International Summit on Science Technology and Humanity (ISETH2019)
Advancing Scientific Thought for Future Sustainable Development
p-ISSN: 2477-3328
e-ISSN: 2615-1588

Conceptual Model of Accelerating the Adoption of Small and Medium Industries in Implementing Industry 4.0 with the Lean Manufacturing Approach

Risma Fattahatin Muizzullah[1,*], Komarudin[1], Akhmad Hidayatno[1]

[1]Department of Industrial Engineering, Faculty of Technology, University of Indonesia, Depok, Indonesia

*Corresponding author: risma.fattahatin71@ui.ac.id

Abstract

Purpose: Making a conceptual model that can provide the policy strategy in accelerating the adoption of industry 4.0 in Small and Medium Industries (SMI) using lean manufacturing approach.

Methodology: Using the conceptualization process in system dynamics methodology to get causal relation among the factors which can affect the implementation of industry 4.0 in Small and Medium Industries. The lean management approach was used to get these factors and compile their causal relation with readiness of industry 4.0 as a conceptual model.

Result: A conceptual model that shows important variables and its relationship structure that could be used in better understanding the adoption proceeses of Industry 4.0 technology. Several interconnection loops are identified in the conceptual model that can be the basis for better policy design by focusing on adjusting one or more variables in the loops, in the manner of understand the relationships that occur in the conceptual model, the government can predict the outcome of the policy to be implemented.

Applications/Originality/Value: Providing a better understanding of adoption process for better policymaking by the Indonesian government, particularly the Ministry of Industry, to encourage the readiness of industry 4.0 implementation in Small and Medium Industries.

INTRODUCTION

Industry 4.0 has been a global trend worldwide, introduced for the first time in Germany in 2011 by Hannover Messe; in 2013, it was officially published as "*industrie 4.0*" which explained the fourth industrial revolution in details (Liao et al., 2017). Industry 4.0 is a strategic initiative to transform industrial manufacturing through digitalization and implementation of new technologies in order to improve its efficiency and effectiveness. It is an integration of the business and manufacturing process with the integration of a company's value chain (Andreja Rojko , 2017). It means that every process which brings value will be supported with recent technologies.

There are advantages of its adoption, including (Andreja Rojko, 2017) shorter time to market new products, improvement of customer responsiveness, enabling custom mass-production without increasing overall cost, a working environment which is more flexible and more friendly, and efficiency of resources and energy.

The industrial sector is important to the country's economic growth. In Indonesia, it contributed 20.52% of Gross Domestic Product (GDP) in 2016 (CBS, 2017). The number of small and medium industries reached 4.4 million with the largest number is the food and beverage sector which accounted for 43% of the total number of SMIs. SMIs contributes 19,51% to the total of non-oil and gas industries output value (MOI, 2017).

Indonesian government has established an initiative to implement the fourth industrial revolution, called "Making Indonesia 4.0", but the strategy for its implementation in Small and Medium Industry (SMI) is still unclear. With the limitation of small-medium industries and their

unawareness to its benefit, it is difficult to implement industry 4.0. Furthermore, industry 4.0 is the interconnected technology with a complex system. It is easier for SMIs if they can adopt it in the stages, while they are most likely to lead this change as long as they are capable of quickly implementing it with the development of information technology structure which is simpler (Bahrin et al., 2016). Besides, SMIs need support form governmental institutions, to understand finance and prerequisites for Industry 4.0 implementation (Muller et al., 2018).

This paper aims to provide recommendations on how to implement industry 4.0 in the Small and Medium Industries with its lean manufacturing approach by developing causal loop diagram for mapping the factors affecting implementation of industry 4.0.

LITERATURE REVIEW

This section explains the phenomenon of industry 4.0 and its effect, explanation about Small and Medium Industries in Indonesia, and their opportunity in the implementation of industry 4.0. It also explains lean manufacturing and analysis of its policy implementation using technology.

About Industry 4.0

Industry 4.0 results in the manufacturing sector as well as socioeconomic aspect in society and education. World Economic Forum 2016 has stipulated industry 4.0 as a global issue since technology breakthrough brings transformation in social life aspect. Paradigm of new economy is how internet and data make values for society, not only as a communication channel (Mohrar et al., 2017).

In education field, industrial revolution 4.0 has changed the educational landscape since it is controlled by AI and connectivity between machine and human being. Revolution, with its fast innovation, brings model of Education 4.0. Education makes use of information and capability irreplaceable by robot (Shahroom & Hussin, 2018).

Meanwhile, in the sector of manufacturing industry, industry 4.0 aims to improve productivity and efficiency (Ciminil et al., 2011). Company offering data analysis-based service can significantly increase its income. The customized product (which is made based on data analysis) results in a larger margin, compared with mass product (Arnold C. et al., 2016). Company with implementation of vertical and horizontal integration has more control in production and management processes, so it can apply total quality management (Keagerman et al., 2013).

About Small and Medium Industries (SMIs) in Indonesia

Definition and criteria of Small and Medium Industries are determined in general based on its labour and asset, refer to Regulation of Minister of Industry of the Republic of Indonesia No. 64 Year 2016.

Small industry is an industry that employs a maximum of 19 workers and has an investment value of less than 1 billion, excluding land and buildings. Medium industry is an industry that meets the following conditions: employs a maximum of 19 people and has an investment of at least 1 billion OR employs at least 20 people and has an investment of at most 15 billion.

Small and Medium Industries in Indonesia in 2015 reached 3.68 million units (MOI, 2017). Meanwhile, total business units in the industry reached 3.69 million, so small and medium industries were 99.62% of all business units in Indonesia. Although Small and Medium Industries dominated, they only contributed 19.14% of total industrial output and 20.07% of total value-

p-ISSN: 2477-3328
e-ISSN: 2615-1588

added of the manufacturing industry in Indonesia. The Productivity of SMI is low, it means that the output of products is limited since its process is simple and capital is limited.

SMIs and Industry 4.0

Industry 4.0 changes the business model of Small and Medium Industries. In order to get the benefit of industry 4.0 in its implementation, Small and Medium Industries need to make innovation in their business model, particularly value creation, value capture, and value offers. Innovation is oriented to the customer-driven, not product innovation (Muller et al., 2018). The benefit of applying big data is to make decision and policy in the company which are more accurate in terms of marketing and business model. Better decision making results in operational efficiency, cost reduction, and risk reduction (Ogbuokiri et al., 2015). Small and Medium Industries consider that industry 4.0 is not yet relevant, though they can be big winners in this revolution. Small and Medium Industries can implement digital transformation more quickly since they can develop and implement new information technology structure more easily (Bahrin et al., 2016).

Making Indonesia 4.0

Indonesian government has launched Making Indonesia 4.0 in 2018, a roadmap to prepare for industrial revolution 4.0 in Indonesia. Indonesian government expects the revitalization of manufacturing industry sector through fourth industrial revolution, to occupy top ten ranks in economic strength worldwide in 2030 based on the gross domestic product. Making Indonesia 4.0 determines five sector focuses as follows: Food and Beverage, Textile and Apparel, Automotive, Electronic, Chemistry (MOI, 2018). Besides, Making Indonesia 4.0 sets 10 national priorities; one of which is empowerment of Micro, Small and Medium Enterprises through technology (MOI, 2018). Making Indonesia 4.0 does not yet clearly define the strategy for implementing industry 4.0, so it requires the conceptual model of policy strategy which can be used in compiling its implementation strategy.

In order to measure the readiness of Indonesian industry in implementing industry 4.0, government launches Indonesia Industry 4.0 Readiness Index (INDI 4.0). INDI 4.0 will be a national reference to measure the readiness of industry to transform. Result of this measurement is used to identify challenge, to determine strategy, and to be basis in determining the policy of government for encouraging industry to transform.

Lean Manufacturing (LM)

Lean manufacturing is based on production management which is performed by industry in Japan, namely Toyota Production System which focuses on eliminating waste and improving customer satisfaction. LM is a set of principles, philosophies, and business processes to enable its implementation, which has been widely known and implemented since 1960. LM is focused on the manufacturing without waste. In other words, lean manufacturing is defined as a production system which focuses on the continuous flow within supply chain by eliminating all wastes and performing continuous improvement toward product perfection (Rose et al., 2011). Waste is anything besides the required equipment, materials, parts, space, and working time. The increasing demand for high-quality products and highly capable business processes by large organization has left no choice for the SMIs to consider LM implementation. Small companies have advantages in which they are more agile, much easier to get management support and commitment, as opposed to large organizations (Anthony, J. and Kumar, M., 2005).

From Lean to Smart Manufacturing

Some researches about lean implementation with the aid of technology have been conducted; one of them is lean implementation using ERP (Enterprise Resources Planning) which explains mutual support relation between lean implementation and the use of ERP. The research also emphasizes that ERP implementation without lean principle will not bring change on productivity, reduction of delay and reject (Ho., 2018).

Technology supports better lean implementation. Lean manufacturing using technology will keep growing, while lean production in a company with low technology adoption will decrease at last. The research also shows that the use of technology too much will drain financial resource in the company with growth of lean production which is not too significant (Nasab, et al., 2013).

Policy modelling using system dynamics

System dynamics is closely related to system thinking; they have aspects of dynamic behaviours in the system and similar concept, such as causal loop, variable, feedback loop, delay, and so on (Prahasta, 2018). System dynamics is focused on study about the existing system behaviours in human life, environment, and global world. System dynamics works based on causal relation and feedback theory. Policy analysis is a systematic process to assess the choice of public policy which is complex (Walker, 2000). It aims to support the policy maker in choosing steps by clarifying problems first, elaborating alternative solution, and showing what must be anticipated as consequence of step to be taken.

System dynamics has been used in the study related to policy analysis, starting from health (public health), energy and environment, social well-being, and sustainable development (Ghaffarzadegan et al., 2010).

CONCEPTUAL MODEL DEVELOPMENT

Actor Analysis

A simple table proposed by (W. A. . Thissen and W. E. Walker., 2013) was adopted to analyze key characteristics per actor (Government and SMI's) as shown in Table 1. Based on the actor analysis, some factors need to be considered by government in compiling the policy strategy for industry 4.0 implementation in SMIs.

- Limited resources at SMIs
- Productivity and profitability which are the interests of SMI
- Low added-value and limited production output
- Low use of technology in SMIs
- SMIs need support from government

Causal Loop Diagram

Causal loop diagram (CLD) is an important tool for describing the feedback structure system. CLD is remarkable for quickly capturing hypotheses that cause dynamics, getting mental models from individuals or teams, and communicating important feedback that is believed to be responsible for a problem (J. D. Sterman, 2000). These variables are connected by causal link indicated by arrows. Each causal link is marked by polarity, both positive (+) or negative (-) to indicate how the dependent variable changes when the independent variable changes. Positive polarity (negative) means variable changes in the same direction (different). The loops in the diagram are identified by

p-ISSN: 2477-3328
e-ISSN: 2615-1588

the loop identifier whether the loop is positive (reinforcing) or negative (balancing) feedback (J. D. Sterman, 2000).

Table 1. Actor Analysis

No.	Actor	Roles & Responsibility	Problem Perceptions	Objectives	Interest	Cause of Problem	Resources
1	Ministry of Industry	Regulating and implementing policies in small and medium industries	The strategy to encourage the readiness of SMIs to implement technology toward industry 4.0	Improving productivity and profitability of SMIs	The right policy strategy so that SMIs can provide added-value and greater production output	Reluctance to change Limited resources at SMIs Weak business mind-set	Regulation Facilitation Subsidy Education
2	Small and Medium Industries (SMIs)	Business activities that process raw materials into finished goods (producers)	Added value and limited production output	Producing goods at affordable prices and good quality	Profit increase	HR competency and capital which are limited Low use of technology	Production machine competence in making products

CLD used in this research refers to CLD from (Nasab et al., 2013). CLD in figure 1 illustrates the implementation of new technology which refers to lean manufacturing principle. New technology which is implemented will improve the readiness of Small and Medium Industries toward industry 4.0. Effect of every new technology which is implemented will change organization and company culture. It also applies to every person in the organization who will be affected by the implemented technology, so it requires competence improvement. CLD in Figure 2 has 10 main loops which consist of 2 balancing loops and 8 reinforcing loops.

Loop R1 : Lean manufacturing drives the technology implementation

Lean manufacturing principle applied in a company will bring strategy change in the company as seen in figure 2, including small and medium industries. That strategy change requires a new program, so it brings need for new technology implementation. Thus new technology implementation will make manufacture more lean based on productivity and financial resources, but it also depends on whether the technology provider available or not. Implementation of lean manufacture considers the complexity of the industries.

Loop R2 : People and productivity

When a new technology is implemented, human factor is still considered by improving their competency so they can used the new technology. These workers will interact among them and create a new culture based on new competencies. Team work will be formed from a new culture that is adapted to the new technology. Implemented technology brings effective culture (behaviour) for improving productivity as seen on figure 3. Culture (behavior) is often a reason in Small and Medium Industries to reject the change brought by new technology.

Loop R3 : People in organization to industry 4.0 readiness

Human factor is one of the determinants in readiness toward industry 4.0. Openness to change (with new technology) will make a technology acceptable and executable by human being. Therefore, openness to change plays a role in improving readiness index in industry 4.0 as seen on figure 4. As described above that industry 4.0 will improve the productivity.

Figure 1. Causal Loop Diagram of Industry 4.0 Implementation with Lean Manufacturing Approach

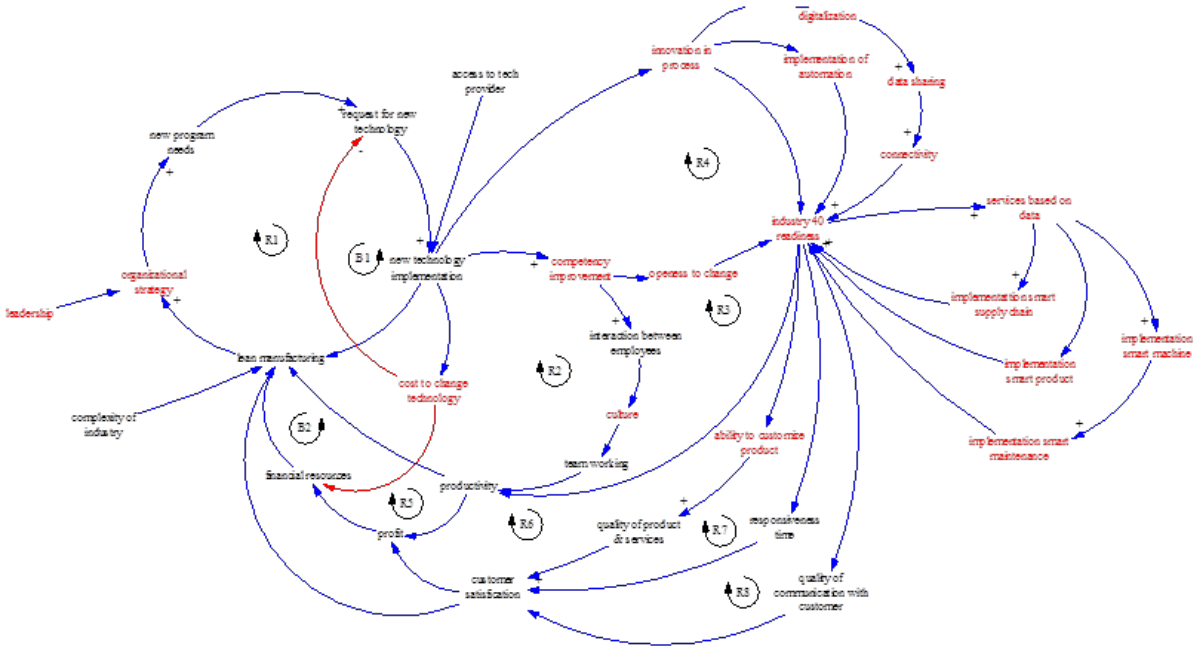
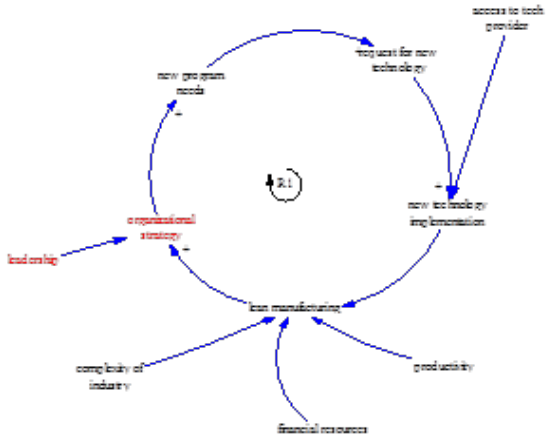


Figure 2. Lean manufacturing drives the technology implementation Loop



p-ISSN: 2477-3328
e-ISSN: 2615-1588

Figure 3. People and Productivity Loop

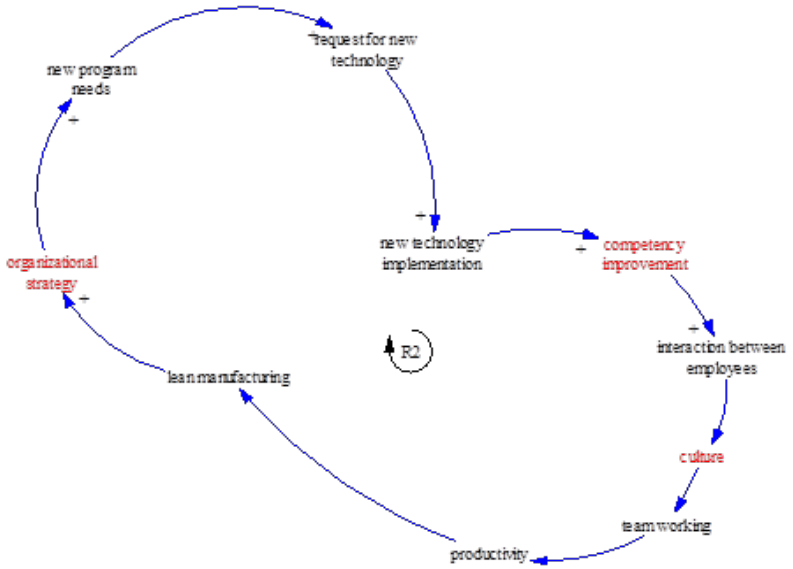
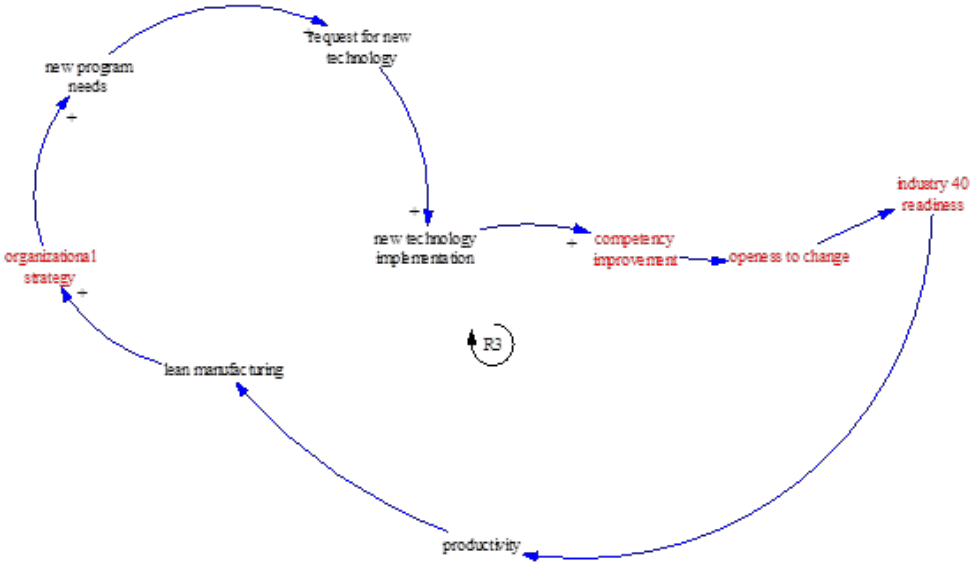


Figure 4. People in organization to industry 4.0 readiness



Loop R4 : Innovation boosts industry 4.0 readiness

Industries needs specific nature of technology is adjusted to the principle of lean manufacturing, therefore innovation and availability of technology providers are needed. This innovation requires the implementation of digitization, automation, data sharing, and connectivity to be able to raise the level of readiness of industry 4.0. The more technology adoption of a company will encourage the implementation of other industry 4.0 technologies, such as data-based services, smart products, smart machines, smart maintenance, and smart supply chains. The industry can be phased in adopting the technology, it does not have to implement all of them, because each technology adoption is carried out, the organization will change, the culture changes, and of course the competence of the people must be improved as seen in figure 5.

Loop R5 : Productivity – Financial resources

Figure 6 shows productivity will increase company profits so that the company's financial resources will be stronger. With sufficient financial resources, the company will continue to keep lean by developing new organizational structures so that industry 4.0 readiness will also increase.

Figure 5. Innovation boosts industry 4.0 readiness Loop

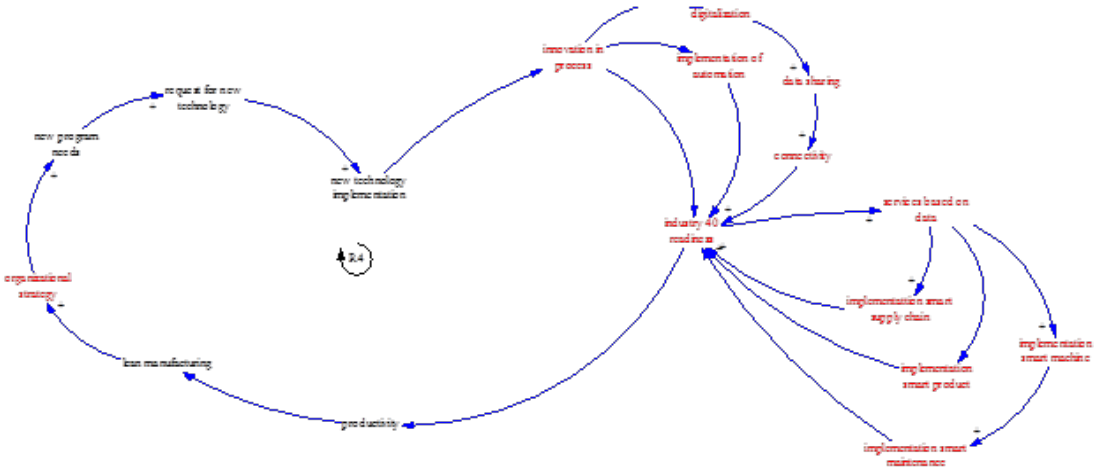
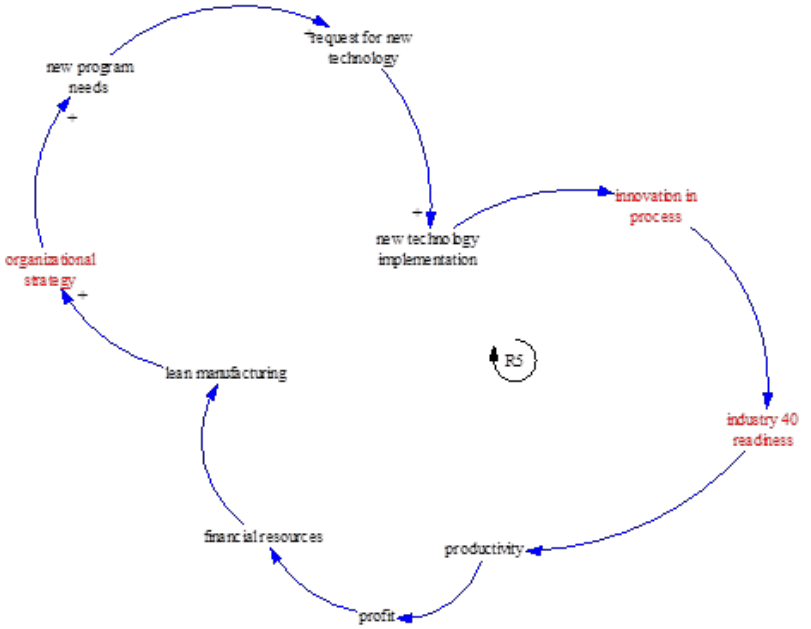


Figure 6. Productiviy – Financial resources Loop

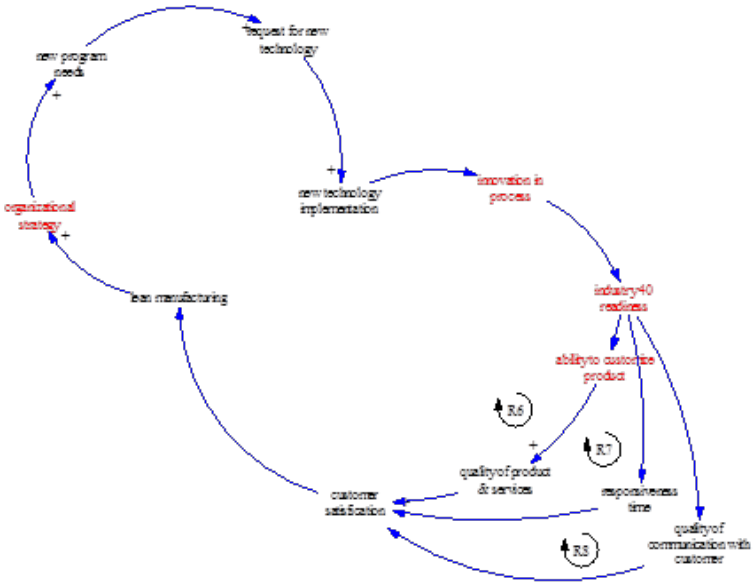


Loops R6, R7, R8 : Customer satisfaction – Lean Manufacturing

Figure 7 shows the higher the level of industry 4.0 readiness a company will be able to increase the level of customer satisfaction through the speed of customer response, product quality that is tailored to the wishes of the buyer, and the quality of communication with customers. Customer satisfaction is one of the focuses of lean manufacturing.

p-ISSN: 2477-3328
e-ISSN: 2615-1588

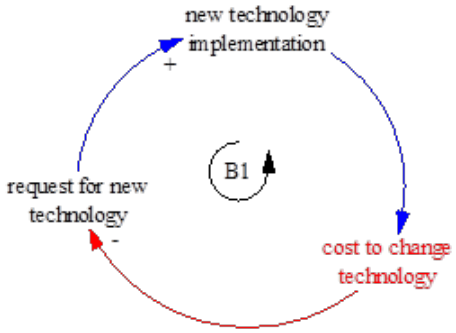
Figure 7. Customer Satisfaction – Lean Manufacture



Loop B1 : New technology requirement brings cost

Figure 8 shows that new technology will bring cost for its implementation and procurement, this cost calculation can affect a program will be continued or not.

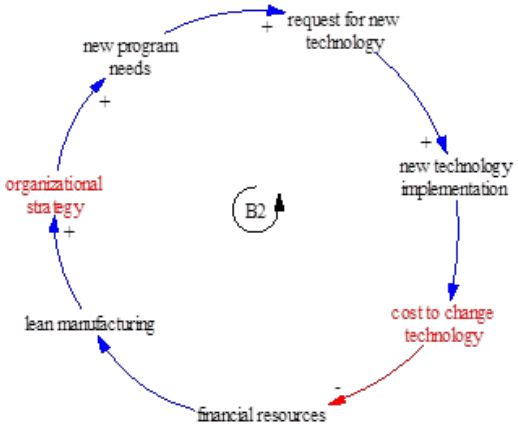
Figure 8. New technology brings cost loop



Loop B2 : Cost of new technology to financial resources

Figure 9 shows that changes in the organization that aim to make the company lean require implementation costs. Investments in new technology can reduce the company's financial resources.

Figure 9. Cost of new technology to financial resources loop



Understanding the Structure of System using System Diagram

System Diagrams describe a system as part of reality that is influenced by certain inputs which are called factors and produce a certain outcome. There are two input types as factors that influence the system uncontrollable by the problem owner, which are called external factors that can be intentionally influenced by the problem owner which is called policies (W. A. Thissen and W. E. Walker, 2013). According to the actor analysis and causal loop diagram above, the system diagram of this research can be illustrated in Figure 10. System diagram illustrates the problems faced by the government as a problem owner, while SMIs are stakeholders and objects to improve their competitiveness. Influential external factors are business competition, technology development, and innovation ecosystem.

Policy choices which can be used as a strategy for industry 4.0 implementation in Small and Medium Industries are socialization/education, technology financing, fiscal policy, assistance, and access to technology provider, vocational education, and success story. Policy option is described in the next section of this paper.

RESULT AND DISCUSSION

Based on the conceptual model above, there are some key variables which can determine the success of technology implementation in Small and Medium Industries as shown in Table 2.

p-ISSN: 2477-3328
e-ISSN: 2615-1588

Figure 10. System Diagram of Industry 4.0 Implementation with Lean Manufacturing Approach

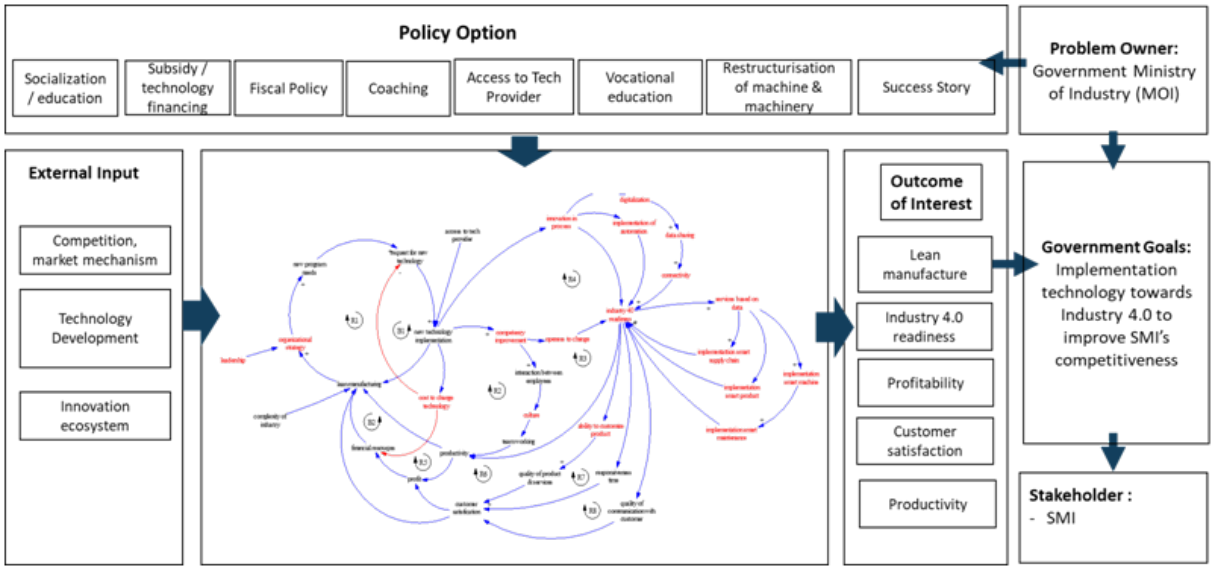


Table 2. Connection of Key Variables and Policy Option.

Key variables	Intervention Policy Options
Lean Manufacturing Index	Fiscal policy, coaching,
Readiness Industry 4.0 Index	Socialization / education, access to tech provider, success story, Fiscal Policy
Financial Resources	Technology financing / subsidy
Productivity	Vocational education, coaching, Restructuration of machine & machinery

These government interventions or policies proposed are as follows:

1. Fiscal Policy as Incentive of Small and Medium Industries

   As previously described, Small and Medium Industries are reluctant to change, so they require national and mass policies to encourage transformation with new technology. Fiscal policy which can be given as incentive is tax reduction for Small and Medium Industries. It can be tolerated since Small and Medium Industries invest for implementation of new technology.

2. Financing New Technology Implementation

   Consideration of Small and Medium Industries for being reluctant to use new technology is cost to implement technology, while effect of the technology implementation cannot be confirmed in accordance with the expected concept. Risk of finance loss can be borne by government partially or completely, so it can reduce the burden of Small and Medium Industries.

3. Machine Restructuration and Small and Medium Industries Equipment

   One of the implications from lean management implementation is the reduction of waste which may come from a highly manual process or machine which has been inadequate, so the government needs to prepare the subsidy scheme for purchasing new machine for Small and Medium Industries.

4. Socialization, education, and assistance

   In order to improve leadership in an organization to implement new technology, government needs to continuously perform socialization and education about benefit of industry 4.0

implementation to Small and Medium Industries. However, socialization and education must consider the lean manufacturing principle to be accepted better by Small and Medium Industries, since lean management principle is in accordance with the businessmen principle oriented to profit, customer satisfaction, and productivity. Besides socialization and education, government must also provide assistance program to Small and Medium Industries for analyzing lean management index, supporting organizational change, and defining new organizational strategy in line with implementation of new technology.

5. Access to technology provider

   Resource of Small and Medium Industries is not yet capable of building technology innovation itself because of the limitation of human resource. Therefore, Small and Medium Industries need to meet technology provider to bring solution as needed. Government can perform link and match, technology exhibition, and socialization of technology from provider.

6. Vocational education

   As mentioned above, human is an important factor for a technology to be accepted and implemented; without improvement of competence from labour, technology cannot be implemented well. Therefore, government needs to build vocational education adjusted to technology requirement for Small and Medium Industries; with availability of vocational labour, the cost for labour can be reduced.

CONCLUSION

Conceptual model shows the understanding of relation in the implementation of lean manufacturing principle in encouraging industry 4.0 implementation in Small and Medium Industries. Lean manufacturing is a reference for technology requirement in industry, so it still focuses on productivity, customer satisfaction, and capability of financial resource. Government can support implementation of industry 4.0 in Small and Medium Industries starting from leadership, organization orientation and culture, and human resource by socializing and educating Small and Medium Industries about lean management principle to stimulate requirement of technology for Small and Medium Industries, and funding for technology, subsidy, and fiscal incentive. Strategy policy taken by government needs to be implemented at once, so government target can be implemented more quickly and it is expected to bring positive effect to Small and Medium Industries and national economy.

REFERENCES

Liao, Y., Loures, E. R., Deschamps, F., Brezinski, G., & Venâncio, A. (2017). The impact of the fourth industrial Revolution: a cross-country/region comparison. *Production, 28, e20180061*. DOI: 10.1590/0103-6513.20180061.

Andreja Rojko (2017). Industry 4.0 Concept : Background and Overview. iJIM – Vol. 11, No. 5, 2017.

Ministry of Industry Republic (MOI) of Indonesia (2018). Achievement of the Industrial Sector Performance 2014-2017.

Central Bureau of Statistics Republic of Indonesia (2017). Economic Census 2016.

Ministry of Industry Republic Indonesia (2018). Making Indonesia 4.0.

Mohd Aiman Kamarul Bahrin. Mohd Fauzi Othman. Nor Hayati Nor Azli. Muhamad Farihin

p-ISSN: 2477-3328
e-ISSN: 2615-1588

Talib (2016). Industry 4.0 : A review on industrial automation and robotic. *Jurnal Teknologi (Sciences & Engineering) 78: 6-13 (2016) 137–143, 2016.*

J. M. Muller, Oana Buliga, K. Voight. Fortune Favors The Prepared : How SME Approach Business Model Innovations in Industry 4.0. *Technological Forecasting & Social Change 132 2-17, 2018.*

R. Mohrar, H. Arman, S. Mousa (2017). The Fourth Industrial Revolution (Industry 4.0) : A Social Innovation Prespective. *Technology Management Review November 2017(Vol7, issue 11).*

Shahroom, A. A., & Hussin, N. (2018). Industrial Revolution 4.0 and Education. *International Journal of Academic Research in Business and Social Sciences, 8(9), 314–319.*

C. Ciminil, G. Pezzotta, R. Pinto, S. Cavalieri (2018). Industry 4.0 Tehcnologies impacts in the manufacturing Supply chain Landscape : An Overview. *SOHOMA 2018, SCI 803, pp. 109–120, 2019. https://doi.org/10.1007/978-3-030-03003-2_8.*

Arnold, C., Kiel, D., Voigt, K.-I (2016). How Industry 4.0 changes business models in different manufacturing industries. *In: ISPIM Innovation Symposium. p. 1. The International Society for Professional Innovation Management (ISPIM)*

Kagermann, H., Helbig, J., Hellinger, A., Wahlster, W (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group.

Ministry of Industry Republic of Indonesia (2017). IKM Dalam Angka 2017.

Ogbuokiri, B.O.(MSc.), Udanor C.N. (PhD), Agu, M.N. (PhD). (2015) Implementing bigdata analytics for small and medium enterprise (SME) regional growth. *e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 17, Issue 6, Ver. IV (Nov – Dec. 2015), PP 35-43.*

Rose, A.M.N., Deros, B.Md., Rahman, M.N.Ab. & Nordin, N (2011). Lean manufacturing best practices in SMEs. *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management Kuala Lumpur, Malaysia, January 22 – 24, 2011*

Anthony, J. and Kumar, M.. (2005). Six sigma in small and medium sized UK manufacturing enterprises. *Int.journal of Quality and Reliability Management, 22(8), 60-874*

Ho, Thi Phuong Dung, (2018). Using system dynamics approach to examine the impact of ERP and Lean on manufacturing performance. *Proceedings of the International Conference on Industrial Engineering and Operations Management Paris, France, July 26-27, 2018*

Hasan Hosseini-Nasab, Mohammad Dehghani, and Amin Hosseini-Nasab (2013). Analysis of Technology effectiveness of Lean Manufacturing Using System Dynamics. *Hindawi Publishing Corporation ISRN Industrial Engineering Volume 2013, Article ID 237402, 10 pages*

Prahasta, Eddy (2018). System Thinking dan Pemodelan Sistem Dinamis. *Bandung. Penerbit Informatika*

Walker E. Warren (2000). Policy Analysis : A Systematic Approach to Supporting Policymaking in the Public Sector. *Journal of Multi-Criteria Decision Analysis 11-27*.

Ghaffarzadegan, Navid. Lyneis, John. Richardson George P (2010). How small system dynamics models can help the public policy process. *System Dynamics Review vol 27, No 1 (January–March 2011): 22–44*

W. A. . Thissen and W. E. Walker (2013). Public Policy Analysis: New Developments. *International Series in Operations Research & Management Science.*

J. D. Sterman (2000), Business Dynamics: System Thinking and Modeling for a Complex World. McGraw-Hill.