A Socio-Technical Approach to Assess Readiness of Organizations for Industry 4.0

M H Sitepu¹, A R Matondang¹ and M T Sembiring¹

¹Department of Industrial Engineering, Universitas Sumatera Utara, Medan, Indonesia

Email: mhd_haikalkarana@usu.ac.id

Abstract. Industry 4.0 is marked with technological advancements that change the way of interactions between human and machines, suppliers and producers, as well as customers and distributors. Digitalization, internet of things, big data and cloud computing are example of technologies used in Industry 4.0. Readiness assessment is needed to evaluate the existing condition of organizations. The information from this assessment is used to design strategy in adopting industry 4.0. This adoption requires modifications in all aspects of organizations including vision, culture, people (social aspects) as well as technology, process and infrastructure (technical aspects). Modifications in selected aspects only, for example, modification in technology and infrastructure aspects only, might lead to failure in adopting industry 4.0. To overcome this, systemic approach is needed to assess the readiness of organizations to adopt industry 4.0. This paper uses socio-technical framework and composite indicators to assess the readiness of organizations to adopt industry 4.0.

1. Introduction

A development in information and communication technology is marked with an appearance of digitalization, internet of things, big data and cloud computing. These technologies has revolutionized the industry that is coined as Industry Revolution 4.0. This revolution has changed the way of interactions between human and machines, suppliers and producers, as well as customers and distributors. For example, the emergence of internet of things has increased autonomous of machine by equipping the machine with sensors to detect alterations from surrounding. Furthermore, these sensors will generate big data that can be used to support decision related to production.

Technologies in industry 4.0 carry out positive impacts to organizations such as increasing productivity and upgrading communication and coordination vertically (within organization) and horizontally (between organization, supplier and customer). These positive impacts turn out to be competitive advantages of organization. Hence, to gain these, the adoption of industry 4.0 technologies is necessary. Similar with other technology adoption, the adoption of industry 4.0 needs a strategy for adoption. To formulate this strategy, an evaluation of existing condition of organizations is needed. The readiness assessment tool is required to evaluate the existing condition. According to Mittal et al. [1], readiness assessment is the evaluation tool to investigate the level of preparedness of the system required to pursue its goal. In this context, the goal is the integration of industry 4.0 technologies and principles in organization. Several researchers and academics proposed...
readiness assessment tools that consist of different dimensions and indicators. For example, Blanco et al. [2] proposed the readiness model using two indicators including industry 4.0 infrastructure maturity and big data maturity. Based on these indicators, they divide the manufacturing company into five clusters: Leaders, Industry 4.0 infrastructure, Big data maturity, Laggards and Average. Jung et al. [3] developed smart manufacturing system readiness assessment that focused to evaluate organizational maturity, information technology maturity, performance management maturity, and information connectivity maturity. Gurdur et al. [4] used readiness model developed by Acatech Industry to evaluate the readiness of Swedish Industry. This model consists of four dimension including resource readiness, cultural readiness, organizational readiness, and information system readiness.

However, the adoption of industry 4.0 requires modifications in all aspects of organizations including vision, culture and people (social aspects) as well as technology, process and infrastructures. Modifications in selected aspects only, for example, modification in technology and infrastructure only without modification in people, might lead to failure in adopting industry 4.0. Hence, the readiness assessment must include social and technical aspects of organization. Nevertheless, there is no readiness assessment tool in literature includes the complete technical and social aspects of organization. For example, Schumacher et al. [5] proposed the readiness tool with focused to evaluate nine dimensions including: strategy, leadership, customers, products, operations, culture, people, governance and technology. Infrastructure dimension is not included in their model, although industry 4.0 requires good information and communication infrastructure to achieve interoperability, interconnectivity and virtualization. This paper proposes the use of socio-technical system thinking and composite indicators to assess the readiness of organizations in adopting industry 4.0.

This paper consists of four sections. In section two, socio-technical system thinking and composite indicators are presented as research method. This is followed by section three that focused to explain the architecture of proposed readiness assessment tool, which consists of socio-technical framework, composite indicators and readiness level. Finally, in section four, the limitations of tool and possibility for future research are discussed.

2. Research Methods
This research has an objective to develop the readiness assessment method for evaluating the readiness of organizations in adopting industry 4.0 technologies. To achieve this objective, socio technical system thinking and composite indicators are used as research method. This section explains the concept socio technical system thinking and composite indicators as well as their applications in recent research.

2.1. Socio Technical System Thinking
The concept of socio technical system thinking emerges while human started to use machinery to support their activities. In the beginning, this concept focused to observe the connection between technological aspects and social aspects in the workplace. Then, the focused of this concept evolves to include wider scope of the system such as industry supply network. Moreover, although this concept originated in social sciences, it has been used by people across disciplines such as engineering, psychology and information technology. With the emerging of industry 4.0 technologies that affect significantly the social aspects, the demand of socio-technical system for analyzing this effect is getting bigger.

The concept of socio technical started to grow when Cherns (1976) emphasized the transformation of organization that needs to consider technological and social factors [6]. Then, in 2000, Clegg [6] introduced socio-technical principle. He argued that the organization consists of interdependent components, hence, the transformation in this organization need to consider the effects to these components, which he called “Design is systemic”. To describe the relationship between technological and social aspects in organizations, Matthew et al. [7] introduced socio-technical framework that
consists of three external factors and six internal factors. There external factors have been identified to influence the connection between technological and social aspects including regulation, financial circumstances and stakeholders. The internal of organizations can be categorized into three technological aspects: technology, infrastructure, procedure, and three social aspects: goal, people and culture. This paper uses this framework as part of the approach to assess the readiness of organizations in adopting industry 4.0. Figure 1 shows the socio-technical framework.

Figure 1. Socio-Technical Framework (adapted from [7])

2.2. Composite Indicators
Composite indicators are a method to generate single performance indicator, which is aggregated from multiple indicators value. To evaluate the performance of organization, several indicators might be required. This will generate different indicators’ value. However, to avoid the confusion about which indicator’s value is used to represent the performance, single performance indicator is required to describe the overall performance of organizations. Composite indicators have been used to support the performance assessment in different sectors. For example, Tajbakh and Hassini [8] proposed composite indicators to generate sustainability performance in supply network sector, Areal and Riesgo [9] used this method to generate environmental impacts of different crops in agricultural sector, and Badea et al. [10] used composite indicators to calculate security of energy supply. The application of composite indicators to support the assessment of the readiness for industry 4.0 adoption is not found in literature. Composite indicators method consists of three main steps including normalization, weighting and aggregating [11]. Normalization is needed when indicators are measured using different measurement units. Normalization is used to transform indicators values with different measurement units into uniform unit. Then, at weighting step, weight is assigned to each of indicators. This weight is used to reflect the importance level of indicator. This is followed by aggregating step that is performed to generate single performance value from different indicators values. This paper uses composite indicators method as part of approach to assess the readiness of organization for industry 4.0 adoption.

3. System Architecture of the Approach for Assessing the Readiness of Industry 4.0 Adoption
System Architecture displays the connection between methods used for assessing the readiness of organization to adopt industry 4.0. The approach consists of three methods including socio-technical framework, composite indicators and readiness level. Each element in socio-technical framework is applied as indicator to evaluate the existing condition of organization. For example, element goal is used
There is no regulation related industry 4.0
There is general regulation related industry 4.0
There is general and specific regulation for limited sector
There is general regulation and specific regulation for all sectors

Figure 3. Scale for Regulation Indicator
3.1.2. Economic/ Financial Situation. The adoption of Industry 4.0 requires extensive capital particularly for modification technical aspects such as improving technologies and infrastructures. Economic situation influences the ability of financial institution to support investment in adopting industry 4.0. Figure 4 displays scale for Economic/Financial Situation indicator.

![Figure 4. Scale for Economic/Financial Situation Indicator](image)

3.1.3. Stakeholders. Stakeholders play important role to push the adoption of industry 4.0. Two important characteristics in this indicator are commitment from related stakeholders to support industry 4.0 and the application of supports. If related stakeholders have had good commitment and have applied the support to adopt industry 4.0, the readiness of organization might increase. Figure 5 presents scale for stakeholders’ indicator.

![Figure 5. Scale for Stakeholders](image)

3.1.4. Goals. This indicator reflects a vision of organization and a desire from top management in adopting industry 4.0. Organization that includes the adoption of industry 4.0 in its vision will have better readiness level particularly if this organization has translated its vision into strategic and operational plan. Figure 6 displays scale for goals indicator.

![Figure 6. Scale for Goals Indicator](image)
3.1.5. **People.** People reflect human resources within the organization. People have responsibility to do several tasks with the help of technologies. The adoption of industry 4.0 requires an adaptation from human resources towards new technologies, which will change the way to do the tasks. Since, industry 4.0 lies on the development of information and communication technology, the ability of people to adapt with industry 4.0 is mainly influenced by the knowledge and skill related to information and communication technology. Figure 7 shows scale for people indicator.

![Figure 7. Scale for People Indicator](image)

- The employees have no awareness and knowledge related industry 4.0
- The employee have no skill and knowledge to use information and communication technology
- The employees have limited awareness and knowledge related industry 4.0
- The employee have limited skill and knowledge to use information and communication technology
- The employees have average awareness and knowledge related industry 4.0
- The employee have average skill and knowledge to use information and communication technology
- The employees have good awareness and knowledge related industry 4.0
- The employee have good skill and knowledge to use information and communication technology

3.1.6. **Culture.** Culture reflects the behaviors of people in organizations. Two important behaviors have been identified as influential factors including the openness for innovation and new technologies and resistance to change. Industry 4.0 consists of new technologies such as internet of things and virtual reality. These technologies require people to change the way of interaction with machine, suppliers and customers. Figure 8 presents scale for culture indicator.

![Figure 8. Scale for Culture Indicator](image)

- The employees are not open for innovation
- Resistance to change
- Some of the employees are not open for innovation
- Resistance to change
- All the employees are open for innovation
- Some of employees still resistance to change
- All the employees are open for innovation
- No resistance to change

3.1.7. **Infrastructure.** The adoption of industry 4.0 requires good infrastructure for sharing information and communicating between people within organization. Information and communication network such as fibre cable, local area network, wireless connection is example of infrastructure. The organization with good infrastructure that has connected all areas within the organization will be ready for industry 4.0 that requires the connection between all parts in organization. Figure 9 displays scale for infrastructure.
3.1.8. Technology. Industry 4.0 brings new technologies that are based on information and communication technologies. For example, internet of things used information and communication network to link between machines and between machines to people. As a result, information and communication technologies play important role in adopting industry 4.0. Figure 10 presents scale for technology indicator.

3.1.9. Process. This indicator reflects the procedure for performing tasks within organizations. Three important characteristics to support the adoption of industry 4.0 are the availability of standard operating procedure, digitalization data and information, and the use of data to support decision making. Figure 11 displays scale for process indicator.

3.2. Composite Indicators for Generating Readiness Index
Composite indicators method is used to calculate readiness index from the scores produced by socio-technical analysis. There are two important steps of composite indicators method including weighting and aggregating. Weighting is used to assign the importance level for each indicator used for assessing the readiness. Then, aggregating is applied to generate single index from value of indicators. Equal weighting is used for assigning the importance of indicators. This method assigns similar weight for all indicators. This method is used when there is no indicator requiring prioritisation. Linier aggregation
method is used to generate readiness index from the value of indicators. The formulation of linear aggregation method is presented by equation 1.

\[ I_{\text{Readiness}} = \sum_{i=1}^{9} M_i \cdot w_i \]

\[ \sum_{i=1}^{9} w_i = 1 \]

\[ w_i > 0 \] (1)

3.3. Readiness Level

Readiness level describes the preparedness of organization in adopting industry 4.0. This research introduces readiness level that consists of four quadrants. First quadrant in readiness level reflects organizations with low preparedness for adopting industry 4.0. This is characterized by low score in social and technical aspects. Second quadrant and third quadrant reflect organizations with average preparedness level. This quadrant is characterized by medium score in social aspect or technical aspect. Second quadrant is categorized as social dominant. The organization in this quadrant shows good condition in social aspects but having poor condition in technical aspects. In contrast, third quadrant is classified as technical dominant. The organization in this quadrant displays good technical aspects and poor social aspects. Finally, fourth quadrant reflects organizations with high preparedness for adopting industry 4.0. The organization in this quadrant has good condition of social and technical aspects. Figure 12 presents readiness level of organization for adopting industry 4.0.

![Figure 12. Readiness Level of Organization for Adopting Industry 4.0](image)

4. Conclusion and Possibility for Future Research

4.1. Conclusion

Based on the results, some conclusions are obtained as follows.

- The adoption of industry 4.0 requires modification in social and technical aspects within
This paper demonstrates the use of socio-technical analysis and composite indicators method as approach for evaluating the readiness of organization to adopt industry 4.0.

This paper presents the scale and characteristics for each indicator used for evaluating the readiness of organization to adopt industry 4.0.

4.2. Possibility for Future Research

Based on the analysis of reviewed papers several possibility for future research are identified:

- Future research is required to apply the approach for assessing the readiness of organization in adopting industry 4.0.
- Due to different culture and people characteristics, future research is required to evaluate the scale and characteristics for each indicator for implementing the approach to evaluate the readiness of organization in other countries.

5. References

[1] Mittal S, Khan M A, Romero D and Wuest T 2018 A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs) J. Manuf. Syst. 49 194–214

[2] Castelo-Branco I, Cruz-Jesus F and Oliveira T 2019 Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union Comput. Ind. 107 22–32

[3] Jung K, Kulvatunyou B, Choi S and Brundage M P 2016 An Overview of a Smart Manufacturing System Readiness Assessment (Springer, Cham) pp 705–12

[4] Gürdü D, El-khoury J and Törngren M 2019 Digitalizing Swedish industry: What is next?: Data analytics readiness assessment of Swedish industry, according to survey results Comput. Ind. 105 153–63

[5] Schumacher A, Erol S and Sihn W 2016 A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises Procedia CIRP 52 161–6

[6] Clegg C W 2000 Sociotechnical principles for system design Appl. Ergon. 31 463–77

[7] Davis M C, Challenger R, Jayewardene D N W and Clegg C W 2014 Advancing socio-technical systems thinking: A call for bravery Appl. Ergon. 45 171–80

[8] Tajbakhsh A and Hassini E 2014 A data envelopment analysis approach to evaluate sustainability in supply chain networks J. Clean. Prod.

[9] Areal F J and Riesgo L 2015 Probability functions to build composite indicators: A methodology to measure environmental impacts of genetically modified crops Ecol. Indic. 52 498–516

[10] Badea A C, Rocco S, C M, Tarantola S and Bolado R 2011 Composite indicators for security of energy supply using ordered weighted averaging Reliab. Eng. Syst. Saf. 96 651–62

[11] Zhou P, Fan L-W and Zhou D-Q 2010 Data aggregation in constructing composite indicators: A perspective of information loss Expert Syst. Appl. 37 360–5