Future Role of Application of New Technologies in Small-and Medium Scale Manufacturing Systems

Regarding Intelligent and Advanced Manufacturing Systems in Northern Peripheral Area

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***Abstract*— Nowadays the concept of Industry 4.0. and the relating intelligent manufacturing system are getting more and more current and well-known. In the past years the outstanding development of different areas such as information technology computer science, machining, robotics and so on, made possible a comprehensive transformation of the manufacturing systems. Present paper aims to give a general overview of the technologies and features of an advanced manufacturing system. Furthermore our study intends to justify why essential to apply these innovative technologies and realize the consequence of these changes in term of the customers and the different industries. The research mainly focuses on small and medium scale enterprises and their challenges to achieve competitive advantages with intelligent manufacturing systems in NPA regions especially in Norway.**

Keywords—manufacturing system, small and medium size, intelligent, advanced, responsive

I. Introduction

The manufacturing is without doubt has a huge potential, this can be the key area to achieve wealth and provide high quality of life

and qualified jobs. Additionally manufacturing has a good effect on economic activities, improves the international trade relationships and increases the GDP. In 2009 according to European Commission survey [1] the industry sector employed around 32 million persons and generated the 17 % of the GDP in the European Union. These statistical results are extremely important for our research because a small and medium size enterprises play an essential role in the European Manufacturing Systems, numerically 99,2 % of the companies can be considered for SMEs. They provide 45 % of the value added manufacturing and 59 % of the manufacturing employment and 39 % of manufacturing sales [1, 2]. On the other hand, despite of these impressive results over the recent decade Europe's contribution to the global market decreased steadily. Not only Europe faced with this decline, United States and all of the other developed welfare countries were under the pressure by the dynamic shift in cost competitiveness. Explanation of these transformations is the following: the developed countries could not compete with the developing countries low wages and costs. In Asia particularly in China, beside the huge and low-cost workforce, significant investments were made for increasing the capacity, because they realized and lived with this outstanding opportunity. Now, China is the world's number 1 industrialized country, in 2013 they achieved 1,91 euro added value meanwhile in Europe this indicator was just 1,6. In Fig. 1. it can be seen that Europe's share from GDP dropped from 19,1 % in 2000 to 15 % in 2013, in the same time USA performed very similar tendency (from 15% to 13%) [1].

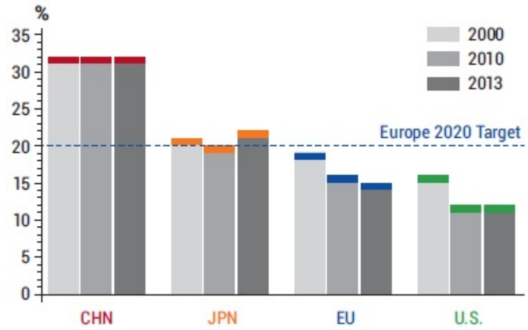

Fig. 1. Manufacturing's share of total GDP in the selected economies [1]

On the other hand China kept its high share around 33 % over the last decade. According to another survey [2], which examined the gross added value of the top 10 manufacturer countries starting from 1980, China stepped forward form the 7th place to the 1st. Despite of these tendencies and results, according to the expert's forecasts the outsourcing towards Asia and developing countries is getting over. The future competition will not take place in lower and lower wages, especially that the developing low-cost countries' work labors become more and more expensive. To mention some of the main reasons, why China and other Asian countries are becoming less attractive for outsourcing [3]:

- Less saving: not only the wages, but the shipping and electricity costs are also increased (the cost of a factory worker in China was 3 % of the cost in USA in 2000, while in 2015 this value increased to 17 %)
- Customization and responsiveness: beside financial reasons, further challenge is that customized and

individual products are getting more popular, than cheaper mass products. Responsiveness also plays an important role combined with customization, because both can not be accomplished if the product is made thousands of kilometers away from the customer

- Outsourcing makes more difficult for the companies to be innovative, and come up with new ideas
- Outsourcing causes not just longer shipping, but longer and more complex supply chain. Therefore this could lead to more serious problems with communication and suppliers, causing delay or not appropriate quality

To be competitive, responsive and cost effective, the comprehensive transformation of the manufacturing systems is required. Innovative investments, new, intelligent and adaptive technologies are necessary in order to shift back the industry share to Europe. Instead of decreasing the manufacturing costs by lower wages, they have to be decreased by more effective technologies and adaptive capacities. Literally making steps towards Industry 4.0 is the key solution for all countries and all manufacturing systems (regardless on the size, micro-small-medium enterprises and for mass production as well). In the following sections (II and III) the detailed position and specifications of Norwegian Manufacturing and Small-scale Intelligent Manufacturing will be introduced. While in section IV. those future technologies and –based on the technologies- future manufacturing strategies will be discussed, which can be crucial for the above mentioned sectors. Finally in Section V. the main findings of the paper is summarized.

II. Manufacturing in Norway

The comprehensive transformation of the manufacturing systems provides a challenge and an opportunity for Norway as well. The Norwegian industry basically stands on oil and gas revenues which greatly contribute to strong economy and high cost-level. On the other hand strategically standing on several legs and diversification are very important in case of a private person, company or a country's economy. Once the oil prices and oil industry will start to decline the Norwegian Government could face with a serious problem. This tendency has may already started, from 2013 the oil prices have decreased significantly (Fig. 2) and that may contribute for the Norwegian krone poor performance (Fig 3).

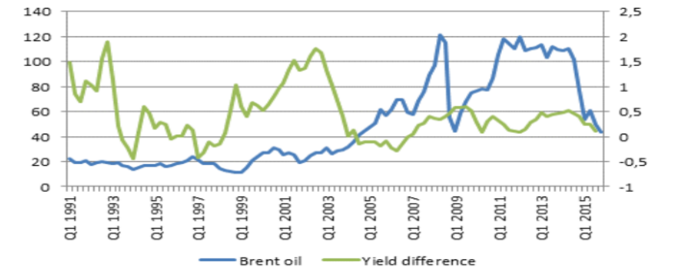

Fig. 2. Brent oil price in USD (left hand axis) and yield difference between Norway and the major markets (right hand axis.) 1991 Q1 -2015 Q4 [4]

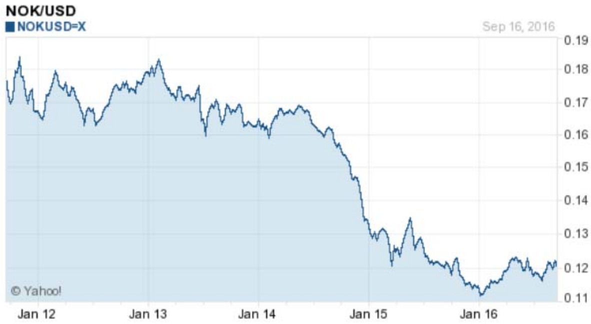

Fig. 3. NOK/ USD exchange rate charts in the past five years [5]

According to many other charts and surveys [3, 4, 5] the financial and economical position of Norway is still incredible strong. Despite of this, investments and developments of the other fields of industry should not be put off. The most up-to-date review of Norwegian industrial policy called "Mangfold av vinnere" and was published on 7 June 2013. This report intends to show the fundamental directions of the Norwegian governmental policy and to which areas to invest in. It highlights tourism, shipping, renewable energy and so on but lacks a detailed plan, and analyses about how could the advanced manufacturing systems contribute the future success of Norwegian industry. Afterwards the Norwegian Board of Technology published a work called "Made in Norway" which tries to focus on developing manufacturing systems. Compared to the other governments' similar studies (like: USA's "Advanced Manufacturing Partnership", Germany's "Industrie 4.0" and Den-mark's "Produktivitetkommission") it also lacks exact detailed plans and only declares the expectations. The study identifies only three main areas which are mentioned related to applying advanced technologies in manufacturing [3]:

- 3D printers
- Industrial Robots
- Digitized manufacturing

Beside some difficulties of Norway which it has to overcome (like depending on oil industry, high-cost level, isolation, length of shipping required). Norway has also many advantages which could be used out. Their economy is very strong; therefore they possess enough capital for investments in intelligent manufacturing systems, which are extremely expensive and just a few developed countries could afford these expenditures. Furthermore the new manufacturing systems generate and require a lot of highly qualified work labor. It could be very beneficial for the Norwegian population and government and the foreign work labor as well. Due to the high cost level and high salaries Norway is a very attractive country for the foreign work labor. No doubt, if Norway would like to be a leading, innovative, dynamic and knowledge-based economy within prioritized areas, it has to be up-to-date in technological development and continually on the lookout for new knowledge.

III. SMALL-SCALE INTELLIGENT MANUFACTURING (SIMS)

Before suggesting an exact definition for SIMS, a short explanation of Small and Medium Scale Enterprises will be given. The term of SMEs means small business which employs a small number of workers and does not have a high volume of sales. Such enterprises are generally privately owned and operated sole proprietorships, corporations or partnerships. The legal definition of a small-scale enterprise varies by industry and country, for example in USA fewer than 500 workers in Asian countries fewer than 100. According to an official declaration in the European Union this limit is 250 employees [6], despite of this Norway has its own classification due to its low population, and low population density [7]:

- Small enterprise:1-19 employees
- Medium enterprise:20-99 employees
- Large Enterprise: more than 100 employees

Fig. 4 confirms that applying a different grouping system in Norway is very reasonable, because according to the European Union's classification 99,8 % of the enterprises are SMEs in Norway.

	Enterprises		FTE		GVA	
	Total	% SME	Total	% SME	Total	% SME
EU28	22 346 729	99.8	133 767 348	67.0	6 184 825	57.5
Belgium	566 006	99.8	2 718 355	70.1	189 086	62.2
Bulgaria	312 608	99.8	1 872 997	75.5	18 246	62.3
Czech Republic	1 007 441	99.9	3 521 520	69.8	84 142	56.0
Denmark	213 358	99.7	1 602 105	65.0	119 936	62.5
Germany	2 189 737	99.5	26 401 395	62.5	1 385 501	53.3
Estonia	58 408	99.7	393 545	78.1	9 338	74.9
Greece	726 581	99.9	2 198 986	86.5	54 703	72.8
Spain	2 385 077	99.9	10 923 323	73.9	434 156	63.0
France	2 882 419	:	15 495 621	:	890 597	:
Croatia	148 573	99.7	1 002 905	68.3	19 115	54.8
Italy	3 825 458	:	14 715 132	:	646 476	:
Cyprus	46 139	99.9	224 915	:	7 864	:
Lithuania	141 893	99.8	835 630	76.2	12 155	68.5
Latvia	91 939	99.8	573 580	78.8	9 269	69.2
Luxembourg	29 265	99.5	242 533	68.3	19 250	70.7
Hungary	528 519	:	2 430 681	:	46 497	:
Malta	26 796	99.8	119 224	79.3	3 548	74.9
Netherlands	862 697	99.8	5 359 446	66.7	310 022	62.9
Austria	308 411	99.7	2 671 477	68.0	164 976	60.5
Poland	1 519 904	99.8	8 326 839	68.9	171 627	50.1
Portugal	793 235	99.9	2 942 895	:	66 360	:
Romania	425 731	99.6	3 837 868	66.4	48 432	:
Slovenia	119 644	99.8	574 479	72.3	17 140	62.8
Slovakia	398 392	99.9	1 417 228	69.7	32 922	60.5
Finland	226 373	99.7	1 457 599	63.0	86 957	59.6
Sweden	661 822	99.8	3 025 006	65.4	210 859	58.5
United Kingdom	1 703 562	99.7	17 784 620	53.0	1 037 293	50.9
Norway	278 899	99.8	1 510 838	67.6	230 661	58.6

Fig. 4. Number of enterprises, persons employed and gross value added (GVA) and the share of SMEs, 2012 [8]

The growth-generating potential of SMEs has been the subject of many academic studies. Although there is no general agreement in the literature on whether SMEs generate more growth than large enterprises, some recent studies suggest that large enterprises are more pro-cyclical, which means that they are more affected by international business cycles than SMEs are [6]. In Table 1. the most important advantages and disadvantages (in brackets) of SMEs and large enterprises are summarized [7].

TABLE I. COMPARISON OF SMES AND LARGE ENTERPRISES [7]

Fields	**SMEs**	**Large Enterprises**
Marketing	Ability to react quickly to keep abreast of fast changing market requirements (Market start-up abroad can be prohibitively costly).	Comprehensive distribution and servicing facilities. High degree of market power with existing products
Management	Less bureaucracy. Dynamic able to react quickly to take advantage of new opportunities (often lack management specialists).	Managers able to control complex organizations and establish corporate strategies (complex bureaucracy. lack dynamism with respect to new long term opportunities).
International Communication	Efficient and informal internal communication Networks, fast response to internal problem solving	(Internal communications often cumbersome; slow reaction to external threats and opportunities)
Qualified manpower	(Often lack suitable qualified technical specialists. Often unable to support a formal R&D effort on an appreciable scale)	Ability to attract highly skilled technical specialists. Can support the establishment of a large R&D laboratory
External communications	Often lack the time or resources to identify and use important external sources of scientific and technological expertise).	Able to 'plug-in' to external sources of scientific and technological expertise. Can afford library and information services technological information and Technology, subcontract R&D to specialist centers.
Finance	(Can experience great difficulty in attracting capital, Innovation can represent a large financial risk. Inability to spread risk over a portfolio of projects).	Ability to borrow on capital market and spread risk over a portfolio of projects. Better able to fund diversification into new markets.
Economies of Scale	(In some areas economies of scale form substantial entry barriers for small firms. Inability to offer integrated product lines or systems).	Ability to gain economies of scale in R&D production and marketing. and to offer arrange of complimentary products. Ability to bid for large turnkey projects.
Growth	(difficulties in acquiring external capital for rapid growth.	Ability to finance expansion of production Base and to fund growth

	Entrepreneurial managers unable to cope with increasingly complex organizations)	via diversification and acquisition.
Government Regulation	(Often cannot cope with complex regulations. Unit cost of compliance for small firms often high).	Ability to fund legal services to cope with complex regulatory requirements. Can spread regulatory costs.

From the comparison (Table 1) it is obvious that SMEs most serious issue can be the lack of capital and this could lead for the further obstacles e.g. growth, finance, lack of innovative solutions, technologies, qualified manpower. Due to the strong economy, Norwegian SMEs with a strong government support could overcome these challenges.

SIMS can be considered as a subgroup of SMEs, because Enterprises can be a wide range of any businesses (e.g. bakery service sector, architecture, health care, etc.). SIMS-from the definition of manufacturing- deals with converting raw materials into finished product. Using the term "intelligent" related to manufacturing different levels can be distinguished (From low intelligence to high intelligence) [9]:

- *Control level*: the technologies, like computer numeric controlling, the programmable logic controlling, and probability statistics analysis etc., are used for replacing the labor force and optimizing the production efficiency
- *Integration level:* Internet of Things and Cyber Physical Systems technology are going to be applied in manufacturing based on the control level technologies, generating the digital manufacturing environment and networks. It does not only connect the hardware but also builds the communication between the controlling systems. The data is collected from sensors, machines, production lines, or manufacturing controlling and management systems, and it is also received from outside of the factory, such as the customer feedback and the supply chain. On this level more valuable information is discovered, which helps people to improve manufacturing.
- *Intelligence level*: the manufacturing uses data or information obtained from the integration level to create the plan and make decisions by intelligent technologies, such as advanced data mining and big data analysis. In addition, the intelligent manufacturing system can self-aware, self-optimization, self-configuration, etc., which are the concepts of Industry 4.0. Applications of this level tend to be the implementation of Industry 4.0

- Small–scale Intelligent Manufacturing Systems are currently mostly on the control level, and the intelligence level has been unachievable so far. SIMS could be defined as type of manufacturing systems which employs few workers (eg. less than 100 depending on the country), typically uses small volume and batch sizes, high product variability and tends to be responsive and competitive applying advanced technology and automation (e.g. industrial robots, hybrid CNC machine, 3D printer, complex internet based integrated communication system)

IV. FUTURE TECHNOLOGIES IN MANUFACTURING

In present section a listed summarization of the future technologies can be found which could play an essential role in above mentioned sectors.

A. Robotics

Robot is a programmable machine which - depending on the type - is able to move along or rotate around different axes and execute different tasks. In the past years this field has progressed significantly, therefore robots are perfectly able to replace human workload in many sectors such as agriculture, fisheries, packing/distribution, pharmacy, health, the oil and gas industry, as well as in discrete manufacturing, e.g. cars and electronic components. For example robots are also suitable for welding, a Norwegian welding company called *Kleven Industrier AS* put an investment in a new robot welding system, therefore they managed to improve the welding speed from 25 cm/minute (human) to 2,5-2,7 m/minute [3]. Thus one welding robot can replace 10 welders and beside the quality of the welding also improves. Currently, around 1.1 million industrial robots are in use throughout the world. Due to the exploitation of the facilities, lower costs, better efficiency, higher level of automation and quality, robots became an essential part of the advanced manufacturing systems. Although the statistics of the International Federation of Robotics for 2012 show that the number of industrial robots per employee in manufacturing in Norway is lower (less than 40/10000) than the average for the organization's member countries, and also below countries like Denmark and Sweden (150/10000). In the sales value Norway performs also very poorly 80-120 sales in 2012 meanwhile in Sweden and Denmark 900-1000 and 225000 in China. Robotics laid the foundation of many R&D projects like mobile robots (Fig. 5.) – they are able to change not only their positon, but their location as well - human-robot interaction (teaching and co-work). [3, 10, 11]

Fig. 5. Example of a mobile robot [12]

B. Advanced Materials

Innovative advanced materials with improved functional performance such as wear resistance and hardness have the potential to generate significant advances along the life cycle of production equipment: at design stage, a reduced consumption of resources may be achieved through materials such as advanced metallic and composites as well as high performance plastics and textiles. At the use stage, benefits such as higher performance, easier system reconfiguration, lower energy consumption, reduced pollution, increased durability and reliability at system and component level, high quality of manufactured parts and easier maintenance can be achieved, all this together with reduced total life cycle costs, both environmental ones and economic ones. Further opportunities could be the multidisciplinary approaches advanced materials combined with sensing, active elements. [2]

C. Advanced Machine Tools

Machine tools provide a wide range of devices depending on the shape, quality, amount, speed. A few years ago milling, turning welding, lathe and some highly automated devices such as 5- axis CNC machines, manufacturing cells were considered as an essential part of future manufacturing systems especially for small scale. According to recent studies [1, 2, 3] additive manufacturing tools particularly 3D printers can be considered as pioneers in the future. They can especially be utilized in small-scale, because the production time does not depend on the batch size; they decrease production lead time, set up and material preparation. Additional advantages that they are able to create highly complex geometric shapes, with a precision down to 0.1–0.2 millimeters, extremely small geometric details can be generated with a high degree of accuracy. The number of printers sold on the Norwegian domestic market has increased tenfold in three years, from 1,900 in 2009 to around 6,900 in 2010 and around 35,000 in 2012. On the other hand 3D printer has existed years ago and has not become extremely widespread; therefore probably there will be another exploitation of additive manufacturing devices. For example a CNC machine integrated with an additive manufacturing system can be new unique hybrid machine. Investigation has shown hybrid concept systems have the potential and effective use for high functionality mold production, Near-net shape manufacturing, repair processing and coating. Among the many different types of these hybrid machines an example of 5 axis CNC machine center combined with Lase Metal Deposition can be seen in Fig. 6. [3, 13].

Fig. 6. Example of a hybrid machine: INTEGREX i-400 AM [13]

D. Photonics

Photonic tools can provide ways to new process chains and take account of the growing ‘system relevance’ of photonics for production and product planning. Photonics include adaptive production concepts based on intelligent laser networks and optical sensor and control systems. A focus should also be on generative photonic processes (layer-by-layer production of complex components by laser from the raw material, e.g. 3D-printer). [2]

E. Micro- and nano-electronics

High‑precision manufacturing and micro‑manufacturing oblige precision manufacturing to increase with one order of magnitude in the accuracy of conventional machines and controls. The issue is that this requirement of extremely high precision can arise both in micro and macro‑production environments. Therefore, new machine conception approaches together with innovative technologies are required to enable manufacturers to achieve high quality and high precision in manufactured products that can range in their size from a few microns up to several meters. [2]

F. Simulations and virtual manufacturing

Simulation software has played an important role over a long time on product level. CAD/CAE/FEM software makes possible to design, test, analyze a product before manufacturing (without expenditure, waste of material etc.). In the future simulations and models will play a much more integrated and comprehensive role. These will be used for co-design and management of integrated, product–process–production systems and spanning all levels of the factory life and its life cycle. Basically the whole factory with every device will be created in simulations before the factory would be implemented in real, therefore the whole production line, lay out, production time, costs can be evaluated and optimized. Furthermore integrated with the information technology not just the factory and manufacturing, but the whole supply chain can be analyzed. [14]

G. Intelligent Products

Nowadays supply chain has become more and more complex, due to the globalization, smaller volumes of customized products, shorter product life cycles etc. In order to develop supply chain by merging logistic and manufacturing operations together intelligent products can be the key elements. Intelligent products can be defined in many different ways – e.g. depending on the intelligence level- but their basic concept is that they are capable of communicating with the environment and make decisions relevant for their own destiny for instance routing through the system. Furthermore they can be able for forecasting in order to make better local decision, the can be tracked and followed in more effective way than the ordinary ones. Further researches and evaluations are yet to be carried out but obviously they will be a key part of future manufacturing systems [15].

H. Information Computer Technology (Cloud Based, Big Data)

Among the major challenges that manufacturing companies face today are the growing complexity of their processes and supply networks. In order to come over these collaborations (collaborative supply network, customer collaboration) are essential. Information technology aims to support collaboration, connectivity and mobility. Further solutions expected from ICT [16]:

- factory floor and physical world inclusion
- next generation data storage and information mining
- implementing secure, high‑performance and open services platforms

V. CONCLUSION

Small and Medium Size enterprises particularly in Northern Peripheral Area like Norway face considerable challenges. Beside geographical isolation from major markets, higher labor costs, there was a strong shift in manufacturing towards developing, low-cost countries. Based on recent researches and studies the 4th Industrial Revolution will happen nowadays [17, 18]. This means comprehensive transformation and developing of the manufacturing systems, due to the application of new advanced technologies. Due to the future technologies the whole structure, strategy and basic characteristics of the manufacturing systems will change. Robots and advanced machine tools make possible a flexible and adaptive manufacturing system, with less human workforce and with effective co-work to be human centered. Applying - the additive manufacturing devices, advanced materials and high automatization – sustainability and resource effectiveness will be also the key targets. Cloud based developed information system big data analyses, simulation, virtual manufacturing and smart products will lead to an integrated, intelligent manufacturing system. Responsiveness and customization can also be the key factors to achieve competitive edge, especially for SMEs. SMEs especially in NPA regions are in a very challenging and difficult position. In order to sustain and strengthen their competitiveness in a global market they are forced to seize the opportunities provided by the new technologies. Otherwise they neither will be enough cost-effective nor responsive, and will not be able to survive the competition against big companies with huge amount of capital. SMEs can face with bigger challenge to change the systems and make investments, because they possess smaller budget and fewer resources than their competitors. Despite of this they have to make this effort- maybe with some government support- for the future success. [19, 20, 21]

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