growing at 20%) and 3G penetration, and increasing smart phone users. It is estimated that currently there are 27 million mobile Internet users in India, out of which 4% are buying products on mobile. This figure is expected to increase to 20% mobile shoppers in the next four years.

The key challenges in the Indian Retail Industry include

a. **Real Estate:** It is difficult to find suitable properties in central locations for retail at reasonable prices posing a challenge to the growth of organized retail sector.

b. **Industry Status:** The retail sector does not have a industry status yet making it difficult for retailers to raise financing from banks to fund their expansion.

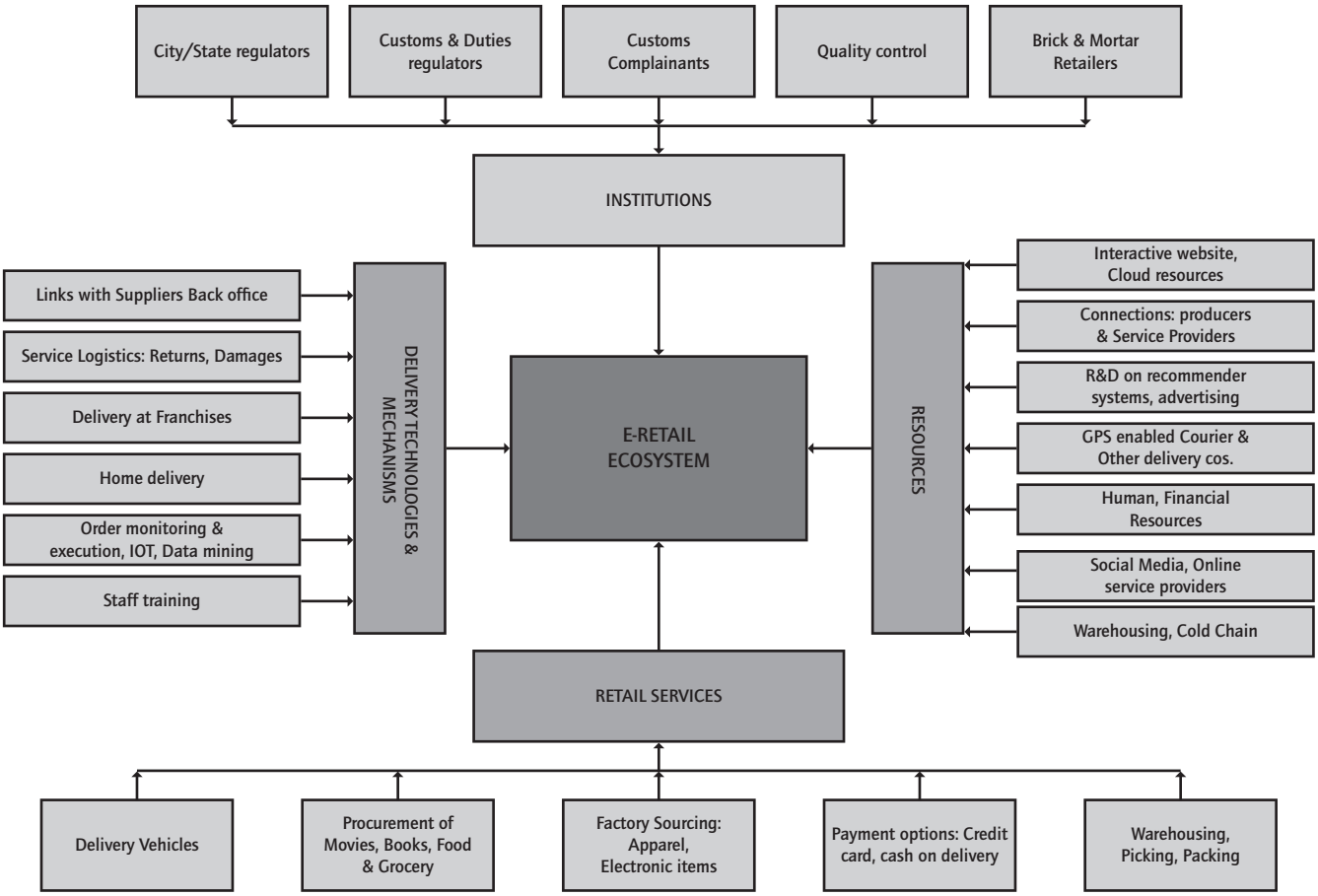
c. **Inefficient Supply Chain:** The supply chains are inefficient and are not well managed. Improving supply chain and logistics will enable retailers in India to significantly enhance overall competitiveness and deploy growth initiatives.

d. **Shortage of Skilled Manpower:** There are very few courses specific to the retail sector offered at educational institutions in India. Also, in the dominant unorganized sector manpower is not equipped with basic retail specific customer service skills

e. **Shrinkages:** Retail shrinkage is the difference in the value of stock as per the books and the actual stock available in the shop. The causes of retail shrinkage are mainly employee theft, shoplifting, administrative errors and vendor fraud. Effective online monitoring system need to be implemented.

Physical dispatch capabilities, minimising order processing errors, providing secondary in-city distribution channels and embedding technology into the entire transaction is the only way to survive.

Figure 5: Online Retail in India



The online retail ecosystem shown in Figure 5 which presents all the services it provides and the resources, regulations and delivery issues it needs to address.

Online retail is booming in India. Flipkart.com, India's largest online retailer went live in 2007 and since then has grown rapidly with the introduction of innovative features such as collect money on delivery, 30-day replacement guarantee and having its own delivery network. Today its product portfolio ranges across 14 categories from books to music, mobiles, computers, cameras, home and kitchen appliances, TVs and home theatre systems, personal and healthcare products, and the newly launched stationery items. The site ranks among the top 30 in India and receives more than 12 million visits every month. Flipkart manages its own warehousing and logistics.

We feel that e-retail has high potential in India particularly in the big cities. The retail logistics in large cities could become vastly different with customers buying goods online looking for both price advantage and convenience. Some market leaders offer food fresher than conventional supermarkets through continuous cold-chain and direct delivery from the producer's site via a standard parcel network. Demand is constantly growing, especially for home delivery of fresh and frozen food. This requires the development and implementation of special delivery processes and smart, reusable, and recyclable packaging.

4.16 URBANIZATION AND LOGISTICS

Today's cities offer employment, education and healthcare to many of their citizens. The megacities of tomorrow also promise

unprecedented lifestyle opportunities. It is widely estimated that by 2050 the world's population will reach 9 billion, with 70% of people living in urban agglomerations. All cities are concerned with flows: of people, vehicles, goods and services, waste, energy and even data – all necessary to enhance cities' liveability and growth. Traditionally, the answer to this challenge has been investment in fixed assets: such as roads, railways, housing complexes and shopping centres. Scarcity of space leads to the "verticalization" of business districts and residential areas, posing different types of retail logistics challenges. City logistics dealing with freight transport within the city and waste management is an important topic that needs attention in India.

4.17 INDO-GERMAN TRADE: STATUS AND OPPORTUNITIES

It is often said that India wants German Machinery, Germany wants Indian Textiles. India imported Machinery worth 726 Million Euros during the first quarter of 2013 (over 30% of total imports). Electro-technological products formed the second-most important category, with imports amounting to 293 million Euros and a share of 12.2%.

Textiles remained the most important Indian exports to Germany, with 503 million Euros (share of 28%), Chemicals followed with a volume of 278.4 million Euros and a share of 15.5%. Metal & metal products, food, beverages and tobacco follow next.

India was Germany's 24th largest trade partner in 2010. India has seen a lot of foreign direct investments (FDI) from Germany and with a cumulated FDI volume of approximately $4.3 billion it is India's 8th largest source of FDI.

Creating a German brand in India

Till date, the economic relations between India and Germany have been strategic in nature. Both countries are democracies with a federal-structure and share a broad range of similar values as well as common views on international issues. German companies have an excellent reputation in the world, as they do in India. "Made in Germany" represents a seal of quality that stands for innovation and cutting-edge technology.

The top five most popular brands with the highest awareness are sportswear bellwether Adidas, consumer goods brand Nivea, insurance player Bajaj Allianz. Automotive brands BMW and Mercedes-Benz. Most Indians associate German brands mainly with the automotive industry. Machinery (49 per cent), pharmaceuticals and medicine (43%), home appliances (42%) and football (39%) follow.

Indian consumers from the upper middle class and higher income segments rank German brands highest on the attributes of excellent quality, high durability and outstanding design. However, brands of German origin are too costly for local customer needs and customers favour Indian brands that they find to be better value for money, providing good after-sales service.

Global companies across IT, telecom, biotechnology, chemicals, automobiles, consumer goods and pharmaceuticals have set up their R&D hubs in India. Global pharma majors are increasingly outsourcing parts of their drug development and manufacturing activities to India.

India offers tremendous market potential for food products, consumer goods and organized retailing. India is second largest food producer, as it is endowed with a large production base for a variety of raw materials. German companies are expanding their operations to India across various areas of the Indian food industry ranging from food technology and to ready meals. German retailers can source from India following Wal-Mart, Tesco etc. German wholesaler Metro cash and carry has operations in Bangalore and Hyderabad.

There are huge possibilities for India and Germany to strengthen cooperation, including in the defence sector. India wants to achieve its objectives of a more self-reliant defence industry and armed forces equipped with the latest technology to meet future challenges. .India could long-term strategic partner with Germany if technology transfer is offered through FDI. Also Cooperation in space technology and aviation would be immensely beneficial. ISRO launches satellites for other countries and India has huge demand for airplanes, servicing and also in training the staff in service sector.

Going forward, both India and Germany are likely to be key beneficiaries of the rising Indo-Europe trade. Germany's central location in the EU and well-developed infrastructure is encouraging Indian logistics players to make Germany a distribution centre for their European operations. Similarly, India's emergence as a competitive production and sourcing hub has global logistics players to establish an India presence.

4.18 RECOMMENDATIONS

A country's economic growth depends on the availability of a robust and seamless multimodal logistics infrastructure. Transportation, warehousing, handling of material, inventory management and order processing are the major logistics activities, which impact the customer cost and operation. The speed of the movement of goods depends to a great extent on the various modes of transportation like rail, road, air, and sea. An integrated approach to logistics i.e. multimodal logistics and soft infrastructure helps in reducing costs and enhancing the customer service level.

Logistics in India is dominated by a large number of fleet operators and warehouses and therefore small capacities and poor technologies. In addition, poor maintenance of equipment and facilities including roads result in low average trucking speed of 30–40 Kilometers per hour, overloading of trucks, inefficient turnaround times at ports and airports and poor intermodal connectivity. Further, the Clusters and manufacturing plant locations are now at the forks (Delhi, Chennai, and Mumbai), not at the hubs creating need for outbound logistics i.e. Finished Goods transport. All these issues hinder an efficient multimodal logistics network around the country. Despite these issues, logistics has a bright future in India.

The manufacturing and logistics scenarios are changing very fast with evolution of new technologies such as IOT, augmented reality, social media, mobile and cloud etc. With these developments in ICT, the logistics infrastructure requirements also change rapidly. To improve the logistics, India can redesign the existing network using ICT technologies. An infrastructure alternative could be high speed rail freight network with cross docking and distribution facilities at the railway stations. The distribution centers could be located nearer the railway stations and also outside the cities following the path of goods flow principles[3]. The Cities where distribution centers are located act as hubs for distribution using the road transport.

Along with growth and infrastructure development, emphasis should be paid on sustainability and use of strategies and technologies that reduce carbon footprint and toxic air emissions. The multi modal approach will use the existing rail road infrastructure and has significantly less carbon foot print. The local distribution from Hubs to the retailers can use technologies that offer promise as effective means to achieve a reduced carbon footprint include electric vehicles and alternative fuel technologies like LNG and biofuels. For overseeing the development of a seamless integrated transport and logistics system, creation of a central body to integrate and coordinate various modes is essential.

The impact of digital technologies is being felt differently from country to country, from vertical to vertical and from firm to firm.

At the **national level** the economy must be digital technology "ready" before digitization of the end to end supply chain can take off.

- Development of high speed rail freight network with cross docking and distribution facilities along the path of goods flow.
- Reshape the logistics industry taking into the dwindling resources, unpredictable fossil fuel prices, and the impact on climate change
- Physical infrastructure is only a third of the logistics requirement for efficiency. *How much of the physical infrastructure is essential and can the ICT replace or substitute some of these.*
- Encourage research in digital technologies for logistics and supply chain at the Universities through the government funding agencies.

At the **industry level** the impact of digital delivery is greater in sectors with scale economies (e.g. Food and Groceries). Distribution via home delivery enables firms to achieve lower average costs. Standardization, sustainable business models needs to be developed at the industry level. For example the Food and groceries is 59.5% of the retail sector and 48% of household expenditure, hence it is prudent to improve the food supply chain and logistics. In the auto and other industry sectors, Plant locations are at the forks and not at the hubs creating outbound logistics (Finished Goods) problem. In the transportation industry the truck market, where majority of operators are owner-drivers with a single truck should be organized as logistics mall social network.

At the Firm level, increased sales resulting in large scale shipments of small quantities need to be handled carefully, social relationships digital message and content orientation is an absolute necessity, the risks of wrong delivery are higher with large number of small shipments hence the formal Governance structure should select partners carefully for each order and

[3] Viswanadham et al. 2008.

coordinate the order in terms of who needs what and finally monitor the execution of the order.

In summary, It is possible to build a highly competitive multi-modal Indian logistics industry through use of recent information technologies and also through effective and efficient planning.

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5 INDUSTRY 4.0 INTERRELATIONS BETWEEN ADVANCED MANUFACTURING AND URBANIZATION IN INDIA[1]

T.G. SITHARAM

5.1 EXECUTIVE SUMMARY

The bidirectional link between industrialization and economic development along with other factors such as human migration, changes in sociological processes including poverty and urban culture, and modernization has created urbanization. Urbanization in India was mainly caused after independence due to a mixed system of economy which gave rise to the private sector. Together with other Asian countries, India will lead the world's urban population by 2050 as the World Bank reports. Urbanization and development are never observed alone, however growth of cities is heavily linked to economic growth and human development. In India, advanced manufacturing policies and urban policies work in silos. However, newer policies of the Indian Government are directed towards the identification and support of cleaner high technology industry clusters within the partnership for sustainable communities and are in turn aligned with regional economic development. They are seriously looking towards advanced manufacturing to boost the economy.

No doubt, India has witnessed a wave of economic growth over the last two decades. Much of this is due the demographic dividend of young India. A vast pool of skilled, qualified, low-cost professionals has been a key driver of growth in the high tech sector. But to sustain growth over the long haul, it is imperative that India re-architects itself as an innovative society and a knowledge-driven economy along with a focus on advanced manufacturing. This presentation discusses the interrelationship between advanced manufacturing and urbanization in India. This study highlights the issues of advanced manufacturing and urbanization with case studies of Bangalore city, Pune city and Noida in India concentrating on the urban planning and management instruments and stakeholders. The cluster of industries concept has really worked well for the growth of the sector in these cities. The report identifies the major preconditions for advanced manufacturing and its status. Further, it highlights the potential major positive and negative consequences and threats of advanced manufacturing on the urban development in Indian metropolitan areas. Changes in technology, public policy, security, and the financial and energy market changes are among the factors accelerating the change in manufacturing in India. Challenges and opportunities to realize sustainable manufacturing is to shift the focus from research to innovation and encourage entrepreneurship among locals with the engineering colleges serving as focal points.

5.2 PREAMBLE

Acatech requested Prof. T.G.Sitharam, Professor in Civil Engineering at Indian Institute of Science, to study and present the interrelations between Advanced Manufacturing and Urbanization in Indian metropolises. This study focuses on the preconditions and impacts of advanced manufacturing followed by policy recommendations to ensure its success in India.

The objectives of the study on "Interrelations between advanced manufacturing and urban development – the case of metropolitan areas in India" are:

(a) to identify major preconditions for advanced manufacturing (including logistics) and to assess their current status in Indian metropolitan areas; the study shall identify possible gaps between the actual status and future requirements;

(b) to identify major potential positive and negative effects of advanced manufacturing (including logistics) for urban development in Indian metropolitan areas; the study shall identify issues of urban development which will be affected by advanced manufacturing (including logistics) in a positive and negative way;

(c) to derive policy recommendations regarding (a) and (b), and the interrelations between advanced manufacturing (including logistics) and urban development taking the case of Indian metropolitan areas; the study shall identify major actions which can be undertaken to strengthen the interrelations, positive impacts as well as externalities between advanced manufacturing (including logistics) and urban development, and it shall point out the major stakeholders, the related institutional set-up and the necessary governance structures required for promoting urban development with regard to advanced manufacturing.

[1] This report should not be published or distributed either in part or in full without permission in writing.

5.3 INDIAN MANUFACTURING

5.3.1 Relevance

There are nearly 5.3 million manufacturing units in India. These are classified as Micro, Small, Medium and Large and Very Large industries based on the number of people employed in these enterprises. About 99% of these belong to the Micro and Small category (less than 100 employees). There are less than 50 units that are Very Large (greater than 10.000 employees); about 5000 units that are Large (1000 to 10.000 employees) and about 86.000 units that are Medium (100 to 1000 employees)[2].

After years in the shadow of its behemoth manufacturing neighbour China, India is poised for growth in the high-end manufacturing sector, especially in precision areas such as machine tool manufacturing. This new focus on manufacturing and service and its movement away from the country's traditional agro-economy, can be attributed to a collectively increasing sophistication of the country's workforce and infrastructure and the potential need for global companies to diversify away from the Chinese manufacturing base.

However, industry accounts for 15% of the GDP and employ about 12% of the total work force. India is 12th in the world in terms of nominal factory output in absolute terms. This is pretty low when compared to other Asian economies: China (39.3%), Thailand (35.2%), Malaysia (31.1%), Indonesia (24.7%) and Vietnam (20.8%)[3]. The reasons for low performance are erratic electricity supplies, poor roads, and gridlocked seaports and airports, governance issues, labor polices, etc. One of the main reasons has been that multinational companies (MNCs) as well as Indian companies always focused on Indian demands and never considered India as a base for global supplies. Meanwhile technology advancements led to a consolidation of global capacities in many manufacturing sectors. Indian manufacturing capacities remained stagnant at local levels. Their capabilities to change to global levels also diminished. In sectors led by high-end competitive prices, India lagged behind[4]. However, Information and Communication Technologies (ICT) are expected to play a major role in this transformation[5].

Manufacturing creates two to three additional jobs for each manufacturing job[6]. It is also plays a vital role in the overall growth, security and technological advancement of a nation. Figure 1 shows the employment based on industry sectors and makes it very clear that manufacturing constitutes about 12% of the employment rate.

5.3.2 Indian policy

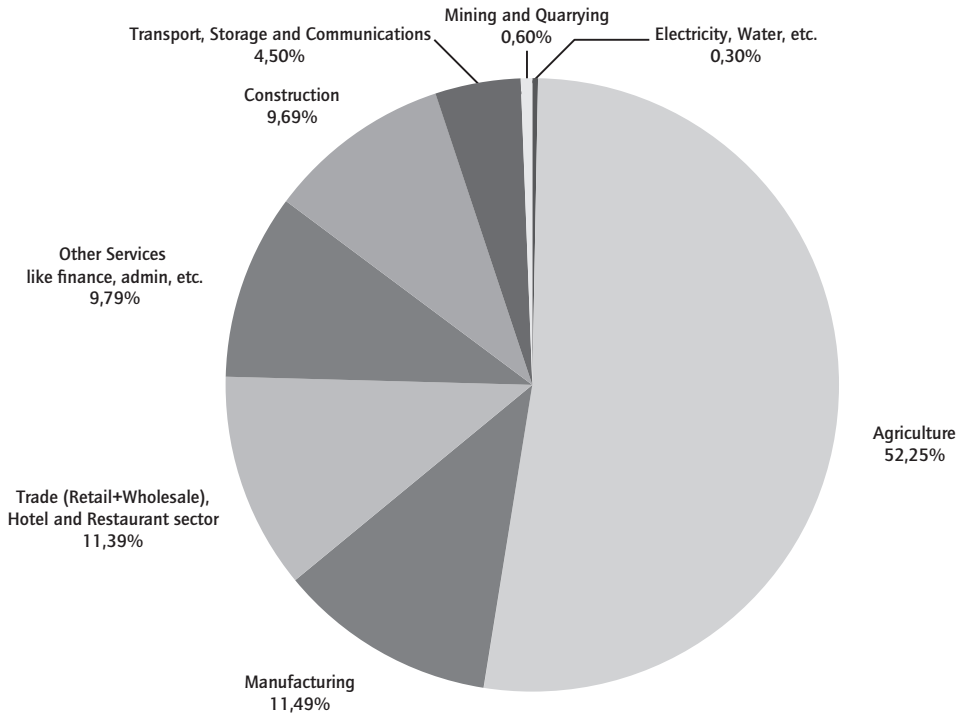
Indian Government recognizes that the limited infrastructure and skill power along with complex regulatory procedures have been limiting India's manufacturing sector. ICT adoption in Indian manufacturing has significantly lagged behind its global peers. Hence, in November 2011 Indiabrought out a policy to create 100 million jobs and increase the share of manufacturing in GDP from about 15% to 25% by 2022. It wants to achieve this aim by spurring industrial growth through enabling policies, and by encouraging public-private partnerships for infrastructure development. This policy doesn't discriminate any sector or location but, as far as technology is concerned, it encourages green technology via incentives.

To increase the share of manufacturing in the GDP from the current 16 percent to 25 percent by 2025 and in the process to create an additional 100 million jobs, a high level committee chaired by the honourable former Prime Minister Dr. Manmohan Singh has approved in principle the National Manufacturing Policy[7] in 2011. The salient features of the policy are:

- to create National Investment and Manufacturing Zones (NIMZs) with world class infrastructure facilities. The proposed zones will enjoy special policy regime, tax concessions, less stringent labor and environment laws, and flexible compliance norms;
- to set up a Manufacturing Industry Promotion Board (MIPB) at ministerial level (Union Minister of Commerce and Industry) to ensure coordination amongst Central Ministries and State Government and to ensure effective implementation of the policy;
- to set up a Technology Acquisition and Development Fund to promote acquisition and development of appropriate (primarily green technologies) technologies;

2 NMCC/NASSCOM 2010.
3 NMCC/NASSCOM 2010.
4 Planning Commission 2012.
5 NMCC/NASSCOM 2010.
6 Ministry of Commerce and Industry 2011.
7 Ministry of Commerce and Industry 2011.

Figure 1: Employment Based on Industry. (Data: Ministry of Commerce and Industry 2011)



– to introduce policy measures to facilitate the expeditious redeployment of assets belonging to non-viable units, while giving full protection to the interests of employees. This will be done through appropriate Insurance Instruments and/or Sinking Fund.

The new government, elected in 2014 with honourable Prime Minister Mr. Narendra Modi, has also shown interest to augment the advanced manufacturing and increase the employment opportunities. The new government has plans to build one hundred new cities focussed on specialized domains and equipped with world class amenities[8] along with the modernization of the infrastructure and augmenting electricity generation. When the Indian union budget 2014 was presented on July 10th 2014 by the new government to boost the Indian economy, massive emphasis was laid on the Indian manufacturing sector. Development of industrial corridors with emphasis on smart cities linked to transport connectivity to spur growth in manufacturing and urbanization will be accelerated. Skill India a national programme has been proposed to develop skill sets in the youth with an emphasis on employability and entrepreneur skills. Government of India has launched a National Skill Development Mission consisting of following three institutions:

1. Prime Minister's National Council on Skill Development - under the chairmanship of Honourable Prime Minister for policy direction and review of spectrum of skill development efforts in country;

2. National Skill Development Coordination Board - under the chairmanship of Dy. Chairman Planning Commission to enumerate strategies to implement the decisions of PM's council,

3. National Skill Development Corporation (NSDC), a non-profit company under the Companies Act, 1956. Investment allowance, rationalization in the tax provisions, and boost in domestic production of electronic items are some of the measures mentioned in the Indian budget of 2014[9]. Information and Communication Technology (ICT) has shown to be a significant potential driver for advance manufacturing across the world.

8 Modi 2014: President's address to the joint sitting of the parliament on June 9th, 2014.
9 Key Features of Budget 2014-15.

5.4 INDUSTRY 4.0

Industry 4.0 is relatively a new term that was defined in year 2011[10]. It refers to the fourth industrial revolution which is about to bring a paradigm shift in the way the manufacturing industry works. At the core of it is the capability of each component of manufacturing being aware of its location, history and its destination and also its ability to communicate with other elements of the system on a real time basis. This philosophy of the "Internet of Things" will have wide ranging implications on the manufacturing industry as a whole by making it more dynamic, efficient and reliable.

5.4.1 Importance of Industry 4.0

India is at the right juncture of emerging technology of Industry 4.0 and willingness of advanced industrial economies to partner with India and the country's need to shift its base from a predominantly agrarian employment to a more advanced and sustainable economy. India needs to seize this opportunity.

Industry 4.0 will not only create high skilled jobs but also create additional jobs in education and training and other areas which are necessary for highly skilled labor. It will further enhance the country's technological edge.

Acatech has proposed two studies on this topic "Importance of Industry" carried out by German and Indian experts and for details one may refer to these companion reports.

5.4.2 Preconditions of Industry 4.0

The availability of raw materials, skilled labor and sufficient land are three important preconditions for setting up an advanced manufacturing plant.

Apart from these, the new plant will also need assurance of enough water supply and electricity to run the plant and better roads and intermodal facilities to connect the plant with the supply of raw materials and the distribution of finished products.

It also needs assurance of educational institutes to train the work force continuously. Finally, the industry would need government policies that make it easier to setup and expand the industry.

5.5 URBANIZATION IN INDIA

This report investigates how well the preconditions are met for the advanced industry to take root in Indian urban areas.

Globally, there is no standard definition of what defines an urban area. In an Indian context, an urban area is defined based on the following three conditions[11]:

1. at least 5000 people,
2. 75% of men engaged in non-agricultural work force,
3. a population density of at least 400 people/km^2.

There are nearly 8000 urban areas out of which a little over half are statutory towns while the remaining are census towns[12]. The census towns qualify as an urban area but are currently administered as rural areas.

India has witnessed a rapid urbanization in the recent past. During the last fifty years, while the population of India as a whole has grown two and half times, that of urban India has grown nearly five times. The urban population rose from 210 million in 1992 (25 percent of the total population) to approximately 400 million in 2008 (30 percent of the total population). This rapid urbanization has been the marker of India's economic progress, where its major urban centres make substantial contributions to its GDP. Although less than 1/3 of India's people live in cities and towns, these areas generate over 2/3 of the country's GDP and account for 90 percent of the government revenue. In 2011, there are 468 cities above 0.1 million and 53 cities greater than 1 million in population (see Table 1).

Table 1: Number of cities > 0.1 million population as per 2011 census

CITIES AS PER POPULATION	NO. OF CITIES
> 10 million	3
5 -10 million	5
2 - 5 million	10
1 - 2 million	35
Total (million + cities)	53
0.5 - 1 million	43
0.1 - 0.5 million	372
Total number of cities	468

[10] Zuhlke 2013.
[11] High Powered Expert Committee 2011.
[12] Pradhan 2012.

About 377 million people now live in about 8000 cities and towns in India constituting almost 38% of the Indian population and contribute more than 50% of the country's GDP together. This rural to urban demographic transition is expected to see a jump in urban population to around 600 million people by 2031 which constitutes almost 40% of the Indian population. The services sector accounts for more than half of India's output, and growth of employment (main workers) in urban India during 1981–91 was recorded at 38 percent as against 16 percent in rural areas and 26.1 percent in the country as a whole. This explosive growth of Indian cities in the last decades of the 20th century has created a huge strain on the physical infrastructure of cities. Power shortages, mismanagement of monsoon deluges, collapse of law and order and of traffic systems, pollution and congestion area few of the innumerable instances that expose the fundamental issues in the delivery of services in urban India. Overcrowding is endemic while the urban poor, driven by unemployment and low productivity, suffer the outcomes of inadequate housing and poor basic services provisioning. Paucity of affordable housing in cities has made India home to the largest urban slum population in Asia. India has over 170 million slum dwellers. Each major city in India faces its own set of challenges with regards to electricity, transportation, water systems, housing, solid waste management, infrastructure bottlenecks and poor service delivery.

Urbanization challenges in India can be classified in two categories: 1. Structural challenges, driven by the nature of urbanization in India, and 2. Execution challenges, faced in implementing initiatives to improve urban infrastructure. Structural challenges are unprecedented scale, high density cities and Brownfield urbanization (driven by natural population growth as opposed to migration). The execution challenges are a lack of efficiency in governance (which suffers from policy limitations and administrative problems) and resource constraints (which are too much dependent on state and central government resources for development). Resource constraints are not only financial but also capability driven. Planning capabilities often do not match up to requirements. Consequently, city development has mostly been short sighted and not holistic.

As India continues to urbanize, demand for basic urban services will be exploded even as population density makes it difficult to build and maintain the robust infrastructure needed to satisfy that demand. To address the key issues and various other urban developmental concerns, the Ministry of Urban Development (MoUD) and the Government of India launched a significant initiative in 2005, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) with the specific objective 'to create economically productive, efficient, equitable and responsive cities'. Under JNNURM, financial assistance is being provided to each of the cities for specific project planning, development and implementation for projects of water supply, sewerage, drainage, solid waste, urban transport, urban renewal, heritage preservation and slum improvement. Amongst these sectors, urban transport is one of the primary areas of focus of the program. Planning for urban transportation in India also got a sense of direction by the formulation of the National Urban Transport Policy and the recommendations of Working Group on Urban Transport for the 12th Five Year Plan. They have correctly recognized the need for a safe, affordable and sustainable urban transportation infrastructure as the key to future development.

Under the broad ambit of the policies framed by MoUD, the direction of planning for urban mass transportation would be focusing on building sustainable modes of urban transport guided by the following key points[13,14]:

- Integrated use of land and transport planning and equitable allocation of road space,
- Enhanced use of public transport through establishment of quality focused, multi-modal and technology-advanced public transport systems such as BRT's, Metro, monorails, elevated sky-bus among others,
- Introduction of intelligent transport systems for traffic management,
- Enhanced quality and optimised pricing of Public Transport,
- Effective regulatory mechanisms to allow level playing field for all operators,
- Pollution control through establishment of infrastructure for use of cleaner technologies such as electric trolley buses and other non-motorised modes of transport.

India spends 13% of its Gross Domestic Product (GDP) on logistics as opposed to the usual practice of 10% by other developing nations. The Indian economy is striving for improvements in the field of logistics and supply chain management to gain the competitive edge in today's worldwide economy. The domestic logistics market is estimated to grow at a very high rate. Such high growth will change the landscape of the logistics

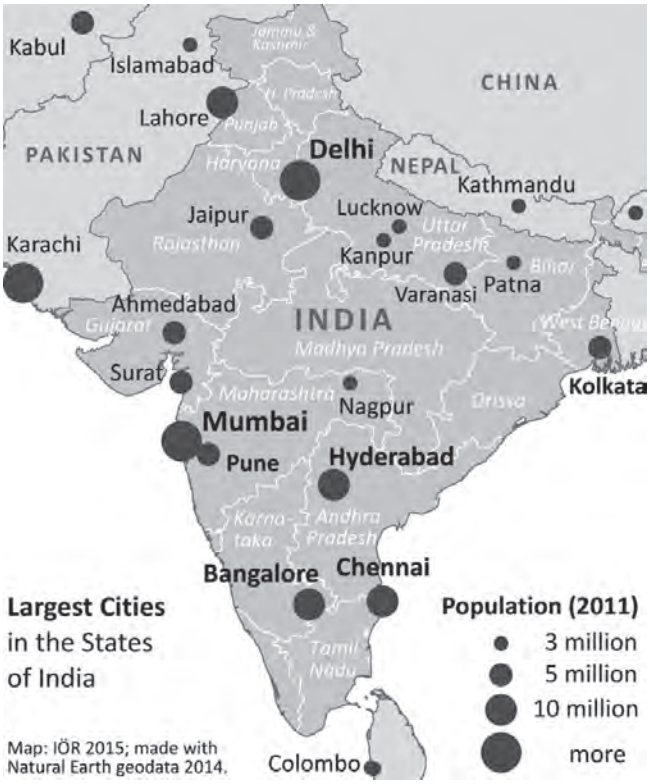
13 MoUD 2008/Planning Commission, 2008.
14 MoUD 2012.

industry which is highly fragmented and unorganized; marked by the presence of a large number of small players, including transporters, express cargo movers, courier operators, freight forwarders, container companies and shipping agents. Logistics management in India has become complex, with about ten million retail outlets to cater to the needs of one billion people. Indian entrepreneurs are forming new companies and taking advantage of government policies designed to promote greater efficiencies in a sector where large global businesses have yet to make their mark. Important forms of Logistics Facilities that India is trying to develop are: Distribution Centers/Warehouses (for Retail Logistics, etc.), Inland Container Depots (ICD)/ Container Freight Stations (CFS), Free Trade Warehousing Zones (FTWZ) and Logistics Parks.

Major preconditions to advanced manufacturing products in India are: proximity to demand, Government regulations and intervention, ability to innovate, access to raw materials and suppliers, transport costs and infrastructure, cost and availability of energy, and labor costs. To understand differences among the manufacturing sectors, one can look at criteria about cost (capital costs, labor costs and energy costs), availability of skilled labor, innovation (R&D intensity, measured R&D output) and tradability (measured export and internal consumption). Technology infrastructure with special emphasis on high speed internet infrastructure (including Cloud Computing) to support advances in existing manufacturing and skilled workforce is needed for advanced manufacturing. Achieving success in the global production and market requires a shift in the way logistics is handled within the industry. There is a need for a quick international movement of raw materials, parts and finished products flow every day. Commercial borders have effectively gone beyond the national borders. In India, this process needs to be done much more effectively by changing tax structure and interstate movement of goods. There is an urgent need for integration of logistics into the design and management of the global manufacturing strategy. Skilful management of logistics should be essential to time-based completion. ACATECH has proposed two studies on this topic "logistics" carried out by German and Indian experts and for details one may refer to these companion reports.

In general, growth has been very uneven across India's vast territory and population, increasingly so in the last two decades. Urban centres, especially metropolitan cities, have become the main nodes of growth; their contribution to GDP is estimated to be about 60%. Not surprisingly, the States experiencing the highest growth rates are those with the largest cities (or in close proximity): Haryana – Delhi, Maharashtra – Mumbai (ex Bombay, Pune); Tamilnadu – Chennai (ex Madras), Andhra Pradesh – Hyderabad, and Bangalore – Karnataka (see figure 2).

Figure 2: Largest cities in India by population (2011)[15]



Metropolitan regions in particular have attracted new investments, a pattern that is consistent with global trends. Not only are these areas the most developed in terms of infrastructure, both quality and quantity, but growing incomes in cities feed the demand for commercial and real estate activities. Indeed, the rapid growth of the last 15 years has primarily benefited the urban middle classes, for instance through employment opportunities in the tertiary sector. This concentration of wealth and opportunity for capital accumulation places India's largest cities at the core of its political economy. State agencies have long been involved in creating and managing industrial infrastructure, but there have been significant changes in the goals and the modalities of their interventions, starting in the 1990s. Most, if not all, States formed industrial development and/or infrastructure corporations in the 1960s, which were put in charge of acquiring

[15] Map layout: IÖR 2015.

land and building industrial estates equipped with basic infrastructure (roads, water, electricity and telecom connections), where production units could lease space and set up operations quickly. One of their foremost missions was to promote industrialization in specially designated "backward areas", territorial units (districts or development blocks) whose relatively weak socio-economic indicators made them eligible for special attention from government. Special economic zones (SEZ) are not new in India, but the national law passed in 2005 marks the beginning of an era, a sign of the commitment of India's political elite to a liberalization agenda. These zones are to be financed and managed primarily by private developers. Their response has been enthusiastic: by June 2009, 578 projects had received formal approval from the central board, and 322 zones had been notified. Regarding the sectoral distribution of notified SEZs: 64% are in the category IT/ITES/Electronic Hardware, followed by about 5% each for engineering and pharma/chemicals and 4% for bio-tech. Less than 4% are in the textile/apparel/wool category. The Delhi-Mumbai infrastructure corridor with new green cities along its corridor would be an ideal location. Similarly, the Bangalore-Chennai and Bangalore-Mumbai corridor also posts many advantages. For this report, we investigate three urban areas surrounding the cities of Bangalore, Pune and Delhi.

5.6 STATUS OF THREE INDIAN CITIES: BANGALORE, PUNE, AND NOIDA

5.6.1 Bangalore City (Karnataka)

The Bangalore or Bengaluru city is located in the southern part of India at an elevation of 900 m above sea level. Bangalore is the 3rd largest city with an estimated population of 10.2 million people with a metropolitan area of 721 km^2 (see Figure 3). It has salubrious climate throughout the year and is home to many higher technical education institutes and industries. It is also called the Silicon Valley of India having many IT companies. It is home to many technology and software companies and has been considered one of the best cities for visitors to work and live in India. It is a software and technical power house contributing nearly a third of IT exports. It is the second fastest growing metropolis in India and is the fourth in fast moving consumer goods.

The city which was 28.85 km^2 in 1901 increased to 174.7 km^2 in 1971 to 272 km^2 in 1986 and 437 km^2 up to 2007 and has been expanded to nearly 800 km^2 (see Figure 3).The city is very investor friendly and has a single window clearance to set up an industry instituted by the Government of Karnataka. The cost of land varies from Rupees 1500 to 4950 per square metre[16]. Some of the important existing industrial clusters in Bangalore are machine tools, power looms, electronic goods, readymade garments, light engineering and leather products. Apart from having national science, management and research institutes, the city also has several engineering colleges and industrial training institutes (ITIs) which can help to train the workforce.

The existing weak links of the city are its roadway infrastructure, and water and power supplies. The Bengaluru metropolitan region development authority (BMRDA) has been given the responsibility of planning the 8000 km^2 of Bengaluru Metropolitan Region (BMR) consisting of 2191 km^2 in the urban districts and 5814 km^2 of rural districts. The planning areas falling in the BMR are given in Table 2. Figure 4 shows the spatial distribution of existing land use and proposed land use for the Bengaluru metropolitan area.

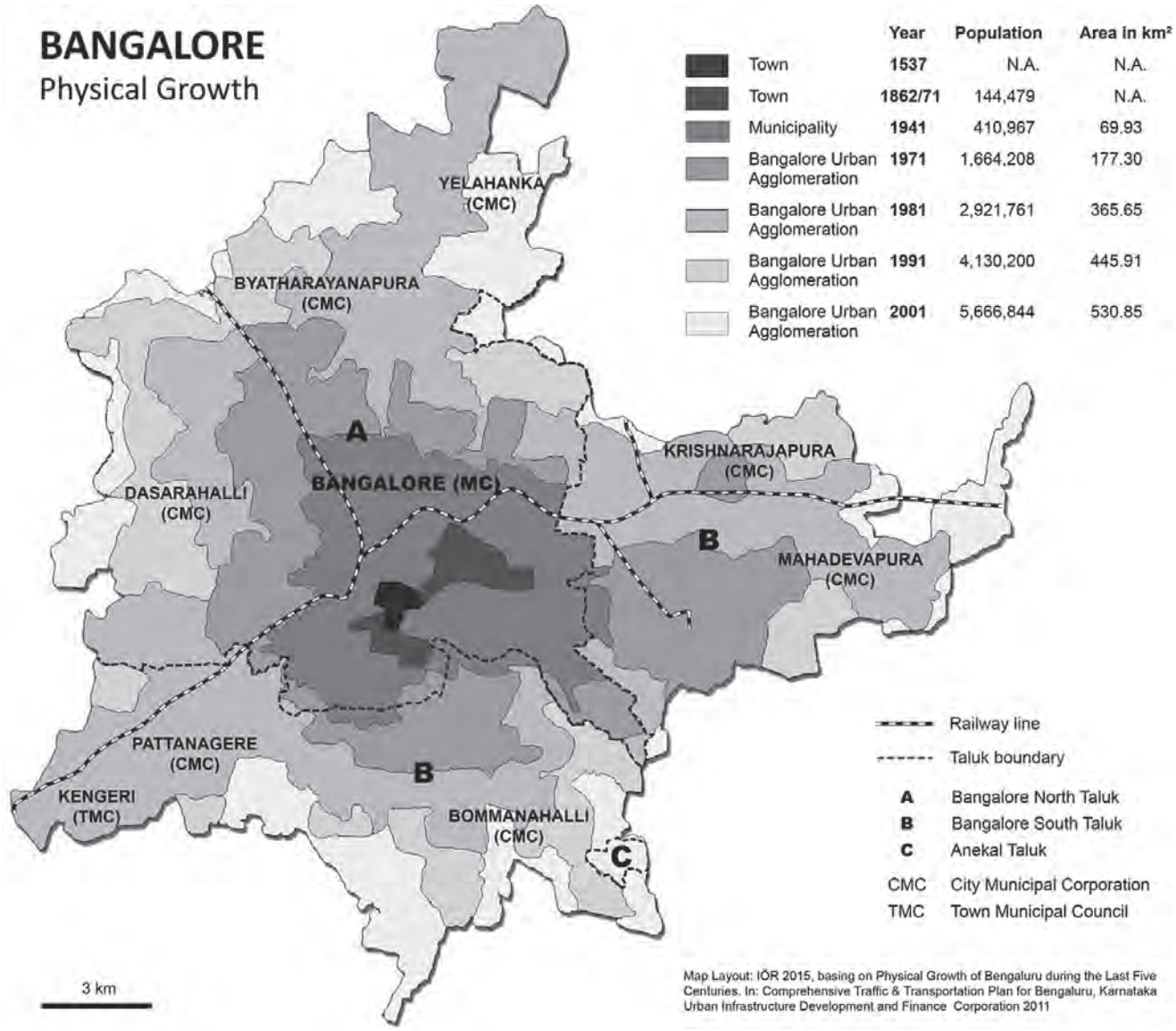
Table 2. Local planning areas in the Bengaluru metropolitan region

SL. NO.	AREA	AREA SQ. KMS	
1	B M A		1240.69
2	BMICAPA (within BMA)	65.31	
3	BMICAPA (outside BMA but within BMR)	338.74	404.05
4	Ramanagaram Taluk		200.25
5	Channapatna Taluk		110.60
6	Bengaluru South Taluk		27.89
7	Anekal LPA		406.00
8	Nelamangala LPA		750.00
9	Magadi LPA		501.00
10	Hosakote LPA		591.00
11	Kanakapura LPA		879.00
12	BIAAPA LPA		985.00
13	RCUDA LPA		62.50
14	APZ-1 (excl. RCUDA)		462.50
15	Industrial Zones in BMR		1723.26
	Total		**8005.00**

It is clearly seen that the lack of effective planning and land use controls has resulted in a rampant sprawled development of Bangalore city extending rapidly in all directions, far beyond the old city boundaries into the distant countryside. In most cases,

[16] KIADB 2012.

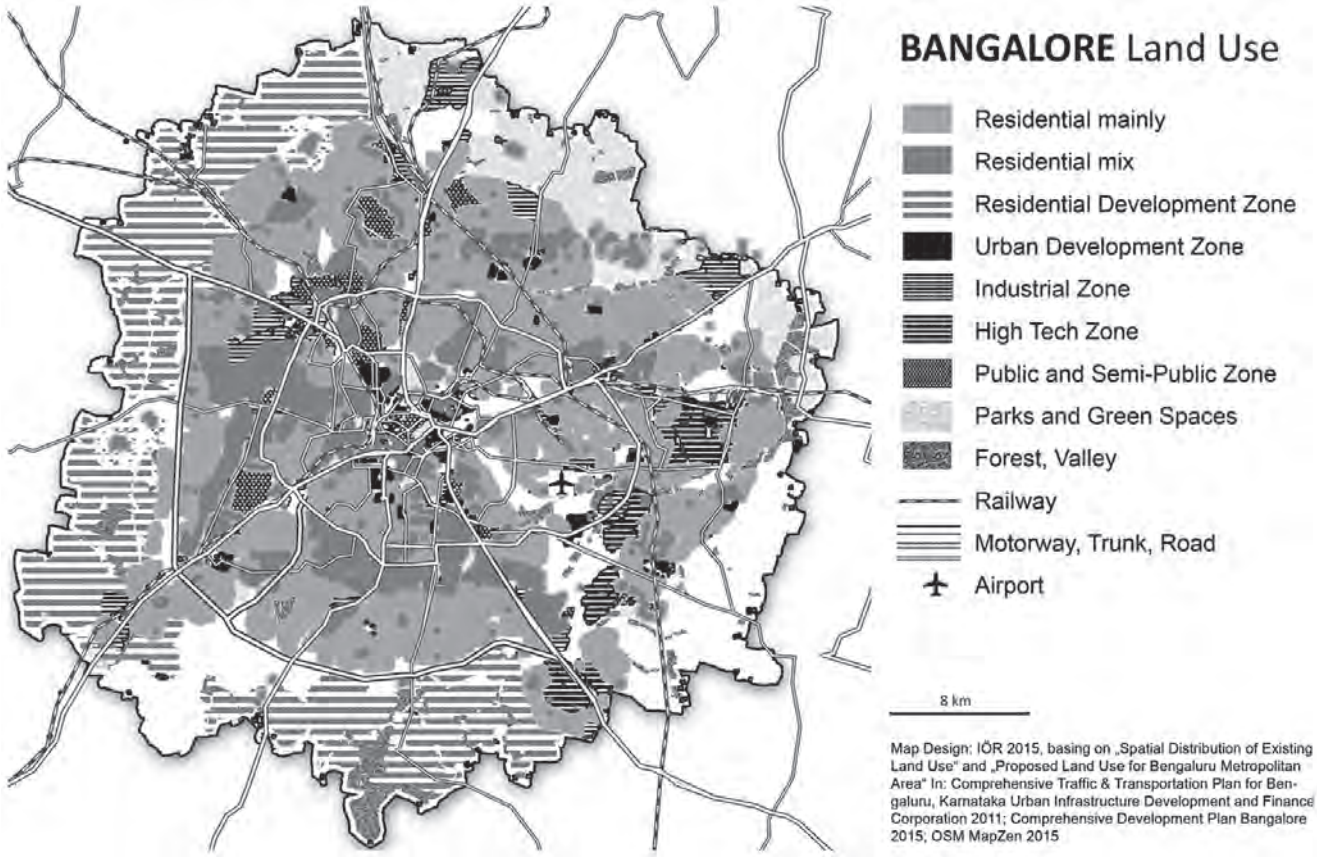
Figure 3: Physical growth of Bangalore during the last five centuries[17]



there is an inadequate infrastructure to serve these new suburban developments and the residences locating around them. Most public policies in India actually encourage sprawl. In an explicit attempt to decongest city centres, government regulations limit the ratio of floor areas to land areas for buildings in the centre, and thus restrict the heights of buildings and density of development in the centre. Government regulations permit higher floor space/land area ratios in suburban developments, thus leading to a greater inducement for firms to decentralize. Indeed, local governments even advertise the less stringent regulations in the suburbs to promote more development there. Such land use policies obviously discourage development in the centre and force both firms and residences to seek locations on the suburban fringe. Moreover, local governments have permitted scattered commercial and residential development in outlying areas without the necessary infrastructure such as roads, utilities, hospitals, shopping, and schools. That generates long trips between residences and almost all other destinations. This

[17] IÖR map layout basing on CTTP Bengaluru 2011.

Figure 4: Spatial distribution of existing land use and proposed land use for the Bengaluru Metropolitan area[18]



also greatly increases the number and length of trips for most Indians, including those by public transport. The existing public transport is congested and carries very high volumes of passengers through dense and congested urban areas. The leap-frog development typical of suburban sprawl tends to follow major highways out of Bangalore to the distant countryside. This has led to a rapid growth in car and motorcycle ownership and use and thus to increasingly congested roadways that slow down buses, increase bus operating costs, and further discourage public transport use. Buses carry more than 4.000.000 million passengers every day and no rail transport for commuter in the urban area of Bangalore exists. Instead, they rely mostly on two wheelers, cars, buses, vans, mini vans, auto rickshaws and taxis. Thus, the rapid growth of large cities increases further the demands for public transport. The traffic problems of Bangalore are a direct consequence of the growth of land use, economic developments in the city, and the type and quantum of supply of transport infrastructure. The low density of development of the city, radial intercity road network converging on the city centre, inadequate by-passes to the city as well as city centres, absence of a marked hierarchical road system, an inadequate public transport system, the insufficient width of main roads, and the absence of a comprehensive parking policy have all contributed to the current problematic traffic situation. To solve this problem of congestion and improve operation, BTRAC 2010 (Bangalore traffic improvement programme 2010[19]) was mooted by Bangalore traffic police. Its scope was to provide a central area traffic control system, corridor traffic control system, traffic police modernization and capacity building along with introduction of new technologies and automating a traffic enforcement system using modern devices like cameras, communication devices and state of the art wireless communication systems, modern buildings, vehicles and equipment. It also attempted to integrate the existing infrastructure and mass transit. A new state of

[18] IÖR map layout basing on CDP Bangalore 2015.
[19] BTRAC 2010.

the art traffic management centre has been created along with a traffic training institute (see BTRAC 2010 report[20] for details).

The Government of Karnataka has developed a list of special economic zones (SEZ) to be created in Bangalore[21]. The major stakeholders, the related institutional set-up and the necessary governance structures required for promoting urban development are already existing and functioning in Bangalore. The funding, governance and institutional framework must adopt Green cities practices with effective land uses and address the impacts of urban sprawl by encouraging compact, mixed-use developments and promotes higher urban densities without affecting the quality of life. A balance between needs and infrastructure was not achieved. The recommendations of the Comprehensive traffic and transportation studies (CTTS) for Bangalore should be followed for a comprehensive mobility plan, various modes of public transportation and diverting development along transportation and transit corridors for achieving mobility for people, facilities and goods. The recommendations of the URDPFI guidelines (2014) by the Ministry of Urban Development must be followed for creating detailed, comprehensive, sustainable and enforceable plans for Bangalore. The Report on Indian Urban Infrastructure and Services[22] lists various funding options for infrastructure projects required in India.

New Urban Settlements: As a decentralization process, the Bangalore Metropolitan Regional Development Authority (BMRDA) has undertaken the development of five integrated townships or new urban settlements following an all-round Work-Live-Play concept at Bidadi, Ramanagara, Sathanur, Solur and Nandagudi. The concept behind this policy is the development of thematic townships. Each township is to be designated for specific economic activities, for example: "T-BT City," "Health City," "Education City," "Finance City" etc. The development of the new integrated urban settlement has aimed in each case to create a self-contained habitat within the Work-Live-Play concept. The master plan for each township has been prepared by the developer and approved by the government, and implementation will be monitored by BMRDA to ensure compliance with the project objectives. BMRDA will provide external infrastructure by way of access roads and radial and ring roads for speedy access to and from downtown Bangalore and the new International Airport. The private developer is required to finance and develop the entire internal project infrastructure including roads, storm water drains, civic amenities, telecom connectivity, water and power supply, and waste treatment and disposal, as well as bearing the capital cost of bringing drinking water and power up to the periphery[23].

In the case of Bangalore, the following agencies deal with urban planning and transportation issues:

- Bruhat Bangalore Mahanagar Palike (BBMP) – responsible for urban amenities developments(education, health, road concerns)

  Bangalore Development Authority (BDA) – responsible for preparing the Comprehensive Development Plan (CDP) that is subject to revision every 10 years and monitoring and implementing plans in the Bangalore Metropolitan Area (BMA)

- Bangalore Metropolitan Regional Development Authority (BMRDA) – responsible for developing outer regional development (areas outside the responsibility of BDA). BMRDA also has an overseeing role over BDA with the authority to control and reject plans.

It also creates local planning authorities for the Bangalore International Airport Planning Area (BIAPA), the local areas of Anekal, Hoskote, Kanakpura, Nelamangala and Magadi, the Bangalore Mysore Corridor Infrastructure Planning Area (BMICA) and the Ramanagara Chanapatna Urban Development (RCUDA) and prepares structure plans for the planned development of the Bangalore Metropolitan Region (BMR).

- Bangalore Metropolitan Transport Corporation (BMTC) is responsible for intercity bus operations and management
- Bangalore Metro Rail Corporation Limited (BMRCL), a joint venture of the Government of India and the Government of Karnataka is a Special Purpose Vehicle entrusted with the responsibility of implementation of Bangalore Metro Rail Project[24].
- The Bangalore City traffic is managed and controlled by the Bangalore City Traffic Police[25].

20 BTRAC 2010.
21 Karnataka.com 2008.
22 High Powered Expert Committee 2011.
23 Hayashi 2007.
24 Hayashi 2007.
25 Source: http://www.bangaloretrafficpolice.gov.in/BTPHome.aspx.

– Karnataka Industrial Areas Development Board (KIADB) is responsible for land acquisitions for industrial and infrastructure projects including the Bangalore Metro.

In recognition of the need for an integrated land use and transport plans, the Karnataka State Government established the following two new planning authorities:

– Directorate of Urban Land Transport (DULT) - set up by the Government of Karnataka under the Urban Development Department. It is responsible for coordinating planning and implementation of urban transport projects and programs in the State of Karnataka.
– Bangalore Metropolitan Land Transport Authority (BMLTA) – set up by the Government of Karnataka. It is responsible for overseeing all the Urban Land Transport Initiatives in
– Bangalore Metropolitan Region (BMR). All transport projects (excluding Railways) in the BMR are under the purview of the BMLTA[26,27].

Bangalore is a Major Transportation Centre due to its location & connectivity as well as a major production & consumption centre. As per information from the Karnataka Goods Transporters Association (KGTA), everyday around 3000–3500 trucks reach the outskirts of Bangalore, out of which around 1000–1500 trucks enter the city while around 2000 trucks bypass the city and have no loading/unloading requirements within the city. The existing D. Devaraj Urs Truck Terminal at Yeshwanthpur handles around 600–700 trucks per day, over & above the 500 small vehicles using the facility for carrying the goods to the city. The KGTA has expressed the need for the development of a Goods Transport Complex, similar to the Transport Nagars in north India (e.g. Sanjay Gandhi Transport Nagar in Delhi), of at least 200 acres area in the Nelamangala region (NH-4). According to the association, its 600 members require a minimum area of around 4500 sq. ft. (500 sq. yds.) each and its 1000 agents require a minimum area of around 2250 sq.ft. (250 sq.yds.) each, while the support facilities like repair shops require a minimum area of 1080 sq.ft. (120 sq yds.). The association has further indicated the requirement of around 1000 shops and a minimum of 10–15 acres for idle parking of the trucks. The KGTA has also expressed the need for proportionately smaller facilities along Hosur Road (NH-7), Old Madras Road (NH-4) and Bellary Road (NH-7). According to the D. Devaraj Urs Truck Terminal Ltd. (DDUTTL), there is a demand for an organized truck handling facility of about 30 acres area along the Bellary Road (NH-7). DDUTTL is under the process of land acquisition of about 9 acres through the Bangalore Development Authority (BDA) in Kogilu, Yelahanka to create a Truck Terminal facility. However, the project has been delayed due to land acquisition issues. Thus, even if the facility is developed, there will still be a Demand-Supply gap of about 21 acres along Bellary Road (NH-7).

Housing in Bangalore

The housing industry has shown strong growth in the past few years. Between 2006 and 2008, the demand accelerated due to employment opportunities created by the information technology (IT)/information technology enabled services (ITeS) industry, growing population, urbanization, rising incomes and increasing number of nuclear families. Residential capital values catapulted as demand outstripped supply, with the bulk of the supply coming up in the premium category. However, the economic downturn of 2008 led to demand plummeting, resulting in developers holding huge inventories. A sizeable pent up demand for affordable housing remained, though, which led to a substantial shortage in the mid-income and low income categories. In the fourth phase Credit Rating and Information Services India Limited (CRISIL) Research expect the demand growth to revive and the industry to consolidate its position.

The city today is home to over 8.4 million people[28]. The Bangalore Development Authority (BDA) has been designated as the Special Planning Authority for the Bangalore Metropolitan Area. The BDA came into being with effect from 6th January 1976 under a separate Act of the State Legislature viz. the BDA Act 1976. This Authority combined in itself the planning functions of the City Planning Authority and the developmental functions of the former City Improvement Trust Board (CITB). As part of its mandate, the BDA has been developing layouts for housing across Bangalore in order to streamline growth in the metropolitan area. BDA has been investing significantly in developing the transport infrastructure for the area under its jurisdiction. However, the ever increasing size of population has put immense pressure on the demand for land not only for residential facilities but also for developing adequate transportation infrastructure. Of late, the BDA has also initiated the construction and allotment of affordable houses. These houses are developed by

26 Source: http://urbantransport.kar.gov.in/index.html.
27 Source: http://bmlta.org/.
28 Census 2011. http://www.census2011.co.in/.

BDA and then are sold at nominal costs to the public through a "first come first serve" basis. However, BDA has been developing these houses based on an Engineering, Procure and Construct format so far.

The affordable housing concept has gained ground in Bangalore City, mainly due to a few graded developers like Purvankara, Brigade Group, Shriram Properties, Golden Gate Properties, Ozone Group and Nitesh Estate who are focusing their projects for the customer segment. The demand from this segment comes from extremely price sensitive buyers – therefore, affordable projects are developed in the suburbs as these areas offer large land parcels at lower acquisition costs. Areas such as Mysore road, Hosur road, Kanakapura road etc. have witnessed a high demand for this segment. With increased demand, 'affordable' housing projects have witnessed an increase in the capital prices and are now priced higher than or similar to mid-income segment projects. Major national level players and local developers have plans to enter the affordable housing segment of Bangalore. These include Tata Housing, Usha Breco Realty, Godrej Properties, Ashoka Group, Jannaadhar Construction, CSC Builders, Brigade Group, etc. Bangalore's residential segment is likely to grow annually by 15% for the coming year until 2015. Bangalore has absorbed 23.000 units in 2012. A total of 55.000 residential units were available for occupation in 2011 out of which 44.000 units have been launched in 2011 alone. There are 107 ongoing residential projects in Bangalore out of which very few are due for possession in 2014. The prices of apartments range from Rs. 3000 to Rs. 29.000/sq.f.t with median price being 4600/sq.ft. JP Nagar is the most popular real estate destination in Bangalore with more than five ongoing projects followed by Hoodi and Whitefield. Electronic City is the most affordable locality in Bangalore with a median price of 3375/sq.ft. followed by Kengeri and Electronic City . Most affordable projects in Bangalore are DS Max Saviour, Eternity Ecstasy and DS Max Sundale while Nitesh Park Avenue, HM Grandeur and Shobha Indraprastha are the most luxurious projects[29]. Bangalore boasts the highest growth rate in India.

Plan for Growth of Advanced Manufacturing and Urban Planning in Bangalore city:

The Indian manufacturing landscape is changing dramatically. Trained workforce, insecurity of energy supplies, logistics and infrastructure access, and environmental concerns are the key features which are affecting dramatically the innovation potential of advanced manufacturing in India. Future markets in India will favour manufacturers that demonstrate responsible behaviour with regard to energy usage, waste disposal and recycling. The preconditions for advanced manufacturing exist in Bangalore. Among the preconditions for advanced manufacturing, Bangalore's advantage is a highly skilled workforce and technology[30]. Bangalore is a hub for the information technology, aerospace and aviation industries, heavy manufacturing industries, space technology, biomedical and other industries like floriculture, silk etc.

Specifically, details of the above industries in Bangalore are as follows:

Information technology: Bangalore's IT industry is divided into two main „clusters": Electronics City and Whitefield. New clusters in Bellandur, Hebbal and Challaghatta have emerged in the last few years along the Outer and Inner Ring Roads and in C. V. Raman Nagar near Old Madras Road. The City is home to more than 900 IT firms.

Aeronautics - The Hindustan Aeronautics Limited (HAL) headquarters is based in Bangalore, and is dedicated to research and development activities for indigenous fighter aircraft for the Indian Air Force. The National Aerospace Laboratories (NAL) is also headquartered in Bangalore and is dedicated to the development of civil aviation technologies. A 1000 acre (4.0 km^2) special economic zone for the aerospace industry is being set up near the Bangalore International Airport. Bangalore is also home to large domestic airlines - Simplify Deccan (sold to Kingfisher airlines and now closed) and Air Asia jointly with Tatas.

Heavy industries - Other heavy industries in Bangalore include Bharat Electronics Limited, Bharat Heavy Electricals Limited (BHEL), Indian Telephone Industries (ITI), Bharat Earth Movers Limited (BEML), HMT (formerly Hindustan Machine Tools), Hindustan Motors (HM) and ABB Group.

Automotive - Bangalore is also becoming a destination for the automotive industry.

Small scale industries - Bangalore houses many small and medium scale industries in its Peenya industrial area that claimed to be one of the biggest in Asia 30 years ago.

Space technology - ISRO, India's premier space research organization is headquartered in Bangalore.

[29] Source: http://www.houseincity.com.
[30] Ducker 2014.

Biotechnology - Bangalore accounts for at least 97 of the approximately 240 biotechnology companies in India. Interest in Bangalore as a base for biotechnology companies stems from Karnataka's comprehensive biotechnology policy, described by the Karnataka Vision Group on Biotechnology. In 2003–2004, Karnataka attracted the maximum venture capital funding for biotechnology in the country - $8 million. Biocon, headquartered in Bangalore, is the nation's leading biotechnology company and ranks 16th in the world in revenues.

The Institute of Bioinformatics and Applied Biotechnology (IBAB), initiated by Biotechnology vision group, ICICI and Biocon (located at ITPL) is trying to shape revolutionary scientists in the field. The biotechnology industry had access to talent from the National Centre of Biological Sciences (NCBS) and the Indian Institute of Science (IISc). Indian Biotechnology Research Organization (IBRO) is currently under process of development to boost Biotechnology Growth in India, providing the Advanced Research and Talent pool to India from IBRO, whose mission and vision is Research and Development in Biotechnology to make India a global leader in Biotechnology[31].

The informal sector in Bangalore also contributes significantly to Bangalore's economy. Bangalore is also home to premier research institutions and higher education institutions that contribute to research and development for various disciplines.

Bangalore has a number of SEZ (Special Economic Zones) for the above industries. SE Zones were set up in India to attract foreign investments or international businesses. Bangalore's rapid growth in the recent years is a consequence of the ongoing relationship between the preconditions of urban development for advanced manufacturing that existed in Bangalore and growth of advanced manufacturing in Bangalore in the recent years. Bangalore is continuing to be a top destination for the above industries due to the preconditions that exist.

Broad data on the current and projected urban development scenario in Bangalore can be used as background information to evaluate the advanced manufacturing industries' location and surrounding urban environment. Broad suggestions for policy formulation, implementation and enforcement for creating the urban environment for future needs of advanced manufacturing can be made based on best practices and existing government guidelines and plans for urban development for future needs of advanced manufacturing. Based on these further studies, broad suggestions whether to decentralize advanced manufacturing to satellite towns, integrating advanced manufacturing within the City's framework, integrating some functions of advanced manufacturing within transportation corridors (for instance call centres for customer support) can be made.

The International Tech Park in Bangalore can be used as an example to develop criteria and benchmarks for advanced manufacturing. The International Tech Park Bangalore (ITPB) is the icon of India's IT success story, and continues its contribution to the development of Whitefield as a major IT hub in India's Silicon Valley. Located just 18 km from the city centre, ITPB catalyzed the growth of Whitefield as a flourishing suburban district of Bangalore. It includes a wide variety of purpose built office spaces, built to suit and multi-tenanted facilities, business centres, retail spaces, social infrastructure and supporting infrastructure that includes a dedicated power plant, shuttle services, parking, safety and security, sewage treatment plant and building and management systems[32]. As Bangalore is an internationally recognized destination for technology-related investment, properly planned facilities should be present for the investors to plug, play, live and learn. Necessary infrastructure facilities should be provided for the efficient operation of the industry. The present major IT hubs are facing problems of crumbling infrastructure, environmental pollution, traffic congestion, increasing cost of living and a tired workforce[33]. There are a number of reasons why Bangalore attracts a large number of ITES and BPO customers. Moderate climate, good labor relations, excellent education and research institutions, good telecom connectivity, advanced infrastructure, better state policy and investor perception are just some of these reasons. In a survey conducted by KPMG and NASSCOM, ITES customers were more attracted to a place if there was a proactive government who had the ability and willingness to facilitate new investments. Bangalore scored over all other Indian cities in the survey in terms of human resources, policy support and nature of work[34]. Bangalore would continue to be a preferred location for the IT industry because of its telecommunications infrastructure, availability of IT parks, government policies, skilled labor, specialized services, link between the industry and research institutions etc[35]. The administration

[31] Economy of Bangalore http://en.wikipedia.org/wiki/Economy_of_Bangalore.
[32] Source: http://www.itpbangalore.com/.
[33] ITPI 2009.
[34] Source: www.outsource2india.com.
[35] Srinivas 1998.

has paved the way for creation of an economic development agency, Software Technology Parks of India (STPI), to enhance the IT growth sector. Often regulations and land use zoning laws were relaxed to make way for the large technology parks. Setting up high-end infrastructure necessary for technology industries was often done at the cost of other basic amenities like laying out arterial roads, developing open spaces, and providing efficient means of public transportation. Most of the technology parks were established outside the limits of the city creating urban sprawl without the support of an efficient public transit system. This also led to creation of satellite townships; sometimes isolated from the urban fabric of the main city[36]. The major positive effects of growth of IT are illustrated to a certain extent by the existing economy in Bangalore. The positive effects of IT are increased job growth, economic growth and being part of the global market. The major negative effects are climate change, strain on infrastructure and population growth.

Urban prerequisites for advanced manufacturing growth in Bangalore city:

The preconditions for advanced manufacturing exist in Bangalore. The current status and gaps for future requirements will have to be studied by evaluating each of the above sectors. Policy frameworks and mandates must be created for integrating urban requirements like housing, land use and mobility requirements to create the desired socio-economic and sustainable environment for the enhancement of advanced manufacturing in Bangalore. In addition, the technical and logistical needs must be evaluated and provided for by each of the advanced manufacturing sectors.

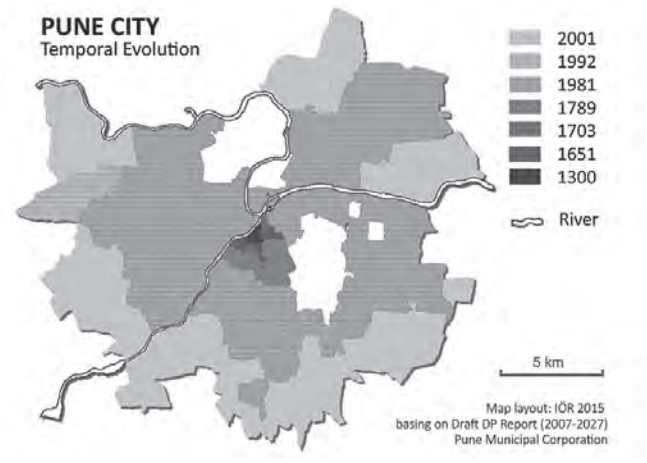
Strategies for urban development for advanced manufacturing:

Mobility of the population rather than automobiles should be emphasized to reduce the traffic problem in Bangalore. A major budget needs to be allocated to develop footpaths, pavements and cycle paths to increase and sustain the walk lengths and the use of non-motorized transport in our city. The road network must be strengthened by connecting arterial and sub arterial roads and also improve the quality of roads. Excellent public transport (road and rail based) should be developed for increasing the modal share of the public transport system to 70% or double it by 2020. Creation of bus bays, marking of bus stops, display of bus routes, passenger information regarding bus routes based on latest technologies will augment the accessibility of public transport to the citizens. Further, there should be inclusive growth in public transport by making bus fares cheaper for the lower income groups. Development of bus priority lanes, bus rapid transit system lines along the ring roads, high density bus routes will attract the passengers from individual motor vehicle owners. Parking management must be adopted in the central business districts[37]. Policy frameworks and mandates must be created for integrating urban requirements like housing, land use and mobility requirements to create the desired socio-economic and sustainable environment for the enhancement of advanced manufacturing in Bangalore.

5.6.2 Pune City (Maharashtra) with an emphasis on Pimpri-Chinchwad Municipal Corporation

Pune, a city in the Maharashtra state is situated at 560 metres above sea level on the Deccan plateau at the right bank of the Mutha river. Pune is the second largest city in the Maharashtra state and the seventh in the country with a population of 0.82 million people with a metropolitan area of 712 km^2. It is the automotive capital of India with many national and international automobile companies setting up plants to manufacture the whole spectrum of automobiles, from two wheelers to trucks. The city also has a large German collaboration with over 225 German companies setting up their base in Pune. Figure 5 shows the temporal evolution of the Pune city.

Figure 5: Temporal evolution of Pune city since 1857 to 2001[38]



[36] PRATIK MHATRE 2013.
[37] CiSTUP. White paper on mobility for IFHP.
[38] IÖR map layout basing on Pune City 2007-2027.

Figure 6: Map showing transport network and recommended industrial development in Pune Region[39]

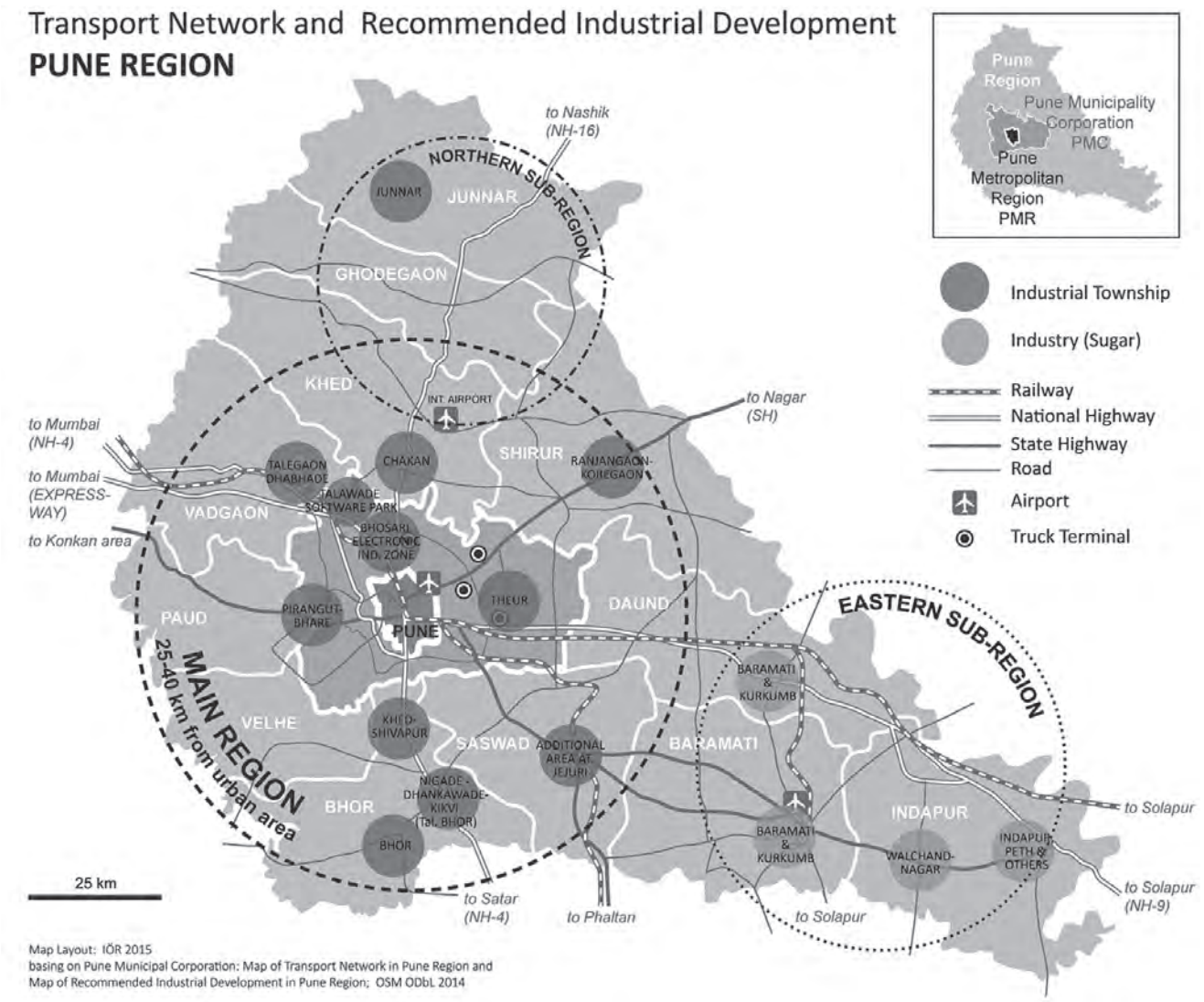


Figure 6 shows the transport network in Pune district and highlights the recommended industrial development plan in Pune region.

Pune has several national level research institutes including the Automotive Research Association of India (ARAI). It is home to more than a hundred educational institutes and nine universities. It is home to the College of Engineering, Pune, one of the oldest engineering colleges in the country, established in 1854.

The industrial land prices in Pune vary from Rs. 70 to Rs. 9310 per square metre[40].

The following list shows the top manufacturing companies in Pune[41]. The top ten lists consist of Automobiles, Pharmaceuticals, Cooling Systems, Sensors and Automation Systems: all the products that signify a growing urbanization.

39 IÖR map layout basing on PMC.
40 MIDC.
41 Manufacturing Companies in Pune 2013.

1. Bajaj Auto Limited
2. Tata Motors Limited
3. Mercedes-Benz Private Limited
4. Emcure Pharmaceuticals
5. Hindustan Antibiotics Limited
6. Finolex Cables Limited
7. Kirloskar Chillers
8. John Deere India Private Limited
9. Honey Well
10. Total Automation Services

Pimpri-Chinchwad is a city in the Pune Metropolitan Region in the state of Maharashtra, India. It is considered as the ‚twin city' of Pune. It consists of the towns of Pimpri, Chinchwad, Nigdi, Bhosari, Moshi, and Sangavi which are governed by a common municipal body (the Pimpri-Chinchwad Municipal Corporation or PCMC). It is located in the North-West of Pune and is well connected to the centre of Pune city via the Old Pune - Mumbai Highway. The twin cities of Pimpri-Chinchwad are located 15 km from the Pune city centre. They form a continuous urban stretch, adding to the overall Pune Urban Agglomeration, and contain a thriving industrial belt that primarily consists of engineering and automobile industries. Pimpri-Chinchwad had a population of 1.729.320 as per 2011 census data. Pimpri-Chinchwad has an average literacy rate of 87.19, higher than the national average of 74.04%. Pimpri-Chinchwad is known as Industrial Township with the presence of many national and multinational automobile companies. A number of international brands - especially from automobile and auto component sectors - are making a beeline to set up their production units here. The region is registering 15 percent growth annually, according to government officials. At present, the region has more than 4000 industrial units, including small and medium-scale enterprises (SMEs) as well as multinational companies (MNCs) such as Tata Motors, Kinetic Engineering, Force Motors, Bajaj Auto, SKF Bearing India Ltd., Thermax, Forbes Marshall etc. IT majors - such as Infosys, Wipro, IBM India, KPIT Cummins etc. - also set up their bases here with the establishment of the Rajiv Gandhi Infotech Park in Hinjewadi and Talawade. The Pimpri Chinchwad Municipal Corporation Administration, one of the forward looking democratic bodies with ample chance for citizens to interact with a citizen charter, has committed itself to the goals of sustainable development as well as the pursuit higher quality of civic life. This charter documents the citizens' entitlement to municipal services, quality of services, access to information stages to decision making and time-bound schedules of services, sanctions and approvals. It also indicated the functionaries citizen can meet to resolve the respective matters. The charter will be widely publicized so that the citizens can use it in dealing with the municipal administration. The corporation is IT savvy and uses lot of ICT applications for the benefit of the citizens.

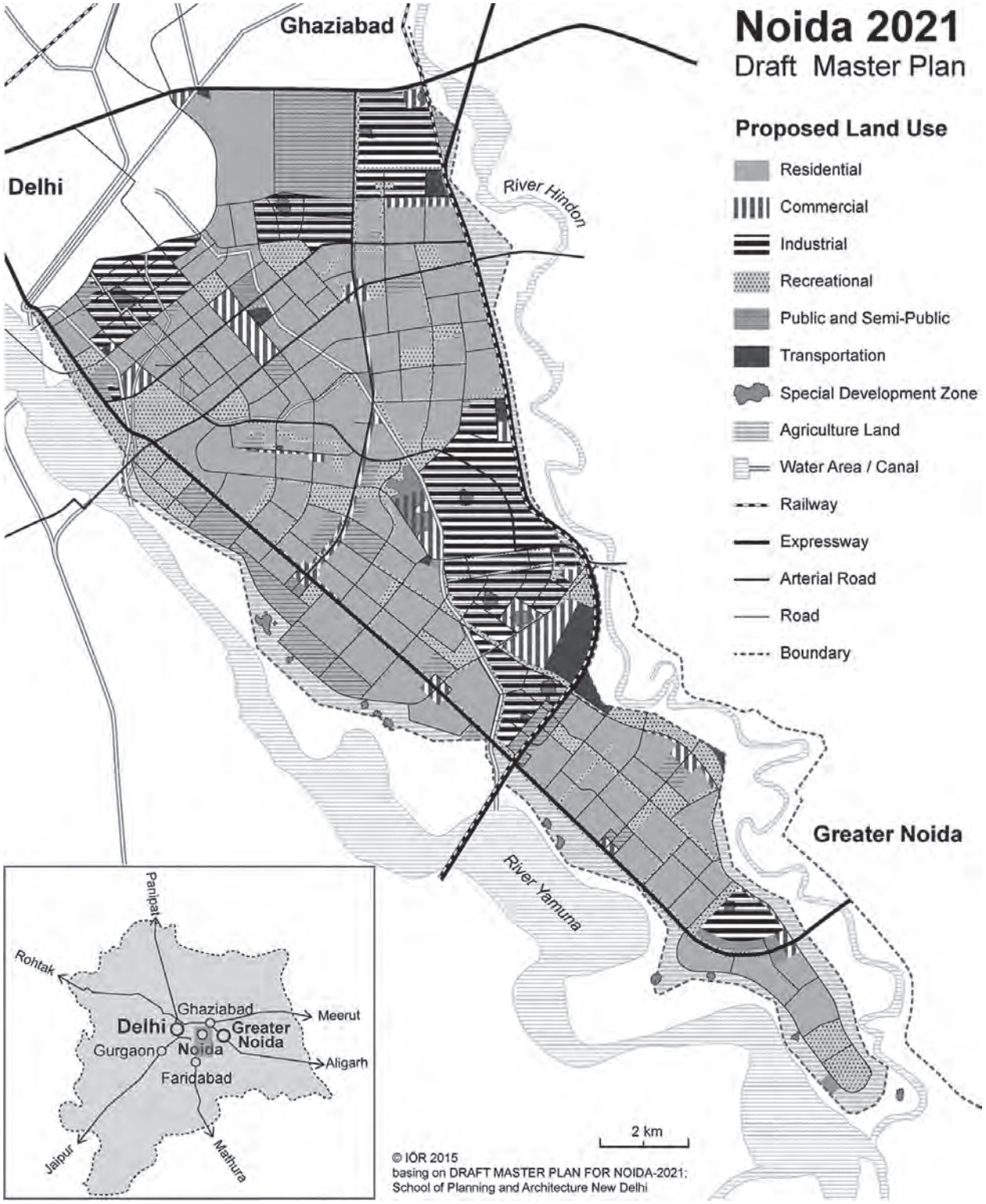
5.6.3 Noida (Uttarpradesh)

Noida is located in State of Uttara Pradesh located at an elevation of 200m above mean sea level and has a population of 642.381. Most of the land in Noida is not very fertile and the agricultural output is low. It is in the flood plains of the Yamuna River on one side and the Hindon River on the other. Noida is in Uttar Pradesh but it belongs to the National Capital Region (NCR). The State Government also constituted a new statutory body, namely the New Okhla Industrial Development Authority (NOIDA) to ensure planned development of the area for industrial and allied uses. Accordingly, the Authority prepared a master plan for the area for the year 1991. The Plan had the provision to provide newly developed sites for about 10.000 small-scale industrial units; to provide employment for about 41.000 industrial workers; and to achieve a conducive living and work environment for the workers engaged in manufacturing and allied activities. The industrial land prices in Noida vary from Rs. 3750 to Rs. 6500 per square metre[42]. Figure 7 shows the revised master plan of Noida 2021. Noida is the city of the future, which boasts of an unparalleled infrastructure. The Master Plan of Noida envisages systemic development to enhance the quality of industrial as well as social life. It has emerged as a hot favourite of industrialists, professionals and entrepreneurs. Noida is a highly integrated township, offering facilities for all activities: Industrial, Commercial and Residential.

Noida is the location for the Uttar Pradesh Technical University and various other colleges affiliated to it. It is also home to many prestigious centres of higher learning, including NIET Noida Institute of Engineering & Technology, Amity University, Jaypee Institute of Information Technology, Jaipuria Institute of Management, and JSS Academy of Technical Education. Even IIM Lucknow has its extension campus in Noida. Noida is a major hub for multinational firms outsourcing IT services e.g. Sapient, Fiserv, Headstrong, EXL Service, First Flight Courier LTD, Students-Leads, IBM, Miracle, AON Hewitt, Fujitsu, CSC, TCS, WIPRO, Padma Infocom, HCL, Tech Mahindra, Adobe Systems, Ericsson, Dell, Sparta Consulting, Patni Computers, Corbus, Accenture, Samsung etc. Many large software and business process outsourcing companies have their offices in the city.

[42] GNIDA 2014.

Figure 7: Revised master plan of Noida 2021[43]



[43] IÖR map layout basing on Noida-2021.

In the planned integrated industrial township of Noida the major industrial sectors were developed in three phases; namely, Industrial Area Phase I, Industrial Area Phase II, and Industrial Area Phase III. The residential, commercial, recreational, institutional and other urban use areas have also been developed in large parts of the township in the form of sectors. The remaining area of the township is in the process of being developed. The development potential in Noida area emanates not only from its proximity to Delhi but also due to the fact that it lies in the midst of a rich agricultural belt extending over western Uttar Pradesh and Haryana. Prospering cities like Ghaziabad, Sikandrabad, Bulandshahar and Khurja in Uttar Pradesh and Faridabad and Ballabhgarh in Haryana surround it. According to Potter and Kumar, the main industry in Noida is hosiery and garment manufacturing followed by paper, paper products, printing, machinery, machinery tools & electric machinery products[44].

There are several big companies like Honda, Yamaha, Videocon, LG Electronics, Bayer and Asian Paints[45].

Noida has been planned on a gridiron pattern. The major roads have been planned horizontally from southwest to northeast interconnected by perpendicular roads forming a grid and dividing the area into sectors. The township is planned on the concept of a self-contained integrated township. The high-density residential areas are located close to the work places. The commercial centres are well distributed over the space with the main commercial hub in the city centre. The sub district centres are distributed with respect to residential catchment areas. Residential sectors are to be developed at varying densities. Few sectors have been planned for high density group housing with provision of large size recreational/green areas. The central park and major public and semi-public uses are located so as to run linearly in a north-south direction more or less centrally through Noida. A railway station complex is proposed in the south-western part of Noida.

Noida is well connected to Delhi and other towns and cities of Uttar Pradesh. Within Noida, the entire township has wide roads. State Road Transport bus services throughout the township provide regular and frequent connectivity to the people to and from Noida and Delhi, Ghaziabad and other major cities of Uttar Pradesh. While Noida's linkages with the City of Delhi are being upgraded and strengthened by the development of expressways and by the addition and widening of bridges over the river Yamuna, the city's own internal network requires upgrading in capacity, access control and hierarchy. The mismatch between the macro and micro networks does exist in the development of the city. The weaknesses of the transportation system of Noida are becoming too apparent. Provision of adequate uninterrupted power supply is crucial for industrial production and as a special case, Noida has been declared a free from all power cuts zone by the Uttar Pradesh State Government to ensure sustainable industrial growth. Noida is connected with one of the best telecommunication networks. All the exchanges in Noida are electronic and are connected with digital and optical fibre based telecommunication facilities. Presently, there are 7 telephone exchanges functioning in Noida with a total capacity of 75.000 lines against the demand of 63.000 lines. All the towns and cities surrounding Noida city are growing up with a strong industrial base. The job opportunities in these urban settlements are attracting migrants and thus the settlements are experiencing fast rate of growth of population, a trend likely to continue in the future. Transportation across the river Yamuna may become a major limitation for the development of Noida in the long run, if not addressed properly. Hence, this area is difficult to manage from the point of view of drainage and sewerage. The notified area of Noida has definite boundaries, being bounded by the rivers Hindon and Yamuna on three sides and the National Highway no. 24 in the north. Hence the areal spread of the city is bound to stop after the entire notified area is developed.

5.7 FINAL REMARKS

Major preconditions to advanced manufacturing products in India are: proximity to demand, Government regulations and intervention, ability to innovate, access to raw materials and suppliers, transport costs and infrastructure, cost and availability of energy, and labor costs. For advanced manufacturing and smart factories in the above three cities viz. Bangalore, Pune and Noida in the NCR region, technical infrastructure and human resources/skills exist. Even the socio-economic environment is present. However there is concentrated need of logistics and mobility including CPS based infrastructure. Noida, being close to National Capital and within NCR, is better placed in terms of urban structures, logistics and mobility.

44 Potter/Kumar 2004.
45 Source: http://en.wikipedia.org/wiki/Noida.

Unplanned urban growth for instance, causes growth of slums and squatter settlements, varying effects on environmental degradation and increased burden on existing infrastructure. The general problems which are the by-product of a certain kind of urbanization characteristic of India are: shortage of houses, critical inadequacies in public utilities viz., power, water, health facilities, sanitation etc., deteriorating urban environment, urban unemployment, congestion, acute poverty and slums proliferation.

Technology infrastructure such as high speed internet infrastructure including Cloud Computing exists in Indian cities to support advances in existing manufacturing. India has a fairly good and wide information, communication and technology (ICT) network, which is getting better with time. Internationally ICT is playing a major role in advanced manufacturing. In addition to its advantages in the workforce and technology, India also has abundant natural resources needed in production - notably, iron ore and aluminium for engineered goods, cotton for textiles, and coal for power generation. Further, skilled workforce needed for advanced manufacturing can be trained from the available highly educated engineering and diploma graduates in the country. Achieving success in the global production and market requires a shift in the way logistics is handled within the industry.

In general, growth has been very uneven across India's vast territory and population, increasingly so in the last two decades. Urban centres, especially metropolitan cities, have become the main nodes of growth; their contribution to GDP is estimated to be about 60%.

India's population is young and its median age is about 26 years and nearly 600 million people are in the working age group. This demographic dividend is to be contrasted with the ageing population in most developed economies such as China, the European Union, US, Japan, etc. thereby leaving a decreasing fraction of their population as work force. Innovation is identified as almost synonymous with young age and good education. Very high number of engineering graduates is available who can be trained reasonably quickly.

The new generation workforce is comprised of highly-skilled individuals who have the ability to quickly grasp the new concepts and technology demanded by the manufacturing and services industries. Naturally, such activity is in larger cities, which are now seeing an influx of young adults eager for new job opportunities. After years of serving as the outsourced service workforce for Western companies of all stripes, the average Indian worker is highly skilled at adapting new technologies to suit local requirements. As a result, India is increasingly adopting a global approach to become a strategic player on the international platform. The entry of foreign companies in the manufacturing industry has anchored a technology-based orientation which has subsequently helped India to create an advanced manufacturing sector.

Stakeholders who influence urban development in Indian Metropolitan areas are from a wide list which includes:

a. Top management involves MPS & MLAs (5300), Higher judiciary (650), IAS and IPS (8200), etc.

b. Government Bodies like Municipal corporations, Development Authorities, Public Works Departments, Traffic Police, Transport Department, Environment Pollution Control Authority (EPCA), Fire and Ambulance Services, Environment Department, Cantonment Board, Transport Corporations, etc.

c. Experts in the field of transport from Academic Institutes and Research bodies and Consultants or Practitioners in the field.

d. Media: Both print and electronic media

e. Non-governmental organizations (NGOs)/Civil Society Organizations (CSOs)

f. Elected Representatives from city (Ward councillors/Corporators), state (MLAs, Transport minister) or centre (MP).

g. Operators like auto rickshaw unions, private bus operators.

h. Others like Unions, Bus and Cycle Manufactures, owners and operators of transport infrastructure

i. User groups like resident welfare associations, local businesses, etc.

Out of the above stakeholders including top and middle management, the percentage of those educated and trained in urban practice is about 20%. Classifying stakeholders on the basis of their role in transport / logistics are:

a. Organizations or individuals responsible for making decisions regarding transport. These organizations could be involved either at city level planning of transport or framing policies or in transport operations. That is, government organizations for which transport is in the primary focus are directly involved.

b. Organizations or individuals who are not part of the government but are directly involved in the transport operations in the city. This could include auto rickshaw unions, taxi drivers associations, parking lot managers or owners, travel associations, etc. This group could also include private players who are involved with the government in various transport based PPP operations like operation of buses, toll roads, etc.

c. Organizations or individuals (government or non-government) whose activities tend to shape the transport needs and demands of the city. This will include large industrial units, urban development authorities, ports, railways, etc. as well as regular citizen groups represented through RWAs.

d. Organizations and individuals (government or non-government) who hold prominent positions are important opinion makers in the city. This will include the Press; Universities, colleges and other educational institutes; popular NGOs and other popular representative organizations like the Confederation of Indian Industry.

CDP or Master Plans are a prime data source for reviewing existing land use patterns. However, there are well-documented concerns about poor development control in India, and development plans and Master plans often do not represent actual development on the ground. A Master Plan/Development Plan is an important instrument for urban planning and development. All these exist in Indian cities and particularly the three cities studies. Details have been enclosed separately. Perhaps the main challenge currently facing local governments of large cities in India is how to provide essential services – including housing, energy, water, sanitation, health and education – to meet the basic needs of an ever-growing population.

National Urban Information System (NUIS) data is available online from the Ministry of Urban Development, the Government of India and this also provides a possibility for merging it with property tax data, thus creating an extensive data set with information on use of land, along with floor space developed per land use. NUIS Scheme has GIS databases for 152 towns/cities (March 2009) in the country in two scales that is 1:10.000 and 1:2000. Apart from spatial data, this database has attribute data which will be useful for preparation of Master/Development plans, detailed town planning schemes and serve as decision support for e-governance. NIUS database was used for the LCMP of Rajkot and consisted of spatial data of each building, information on all roads, and other utilities including street furniture.

In cities where NUIS data is not available, CDP or Master Plans can be used in conjunction with remote sensing data and property tax data. One important land use element that is missing in all conventionally available statutory and non-statutory data sets in India is information on street activities like hawkers and other temporary establishments.

Urban management policies and practices are always likely to impact strongly on social issues, so tools and approaches for promoting social inclusion are especially important. Promotion of public participation in decision-making is vitally important in urban management. Tools for urban assessment, visioning, scenario development and strategy planning can stimulate social and organizational learning and provide a process for enhancing stakeholders' understanding of how to prepare for and manage change, risk and uncertainty. Engaging grassroots and neighbourhood level participation in urban management, including in participatory budgeting, helps to put new urban solutions into practice. However, this process is slow in India. In the three cities Bangalore, Pune and Noida, this process is reasonably better than in other tier II cities in India. This is due to access to information on the alternatives; greener industries which can co-locate with the habitat and options of the community leaders. Toolkits for urban development for comprehensive mobility plans developed by MOUD have already being pursued by many cities which is strengthening the interrelation between manufacturing and urban development plans. These guidelines have been established from the experience gained from preparations of „Promoting Low Carbon Transport in India" in the cities of Rajkot, Vishakhapatnam and Udaipur. Indian cities are urbanizing at a very fast pace and India's urban environment is going to contribute or develop a new agenda for urbanism in the 21st century.

Innovation potentials of advanced manufacturing / Industry 4.0 in the context of urban development:

Changes in technology, public policy, security, and the financial and energy markets changes are among the factors accelerating the change in manufacturing in India. Five major drivers that

are transforming virtually every manufacturing sector in India are: Energy & Waste; Effective utilization of resources to reduce waste and energy consumption while optimizing production; Safety & Security of human, physical and intellectual capital across the connected supply chain; Social corporate responsibility assessment and availability of information on Carbon and GHG emissions across the Product Life Cycle, and harmonized standards of supply chain integration with availability and automated global standards across interoperable systems.

Challenges and opportunities to realize sustainable manufacturing are the research and development that will provide the foundation for manufacturing success in India. They are:

1. Focus on dynamic links to plant manufacturing equipment and energy sources,

2. Standards to support dynamic grid interfaces and linkages to plant control to drive sustainable manufacturing and optimal economic performance,

3. Knowledge standardized approach needed for encoding process and product information,

4. Distributed energy & energy storage,

5. Manufacturing Technology with less energy, smart energy awareness machines and controllers, more efficient OEM equipment, and,

6. Methodologies for agile integrated manufacturing capabilities to support demanding requirements for capturing core capabilities and integration of those capabilities.

Strategy & recommendations to ensure India's leadership in advanced manufacturing:

A cluster of industries concept has really worked well for the growth of the sector in Bangalore, Pune and Delhi NCR regions. The Government of India should support applied research programs in new technologies with the potential for transforming impact and co-investing in public-private partnerships (PPPs) to facilitate development of broadly applicable technologies with transformative potential. Supporting the creation and dissemination of powerful design methodologies that expand the ability of entrepreneurs to design products and processes shall be encouraged. Investing in shared technology infrastructure is an ideal method that would help companies to improve their manufacturing capabilities. The Government shall focus on creating a fertile environment for innovation in these areas by encouraging companies to create R&D and manufacturing at same location (co-locating universities with industries). There is clear need for Supporting a robust basic research enterprises where advanced manufacturing units are coming. The system shall ensure the supply of skilled force through policies and attract high skilled talent along with an Improvement in tax policies.

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6 ADVANCED MANUFACTURING – WHY THE CITY MATTERS, PERSPECTIVES FOR INTERNATIONAL DEVELOPMENT COOPERATION

BERNHARD MÜLLER, PAULINA SCHIAPPACASSE[1]

EXECUTIVE SUMMARY

Industry 4.0 and advanced manufacturing are topics of high international relevance. They are currently intensively discussed both in academic literature, and in practice within the framework of what is called the 4th industrial revolution based on Cyber-Physical Systems (CPS), the Internet of Things and Services (IOT) as well as Cloud Computing. They depend to a high degree on the availability of adequate digital infrastructure and well-functioning logistics systems, and they have a number of repercussions on cities and regions.

Taking this into consideration, it is surprising that there has not been much work done yet regarding the interrelations between Industry 4.0/advanced manufacturing and urban development. With the GIZ sponsored and BMZ commissioned project on "Advanced Manufacturing/Industry 4.0 and Urban Development - Connected, sustainable and urban economic activities in the industrial sector in the context of local, regional and global ICT-based value and logistic chains using the example of selected Indian metropolises", the National Academy of Science and Engineering (acatech) is therefore stepping into a new field of academic and practical interest, especially as it also takes up an international development cooperation perspective.

Within the framework of the project, the study presented here was commissioned by acatech. It had the objectives to identify major trends and preconditions of urban development with regard to advanced manufacturing (including logistics) and to assess their current status in an international context, to identify major potential positive and negative effects of advanced manufacturing (including logistics) for urban development in an international context, and to derive policy recommendations.

The study gives a general outline of the inter-relations between Industry 4.0, advanced manufacturing and urban development. Overall trends, such as those related to the development of smart cities, are discussed. Furthermore, the urban context of potential advanced manufacturing activities in rapidly growing urban areas in developing and emerging countries is discussed. Urban challenges as well as characteristics of competitiveness and necessary shifts in planning are highlighted. In a further part, the study deals with inter-relations between advanced manufacturing and urban development in detail. Strengths and weaknesses are presented.

Based on these activities, the following recommendations were derived and specified:

- Advanced manufacturing in the urban context is an important new topic for German development cooperation. Industry 4.0 in the urban context should be an issue of German international development cooperation. ICT, business orientation and urban development could be feasible entry topics for development cooperation.
- There are a lot of development potentials of the nexus between advanced manufacturing and urban development. They should be made use of in German development cooperation. However, development projects have to pay attention to coping with existing challenges and providing favorable framework conditions for Industry 4.0.
- Industry 4.0 requires the facilitation of knowledge creation and the building up of a well-educated and trained society. This should be better reflected in urban development and development cooperation related to it.
- Existing urban planning approaches have to be re-examined, and the potentials of Industry 4.0 to accelerate sustainable urban development should be better used.
- Urban governance should be accentuated and transparent partnerships between policy making, business and academia should be fostered.

[1] With the assistance of Xiaping Xie, Leibniz Institute of Ecological Urban and Regional Development (IOER), as well as Janina Dreier and Sinead Anja Hering, Technische Universität Dresden.

6.1 INTRODUCTION

Industry 4.0 and advanced manufacturing are topics of high international relevance. They are currently intensively discussed both in academic literature, and in practice within the framework of what is called the 4th industrial revolution based on Cyber-Physical Systems (CPS), the Internet of Things (IOT) and Services as well as Cloud Computing. They depend to a high degree on the availability of adequate digital infrastructure and well-functioning logistics systems, and they have a number of repercussions on cities and regions. Here we have to note that the manufacturing advancements and the leaps of urban development have always been in tandem. The visions of new technology have created ideas of urban utopias and inspirited practical urban development.

Taking this into consideration, it is surprising that there has not been much work done yet regarding the interrelations between Industry 4.0/advanced manufacturing and urban development. With the GIZ sponsored and BMZ commissioned project on "Advanced Manufacturing/Industry 4.0 and Urban Development – Connected, sustainable and urban economic activities in the industrial sector in the context of local, regional and global ICT-based value and logistic chains using the example of selected Indian metropolises", the National Academy of Science and Engineering (acatech) is therefore stepping into a new field of academic and practical interest, especially as it also takes up an international development cooperation perspective.

Within the framework of the project, two studies were commissioned with special attention to urban development. As Industry 4.0 is still a vision and far from being implemented, both studies focus on advanced manufacturing. Reference to Industry 4.0 is made wherever possible and necessary.

The study on "Interrelations between advanced manufacturing and urban development – the case of metropolitan areas in India" highlights the preconditions of urban development for advanced manufacturing as well as possible consequences of advanced manufacturing for urban development in the case of metropolitan areas in India[2].

The study on "International perspectives of interrelations between advanced manufacturing and urban development" presented here has a wider scope. The objectives of the study are:

a. To identify major trends and preconditions of urban development with regard to advanced manufacturing (including logistics) and to assess their current status in an international context; the study shall identify possible gaps between the actual status and future requirements;

b. To identify major potential positive and negative effects of advanced manufacturing (including logistics) for urban development in an international context; the study shall identify issues of urban development which will be affected by advanced manufacturing (including logistics) in a positive and negative way;

c. To derive policy recommendations regarding (a) and (b), and the interrelations between advanced manufacturing (including logistics) and urban development in an international context based on findings with regard to Indian metropolitan areas; the study shall identify major actions which can be undertaken to strengthen the interrelations between advanced manufacturing and urban development, and it shall point out to the major stakeholders, the related institutional set-up and the necessary governance structures in order to promote urban development with regard to advanced manufacturing.

The study complements the Indian results which are taken into consideration. However, it also takes a look at German development cooperation. And it looks especially at urban development from a more international angle. The interrelations between advanced manufacturing and urban development are discussed with regard to their relevance for other economically developing countries and emerging economies, as well as for international development cooperation. The study is based on a broad literature review, official documents and further reports. Moreover, the results of a number of interviews which were conducted in India during a visit in May 2014 are incorporated.

In the following we start with a general outline of the inter-relations between Industry 4.0, advanced manufacturing and urban development. Overall trends, such as those related to the development of smart cities, are presented. Afterwards, the urban context of potential advanced manufacturing activities in rapidly growing urban areas in economically developing and emerging countries is discussed. Urban challenges as well as characteristics of competitiveness and necessary shifts in planning are highlighted. In a further part, the study deals with inter-relations

[2] Sitharam 2015.

between advanced manufacturing and urban development in detail. Strengths and weaknesses are presented. Finally, conclusions are drawn and recommendations for international development cooperation are highlighted.

6.2 INDUSTRY 4.0, ADVANCED MANUFACTURING AND THE CITY

Whereas Industry 4.0 is a rather new term, advanced manufacturing has been under discussion for a long time. However, besides technology inspired urban utopias in the past, neither in practice nor in academia, the relation of advanced manufacturing with urban development has rarely been a focus of attention in the current discussion. In this chapter we will have a look at both, Industry 4.0 and advanced manufacturing and at more recent developments where urban development has become a topic of concern.

6.2.1 Industry 4.0 – new perspectives for urban development

The term "Industry 4.0" has been generated in Germany by the German Federal Ministry of Education and Research (BMBF), the Federal Ministry of Economic Affairs and Energy (BMWi), the Research Union of the German Federal Government, the body in charge of implementing the government's high-tech strategy, and acatech. It has been created in order to denote the process of tightly integrating information and communication technologies (IT) in manufacturing and logistics through the possible use of Cyber-Physical Systems (CPS) as a "4th industrial revolution": CPS allow for a continuous data collection and evaluation along the complete chains of value creation networks through Machine-to-Machine (M2M) communication using the Internet of Things (IOT). There are several research programs funded by the BMBF and the BMWi, and the German industry is very actively participating in these programs. Large industrial and business associations, such as VDMA, ZVEI, and BITKOM have produced the platform "Industrie 4.0" in order to coordinate the progress in this essential field.

The use of these concepts is not restricted to the German industry: in the USA there is an initiative called "Smart Manufacturing Leadership Coalition" (SMLC) which is a non-profit organization to enable the manufacturing industry to develop the approaches, standards, platforms and shared infrastructure for the general adoption of manufacturing intelligence. Also General Electric has started the initiative "The Industrial Internet" with the same goals.

Although Industry 4.0 technologies will only be introduced into manufacturing and logistics within the next decade there are already industries which are very well positioned even today, such as the automotive and the electronics industry. It is very probable that Industry 4.0 concepts will constitute the kernel of manufacturing including logistics within the next decade and completely change the world of industrial production (for example[3,4]). What we can experience already now in our everyday life, for example using mobile devices which interconnect different services and provide information automatically, will be a standard in industrial production of tomorrow.

It is obvious that – given this situation – it will be very difficult to participate in global value creation networks in the future without Industry 4.0 technologies and to embark on advanced manufacturing strategies as soon as possible. By no way, this will make the task of urban managers easier: "Space" will matter here as industry is dependent on site location and a certain local and regional production environment (for example infrastructure, labor, government). Although there is almost no experience in this field until now, some assumptions can be made.

Under the assumption of quasi-ubiquitous internet connectivity in the future, Industry 4.0 will make companies much more flexible. It will allow them to further individualize their products, modularize their value creation chains and interconnect production processes worldwide within their own entity and between related companies (for example suppliers, ancillary industry). On the condition of well-functioning logistics systems – still one of the major bottlenecks in many countries, especially in the developing world today – Industry 4.0 may diminish the dependency of companies on locational production factors. It will enlarge their degrees of freedom regarding the sizes of enterprise units and production facilities as well locational choices related to them. And this will make it more difficult for cities to compete.

Industry 4.0 is also expected to further the creation of dynamic and flexible enterprise networks. It will facilitate related companies to associate for a given time span, and to form temporal virtual production or service clusters. This may diminish the importance of regional cluster approaches but it may make

3 Forschungsunion/acatech 2013.
4 BMBF 2013.

international networking of cities more necessary. Sensor technology and the availability of real-time data contribute to optimizing production processes and will lead to environmental gains, that are more energy efficiency, less use of raw material and natural resources and cleaner production in general. This may prove to be an important benefit for sustainable urban development and create new opportunities for urban management.

6.2.2 Advanced manufacturing on the rise: upcoming initiatives

Whereas Industry 4.0 is a term which has only recently come up, advanced manufacturing is not a new topic at all. Regarding academia, for example, "The International Journal of Advanced Manufacturing Technology", one of the major peer-reviewed journals in the field is published by Springer since 1985 with 36 issues per year. And in practice there are many approaches worldwide towards constantly improving industrial production by using Advanced Manufacturing Technologies (AMT).

Nevertheless, advanced manufacturing – as Wial[5] writes – still has no precise, widely accepted definition. It generally refers to the use of advanced technologies in the manufacturing process or the creation of new products using those technologies. It is described as "a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies"[6].

Nowadays, the topic ranks high on research agendas. Companies together with universities and other research institutions have established pilot projects. For example, in October 2012, the European Commission issued a Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on "A Stronger European Industry for Growth and Economic Recovery"[7]. Markets for Advanced Manufacturing Technologies for clean production were mentioned as one of six priority areas.

The Communication describes Advanced Manufacturing Technologies as "a key part of the new industrial revolution. For example, 3-D printing allows production in much smaller quantities than is currently economically feasible, enabling low-cost customised production for new niche products and opening up new market opportunities for innovative SMEs. Tomorrow's factories will use energy- and material-efficient processes, employ renewable and recycled materials, and increasingly adopt sustainable business models such as industrial symbiosis to recover materials and dissipated heat and energy. These technologies represent an important business opportunity, with a global market that is expected to double in size to over € 750 billion by 2020. EU industry is already a world-leader in these technologies, with a world market share of over 35% and a patent share of over 50%"[8].

The European Union Task Force on Advanced Manufacturing for Clean Production recommends the integration of advanced manufacturing in regional strategies when appropriate and makes reference to the Structural Funds 2014–2020, in particular the European Regional Development Fund (ERDF), as a source of funding for the deployment of advanced manufacturing by companies in European regions. "To maximise the ERDF64 impact towards smart and sustainable growth, under the 2014–2020 programming period, the ERDF rules provide for investments to be concentrated on four key thematic objectives: (1) innovation and research, (2) the digital agenda, (3) support for SMEs and (4) low-carbon economy. ... However, as a precondition for the use of the funds, the needs for such investments would have to be included in the smart specialisation strategy"[9].

Europe is not alone in its efforts to promote advanced manufacturing. For example, the US government issued a "National Strategic Plan for Advanced Manufacturing" in February 2012. It states that advanced manufacturing "is a matter of fundamental importance to the economic strength ... of the United States"[10].

In Germany advanced manufacturing and Industry 4.0 are among the top priority issues of the National High-Tech Strategy. They have entered policy making and research agendas. However, they are only slowly entering the discussion about

5 Wial 2014.
6 President's Council of Advisors on Science and Technology 2012, p. ii.
7 European Commission 2012.
8 European Commission 2012, p. 8.
9 European Union 2014b, p. 22.
10 National Science and Technology Council 2012.

future cities although they are connected with urban development in many ways.

One of the initiative which links advanced manufacturing with urban development is the "Morgenstadt" (City of tomorrow) Initiative by Fraunhofer, Europe's largest application-oriented research organization. It describes the link between the city of the future on one side, and production and logistics on the other as follows: "In the future city transportation and handling of goods will happen fluently within intelligent structures of production and distribution - presenting the backbone of sustainable trade, services and urban production. At the same time essentials have to be provided at any time to all citizens. The city of tomorrow will be involved more deeply in the provision of production and logistic services by providing, planning and monitoring specific urban infrastructure and services for production and logistics (Morgenstadt)."[11]

And furthermore: "In the city of the future, life and work will be characterized by short distances and by the freedom to realize individual life- and work styles. At the same time people will have multiple opportunities for participating in decisions on the development of their city. Rigid value chains will be replaced by innovative and flexible value patterns. Regarding consumption and economy, the possession of goods will be less important than the sustainable use of goods and systems. Inhabitants of Morgenstadt won't be exclusively consumers anymore – they become prosumers: producing consumers."[12]

Fraunhofer has chosen "Production and Logistics" as one of its seven research fields in the future city research initiative. The others research fields are: Energy, Buildings, Mobility, Information and Communication, Urban Processes and Organization, and Security. This puts advanced manufacturing in an urban context. There are some examples of advanced manufacturing oriented companies which have set up their production facilities in close vicinity to housing areas. One of them is Wittenstein AG, a mechatronic and drive technologies company which set up a smart factory in a DGNB certified building close to housing.

Furthermore, there are also a number of international city initiatives worldwide which demonstrate that cities are preparing for changes in the industrial world. According to Roberts and Hohmann[13] some cities like Toulouse in France, Boston and Seattle in the USA, Bangalore in India, Busan in South Korea and Curitiba in Brazil, are among the cities which have become global leaders in knowledge and advanced manufacturing industries.

Other cities, such as Guangzhou in the Pearl River Delta in China, have embarked on strategies to actively promote advanced manufacturing. In this case, advanced manufacturing is demarcated as one of five categories of major investment projects in the city besides infrastructure, social undertakings, strategic emerging industries, and modern services. A number of major investment projects have been identified[14] to promote advanced manufacturing.

In order to become a global competitor with regard to advanced manufacturing, the city administration is aware that it is not enough to implement such projects but to also give special attention to the business environment in general. Therefore Guangzhou has also developed a number of related initiatives, for example to make best use of its favorable geographical location, to facilitate a good living environment and to protect the environment, to establish industrial clusters and facilitate comfortable and convenient transportation, to foster education and human resources, to establish efficient customs clearance, to protect intellectual property rights, and to establish effective administrative services.[15]

Similarly, South Korea has developed the concept of six Free Economic Zones (FEZ) - areas which are specially designated to provide companies with an optimal environment to engage in global business activities. They are designed to become logistics hubs of Northeast Asia, as well as hubs of value-added service and of cutting-edge industries. For example the Incheon Free Economic Zone (IFEZ)[16], located in Seoul's neighbour Incheon, a 2.5 million inhabitants city in the capital agglomeration, was nationally designated in August 2003 with an area of 170 km^2 and an estimated future population size 640.000 people. IFEZ consists of three areas which are

11 Fraunhofer-Gesellschaft 2014.
12 Fraunhofer-Gesellschaft 2014.
13 Roberts/Hohmann 2014.
14 They are: Huangpu Intelligent Innovation Base, Guangzhou Liandong U Valley International Manufacturing Harbor, Guangzhou Huadu Locomotive Manufacturing Park, Non-Seine Area of Guangzhou Baiyun Airport Comprehensive Bonded Zone, High-tech Industrial Base of Guangdong Conghua Economic Development District, and Guangdong Conghua Economic Development District Pearl Industrial Park.
15 Guangzhou International 2014.
16 The others are: BJFEZ (Busan-Jinhae Free Economic Zone), GFEZ (Gwangyang Bay Free Economic Zone), YESFEZ (Yellow Sea Free Economic Zone), DGFEZ (Daegu/Gyeongbuk Free Economic Zone), SGFEZ (Saemangeum Free Economic Zone).

interlinked by large bridge: (1) Songdo, a worldwide known smart eco-city which shall become the business and IT center, (2) Yeongjong, including Incheon International Airport, as a logistics center, and (3) Cheongna, which is designated to be among others a hub for business, finance, and advanced industry (for example Incheon High-tech Park (IHP) for automobile parts, new materials, IT, biotechnology, nanotechnology, advanced R&D and robotics industry; moreover advanced aviation industry). The planned infrastructure allocation was more than 36 billion US dollars. The first phase was completed in 2009 with a total infrastructure investment including land reclamation of 41 billion US dollars. The total development shall be completed in 2020. However, due to the global financial crisis some projects have already been cancelled.

6.2.3 The smart city - information and communication technologies in urban development

Information and communication technologies (ICT) are more and more widespread. About 40 per cent of the world population is currently using the internet with the highest penetration rates in North America (85 per cent) and Europe (69 per cent), and the lowest ones in Africa (21 per cent) and Asia (32 per cent). Today, access to internet is about seven times higher than at the turn of the millennium with the highest growth rates since then in the developing world[17]. According to the International Telecommunications Union, it is estimated that around 40 per cent of households in developing countries will be connected to the internet by 2015. In 2013, 28 per cent of households in developing countries and 80 per cent of households in industrialized countries were connected[18].

Access to internet is one of the most apparent prerequisites of advanced manufacturing and Industry 4.0. Any region or urban area being interested in becoming or being targeted as a (potential) advanced manufacturing site will have to put attention on it. However, in many parts of the world, especially in urban/metropolitan areas, missing internet access is not an obstacle for business anymore.

ICT has become an issue of discussion in urban development over the past decades. This is due to the fact that ICT eases information collection and processing, allows information integration across sectors and levels, and facilitates fast and efficient communication. Therefore, it has become increasingly attractive for city managers and other stakeholders in urban development. E-government, e-participation, e-mobility, e-learning, e-health, e-inclusion, just to name the most widespread ones, have been implemented in many cities. They belong to standard ICT based e-applications.

What started with a variety of labels such as the "digital city", the "virtual city" and the "intelligent city" more than two decades ago has moreover resulted in a broad worldwide movement promoting "smart cities". Meanwhile, there is a multitude of mainly practice led initiatives worldwide to develop and implement smart cities.

In many cases, these initiatives are not only technologically but also environmentally driven, and they complement eco-cities initiatives. While some of the initiatives are oriented towards retrofitting or "technologizing" entire existing cities or parts of them, others are related to the creation of new, hyper-modern satellite towns and new cities or city districts within and outside of urban agglomerations. Just to name a few: Copenhagen, Aarhus, Amsterdam, London, Vienna, Barcelona, Santander, Berlin, Cologne in Europe, and Singapore as a well-known example from outside of Europe, belong to the first group. Cities like Abu Dhabi/Masdar, Sao Paolo/Heliopolis, Tianjin/Tianjin Eco-City, Seoul/Songdo, Delhi/Cyber City and Bangalore/Electronics City belong to the latter one.

Although there are many approaches in practice and academia to concretize what makes cities "smart"[19], the underlying concept of a "smart city" still appears to be a rather loosely defined and fuzzy one. However, there is more and more consent that it cannot be defined merely on the ground of ICT applications.

For example, Caragliu, Del Bo, and Nijkamp[20] define "a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."

Carius, Giorgi, Schmid[21] describe in a study for GIZ (by adelphi) smart cities as cities "which deliberately engage in participatory

17 Miniwatts Marketing Group 2001 – 2014.
18 GIZ 2014.
19 European Union 2014a.
20 Caragliu et al. 2009, p. 70.
21 Carius et al. 2013, p. 1f.

learning and evidence-based policy-making in order to improve their services and infrastructure and, in this process, make use of advanced information and communication technologies. ICTs are used to improve connectivity, at the infrastructure level (i.e. from machine to machine) as well as at the level of services (i.e. from human to machines). Given the right conditions, this improved connectivity contributes to resource efficiency (hence also to environmental sustainability) as well as to the betterment of social services (hence, indirectly, to the reduction of social inequalities and increased societal participation)."

From a more critical perspective one may also come to the conclusion that "a 'smart city' represents a positively valued, multi-objective policy strategy of integrated urban and ICT development, promising to tackle problems of economic competitiveness, social equity and environmental performance. Such a strategy attracts stakeholders for its ability to reduce complexity and provide capacity to act in situations characterised by wicked problems and uncertainty, claiming efficient (time and resource constraints) and effective intervention (extent of impacts). It is therefore also a proposition that is rather difficult to reject, thus paving the way for political majorities and implementation alliances."[22]

Nevertheless, smart cities have attracted a lot of worldwide attention during the last years[23]. In Germany, the German National Academy of Science and Engineering[24] has published a position paper on smart cities. DIN (German Institute for Standardization) and DKE (German Commission for Electrical, Electronic & Information Technologies) have started to elaborate a standardization roadmap on smart cities. GIZ commissioned a study on key concepts, actors and potential entry points for German Development Cooperation regarding smart cities in 2013[25].

Smart cities are currently also playing a role in the German "Nationale Plattform Zukunftsstadt" (NPZ, National Platform Future City), a large initiative involving four federal ministries under the leadership of BMBF[26] to define major future research topics on urban issues in Germany. Although NPZ will present its final results only in early 2015, the draft papers show the importance of ICT driven urban development and smart cities in the future research agenda. This is an important link for any activities regarding advanced manufacturing within the framework of international development cooperation.

If we look at the international context, it may be of interest, that in India the Government is on the way to implement a new "100 Cities Program". It wants to create 100 eco- and "smart" new urban settlements all over the country as a path towards smart growth and sustainable urban development[27]. Conceptually, the concept is linked with the Indian Corridor Concept which was elaborated together with JICA.

To some extent, many new private sector driven urban developments, for example in the National Capital Region (NCR), that is the Greater Delhi Metropolitan Area (for example DLF Cyber City, Gurgaon, NOIDA) or Bangalore (for example Electronics City) can in principle demonstrate advantages of such an approach[28]. The initiatives may make a positive contribution to providing a positive framework for advanced manufacturing and Industry 4.0 by providing a smart environment for smart factories.

However, they also show how important it is that urban extension goes hand in hand with integrated urban planning and infrastructure development. This has rarely been the case yet. For example, the urban expansion along the Delhi-Mumbai Corridor seems to have some deficits with regard to planning and implementation. New industrial and housing areas are mushrooming along a stretch of about 100 kilometers between Delhi/Cyber City/Gurgaon and Raffles City south of New Delhi. However, the area which is under heavy urban development lacks proper infrastructure and transportation facilities. For example, the Delhi-Jaipur highway is being extended and improved causing numerous construction sites. Moreover, new flyovers are (seemingly for some time already) under construction leading traffic to collapse frequently and reducing the average speed in many parts to less than 30 kilometers per hour.

Another more local example is the flyover in Bangalore which connects the City of Bangalore with the Electronics City. The flyover was built on the initiative of the companies located in

22 Wolfram 2012, p. 172.
23 European Union 2014a.
24 acatech 2011.
25 Carius et al. 2013.
26 The other ministries are BMUB, BMVI and BMWi.
27 India Briefing 2014.
28 Another example may be the ICT-based New City Kolkata.

the Electronics City and meant to alleviate the access of their 100.000 employees to their workplaces. However, during rush hour periods, the flyover is constantly overcrowded.

The 100 Cities Program is one of the official measures to cope with the rapid increase of urban population. For example, 410 million people, that is 32 per cent of the total population, live currently in urban areas in India. There had been a net addition of 188 million urban dwellers, that is an increase of 85 per cent over the last two and a half decades. Until 2050 India is projected to nearly double its urban population, adding 404 million urban dwellers between 2014 and 2050. This will be the highest growth of urban population in absolute numbers worldwide[29].

One of the first of its kind and a showcase for other smart cities of the 100 Cities Program is the Gujarat International Finance and Tec-city, known as GIFT City close to Ahmedabad which is currently in the making[30]. In future, India seems to give much higher attention to urban issues, and especially to smart cities' development, than in the past[31].

Here it may be of interest that Singapore recently offered help to build a new model smart city in India which can be replicated within the framework of India's new Prime Minister's plan to orientate the national 100 cities program towards smart city developments[32]. The Foreign Minister of France offered the same, and others may follow.

The 100 Cities Program is creating huge international market potentials, and moreover, it will also contribute to thousands of less qualified and poorer paid jobs, for example in the Indian building industry in the coming years.

Whereas new urban settlements create a lot of new business opportunities and are thus frequent, urban renewal of inner urban areas is still in an infant stage. For example, in Bangalore, a local NGO[33] has taken over some street upgrading projects, organizing coordinated interventions of public services providers, and street beautification. Digital infrastructure does not play a role here. Similarly, there is no concern regarding the informal sector (other than providing special spaces for commercial activities) or micro- and small enterprises which could eventually be linked with large companies via internet and digital connections.

In some areas, service businesses, such as engineering design companies (here Magna Steyr in Pune), have been located in direct vicinity to housing areas. Technically this is no problem and provides for opportunities for more mixed developments which could also be promoted by advanced manufacturing. However, if a company has a two- or three-shift system with employees leaving around midnight, and with the absence of regular public transport facilities, this leads to noise pollution which becomes a nuisance for the residents living in this area.

In China, just to quote another example where relatively new urban development concepts such as eco-/techno-/smart cities also gain higher relevance, urban growth is already a strategic goal as urbanization and economic development are seen as complementary[34]. The country with an urban population of currently about 760 million is projected to have about 1050 million urban dwellers in 2050. This will equal 76 per cent of the total population[35]. According to the recently approved Urbanization Plan, 60 per cent of China's more than projected 1.3 billion people shall live in urban areas by 2020.

At first glance, this may sound not too ambitious compared to the 54 per cent who live in urban areas already now. However, it means that in its attempt to accelerate economic growth, the Chinese government intends to realize a population shift of almost 100 million people to cities in the coming few years. This has boosted he construction sector. New cities, in many cases on the edges of large metropolitan areas, are mushrooming in many parts of the country. All cities with more than 200.000 inhabitants are planned to have a rail connection, and those with more than 500.000 inhabitants shall have even high-speed rail[36]. This does not only imply a gigantic urbanization program but it also requires huge infrastructure investments within an extremely short period of time.

29 UN 2014.
30 India Briefing 2014.
31 Express News Service 2014.
32 Bagchi 2014.
33 Janaagraha 2014.
34 China News 2014.
35 UN 2014.
36 China News 2014.

India and China are not single cases of the urbanization boom, especially in the rapidly urbanizing developing world characterized by the making of new large urban projects. The two examples show, however, that with new cities to come, especially in Asia and Africa, but also in Latin America, there is a huge potential in urban development to create new and better preconditions for advanced manufacturing and to pave the way for Industry 4.0, at least in countries which are on the radar of the new manufacturing world. But there is also a danger that new developments will become "white elephants" if the specific urban contexts are left aside. The "ubiquitous city" or U-city[37], as some of the smart cities, such as Songdo in South Korea, are sometimes called is becoming ubiquitous in the sense that it is more and more becoming a stereotype one-fits-all worldwide model for urbanization irrespective of the specific contexts of the respective countries. This is worrying and will be discussed in the next chapter.

6.3 THE URBAN CONTEXT: CHALLENGES, COMPETITIVENESS AND PLANNING

6.3.1 Urban challenges

We are living in an urban age. According to the latest UN[38] figures, 3.9 billion people or 54 per cent of the world's population live in urban areas, and it is expected that by 2050 the share of urban population worldwide will have risen to about 66 per cent. Urban growth will primarily take place in economically developing regions with an average annual growth rate of almost 2.3 per cent, contrasting about 0.5 per cent in developed regions. Whereas developed regions as well as countries in Latin America and in East Europe will experience slower urban growth rates, or even some decline in numbers of urban population, rapid urbanization will occur in a number of countries in Africa and Asia[39].

Today, around 12 per cent of the world's urban population lives in the 28 megacities which are the 10+ million urban agglomerations. By 2030 the number of megacities will have increased to 41, and the Indian National Capital Region (Delhi) with then 35 million inhabitants is about to overtake Tokyo as the largest urban agglomeration worldwide[40]. Nevertheless, while a large part of urban growth is generally attributed to the rise of these cities, its major part is predicted to happen in much smaller settlements, for example in settlements with 100.000 to 250.000 inhabitants[41]. All in all, about half of the world's urban population lives in cities with less than 500.000 inhabitants[42]. Between 2007 and 2025, these cities will absorb nearly half of the expected increase of the urban population. And they also have to provide a very large part of new jobs to be created, and housing to be constructed.

Rapid urban growth on the one hand and rather weak national, regional and local government mechanisms to direct urbanization processes on the other, have led to many problems and challenges in urban areas worldwide, especially in the lower-middle-income countries where the pace of urbanization is fastest[43]. Although there is large diversity of urban contexts, some general difficulties can be identified, for example high levels of poverty and unemployment, sharp social segregation, urban sprawl, rapid growth of slums and squatter settlements, and critical living and environmental conditions.

Other problems are related to the limited ability of governments to provide urban infrastructure, and the scarce capacity of urban residents to pay for such services. For example, deficient public transportation, unequal mobility and accessibility conditions, as well as poor water provision, sewerage and waste disposal systems are among the consequences. In general, there is also a very limited ability to cope with natural disasters, affecting especially the urban poor. According to UN Habitat figures, in "the developing world, close to 37 per cent of the urban population currently live in slums in inequitable and life-threatening conditions, and are directly affected by both environmental disasters and social crises"[44].

Given these conditions in many urban areas today, it may sound cynical to speak about the 4th industrial revolution. Nevertheless, we have to keep in mind that in fact many urban areas are

[37] The "ubiquitous city" is a concept which integrates ubiquitous computing within an urban environment. It can be described as a merge of information systems and social systems (Mola/Pennarola/Za 2014).
[38] UN 2014.
[39] UN Habitat 2009.
[40] UN 2014.
[41] UN Habitat 2009.
[42] UN 2014.
[43] UN 2014.
[44] UN Habitat 2009.

integrated in the international value creation chains, and they are also places which offer a number of opportunities to a large population in a comparatively cost effective way. These include access to better services, such as education and health care, as well as to housing, public transportation, and urban infrastructure. Moreover cities in general provide easier access to larger and more diversified labor markets and provide a broader range of income opportunities for all groups of the population[45]. However, cities can only make use of these opportunities in a meaningful way if they are prepared for new technologies and a new manufacturing age, and have a comprehensive planning system in place which is oriented towards sustainable development, that is the integration of economic, social and environmental concerns with short-, medium-, and long-term perspectives. The question is not whether or not advanced manufacturing is a boon or bane for urban development but how cities can avoid negative impact and make the best out of potential benefits in pursuing sustainable development.

6.3.2 Urban competitiveness

According to Joan Clos, the Executive Director of UN-HABITAT, "poverty is moving into cities, mostly in developing countries, in a process we call the *urbanisation of poverty*. ... The persistent problems of poverty and slums are in large part due to weak urban economies. ... Cities act as engines of national economic development. Strong urban economies are essential for poverty reduction and the provision of adequate housing, infrastructure, education, health, safety, and basic services"[46].

In other words: If urban areas in economically developing and emerging countries want to be and remain competitive in the future and be able to manage their challenges successfully, they are well advised to prepare themselves for advanced manufacturing and integrate themselves into worldwide value creation chains. Thus urban competiveness is an important issue for them.

Urban competitiveness is especially a serious problem in secondary cities in many developing countries. They tend to be weaker economically than larger urban metropolitan regions, but many are growing very fast, as urban-rural migration accelerates. Most have poor local government administration and governance systems, weak and poorly regulated land and property markets, and no planning and development control enforcement. Low skills, limited application of advanced technology and e-governance systems together with poor infrastructure and urban services also undermine their competitiveness.

In general, internet development and the quality of access to it have had a strong influence on urban competitiveness. Some cities have embarked on respective strategies, for example becoming "smart cities", and market themselves very successfully. Others are lacking behind. However, as broadband internet access is not at all an insurmountable obstacle anymore, and as it is a potentially quasi-ubiquitous good in many parts of the world, urban competitiveness regarding advanced manufacturing is strongly determined also by other factors.

Traditionally, competitiveness is associated with "having a strong urge to win"[47]: An externally defined goal of a competitive activity is accepted by the competitors. All policies and resources are then oriented towards it. Performance is measured comparatively. And at the end there are winners and losers, those who have come in first, and those who have come in last. Contrasting to this, there is another, more appropriate definition of competitiveness: knowing to "play the game" well and playing it together with the best without necessarily intending to beat the others. Being or becoming a world class city and staying in the "champions' league" of cities may be a goal, and not becoming the number one according to which criteria and ranking ever. Whereas the first notion is related to the result of an activity, the second one is based on the way of conducting an activity, and the latter applies better to the topic under discussion here[48].

Thus, following UN Habitat[49], we can define urban competitiveness as a function of economic and strategic determinants with the goals to be better integrated in international value creation chains and to achieve a more equitable and sustainable development internally. Among the economic determinants of competitiveness are the factors of production, such as land, resources and energy, labor, human and intellectual capital including the availability of workforce, human skills, knowledge and entrepreneurship, as well as capital in monetary and financial terms. Moreover they consist of features of location, the capability to provide the necessary infrastructure and the availability and

45 UN 2014.
46 UN Habitat 2013.
47 Oxford compact English Dictionary op. cit. UN Habitat 2013, p. 3.
48 UN Habitat 2013.
49 UN Habitat 2013.

quality of urban amenities. Strategic determinants are associated with governmental effectiveness, good governance, the existence and quality of a clear urban strategy, the well-functioning of public-private sector cooperation as well as institutional flexibility. Also social capital may be included here.

Moreover, the equal access to education and the labor market for all is seen as an important prerequisite for raising urban competitiveness and thus become more sustainable: "Cities will never be able to achieve their true maximum competitiveness if they are components of national societies in which ethnic groups and/or immigrants are subject to discrimination and in which women are precluded from gaining access to educational institutions and from functioning as productive participants in the economy of the nation and, thereby, of the city"[50]. Thus, regarding the competition for jobs and production facilities, the "city of divisions", that is the city with severe inequalities and exclusions, for example regarding income, poverty, opportunities, the social divide in terms of health and hunger, and education, has a handicap compared to other cities where this divide is less severe or non-existent[51].

For a long time, it is usually not the individual enterprise anymore producing in isolation that generates long-term economic success. In fact, agglomerations, clusters and networks have become the dominant structures in the economy:

- Agglomerations of firms usually operate in close proximity to each other. They provide for so-called agglomeration economies and they can benefit from the joint use of services and urban amenities.
- Clusters are formed by inter-related firms that are situated in close proximity. They have been the focus of regional economic development research and economic development policies for a long time. Many successful urban and regional industrial locations are characterized by cluster approaches, and cluster concepts rank still high on political agendas.
- However, globalization is meanwhile also strongly promoting the role of a third type of structures, that is networks. Such networks are constituted by firms which are globally inter-connected rather than on a local or regional scale.

Among other factors, the evolution of multi-locational networks was eased by the rapid progression of Information and Communication Technologies (ICT) allowing companies to make best use of individual local production factors of each location where they operate in internationally connected value creation chains. Meanwhile Advanced Manufacturing Technologies (AMT) and Cyber-Physical Systems (CPS) are strongly contributing to make networks a predominant structure in modern competitive globalized economies. As a side effect, locational "remoteness" is redefined: Formerly remote areas are not isolated anymore because they are just one click away from the world if they have the necessary IT infrastructure. However, from a company perspective this also means that traditional location factors (for example geography) may play a lesser role in the future.

UN Habitat[52] has proposed five aspects of policy to enhance urban competitiveness:

- Firstly, it is not the emulation of ideas and so-called best-practice examples from elsewhere what makes a city successful but strategic economic planning based on the individual strengths and weaknesses, opportunities and potentials.
- Secondly, the mobilization of local talents and energies is extremely important. This requires a strong focus on the creation and enforcement of human capital, local knowledge base and well-trained local labor force. It urges cities to put emphasis on solid education.
- Thirdly, effective governance is needed. „Governance ... refers to a broader management of the affairs of the state through the collaboration between government officials and agents from private sector entities including universities, business firms, professional associations, social service entities, ethnic communities, the chamber of commerce, and other similar entities."[53]. Also, civil society institutions may be added here.
- The fourth aspect picks up the importance of creative thinking. This is related to „using innate creativity to find imaginative solutions to the problems and challenges that face a city"[54].
- The fifth aspect is related to the question of whether a city should adapt a way of path dependence, building up on its historical strengths, or follow a new path, giving way to new ideas and initiatives which may challenge the existing structures. Whereas the first option is usually a rather safe

50 UN Habitat 2013, p. 11.
51 UN Habitat 2013.
52 UN Habitat 2013, p. 27ff.
53 UN Habitat 2013, p. 29.
54 UN Habitat 2013, p. 31.

choice for decision makers and therefore more likely to be followed, the latter may be more risky but it is also rewarding and has a very high payoff if it works successfully as it may open new doors to outsiders that bring in new technologies, practices and products.

This shows that there are many factors involved when promoting a strategy to attract advanced manufacturing to a region or even to make it a selling point. Political stability, economic rationality and adequacy of local assets are some standard issues of high relevance. Good governance, openness and social inclusion are of similar importance.

6.3.3 Planning for sustainable development

Taking the urban challenges into consideration the question comes up what role urban planning can play to support urban competitiveness and to foster sustainable urban and regional development. One answer may be to improve the planning system and to orientate urban planning more than until now towards sustainable urban development – or "smart growth"[55], as it is called in some countries. However, the capacity of cities and especially urban planning to cope with the challenges and to render practicable solutions is generally rather reduced due to many factors, for example weak governance and symbolic policy making as well as outdated planning systems and deficient plan implementation. Many countries in the developing world introduced urban planning systems during colonial times. In many cases, planning laws remained widely unchanged even after independence.

Some of the challenges related to the planning systems in many countries may be described taking the example of India. The country still has a rather traditional town and country planning system of British provenience. It was introduced by the British colonial administration at the end of the 19th century. The respective law (Land Acquisition Act) was enacted in 1894 and remained unchanged for more than 100 years.

Urban planning and development issues are mainly the responsibility of the respective State governments, and in general, municipal powers are rather limited. This has led to a multitude of different planning approaches which, however, are according to planning scholars sometimes characterized by centralism, lack of local/municipal influence and limited direct participation of the different concerned stakeholders other than government institutions.

Moreover, co-operation between the States regarding urban development is sometimes still rather weak. Thus, for example the National Capital Region (NCR) is hit by rather uncoordinated urban growth and development competition between the respective States. For example, there is a Planning Board for the NCR. However, it lacks influence, and the present Regional Plan dates back to the 1980s. Nowadays, urban development projects are mushrooming at the outskirts of the capital city. Many of them have turned into major cities themselves, such as DLF Cyber City, Gurgaon and others.

Furthermore, cooperation between cities seems to be weak. This is especially problematic in a situation where so-called "Census Cities" and "Urban Villages" (for example many parts of the NCR are considered as urban villages) have building rights. Many of them seem to rely on private developers. This leads to a situation where urban planning by public authorities seems to be weak as compared to private developers who are the major driving forces behind new urban development projects. This leads to a large gap between planning and implementation (for example Electronics City/Bangalore).

Especially in metropolitan areas, land development is dominated by the private sector, mainly real estate developers. Due to the absence of integrated planning concepts, it is relatively easy for private stakeholders to acquire large pieces of land for development. As in many cases the necessary infrastructure facilities cannot be provided or secured at a reliable level, national and international companies try to become autarkic and self-sufficient with regard to urban services, establishing own water and power supply as well as sewerage plants on their properties. These trends in land development lead to uncontrolled land use patterns. Environmental costs become high. However, monetary costs for the businesses are obviously still manageable and outweighed by the rather low employment costs.

Moreover, new housing estates, though in many cases in a rather close vicinity to the industrial and services oriented business areas, are also developed in a rather haphazard and uncoordinated way. Only in few cases, employees who work in the industrial areas seem to live in these nearby housing areas. Many employees have to cope with rather long commuting distances and times (several hours daily) between their workplace and the place where they live. Companies organize transport facilities due to the lack or bad quality of public transportation.

[55] In this context, the term "smart" is not at all related to a digital agenda and ICT. "Smart growth" as it is, for example, understood in the USA is used as a rather widely accepted synonym for the, in contrast, mostly not very positively connoted expression "sustainable development".

Another bottleneck of the planning system is that direct links between spatial planning and other stakeholders in urban development seem to be weak or non-existent. For example, when asked during a field visit in India in May 2014, how the local industries were involved in the elaboration and discussion about the Master Plan of a major city in India, the Director of Town and Country Planning of the State Government referred to the Department of Industrial Development of the Government from which the Town and Country Planning Department had received all relevant information about industrial/business development in the area. There was obviously no direct involvement of industrial sector representatives in plan elaboration.

In some Indian states, however, the situation is starting to change as new, more innovative initiatives have come up, for example in Gujarat with the Center for Environmental Planning and Technology (CEPT) (Ahmedabad), a university created in 2005, applying more modern principles of urban and regional planning. Other states have already modernized or are in the process of modernizing their planning legislation. The Confederation of Indian Industries (CII) has become aware and is concerned about the problems of urban development and its consequences for industry.

Reflecting these few aspects, one may understand how important and challenging at the same time is what the Global Planners Network (GPN) formulated as "10 Principles of New Urban Planning" some years ago: 1. Promote sustainable development, 2. Achieve integrated planning, 3. Integrate plans with budgets, 4. Plan with partners and stakeholders, 5. Meet the subsidiary principles, 6. Promote market responsiveness, 7. Ensure access to land, 8. Develop appropriate planning tools, 9. Be pro-poor and inclusive, and 10. Recognize cultural diversity[56].

In a similar way, UN Habitat in its Global Report on Human Settlements promotes a paradigm shift in urban planning because "while in some parts of the world, governments are using planning in positive ways to manage change in cities and towns, in other parts, little attention has been paid to the functioning of the planning system, and as such, legislation, regulations and processes are out of date, or are insufficiently reformed to be able to deal with the major challenges of the 21st century. Urban planning approaches in some parts of the world are directly constraining the ability of governments and civil society to deal with urban challenges and, indeed, may be contributing to urban problems. Nonetheless, it is also possible to argue that the challenges currently facing urban settlements are of such a magnitude that governments, in partnership with other sectors of society, will have to play a stronger role in managing urban change in the decades to come"[57].

UN Habitat interprets modern and up-to-date urban planning and development as a form of governance or collective action. Therefore it has an overarching role to play, and a rather wide scope in form and content which goes far beyond the traditional master planning or merely land use planning approaches. The UN organization identifies climate change, the global economic crisis, energy supply and impacts, food security, changing population size of towns and cities, income inequality and cultural diversity as global urban planning and development issues. Urban informality, urban growth, income inequality and poverty, the "youth bulge", peri-urban areas/uncoordinated urban sprawl, linking the green and brown agendas, as well as institutional and professional capacity were identified as some of the most pressing urban planning and development issues in developing countries[58].

Furthermore, a need is seen to embed innovative ideas, and to face the relationship between urban planning and the market better[59]. The latter is considered as extremely important especially in fast growing cities, for example with regard to the escalation of urban land prices, urban development driven land speculation and developer-driven projects. Such projects place additional demands on urban infrastructure, result in fragmented and inefficient urban development patterns and lead to negative social and environmental impacts[60]. Certain basic changes are seen as necessary, such as shifts in guiding values of planning, the form of plans, and the planning processes. Moreover, planning should work with and do more for informality, it should be institutionally better integrated, and a number of contextual and institutional changes are necessary to make urban planning more effective.

On the one hand, there is hardly anything to add to this list of proposed changes for a more modern and efficient planning system oriented towards sustainable urban development. Related steps should be undertaken immediately. On the other hand, UN Habitat describes a quasi-ideal state of planning

56 UN 2010, p. 3.
57 UN Habitat 2009, p. 201.
58 UN Habitat 2009, p.201ff.
59 UN Habitat 2009, p. 211ff.
60 UN Habitat 2009, p. 212.

sustainable cities and it shows how futile and idle it may be to expect all or a majority of the described changes in the near future. This, however, would be the time when they are most urgently needed, for example to control and direct rapid urban growth. Good practice examples[61] may guide the way. However, their capacity to lead to basic changes rapidly is very limited.

Going beyond urban planning, the World Urban Forum (WUF) recently promoted a call for a new urban agenda "that can overcome the challenge of the lack of adequate legal framework and planning, which leads to the relentless expansion of cities, intensive energy use, alarming and dangerous on climate change impacts, multiple forms of inequality and exclusion, and increased difficulties in providing decent work for all. This agenda should promote an urbanization model that is people-centered, based on 'Cities for Life'."[62] In contrast to other initiatives which give little attention to urban digital agendas or links between technological innovation and sustainable urban development, the WUF states that the "new urban agenda requires new technologies, reliable urban data and integrated, participatory planning approaches to respond both to present challenges and emerging needs of cities of the future."[63]

According to the WUF Declaration the new urban agenda should:

(1) "encourage governments to develop and use methods, such as national urban plans and policies, that link current urban development with future needs, and that are solidly grounded in the fundamental principles of equity, justice and human rights;

(2) advance greater social cohesion and break down social divides, promoting equity through empowering all segments of society, particularly women, youth and indigenous peoples;

(3) promote participatory and inclusive local governance that (a) empowers all inhabitants, (b) recognizes key contributions of various levels of government, including regional, sub-regional and municipal levels, (c) strengthens formal coordination mechanisms, (d) defines joint responsibilities, and (e) provides each level of government with the necessary resources and incentives to carry out their respective roles effectively;

(4) promote sustainable urban development, based on (a) urban planning that promotes youth participation, gender equality, balanced territorial development, (b) strengthened resilience to climate change and natural disasters, (c) the upgrading and prevention of slums, and provision of housing, basic services and land tenure security, (d) access to safe, affordable, accessible, and sustainable transport; and (e) access to safe public spaces and services for all; and

(5) promote active and committed participation of the private sector, civil society, including grassroots communities, and other constituencies through partnerships to ensure broad-based economic and social development, in order to reduce poverty and create jobs for all."[64]

Urban planning will not be able to contribute much to sustainable urban development and to urban competitiveness with regard to advanced manufacturing if there are no basic reforms. These start with not less than a paradigm shift towards more integration, responsiveness and process orientation in urban planning.

6.4 ADVANCED MANUFACTURING AND URBAN DEVELOPMENT - WHY SPACE MATTERS

Advanced manufacturing and Industry 4.0 are progressing at a high speed. As new manufacturing technologies do not exist in a spatial vacuum they will have serious repercussions on spatial development, and they are likely to have a strong impact on shaping the position and the face of cities in the 21st century worldwide. According to Helper, Krueger, and Wial[65], they are overwhelmingly located in metropolitan areas, and high technology manufacturing even more so. Nevertheless, there are rarely any hard facts concerning the interrelation between advanced manufacturing and urban development until now. Therefore, any research in this direction is still highly exploratory and in a certain way speculative in this moment. It may rather contribute to the formulation of new hypotheses than test existing ones.

61 UN Habitat 2010.
62 WUF 2014a. World Urban Forum: Urban Equity in Development – Cities for Life" http://wuf7.unhabitat.org/wuf7theme
63 WUF 2014b.
64 WUF 2014b.
65 Helper et al. 2012.

In this chapter, we will have a closer look at the nexus between advanced manufacturing and urban development. In doing so, we will discuss spatial issues from two angles: one which looks at spatial consequences more from a technology driven and economic geography point of view[66], and a second one which focuses on urban development and planning aspects. As there is not much experience regarding the subject yet, both sub-chapters are highly hypothetical in nature, and the presented propositions are meant as inputs for further discussions and research to come.

6.4.1 Spatial consequences of advanced manufacturing – A technologic and economic view

Among the few studies taking up spatial issues regarding new manufacturing technologies, Wial[67], in a forthcoming publication, has formulated a number of hypothetical consequences taking a special look at metropolitan areas in the United States. His argumentation is illustrative and his conclusions may nurture thinking concerning future steps to be undertaken. He looks at what may happen if we look at locational rationale in the context of modes of production and logistics. For this purpose, he differentiates between seven technologies:

- Advanced sensing and process control which are sensors attached to or embedded in objects collecting data about the object's location and use automatically allowing manufacturers to quickly adjust deliveries and production schedules, cutting inefficiencies and improving responsiveness to changes in demand.
- Cloud Computing, that is the storage and processing of data and the storage of software on remote servers rather than on on-site hardware facilitating manufacturers' ability to collect, store, and analyze large amounts of data about their production processes.
- Industrial robotics used to perform tasks that are too dangerous, difficult, or impractical for humans; the next generation of advanced robots will have greater dexterity, mobility, flexibility, and adaptability.
- Modular pharmaceutical manufacturing developed by pharmaceutical manufacturers and based on a set of small programmable (permanent reusable or small mobile) factories that could be reconfigured, providing more flexibility and real-time monitoring capability.
- Advanced materials with novel internal structures that yield superior properties and facilitate transformative changes in manufactured products.
- Digital manufacturing referring to the increased use of information technology, including software and the internet, to reduce costs and increase throughput in the entire manufacturing process, including computer control of the entire supply chain.
- Additive manufacturing/3-D printing, that is a process in which manufactured products are made by building them up from a series of layers of materials; materials used for printed objects are assumed to be lighter in weight.

Wial hypothesizes that impacts of these technologies could come about via the locational and land-use decisions of manufacturers, non-manufacturing businesses, and households, and via the public policies that influence them. Based on economic theories of location and land use as starting points for assessing potential impacts, he differentiates between five important factors that will shape such impacts: agglomeration economies, amenity values, transportation costs, plant-level scale economies, and input requirements.

According to Wial's argumentation these channels of spatial impact differ substantially by technology which then leads to different consequences for spatial development. The arguments regarding the three most important technologies are quoted here:

- Additive manufacturing with its lower material requirements will reduce scale economies, enabling factories and manufacturing firms to be smaller. The opportunities that additive manufacturing creates for smaller companies may make manufacturing more likely to be located in metropolitan areas, especially large ones, since those places have the supporting institutions that new entrepreneurs need. The smaller factories will require less land than conventional factories, enabling them to locate in more dense metropolitan centers. Their absence of industrial waste and relatively quiet production processes could make them less undesirable as neighbors to households and a wide variety of service firms. Residents' demand for zoning that separates industrial from commercial and residential uses could decline.

  Moreover, additive manufacturing could reduce the number of workers needed to produce an individual unit of a product and, if the technology becomes sufficiently widespread, perhaps even the total number of manufacturing workers. It is also likely to change the mix of workers required.

66 Wial 2014.

67 This sub-chapter is based on and quotes Wial 2014.

Additive manufacturing also has a strong potential to lead to the desagglomeration of manufacturers that use it. Compared to conventional processes, it requires less material input per unit of a finished product and produces lighter-weight products as outputs, thus making transportation costs less important as determinants of manufacturers' locations. The reduced importance of transportation costs reduces the economic value of geographic clustering of any kind. Thus, additive manufacturing could lead to a situation in which manufacturing could occur anywhere.

– Regarding digital manufacturing it is argued that in the short term its early adopters are likely to be large companies capable of making what are now relatively expensive investments in computer simulation and testing. However, in the long term, as costs decline, digital manufacturing could reduce economies of scale because product design, testing, and access to assemblers and larger suppliers all become less expensive than they are at present. Thus, the technology could open up new opportunities for small suppliers.

  Although digital manufacturing will, in principle, increase opportunities for suppliers that are located far from their customers, it may not increase the geographic dispersion of supply chains very much, if at all. Just as the spread of electronic communication does not necessarily reduce the importance of geographic proximity for individuals, especially for complex communication, the spread of digital manufacturing will not necessarily make geography less important for suppliers.

  Although digital manufacturing has no direct impact on the cost of freight transportation, the spread of this technology could place pressure on governments to upgrade highways, railroads, and airports.

– Advanced sensing may probably have some but not all of the impacts of digital manufacturing, and these impacts are likely to occur sooner because advanced sensing is already being applied commercially. Large firms that currently move large quantities of manufactured goods through their factories will probably be the earliest adopters of advanced sensing. However, as the costs of sensors fall, this technology could become increasingly accessible to small firms. Eventually it could erode the advantage that large firms currently have in tracking their products, thereby reducing one source of scale economies.

  Like additive and digital manufacturing, advanced sensing may ultimately be a force for smaller factories, which may be more likely to be located in metropolitan areas and especially in denser parts of those areas.

  Advanced sensing may also increase the demand of logistics specialists and technicians who are expert in analyzing the large amounts of data that advanced sensors produce. If these workers are not geographically ubiquitous, then manufacturers may cluster in places where there are large concentrations of them.

Furthermore, Wial argues that most of the technologies are likely to reduce scale economies sufficiently to create new opportunities for small and medium-sized manufacturers. This may result in larger shares of manufacturers and manufacturing jobs being located in metropolitan areas, and in dense metropolitan cores.

Except for additive manufacturing, none of the technologies is likely to make manufacturers more pleasant neighbors for households or service firms. Therefore, the technologies may not – at least in the US – be a force for the integration of residential and commercial land uses with manufacturing within metropolitan areas.

Most of the technologies may create a demand for new kinds of skilled production and maintenance/repair technicians. The presence of those workers could be a magnet for the creation of new regional clusters of manufacturers and the continued strength of existing clusters in regions that develop education and training programs for the new skills.

Finally, digital manufacturing and advanced sensing could make nearby high-quality freight transportation facilities a more important locational factor for manufacturers. This could also be true to a lesser extent for other technologies that accelerate the production process, such as additive manufacturing, robotics, and Cloud Computing.

6.4.2 The nexus between advanced manufacturing and urban development – opportunities and challenges for sustainable development

Just like the first industrial revolution has changed the competitiveness and shaped the face of the 19th century city, and the second industrial revolution has determined the structure of the 20th century city it can be expected that Industry 4.0 will have an impact on urban competitiveness and form the urban landscape

in the 21st century. Although a specific analysis would be necessary to identify all possible future interrelations in a systematic way, some propositions regarding the relation between advanced manufacturing and Industry 4.0 on the one side and urban development on the other can be formulated already now, thus complementing Wial's[68] more technologic and economic perspective.

There are opportunities and challenges of the nexus between advanced manufacturing and urban development (see Table 1). Some of them are rather general and similar to those which have already been discussed in 1980s and 1990s (for example[69,70,71]) while others are rather new and specifically connected with the development of advanced manufacturing.

The table summarizes the propositions concerning the nexus between concerning advanced manufacturing and urban development. The table is self-explaining so that further explanations are not necessary at this point.

Table 1: Potentials and challenges of the nexus between advanced manufacturing (AM) and urban development (Source: Own design by the authors, 2014) © Müller, Schiappacasse 2014

OPPORTUNITIES	CHALLENGES
Urban economy	
- Competitiveness of cities may be enhanced through core functions and pioneer establishments related to advanced manufacturing. - There may be additional opportunities for new entrepreneurial activities and small scale enterprises, especially unconventional and creative ones, to connect with larger companies, and to offer new or better services to them. This may lead to more inclusiveness, economically and socially. - Urban economy may benefit from an increase of advanced manufacturing companies: taxes, income generation, multiplier effects, supply chain, etc. - Specialization may make better use and enhance local development potentials.	- Competition may become stiffer as companies have more locational choices due to their shrinking dependence on local production factors. - Integration into advanced manufacturing value creation chains may contribute to socio-spatial disintegration within cities (between those groups and areas which are linked with and those which are not linked with advanced manufacturing); growing social segregation as well as rising disparities between urban districts may be among the consequences. - Specialization may lead to higher economical and development vulnerabilities and risks and it may diminish resilience in case of crisis. - Good urban governance and fruitful cooperation between stakeholders (state, business community) are necessary and crucial factors for successfully raising competitiveness. This is not easy to achieve.
Urban-regional development	
- Enterprises become, to a higher degree than today, multi-locational entities. - Individual locations of companies may take over more specialized and focused functions in value creation chains. - AM may diminish the companies' dependency on locational production factors. It may enlarge degrees of freedom regarding the sizes of their enterprise units and production facilities as well their locational choices. - Location factors will be re-defined. Also remoteness will be redefined. Formerly "remote" areas have more equal chances to compete successfully. - Competitiveness of regions and urban-regional development may benefit from advanced manufacturing. - Regional development may profit through regional value-added production, specialization, additional income generation, regional ancillary industries and services, multiplier effects etc.	- The availability of knowledge creation institutions (universities, research institutions), research and development activities, for example within companies, and interest of companies in regional connections are important prerequisites. - AM strategies are helpful, like smart specialization or urban (economic) development strategies. These require respective initiatives by the public and private sectors. - AM may widen (inter-) regional disparities (and those between cities), that is those which are and those which are not integrated. - Specialization may lead to higher risks for regional development.
Value creation	
- AM may enhance production and enlarge local and regional value creation chains. - AM may create new opportunities for local regional companies and the informal sector.	- Experience shows that in many cases AM puts more emphasis on international orientation and worldwide integration than on regional embedment.

68 Wial 2014.
69 Leborgne/Lipietz 1988.
70 Scott/Storper 1990.
71 Scott/Storper 1992.

OPPORTUNITIES	CHALLENGES
Integration and networking	
- AM leads to more networked economic structures and processes. Industrial production will be more and more characterized by multi-locational networks. - AM furthers the creation of dynamic and flexible enterprise networks. - AM facilitates related companies to associate for a given time span and to form temporal virtual production or service clusters. - AM manufacturing raises the international inter-connectedness and visibility of cities and regions.	- Networking has high transaction costs and investment (for example time, efforts, personnel). - Network access may be difficult. To a high degree, it depends on decision making by company involved in AM. - Interests of companies and local/regional stakeholders may be different (for example orientation on competitive production on the one hand, and socio-spatial integration on the other).
Knowledge creation	
- AM may contribute to raising the educational level of a city as it requires a well-qualified labor force. - AM may contribute to facilitating the establishment and strengthening of universities and research facilities. - AM may support public-private partnerships for knowledge based urban and regional development.	- AM may contribute to social exclusion by making the access to knowledge creation for certain groups of society (for example urban poor) even more difficult.

6.5 ADVANCED MANUFACTURING AND URBAN DEVELOPMENT – NEW OPPORTUNITIES FOR INTERNATIONAL DEVELOPMENT COOPERATION?

6.5.1 Advanced manufacturing in the urban context as a new topic for German international development cooperation

Industry 4.0 and advanced manufacturing have not extensively been discussed in the context of the German international cooperation yet. Also the role of urban development in this context is a rather new subject. Until now, the priorities of German international development cooperation as defined by BMZ and as a general guideline for the work of its implementing agencies GIZ and KfW are different. As expressed in the German Government's 14th Development Report, presented in May 2013, "shaping sustainable global development is a key challenge for the 21st century. Poverty, population growth, food security, migration, climate change, fragile statehood and unstable markets call for political action. Protecting global public goods poses immense challenges which can only be overcome through global cooperation. ... The Millennium Declaration and the eight Millennium Development Goals (MDGs) derived from it are the main international frame of reference for poverty reduction worldwide and for shaping sustainable global development. This is the focus of German development policy as well"[72].

In its report BMZ has also outlined the general future orientation of the German development policy, as an integral part of the German government's international policy. It shall contribute to a global sustainable development in future, particularly in the following areas: (1) reduction of poverty, (2) promotion of modern and sustainable models of growth, (3) safeguarding regional and global public goods such as the environment and resources, climate and health, (4) policy coherence through international coordination, and (5) strengthening dialogue and knowledge exchange with new players[73].

For example, during the last years the German-Indian development cooperation has addressed the following aspects: improving basic services in cities, supporting environment-friendly technologies and practices, tackling effects of climate change in rural areas, promoting the solar sector, advancing renewable energy developers, boosting energy efficiency in residential buildings, encouraging socially, environmentally and commercially responsible practices, enhancing financial inclusion of the poor and excluded, securing the human capital, and bringing public and private partners together. Furthermore, the importance and willingness to support SMEs is emphasized.

Regarding urban development, the German government has recently outlined its position[74]. And it has given a number of reasons why urban development is regarded as an important part of its international development policy activities, for example the following[75]:

72 BMZ 2013a, p. 3ff.
73 BMZ 2013a, p. 23.
74 BMZ 2014a.
75 BMZ 2014a.

- Prosperity: productive cities lay the foundation for economic development
- Successful poverty reduction: international commitments are implemented with cities
- Climate change and biodiversity: cities are involved in decisions on global climate targets and have a significant impact on ecosystems
- Equal opportunities: promoting a socially inclusive city
- Governance: good governance becomes tangible in cities
- Urbanity: cities are innovative catalysts for development

BMZ has outlined its major fields of future action in the same document: Green urban economy, cities and climate change, cities and safety, cities and good governance, municipal financing and urban development, cities and poverty, cities and human rights, cities and resource efficiency – the urban nexus, and sustainable development of metropolitan regions[76].

In the coming years this general orientation seems to stay the direction to be followed. According to the Coalition Agreement of the present German government, within the framework of its international development cooperation, Germany will work along the described lines. It also will put special emphasis on rural development, it will support education as a key to development, and it will focus on the protection of means of livelihood for future generations. Within the framework of the latter, climate change mitigation and adaptation, and the efficient supply through renewable energy, as well as the protection of forests and of biodiversity are mentioned as being of major interest. India will continue to be a strategic partner of Germany. Political, economic and civil society collaboration shall be extended.

Whereas German international development policy mainly focuses on poverty, climate change and natural resources as concerns affecting especially the low income groups of societies and those in danger to be most affected and excluded, advanced manufacturing seems to address the opposite side of society and economy at first glance. However, there are a number of potential connections. In an urban context, they are mainly related to the potential gains regarding:

- Modern models of growth: advanced manufacturing may help emerging countries in particular to integrate better into future oriented global production and value creation chains.
- Green urban economy: advanced manufacturing is oriented towards cleaner technologies minimizing negative environmental effects, optimizing energy efficiency in the production chain and minimizing the use of material resources.
- Cities as innovative catalysts of change: cities where advanced manufacturing takes place are usually better integrated into the global setting, and they are in a favorable position as change agents in societies.

Moreover, the following issues should be addressed:

- Good governance: cities which are oriented towards advanced manufacturing are in a more competitive situation when urban and regional governance is regarded a priority.
- Socially inclusive city: the local and regional integration of social groups along production chains and based on multiplier effects has to be specially addressed in order to avoid the widening of socio-economic gaps and to attain more social cohesion.
- Education as a key to development: advanced manufacturing is dependent on a strong knowledge based labor force with solid education and training; this puts special emphasis on modern and future oriented education, in general and locally.
- Improvement of technical infrastructure: advanced manufacturing is dependent on well-functioning logistics; this could be especially considered when improving transportation infrastructure in cities.
- Public-private partnerships: companies oriented towards advanced manufacturing provide a huge potential for improving the local economic base and social situation if fruitful partnerships between the public and private sectors are established.

6.5.2 ICT, business orientation and urban development as entry topics?

There are a number of issues in international development policy which are closely related to advanced manufacturing in an urban context. They could become entry points for future German international development policy activities regarding advanced manufacturing and urban development.

For example, BMZ[77] has repeatedly emphasized the role of ICT in international cooperation based on its specific potentials for sustainable development: ICT boosts economic growth, it contributes to political participation and democratization, and it

[76] BMZ 2014a.
[77] BMZ 2013b.

backs socio-economic and ecological development goals. Therefore, German international development cooperation supports ICT development based on ten principles: (1) liberalized but adequately regularized markets which provide effective and sustainable access to and use of ICT; (2) compensation of market failures and maximizing social and economic benefits related to ICT; (3) establishing a favorable framework for ICT, and supporting private businesses regarding their participation in ICT markets; (4) development of demand-oriented ICT-based innovations; (5) strengthening local capacities for ICT application in different sectors; (6) cross-border and cross-sectorial exchange of ICT know-how; (7) increasing the effectiveness of measures and of international development cooperation; (8) development of local ICT capacities and establishment of ICT sectors in partner countries; (9) complementation of national ICT programs and of commitment of other donors; (10) fit to local conditions, orientation towards sustainability.

Also GIZ has recently addressed ICT and the digital change in its magazine akzente[78]. Based on a large number of examples from different parts of the world it demonstrates the wide application of ICT and its fast spread. Although the access to the digital world is still unequal and dependent on various social, economic, political, scientific and technological factors, the conclusion can be drawn that the digital divide is narrowing, not only globally but also within developing countries. ICT is given special attention and based on the experience that it worked well as a tool for achieving the MDGs in the past it will be an important feature on the international follow-up agenda after 2015, the Sustainable Development Goals (SDGs).

As well, BMZ acknowledges that "German businesses make important contributions to the attainment of development policy goals – by creating jobs through direct investment, by transferring know-how and technology, and by ensuring compliance with labour, social and environmental standards in developing countries ... For that reason, ensuring that German businesses play a stronger role in development policy is a priority for the German government ... It is thus to make better use of the private sector's capital, knowledge, technologies and values for development to mutual benefit"[79]. This could be an important starting point for giving more attention to advanced manufacturing in the future.

A third aspect to be mentioned in this respect is urban development and its role in German international development cooperation. According to BMZ[80] sustainable urban development is the key to achieving the Millennium Development Goals (MDGs). It is therefore regarded as an important field of German development policy. Within the framework of technical and financial cooperation, more than 210 urban development projects with a total volume of some 2.1 billion euros are currently being carried out in over 50 countries.

Priorities are related to "contribute to making a lasting improvement to the lives of the urban poor, to enable citizens to participate in political and economic life, to limit the negative consequences of urban growth, to maintain the natural bases of cities and their surroundings, and to tap into the potentials in settlements, in particular in cities, to benefit a country's development. ... The aim is to create cities that are worth living in, so that they can provide diverse opportunities for shaping life and development. ... All citizens must have equal access to infrastructure, services and housing. At the same time, resource consumption needs to be reduced and irreversible environmental and climate damage avoided. ... According to the BMZ's Sector Strategy Paper on Sustainable Urban Development, lasting improvements are in particular to be made to the living and working conditions of the poor urban population. ... German development cooperation thus addresses the following fields of activity: Poverty reduction and social integration in cities, sustainable urban development for climate protection and resource efficiency, decentralisation: good governance and local action, needs-based and efficient urban management, and regional development, spatial planning and inter-municipal cooperation."[81]

Recently, GIZ has also explored the potentials of smart city development for international development cooperation. In the related study[82] certain entry points for smart cities into the development agenda were proposed. They range from mainstreaming, that is addressing the lack of awareness about technological development; strengthening frameworks for social innovation, to establish network on smart cities in developing countries, and to explore options for financial cooperation, to innovation, that is to establish a framework that facilitates public-private partnerships, to open a call on "Smart cities and development" and to establish a competence centre of "Smart Cities and Development".

78 GIZ 2014.
79 BMZ 2013a, p. 43.
80 BMZ 2014b.
81 BMZ 2014b.
82 Carius et al. 2013, p. 28ff.

6.5.3 Advanced manufacturing and urban development in German development cooperation – making use of opportunities and coping with challenges

Advanced manufacturing contributes to the integration of national economies into international markets, and may enhance production and enlarge local and regional value creation chains. It may thus create new opportunities for local development. Companies benefit from new business opportunities and this may even be true for the informal sector – if especially taken care of. Until now, advanced manufacturing is, however, not an issue for all countries and urban areas in the world though their number may increase as ICT connectedness is redefining remoteness bearing at least the possibility to better integrate further away areas into national and international advanced manufacturing value creation chains. Formerly "remote" areas have more chances to compete successfully. However, experience of the last decades in many countries shows that these potentials should not be overrated and one has to analyze carefully whether and how the more remote urban areas outside the large urban agglomerations may become more attractive for businesses. Logistics and the accessibility through traditional transport infrastructure as well as other factors determining urban competitiveness, such as local know-how and well-educated labor force, may play a crucial role here.

As shown above, there are a number of interfaces between advanced manufacturing and urban development which can be taken as starting points for further action and eventually also as entry points for international development cooperation. On the one hand, the existing opportunities should be made use of in the best possible ways, whereas, on the other hand, future challenges require serious actions by the concerned stakeholders in order to cope with them. Here we can also take Wial's[83] recommendations into consideration.

First of all, the promotion of advanced manufacturing and supportive framework conditions is a task of the respective state and local institutions, for example those responsible for economic development, urban planning and municipal affairs. However, international development cooperation may advise these stakeholders in order to strengthen their capabilities and capacities, and to eventually identify further fields for concrete joint action.

Based on the results of chapter 4, there are five major fields which are apt to government policies and international development cooperation regarding advanced manufacturing in an urban development context. The following recommendations are made:

Making use of economic potentials and avoiding social exclusion

- Advanced manufacturing may contribute to creating new jobs and more income opportunities for the urban population. With this it may also have supportive effects for the formation and stabilization of a strong middle-class population. It may also play a role in alleviating poverty through the creation of additional jobs in the industry and service sector which are more accessible for the urban poor. This may even have an impact for the informal sector. However, these potential positive effects do not occur by themselves, and have to be considered carefully in development strategies. On the contrary, it is often argued that advanced manufacturing may lead to job losses especially regarding the less-qualified and less-paid jobs through rationalization and automation, and that it makes access to jobs more difficult, especially for the less-educated and poorer segments of society thus even contributing to increasing poverty. However, until now there is hardly any evidence in either direction in developing and emerging countries. Therefore, a specific study or accompanying research should be conducted in order to gain more experience regarding this crucial development issue.
- Advanced manufacturing may be tempting for local decision-makers as a new catchword for local and regional development. However, advanced manufacturing will not be possible or successful everywhere. Little is known until now regarding the supportive framework conditions related to urban and regional economic development. In order to avoid haphazard and precipitous local and regional decision-making about future strategies, a sound and realistic analysis of the existing potentials and expected benefits of advanced manufacturing should be conducted. A guideline for such (rapid) analyses to be conducted by local administrations could be a useful fundament for rational decision-making. For example, it could contain a tool-box providing elements for a SWOT analysis and for answering questions such as whether higher specialization through advanced manufacturing may carry higher regional economic development risks and whether this may have a negative or positive effect on urban and regional resilience in case of crisis. The potential economic and image gains of a city through advanced manufacturing should be carefully outweighed with the

[83] Wial 2014.

realistic chances to be successful in using existing potentials. The potential financial benefits from industry, especially those with advanced manufacturing potential, regarding taxes, income generation, multiplier effects, supply chain effects, etc. should be carefully taken into consideration.

– Regional development may profit through regional value-added production in advanced manufacturing. Regional specialization may lead to additional income generation, as well as to the growth of regional ancillary industries and services. Multiplier effects, for example regarding service industries and consumption may be generated. However, the concrete effects are not known in detail and they should be scrutinized in each case very carefully. The analysis should include the question of how strong regional embedment is as opposed to a primarily outward looking orientation of the advanced manufacturing businesses, and which gains concerning, for example R&D can be expected. Also here, the elaboration of a guideline and respective training may be worthwhile.
– Advanced manufacturing may widen inter- and inner-regional disparities existing between and within urban areas. The same applies to groups of society: those who are and those who are not integrated into the respective national and international value creation chains. This would widen development gaps within a country, urban area or society, and it may require counterbalancing measures. For example, it may give rise to regional and urban balancing and cohesion policies by national, state and local governments in order to avoid inter-regional conflicts and intra-urban segregation.
– A similar effect could become apparent through the (necessary) improvement of logistics and transport infrastructure networks. Priority setting should take this into consideration. Widening gaps between well-connected and remote areas could outweigh potential positive effects of advanced manufacturing for more remote areas. Therefore participation oriented, well-balanced and transparent infrastructure planning should be supported. Locally, infrastructure planning should be oriented towards assuring accessibility for all groups of the society, including the urban poor who may not have the financial means to pay for respective services, but who nevertheless should have access to the value creation chains.

Facilitating knowledge creation and building up a well-educated and trained society

Advanced manufacturing may contribute to local knowledge creation. However, without the existence of adequate partners that can make use of the respective knowledge creation potentials, the positive impulses cannot become effective. Therefore the availability of knowledge related institutions, such as universities and research establishments are important prerequisites for the success of regional strategies related to advanced manufacturing. This fact should be given special attention to by municipal and state institutions.

In many economically developing countries, a large share of value creation depends on small and medium-sized companies. They may either not be able or not have the capacities to do much R&D. The same applies to companies eventually spun off from university labs[84]. The growing role of small and medium-sized companies in manufacturing may therefore threaten a country's ability to innovate. Therefore, incubators - Wial[85] calls them manufacturing innovation centers - supported by public and matching private funds, could help solve this problem.

Small and medium-sized manufacturers often are in need of improved management capacities and related expertise in order to be able to become adequate partners for advanced manufacturing companies. International development cooperation could help building up such expertise assuring that (micro-), small and medium-sized companies can become adequate partners of the main drivers of advanced manufacturing.

Advanced manufacturing requires a highly qualified workforce. Therefore, high quality education and training should locally be given special attention. Thus advanced manufacturing may contribute to raising regional and local educational levels. However, this requires a full understanding of the interrelation between education and advanced manufacturing and respective endeavor for making quality education a priority. Thus, education and training programs will be needed to meet the demands for skilled technical workers in advanced manufacturing companies. They should be made accessible irrespective of social status or financial abilities.

Revisiting urban planning approaches and accelerating sustainable urban development

– Traditional structure/master planning approaches with their focus on regulating future land uses will not suffice to cope with the challenges of today's urban development challenges. This is especially true for the relation between urban development and advanced manufacturing. In fact,

84 Helper/Wial 2011.
85 Wial 2014.

urban development approaches which integrate all fields of sustainable urban development, economic, social, environmental, and land use will be necessary. Urban planning and urban development strategies should take issues of urban competitiveness, especially regarding the potentials of advanced manufacturing and logistics, into consideration where relevant. A careful analysis of strengths and weaknesses should be made in these cases. This should include an analysis of potentials of urban areas to be better integrated into advanced manufacturing value creation chains. Also, issues of socio-spatial disintegration within cities, that is between those groups and areas which are linked with and those which are not linked with advanced manufacturing should be taken into account. UN Habitat has described the way towards planning for sustainable urban development. The recommendations should be taken up here.

- Advanced manufacturing may facilitate more mixed urban structures through its diminishing lot size needs and environmentally friendly integrated "urban production". This may facilitate that for example production sites can be located more closely to or within housing areas. Thus, advanced manufacturing may have positive effects on the realization of the "compact city" and the "city of short distances". However, this is not an automatism, and requires smart planning. On the contrary, there are strong indications for the validity of the hypothesis that advanced manufacturing may tend to foster urban sprawl: A location at the edge of overcrowded urban metropolises is much more attractive for companies as land prices are much lower and the access to and from the location, especially regarding logistics, is much easier. Employees may in such cases be the losers as they have to take long commuting distances on congested roads or in cramped buses into account. Therefore, urban and regional planning should seek the direct cooperation of all concerned stakeholders in order to elaborate sustainable development concepts. Collaborative planning is a necessity.
- The growing importance of small and medium-sized manufacturers may also increase manufacturers' demand for metropolitan locations, including dense core locations[86]. However, central cities may either "zone out" manufacturing or leave manufacturers to compete with other land uses, such as retail stores or luxury housing, that generate higher property values. Such policies work against the potential social benefits of advanced manufacturing that are best realized in the more dense parts of metropolitan areas but that are not fully reflected in market-determined property values. To solve this problem, it is proposed[87] that municipalities create special manufacturing zones for micro-, small and medium sized enterprises in some of their densely developed areas.
- By accelerating the process of transporting products from suppliers to manufacturers and then to final customers, improved logistics and freight transportation complement the application of Advanced Manufacturing Technologies and its potential to accelerate the production process. Public investment in rail with its environmental benefits and better maintenance of highways and airports would improve the freight network. The regions with the best freight hubs could develop a long-lasting advantage in attracting and retaining manufacturers that use the technologies that place the greatest premium on high-quality freight transportation.
- Advanced manufacturing will lead to cleaner production and more energy efficiency through sensor technology, high precision control and real-time information. Also material consumption and waste will be reduced. All in all advanced manufacturing will thus also make a contribution to climate change mitigation. Moreover, it will require less storage capacities due to real time information processing and advanced logistics. This may result in less land "consumption" for industrial purposes. Smart products may also be easier recycled. This has an additional effect on reducing the amount of waste. However, there may be rebound effects. As production sites may be located at the edge of the city or metropolitan area, commuting distances may grow. Because of difficult traffic conditions, time and energy consumption through commuting may increase if no efficient and effective public transportation systems are in place. Production sites may be designed as to deal with a variety of difficulties, for example regarding infrastructure provision. Companies may want to become or continue to be autarkic regarding water and energy supply as well as sewerage. This may lead to environmental threats, for example regarding the ground water table through uncoordinated and increased water consumption, inefficient use of natural resources and increased land "consumption" by industry. The situation worsens if the speed of urban growth overrides the capabilities to establish necessary infrastructure thus widening the gap between serviced and non-serviced, or in the case of companies, auto-serviced areas. Furthermore, real time production requires just-in-time delivery. This may lead to higher pressure on transportation as more trucks become mobile storage facilities like in just-in-time production. Modern

86 Wial 2014.
87 Wial 2014.

urban planning may help here to profit from the environmental dividend of advanced manufacturing. However, it needs competent partners, for example the responsible providers of the respective services and mobility management. Only if urban planning and these stakeholders work hand in hand, it is possible to maximize the environmental gains of advanced manufacturing and make them a part of sustainable urban development strategies.

Accentuating urban governance and fostering partnerships

- Urban competitiveness requires good urban governance. Urban governance plays a crucial role in establishing favourable business environments, fostering a positive local and regional development spirit, and successfully implementing integration oriented policies. If cities and regions want to become sustainably successful as locations of advanced manufacturing industries which make an effective and lasting positive difference to their development, urban governance should be given high priority. It should be accompanied by participatory decision-making processes and transparency. Local discussion platforms about advanced manufacturing and their potential effects could support informed decision-taking.
- Municipalities and those responsible for urban planning and development should establish links with advanced manufacturers in their area in order to strengthen local ties and to learn more about specific requirements to develop successfully. Municipalities should try to provide satisfactory and flexible business environments as in the future low wages will not be the comparative advantage and decisive factor anymore for the location of advanced manufacturing industries. Issues relevant to companies should be integrated in local development planning. Good urban governance and fruitful cooperation between the relevant stakeholders, including municipalities, state institutions, the business community and the civil society are necessary and could be decisive in moments in which advanced manufacturing companies may further decentralize and modularize their production, and may take the decision to re-locate at least parts of their production.

Fostering Industry 4.0 in German international development cooperation

- Advanced manufacturing and Industry 4.0 are relevant topics for future international development cooperation as they have potentials to foster economic development in a globalized business world, to establish new international and national value creation chains, to enhance logistics and to spur urban and regional development. We have seen that advanced manufacturing in an urban context is more than just the provision of digital infrastructure which anyhow may be entirely the task of private or state owned service providers in the telecommunications sector. As shown above, there is a multitude of other factors to be considered which could be addressed by international development cooperation. The potential of advanced manufacturing regarding the formulation of the new international development agenda beyond 2015 (Sustainable Development Goals) should be carefully explored and eventually introduced into the international debate. Furthermore, cyber security should be addressed.
- It is not clear in which countries and in which regions within such countries advanced manufacturing can play a major role in the future. Therefore German development cooperation may be well advised to commission a benchmarking study on the current relevance and future potentials of advanced manufacturing in developing and emerging countries. The study should have a worldwide scope and clearly identify countries and within these countries the respective urban areas which could be relevant for German international development cooperation with regard to advanced manufacturing. As a starting point, a survey among the relevant German companies, involved in advanced manufacturing, could be made. Besides the identification of potential partner countries and regions, relevant linkages between advanced manufacturing, logistics and urban development should be specified. Also GIZ, KfW and DEG should be involved and bring in their international experience. The survey could complement an international benchmarking study which is currently under preparation by acatech[88]. The benchmarking study, however, focuses on international competitiveness and does not address international development cooperation.
- In relation to the Indian National Manufacturing Plan there is a perspective to promote advanced manufacturing and Industry 4.0 technologies in India in order to keep up with the development in, for example Germany, Europe, China, and the US. There could be a combined German-Indian effort for selective manufacturing sectors such as automotive, microelectronics, and IT in order to probe the

[88] acatech 2014: Industrie 4.0 – Internationaler Benchmark, Zukunftsoptionen und Handlungsempfehlungen. The number of countries dealt with in this project, especially economically developing and emerging ones, is very limited (for example India, Saudi-Arabia, Nigeria, Indonesia, Brazil, China, Malaysia, Singapore, South Korea).

opportunities for Industry 4.0 technologies, consult the industry in respect to appropriate technologies and their introduction, to establish transfer projects, and to create best practices for other industry sectors. Logistics should become a focus of attention for joint cooperation activities. Moreover, urban development issues provide a large variety of cooperation opportunities. In this context the following could be additional entry points: the improvement of the urban and regional planning systems, the strengthening of urban governance, participation in and transparency of land use policies and decisions, and direct communication between planning authorities on state and municipal levels, real estate developers, and industries' representatives, as well as issues of better infrastructure provision, the creation of "green industrial areas" which are environmentally friendly industrial areas, regulations for mixed use developments, and "soft factors" of urban development. Finally, German-Indian development cooperation should promote discussion forums regarding advanced manufacturing and Industry 4.0, its relation to logistics, as well as the preconditions and consequences regarding urban development. INAE and CII could be suitable partners.

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LIST OF ABBREVIATIONS

acatech	Deutsche Akademie der Technikwissenschaften
AM	Advanced Manufacturing
AMT	Advanced Manufacturing Technologies
BITKOM	Bundesverband Informationswirtschaft, Telekommunikation und neue Medien
BMBF	Bundesministerium für Bildung und Forschung
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit
BMWi	Bundesministerium für Wirtschaft und Energie
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
CEPT	Center for Environmental Planning and Technology
CII	Confederation of Indian Industries
CPS	Cyber-Physical Systems
DIN	Deutsches Institute für Normung
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen – German Sustainable Building Council
ERDF	European Regional Development Fund
FEZ	Free Economic Zone
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPN	Global Planners Network
INAE	Indian National Academy of Engineering
ICT	Information and Communication Technology
IFEZ	Incheon Free Economic Zone
IHP	Incheon High-tech Park
IOER	Leibniz Institute of Ecological Urban and Regional Development

IOT	Internet of Things
Janaagraha	Janaagraha Centre for Citizenship and Democracy (India)
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau
MDGs	Millennium Development Goals
MSMEs	Micro, Small and Medium Enterprises
M2M	Machine to Machine
NCC	National Committee on Competitiveness
NCR	National Capital Region
NPZ	Nationale Plattform Zukunftsstadt
R&D	Research and Development
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
SMLC	Smart Manufacturing Leadership Coalition
UN	United Nations
WUF	World Urban Forum
VDMA	Verband Deutscher Maschinen- und Anlagenbau
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie

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