UiT
THE ARCTIC UNIVERSITY OF NORWAY

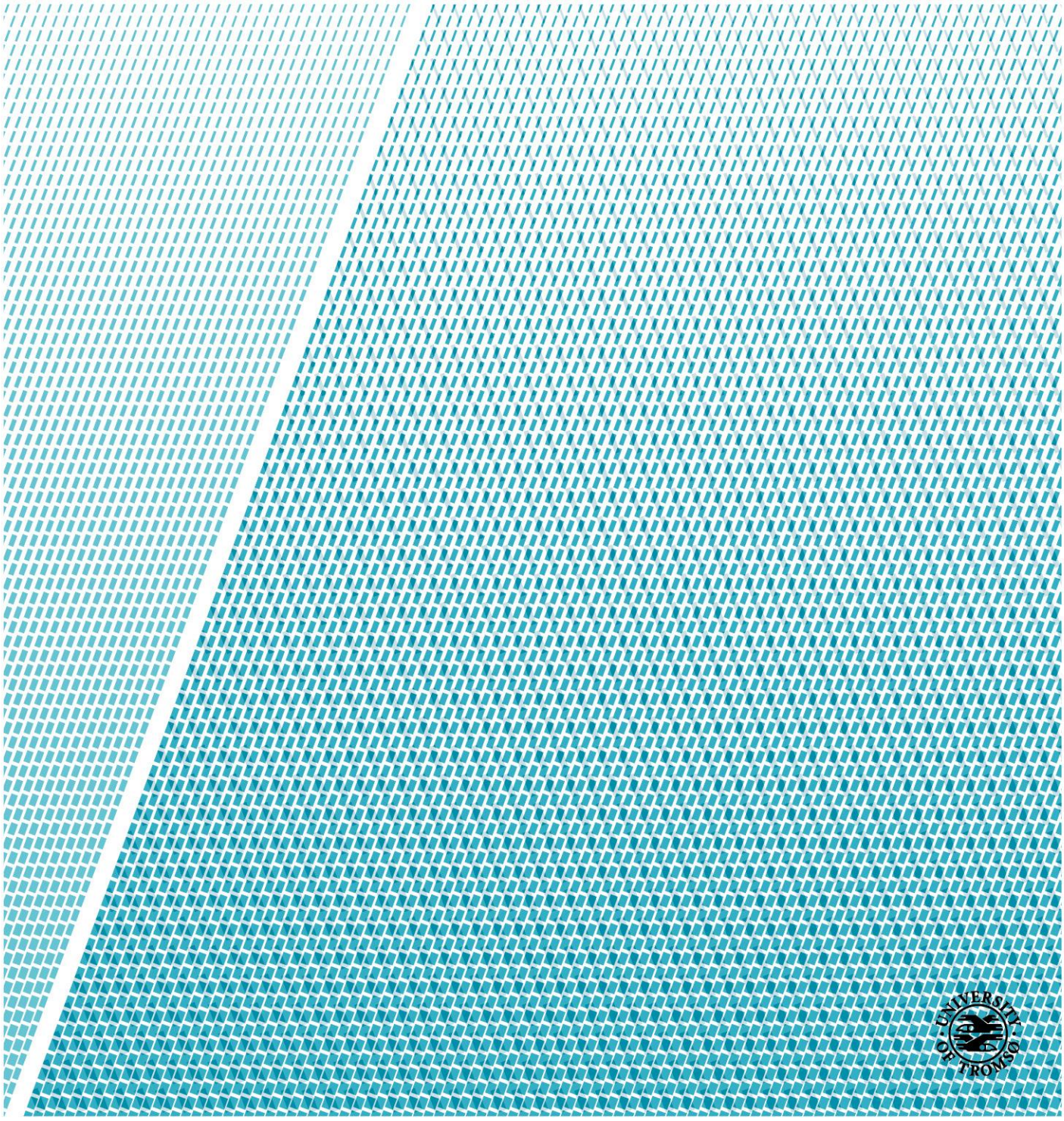
Department of Industrial Engineering

Transformation towards Small-scale Intelligent Manufacturing System (SIMS) - a case study of the workshop at UiT Narvik

Faculty of Engineering Science and Technology

Zhiwei Chai

Master's thesis in SHO6266, 02.06. 2017



Title: Transformation towards Small-scale Intelligent Manufacturing System (SIMS) - a case study of the workshop at UiT Narvik	***Date:*** 02.06.2017
	Classification: Open
Author: Zhiwei Chai	***Number of Pages:*** 57
Student no:490507	***Number of Attachments:***
Subject Name: Master's Thesis	***Subject Code:*** SHO6266
Department: Faculty of Engineering Science and Technology	
Master Program: Industrial Engineering	
Supervisor: Professor, Wei Deng Solvang	
Co-supervisor: Phd Hao Yu	
External Organization/Company:	
External Organization's/Company's Liaison:	
Keywords (max 10): SMEs analysis; SIMS; Transformation of intelligent manufacturing; SIMS workshop; CNC; Robot; Visual Component; NPA	

Abstract (max 150 words):

With the development of increasing globalization of markets, the small and medium-sized enterprises (SMEs) are necessary to improve their innovation ability, and enhance their competitiveness in the global market. This project analyzes the global and region current situation of SMEs, and then provide the conclusion of advantages and challenges of SMEs, especially the sort of small manufacturing enterprises in distinct field such as economy, social and environment. Traditional approaches to manufacturing systems do not fully satisfy this new situation. In order to deal with this problem, Small-scale Intelligent Manufacturing Systems (SIMS) is introduced. This report summarizes the SIMS' concept, component, tools, execution, challenges and trends. Finally, based on the evaluation and analysis of the existing workshop in UiT Narvik, a proposed study has been formed for the transformation from current workshop to the SIMS workshop.

Abstract

Under the context of globalization and liberalization of the international trade, small and medium- sized enterprises (SMEs) are facing new opportunities and encountering with new challenges. This project analyzes the global and region current situation of SMEs, and then provides the conclusion of advantages and challenges of SMEs, especially the sort of small manufacturing enterprises in distinct field such as economy, social and environment.

The manufacturing environments are in dire need to be changed correspondingly. It's necessary for enterprises to redesign products and reconfigure manufacturing systems on a regular basis. In this case, the conventional methods applied to manufacturing systems are unable to fully meet this new trend. In order to deal with this problem, Small-scale Intelligent Manufacturing Systems (SIMS) is introduced which has diverse methods and innovative technologies that can be applied and integrated.

This thesis summarizes the SIMS' concept, component, tools, execution, challenges and trends through the research study of SIMS. Finally, based on the evaluation and analysis of the existing workshop in UiT Narvik, a proposed study has been formed for the transformation from current workshop to the SIMS workshop.

Preface

This Master' Thesis project was conducted during November 2016 to June 2017 as a part of Master' program in Industrial Engineering at UiT The Arctic University of Norway, Campus Narvik. This report is the result of the work performed for transformation towards of existing workshop in UiT Narvik to SIMS work shop basic on research study of Small-scale Intelligent Manufacturing System (SIMS).

I would like to thank Professor Wei Deng Solvang and Phd Hao Yu for their help and guidance during this work.

Narvik, 01.06.2017

Zhiwei Chai

Table of Contents

Abstract I
Preface III
List of Tables VII
List of Figures VIII
1 Introduction 1
2 Background 2
3 Small and medium-sized enterprises (SMEs) 3
3.1 SMEs in the global scene 3
3.2 Definition of small manufacturing enterprises 5
3.3 Differences between small and large manufacturing enterprises 8
3.4 Strengths and weaknesses of small manufacturing enterprises 10
3.4.1 Advantages of small manufacturing enterprises 11
3.4.2 Challenges of small manufacturing enterprises 12
3.5 Potentials of small manufacturing enterprises 13
3.6 Problems of small manufacturing enterprises 15
3.6.1 Social problems 15
3.6.2 Economic problems 16
3.6.3 Environmental problems 17
4 Small-scale Intelligent Manufacturing System (SIMS) 20
4.1 The concept of SIMS 20
4.2 Components of SIMS 23
4.3 Properties of SIMS 26
4.4 Tools and technologies for SIMS 28
4.5 Implementation of SIMS 29
4.6 Execution of SIMS for small manufacturing enterprises 32
4.7 Challenges and trends of SIMS 33
5 Transformation of existing workshop to SIMS workshop 36
5.1 Existing workshop in UiT Narvik 36
5.2 Suggested lay out design for transformation 39
5.3 Flow chart 41

5.4 Executive process 42
5.5 Visual Components 44
5.6 General control system 47
5.7 Advantages of SIMS workshop 50
5.8 Challenges of SIMS workshop 51
5.9 Future work 52
6 Conclusion 53
Reference 55

List of Tables

Table 1. SMEs in the global scene 4
Table 2. Definition of small manufacturing enterprises in EU 6
Table 3. Differences between small manufacturing enterprises and large-scale enterprises 9

List of Figures

Figure 1. Objectives of manufacturing 23
Figure 2. Components of SIMS 25
Figure 3. Existing workshop of master industrial engineering department in UiT Narvik 36
Figure 4. Equipment applied for simulation and optimization of processing technology 37
Figure 5. Two Kuka robot arms 37
Figure 6. ABB parallel robot 38
Figure 7. CNC milling machine 38
Figure 8. CNC turning machine 39
Figure 9. Suggested lay out design for transformation 40
Figure 10. Flow chart of SIMS workshop 41
Figure 11. Visual Components 44
Figure 12. The visualization of SIMS workshop No.1 46
Figure 13. The visualization of SIMS workshop No.2 46

1 Introduction

As the global competition becomes fiercer and customer demands change faster, the manufacturing environments are in dire need to be changed correspondingly. It's necessary for enterprises to redesign products and reconfigure manufacturing systems on a regular basis. In this case, the conventional methods applied to manufacturing systems are unable to fully meet this new trend.

The preponderantly small and medium-sized enterprises (SMEs) play a crucial part compared with enterprises in other scales. In particular, SMEs exert significant functions and influence in the manufacturing industry, and take a strategic position in promoting the social economy growth. The SMEs usually cover more than 90% of all enterprises excluding agricultural industry, which compose the main employment source and create the considerable earnings both in the domestic and foreign markets. Therefore, the development of SMEs is of great importance to reduce poverty [1].

In Northern Peripheral Area, the manufacturing companies are mainly in small and medium size, which are trapped by many thorny problems, such as geographic isolation and deficiency in benefits from the industrial cluster. To improve their global competitiveness, the companies are required to make innovation and apply new methods, only in doing so, they could make response in a timely manner according to market changes, satisfy customers' requirements, less the time for bringing products to market and reduce cost.

In order to deal with this problem, Small-scale Intelligent Manufacturing Systems (SIMS) is introduced which has diverse methods and innovative technologies that can be applied and integrated. This paper gives an introduction of SIMS, defines its design objectives, and summarizes concept, component, tools, execution, challenges and trends for the development of SIMS, to generate a facilitative environment for SMEs to embrace new and innovative technologies. At present, there is an industrial workshop located inside UiT Narvik that needs to be upgraded to an intelligent SIMS workshop, which is the main target of this master thesis.

2 Background

Having a significant strategic position in the economic growth and the impartial development of all countries, the small and medium- sized enterprises (SMEs) account for 90% of all enterprises in most counties, and are counted as great impetus for numerous innovations. It helps to invigorate economy by creating job opportunities, making investments and conducting exportation.

Under the context of globalization and liberalization of the international trade, SMEs are facing new opportunities and encountering with new challenges. Recently, most of the SMEs are incapable of getting to know and taking these new opportunities and overcoming these challenges. We can see that, in the developing countries and countries in transition, most of the SMEs are unable or not completely able to take the advantage of globalization, and moreover, to make the circumstance worse, these enterprises are also facing with pressures from the local or domestic markets concerning the cheaper prices brought about by importing and competition with foreign companies. With the development of increasing globalization of markets, the SMEs are necessary to improve their innovation ability, and enhance their competitiveness in the global market, in doing so, to fully tap their potential and make full use of their advantages.

The stricter customer demands and fiercer international competition drive the market and technology changes and bring about a rapid development and innovation. The technological innovation has two common modes, one is to apply new technologies in manufacturing process, and the other is produce new products by applying the advanced technical components [2].

In order to help SMEs to solve the aforesaid problems and to get access to new technologies for improving their global competitiveness, it's necessary to bring in the small-scale intelligent manufacturing systems (SIMS) which offers various means and innovative technologies to satisfy different requirements on application and integration (among systems, parts, technologies, enterprises, value networks, and means) [3].

For the goal of enabling SMEs to embrace the next generation of innovation and technology, this study identifies SIMS design objectives and summarizes concept, component, tools, execution, challenges and trends.

After research study of SIMS, need to update the existing workshop which located inside UiT Narvik to a SIMS workshop.

3 Small and medium-sized enterprises (SMEs)

In the past few years, the development issues of SMEs have been put on the first place in the agenda of many countries, which indicates that SMEs development has gained gradually greater economic significance. As shown in the evidences collected world widely, there is an obviously growing indication of the SMEs. For both the developed and developing economies, SMEs account for the overwhelming majority, and have made great and significant contribution to development of economy and society. In general, they have created numerous job opportunities, and their turnover is 1/3 to 2/3 to that of all the private enterprises.

The typical countries undergoing transition in economies have provided successful exemplifications with regards to changes in structure of ownership, commercial culture and entrepreneur in the last ten years. In the past twenty years, SMEs are the main impetus for increase of employment and production for many countries.

SMEs have a great contribution to development of global economy. For instance, almost 90% enterprises in EU are in small and medium size, which cover 70% of various economy activities. In addition, SMEs are crucial to the economic development of developing and transitioning countries. SMEs cover over 90% of enterprises in all industries excluding agriculture, which create the majority of job opportunities and make considerable revenue both at home and abroad. With all the above positive influences, SMEs play a significant role in alleviation of poverty.

Under the context of globalization and liberalization of the international trade, SMEs are facing new opportunities and encountering with new challenges. Recently, most of SMEs are incapable of getting to know and taking these new opportunities and overcoming these challenges. We can see that, in the developing countries and countries in transition, most of SMEs are unable or not completely able to take the advantage of globalization, and moreover, to make things worse, these enterprises are also facing with pressures from the local or domestic markets concerning the cheaper prices brought about by importing and competition with foreign companies. Therefore, with respect to improving the development of SMEs, we mainly aim at adjusting the balance between these two kinds, and to make SMEs better qualified to cope with problems and challenges brought about by globalization and take chances to make benefits [4].

3.1 SMEs in the global scene

On a global scale, the overwhelming majority of enterprises are SMEs. Although their proportion in each country differs, but the fact remains that they certainly have accounted for a considerable part of all the enterprises.

	EU	Asia			USA
		China	Japan	Korea	
Number of Enterprises	23 million	42 million	3.809 million	3.017 million	28 million
Number of Employees	75 million	315 million	33.61 million	10.88 million	83 million
Representing present of all enterprises	99%	99.8%	99.7%	99.9%	99.9%

Table 1. SMEs in the global scene

- The EU

  In the European Union, there are approximately 23,000,000 SMEs that account for 99% of all the enterprises and created about 75,000,000 jobs opportunities. So, SMEs are crucial to the economic development of the EU by creating new jobs, cultivating new concepts and generating wealth.

- The OECD countries

  There are thirty (30) countries in the Organization for Economic Cooperation and Development (OECD), among which 19 are EU members, 1 is the candidate county of EU, and 3 are the European countries excluding EU members. And the remaining seven countries include the United States, Canada, Australia, Mexico, Japan, New Zealand, Korea and Australia. Most of the OECD members have issued numerous policies and made various programs to provide assistance in developing SMEs as well as fostering and promoting entrepreneurship. In doing so, to help to overcome some of the difficulties frequently encountered by SMEs, and to solve problems relating to finance, e-commerce, management, technology and innovation and internationalization etc. [5].

- United States

  SMEs in the United State can obtain the direct cash injection. As specified in the Small Business Act, the transaction with a contract value of more than US$ 2,500 but no more than US$ 100,000 shall be exclusively applicable to the small enterprises (unless the quotation is unable to be obtained by the purchaser from two or more competitive small enterprises and the goods or service quality can't be guaranteed). So, we can see that, the purchasing policies are inclined to help the small enterprises, disadvantaged enterprises, women-owned small enterprises and veteran-owned small enterprises to be better engaged in competition.

- Latin America

  In the past, Latin American countries have made continuous endeavors to seek large investments and attract multinational corporations, but nowadays, the governments of Latin American countries

began to aware that, SMEs are the one which create the majority of job opportunities and play a significant role in the technology innovation and supply chain. Therefore, the governments of all Latin American countries have greatly cut down their unnecessary official rules, procedures and restrictions in respect to SMEs, in order to make a quick response to satisfy needs of the SMEs.

- Asia

  On a world scale, some economies with best development have treated SMEs as fundamental, typically Hong Kong and Taiwan in Asia. For instance, in 2005, nearly 270,000 SMEs in Hong Kong have covered more than a half of all employment, which offered 1,200,000 people with job opportunities. These SMEs are mainly specialized in service industry, typically the retail, wholesale, import and export business. In Japan, SMEs refer to enterprises with the employees' number of more than 4 but up to 299, and a sales revenue of less than 100 million yen. These enterprises account for 99.7% of all the enterprises, in which the manufacturing and retail industries are prevailing. Korea also has been aware of significance of SMEs, and has taken various actions in this respect, such as reduction of taxes and loan interest for the newly established small enterprise in rural area [6].

- The developing countries

  With respect to the developing countries, there are millions of underprivileged communities with no large enterprises, in which SMEs are the only source to get jobs. In the developing countries, the majority of SMEs are engaged in traditional industries and only aim at their local market with small size, thus, they are unlikely to make technology innovation. And it's turned out that, the aforesaid enterprises have rarely grown into enterprises with larger scale or more advanced technologies. In these developing countries, there is no need to strongly stress the small enterprises' importance in economic development, however, what should be concerned is their vitality, which expressly indicate the economic health.

3.2 Definition of small manufacturing enterprises

- As for most countries in European Union

The definitions are different from legal perspective and statistical perspective. According to EU recommendation number 2003/361/EC, from the legal perspective, it’s mainly defined the employees’ number, independence, annual balance sheets and revenues (see Table 2. below). In some cases, the monetary thresholds have been adapted (Italy). More generally, this definition has served as a basis for other European countries, such as accession countries (e.g. the Czech Republic) and Turkey [4].

Enterprises	Employees	Annual turnover	Annual balance sheet	Autonomous
Micro enterprise	1 to 9	< 2 million euro	< 2 million euro	Conform to the criterion of independence as the enterprise should own 25% or more of the capital, or voting rights by one enterprise.
Small enterprise	10 to 49	< 10 million euro	< 10 million euro	
Medium enterprise	50 to 249	< 50 million euro	< 43 million euro	
Large enterprise	More than 250	> 50 million euro	> 43 million euro	

Table 2. Definition of small manufacturing enterprises in EU

- As for the United States

  The Size Standard Office of the Small Enterprise Administration (SBA) has defined small manufacturing enterprises. Differing form, the countries in EU that have one general definition applicable to all the sectors, the United States has laid down the specific standards of enterprise scale for each systematically classified industry listed in the North American Industry Classification System (NAICS), by doing so, to take into consideration and show distinction and diversified features of each industry:

  - For enterprises in manufacturing and mining industries, the employees number shall be 500
  - For enterprises in wholesale trade industries, the employees number shall be 100
  - The annual avenues for most enterprises in retail and service industries shall be no less than $ 6 million
  - The annual revenues of most enterprises in common and heavy construction industries shall be $ 28.5 millions
  - The revenues of all the special trade contractors shall be $12 million
  - The revenues of most enterprises in agriculture industries shall be $ 750,000 [7]

- As for Japan

  Small manufacturing enterprises are defined by taking into account of the employees' number, capital or total investment in Japan. However, although with the same standards, the minimum requirements and standards for all these elements are different in each individual industry. Taking the following as an example, the upper bound of a small manufacturing enterprises in Japan is 8, the standards regarding the number of employees, capital or total investment shall apply as bellow:

- For enterprises in manufacturing, construction and transportation industries, the employees' number shall be 300 with the capital/total investment of 300 million yen

- For enterprises in wholesale industries, the employees' number shall be 100 with the capital/total investment of 100 million yen

- For enterprises in service industries, the employees' number shall be 100 with the capital/total investment of 50 million yen

- For enterprises in retail industries, the employees' number shall be 50 with the capital/total investment of 50 million yen [8]

- As for India

  In the last century, Indian government has changed its limitations on investment number of small manufacturing enterprises. In 1960, small manufacturing enterprises was defined as the enterprises with the employees' number of no more than 50 or 100 and the fixed assets up to Rs 500,000. In the year of 1966, the limitation on investment number of small manufacturing enterprises in plant and machinery were raised to Rs 750,000 with the employees' number remain unchanged. During the period from 1966 to 2001, such limitation was increased for many times, which has reached Rs 10,000,000 in 2001. By the year of 2001, small manufacturing enterprises in India were defined as: the manufacturing entities with no more than Rs 10,000,000 leased or purchased fixed assets investment in respect of plant and machinery, (provided that it is not owned by, under the control of or affiliated to any other manufacturing enterprises). With respect to the small manufacturing enterprises, the investment amount for plant and machinery is limited to Rs 2.5 million, wherever they are located. The Small-Scale Service/Enterprises (SSSBEs) refer to the enterprises or services in relation to the SSSBEs industry to which the investment is limited to Rs 500,000 (exclusive of building and land), and such limitation has been increased to Rs 1000,000 on 10th September 2000 [9].

- As for China

  In February 2003, the government authority of China made the definition for its official domestic small manufacturing enterprises. In China, small manufacturing enterprises shall have no more than 2000 employees, or hold less than RMB 400 million assets in total, or make at most RMB 300 million annual revenues; as for enterprises in retail and wholesale industry, the number of employees shall be no more than 500, with an annual sales revenue of RMB 150 million; as for enterprises in transportation industry, the number of employees shall be no more than 3,000, with an annual revenue of 300 million. While conducting a worldwide analysis, the current international criteria in respect of small manufacturing enterprises will also be taken into consideration, with more attentions paid to the enterprises side rather than only emphasizing on the official definition [10].

3.3 Differences between small and large manufacturing enterprises

"Of course, there are other characteristics of small business that may be added to the list; perhaps the most obvious is the severe limitation of resources faced by small firms, both in terms of management and manpower as well as money." [11]. The above standpoint puts emphasis on the qualitatively and quantitatively essential distinctions between small manufacturing enterprises and those in large scale, and indicates that these enterprises not simply differ, from the quantitative view, in scales, employees' number and money. Actually, bearing many distinguishing features, small manufacturing enterprises can be easterly told apart from the enterprises in large scale.

- Personalized management

  As the owner/manager of small manufacturing enterprises can make decisions for all the company issues at his/her own discretion, his/her personality may be largely reflected in and affect the spirit of the enterprise. The business operation and cooperation in such enterprise will largely rely on the manager, therefore, if he/she has some acts or omissions with adverse impact, the business is more easily to be failed. In general, the manager or owner of small manufacturing enterprises always make decisions and participate in all aspect of the enterprise, so, he/she shall play a positive role in company management in every aspect.

- Small Market Share

  Small manufacturing enterprises are incapable of deciding the market price and make little difference to the total quantity sold in the market. In addition, small manufacturing enterprises have limited purchasing capacity, and with a small procurement quantity, they may get no discount but have to pay a relatively more expensive price. Based on the aforesaid situation, the cost of their products would be higher than the large-scale enterprises, which lead to a higher selling price of their products as well as a lower competitiveness. Small manufacturing enterprises are usually engaged in the specialized products or commodities and make a niche market in order to atone for the above shortcomings.

- Loyalty of Customers

  Having a niche market, some of small manufacturing enterprises are relying on a small group of customers with loyalty to them. In case of loss of one or two of such customers, such enterprise is likely to be failed.

- Finance

  Small manufacturing enterprises always encounter with problems regarding financing for its growth and development. If the customers fail to make payment due in a timely manner, the enterprise is likely to have capital turnover problems which may jeopardize its survival. More often, it may be even worse that, once the payment due hasn't been made by customer in a timely manner, their transaction fails.

Some more differences between small manufacturing enterprises and large-scale enterprises can be clarified in Table 3. which classifies the enterprises according to 8 criteria as follows:

Comparison factors	**Small manufacturing enterprises**			**Medium enterprises in factory**	**Large-scale Enterprises**
	Micro		**Small enterprises in factory**		
	House enterprises	**Environmental and handwork enterprises**			
Place	House	Enterprise	Factory	Factory	Factory
Location	Villages and cities (Small-medium-large)	Villages and cities (Small-medium- large)	Large villages and cities (Small-medium-large)	Medium and large cities	Large cities
Ownership pattern	Individual	Individual and combination	Individual or personal companies	Personal and capital companies	Capital companies
Number of employees	Less than 5 employees	5-10 employees	10-50 employees	50-100 employees	More than 100 employees
Mechanical lever	Handicraft (work that requires both manual and artistic skill)	Handicraft + simple equipments	Handicraft + half automatic	Half automatic and automatic	Automatic
Market size	Family and friends	District and village	Local market	Local and national market	National and international market
Raw-materials	Cheap and localized	localized	Localized and sometimes imported	Localized and imported	Localized and imported
Energy use	Very low	Low	Medium	High	Very High

Table 3. Differences between small manufacturing enterprises and large-scale enterprises

3.4 Strengths and weaknesses of small manufacturing enterprises

Presently, as the global market changes, small manufacturing enterprises encountered with a series of difficulties and challenges, like more opened business, fiercer global and domestic competition, and unforeseeable expanding environment.

Rules for competition in the 21st century (the "New Competition") are now growingly dependent on structure flexibility, adoptable specialization, and flexible production process. All of which are product-oriented but not price-oriented competition, and the sustained innovation, just-in-time principles, and production innovation relating to the knowledge-based activities (including design, quality control, and new management methods involving team cooperation), will be conducive to create good working environment, and to conduct the inter-firm cooperation regarding infrastructure [12].

Where small manufacturing enterprises plan to have more competitiveness through achieving greater production efficiency but do not want to be marginalized, it's essential for them to satisfy the new market demands; obtain the required skills and knowledge; bring in the innovative technologies to be applied on their products and production process; conduct operations restructure (that is to say, build a leaner structure); upgrade technology; improve the working environment; and provide a competitive price. If the small manufacturing enterprises intend to maintain their economic competitiveness in the context of globalization, the aforesaid New Competition rules are to be adopted in the continual process of change, rather than to be treat as the end-states [13].

The evaluation of enterprise performance and setting of goals are helpful to the enterprise's persistent improvement of its products and services, even so, small manufacturing enterprises usually do not have enough time, sufficient money and advanced information to do so. Moreover, it's too complicated for them to follow the prevailing management scheme for international environment. So, small manufacturing enterprises are necessary to deepen their cognition of socially and environmentally beneficial production mode, and learn how to incorporate the issues relating to society and environment into their daily operation practice, and build reward mechanism for the above efforts.

The small manufacturing enterprises' contribution to the overall manufacturing environmental impact remains unknown, however, collectively, the sheer numbers indicate that they have a considerable impact on ecosystem. Furthermore, most of the small manufacturing enterprises occupy the resource and emission intensive business such as leather tanning, brewing, metal finishing, textile manufacturing, printing and dyeing, chemical production, food processing, fish farming, dry cleaning etc. [14]

Small manufacturing enterprises have been among the first to manage their social and environmental influences by adopting several well-designed methods, including establishment of environment management system, provision of training and qualification for their employees in respect of the social and environmental issues, reporting their social and environmental performance, and cooperation with other companies in the supply chain, in order to reduce the impact of their products and services to the local society and environment. However, the majority of small manufacturing enterprises, especially those in developing countries and countries in transition, are still characterized by their lack of awareness of their own environmental and social impacts and their less structured management of such issues [15].

Notwithstanding of the aforesaid, there is still a great possibility for small manufacturing enterprises to become the main driving force for improving the local economic activities chain, in order to realize the sustainable development in the region. Under the context of sustainability, the strengths and weaknesses of small manufacturing enterprises in this respect will be specifically explained below.

3.4.1 Advantages of small manufacturing enterprises

- Close monitoring

  The small manufacturer may monitor his business on his own, and he may pay his attention on every detailed issue. Under his supervision, the employees will try their best to protect equipment from being damaged and to economize materials with no fraud or equipment idleness. In addition, keeping his eye on the business, he will attempt to minimize production cost while pursue the ultimate profits.

- Specialized demand

  If the demand is small or changes frequently, in light of the small manufacturer' specialization, he may be more suitable than those with a large scale.

- Generating more job opportunities

  Facing the massive unemployment problems, the rapid and stable development of small enterprises will certainly do benefits to generate more job opportunities. It's because small enterprises in manufacturing industry is labor-intensive, which needs more labors rather than machines. Hence, the newly established small-sized enterprises have recruited a plenty of the unemployed, in this way, the unemployment problem has been alleviated.

- Requirement of small capital

  By simply inputting small capital, you can easily start the manufacturing in small scale. In case of a fund shortage, manufacturing in small scale is significantly beneficial to the industrial development.

- Close connection between the employers and employees

  The small enterprises in manufacturing industry usually have not too many employees. Hence, the employers have chance to know each of the employees deeper and keep a direct connection with each of them. Relying on this close connection and better understanding with their employees, the employers can take good care of their employees' emotions, physical and mental health, and to encourage them to devote in their work, and by doing so to make the work go well with satisfaction and no dispute.

- Direct contact between the client and manufacturers

  The main purpose for establishment of small enterprises is to satisfy the local needs. Therefore, these small enterprises can contact customers directly. Since a small manufacturer can get to know

his customer on his own, he can customize the product for each customer according to his or her demand and preferences.

- Simple management

  The small enterprises are easy to be operated and managed. They can be well managed only by a few employees adopting simple accounts.

- Have freedom at work

  The small enterprise has freedom to make decision for all the business affairs, such as deciding the number of employees. In addition, since they don't rely on capitalists, they can operate the business according to their own thoughts and concepts.

- External economies

  Both the large and small-scale manufacturing are capable of securing various external economies, which include qualified technicians, timely banking and insurance services; and advanced power, communication and transportation facilities and etc.

- No maladies of lager scale manufacturing

  Manufacturing in small scale can avoid undergoing the maladies of those in large scale, such as overcrowded environment and ills of plant system.

- Other advantages

  Compared with manufacturing in large scale, manufacturing in small scale has several significant advantages including:

  - Prompt supply adjustment upon changes in needs at any time.
  - Shutdown and strikes are less likely to happen, and moral degradation of labors is seldom.
  - Monopolistic institutions have no dangers.

3.4.2 Challenges of small manufacturing enterprises

- High manufacturing cost

  The unit manufacturing cost is higher as a result of the higher labor cost, the limited labor division scope and the lower usage of machine.

- Inability to make full use of by-products

  Compared with manufacturing in large scale, manufacturing in small scale usually wastes its generated by-products instead of making full use of them.

- Relatively less machiness application

  Manufacturing in small scale cannot benefits from machinery as they have relatively less needs and smaller scope for machinery usage.

- Deficient labour division

  Manufacturing in small scale usually has a small production scale, so the labor division is deficient and the profits is not high.

- Greater difficulty in obtaining loans

  The small-scale manufacturers have no access to the financial economies, and are less likely to obtain funds, even if they are funded, a relatively higher interest rate needs to be paid.

- Difficulty in surviving the economic crisis

  With limited resources and weak finance, manufacturers in small scale can't afford to bear a long-term loss, so they are difficult to survive the economic crisis. Actually, many small plants have shut down when encountered with a small economic crisis.

- Expensive raw materials

  With a small production scale, the small enterprises usually have a small demand on raw materials, therefore, there would be no discount for the raw materials. Compared with large enterprises, their cost for raw materials is higher.

- Difficulties in standardization of products

  Manufacturers in small scale are difficult to control the standardization of quality of products, and their products often fail to meet qualifications. So, they may have a poor sales performance because of their unqualified products or products with uneven quality.

3.5 Potentials of small manufacturing enterprises

The small manufacturing enterprises is one of the significant sector of the national economy. They have characteristics of reliability, flexibility and innovation partner along the product chain [15]. The small manufacturing enterprises sector is regarded as one with equity benefits with respect of income allocation, especially those in developing countries having less capital and a large number of labor that are suitable for development of small-sized enterprises, in particular, for countries which were over-unemployed [16]. In general, it’s important to improve the economy and society development in the developing countries by developing the small-scale industries, for which the advantages and importance are listed as below [17].

- Since the small manufacturing enterprises are usually labor-intensive, compared with enterprises in other sizes, it’s of great help to create new employments and solve the unemployment problems, in which way it benefits the region by alleviating poverty and improving living conditions.

- Small manufacturing enterprise provide jobs to poorly skilled and semi-skilled employees. The matter which helps to integrate this type of employees in the society and gives them the sense of belonging. Accordingly, this will lead to the stability among the different classes in the society.

- The small manufacturing enterprises offer jobs for people with few or not enough specialized ability or skills, through which they help to fitting this kind of people into society and guarantee their basis life. In this way, they do good to narrow the gap between the rich and the poor and build a harmonious and stable society.

- With respect to the rural and undeveloped areas, the local small manufacturing enterprises help to retain the local residents and reduce their mobility to large cities, as well as do benefits for the inter-regions geographical expansion. In the developing countries, the immigration issues are of great importance, which are urgently needed to be addressed. The small manufacturing enterprises help to relieve the pressure in this respect, and keep the rural and urban population distribution in balance.

- The small manufacturing enterprises are very vigorous, which help to prevent the economic recession and reduction of national income caused by failure of large-scale enterprises. Contrary to the large-scale industries' obvious effect on the national economy, the small manufacturing enterprises with a large quantity and a relatively small amount of capital, have little effect on economy when some of them have failed.

- In the rural area, the small manufacturing enterprises generate and offer employment opportunities for the local residents, in which way make it easier for these residents to get employment, and thus, is conducive to maintain the stability of society in the rural area.

- Small manufacturing enterprises often depend on local raw-materials, and this means decreasing importation of these materials from abroad. The matter which helps to save foreign coin using to import these materials from one hand and from another hand, it avoids the environment polluted emissions resulting from the transportation of imported raw-material for thousand kilometers.

- The small manufacturing enterprises are apt to procure raw-materials in or near their local area, which help to make the full exploitation of the local resources and reduce import from overseas. In this case, the small manufacturing enterprises help to reduce fund outflow for the purpose of procurement of raw-materials, and protect the environmental pollution arising from long-distance transportation of the imported goods.

- With a relatively low productivity, the small manufacturing enterprises have a great potential for further improvement in this respect;

- By providing numerous jobs for the less skilled or vulnerable group of people, the small manufacturing enterprises do benefits to reallocate the income of local residents in a fair way. Since the small manufacturing enterprises have urged the fair wealth redistribution between the rich and the poor, and have avoided gathering money only in hands of the rich, so this is accounted as a great advantage for expansion and development of the small manufacturing enterprises in the local area.

- While the enterprises in large scale may have some difficulties in communication and cooperation between employers and employees, the staffs in the small manufacturing enterprises usually directly report to and maintain a closer relation with managers, therefore, the employees and managers can communicate and work together in a better way. Since the managers and staffs in the small manufacturing enterprises have the amiable, relaxed but not restrained relationship, it provides a flexible environment to directly discuss issues and problems with managers, which help to solve these problems in a timely manner without unnecessary restrictions, and improve the work efficiency of both employers and employees. In addition, through this communication mode, there would be fewer misunderstandings and restrictions between them, and in case of any problems, it would be figure out and solved promptly. Based on the aforesaid closer relationship, the employees are more willing to trying their best to solve all problems and difficulties encountered by the enterprise, even if it may require them to work extra hours or cause delay in payment of their salary. With this kind of relationship, cooperation and mutual understanding, the small manufacturing enterprises are empowered to overcome challenges and survive crisis, and are more likely to realize the sustainable development.

- In the small manufacturing enterprises, the managers often work together with technicians and even may have a good knowledge of the relevant techniques, therefore, when encountered with technical difficulties and problems, they may lead the technicians to solve the problems in an innovative way. Compared with enterprises in other scales, the small manufacturing enterprises have a higher potential in the industrial competition.

3.6 Problems of small manufacturing enterprises

Some small manufacturing enterprises have difficulties in promoting productivity and optimizing working conditions as they are stuck with environmental, social, financial problems, which may restrict their expansion and sustainable development.

3.6.1 Social problems

Small manufacturing enterprises face with many social problems, which may obstruct their expansion and do harm to their sustainability. Such social problems including:

- Small manufacturing enterprises have difficulty in recruiting skilled talents. Compared with large scale enterprises, jobs offered by the small manufacturing enterprises often have lower salary, so it’s less attractive for the skilled talents. With only a small scale, there won’t be many vocational development and promotion chances for the outstanding skilled employees in the small manufacturing enterprises while having more working hours and higher working strength compared with enterprises in large scale.

  Furthermore, in the small manufacturing enterprises, it’s harder to get satisfaction in comparison with those working in large scale enterprises. Therefore, actually only the less skilled people who are not qualified to be employed by enterprises in large scale would choose to serve the small manufacturing enterprises.

The matter is more likely to lead to a low-quality production with less competitiveness, affected by which, the small manufacturing enterprises will gradually move towards failure. Besides, since their staffs are low-skilled, the small manufacturing enterprises fail to produce in a recyclable manner which would cause waste of the used raw-materials and also produce more solid and liquid wastes. Moreover, they will consume a larger volume of energy in its manufacturing process compared with large-scale enterprises [18].

- Small manufacturing enterprises are short of management knowledge and occupational safety and health awareness. Small manufacturing enterprises, especially those in developing country mostly haven't guaranteed the safety working environment for their staffs. Furthermore, these enterprises do not maintain the social insurance for their employees. In this case, the employees may lack of stability feelings and will certainly do harm to the manufacturing system [18].

- Some of the small manufacturing enterprises are relying on the managers' characteristics and ability. The capability, thoughts and personality of owners of such enterprises have decisive influence on business development, marketing and sales performance of such enterprises. Managers in the small manufacturing enterprises are in charge of operating, managing and monitoring all kinds of business, including procurement, manufacturing, sales and marketing, transportation and etc. It's very hard for the owners to make decision for and deal with issues and problems in all operation processes as it may require knowledge and experience in all these aspects, and once the owners have some failure, their enterprises are likely to have crises.

- The nepotism issue shows that, if small manufacturing enterprises only favor and recruit friends and relatives, their stable relationship with partners may change to be weak. The nepotism problem faced by small manufacturing enterprises made it difficult for outsiders and specialists to join their business and conduct professional management [19]. In addition, as we know, some of the small manufacturing enterprises having the issue of nepotism have failed as there were conflicts between the business interest and family interest.

- As the environmental issues may increase production cost of small manufacturing enterprises and there is no supervision network for tracking their performance in this field, the small manufacturing enterprises are reluctant to pay emphasis on and take active actions to protect environment and prevent pollution in their production process, this situation may be even worse in the developing countries. To realize the sustainable development, the relevant government authorities and non-governmental institutions shall work together to improve this situation by vigorously promoting the concept of sustainable development and issuing policies to make the small manufacturing enterprises to pay more attentions on environmental protection.

3.6.2 Economic problems

The small manufacturing enterprises have the potential to play an important role in sustainable economic development, however, they have encountered with many severe economic problems which may jeopardize their survival and further development. The economic problems including:

- Having only a small amount of investment and difficulties in financing, the small manufacturing enterprises often have financial problems. Compared with the large enterprises, lending money to

those in small scale have a higher risk, so banks usually prefer not to lend money to the small manufacturing enterprises.

Furthermore, since the small manufacturing enterprises' lack of capability of assessing their fund needs, so they usually started with certain amount of funds, but soon later, will find that such amount must be redoubled, and the funds problem may bring about other problems [18].

- The industrial weakness probability is an important issue required to be concerned. The factors which reduce competitiveness of the industry include: high capital and production inputs, incapable of catching up with technology developments, various change in the global industrial situation, long-term high inflation rate, incapable of keeping macro-economy stability, fail to reach the international standards for after-sale services, fail to apply the advanced technologies, insufficient capital accumulation, small production scale and fail to produce products in good quality. Relying on an inefficient control mechanism, the resources as distributed for improving the industrial development have not yet been utilized. In the context of economic globalization, the small manufacturing enterprises are driven to face the fiercer competition against enterprises in large scale [18].

- The small production scale of these enterprises is a weakness in their competition with large scale enterprises. Although the small production scale enables the small manufacturing enterprises to satisfy customer's demands and produce specialized products in a customized way, if there is a large demand, the small manufacturing enterprises will have a higher production cost. Moreover, even with a smaller scale, some kinds of cost are same for both large and small enterprises, such as cost for the environmental protection devices, which is seldom applied by the small manufacturers, research cost etc... Since research and development are crucial for innovation of small manufacturing enterprises, to these benefits, the small manufacturing enterprises have to reserve research funds. In comparison to the large-scale manufacturers, the small enterprises have less sales revenues and a considerable high cost, hence their fixed cost accounts for a larger proportion.

- The relative small size of small manufacturing enterprises makes their capability to incur and cover the temporary losses very limited. The small manufacturing enterprises in developing countries could not afford to assume 35000 $ (as an example) without re-evaluation on enterprise efficiency or working environment or without temporary shutdown, but such losses are affordable by the large-scale enterprises. In addition, having only a relatively small scale, the SMEs is incapable of modifying their products to spread risks [18].

3.6.3 Environmental problems

With respect to sustainability, the small manufacturing enterprises encountered with many internal and external difficulties and problems. Since the small manufacturing enterprises mainly pursue the better economic benefits, they usually make light of the environmental benefits, and regard the environment related issues as a burden as it may increase their cost.

The employees in small manufacturers usually have no awareness and professional knowledge in respect of environmental protection and pollution prevention, so they are incapable of solving the environmental problems in a correct manner. Even if they have been aware of importance of environmental protection,

it’s too complicated for them to comply with the prevailing international environmental protection practices and scheme. Once a small manufacturing enterprise has started to implement an environmental management scheme, the process is frequently found to be unexpectedly expensive and is therefore often interrupted [20].

The small manufacturing enterprises have less awareness and bad performance in respect to the environmental protection and sustainable development. The increasing number of small manufacturing enterprises and their repaid regional expansion have brought about more negative impact on environment, which made the situation even worse. The environmental problems including:

- As the prices of environmental-friendly products increase, the small manufacturing enterprises' burden regarding environmental cost for recycling, environmental-friendly technologies and waste disposal can be relieved. Since the small manufacturing enterprises only have a small amount of capital and limited finances, they can’t afford to take the high cost for treatment or recycling process on their own, therefore, they may do harm to the environment [21].

- Due to the lack of disposing devices as well as insufficient supervision and enforcement, many small manufacturing enterprises dispose the harmful waste indiscriminately.

- The small manufacturing enterprises in rural area and urban area have the same management problems and concerns. But, each of the rural and urban areas has its specific unique conditions and problems. The environmental problems in urban area (mainly the pollution problem) tend to have a direct and prompt impact on the living quality of the residents. Different cities have different kinds of environmental problems since their commercial activities differs from others.

- The small manufacturing enterprises have difficulties in acquiring high-quality raw materials. Since there is no cooperation in supply of raw materials among these small manufacturing enterprises, they have to satisfy their respective demand on raw materials on their own, in this case, they may have to bear a high material cost. The domestic alternative of raw materials is low quality and its use leads to lose great ratio of raw materials. In both cases the chance of small manufacturing enterprises to produce competitive products decrease [21].

- The old plant and outdated equipment. In the developing countries, the small manufacturing enterprises usually have no access to or can’t afford to buy the most advanced equipment. However, the application of old plant and outdated equipment may result in a waste of raw materials, environmental pollution, as well as production of off-spec products.

To help the small manufacturing enterprises to solve the aforesaid issues, transform to the intelligent manufacturing enterprises, and build their competition strengths in the global market, the government shall make the relevant policies and schemes, provide favorable conditions and environment, encourage and emphasize research and cooperation, and transform to the technology-based economy. The stricter customer demands and fiercer international competition drive the market and technology changes and bring about a rapid development and innovation. The technological innovation has two common modes, one is to apply new technologies in manufacturing process, and the other is produce new products by applying the advanced technical components.

When conducting research on new methods and basic actions to support the small manufacturing enterprises by applying new technologies and the most advanced processes, the concept of Small-scale Intelligent Manufacturing Systems (SIMS) has been introduced, which applies various means and creative technologies and emphasize on integrating all the processes (such as systems, components, approaches and techniques, enterprises and value networks). The integration of products into the service period and combination of technical innovation with marketing and key management will be conducive to enhance the competition strengths and value of enterprises in manufacturing industry. In general, SIMS is designed to build an automatic production environment with high integration and efficiency for the small manufacturing enterprises.

4 Small-scale Intelligent Manufacturing System (SIMS)

Intelligent enterprise is the latest phase of “Integration of informationlization and industrialization” in the modern enterprises, which utilizes internet, internet of things, big data and other information technologies to change the original relatively indurated production lines and production system and make design, research and development, manufacture, sales, logistics and all other links have a closer connection, to form a new trend in respect to quick linkage of production chain, service chain and value chain, in order to achieve a complementary relationship between individuation and large-scale production.

The automation level of workshop is not high, with a lack of efficient management and a not completely established collaboration platform and information integration platform for industry chain. In the meantime, the workshops also face many problems, such as the shorter and shorter delivery period, more and more batches of customized and semi-customized production demands, higher and higher requirement for flexibility of production and other problems, along with an increased labor cost, more intensive restriction on land resource and environmental factors and many other external shocks.

The enterprises accelerate transition to the innovation-driven type, in which they transform from the traditional enterprise mode to the intelligent enterprise mode, and simulate the upgrade from the traditional manufacturing to the intelligent manufacturing by a series of means, such as application of information technologies, intensive interconnection, information interaction, process reengineering, so as to satisfy customers' diversified and customized demands, promote production flexibility and bring about a lower manufacturing cost.

4.1 The concept of SIMS

In Northern Peripheral Area, the manufacturing companies are mainly in small and medium size, which are trapped by many thorny problems, such as geographic isolation and deficiency in benefits from the industrial cluster. To improve their global competitiveness, the companies are required to make innovation and apply new methods, only in doing so, they could make response in a timely manner according to market changes, satisfy customers' requirements, less the time for bringing products to market and reduce cost. With the progress of study, there is a growing awareness that intellectualization is imperative for solving all kinds of problems, while Internet/Intranet technologies and other information technologies are indispensable in development and application of technologies. Therefore, all the challenges and problems facing in manufacturing industry come down to manufacturing technology intellectualization. Self-organizing determines the automation degree of manufacturing systems. Nowadays, there appears a latest developing direction called the Small-scale Intelligent Manufacturing System(SIMS), by integrating computer science, the automatic technology and the artificial intelligence, it has become the most significant trend in manufacturing industry.

In the last two decades, the manufacturing concepts have been redefined for many times. In the 1980s, the flexible manufacturing systems (FMC) was brought in for development and production of a group of products bearing similar dimensions and restrictions, but recently, the reconfiguration capacity is key to improve the operations of industrial process [22].

Actually, we are mainly aiming at making quick adaption to new production and making quick response to failures we encountered. The intelligent manufacturing system (IMS) is flexible and reconfigurable, but besides the software intelligence aspects, it also has features in flexibility, efficiency, self-regeneration autonomy, learning, decentralization, and reliability. One important problem we presently facing is the development of manufacturing control systems with synergy and re-configurability, which bring in some innovative features including modularization, agility and adaptation to effectively adapt to the small quantity with lower cost and higher quality.

The international standard definition of the SIMS has not yet established. SIMS has been built on the basis of the intelligent manufacturing technologies which are regarded as integrating the artificial intelligence into manufacturing technologies. At the beginning, SIMS was known as an intelligent and integrated manufacturing system with high flexibility, which is used to replace and extend certain kinds of human mental labor in manufacturing industry. But, recently, the conceptual range of the SIMS is undergoing an extension. SIMS, by utilizing computers to simulate human intelligence actions including analysis, estimation, determination and other rational activities, to collect, share and develop human experts' experience in relation to manufacturing, and to replace and extend human's mental labor, has been applied to manufacturing industry with high flexibility and integration. Someone treats SIMS as stimulation and improvement of human's intelligence and mental labor, and they thought that it is for the ultimate purpose of realizing the all-round automation, the artificial intelligence has been applied in product design and management and other links to replace human's mental labor.

SIMS has the following functions:

- Through decomposing human's mental labor to simulate, replace and extend the experience and individual intelligence of specialists in manufacturing industry, for which the simple but onerous parts will be done by applying computer technologies, leaving the innovative part to be carried out by human.

- It is capable of simulating, replacing and extending the collective intelligence, specifically in the aspects of coordination, learning, management, communication, and cooperation of manufacturing system.

- By using the advanced technologies to integrate human intelligence and mechanical intelligence, which forms a complementary relation with their respective advantages. Furthermore, humans are able to cooperate with machine instead of simply control.

- Intellectualization has advantages in settling uncertainty and imprecision in manufacturing industry, so, with an ability to make quick response and high flexibility, SIMS is able to adapt to the new changes in manufacturing environment and conditions.

In summary, by applying computer technology to simulate, replace and extend humans' personal and collective intelligence, and through synthesis and integration of human intelligence and mechanical intelligence, SIMS possesses intellectualization and high flexibility, which could benefit enterprises to quickly adapt to the changeful market conditions and environment, as well as to promote corporate profitability. Greatly benefits from intellectualization, SIMS is highly integrated, which has fundamentally enhanced the comprehensive capacities of the system. Human labor has been partially

replaced by SIMS, which will help to relieve pressure of simple mental labor, and reduce the specialists' mental labor and give them more space for innovation. In particular, it helps to solve the problem of excessive high labor cost faced by the developed countries for a long term.

The enterprises have a lot of inactive and veiled information and knowledge. With the development of SIMS, all the manufacturing information and knowledge, whether active or inactive, are collected and integrated, thus to help enterprises to enhance their ability to fully master and utilize all the information and knowledge. In the era of knowledge-driven economy, the product intelligence (i.e., the knowledge contained in products) plays a crucial role in competition. Knowledge collection enables a closer interaction among different departments in the enterprise, in doing so, they could work together to focus on knowledge share, add more product content, enhance knowledge productivity and finally achieve automation of plant. Hence, the application of small intelligence system has benefits to promote the enterprise's competitiveness.

SIMS has added the "intellectualization" and "integration" into the scope of automation. SIMS possesses the abilities of auto-adaption, self-learning and self-organization. If the enterprise has no way to know about the specific and accurate information or is under an unpredictable situation, SIMS could exert self-organization ability to utilize the imprecise or fragmentary information to carry out system operations and finish product assignments. The above example indicates the high flexibility and quick response of enterprises supported by such system. Moreover, the development of mechanical intelligence could further improve intelligence of SIMS and give the system a capability of self-evolution.

SIMS is capable to have control over complex situations. Since the manufacturing system has a complex process, in which all the departments in the enterprise need to settle various issues through close cooperation, every link in this process has uncertainty. With integration of information and knowledge in SIMS, then each individual piece of information will be included into intelligence, in which way such information and knowledge have become intelligent agents. After integration of knowledge, SIMS is capable of conducting the intellectualized self-organization. The intelligent agents may determine its next step by estimating the specific environmental information and circumstances. As per the rules for completion of tasks, the intelligent agents' actions will form the complex actions of the system. The structural mending is transformed to mending of autonomic rules.

Meanwhile, by following the autonomic rules, enterprise's cooperation become easier, and the social factors' negative impacts have been reduced. In general, by using computer, SIMS simulates and extends partial human mental labor and intelligence. The small intelligence manufacturing system is highly flexible with a quick response with regard to adapting to the changeful conditions and environment. The product quality and productivity are crucial factors of competitiveness of the small and medium- sized enterprises, which can be greatly beneficial from developing the intelligent manufacturing technology and the small intelligent systems in manufacturing industry.

The intelligent systems in manufacturing industry arose in 1980s, which is the progenitor of SIMS. So far, as an indispensable part of automatic manufacturing system, the intelligent manufacturing system has attracted attention of and obtained investment by every country. The United State has regarded SIMS as the manufacturing mode in the future. One of major missions of the Automatic Manufacturing Research Foundation is to make progress in the development of intelligent manufacturing system. The

United States has many projects having connection with intelligent manufacturing, such as Computer-aided Acquisition and Logistic Support, RMCAD, TOM, DICE and ULCE. With respect to the Europe, there is a project named the Future Generation Manufacturing System (FGMS) that is associated with intelligent manufacturing system. With respect to Japan, a group of specialists have firstly proposed to carry out intelligent manufacturing system research in 1989. With the attention of all these countries, the research on the intelligent manufacturing system was booming with numerous research articles in this respect including SIMS. In the year of 1988, the first book concerning the intelligent manufacturing that is named as Manufacturing Intelligence was come out. The "Manufacturing Intelligence" contains analysis of thought of intelligent manufacturing and definition of the objectives of the intelligent manufacturing. A group of people having curiosity about research and development of manufacturing technology with high flexibility has paid a continuous attention on SIMS. At the preliminary stage for definition and exploration, SIMS is still a new idea undergoing its initial development. Both industrial specialists and academic experts of all the above countries have worked together in development of SIMS. Therefore, SIMS, being a prevailing trend in the 21st century, is significant to the competition in the global manufacturing industry.

4.2 Components of SIMS

Prior to analysis on the intelligent manufacturing system and its application problems, there is a necessity for overview of manufacturing operation mode. What are the objectives of manufacturing? In a wide sense, they are:

- Production
- Productivity
- Quality [23]

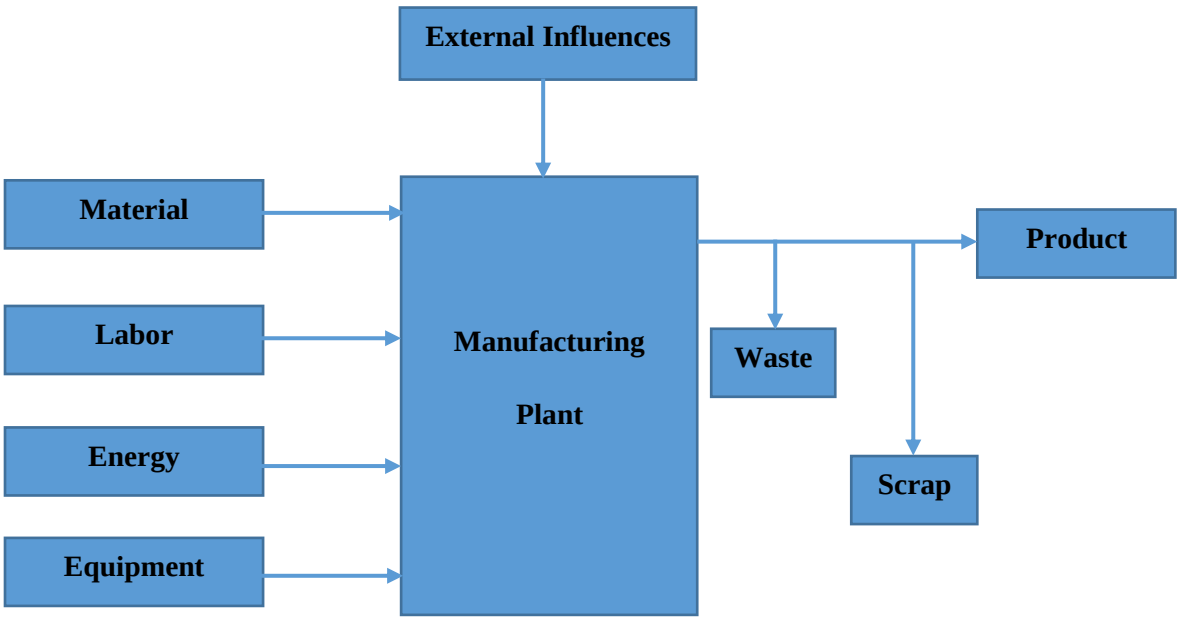


Figure 1. Objectives of manufacturing

In terms of the production cost and quality, the manufacturing system is required to meet some basic requirements:

- The enterprise's internal integrating of software and hardware systems
- Compatible design of manufacturing system to adapt the latest subsystems of hardware or software, or other alive subsystems
- High efficiency of the enterprise's internal or external communication medium and cooperation
- Personalizing human features into the manufacturing system
- Adapting to the changeful orders and internal and external manufacturing environments' sudden disturbances
- Having full tolerance both at system and subsystem levels, which allows to easily detect and recover from system fault and reduce such impact on work flow conditions [24]

The manufacturing process have complexity which could be de-compounded to some parts. We can decompose SMIS into the following components:

- Intelligent design
- Intelligent Process Planning
- Intelligent Quality Management
- Intelligent Maintenance and diagnosis
- Intelligent Scheduling
- Intelligent control [25]

We make slight modification to the de-compounding so as to reflect the current process division of SIMS indicating in the Figure 2. Each individual link is to be briefly introduced here, after which, the operation and function of SIMS in each link will be presented.

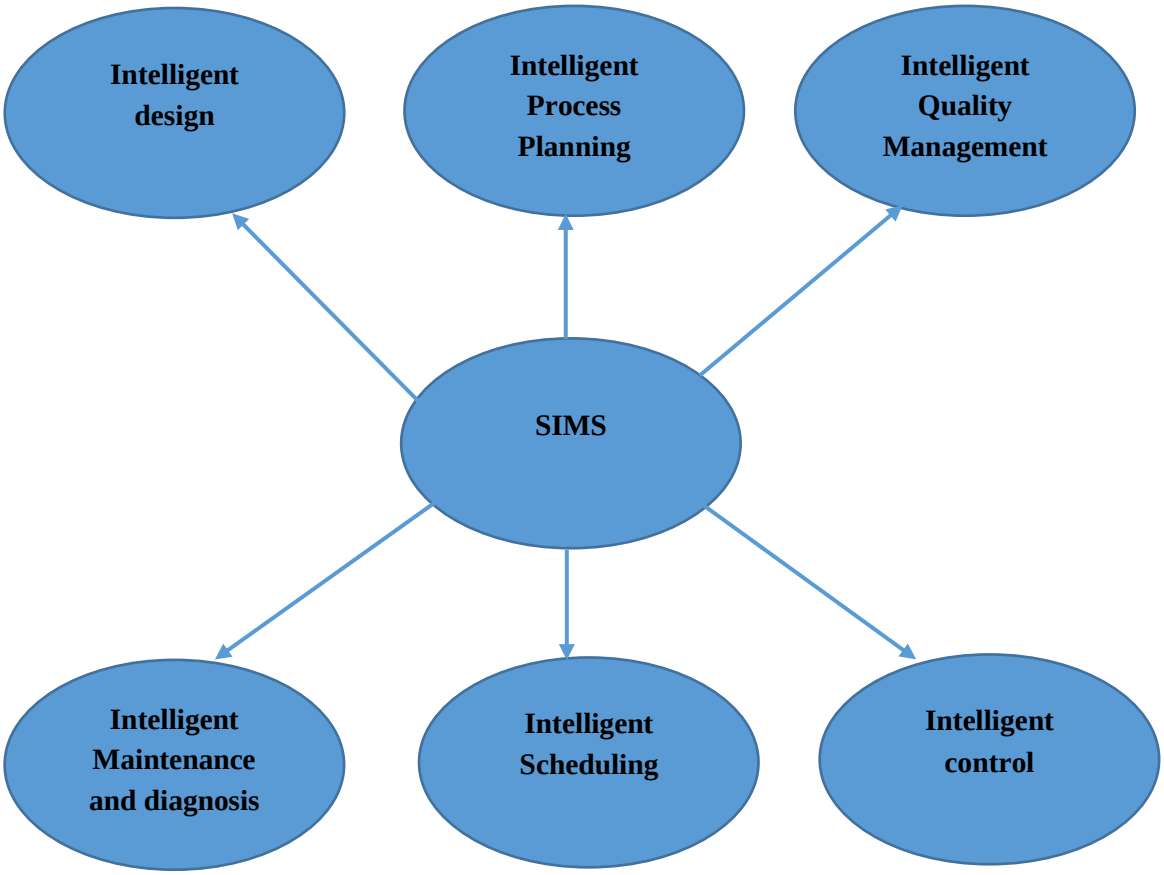


Figure 2. Components of SIMS

- Intelligent design

  The importance of product design is undeniable. A firm's products or services are typically the primary source and focus of contact with its customers, and the development of new designs plays a key role in establishing and maintaining a competitive position for most firms. There are many problems in design manufacturing systems. In this paper, process design is also included in intelligent design [26].

- Intelligent process planning

  Being a complicated and dynamic activity, the intelligent process planning specifically describes manufacturing abilities and demands concerning transformation of the raw material into one finished product [27]. Intelligent process programming is divided into device, Computer-Aided Process Planning (CAPP) and location layout. The Computer-Aided Manufacturing (CAM) and Computer-Aided Design (CAD) are connected through the interface of process programming. Computer-Aided Process Planning is crucial for realizing the final objective of fully integrated plant in the future. Computer-Aided Process Planning system possesses numerous information and knowledge, including best practices regarding arrangement of machine running and machine workshop's specific conditions. Since the efficient inventory management is vital to manufacturing process in which link the changeful conditions and environment needs to be dealt with by utilizing complicated methods, the inventory management also needs to be taken into account. There are

plenty of research articles regarding theoretical individual inventory models, however, the application falls far behind development. SIMS is significant to help implementers to apply such models as well as to solve numerous issues connected with large-scale inventories management.

- Intelligent quality management

  Quality management has gradually evolved from inspection in which quality control techniques such as statistical process control (SPC) were applied, and developed from quality assurance to the current total quality management (TQM) [28]. To guarantee product quality and stable market, the enterprises gradually allow customers to participate in the initial phase of design. Quality could be guaranteed though two methods: active and reactive quality guaranty. The reactive approach adopts sampling plan, batch acceptance confirmation, analysis on obsolescence or rework. Proactive approach utilizes experience, objective causality knowledge, risk analysis and determination.

- Intelligent maintenance and diagnosis

  The failure diagnosis is for the purpose of detecting failure and causes in a promptly manner, to avoid such failure expanding from partial to the whole system. In terms of failure detection, such failure is classified into three types: the component failure, sensor failure, and actuator failure. In terms of failure diagnosis, the first step is the detection of failure, and provision of information regarding size and source. The fault diagnosis can be divided into three steps: signal generation, failure classification and assessment, as well as failure analysis [29].

  The basic components in the operation of manufacturing are management and planning of maintenance. As a significant factor for management of maintenance, the scheduling preventive maintenance is a great challenge to the large and complicated system equipped with thousands of parts. In the market, many business software packages are available to be used to improve maintenance management. But these software packages are applicable with limitation because they were commonly designed for particular purposes.

- Intelligent scheduling

  With restrictions on allocation and sequencing, scheduling is a process to distribute resource which is for optimizing purpose. Through allocating the limited given quantity of resources to certain tasks to optimize cost functions.

- Intelligent control

  Control is for the purpose of offering the proper input signals to an applicable process to generate the demanded action. The complexity in the control process lies in its requirements for uninterrupted human intelligence to guarantee appropriate running.

4.3 Properties of SIMS

SIMS has the following characteristics:

- Adaptation is one of the most essential characteristics of SIMS. They are capable of adapting to conditions and environment without affecting the manufacturing goals.

- Self-maintenance is a significant factor of the SIMS. The system is capable of inspecting faults and correcting without human's guide (as far as possible). In this respect, they can be reconfigured.

- Communication is indispensable for the SIMS, because it is the sole method to create cooperation between components. The system may generate reports, directly command certain components, and coordinate with other systems for certain activities.

- Autonomy indicates SIMS ' independence level, and such level will be restricted where there is no intelligent behavior.

- Learning is the ability of the systems for the purpose of improving their knowledge, provided that such information and knowledge are kept in information and knowledge base. Such ability is regarded as one of the essential characteristics of the SIMS.

- Self-improvement shows that SIMS has the ability to evolve by itself in a timely manner, which could by realized by learning information or updating information to information and knowledge base. Such ability would be activated by inspecting existing information and assessing their usage situations.

- Estimation ability enables SIMS to estimate the variation and their potential impacts on the systems.

- The ability of pursuing goals is to set goals, divide or update existing system capabilities based on system progress and tasks. The expected goals could be realized by breaking down such goal into some detailed targets which is easier to be executed.

- Creativity is also a new feature of SIMS. These systems are able to generate new work rules, concepts, estimation, and so on, which require interaction between human and other sectors at a relatively high autonomy level.

- Replication means the generation or reuse of system components as needed. SIMS offers equipment to be used for same system concurrently in various locations [30].

In the same way, the following attributes can be the main characteristics of intelligent agents, which were regarded as benchmarks in the intelligent manufacturing environment.

- Autonomy: no human direct intervention to operations, which means the system could control over its behavior and internal status.

- Social Competence: use the specific communication languages to interact with others (maybe human beings).

- Reactivity: make quick response to variation, which comes true via being aware of various situations.

- Pro-activeness: take the initiative to show goal-oriented behavior.

4.4 Tools and technologies for SIMS

Following are the tools generally used in SIMS:

- Neural Net Works
- Case tools
- Simulation Algorithms
- Fuzzy logic
- Genetic Algorithms
- Simulation Algorithms
- Artificial Intelligence (AI)

Here it the specific description of each one:

- Neural Network Scheduling

  The objective of Artificial Neural Networks is to build modeling for real neurons networks which are driven by biological brains' flexibility, failure tolerance, robustness, and their learning capability. In additional, the Artificial Neural Networks' building blocks, such as processing factors, neurons and other element are extremely similar to their corresponding biological counterparts.

  Interactive approaches of short-term scheduling bearing system functions and graphical interfaces allow the operators to control the planning making in an interactive way and view the impact of major parameters. This knowledge-based system can effectively respond to emergencies or delays. Neural network technology plays an important role in fixing inconsistent plans to achieve consistent or optimal progress.

- Case - Based Reasoning

This is widely applied as an instrument for explaining the process parameters. Human specialists need to be asked to analyze process results, this gives the specialists' system a change to promote the program. Case-based reasoning refers to knowledge as a case, an example of a problem and a solution that has been encountered in the past.

- Intelligent Design and Analysis Software

  The expert system generates the best parameters subject to all the machine or material restrictions. This is CBR' extension (based on case-based reasoning).

- Fuzzy Logic

The fuzzy logic system provides a method of expressing language variables in appropriate forms of computer fuzzy logic control processing, providing the flexibility to directly describe the state of the process and the control action from the human operator's experience and recommendations. The application of the actual operation experience in the computer control of the variable process. It has a mathematical framework for obtaining uncertainties associated with human cognitive systems such as thinking and reasoning. Control rules are defined to relate to each word, such as high school, low language expression.

- Genetic Algorithms

  GA is a powerful probabilistic heuristic process based on global search and optimization in natural genetic mufti-parameter search space. It uses historical information to locate new points in the search space and improve the performance.

  This is also used as a tool for optimal assembly planning. Adaptive genetic algorithm is based on the natural selection and survival concept of survival. In simple terms, genetic algorithms generate new rules to replace the least useful rules that already exist. These software tools allow users to solve complex issues such as scheduling a large number of conflicting tasks, finding shortest routes connecting multiple locations, or simplifying communication networks. Genetic algorithms are used to optimize the search procedures used in assembly planning to improve the assembly process of mechanical products, thereby minimizing time and cost.

- Artificial Intelligence

  This tool attempts to increase the number of human features, computer and computer control systems. Its principle is to imitate human wisdom. The sub-tool used is: the algorithm is a computer program that can solve the selected problem within a given time. Early visual computers can allow the system to perform calculations by providing low-level data. A higher level of visual computer, allowing the system to achieve higher levels of computing, for example, can identify and reason the target. Knowledge engineering, knowledge comes from experts [31].

4.5 Implementation of SIMS

The proposed design methods for SIMS suggest to build SIMS with open and modular structure, in order to apply many kinds of knowledge presentation methods and to integrate various information processing schemes in the reasoning link, and also to apply some learning approaches. SIMS shall integrate the following modeling with modern knowledge and decision making process:

- Fuzzy logic – technologies and approaches including natural language formalizing, fuzzification, linguistic knowledge and quality information processing.

- Artificial neural networks – Artificial intelligence's most captivating tool, which is able to build modelling for the most complicated functions while have the learning ability in humans' brain to certain extent.

- Genetic algorithms and methods for evolutionary modeling – algorithms on the basis of achievements in evolution theory, which have enriched the aforesaid artificial intelligence techniques [32].

In the process of combining these approaches where the information is expressed in a symbolical way with the traditional specialists' knowledge would provide the possibility to innovate a complicated programmatic system for settling decision-making problems in every link of enterprise's running.

SIMS ' structure is composed of the subsystems and modules as below:

- Modules commonly used in intelligent system structure
  - Inference Engine
  - Explanation Engine
  - User's Interface (graphical or command lines; recommend to use natural language understanding functionality)
  - Databases and knowledge base
  - Knowledge Acquisition Module
- Intelligent technologies' subsystems
  - Specialist's subsystem (e.g. Specialist System Shell)
  - Genetic Algorithms Module (e.g. Genetic Library)
  - Neural Networks Subsystem (e.g. Neuro Solutions or Statistical Neural Networks)
  - Fuzzy Logic Subsystem
  - AI Technologies Integration module
- Domain-oriented Information Systems
  - Management Information System (MIS)
  - Computer Aided Design System (CAD)
  - Computer Aided Process Planning System (CAPP)
  - Computer Aided Quality Management System (CAQM)
  - Management Support System (MSS)
- Problem Analysis Module

- Problem Simulation Module
- Monitoring Module

- Decision selection and assessment subsystem. This subsystem includes the analyzing procedures verified in practice and problem settling probabilistic methods that is proved to be useful in some applications.
- Communication subsystem. Based on computer network technologies and Internet infrastructure, this subsystem can obtain information from external sources [33].

There are several ways to achieve SIMS:

- Existing manufacturing process is to be smarter through taking full use of monitoring and controlling manufacturing conditions.
- The current processes will become smarter through increasing sensor to manage and supervise the product's conditions.
- In order to meet the ideal quality of parts, we can use the latest processes of intelligent designing.
- Using the completely automated technologies to reduce the use of human labor.
- Automatic processes bearing automatic response mechanism
- The manufacturing processes' automatic monitoring and control
- Self-supervision and managing of the process status [34]

The steps for implementation in SIMS including:

- Choose an existing software which can improve the specialist system and then combine with the software for solving tasks.
- Collecting business value, heuristic strategies, precedent experience also requires advice from books, experts and standards
- Generate a checklist for properties and other parts of the property that are required in setting rules.
- Generate meaningful data and information by withdrawing the feature of the part from the object's model information and other necessary attributes.
- Rules that lead this task are classified as repositories.
- Implement the reasoning system as an analytical mechanism to understand the knowledge base and supporting data solutions.
- Combine the conclusions into the modelling while using its examples to figure out a solution [35].

4.6 Execution of SIMS for small manufacturing enterprises

The requirements towards SIMS for small manufacturing companies is as follows:

- Collect and process different kinds of information from all sources, to obtain and simulate the information needed for decision-making in the business decision-making process. Meanwhile, the knowledge-based modeling and processing of the human mental labor are also necessary.

- In the decision making process, the subjective evaluation of the decision maker according to his own knowledge and experience needs to be considered in SIMS.

- There should have modern artificial intelligence technology and the possibility of preliminary information processing and information analysis methods.

- Have the potential to detect emergencies and dangerous situations and respond quickly to them. In the production system or its surrounding emergency, there must be real-time data analysis possibilities.

- The possibility of complex and comprehensive decision-making issues is allowed in strategic management support.

- Both in the surroundings and inside of the enterprise, the lack of stability and change dynamics shall be considered. The SIMS in the design phase, is able to learn from knowledge and experience, and adapt to changeful working conditions.

SIMS specific implementation plan for small manufacturing enterprises:

- In the enterprise strategic level, to establish information and industrialization of integrated management system to promote industrial Internet, cloud computing, large data integrated application of the whole process and the entire industry chain, including R & D design, manufacturing, management, sales and service and etc., Fully deepen the concept of strategic model process and the application of ERP systems, and ultimately the entire industry chain as a whole intelligent and internalization.

- From the information system construction, we should actively build based on Internet + information and communication technology integration of enterprise network physical system, but also to build advanced manufacturing technology, industrial software, and with the monitoring and control equipment processing equipment. Besides, we must strengthen the customer relationship management and supply chain management system to promote the application, speed up product life cycle management, enhance the Group management control, design and manufacturing, production and supply marketing integration, connecting business and finance, in order to achieve intelligent Management and control.

- In the respect of research and development, to explore how to use internet, mobile internet, 3D display, mobile O2O and other advanced technologies to build users aggregation platform, to collect users' individualized requirements, to realize collaborative sharing between enterprises'

internal designers and researchers and those from other external parties all over the world, as well as to reduce enterprises' innovation costs by means of crowdsourcing design and research and cloud manufacturing.

- In the respect of the intellectualized reconstruction of equipment, to accelerate application of the intelligent human-machine interaction, industrial robot, intelligent logistics management, additive manufacturing and other technologies and equipment in production process, to improve and upgrade the numerical control function, numerical control rate, interconnection rate of the various existing traditional machining tools and production lines, to promote interconnection between different production equipment and between equipment and products, and to build the automatic workshop.

- In the respect of capital investment, to break the mindset of attaching much weight to hardware while making light of software, to largely increase the enterprises' capital budget in the functional aspects, such as research, consulting, training, planning, implementation, supervision and after-sale services and etc.

- In the respect of talent team building, to provide the middle and high-level management and business backbones with continuous trainings for various specialized knowledge, including the special topic of intelligent manufacturing, and to carry out management by linking training and examination result with performance, rewards and punishment and development of the trainees, in order to build a talent team with good qualifications and reasonable structure in manufacturing industry.

- In the respect of industrial cooperation, the small manufacturing enterprises need to actively build cloud services platform and intelligent manufacturing industry alliance serving the peripheral regions and large-scale enterprise groups, to promote the intelligent equipment and product research and development, system integration, innovation and industrialization, for the purpose of achieving the collaboration among different enterprises with regards to various production and operation links, including product design, manufacturing, sales, management and etc., and forming a web-based enterprise cluster [36].

4.7 Challenges and trends of SIMS

Showing from the current research and analysis of SIMS, the major difficulties we have faced currently are sum up as below:

- Outsourcing

- Specialization, and emphasis putting on an on-core competitiveness

- Vertical structures' transition to the horizontal structures such as management systems, and transition from high centralization to decentralization (e.g., improve the individual element by is with decision making/ intelligence abilities)

- Self-adaptation evolution usually at low levels. Bearing these features, the manufacturing systems are highly integrated, adaptable, convenient for upgrading and evolution (e.g., when the market conditions were changed) Adequate equipment and machines (e.g., sensors) adequate to new manufacturing paradigms

- To develop new technologies and applications which is available to support all demands as required by manufacturing systems

- Competitiveness: the enterprises shall be competitive, e.g., the relation between costs (e.g., investment funds) and benefits

- Sufficient device and machines (e.g., sensors) enough for the new manufacturing model

- Sustainable development (e.g., taking the environmental issues into consideration for design)

- Selection of proper technology, device and manufacturing systems (e.g., to estimate specifications of different systems according to the quality, system reliability and life cycle)

- Human-machine integration; non-functional features, e.g., failure tolerance

- To be self-adaptable and open; the manufacturing system's individual unit or subunit shall adopt the best determination independently in respect of incorporating scheduling algorithms, resource utilization, planning and control execution techniques), which behave in an objective-motivated and cooperative manner

- Performance assessment [37]

Development and trend of SIMS:

- Artificial Intelligence Technology

  IMS aims at using the intelligent activities of human experts in computer simulation manufacturing industry to replace or extend partial of human mental labor, which makes the artificial intelligence technology one of the crucial technologies for IMS. IMS is closely associated with the artificial intelligence technology (expert system, artificial neural network and fuzzy logic).

- Concurrent Engineering

  With respect to manufacturing industry, the concurrent engineering is an important kind of technological methodology applying in IMS, which helps to reduce blindness and repeatability of product design to the maximum extent.

- Information Network Technology

  Information network technology supports systematization of manufacturing process and the "intelligent integration" of all the links. Meanwhile, it also provides channels for circulation of manufacturing information and knowledge.

- Virtual Manufacturing Technology

  The virtual manufacturing technology is capable of simulating the whole life period of product in its design phase, so that production could be organized in a more efficient, economic and flexible manner, and product could be developed with the shortest development cycle, the lowest cost and the best quality. Furthermore, the virtual manufacturing technology is also a prerequisite for achieving the concurrent engineering.

- Building of Self-Discipline Ability

  which means the ability to collect and understand the environmental information and its own information, analyze, determine and plan its own behavior. The self-discipline ability is based on a strong knowledge base and the knowledge-based models.

- Human-Machine Integrative System

  The intelligent manufacturing system is not only the "artificial intelligence system", but also the human-machine integrative system, which means it's a hybrid intelligence system. Currently, it's unrealistic to fully replace intelligence of human experts in manufacturing process with artificial intelligence and use artificial intelligence to independently analyze, estimate, and determine and undertake other tasks. The human-machine integrative system highlights human's core position in manufacturing system, based on which to better develop human potential in cooperation with intelligent machine, in order to achieve mutual collaboration and coequal joint work, and procure both human and machine to fully exploit their respective advantages and build a complementary relation.

- Self-Organization and Extra-Flexibility

  The various component units in the intelligent manufacturing system are able to form the best structure on their own depending on requirements of work tasks, which shows their flexibility not only in operation mode, but also in structure mode. Therefore, this kind of flexibility is given a name as extra-flexibility, and is similar to characteristics of organism, which just like a group of human experts are putting together as a whole.

Based on this concept, the SIMS method was created, which is based on the combination of well-known artificial intelligence techniques and simulation modeling methods in the decision-making theory. The proposed method will provide the possibility of establishing an open architecture SIMS, and combine the original information system with the subsystem in respect of the production engineering with the artificial intelligence technology to create a comprehensive environment for the decision-making problem in the intelligent manufacturing system [31].

SIMS, as is an up-and-coming manufacturing system, with a goal to target further automation, integrating, optimizing of manufacturing in the future. The data intelligent processing helps to integrate data and make the right strategic analysis. Through analyzing, diagnosing and reporting, the assessment of the actual circumstance can be made at all operation stages. In the near future, SIMS enables companies to operate efficiently and reliably in the global market while meeting their ever-increasing demands.

5 Transformation of existing workshop to SIMS workshop

5.1 Existing workshop in UiT Narvik

The workshop of master industrial engineering department is the main target of this project. This part will first assess and analyze the existing worshop, after that the existing workshop will be transformed to a SIMS workshop based on the research study of SIMS.

The existing workshop for the master industrial engineering department covers an area of about 200 m^2, being a workshop specialized in the intelligent machining, robot applications and new technology development, it's one of the important R&D centers for intelligent machinery manufacturing in northern region of Norway.

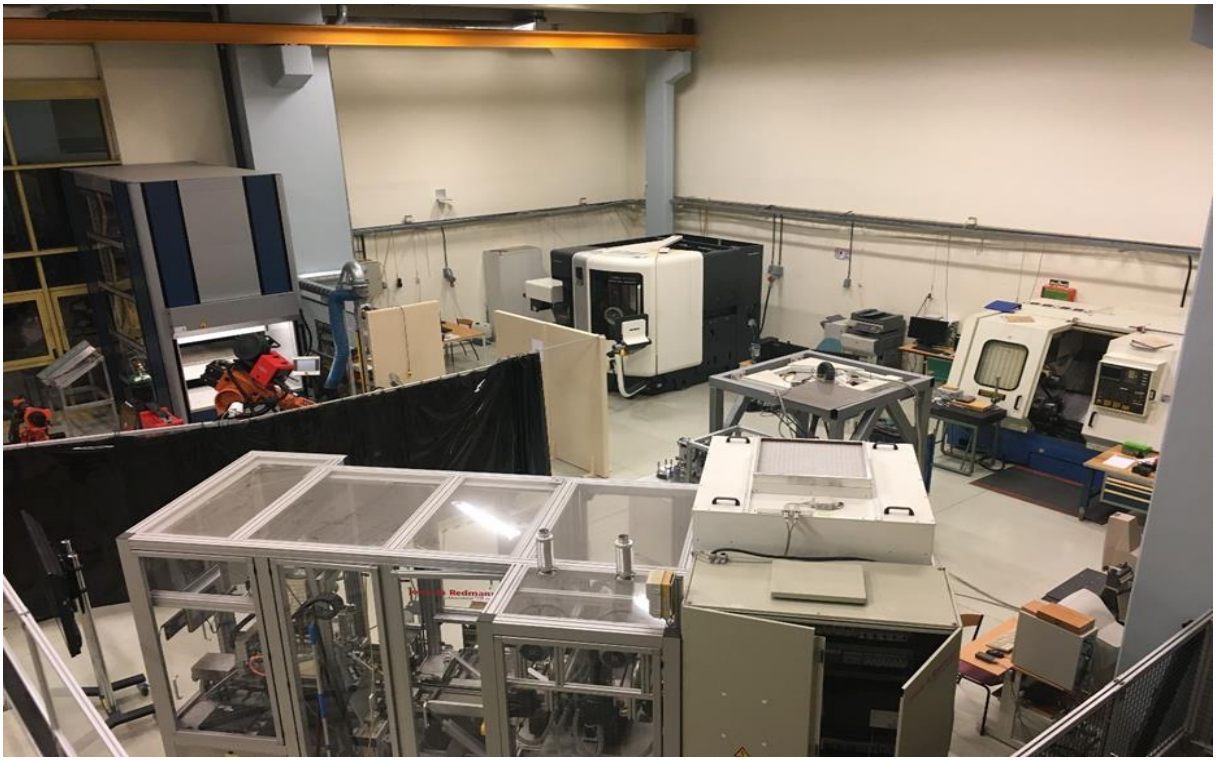


Figure 3. Existing workshop of master industrial engineering department in UiT Narvik

The main equipment in the workshop includes:

- Equipment applied for simulation and optimization of processing technology
- Two Kuka robot arms
- ABB Parallel robot
- CNC milling machine
- CNC Turning machine

Figure 4. Equipment applied for simulation and optimization of processing technology

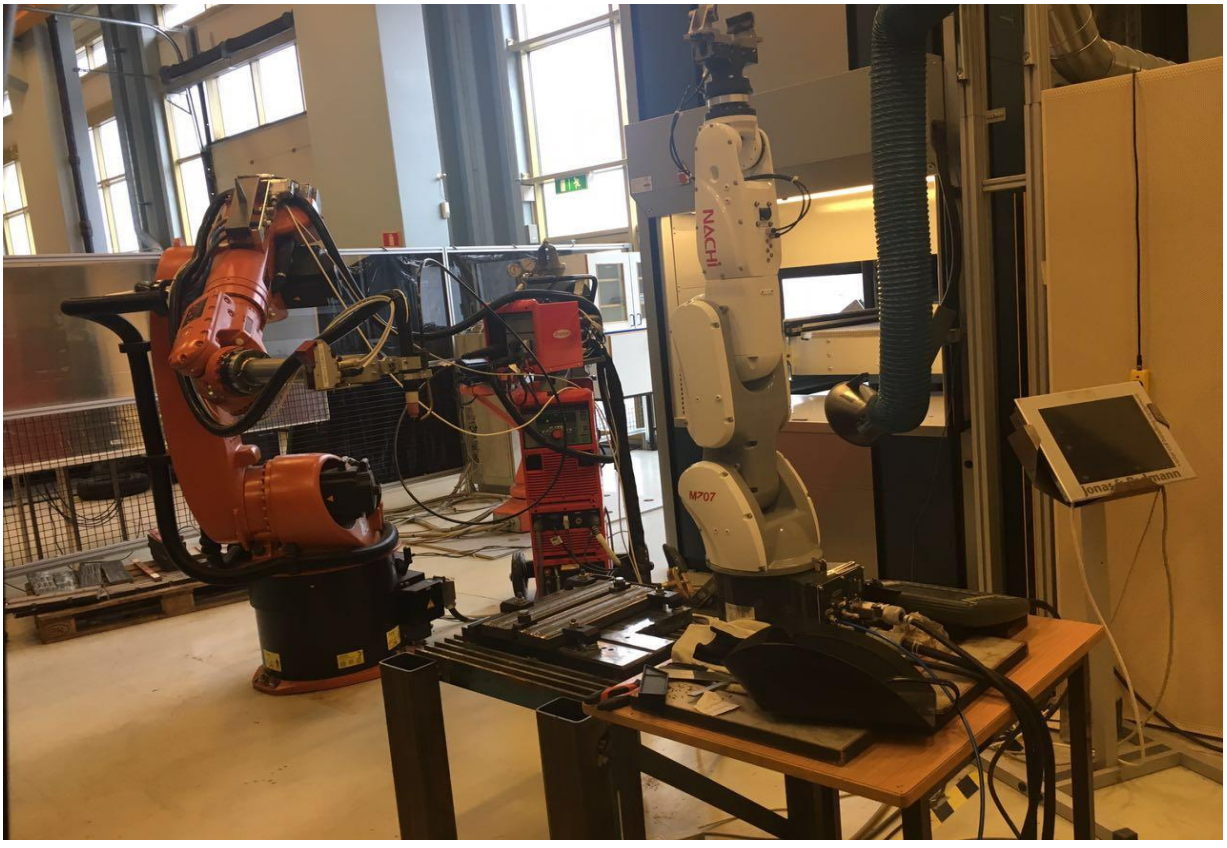


Figure 5. Two Kuka robot arms

Figure 6. ABB parallel robot

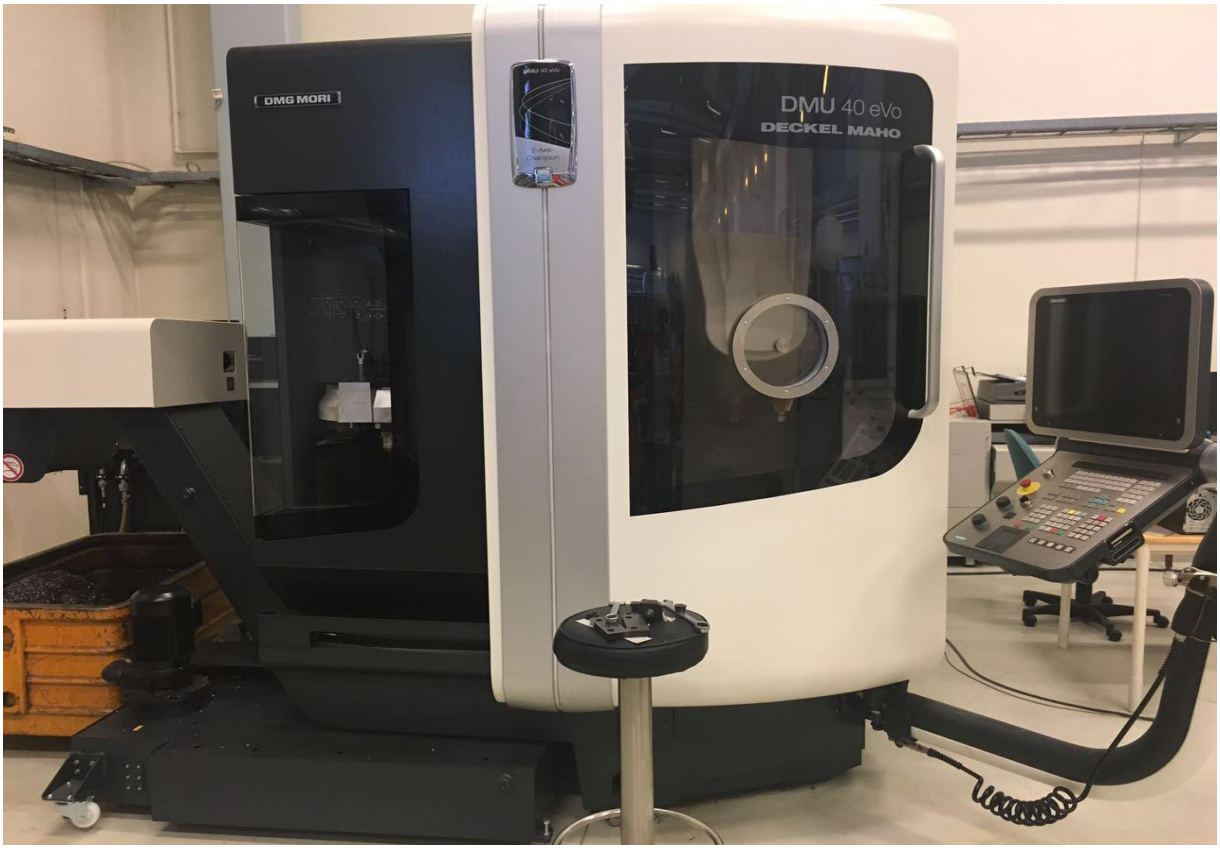


Figure 7. CNC milling machine

Figure 8. CNC turning machine

5.2 Suggested lay out design for transformation

The existing experimental equipment is relatively advanced equipment with high technology content and excellent performance, but all of which are individual equipment, therefore, the problems include: how to transform the existing workshop to a SIMS workshop, how to make better use of the existing equipment, how to connect equipment to other equipment in a way which enable them to be more automated, intelligent, and play the overall effect better.

Based on the analysis on the current status of workshop and equipment assessment, a solution has worked out by integrating the research study of SIMS with technology applications, for which the suggested lay out design for transformation is as below:

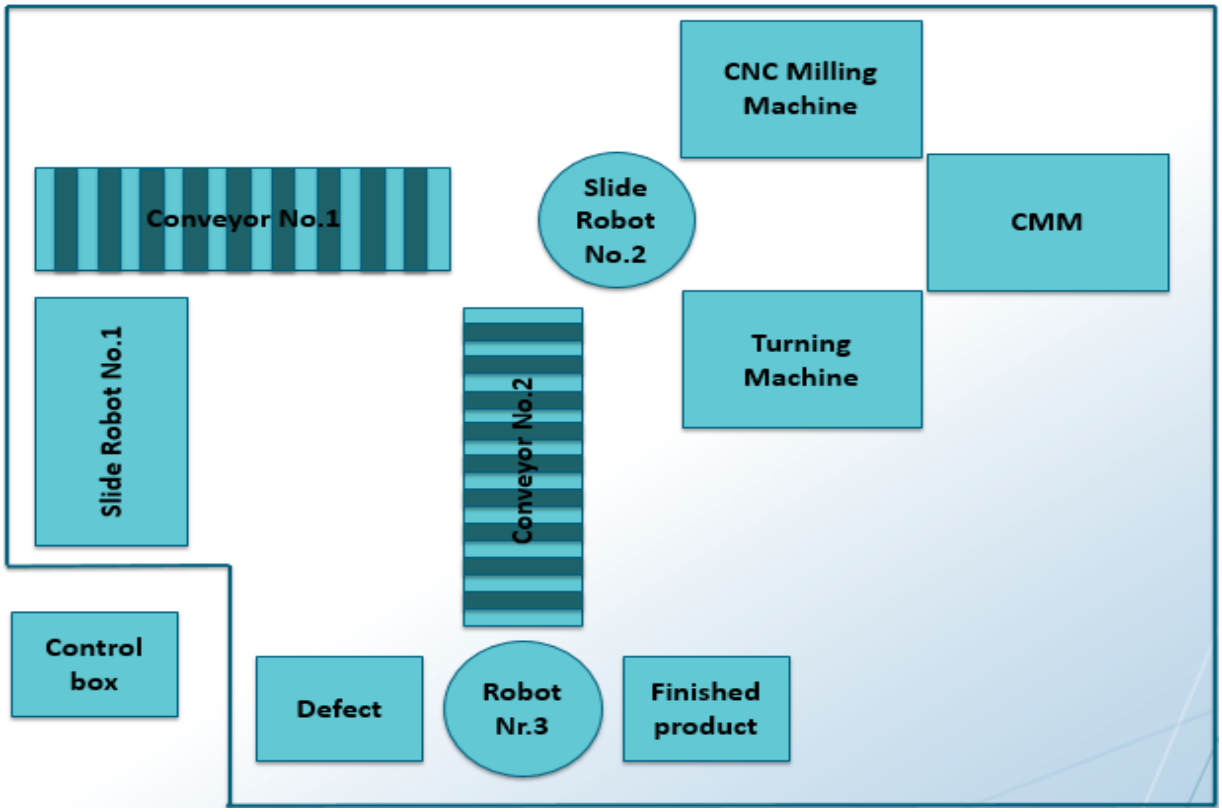


Figure 9. Suggested lay out design for transformation

Upon completion of transformation, the SIMS workshop is mainly composed of the following equipment:

- Two Kuka slide robots
- Two conveyors
- One Kuka robot arm
- One CNC milling machine
- One CNC turning machine
- One CMM (Coordinate Measuring Machine)
- One general control box

There are three equipment in the existing workshop which could be integrated into the SIMS workshop:

- Two Kuka robot arms (one of which will be transformed to slide robot)
- CNC milling machine
- CNC turning machine

5.3 Flow chart

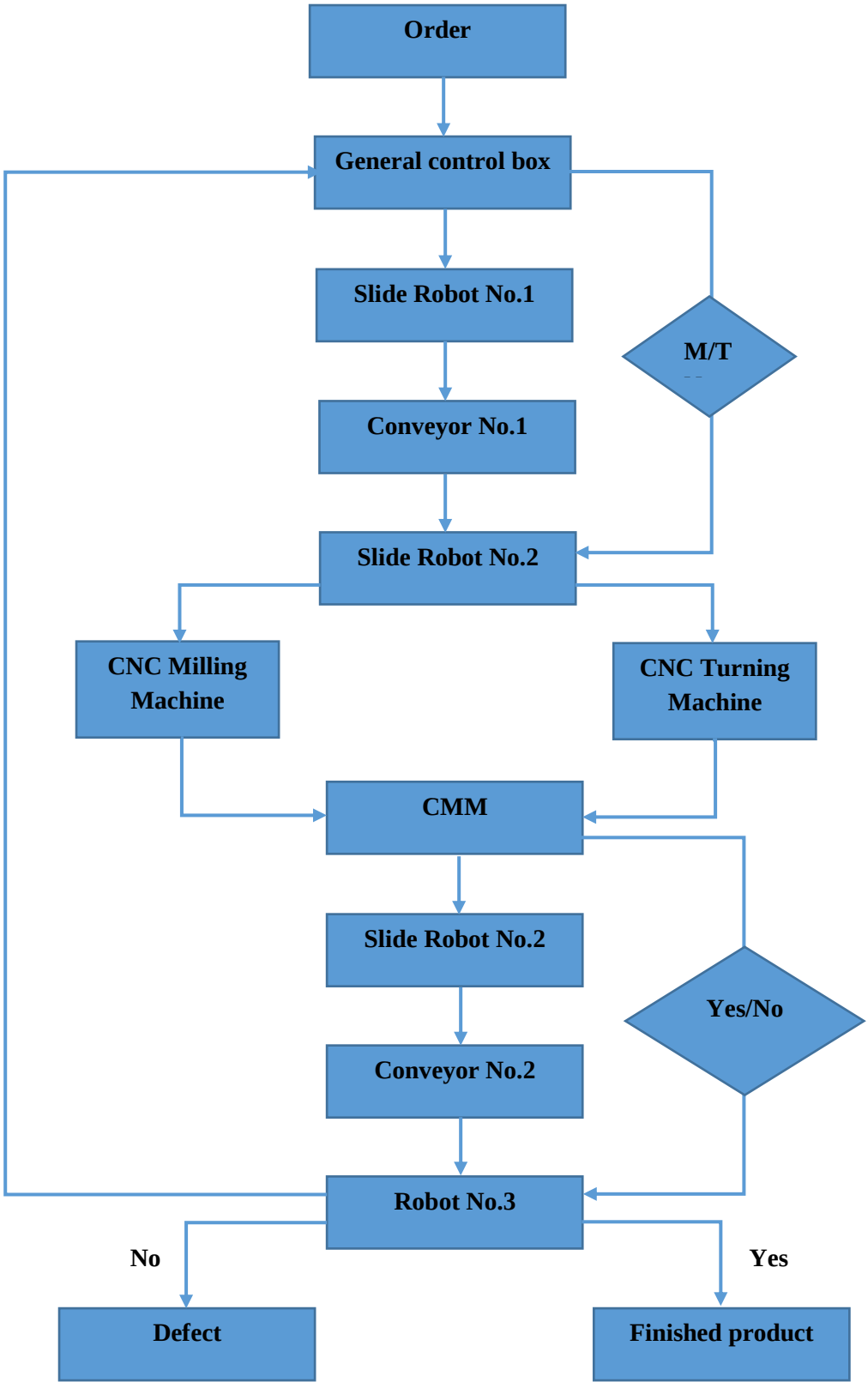


Figure 10. Flow chart of SIMS workshop

5.4 Executive process

After completion of transformation, SIMS workshop will form a fully automated intelligent manufacturing pipelining from the raw materials throughout to the finished products. SIMS workshop is mainly used for manufcturing of the small metal parts, which prosseses high flexibility, high efficiency, stable processing accuracy and capability of processing complex surface, and is able to make a quick response to user needs, hence, the existing workshop's functions and processing capacity have been greatly improved.

Operation steps:

- Order

  The customer places order for products, put forward quality and quantity requirements, and agrees on delivery date.

- General control box

  - According to the requirements of customer orders, the technical staffs to write G-code for processing parts
  - Enter product information into control box (such as G-code, quantity, and artifact quality standards...)
  - According to the quantity of orders, to purchase the raw materials, and put such raw materials on the designated location on raw material shelf in the workshop.
  - At the same time, General control box issues a directive to Slide Robot No.2 and select CNC milling machine/ turning machine according to the work piece processing requirements.
  - General control box is the general control system, with which all the equipment within the workshop can be controlled.

- Slide Robot No.1

  After General control box has issued the command for starting operation, grab the raw material on the shelf and put it on Conveyor No.1.

- Conveyor No.1

  Deliver the raw material to Slide Robot No.2

- Slide Robot No.2

  According to the command issued by the General control box, catch the raw material, and choose to put it into the CNC milling machine or the turning machine.

- CNC milling machine/Turning machine

According to G-code, process the raw materials, and after manufacturing process has been completed, send a signal to Slide Robot No.2.

- CMM

  - Slide Robot No.2 take out the finished work piece from the CNC milling machine / turning machine and place it in the CMM.

  - Inspect the work piece according to the product quality requirements in the General control box

  - According to the results of the test, send command to the Robot No.3, if the work piece meets the quality standards, send yes, if not, send no.

  - After the inspection has completed, send the signal to Slide Robot No.2

- Slide Robot No.2

  Grab the inspected work piece in the CMM and place it on Conveyor No.2

- Conveyor No.2

  Deliver the work piece to Robot No.3

- Robot No.3

  - Grab the work piece on Conveyor No.2 and place into Finished product / Defect according to the command of yes/no sent by CMM

  - Send a signal to the General control box and start to process the next work piece

5.5 Visual Components

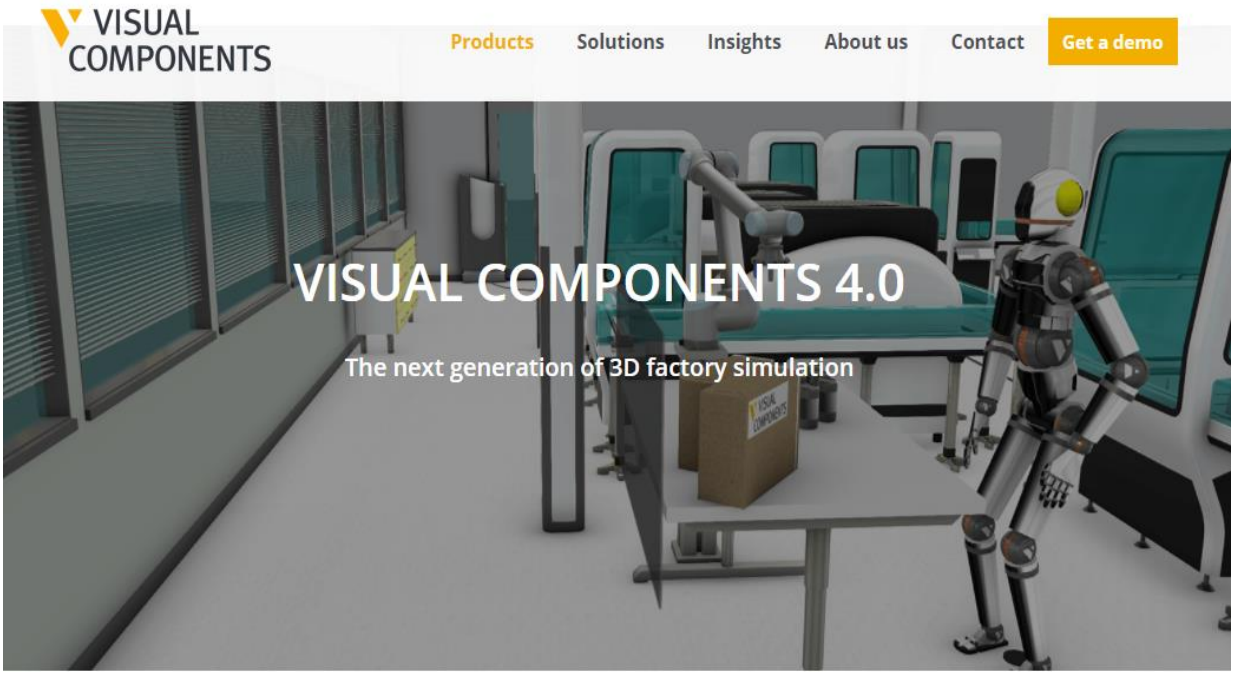


Figure 11. Visual Components

Visual Components is a commercial software relating to 3D discrete event simulation that allows to simulate the robotics and material flow on one platform. Its extended functionality includes off-line programming ability and PLC connectivity. The product family of the Visual Components compose five software variants. Such simulation software can be utilized to plan and optimize the layouts of factory and production line, which is often applied by manufacturing enterprises, machinery builders and system integrators. The two major applications of which include visualization and simulation of production lines.

- Visualization

  Visualization is to be used in each phase of production line design, whether in the early designing phases, or rearrangement phase or modification of the existing line, or when there is no need of hard data for describing a concept. At this stage, with no demand for a detailed layout of production line, the goal is to provide a sketchy idea for visualizing the structure of production line. Visualization could be combined by using the software regarding existing component library.

- Simulation

  The simulation aims to generate a precise virtual production line with all functions. All the parts simulate to be closest to real one. Simulation generation allows technicians to conduct studies on feasibility and collision detection, in doing so, to test and inspect the performance and efficiency of production line in a statistic manner prior to the completion of building.

- Main Features

- Robot brand independence
- Components library
- Drag and drop user interface
- CAD Import
- 3D PDF and video export [38]

Visual Component defines simulation as the production of data and visualization as the representation of data. While 3D visualization technology makes all of the elements look real, simulation technology makes them function as if they were real.

- Achieving real-world accuracy through simulation

  Simulation technology allows program to produce data. In the context of manufacturing, this data helps Visual Component to replicate and reproduce real-world operations of each of the elements present in a production line.

  The data Visual Component obtain through simulation can also help program establish correlations between the resources and their yield, both individually and collectively. Moreover, Visual Component can test different combinations and interaction scenarios in the virtual world first.

- Simplifying data through visualization

  Visualization technology allows Visual Component to represent visually the data that program obtain through simulation. Instead of racking user's brains trying to process raw simulation data, with this technology user can simplify complex information and turn it into a friendly 2D drawing, graph, high-quality picture, or even a 3D animation.

  By providing numerical data in an easy-to-understand format, visualization allows everyone – regardless if they have a technical background – to interpret and analyze data efficiently. This in turn helps to speed up workflows and facilitates communication.

- The power of simulation & visualization technologies combined

  Visual Components' 3D manufacturing simulation and visualization software uses both technologies to offer a complete solution that helps user to create marketing-grade content with engineering-grade accuracy. Thanks to its simplicity, high-level of precision, and ability to export project-ready deliverables – manufacturing professionals everywhere now have the power to design and communicate manufacturing solutions to teams, clients, and stakeholders [39].

There are a lot of software for simulation of production line in the intelligent mechanical manufacturing workshop, but after searching and comparing, it is found that Visual Components is one of the best and most advanced software currently.

Through the study and research of Visual Components, the visualization of SIMS workshop is built. The visualization enables a more intuitive understanding of structure of SIMS workshop and equipment placement, and 3D manufacturing simulation enables a better understand of the entire processing system from the raw materials directly to the finishing product in SIMS workshop. But, because the limited project schedule, the simulation part has not yet completed.

Figure 12. The visualization of SIMS workshop No.1

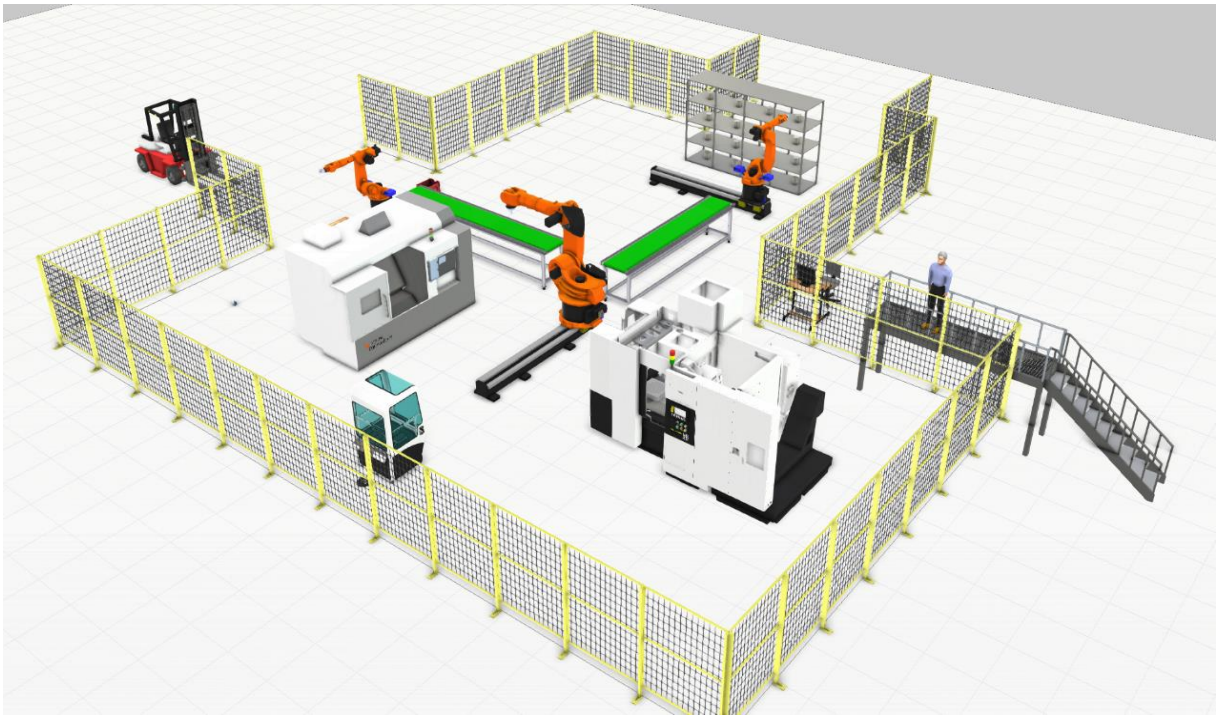


Figure 13. The visualization of SIMS workshop No.2

5.6 General control system

SIMS workshop consists of many devices, and each device has its own separate control system, therefore, how to integrate the control system of each individual device to form a new general control system is a large challenge.

From the current stage of technological development and system software market, workshop general control system technology has been achieved, which could be provided by some companies, such as Siemens PLM Software and I-Plant system from B & P Automation Dynamics Ltd. But the aforesaid two systems both have one request, that is, all the equipment in workshop needs to be products from their own companies.

Seeing from the actual situation, to replace all the equipment in the workshop needs a lot of money. And besides, the equipment in the existing workshop cannot be fully utilized, and cannot be integrated into the new SIMS workshop, which is not a transformation, but a whole replacement.

From the small manufacturing enterprise's point of view, to transform from a traditional manufacturing enterprise to an intelligent manufacturing enterprise, it is necessary to integrate and make planning for the existing equipment, purchase the new equipment in a proper quantity, in order to complete the transformation and establishment of the SIMS workshop, rather than purchase the whole set of new systems and new equipment, which will greatly increase the enterprise's capital investment and product manufacturing costs.

Overall, on the basis of making full use of the existing equipment, the best way is to complete the transformation of SIMS workshop is to work out their own general control system, which means to create a general control system for connecting and operating of all equipment according to the actual situation of the existing equipment and the new equipment.

General control system includes communication, development and design of automatic numerical control production equipment, production line intelligent control core, human-computer interaction, robot control and communication, auxiliary control and execution unit.

Through using the communication module of automation numerical control production equipment, all the equipment in production line can achieve communication connection, and the production information and machine status have been collected by the information processing module in control core of production line. Intelligent core analysis module and decision-making, according to the information obtained by the machine and system settings information, arranges the production process automatically in an optimized way, and using the robot communication module interface to issue command to robot, so as to complete the production control of the entire production line. In the event of a failure or abnormality, the control center can send control commands to a single production equipment to complete shutdown, alarm or other commands.

The information regarding product process, production, maintenance, shutdown and other information of each machine is collected and fed back to the central control system, and input into the center database, based on which the comprehensive analysis, comparison, calculation and display are conducted, so as to achieve the purpose of monitoring.

Download the machine's processing parameters, optimization procedures, maintenance schedules, production index, duty scheduling and other control commands and programs from the integrated control system to each equipment, to optimize the scheduling and distribution, coordination and control, and in order to optimize control and operation of the entire production line.

It can be specifically divided into the following functions:

- Unified management and monitoring of all the control systems of equipment by connecting them together
- Establish monitoring database for product quality
- Collect/take sample of process data/quality monitoring data/maintenance data of each equipment
- Analyze the production process data/quality control data/maintenance data, and produce the intuitive chart/quality report, and evaluate the production/safety/quality conditions according to different circumstances
- In operation, handle shutdown/failure by classifying them into the mechanical failure/electrical failure/software failure/normal maintenance, and make more detailed classification for each category, thereby to enhance production efficiency and reduce the failure times
- Conduct uniformly management of operators, to cultivate their machine operation capacity, fault analysis capabilities etc.
- Make unified planning for equipment production, make dynamic adjustment for production details, and optimize the production process
- Conduct quality tracking/analysis of product parameters to produce optimization solutions
- Establish web management network, which provide convenience for managers to check equipment operation situation/product completion status/customer needs at any place, and propose on-line remote inquiry and comments, and issue management order

The specific function modularization can be divided into the following modules:

- Control assistant
    - Display real-time data
    - Timely identify machine failure
    - Display trend and operating parameters of processing graph
    - Calculate productivity
    - Position waste and efficiency

- Plan assistant
  - Graphic planning board
  - Multilevel plan
  - Replace and change production operations
  - Show raw material availability
  - Show inventory
  - Connect to ERP system
- Quality assistant
  - Acquire and display process parameters
  - Analyze and show the dynamic quality distribution graph
  - Analyze waste rate, waste types and waste reasons
  - Produce and prepare QA analysis documents
  - Compare processes and components as well as program parameters
  - Timely process or repair quality problems by itself
  - Analyze the historical quality relations
- Setup Assistant
  - Upload or download setup parameters and processing programs (G code)
  - Store and manage all processing data and programs
  - Optimize, analyze and contrast settings combination
  - Automatically back up the operating parameters and process parameters of machine through network
- Maintenance assistant
  - Create a maintenance plan
  - Define the maintenance level and cycle
  - Automatically prompt the early alarm

- Manage the various machinery and equipment
- Arrange maintenance procedures

- Human Resources Assistant
  - Shift statistics data
  - Work statistics data
  - Monthly statistics data
  - Duty efficiency statistics data [40]

5.7 Advantages of SIMS workshop

- SIMS workshop is an unmanned workshop where technicians could control all the equipment and the entire production process outside of manufacturing area, meanwhile, SIMS workshop has many functions, including automatic monitoring, alarm, automatic diagnosis, and automatic protection and etc. In the work course, in case of overload, overvoltage, overcurrent, short circuit and other power failures, SIMS workshop is able to automatically take protective measures to avoid and reduce personal injury and equipment accidents, which significantly improves safety in usage of equipment. The mechanical automation products have applied the electronic device, which help to reduce the moving parts and wear parts of mechanical products, so that to make such products bear a relatively high sensitivity and reliability, with low failure rate and extended service life.

- The efficient and flexible production mode enables the SIMS workshop to have a good flexibility for adapting to needs through adjusting software, which is particularly suitable for production of products in multi species and small batches. It is able to shorten product development cycle and accelerate upgrading of equipment and products, and in particular, with respect to the remote locations and sparsely populated regions, it enables to product in a customized way with small batches according to customer's requirements.

- By applying the automated production lines, the manual operation has been transformed to the intelligent machinery and equipment processing, which improves the production efficiency.

- The SIMS workshop bears the functions of automatic processing and automatic control of information. Its sensitivity, accuracy and scope for control and detection have been greatly improved. By applying the automatic control system, the actuator of machine can be ensured to accurately complete the scheduled actions according to design requirements, so that to prevent the subjective factors of the mechanical operator, in order to achieve the best operation, and to ensure the best work quality and relatively high product qualification rate.

- During installation and commissioning period of SIMS workshop, the work mode can be changed by adjusting the control program, in order to meet various requirements of different user objects and for field parameters. These control programs can be entered into the main control system via a variety of means with no need to change any components and parts of products. SIMS workshop

has a storage function, which enables storage of a number of different execution procedures in advance, and by entering the given code signal according to different work objects, the SIMS workshop could start working automatically in accordance with the designed preset program.

- The number of control buttons and handles is reduced significantly, which has greatly simplified operations and made it easier and more convenient to operate. The work process is commanded by the electronic control system step by step according to the preset program, and such system can repeat all the actions. SIMS workshop can seek the best work program by itself randomly in the light of the mathematical model of controlled object and variation of the external parameters, so that to achieve the optimized automation, make adjustment and maintenance simpler, and to improve the operational performance.

- SIMS workshop gets rid of restrictions regarding single technology and single function of the mechanical and electrical products, and it possesses composite technology and composite functions, which has greatly improved the functional level and automation level of products. The SIMS workshop has various functions, including automatic control, automatic compensation, automatic calibration, automatic adjustment, automatic protection, intelligence and other functions, which enable it to be applied to different occasions and areas, in order to meet user needs and have a strong resilience.

- Reduce consumption of the raw material and energy in production process

- Three existing equipment (two Kuka robot arms, CNC milling machine, and CNC turning machine) will be integrated into the new SIMS workshop, which helps to reduce investment funds.

- The experimental conditions and level in UiT Narvik have been greatly enhanced which benefits to improve the university's strength and also allows the students to learn more about and have a better understanding of the specialized Knowledge through SIMS workshop.

- The local and nearby small and medium-sized manufacturing enterprises can go to school for a visit and study, and also can borrow and utilize the SIMS workshop to process and conduct product experiments. In the meantime, the university also provides the paid technology and installation services, in order to provide fund support for maintenance, system and equipment upgrade of the SIMS workshop.

5.8 Challenges of SIMS workshop

- Expensive construction cost

  The establishment of SIMS workshop requires to purchase the new machine and equipment, so it needs the capital investment.

- Site issues

  The existing workshop has a relatively small site, however, to establishment of the SIMS workshop, it may need a larger space.

- Complex control system

  There is many equipment in the SIMS workshop, and each of which has its own independent control system, therefore, it's difficult to integrate the separate control systems for each individual equipment into one general control system.

- Technical support

  The establishment of SIMS workshop requires a lot of technical supports to achieve transformation.

- Researchers

  After establishment of the SIMS workshop, it has very high technical requirements for operators, and in addition, technology and equipment are under continuous invention and innovation with a repaid replacement speed, which requires the professionals to conduct continuous research and transformation.

5.9 Future work

- Research and learning on SIMS

  SIMS will become mainstream of machinery manufacturing industry in future, while technology and inventions regarding SIMS have been updated constantly, so, only through continuous research and learning, the international competitiveness could be improved.

- Simulation making of SIMS workshop

  The visualization of the SIMS workshop has been completed, however, due to the limited project schedule, the simulation part has not yet been completed. More efforts will be put to continue making and improving the simulation part, in order to achieve transformation of the existing workshop in a better way.

- Establishment of the general control system

  The control of SIMS workshop requires a complicated system, so we need to learn more about and conduct researches in this respect in order to make a better control system.

- Continuous learning by technicians and researchers

  The SIMS workshop has high technical requirements on its operators, therefore, only with the continuous research and learning by the experienced SIMS professionals, the equipment and systems establishment and the further maintenance and updating of the SIMS workshop can be completed.

6 Conclusion

Through analysis of the global and region current situation of small and medium- sized enterprises (SMEs), we can see they account for more than 90% of all firms outside the agricultural sector, constitute a major source of employment and generate significant domestic and export earnings, especially in the manufacturing sector, play an important role and occupy a strategic place in the socio-economic growth.

Under the context of globalization and liberalization of the international trade, the small manufacturing enterprises are facing new opportunities and encountering with new challenges. The small manufacturing enterprises are unable or not completely able to take the advantage of globalization, and the conventional methods applied to manufacturing systems are unable to fully meet this new trend. It's necessary for enterprises to redesign products and reconfigure manufacturing systems on a regular basis. To enable the small manufacturing enterprises to overcome the above problems and enhance their access to new technologies for increasing their competitiveness in the international market, a novel concept for Small-scale Intelligent Manufacturing System (SIMS) is introduced.

Affecting by the fiercer global competition, the enterprises in the manufacturing industry are driven to improve competitiveness by shortening their time to market and decreasing cost while guaranteeing the good-quality product bearing the demanded functions. Agility is crucial to the enterprises' survival and development which helps to consolidate the enterprises' relation with customers. In addition, the scientific-technical progress has bridged the physical world with the digital world. In the context of Industry 4.0, the small manufacturing enterprises are motivated to make innovation and find solutions to acquire the competitive advantage.

This paper proposed a new concept called SIMS, in which the definition, tools, parts, implementation, challenges and trends of SIMS are summed up, and later on, the research emphasis could be put on finding a way to give recommendation to the small manufacturing enterprises concerning their respective optimum tools with cost efficiency. With the advantages of high integration, automation and flexibility, the small intelligent manufacturing enterprises are capable of making quick response to customers' requirements on faster goods delivery, so that to make full use of its agility. Furthermore, SIMS will be a knowledge-based and digital system with more connection with network. SIMS is expected to create new chances and bring advantages in order for the small manufacturing enterprises to realize their great potential to vitalize economy, and make contribution to the society and environment.

Based on the research study of SIMS and status analysis of existing workshop in UiT Narvik, an approach is proposed to transform the current workshop to SIMS workshop, as well as the workshop equipment including Kuka robot, CNC milling and turning machines will be integrated into the SIMS workshop.

After SIMS workshop is built, it will be an unmanned workshop with efficient and flexible production mode, automated intelligent production line and high productivity. Control buttons and handles will be significantly reduced to simplify the operation. Raw materials and energy consumption in the production process will be optimized to save the cost. Automatic information processing system and automatic control functions will be built to improve the level of intelligent.

The experimental condition and capability of UiT Narvik will be increased after the transformation. The campus students can learn and understand professional knowledge in more convenience and easier way. Moreover, the small and medium-sized manufacturing enterprises that located around Narvik can visit and learn about the SIMS workshop, it can help them to transform traditional manufacturing to intelligent manufacturing.

There are still some future works from concept to real SIMS workshop during transformation, for instance, the simulation of SIMS workshop processing, the establishment of general control system and training of operators. SIMS is the most promising and future-oriented of production system, and researchers need continuous learning of SIMS, as well as maintenance and updating of workshop to face the rapidly technological development and global competition.

Reference

[1] Promoting entrepreneurship and innovative SMEs in a global economy: Towards a more responsible and inclusive globalisation. Istanbul, Turkey, 3-5 June. 2004

[2] A. Isaksen, and K. Smith, Innovation Policies for SME's in Norway: Analytical Framework and Policy Options. Oslo: STEP Group, 1997.

[3] An introduction of Small-scale Intelligent Manufacturing System. Taoying Huang, Wei Deng Solvang, Hao Yu. Narvik, Norway. 21-24 June 2016.

[4] OECD (Organization for Economic Co-operation and Development), Effective Policies for Small Business a Guide for the Policy Review Process and Strategic Plans for Micro, Small and Medium Enterprise Development, UNIDO, OECD, 2004.

[5] OECD Studies on SMEs and Entrepreneurship. SME and Entrepreneurship Policy in Israel 2016. SBN: 9789264262324. OECD. 21 Nov 2016.

[6] ASIA SME FINANCE MONITOR 2014. Asian Development Bank. ISBN 978-92-9257-067-5. Mandaluyong City, Philippines: Asian Development Bank, 2015.

[7] Small and MediumSized Enterprises: Overview of Participation in U.S. Exports. United States International Trade Commission. Investigation No. 332-508 USITC Publication 4125 January 2010.

[8] Forthcoming in Kushida, Kenji E., Kay Shimizu, and Jean Oi, eds. Syncretization: Corporate Restructuring and Political Reform in Japan: Brookings/APARC, 2013

[9] Das, K. (2008), 'SMEs in India: Issues and Possibilities in Times of Globalisation', in Lim, H. (ed.), SME in Asia and Globalization, Keshab Das Gujarat Institute of Development Research, ERIA Research Project Report 2007-5, pp.69-97.

[10] Study on the potential of sustainable energy financing for small and medium enterprises in China, International finance corporation. ESD China Limited. October 2012.

[11] Burns, P., and Dewhurst, J., Small Business and Entrepreneurship, Second Edition, Houndmills, Basingstoke: Macmillan Small Business Series, Macmillan Press Ltd., New York, 1996.

[12] Nadvi, Khalid, Industrial Clusters and Networks: Case Studies of SMEs Growth and Innovation, United Nations Industrial Development Organization (UNIDO) Small and Medium Industries Branch, October 1995.

[13] ESCWA (Economic and Social Commission for Western Asia), Potential of Manufacturing Small and Medium Enterprises for Innovation in Selected ESCWA Countries, 25 April 2001, (E/ESCWA/ID/2001/2).

[14] Kuhndt, M., and von Geibler, J., How Small and Not-So-Small Businesses can be Assisted in

Improving their Triple Bottom Line Performance, Wuppertal Institute, Eco-Efficiency and Sustainable Enterprise Team Director, Triple-Innovation, UNEP's 7th International High-Level Seminar on Cleaner Production, Prague, Czech Republic, April 29 – 30, 2002.

[15] UNEP (United Nations Environment Programmed), Division of Technology, Industry and Economics: Developing Better Systems for Communicating. Environmental Best Practice in Business, final report, Paris 1997.

[16] Gad, M., Productive Families Project among Environmental Industries, Home Industries and Small-Scale Industries, Ministry of Social Affairs and African-Asian Organization for Rural Activation, The International Colloquium of Management and Planning in Small Scale Industries Field, Cairo, 23 – 27 Jan. 1989.

[17] Gadalla M. Gadalla, The Development of Small Scale Industries in Egypt, Social Affairs Ministry, and African-Asian Organization for Rural Activation, the International Colloquium of Management and Planning in Small Scale Industries Field, Cairo, 23 – 27 Jan. 1989.

[18] Allam, S., Management of Small Manufacturing Enterprises, Department of Businesses Management, Faculty of Commerce, Cairo University, Giza, Egypt, 1993, (in Arabic).

[19] De Vries, K., The dynamics of family controlled firms, Faculty of Business & Management, University of Ulster, Northern Ireland, 1993.

[20] Hillary, R. (Ed.), Evaluation of Study Reports on the Barriers, Opportunities and Drivers for Small and Medium Sized Enterprises in the Adoption of Environmental Management Systems, Imperial College, University of London, 1999.

[21] Howahi, A., The Environmental Pollution of Small Scale Industries - How to Prevent, Friedrich Ebert Stiftung and the Central Productive Cooperative Union, Cairo, 1995, (in Arabic).

[22] Revilla, J., & Cadena, M. (2008). Trends in intelligent manufacturing systems. Proceeding of the World Congress on Engineering, London, UK.

[23] Galina Setlak, Sławomir Pieczonka, "Design Concept Of Intelligent Management Systems", International Book Series-Information Science and Computing, 142-149

[24] Pawan Sharma1, Dr. Manish Bhargava2 Department of Mechanical Engineering Maharishi Arvind Institute of Engineering and Technology Sector-7, Madhyam Marg, Mansarovar, Jaipur, Rajasthan, India-302020

[25] Radovan Holubek1, Peter Kostal1 1Faculty of Material Science and Technology, Slovak University of Technology, Pavlinska 16, 917 24 Trnava, Slovak Republic

[26] Requicha, A.A.G. and Vandenbrande, J. (1988), "Automated system for process planning and part programming", In AI: Implication for CIM, by Kusiak, A. (ed.), pp. 301-326, Kempston, UK.

[27] Proudlove, N.C., Vadera, S. and Kobbacy K.A.H., (1997), "Intelligent management systems in operations: a review", Journal of the Operational Research Society, 49(7), pp. 682-699.

[28] Frank, P.M. and Koppen-Seliger, B. (1997), “New developments of AI in fault diagnosis”, Engineering Applications of Artificial Intelligence, 10(1), pp. 3-14.

[29] Fernando L.F. Almeida, “Designing and implementation of an intelligent manufacturing system”, Journal of Industrial Engineering and Management, 2011 – 4(4), 718-745

[30] Duc Pham Editor, Springer Series in Advanced Manufacturing Cardiff, United Kingdom January 2010.

[31] Vaibhav D. Bhoj, Shubham S. Abhang2, Gunvant S. Bhangale3 INTELLIGENT MANUFACTURING SYSTEM, International Center, YMCA, New Delhi, 2016.02.20.

[32] Pratik Roy, G. S. Mahapatra, Pooja Rani, S. K. Pandey, K. N. Dey, Robust feedforward and recurrent neural network based dynamic weighted combination models for software reliability prediction, Applied Soft Computing, 22, p.629-637, September, 2014.

[33] Galina Setlak, Sławomir Pieczonka, DESIGN CONCEPT OF INTELLIGENT MANAGEMENT SYSTEMS, Intelligent Information and Engineering Systems.

[34] “Intelligent Manufacturing Systems”, B.I.T. Mesra, by Dr. Surender Kumar.

[35] International paper of pawansharma and Dr.ManishBhargava Department of Mechanical Engineering Maharishi Arvind Institute of Engineering and Technology Sector-7, MadhyamMarg, Mansarovar, Jaipur, Rajasthan, India-302020.

[36] 《Intelligent Manufacturing development planning of Guangzhou Province（2015-2025）》 eworks.baijia.baidu.com/article/303776.

[37] C. Chituc a F. José Restivo, “Challenges and Trends in Distributed Manufacturing Systems: Are wiseengineering systems the ultimate answer”, in Challenges and Trends in Distributed Manufacturing Systems, Cambridge, Massachusetts,2009.

[38] "2014 Service pack 2 available". Visual Components. Oct 7, 2014. Retrieved 2015-07-02.

[39] "Simulation VS. Visualization-What’s the difference? ". Visual Components. May 11, 2017.

[40] "Modern Industry 4.0 intelligent automated production line monitoring and control system solutions" wenku.Baidu. July 13, 2017.