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Guidelines for Introducing Industrial Robots to Replace Manufacturing Workforce to Enhance Competitiveness in the Digital Era

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Abstract

Industrial robots have replaced manufacturing labor efficiently, improving production processes and technology, enhancing competitiveness, and creating opportunities to reduce labor costs, production time, and increase product quality. This research aims to develop a structural equation model for the effective substitution of manufacturing labor with industrial robots using mixed methodology research. Qualitative data from 9 experts and 11 successful businesspersons were used to refine the model, while quantitative data from 500 industrial sector managers with granted patents were analyzed through descriptive, inferential, and multivariate tests. The research found that the components of an effective problem-solving approach include 1) Production potential (= 4.15), emphasizing suitable technology and innovation evaluation, 2) Industrial readiness (= 4.10), stressing clear organizational vision and production policy, 3)Integration of cooperation(= 4.07), highlighting collaboration for knowledge exchange, and 4) Government Policies and promotions (= 4.04), emphasizing compliance with government policies. Hypothesis testing found no significant difference between medium and large businesses in adopting industrial robots as labor substitutes in production. The model met evaluation standards and empirical data consistency, indicating strong potential for application (chi-square probability = 0.079, chi-square coefficient = 1.130, congruence coefficient = 0.956, root mean square deviation index = 0.016).

Keywords: *Structural Equation Modeling, Industrial Robots, Manufacturing, and labor.*

Introduction

Introducing industrial robots to replace manufacturing labor for enhancing competitiveness in the digital era is a crucial initiative that should be expedited to support businesses of both medium and large sizes in developing the industrial sector. By deploying industrial robots to replace manufacturing labor, this approach aims to address labor shortages, reduce production costs, and advance Thailand's industrial landscape towards a developed nation status through innovation and technology. This endeavor is envisioned to foster competitiveness and sustainable economic growth.

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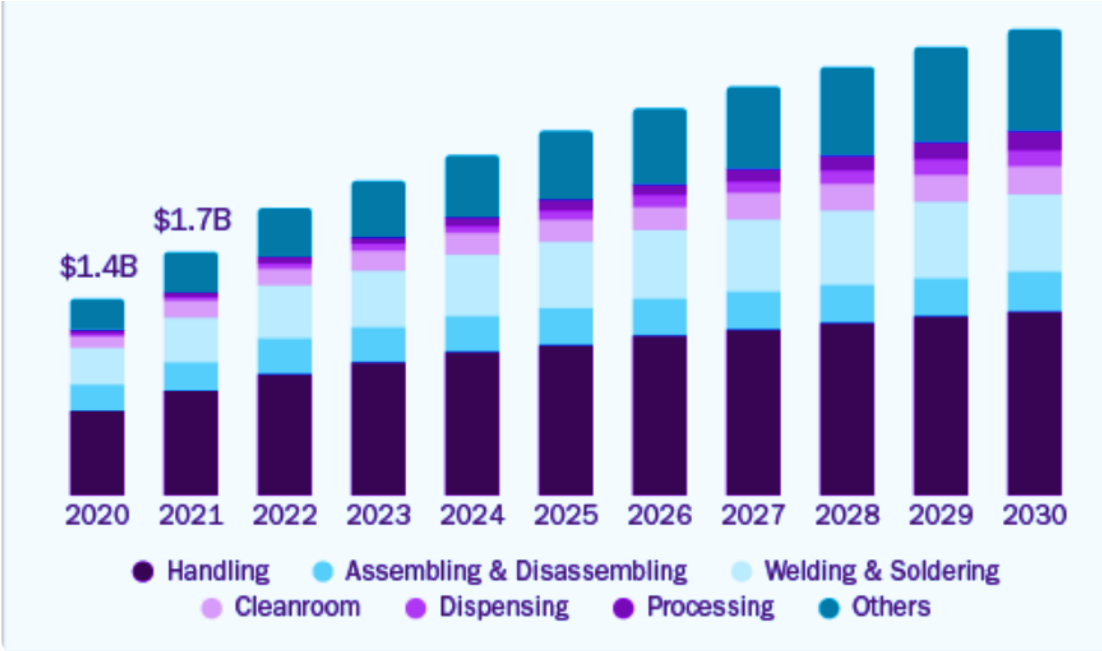

Figure 1 Forecasting the global industrial robotics market size 2023 -2030. (Region,2021)

Within the framework of the Thai population, where the working-age population is decreasing, birth rates are declining, and the country is moving towards a complete aging population, there are several challenges. These challenges include labor shortages, increasing labor costs, and limited income growth in the face of high competition. All these issues have a significant impact on the country's manufacturing industry. To alleviate these challenges, industrial robots have emerged as one of the options for industry operators to adapt to the changing socio-economic landscape. Industrial robots not only have the potential to replace human labor but also allow operators to control the quality and quantity of production. From Figure 1, it illustrates the future trend of incorporating robotics in the industrial sector.(Region,2021) However, the introduction of robots may have implications for the workforce, including changes in skill requirements and potential unemployment in certain labor sectors.

Therefore, addressing these issues requires collaboration between the government and the private sector in terms of labor training and workforce skill development. This will ensure that the existing workforce in the industrial sector becomes highly productive and adaptable to the changes occurring in the new era of manufacturing, characterized by the integration of new technologies into organizations. Efficient management and services will be crucial factors in mitigating the impact on the workforce. In the foreseeable future, it is anticipated that the use of robots and automation technology will play a significant role in the Thai industrial sector, as well as in other countries with similar industrial conditions to Thailand. They will become a key factor in driving the country's manufacturing industry towards becoming a modernized and developed industry, encompassing advanced production technologies and a highly productive workforce.

Theoretical Framework

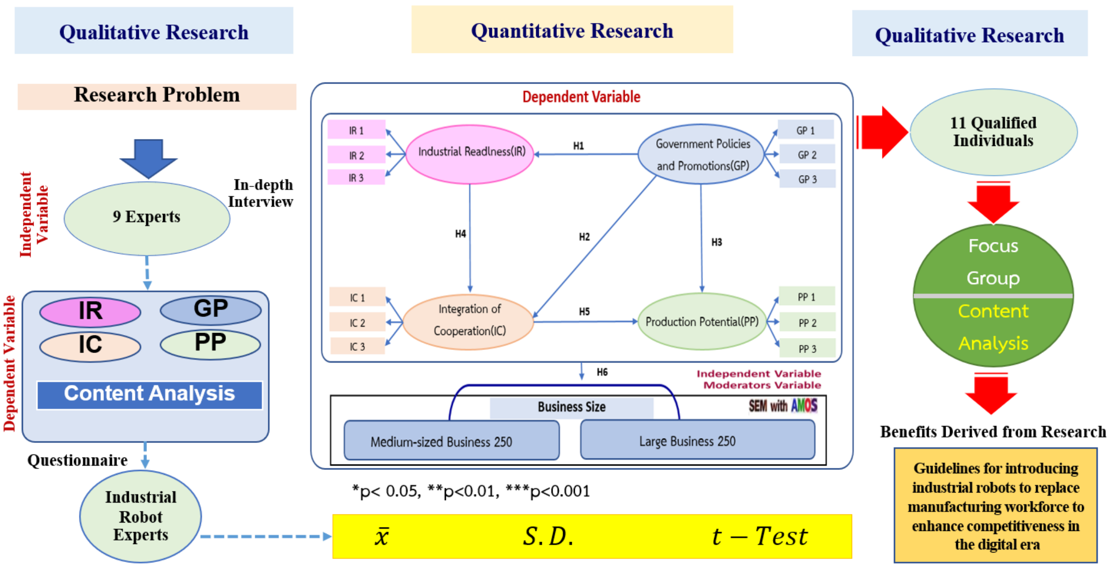

Figure 2 Theoretical Framework of the Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era

Methodology

This research is an inductive research that includes a mixed research approach consisting of 3 parts: qualitative research using in-depth interview techniques, quantitative research using survey data collection methods, and qualitative research using focus group discussion techniques to confirm the validity of the research model

The population used in the qualitative research consists of 9 experts from industrial organizations(Gabaldón-Estevan et al., 2018) that utilize robotics in their manufacturing processes, academics, and individuals from government agencies and related organizations. Clear criteria for the qualifications of these experts were established.On the other hand, the population used in the quantitative research for this study is derived from a total of 7,774 business operators in the industrial sector (Department of Industrial Factories, 2022). The study classified large-scale industrial businesses, which employ more than 200 workers, and medium-sized businesses, which employ more than 50 but not exceeding 200 workers, in accordance with the regulations set. (Ministry of Industry, 2002).

The sample size for this study was determined by applying research criteria involving component analysis and structural equation modeling. This resulted in a substantial sample size of 500 participants (Silpcharu, 2020). The sampling method employed a multi-stage approach, which included a cluster sampling stage. Industrial businesses were classified into two categories based on size: medium-sized and large-scale. Probability sampling was implemented using a lottery method to ensure random sample selection, and data were subsequently collected from the selected sample groups.The qualitative research, using the focus group discussion technique to validate the model, was conducted with a sample population of 11 highly qualified individuals. The purposive sampling method was employed to select the sample group with purposive sampling.

Research Objective

1. To study the structure and operational characteristics of the manufacturing industry sector.

2. To examine the components of the guidelines for introducing industrial robots to replace labor in the manufacturing sector to enhance competitiveness in the digital age.

3.To develop a structural equation model of the guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era.

Hypotheses

H1: Government Policies and Promotions directly influences Industrial Readiness

H2: Government Policies and Promotions directly influencesIntegration of Cooperation

H3: Government Policies and Promotions directly influences Production Potential

H4: Industrial Readiness directly influences Integration of Cooperation

H5: Integration of Cooperation directly influences Production Potential

H6: The level of importance of Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era does not differ significantly when categorized by business size.

Research Instrument

The research tools used in this study were categorized into two types based on their characteristics. Qualitative research employed a structured in-depth interview as its instrument, while quantitative research utilized a questionnaire. The Index of Item-Objective Congruence was employed to assess the alignment of questions with the study objectives. A trial involving 30 participants with similar characteristics to the study population was conducted. Data analysis included calculating discrimination values for each question on the questionnaire, as well as standard deviation. Correlation, reliability, and Cronbach's alpha values were determined for the rating scale questions using the SPSS software. For this study, the questionnaire demonstrated discrimination values ranging from 0.47 to 2.60 and a reliability value of 0.98. For qualitative research involving focus group interviews, a conversation recording form served as the research instrument.

Statistics for data analysis

For the qualitative research, content analysis was conducted to analyse data from the in-depth interviews. For the quantitative research in this study, descriptive, inference, and multivariate statistics were analysed using the SPSS (Jiamwattanapong et al., 2023).and Analysis of Moment Structure (AMOS) programs. The structural equation model was analysed for the related statistics data and the research hypothesis testing interpretation regarding inference and multivariate statistics. The adaptation of latent variables was performed by modifying an observed variable to align with the empirical evidence by the criteria, using a variable from a five-point rating scale question from the data collected by the researchers. First, the researchers modified the model by considering the modification index value. Then, the model was recalculated until the structural equation model was complete and aligned with the empirical evidence. There were four values in the assessment of congruence of the data-model fit. These measures were CMIN-ρ (the chi-square p-value) > 0.05, CMIN/DF (the relative chi-square value) < 2.00, the goodness of fit index > 0.90, and the root mean square error of approximation value < 0.08 (Arbuckle, 2016).

Results

Elements of the Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era

According to objective no. 1, which was to study the elements of the Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era, the qualitative research through in-depth interviews with experts was divided into four element strategies. These strategies were (1) Industrial Readiness, (2) Government Policies and Promotions, (3) Integration of Cooperation, and (4) Production Potential. The analytical results of the importance levels of these four elements are presented inTable 1.

Table 1 Overall means and standard deviations of importance levels

Elements of strategic Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era	$\overline{X}$	S.D.	Importance levels
Overall	4.09	0.52	high
1. Industrial Readiness	4.10	0.54	high
2. Government Policies and Promotions	4.04	0.56	high
3. Integration of Cooperation	4.07	0.58	high
4. Production Potential	4.15	0.56	high

Table 1 presents the analysis of the importance of the Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era and indicates an overall high level of importance ($\overline{X}$ = 4.09). In addition, the importance of each strategy was also at a high level. The mean score for each strategy was as follows: Industrial Readiness ($\overline{X}$ = 4.10, S.D. = 0.54), Government Policies and Promotions ($\overline{X}$ = 4.04, S.D. = 0.56), Integration of Cooperation ($\overline{X}$ = 4.07, S.D. = 0.58), and Production Potential ($\overline{X}$ = 4.15, S.D. = 0.58).

Table 2 Overall means and standard deviations of importance levels of the the Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era categorized by the size of the industrial business sector.

Elements of strategic Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era	medium size			large size		
	$\overline{X}$	S.D.	Sig. level	$\overline{X}$	S.D.	Sig. level
Overall	4.06	0.54	High	4.12	0.51	High
1. Industrial Readiness	4.07	0.56	High	4.13	0.52	High
2. Government Policies and Promotions	4.02	0.56	High	4.06	0.55	High
3. Integration of Cooperation	4.05	0.59	High	4.09	0.56	High
4. Production Potential	4.12	0.59	High	4.20	0.52	High

According to Table 2, it is evident that both medium and large-sized industrial businesses consider the overall importance to be significant. When analyzing the importance level in each aspect, it was found that every aspect holds great significance, ranked in descending order of importance as follows: 1) Production Potential, 2) Industrial Readiness, 3) Integration of Cooperation, and 4) Government Policies and Promotions.

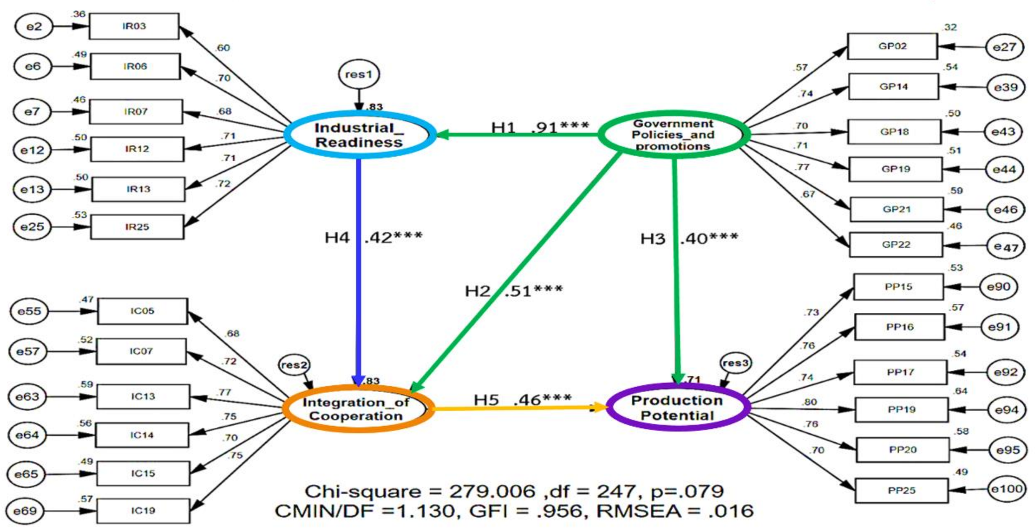

Figure 3 The structural equation model in Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era

The structural equation model for the guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era, following model refinement, comprises 4 latent variables. These include 1 exogenous latent variable, which is the component related to government policies and promotions, and 3 endogenous latent variables, namely industrial readiness, integration of cooperation, and production potential. The government policies component directly influences Industrial Readiness, Integration of Cooperation, and production potential components. The industrial readiness component directly influences the integration of cooperation component. The Integration of Cooperation component directly influences the production potential component.

The industrial readiness consist of 6 observed variables, ranked in descending order of standardized regression weight as follows:1) Risk management plans to address potential situations arising from the use of industrial robots in the organization's production sector (IR25).2) Establishing channels for receiving feedback regarding the implementation of industrial robots from employees in all departments (IR13).3) Improving the mindset of employees regarding the adoption of industrial robots (IR12).4) Workforce skill development for the maintenance and repair of industrial robots (IR06).5) Facility design and modification to accommodate industrial robots in the production process (IR07). 6) Adequate budgeting for investment in industrial robots for the manufacturing process (IR03).

The integration of cooperation consist of 6 observed variables, ranked in descending order of standardized regression weight as follows:1) Collaborating with educational institutions for learning and designing industrial robots to be used as replacements for in-house production labor (IC13).2) Collaborating with educational institutions to develop the knowledge and skills of learners in using industrial robots (IC19).3) Organizing joint meetings with similar industry business networks that use industrial robots to exchange experiences from their usage (IC14).4) Government responsiveness to the introduction of industrial robots to replace production labor (IC07). 5) Collaborating with regulatory agencies in quality and safety standards for the use of robots and product standards produced by robots (IC15). And 6) Integrating cooperation across all departments within the organization to introduce industrial robots to replace human labor (IC05).

The government policies and promotions consist of 6 observed variables, ranked by the value of standardized regression weight from highest to lowest, as follows:1) Collaboration with government educational institutions to design short-term courses for the continuous development of employees' knowledge and skills in line with evolving robotics technology (GP21). 2) Sending technical employees for training to enhance their maintenance and servicing skills for industrial robots with government agencies (GP14).3) Becoming a member of field robotics institutions (FIBO), the Thai Robotics Society (TRS), and the Thai Automation and Robotics Association (TARA) to seek technical assistance in using and maintaining robots (GP19).4)Collaboration with professional qualification institutions to define the competencies of employees working in industrial robot maintenance (GP18). 5) Applying for quality certification for products and goods manufactured by government agencies using robots (GP22). 6) Requesting government subsidies for investment in replacing old machinery with robots (GP02).

The production potential consist of 6 observed variables, ranked by the value of standardized regression weight from highest to lowest, as follows:1) Using industrial robots in manufacturing processes that can increase production capacity without affecting product quality and standards (PP19).2) Employing industrial robots in production processes to enable precise and cost-effective control of production costs (PP20).3) Utilizing industrial robots in the production process to produce products that meet standard formats and Just-In-Time (JIT) requirements (PP16).4) Using industrial robots in the production process to help reduce workplace accidents among human workers (PP17).5) Employing technology in sensor systems combined with artificial intelligence (AI) to analyze and assess losses in the work process (PP15).And 6) Industrial robots demonstrate high precision and accuracy, especially in repetitive processes, ensuring efficient performance (PP25).

Conclusion

The results of the analysis of Guidelines for introducing industrial robots to replace manufacturing workforce to enhance competitiveness in the digital era revealed that it was possible to categorize the components into four elements, namely industrial readiness,government policies and promotions,integration of cooperation and production potential. The production potential of an organization is primarily determined by the efficiency of its manufacturing processes, the use of modern and efficient technology, the utilization of high-quality raw materials, and the systematic management of production processes. When an organization possesses a high production potential, it means that it can manufacture high-quality products efficiently. This, in turn, has a significant impact on the organization's ability to increase sales and profitability. High production potential serves as an indicator of an organization's success. When comparing the components of the guidelines for introducing industrial robots to replace labor in medium-sized and large industries, an overall finding is that there is no statistically significant difference at the 0.05 level of significance. This aligns with Thakur and Tiwari's research (2016), which discussed industrial businesses using industrial robots in the production process and found that the size of the industry is not a significant factor causing differences. This research is consistent with the study conducted by Senangkanikorn et al. (2020) concerning the model for improving efficiency in selecting logistics partners in Thailand. They found that the size of the organization does not affect the management process. Management practices may align with economic conditions and organizational strategies.

The introduction of industrial robots in manufacturing is not just a technological shift but also a catalyst for significant changes in the workforce. It presents both challenges and opportunities, requiring a proactive approach in workforce planning and development to harness the full potential of this technological dvancement.

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