ICIC Express Letters
Part B: Applications
Volume **9**, Number **5**, May **2018**

ICIC International ©2018 ISSN 2185-2766
pp. **421–427**

EMPIRICAL STUDY OF ENGINEERING MODELING AND SIMULATION IN MANUFACTURING INNOVATION TO LEAD 4th INDUSTRIAL REVOLUTION

Jae Yun Jeong[1,2], Yuri Han[1,2], Jae Sung Kim[1,2], Seok Chan Jeong[3]
Mi Hyun Ko[1,2] and Suchul Lee[4,*]

[1]Korea Institute of Science and Technology Information
245, Daehak-ro, Yuseong-gu, Daejeon 34141, Korea
{jaeyun; yurihan; jaesungkim; mihyungo}@kisti.re.kr

[2]Department of Science and Technology Management Policy
University of Science and Technology
217, Gajeong-ro, Yuseong-gu, Daejeon 34113, Korea

[3]Department of e-Business
Dong-Eui University
176, Eomgwangno, Busanjin-Gu, Busan 47340, Korea
scjeong@deu.ac.kr

[4]Department of Business Administration
Mokpo National University
1666, Yeongsan-ro, Cheonggye-myeon, Muan-gun, Jeonnam 58554, Korea
*Corresponding author: suchullee@mokpo.ac.kr

Received October 2017; accepted January 2018

Abstract. *This study discusses the status of engineering modeling and simulation (Eng. M&S) use in Korea, and the effects of Eng. M&S. Eng. M&S is an important technology in the 4th Industrial Revolution. Nevertheless, Eng. M&S has not been used actively and fully in Korea because of the high costs of M&S software and hardware and a lack of experts in the field. To increase the use of Eng. M&S in Korea, the effects of Eng. M&S must be strengthened: important aspects include quality of products, cost reduction, time savings, and manpower reduction. Policy alternatives to expand the utilization of Eng. M&S must also be developed.*
Keywords: Engineering modeling and simulation, Survey analysis, Benefits of adoption, Impediments to adoption, Policy recommendations

1. **Introduction.** The onset of the 4th Industrial Revolution has moved the focus of industry from manufacturing to information and communications technology (ICT) and service. As a result, the entire manufacturing industry requires innovation such as links to information and ICT. Engineering modeling and simulation (Eng. M&S) has become increasingly important as the development of high-performance computing (HPC) and engineering software has accelerated the change in manufacturing. Moreover, Eng. M&S has become a core next-generation technology together with such fields as artificial intelligence (AI), Internet of things (IoT) and robotics [1,2]. The proportion of manufacturing in Korea's GDP and total export value is very high, but manufacturing in Korea has decreased since the 2000s [2]. To reverse this trend, Korea must revolutionize its manufacturing industry by developing and utilizing Eng. M&S. However, in reality, Eng. M&S has not been studied deeply and systematically. Therefore, this paper has academic significance in considering Eng. M&S as a single subject. Moreover, this study evaluates Eng. M&S as the key technology for manufacturing innovation and mainly discusses the status and effects of Eng. M&S utilization. Section 2 explains the concept of Eng. M&S and its functions in the 4th Industrial Revolution. Section 3 presents the research method

and the contents of surveys. Section 4 discusses the results of the empirical study. Section 5 concludes the paper.

2. **Literature Review.** The 4th Industrial Revolution is a change in the manufacturing paradigm to ward integrating ICT into the manufacturing process. This paradigm aims to combine technology from all sectors and to erase physical and biological boundaries [3]. Eng. M&S, especially during the product design phase, will contribute to manufacturing innovation. Eng. M&S is a kind of M&S that sets limits on manufacturing engineering and mainly includes the fields of computer-aided design (CAD) and computer-aided engineering (CAE) [4,5].

Eng. M&S can reduce time and costs of product development by conducting virtual experiments, and consequently could increase the efficiency of the development stage and improve product quality. Thus, Eng. M&S could be regarded as a type of "process innovation", but in the aspect of innovation characteristics, Eng. M&S is also a type of "incremental innovation" because it applies process innovation to gradually innovating products or production processes [6].

M&S as a single technology is positioned in the front of the 'smile curve' to generate higher value added than production and assembly [7,8]. Moreover, the development of Eng. M&S would increase the value added by the manufacturing process in the short term, and advance the whole process in the long term by increasing the possibility of solving analysis problems in product and process design. Thus, Eng. M&S would ultimately increase the entire value added in manufacturing by moving up the whole smile curve. Many manufacturing enterprises could adopt Eng. M&S; as a result, Eng. M&S would arouse a big change in current technology and market. In this context, Eng. M&S can be seen as a "disruptive technology" to destroy the currently-dominant design, development and production technologies or systems in manufacturing [9,10].

3. **Method.** This study consisted of two surveys (Figure 1), one in 2014 and one in 2016, to quantify the utilization and effects of Eng. M&S in Korea. The survey in 2014 considered 500 small and medium enterprises (SMEs) amongst 3,000 manufacturing SMEs that have a high possibility of using HPC. The survey used the focused phone and email survey method. This survey included questions about annual sales, experience in using Eng. M&S, possession of specialized R&D team, tools used to perform Eng. M&S, and obstacles to use Eng. M&S (Table 1).

The survey in 2016 focused on 30 SMEs that had been supported from 2014 to 2016 by the "Supercomputing Simulation and Modeling Project" of the Korea Institute of Science and Technology Information (KISTI). The survey method was the same as in 2014. The purpose of the second survey was to identify the practical effects of applying Eng. M&S to real manufacturing processes. The subjects were asked questions about annual sales,

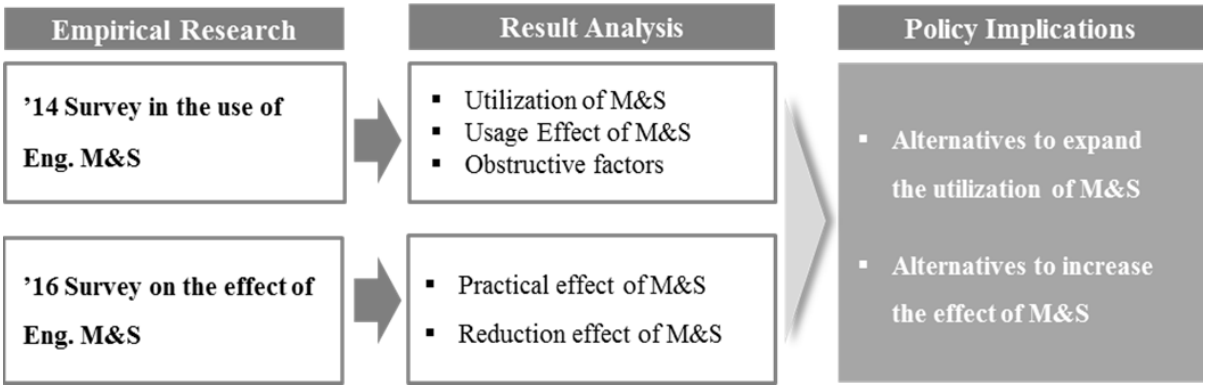

FIGURE 1. Flowchart of research method

Table 1. The contents of survey questionnaire

Classification	The use of Eng. M&S	The effect of Eng. M&S
General information	Annual sales, Possession of R&D specialized team	Annual sales, Main field of business
Utilization of Eng. M&S	Experience on using Eng. M&S, Tools used in performing Eng. M&S, Obstacle factors in using Eng. M&S	N/A
Expected effect of Eng. M&S	Effects of performing Eng. M&S, Increase in annual sales through using Eng. M&S, The amount of increase in annual sales	Sale increase, Export increase, Recruitment of new employees
Reduction effect of Eng. M&S	N/A	Effect of manpower reduction, cost reduction, and time savings

increase in annual sales and export, recruitment of new employees, effect of manpower reduction, cost reduction, and time savings (Table 1).

The collected data from both surveys were analyzed. First, the results of empirical research were identified by using frequency analysis, cross-tabulation, descriptive statistics and analysis of mean differences. Then, policy implications were identified by focusing on the problems.

4. Results Analysis of the Survey.

4.1. Status of Eng. M&S use.

The first goal of this research was to determine whether the SMEs sampled have experience using Eng. M&S. Of the 500 SMEs surveyed, 42% (210) had used Eng. M&S (Figure 2). This proportion is lower than the 57.3% of manufacturing companies that use engineering software in U.S. [11]. Furthermore, 42% does not mean high utilization, because having experience using Eng. M&S is not the same as using it continuously.

The rate of Eng. M&S use shows increases with firm size (Figure 2). In enterprises that have fewer than 5 billion won of annual sales, the proportion of Eng. M&S use is the lowest (32.8%), whereas firms that have over 100 billion won have the highest proportion (51.7%). This trend occurs because Eng. M&S needs high-priced software and hardware, as well as highly-skilled experts to understand and use the software; as a result, the ability to perform Eng. M&S decreases as firm size decreases.

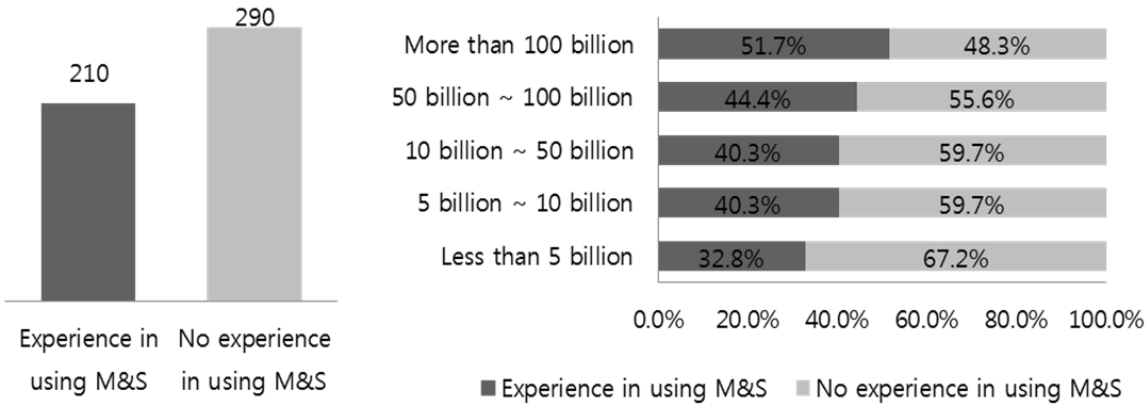

Figure 2. The status of experience on using M&S

Of the SMEs surveyed, 419 (83.8%) had a specialized R&D team, while 81 (16.2%) of the SMEs did not (Table 2). Moreover, SMEs that had such a team showed a significantly ($p < 0.05$) higher proportion of Eng. M&S utilization than SMEs that lacked one. SMEs with having a specialized R&D team are more likely to be equipped with Eng. M&S experts, hardware, and software; as a result, they show a higher rate of using Eng. M&S.

TABLE 2. Cross-tabulation of possession of an R&D team with experience in using M&S

Experience in using M&S	**Possession of an R&D team (%)**			χ^2	p
	Yes	**No**	**Total**		
Yes	197 (93.8)	13 (6.2)	210 (42.0)	26.721	.000
No	222 (76.6)	68 (23.4)	290 (58.0)		

The level of Eng. M&S use was identified by asking which software tools the SMEs used in Eng. M&S (Figure 3). The highest usage was of CAD/CAM (53.3%) followed by product design software (23.1%), and CAE software (19.6%). This result shows that domestic SMEs still focus on using CAD/CAM for design of products or production; few SMEs use simulation, which is considered to be more complicated and important part of M&S than product design.

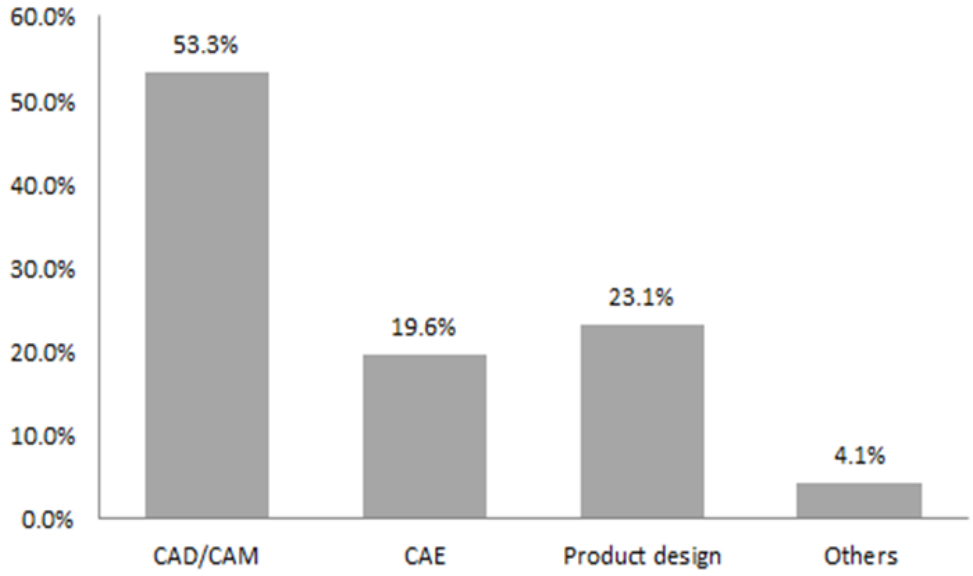

FIGURE 3. Tools used in performing Eng. M&S

The 2014 survey identified general effects of using Eng. M&S as follows (Figure 4): new product development (32% of SMEs), time reduction in production (23%), product quality improvement (20%), and cost reduction of production (16%). Some negative factors that hinder adoption of Eng. M&S were also identified. In SMEs that had experience using Eng. M&S, these were high cost of software (38.5%), lack of experts (36.5%), high cost of hardware (11.5%), and lack of internal support and awareness (6.3%). In SMEs with no experience of Eng. M&S usage, factors that hindered its use were (Figure 5): no need (42.2%), lack of awareness of the resource (22.9%), lack of experts (19%), high cost of software (12.1%) and insufficient hardware (3.9%).

4.2. **The effects of Eng. M&S.** This section describes the practical effects of using Eng. M&S in manufacturing field; these results were obtained in the 2016 survey of Eng. M&S effects by focusing on enterprises that were supported by the KISTI's Supercomputing

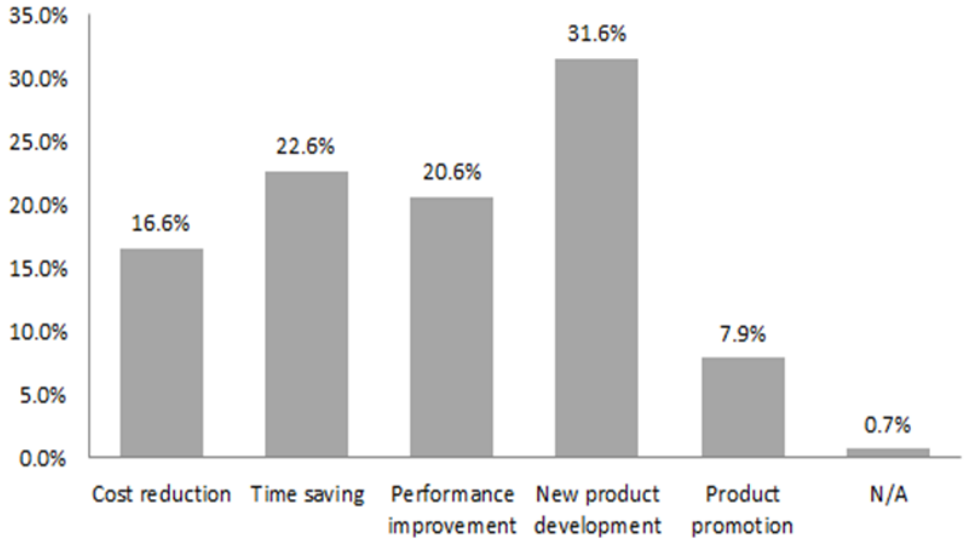

FIGURE 4. Advantages of adopting Eng. M&S

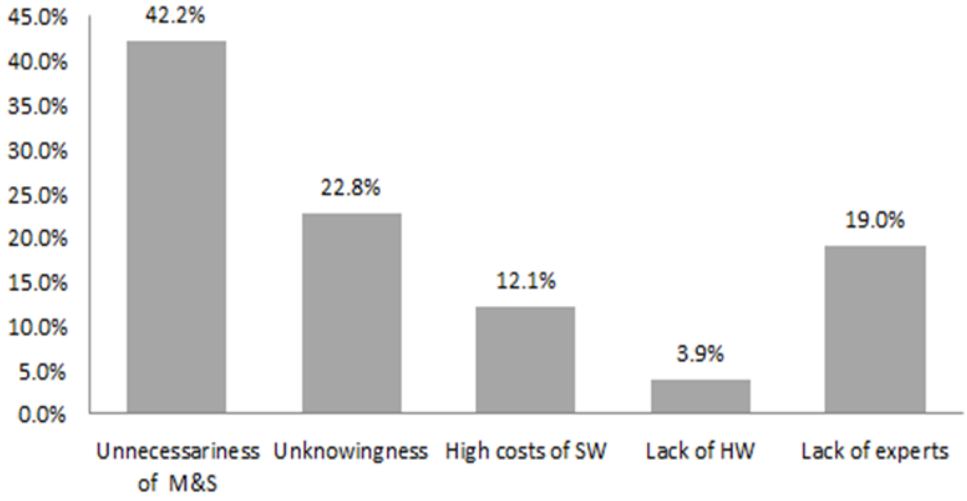

FIGURE 5. Reasons for not adopting Eng. M&S

Simulation and Modeling Project from 2014 to 2016. First, the practical effects on sales increase, export increase, and recruitment of new employees were quantified (Table 2). On average, annual sales increased by 2.4 billion Won, exports increased by 14 billion Won, and only 1.8 new employees were recruited.

Also, Eng. M&S reduces the need for manpower, the expense and time required to develop new products (Table 3). Specifically, the number of workers needed during the development process was reduced from 3.3 to 1.3 (Table 4). Development cost decreased from 110 million won to 25 million won on average while development time decreased from 1,422.5 hours to 362.9 hours. As a result, on average, use of Eng. M&S reduced the number of employees by two, decreased costs by 86 million won, and reduced development time by 1,079.6h (Table 4).

4.3. **Policy implications.** These analyses demonstrate that Eng. M&S has not been used widely and appropriately in manufacturing sites, despite its beneficial effects. The main impediments to adoption of Eng. M&S are that the software is expensive, purchase cost of hardware and management is high, and experts are not available. This section suggests five tactics to increase the use of Eng. M&S and to improve the effects of it.

TABLE 3. Practical effect of using Eng. M&S ($n = 30$)

Criterion	Ave.	S. D.	Max.	Min.
Sale increase (thousand won)	2,440,423	852,447	10,000,000	1,000,000
Export increase (thousand won)	14,204,200	2,153,162	20,000,000	500,000
Recruitment of new employees	1.8	0.9	3	0

TABLE 4. Reduction effect of using Eng. M&S ($n = 30$)

Measure	Mean Manpower (person)	Mean Cost (won)	Mean Time (hour)
Before using M&S	3.3	111,113,333.3	1,442.5
After using M&S	1.3	24,712,666.7	362.9
Difference	2.0	86,400,666.6	1,079.6

(1) Current Eng. M&S software is expensive and foreign-made. This problem could be relieved by developing Eng. M&S software in Korea; if it is less expensive and has quality that is higher than or equal to foreign-made M&S software, then Korean-made Eng. M&S software would be easy to disseminate. To construct industrial infrastructure while focusing on domestic software development, the government should provide financial and policy support to domestic M&S software businesses to support technology development [12]. Furthermore, development and release of open source-based Eng. M&S software would be a beneficial alternative for domestic manufacturing businesses.

(2) Eng. M&S hardware is expensive to purchase and to maintain. To replace the high-priced hardware, the role of the public sector should be strengthened by providing HPC and Cloud-like services to manufacturing companies [2]. This tactic would also increase the rate of Eng. M&S use if cloud service based on HPC was combined with open source-based Eng. M&S software.

(3) To remedy the shortage of skilled Eng. M&S experts, more should be trained. This goal can be met by training top-level talents and high-quality graduates in a well-systematized university education that reflects the real field of manufacturing. Also, because the ability of existing experts engaged in Eng. M&S should be strengthened, various training programs should be developed and educational support should be expanded and improved, especially aimed at these experts.

(4) The government should expand and reinforce specialized projects to support Eng. M&S. To be specific, desirable alternatives for SMEs include providing Eng. M&S experts, technical support and infrastructure needed for conducting Eng. M&S. Also those alternatives should be applied in combination according to the SMEs' needs. Furthermore, SMEs that do not use Eng. M&S should be informed of it and encouraged to adopt it.

(5) To increase the use of Eng. M&S, its important effects in manufacturing development should be emphasized systematically and vigorously. Provision of information is extremely useful in the knowledge service industry based on manufacturing industry [13]. Feasible methods to disseminate this knowledge include public relations through mass media, direct advertisement aimed at manufacturing businesses and seminars.

5. **Conclusions.** This study has reported results of two surveys that were intended to identify the prevalence of Eng. M&S and to verify its effects. The goal of this paper was to suggest ways to increase its use in domestic manufacturing SMEs. Despite the increasing

importance of Eng. M&S at the onset of the 4th industrial revolution, the utilization of Eng. M&S in the manufacturing field is not high in Korea. Furthermore, adoption of Eng. M&S is impeded by several factors such as high cost of software and hardware, and lack of experts. Thus, to improve the beneficial effects of Eng. M&S (e.g., improved quality of products, reduction in costs, and savings in time, and reduction in manpower), policy alternatives are required: supporting development of domestic Eng. M&S software and providing hardware infrastructure service, supporting use of Eng. M&S by SMEs, training of Eng. M&S experts, and publicizing the importance and benefits of Eng. M&S.

We assert that Korea should develop and utilize advanced technologies to strengthen traditional and advanced manufacturing. However, this study has the limitations: the two surveys were conducted independently with totally-separate subjects during different period, and that the contents of Eng. M&S effects were not objectively measured. Thus, future studies are needed to further improve the reliability of surveys about Eng. M&S effects: future surveys should increase the sample size and expand the sample target to general manufacturing businesses.

Acknowledgment. This work is supported by the Korea Institute of Science and Technology Information (KISTI). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the paper.

REFERENCES

[1] Deloitte and Council on Competitiveness, *Global Manufacturing Competitiveness Index*, Deloitte, London, 2016.

[2] Y. Y. Kim, Manufacturing innovation and HPC (high performance computing) utilization, *Journal of Korea Technology Innovation Society*, vol.19, no.2, pp.231-235, 2016.

[3] S. H. Kim and M. J. Kim, Manufacturing innovation policy challenges for next production revolution, *Policy Research Report*, No. 20, Science and Technology Policy Institute (STEPI), Sejong, 2016.

[4] S. H. Lee, S. H. Kim and D. H. Lee, *A Study on Utilization and Development Strategy of Domestic Manufacture-Engineering*, Korea Institute for Industrial Economics and Trade (KIET), Sejong, 2016.

[5] KISTI, *Supercomputing Based Modeling and Simulation 4.0 for Smart Manufacturing Innovation*, Korea Institute of Science and Technology Information (KISTI), Daejeon, 2014.

[6] J. Fagerberg, Innovation: A guide to the literature, *The Oxford Handbook of Innovation*, Oxford University Press, New York, pp.1-26, 2005.

[7] R. Baldwin, T. Ito and H. Sato, Portrait of factory Asia: Production network in Asia and its implication for growth – The 'smile curve', *Proc. of the Hitotsubashi Conference on International Trade and FDI*, 2014.

[8] K. Warwick, Beyond industrial policy: Emerging issues and new trends, *OECD Science, Technology and Industry Policy Papers*, No. 2, OECD Publishing, 2013.

[9] C. M. Christensen, *The Innovator's Dilemma: When New Technologies Causes Great Firms to Fail*, Harvard Business School Press, 1997.

[10] M. J. Song, H. J. Lee and M. H. Choi, Market prospect according to smart TV service innovation: Based on the theory of disruptive innovation, *Information and Telecommunication*, vol.27, no.12, pp.35-43, 2010.

[11] The Joint Relevant Ministries, *The Strengthening Measures for Engineering Industry to Create High Value-Added Jobs*, Meeting of the Economy-Related Ministers, 2016.

[12] G. W. Seo, Importance of domestic CAE software, *Engineering Education*, vol.22, no.4, pp.18-24, 2015.

[13] K. J. Jang and H. J. Choi, A study on the innovation capability strengthening plan for manufacture-based knowledge service industries, *The e-Business Studies*, vol.15, no.4, pp.215-235, 2014.