The Application of TRIZ in The Development of Readiness Assessment Model for The Malaysian Industry4WRD Program

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Abstract. The global industrial revolution has become a major concern for most organizations in the effort to innovate and improve towards competitiveness and sustainability. This initiative has been considered as a disruptive change in manufacturing and also services. Many countries have taken proactive action to learn and adopt the concept of Industry 4.0 in order to be at the front edge of transformation. However, various countries and government agencies are trying to support the local industries with limited knowledge and resources, especially in developing countries such as Malaysia. This paper focuses on the challenges in developing the Industry 4.0 readiness assessment model by adopting innovative methodology called TRIZ. This model is useful in helping the Malaysian government agencies to guide and facilitate the transformation program of Industry 4.0 that has been given a new brand name which is Industry4WRD. The Malaysian industries are able to identify the gaps within the organization and the benchmark with the best practiced Industry 4.0 company by using the readiness assessment tools that have been developed from the research. TRIZ has been the core concept of the readiness assessment model and has also effectively shown result from a case study that is presented in this paper.

1. Introduction

The industrial revolution has evolved across several phases by adopting the technological elements that are impactful on business and improving process performance. Nowadays, digitalization has become an emerging technological element for Industry 4.0 for organization to take a leap forward in the highly competitive market [1]. This revolutionizes on how things are done traditionally and eliminates barriers in business and processes. It connects people from different countries with a minimal cost, improves management of processes to be faster, better and cheaper, and empowers organizations to execute various complex tasks with robotic system. With all the benefits and advantages, it influences the productivity of organization and people in order to create value and produce greater impact on economy, social and well-being [2].

In different perspectives, the disruption creates concerns on how things change for employability, job security and source of income for people [3]. The extreme assumption goes beyond the boundary of full automation and artificial intelligence system that will take away all the job function of manpower [4]. This is not entirely correct because it depends on how we are able to manage the transformation of
Industry 4.0 in clear and positive directions [5]. Several countries are taking steps towards embracing the concept of Industry 4.0 in developing local industries. The government is preparing the policy and guidelines to assist industries to grasp the opportunity from Industry 4.0 technologies and to improve their productivity and business performances [6]. The Industry 4.0 has the potential to improve the business performance at the global level with a greater impact. In the developing countries such as Malaysia, the desire to innovate and to grow aligned with the digital revolution and it is very much critical among ASEAN countries [7]. In Malaysia, the manufacturing sectors are still significant to the contribution of Malaysia income generators and by having Industry 4.0 as a catalyst, it is capable of boosting the growth of GDP of the country with a strategic and clear focus of direction [8].

The development of readiness for all stakeholders is critical to ensure that the sustainability of the ecosystem really creates effective impacts [9]. This requires support to explore and identify the level of readiness towards the performance of the Industry 4.0. One of the common elements used for the stakeholders to apply and quantify the level of readiness is using innovation or transformation indexes that show one level of improvement to another higher level of Industry 4.0 performance [10]. The indexes are useful in guiding the stakeholders for the purpose to understand the current level in the adoption of Industry 4.0 concept and determining the next level to focus on. TRIZ, a Russian acronym for teoriya resheniya izobretatelskikh zadatch of which the English equivalent is the “Theory of Inventive Problem Solving”, is chosen as the fundamental concept of innovation in development of the Industry 4.0 indexes [11]. The critical application of TRIZ for this research is an outcome of the concept of forecasting function on technological and non-technological system innovation [12][13]. The concept is strategically used by the international innovative companies, including Samsung, Huawei, etc. [14].

2. The application of TRIZ for industrial system innovation and Industry 4.0

TRIZ is a methodology used to aid the innovation process in the effort to make it more efficient through a systematic approach. The methodology is originated from Russia by the TRIZ founder, Genrich Altshuller in 1946. The inspiration of constructing the TRIZ methodology started during Altshuller’s assignment into World War 2 as a naval officer who was in charge of managing patented technologies. He introduced three concepts of innovation based on the observation of patented database. One of the concepts is using the database to develop a predictive model for the next innovation of technology evolution. The predictive model shows repeated trends of technological evolution across industries and applications [15]. The strategic abilities of the technology forecasting have the capability to help military engineers in moving on a faster pace in terms of technology advancement and easier methodology to innovate specific technology faster by using TRIZ [11].

As Altshuller focused on improving and perfecting the TRIZ methodology on technology forecasting, he produced a tool namely the Trends of Engineering System Evolution (TESE). There is a total of nine recommended specific trends in improving the value of engineering system, as shown in Figure 1. The trends contribute to the improvement of the system or technology value and pushing the innovation forward against other competitors. The core evolution of TRIZ engineering system evolution is the S-curve phases, which are the infant phase, growth phase, maturity phase and decline phase. Each phase carries different values and it has become the parameter to innovate the targeted engineering system [16].
Figure 1. Trends of engineering system evolution [17]

Figure 2 shows one example of the trends, called the Trend of increasing degree of trimming [17]. There are 4 main phases of system evolution for this trend. The first phase is to trim or take out the element or the system which has the role of transmission. The definition of transmission in this trend refers to the mechanism of certain tools, equipment and machineries that are not replaced throughout the year and holds key limitation to innovate. The second phase is to trim or take out the element that associates with the energy source that is critical within the system itself. This strategy looks forward in terms of sharing the energy source, infrastructure and facilities, instead of generating the energy by our own. The third phase focuses on trimming or taking out the control of processes element. The control should evolve and dynamically expand beyond the boundaries of traditional method and system. The final phase is to take out the element of intelligence from the system and try to upscale the function of decision making and action taking towards a self-control condition. In our research focus, all phases are imposed to develop the transition index of industry 4.0.

Figure 2. Trend of increasing degree of trimming for industrial system innovation

Adopting the conceptual trend of increasing degree of trimming, the core components will be innovated and improved according to the recommended direction of the trend [18]. Figure 3 shows the proposed of the adoption of trends in a common industrial system. The initial condition starts with a high dependency of human function in an industrial manufacturing condition. The transmission used by human is based on their strength of muscle to manufacture their product accordingly. Then the transmission functions from human are systematically transferred into a tool. The tools are capable of speeding up the manufacturing process and require less effort from human. Then the innovation will focus on the tool functionality, shapes and forms. For example, the tools innovated from the non-digital to the digital system. The digital tool is able to innovate further into a few new and complex functions such as data gathering, storing, management, analysis and calculations. This will complement some
critical functions and limitations of human workers that relate to the manufacturing processes, such as human errors, miscommunication, forgetfulness, delivering the wrong information, etc. The significant technology of industry 4.0 in the industrial system at the digital level involves big data analytics.

![Diagram of industrial system stages]

**Figure 3.** Proposed transition of industrial system using the trend of increasing degree of trimming

Then, the innovation on the tools had been pushed to another level where it utilized new field of energy for communication functions, such as the Wi-Fi, internet or frequency. The tools can be connected through a specific network with other systems such as human, other tools, equipment, facilities or at the enterprise level. The connectivity is reliable and consistent regardless of the time and place, as human tends to have difficulty to perform well in a normal industrial condition. The intra-system connectivity changes how manufacturing controls the industrial components. Manufacturing operation can be controlled through the cyber-physical concept by using wireless mode to disrupt the concept of traditional manufacturing system.

The highest innovation level according to the trend followed is the function of intelligence in the industrial system [19]. This focuses on the decision-making element within the industrial system as well as the external systems that change the manufacturing processes. The system is capable of providing feedbacks, highlighting, recommending and taking necessary action on any abnormality coming from the operation. The intelligence function is able to complement human function with less intervention from human workers and management level [20]. Each transition of the industrial system evolution focus will always be value driven towards a better, cheaper and faster manufacturing performance. Beyond the followed trend, TRIZ is able to offer the rest of the 8 trends of engineering system evolution together with the sub trends in order to push to another S-curve of innovation. Therefore, the innovation capability is unlimited for industrial system using the systematic TRIZ methodology.

3. The adoption of TRIZ innovation concept in Industry4WRD model and indexes

In the previous section, the industrial system innovation and evolution have been established and supported by the TRIZ methodology [21]. This proven concept has been taken in to develop a model and indexes for the INDUSTRY4WRD readiness assessment tools. The first concept taken from TRIZ is at the system level;

1. The external system of existing industrial system, known as super-system,
2. The existing industrial system, which refers to system, and
3. The internal industrial system, which is defined as the sub-system
The system level concept that is generic to all industrial systems will relate the system of manufacturing operation at facility level, while the sub-system will associate with the shop floor and the super-system will refer to the enterprise level, as shown in Figure 4.

The system levels based on TRIZ concept shows the vertical setting of an industrial system in a company. This requires a critical element of horizontal integration between systems, based on Industry 4.0 critical areas, especially in Malaysia. Looking at a bigger picture, Industry 4.0 would allow Malaysia’s manufacturing industry to remain pertinent and competitive in a global landscape where changes occur rapidly [22]. It is hoped that the Malaysian-based organizations which adopt the Industry 4.0 would ultimately increase the national productivity, create higher skill and job employment opportunities, raise innovation capabilities and competitiveness; and drive ceaseless growth in the Manufacturing Gross Domestic Product (GDP).

To bolster this, the Ministry of International Trade and Industry (MITI) has crafted the National Industry 4.0 Policy Framework to provide a concerted and comprehensive transformation agenda for the manufacturing sectors in Malaysia [23]. The policy highlights five national strategies which cover funding, infrastructure, regulations, skills and talent; and technologies; and it aims at attracting stakeholders towards the Industry 4.0 technologies and processes and elevating Malaysia’s attractiveness as a preferred manufacturing location. It is expected that this policy will create the right ecosystem for Industry 4.0 to be adopted and would align the existing and future development initiatives; ultimately transforming Malaysia’s manufacturing capabilities in a holistic and an accelerated manner [24]. One of the action plans under the national strategy for regulation is to create the tools and processes to help manufacturing firms assess their capabilities and readiness in adopting the Industry 4.0 technologies and processes [23]. Thus, this document was specifically developed to support the action plan. By undergoing this assessment, it is hoped that organizations are able to acknowledge their present capabilities, their state of readiness in adopting Industry 4.0, as well as understand what is needed to initiate the Industry 4.0 transformation and recognize what the Industry 4.0 best practices are.

The global manufacturing sectors are facing new challenges due to the recent disruptive mega trends on the digital industrialization. The challenges needed to be embraced by the manufacturing organization will be on the digital transformation in the overall value-chain processes. The organization should have connection agility in their business processes and will need to explore opportunity from the innovation to the operation and the supply chain [25]. The manufacturer needs to understand their current condition by assessing their resources and potential in initiating their adoption of the fourth industrial revolution concept [26]. Assessment models are common in measuring the maturity and readiness level of an organization in relation to the fourth industrial revolution state. The assessment model goal is to capture
the baseline and to allow for further development. Regarding the domain of manufacturing sector, the following models and critical areas for assessing readiness or maturity have been published in Table 1.

| Main critical areas | Descriptions | Sub areas | Source |
|---------------------|--------------|-----------|--------|
| Technology          | The application of technological element in improving the manufacturing function | Autonomous | Fragapane et al. [27] |
|                     |              | Connectivity | Maynard [28] |
|                     |              | Intelligence | Posada et al. [29] |
| Process             | The transformation of existing processes from vertical-horizontal perspectives and the impact to product lifecycle | Vertical operation | Pérez-Lara et al. [30] |
|                     |              | Horizontal supply chain | Sun et al. [31] |
|                     |              | Product lifecycle | Stock and Seliger [22] |
| Organization        | The driving element from human capital perspective for the improvement and enhancement towards adopting changes for the organization level | Talent | Jones and Paitoon [32] |
|                     |              | Leadership | Li et al. [26] |
|                     |              | Strategy | Prisecaru [33] |
|                     |              | Management | Saniee et al. [34] |

The concept of developing industrial system is applied in other indexes in the readiness model and aligned with the focus on Industry 4.0 goals. The application of TRIZ industrial system development shows that it is capable of complementing the non-technological areas such as the shift factors process and also people [35]. This expands the functions and contributions of TRIZ beyond the boundaries of product innovation yet bringing an impact onto the process and people innovation development [36]. Figure 7 shows the applied case study of readiness assessment at the aerospace manufacturing plant. The machine is called Autoclave is used to provide heat treatment to the composite product. There are several machines that need some support and control in terms of coordination and maintenance. The machine already reached index number 2 because the machine used programmable logic control (PLC) system which is in digital form and carries function to inform the status of machine operability. This is a diagnostic function that already available in the Autoclave machine. From the assessment, we able to identify potential improvement needed by the system such as machine-to-machine communication and process optimization between autoclave machines. Another potential area of improvement is the predictive or adaptive model to see through potential areas for improvement of industry 4.0 [37].

Figure 7. Case study of shop floor intelligence system at aerospace’s component manufacturing plant

4. Conclusions
The concept of Industry 4.0 has played a big role in influencing the organizations and the government entities and functions as a platform to uplift the level of industrial performance. The main focus is to explore the opportunities and risks in adopting Industry 4.0 at the organizational level. In Malaysia, the
government is critical about the concept of Industry 4.0 in creating impact on the industries performance and national economic growth. As discussed, the significant challenge is to obtain comprehensive information on the value of Industry 4.0 and the know-how in order to successfully execute the goals of the industrial system innovation. This research introduced TRIZ methodology that utilized the Trends of Engineering System Evolution as a foundation in the industrial system development towards the Industry 4.0 performance. By integrating the TRIZ concept of system level for industrial systems and horizontal of industrial focus areas (people, process and technology), a model of Industry 4.0 readiness assessment tool was produced. The trend of increasing degree of trimming has been selected in order to explain how the TRIZ concept is applied in developing the Malaysian Industry4WRD model and indexes. This study potentially serves as a reference in expanding towards developing the intervention strategies of the industrial system improvement in the indexes. This study has the potential to provide significant to extended areas of research, such as manufacturing related services (MRS). The support gained from the intervention tool will strengthen the readiness assessment tools and create substantial impacts on the organization development towards embracing the Industry 4.0.

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