IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 97-103
www.iosrjournals.org

Advanced Manufacturing Technology; Strategy, Policies and Performance: Comparative Study between China and the United States.

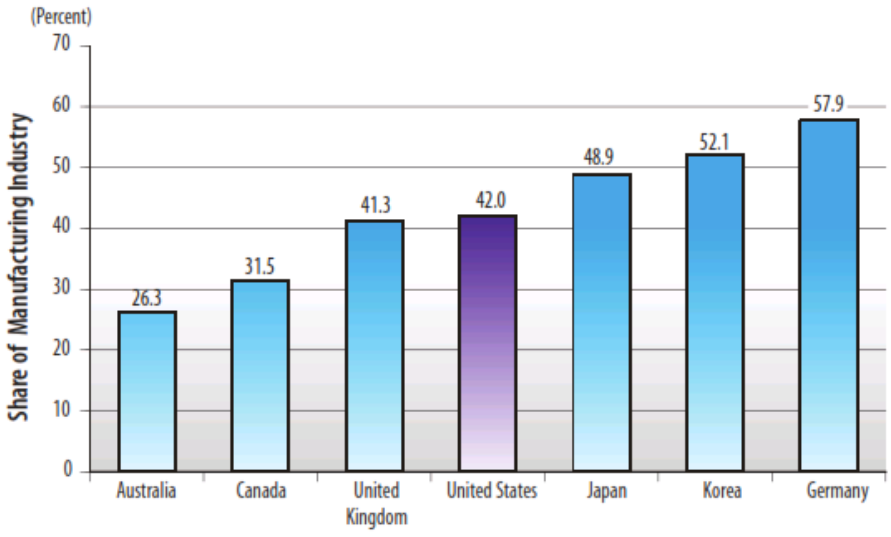
Okonkwo Valentine Tochukwu[1*], David Kanume Koroma[2]

Abstract: *Advanced Manufacturing Technology (AMT) represents a wide variety of modern mainly computer based systems devoted to the improvement of manufacturing operations and enhancement of firm competitiveness globally. With the increasing pace of technological change and the accelerating globalisation of business, Competitive advantage for many manufacturing companies and countries now lies in their ability to effectively implement new products, rapid technological innovation and advances in manufacturing and information technology. This paper is a review of data reports, comparing policies, strategy and performances between China and the United States as regards advanced manufacturing technology. The comparative priorities is centred on manufacturing process, technology, innovations, new product development, responsibility and supply chain.*

Keywords: *Advanced Manufacturing Technology, Strategy, Policies Performance, China, United States.*

I. Introduction

The study of advanced manufacturing technology with emphasis on strategy and performance is receiving increased attention among scholars. Investment on advanced manufacturing technology has been growing steadily for the past decades; countries like the USA, Germany and Japan have shown remarkable advancements in the field. Research works like Waldeck, Diaz et al., Laosirihongtong et al, Machuca et al came up with notions that balancing AMT investment and manufacturing infrastructure investment will result in better performance in profit and growth of the enterprise. With the increasing pace of technological change and accelerated globalization of business, manufacturers are facing unprecedented level of pressure resulting from competition from products, new product introduction and shorter product life. [4]Competitive advantage among manufacturing companies has led to the enhancement and advancement of manufacturing technology globally. And with market pressure on companies globally, companies are forced to look beyond cost and emphasize on speed, quality, agility and flexibility of their manufacturing facilities [(5-6).] Several countries are changing the face of manufacturing globally; in 2009, the United States ranked eighth among industrialized nations for R&D according to the organisation for economic co-operation and development. [(7).] A 2011 report by the information technology and innovation foundation also ranked the United States fourth out 44 industrialized countries following Germany, Korea, and Japan in that order.fig 1 shows the share of manufacturing value –added by research intensive manufacturing sector.



Source: OECD STAN Indicators 2009, "Value-added shares relative to manufacturing,
* Percent of manufacturing sector with 3% or greater R&D intensity, stats.oecd.org/index.aspx?r=228903

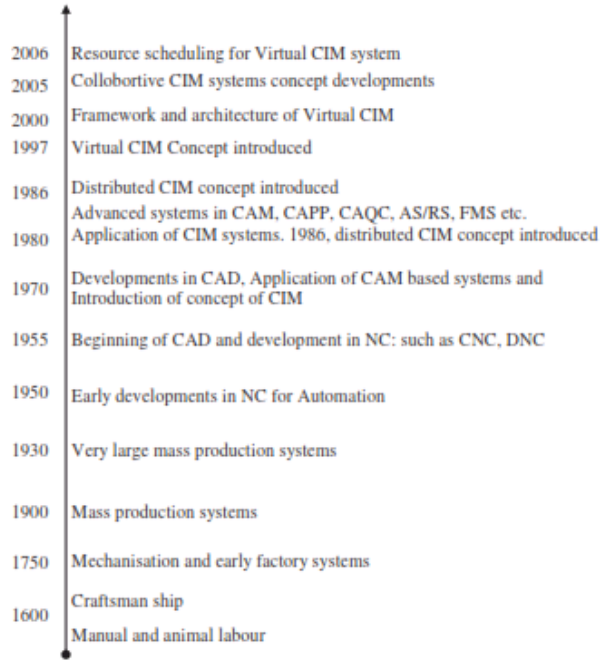
Considering the above statistics, countries like Germany and the United States are evidently in the lead as regards R&D intensive advanced manufacturing. Interestingly however, China has risen to the times, overtaking the United Sates to become the top most economic giant in the world. According to the IMF report released 2014, China's national economic output in real terms of goods and services will outrun the USA by 2 billion dollars at least, which is different from the IMF report of 2000 with the USA producing nearly thrice as much as China.

So the question is how did China rise to attain such height, making rapid progress within a short period? What has China been doing as regards advanced manufacturing knowing now that China accounts for 16.5% of the global economy when measured in real purchasing-power? This paper is centered on advanced manufacturing technology, making a comparative study between China and the United States in terms of their strategy, policies and performance. First, we look at the evolution of advance manufacturing technology and examine the overall situation of the two countries AMTs, after which we analyze strategies, policies and performance of the countries, with an aim of understanding the rapid growth of China's industrialization as regards to manufacturing technology. Results and recommendations are made and conclusions are drawn.

II. Literature Review

Evolution of AMT :

Over the past few decades, manufacturing has gone from a highly labour-intensive set of mechanical processes to an increasingly sophisticated set of intensive information technology process. This trend will continue to accelerate as advances in manufacturing are made [(8)]. From inception with the use of traditional means to the period of mechanization, there has been a growing need to satisfy consumer demand for improved product at short delivery time. This led to the development of programmable automation whose prime objective was to quicken production process and to ensure quality products [(11)]. With this development came the application of computer in manufacturing and emergence of new manufacturing technologies like the computer aided design (CAD), computer aided manufacturing (CAM), robots, flexible manufacturing system (FMS), just-in- time (JIT) and other technologies that help in building advanced manufacturing . Computer applications also facilitated the development ERP (Enterprise Resource Planning) systems which monitored and integrated key activities such as marketing & sales, planning, manufacturing, inventory control and shipping. With ERP systems demanding robust manufacturing processes and Global competition highlighting labour costs, increased emphasis on productivity grew through the nineties. 6-sigma, lean, critical chain and other productivity/waste reduction programmes became increasingly popular. As manufacturing evolved globally, there was a strong need for integration with companies adopting holistic and systematic integration approach rather than individual automation in functional units with each unit acting as an island hindering communication and dissemination of information among themselves. In order to appreciate the historical developments that had taken place during the last four centuries, the evolutions in manufacturing technology towards integrated systems are summarised in Fig. 2. However, the precise time span for the evolutionary stages cannot be determined and are not given in figure shown [(9).]



Overview of United States AMT

Advanced manufacturing is a matter of fundamental importance to the economic strength of the United States. The manufacturing sector accounts for about 72% of all private-sector

R&D spending and employs about 60% of US industry's R&D workforce [(4)] .America's manufacturing system evolved in the 19th century with the extensive use of interchangeable parts and the strong dependence on mechanization in achieving production aim. In the 1850s, the United States' manufacturing system had a sharp contrast with British and other European continental companies based on its extensive use of machines in their assembly line. Within a few decades, manufacturing technology evolved further with the involvement of semi-skilled labour and the use of machine tools and jigs to make standardized equipments. With time, the contradistinction between the United States manufacturing system and Europe's manufacturing system faded with the "American system" adopted globally. The main technological advances of America's manufacturing system came during the midpoint of the 20th century with the improvement of mass production using technology developed and utilized during the World War II. In this period, automation was predicted to reduce the rate of consumption of natural gas causing change in direction of decreasing entropy and increase in system and process [(10)]. The 1960s era focused also on automation, its application to certain routine process and its limitations. In addition, the 1960s placed emphasis on globalization and future proliferation of multinational corporations [(11)]. A new era in US manufacturing came in 1980s down to the early 1990s with the utilization of computer based technologies to automate design, control and handling functions. The concept of a fully automated factory was revived through Computer Integrated Manufacturing (CIM). In the design area, the computer aided manufacturing was not a new technology but its application during this era was novel [(8)]. The introduction of just –in – time caused advances in the computerization of material handling and transport equipment and facilities in US industries. In recent years, with increasing interest in the integration of information and materials handling, United States adopted high value innovative manufacturing approach. Emphasis was on new product development technology such as modelling and simulation, the use of technology for sustainable manufacturing and knowledgeable management practices to ensure effective supply chain integration [(8)]. The U.S department of Commerce, Energy, Defence and the National science foundation sponsored the Integrated Manufacturing Technology Roadmap Initiative (IMTI, 2000) to help direct the future of manufacturing investments. They collaborated with leading companies and executives to address grand challenges for a modern enterprise: lean, efficient production; customer responsiveness; total connectedness; environmental sustainability; knowledge management and technological exploitation.

Also owing to advanced manufacturing technology, industries in the United States have experienced significant growth over the years. BEA GDP by industry shows manufacturing as 8 % of U.S. growth between 1947 and 2009 while the largest growth sector was the finance, insurance, real estate, rental, and leasing, with real estate representing the majority of this growth. GDP grew 501 % between 1947 and 2009 while manufacturing grew 164 %. [(5)]. The above GDP statistics does not imply that the U.S. manufacturing industry does not have deficiency with the U.S. producing more manufactured goods per capita than 92.6 % of OECD countries in 2007; Industry growth however, has been somewhat stagnant in the U.S. when compared internationally.

Overview of China AMT

China's manufacturing industry has seen diverse growth and changes; from the mechanized technology in the 70s, to the computer aided technologies in the 90s, and currently to the most rapid and advanced state of the art technology in the world. China's manufacturing industry has evidently shot up incredibly, providing employment to over 90 percent of the population nationwide. The manufacturing industry in China today creates directly one third of the gross national product and four fifths of the entire industrial product, provides over one third of the income for national finance, and contributes to 90% of total export [(12)]. The employed population in the manufacturing industry takes up 90% of the total employed population in the industry nationwide [(12, 13)].In the 15th century, China's science and technology was among the first class in the world, until the 17th century. After the 17th century, China experienced decline in its manufacturing industry, due to political instability, among many other factors. Since the reform and opening up in the 1970s however, China's manufacturing industry has made rapid development [(14)]. Investment in AMT and manufacturing investment played significant role in china's high level of economic growth and enhanced its position as a manufacturing leader. Since 1953, china's leaders have drafted a five –year plan which is an essential blueprint for china's economic and social development. According to the 12th five-year plan (2011-2015), advanced manufacturing is one of the areas of concentration by the government [(15)]. From 1990 to 2005, the annual growth rate of manufacturing added value of the United States, Japan, Germany and China were 2.07%, 0.65%, 1.38% and 7.79% respectively; with China's manufacturing added value far higher than that of the other three countries. From the view of the manufacturing scale, China's manufacturing added value was 759.661 billion U.S. dollars in 2005, ranking the

third in the world, which surpassed the manufacturing added value of Germany and was equal to 79.79 % and 43.70% of the manufacturing added values of Japan and the United States respectively [(15)].

According to the 2008 international labour organisation, key indicators of labour market database, the agricultural industry boasts of employment opportunities for 39.5 percent of the population, the manufacturing industry for 27.2 percent of the population, and other services for 33.2percent. China's rapid ascent in computing-hardware capabilities and the migration of integrated circuit manufacturing to Asia in the last two decades has led to China's increasing control over the global electronics supply chain. Presently, china's manufacturing core technology accounts for about 30% less dependence on foreign technology and wide application of ubiquitous information causing about 10% increase in productivity [(16)].

III. Methodology

The study is a review of past works on advanced manufacturing technology. A comprehensive review was done to identify published articles, publications and reports. Databases including EBSCOhost online and Wiley online library, were searched for articles related to the topic of interest.

Inclusion criteria- all articles and publications in English from 2000 to 2014 .The comparative study was limited to four reports on strategic plan, policies and performances on advanced manufacturing technology.
Exclusion criteria- all articles published before 2000 and those published in other languages.

Database

The data used in this study was from the 2009 International MS survey (IMSS) and Global competitiveness index 2013.IMSS is a co-operative research network of research groups which aims at developing, maintaining and analyzing, using various perspectives and research questions for the study of manufacturing strategies and performance. IMSS has conducted five rounds of survey, and the fifth round in 2009 contains data from 677 companies in 19 countries. In this survey, United States and China had 72 and 59 number of respondents, respectively.

Global manufacturing competitive index is a collaboration between Deloitte Touche Tohmatsu Limited (Deloitte) and The U.S. Council on Competitiveness (Council). Data was gathered from more than 500 CEOs and senior manufacturing leaders with an aim of examining high complex forces driving the future of manufacturing and many of the structural changes reshaping the global economy.

The comparison between China and United States was done on continental level using the IMSS 2009 report. US together with Canada were included under North America, while China, Japan and India were included under Asia. The comparative priorities are measured considering the following attributes;

Manufacturing process- this includes lean organisation model, continuous improvement, delegation and knowledge.

Technology – this includes process automation, information sharing, flexible manufacturing, tracking and tracing.

New product development – this includes organizational integration, design integration, technological integration.

Responsibility- this includes environmental impact of product, environmental performance, quality along the supply chain.

Supply chain –this includes supply strategy, distribution strategy, coordination with suppliers and risk management.

Further comparison using GMCI was conducted between the two countries, with emphasis on competiveness, talent-driven innovation, physical infrastructure, government investment in manufacturing and innovation, local market attractiveness, legal and regulatory system, energy cost and policies.

Policies- Advanced manufacturing contributes to the economic growth of every nation and government policies act as catalysts to guide the manufacturing industry. Policies on advanced manufacturing between china and the United States were compared to gauge their influence on the progression of advanced manufacturing technology.

IV. Results and Discussion

In a recent research by Ricardo Hausmann and Cesar Hidalgo (Harvard and MIT), they stated that producing more complex products and developing more advanced manufacturing processes leads to greater economic prosperity for a nation and its citizens. They further iterated that the linkage between the knowledge networks and capabilities necessary to drive

Advanced manufacturing and the economic prosperity of a nation is a better predictor of the variation in incomes and rate of competitiveness across nations. Their study compliments the competitive dynamics

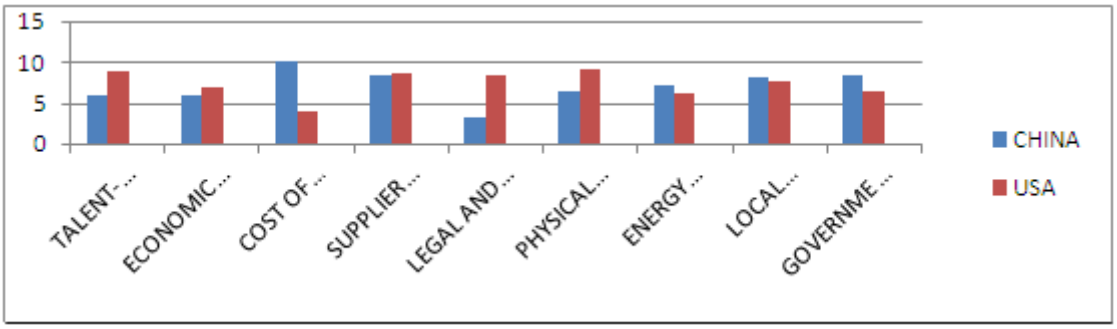
challenging china, the United States and the rest of the nations of the world in their quest in achieving sustained economic growth and prosperity.

Adopted improvement programs	East Europe	West Europe	North Europe	South Europe	North America	South/Central America	Asia	Total
Manufacturing process								
Delegation and knowledge	2.6	3.0	3.2	2.9	3.1	3.5	3.2	3.0
Lean organization model	2.7	3.1	3.2	3.0	3.2	3.9	3.0	3.1
Continuous improvement	2.6	3.4	3.3	3.3	3.7	4.1	3.7	3.4
Obtain process focus	3.0	3.6	3.6	3.5	3.2	4.2	3.3	3.4
Implement pull production	2.8	3.2	3.3	3.3	3.1	4.0	3.1	3.2
Servitization								
Expanding the service offering	2.6	2.6	2.9	3.1	2.6	3.3	3.5	2.9
Developing the skills in services	2.9	2.8	3.1	3.1	2.8	3.4	3.8	3.1
Design products for after sales	2.8	2.7	3.0	3.1	2.8	3.6	3.8	3.1
Technology								
Process automation	1.9	2.3	2.4	2.2	2.4	3.0	2.8	2.4
Flexible manufacturing	2.2	2.3	2.6	2.3	2.5	3.4	2.8	2.5
Tracking and tracing	2.3	2.5	2.9	2.7	2.8	3.6	3.0	2.7
Information sharing	2.3	3.0	2.7	2.9	2.7	3.4	3.1	2.9
Responsibility								
Environmental impact of products	2.2	2.2	2.3	2.3	2.3	3.2	3.2	2.5
Environmental performance	2.6	2.5	2.5	2.9	2.5	3.7	3.4	2.8
Corporate reputation	3.1	2.9	3.1	3.1	3.4	4.0	3.6	3.3
Quality along the supply chain	3.2	3.1	3.1	3.3	3.4	3.9	3.7	3.3
Corporate social responsibility	2.5	2.2	2.2	2.3	2.6	3.3	3.2	2.6
Environmental impact of transportation	2.2	2.2	2.3	2.2	2.4	3.2	3.4	2.5
New Product Development								
Organizational integration	2.6	2.8	2.9	2.9	2.9	3.5	3.2	2.9
Design integration	2.5	2.8	3.0	2.9	2.9	3.6	3.6	3.0
Technological integration	2.7	2.8	2.9	2.8	2.7	3.6	3.5	3.0
Supply Chain Management								
Coordination with suppliers	2.3	2.8	2.7	2.8	2.8	3.3	3.3	2.8
Supply strategy	2.8	2.8	3.0	3.1	2.9	3.4	3.2	3.0
Distribution strategy	2.2	2.2	2.5	1.8	2.4	3.0	3.2	2.4
Coordination with customers	2.4	2.5	2.6	2.4	2.8	3.1	3.4	2.7
Risk management	2.5	2.6	2.8	2.4	2.8	3.3	3.3	2.8

Table 1-analysis showing MPs b/w North America and Asia (1= none, 5= high adoption)

The table shows programs aimed at improving manufacturing function e.g. lean, continuous improvement and process focus in the mentioned continents, with our highlighted continents for emphasis. We see that programs aimed at improving new product development and servitization are very much implemented, with Asia putting more emphasis in improving various aspects of manufacturing when compared to North America. One reason could be that countries in North America have an already established manufacturing function in place and developing countries like China and India are seeking manufacturing improvement to increase their competiveness in today's global market. This is further buttressed by an article in the Washington post, stating that China and developing countries in Asia have in recent years sought to lure more sophisticated manufacturing operations and better jobs by expanding their engineering prowess through government investment in education and research. From the GMCI data 2013 report, China topped the list as the most competitive manufacturing nation. Germany and United States ranked 2nd and 3^{rd,} respectively. Presently, Germany and the United States have further slipped down their ranks with both countries ranked 4th and 5th respectively owing to recent financial crises globally [(17)].

Fig 3 is a manufacturing competitive index between china and the United States showing each country's rating for key drivers of competitiveness. The figure reveals China's transformation through key competitiveness drivers. Although the United States had showed dominance over china in talent-driven innovation having strong innovation index score, China tends to be moving up the maturity path in economic, trade, finance and tax systems resulting in her becoming a topmost economic giant and leader in global trade of manufactured goods. Cost of labour is a major driver in manufacturing competiveness[(8)]and fig 3 shows china having a higher score index. China continues to produce significant labour and material cost advantage over the United States. Chinese companies attach more importance to the service, quality and delivery, but less to the cost [(18)].



As energy becomes scarce and cost continues to rise, 2013 GMCI reports that nations with ability to provide clean and renewable energy at competitive cost will have an advantage over other nations. According to the report, China was ranked higher above the United States though the U.S. ranked better than China in electricity costs (6.9 cents per kWH) and in environmental performance. China rose to the top, overtaking the US in new clean energy investments since 2009 and the government's commitment to further increase the share of renewable energy [19]. This factor contributes to the growth of advanced manufacturing in a nation.

Policies

The state of the manufacturing industries of a country tells us the direction of its government policies. For instance, China's policies that help direct funding of investments in science and technology, employee education and investments in state owned enterprise has provided competitive advantage and boosted the growth of the manufacturing sector. One of such policies is the National high-tech R&D program (863 programs) whose objective is to boost innovation capacity in the high-tech sectors, particularly in strategic high-tech fields, in order to gain a foothold in the world arena; to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security. This five- year plan program is laudable and has affected the manufacturing sector positively because it increased investment in manufacturing capacity and export. This policy nurtures a number of hi-tech companies and strengthens China's industrial structure.

On tax policy, China gives preference in tax in the dissemination of Science and Technology Knowledge Law (2002). Here tax credit is 150% of qualified R&D expenditure for enterprises. Investment on R&D equipment can be excluded from income tax for equipment with a value of less than 300,000 Yuan. Accelerated depreciation is applied to R&D equipment over that [20]. This policy helped to increase the market value, earning power and cash flow of Chinese manufacturing companies, encouraging further development of innovative product. Comparing China's tax policy with that of the United States that allows for more than 50% of the taxpayers qualified current expenditures, we see a favoured advantage for Chinese companies having government support in the growth of the manufacturing sector. The current U.S. tax system actually encourages US multinationals to locate assets and economic activity, earn and realize profit, in other countries where taxes are lower. China's strengths are its supply of inexpensive labour, large internal market, and high investment, both by the government and through high foreign direct investment [20]. China's weakness however, still remains in the low number of skilled workers, even with the policy launched by the Ministry of Education to construct 100 top universities and key disciplines to promote the development of higher education and enhance performance of science, technology and culture (European Union, 2011). The United States exhibits similar weakness with China in terms of skilled workers; a study released by the Harvard Business School found that immigrants comprise nearly half of all scientists and engineers in the United States who have a doctorate, and accounted for 67 percent of the increase in the U.S. science and engineering workforce between 1995 and 2006. The study accounts for the increase in labour costs in US industries; a strong factor affecting competitiveness of the US manufacturing sector. To curb this, the United States has established educational policies to address issues facing shortage of skilled workforce. With the fortifying Science, Technology, Engineering and Math (STEM) program in high institutions and NO CHILD LEFT BEHIND policy set by the Obama administration to the congress on 10th march 2010, the United States tends to bridge the gap in workforce and ensure the increase of skilled labour in the nation.

V. Conclusion

The objective of this paper was to make comparative study between China and the United States as regards advanced manufacturing. The paper reviewed recent key drivers that enhance the growth of advanced manufacturing and rate of competitiveness between both countries. From the data report of IMSS and GMCI, it is clearly seen that reduced labour cost and favourable tax policy has placed china at an advantage over the United States, as these factors contribute immensely to the advancement of manufacturing in a nation. The 2013 GMCI report shows slight difference in competitive priorities between both companies. Talent innovation is

highly prioritized in the United States while the Chinese on their part have emphasized on labour cost and delivery. This study highlights the reasons behind China's recent stride in its economy, and thus becoming one of the topmost leaders in manufacturing worldwide.

Authors' Details
[1] Department of Mechanical and Electrical Engineering,Wuhan University of Technology, no.205, Luoshi road, Hongshan district, Wuhan, Hubei, China. valot222@yahoo.com
[2] Department of Mining Engineering, Wuhan University of Technology, no.205, Luoshi road, Hongshan district, Wuhan, Hubei, China. dskkoroma@hotmail.com

References

[1]. Waldeck, N.E., 2007. Worker assessment and the provision of developmental activities with advanced technology: An empirical study.International Journal of Production Economics 107 (2), 540–554.
[2]. Laosirihongthong, T., Paul, H., 2004. Competitive manufacturing strategy:An application of quality management practices to advanced manufacturing technology implementation. International Journal of Business Performance Management 6 (3/4),
[3]. Machuca, J., Sacristan Diaz, M., Alvarez Gil, M., 2004. Adopting and implementing advanced manufacturing technology: New data on key factors from the aeronautical industry. International Journal of Production Research 42 (16), 3183–3202.
[4]. Karim, M.A., Smith, A.J., Halgamuge, S., Islam M.M., 2007. A comparative study of manufacturing practice and performance variables.
[5]. Nahim, A.Y., Vonderembse, M.A., Subba Rao, S.S., RaguNathan, T.S., 2006. Time-based manufacturing improves business performance—Results from a survey. International Journal of Production Economics 101, 213–229.
[6]. Yusuf, Y.Y., Gunasekaran, A., Adeleye, E.O., Sivayoganathan,K.,2004.. Agile supply chain capabilities: determinant of competitive objectiveness. . European journal of operational research
[7]. National Science Foundation, Science and Engineering Indicators 2012, p. 4-42,
[8]. Stephanie S. Shipp, Nayanee Gupta, Bhavya Lal, Justin A. Scott, Christopher L. , Michael S., Meredith B, Sherrica N, Samuel T 2012 ;Emerging global trends in advanced manufacturing.
[9]. Nagalingam SV, Lin GCI. CIM Still the solution for manufacturing. Robot Computer Integrated Manufacturing 2008; 332-344.
[10]. American Management Association (AMA), manufacturing division (1957),towards the factory of the future, New York: American Management Association.
[11]. Jue Wang, Aselia U, Philip S, Jan Y.2004. A brief history of the future of manufacturing: U.S. manufacturing technology forecast in retrospective, 1950- present
[12]. Lu Y., Strive in unity, pioneer in innovation, build a strongmanufacturing country, Manuf. Technol. Mach. Tool, 2003, 1: 6–13 (in Chinese)
[13]. Song J., Manufacturing industry and modernization, Chin. J. Mech. Eng., 2002, 38(12): 1–9 (in Chinese)
[14]. Tianran Wang, Yi Zhang, Harbin Yu, Feiyue Wang. 2010. Advanced manufacturing technology in china: a road map to 2050
[15]. Swiss business Hub 2013
[16]. Fletcher, Owen. 2011. "China PC Market Tops US." Wall Street Journal.
[17]. Manufacturing Institute. 2009. The Facts about Manufacturing. The Manufacturing Institute, the Manufacturing Alliance, and National Institute of Standards and Technology.
[18]. Global manufacturing competiveness index.2013.
[19]. The Frankfurt School, UNEP Collaborating Centre for Climate & Sustainability Energy Finance, and Bloomberg New Energy Finance, "Global Trends in renewable energy investment", http:// fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf, 2012.
[20]. European Union. ERAWATCH Research Inventory Report for New Research Policy Developments 2011. Available from http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.home.