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A TRIZ-Informed Intervention Framework for Sustainable 4IR Adoption in Malaysian Manufacturing and Related Services (MRS) Industries

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ABSTRACT

Industry4WRD is Malaysia's effort to become a technological frontrunner in the Fourth Industrial Revolution (4IR). Based on the Theory of Inventive Problem Solving (TRIZ) and scholarly insights on technology adoption, this study creates a flexible 4IR intervention framework for Malaysia's Manufacturing and Related Services (MRS) industry. The evidence-focused reviews, Delphi surveys, content analysis, and patent evaluations comprise the framework's backbone and provide direction for MRS businesses adopting 4IR technologies while keeping risks in check. It is of universal interest because it helps governments and businesses deal with the challenges posed by the 4IR. Ultimately, it helps Malaysian MRS industries to flourish in 4IR tech, promote economic growth, generate employment, and enhance the quality of life in a rapidly developing technology context.

1. Introduction

The Fourth Industrial Revolution (4IR), the digitisation and automation of intervention [1], will significantly change work, business, and society in the coming decade. 4IR hurts numerous jobs in the field [2], and many disappear or change. New vocations, sectors, and work styles may also arise [3]. Increasingly, digitisation and automation intervention may be essential challenges to shaping industry strategy, technology development, and disruptive business transformation [3].

Many studies have raised worries about robots [4,5] replacing humans in the workforce due to 4IR tendencies, as IoT plays a vital role in the 4IR [6,7]. Frey and Osborne found that 47% of US occupations may be automated soon. Thus, in 2018, Malaysia launched the Industry4WRD initiative, led by the Ministry of International Trades and Investments (MITI) [8], to accelerate 4IR technology adoption and foster manufacturing growth. Figure 1 The framework of the Industry4WRD policy—technology adoption, talent development, infrastructure, and regulatory frameworks—is crucial for an essential field [9]. The significance of Industry4WRD policy's framework, as illustrated in Figure 1,

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is irrefutable as it centres on four fundamental domains or enablers: technology adoption, talent development, infrastructure, and regulatory frameworks [9].

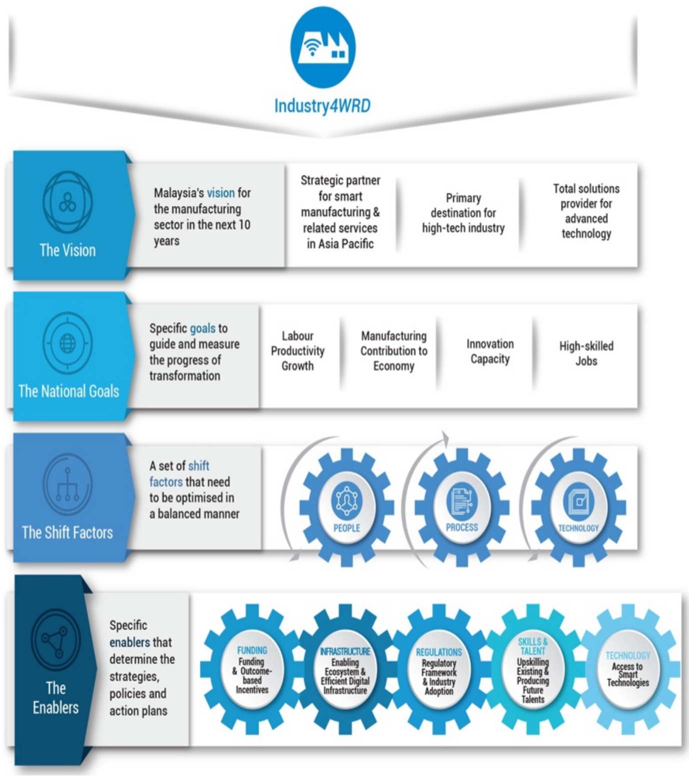

Fig. 1. Industry4WRD policy's framework [9]

Although the digital technologies that form the foundation of the 4IR undoubtedly foster substantial innovative capabilities, they also present several obstacles. These encompass technical intricacies associated with integrating advanced Industry 4.0 solutions, organisational impediments concerning workforce preparedness and skills, and financial limitations about substantial investment demands [10]. A survey has identified three primary obstacles that smart factories must confront: a shortage of digital competencies among employees (14%), apprehensions regarding data security arising from interconnected systems (29%), and the requirement to enhance operational technology (36%). Effective adoption requires unified frameworks that assess an organisation's readiness for technical and social factors and increase change acceptability and viability [11].

Intervention instruments and methods will help manufacturers assess their readiness to implement 4IR technologies and processes as part of the national regulation policy. Doing so will help firms evaluate their strengths and limitations, willingness to adopt 4IR, the steps needed to start the 4IR transition, and best practices [9]. A fundamental intervention approach can help industries evaluate the trend of technology adoption in their value chains and detect mismatches between adoption and expected outcomes [12,13]. Most 4IR research on technology adoption has focused on human aspects such as social dynamics, people management, career development, and education. These investigations are essential, but they still need to examine technological changes in intervention. A study of patented data found few occurrences of similar technical ideas and no actual applications. Three academic articles are listed in the Lens analysis report, as seen in Figure 2. According to the literature, intervention, the 4IR, Trends in System Evolution theory, and TRIZ need more academic study.

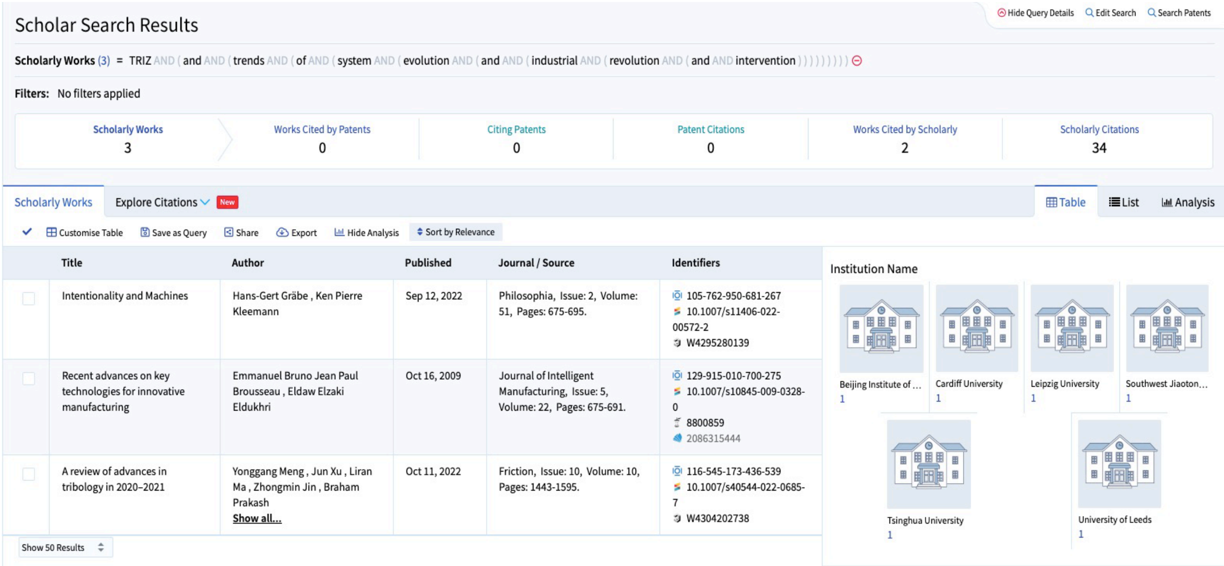

Fig. 2. Lens report on the selected keywords (https://link.lens.org/tLfZl8KvNji)

Based on crucial innovation diffusion theories and TRIZ methodology, this research's Comprehensive Intervention Framework uses S-Curve analysis and other lifecycle-spanning metrics to evaluate 4IR technological capacity, financial commitments, and organisational readiness before intervention. This foundational phase guides the structured intervention phase, which uses TRIZ resources and strategies to creatively address adoption obstacles and objections. Finally, the post-intervention phase monitors and maintains technology integration, giving management practical insights to define talent development, investment, and digitalisation goals [14]. This comprehensive strategy tackles the challenging 4IR transition issues.

The proposed intervention framework leverages theoretical knowledge to enhance effectiveness and gain theoretical insights. It integrates the widely accepted Innovation Diffusion Theory (IDT), which examines the diffusion of innovations within social systems like businesses and industries, with the Theory of Change (ToC), a structured methodology for understanding how interventions lead to desired outcomes [15]. The framework addresses the intricacies and interdependencies of the 4IR through a comprehensive approach [16], combining insights from IDT, tools from TRIZ, and the strategic perspective of ToC [12,13]. This comprehensive strategy empowers Malaysian MRS industries to embrace new technologies, stimulate innovation, and maintain 4IR initiatives. The paper outlines the literature review and methodology in sections 2 and 3. Findings are presented in section 4, followed by conclusions in section 5.

2. Literature Review

The 4IR, called the digitisation and automation of intervention [1], is viewed as the most consequential global social and economic movement, potentially radically altering the character of employment, commerce, and society within the next ten years [17-19]. The last few decades have been dominated by technology. New technologies have encouraged new product development. Many innovations and discoveries have been made because of this technology. The gap between innovations and novel products used to be significant but has shrunk considerably. Something new is invented every day. Whether it's a brand-new idea or a novel take on an existing concept. Customers benefit from his rapid innovation of new ideas, products, and services, but manufacturers and marketers need help to keep up more [20].

2.1 Innovation Diffusion Theory (IDF)

IDT is a well-established theoretical framework that centres on how innovations spread throughout a social system like a company or an entire industry. Everett Rogers proposed the concept in 1962, and since then, it has been widely used to analyse the spread of numerous technological developments [21,22].

Theory utilisation is a prevalent approach in examining the adoption and assimilation of technology and innovation. The theoretical framework in the matter has been employed both independently and in conjunction with other theories, such as the Uses & Gratification (U&G) framework [23], the Technological, Organizational and Environmental (TOE) framework [24-26] and the organisational behaviour [27].

2.2 Theoretical Perspectives and 4IR Interventions

Rogers and Moore & Benbasat argue that many factors influence adopting innovations, including relative advantage, compatibility, complexity, trialability, and observability. The IDT study has uncovered these characteristics [15,28]. Recognising and capitalising on emerging technical trends and innovations to improve industrial processes is essential to industrial intervention. Understanding technological trends is vital for businesses because it helps maintain their competitive edge in a dynamic global market [29].

Incorporating IDT-derived principles into the intervention framework can enhance the comparative advantage of 4IR technologies, assure their compatibility with existing processes, and reduce their complexity. Due to this synthesis, adopting 4IR technologies in Malaysia's MRS sectors can be guided holistically, optimising perceived benefits, harmonising with the prevalent organisation values, and accelerating the implementation [22,29]. Understanding 4IR technologies can be difficult for academics and practitioners because of their complex and multidimensional nature. New theoretical viewpoints and research approaches are required to overcome the main barriers preventing firms from employing 4IR technology and initiatives [30].

2.3 The Introduction to the Theory of Change (ToC) for 4IR Intervention

The Industrial Revolution necessitated strategic organisational changes to boost productivity. The ToC aids these changes by outlining desired outcomes like competitiveness and value creation. However, applying ToC to industrial interventions requires practical approaches due to inherent challenges. The success of these interventions, as shown in case studies, depends on custom strategies that consider each organisation’s unique context and complexity [31-34].

2.4 The Adoption of the ToC for Intervention in the Industrial Revolution

ToC was pivotal in guiding the Industrial Revolution program's intervention at high-level management and operational levels [35]. The initial phase involves defining organisational needs and outcomes using a structured ToC approach, often aided by prioritisation matrices [36]. The organisation designs feasible intervention mechanisms and action plans based on these outcomes. Given the program's potential for diverse products, simulation of interventions is often incorporated into the program's design. Intervention strategies encompass internal and external controls [37], where internal control relies on internal resources and capabilities.

In contrast, external control involves collaborative efforts with external parties, often aligning interests and approaches for mutual benefit [38]. Dynamic deployment and implementation of intervention activities require agility and flexibility to overcome barriers and challenges [39]. Regularly reviewing the intervention strategy at critical milestones is crucial to adapting to changing circumstances and ensuring program success [40]. The intervention strategy operates at organisational and project levels, with the former setting long-term goals and the latter focusing on specific short-term activities at various operational levels. Intervention components address technology, process, and people aspects, translating the organisation's vision, mission, and goals into a strategic plan, detailed activities, and effective performance monitoring, as shown in Figure 3 [41].

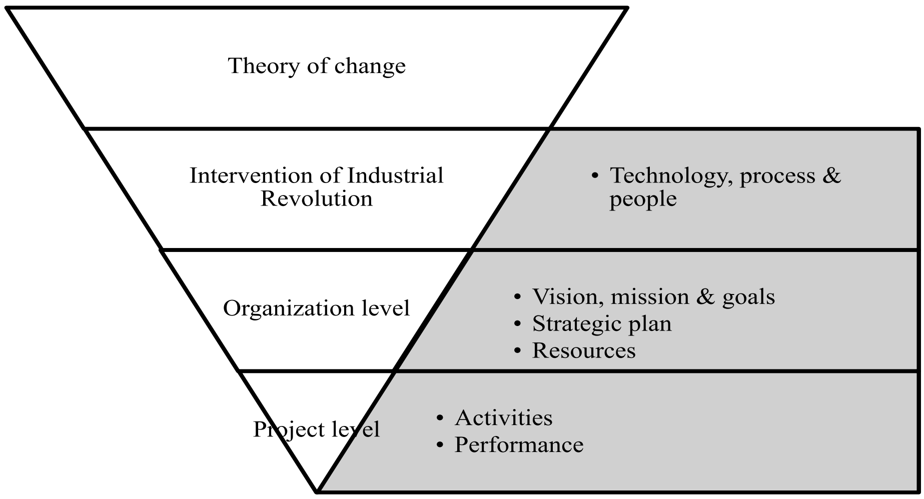

Fig. 3. The model of intervention program at the organisation and project level using the ToC [42]

2.5 Trends of Engineering System Evolution (TESE) of TRIZ

Industrial Revolution intervention needs additional support in establishing inorganization-level and project-level outcomes. In a more practical and project-level intervention mechanism, change theory needs intermediates. TRIZ is required to support this. A systematic intervention innovation, TRIZ can supplement the idea of change in the technical, engineering, and technological development [43]. Genrich Soulvic Altshuller developed it to accelerate the systematic innovation process to overcome engineering obstacles in contradictory scenarios. Altshuller's Trends of Engineering System Evolution TRIZ tool refines this trend. Trends are assessed and verified for the selected system to find its insight and systematically offer an intervention to increase innovation [20]. Various high-level corporations have used this methodology in developing a technology strategy development plan or roadmap for securing high-value technologies and high-value markets at the global level.

The TESE covers nine systematic innovation trends for industrial revolution intervention and organisation direction. At the general level of the technology system, the trends follow the sequential innovation behaviour [44]. In the Industrial Revolution intervention method, lowering human participation benefits technology, processes, and people (Figure 4). The movement began with complete dependence on humans for specific tasks and activities. Very intensive human labour is often needed to meet production targets in production. However, production output is affected if human workforce function varies or is inconsistent due to internal and external variables.

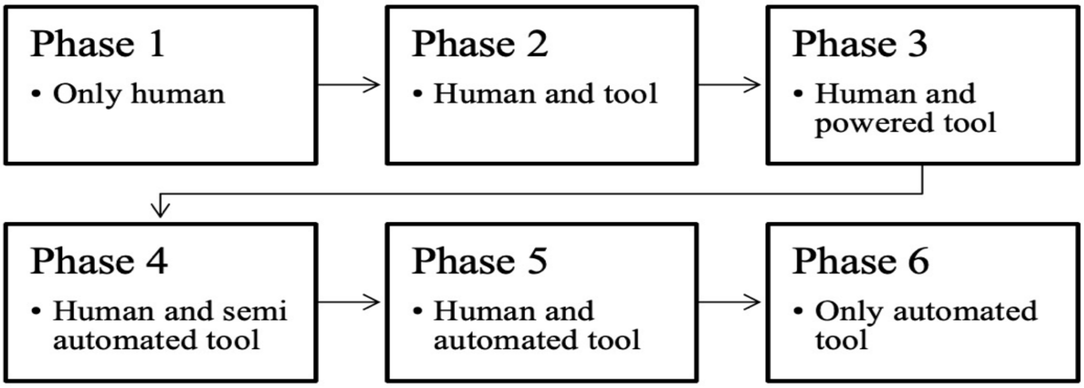

Fig. 4. The TRIZ trend of decreasing human involvement in the intervention program

Human function limitations, fatigue, physical or emotional condition, and human error impair production performance. TRIZ trends suggest introducing equipment or tools as a supporting system in the early phase of innovation. Systems and devices will receive production-process functions from humans. The supportive system reduces human error and harm. The supporting system will partially eliminate product, process, and human damage. At this stage, the support system is begun as a simple tool at a modest cost, cheaper than product problems, delayed delivery, or human error. This was the organisational stage of textile and more straightforward industries throughout the Industrial Revolution [45]. Industrialisation accelerated operations and improved operator performance with powered tools.

The second intervention phase involves upgrading tools with powered energy sources, enhancing operator efficiency and reducing physical strain. This aligns with TRIZ's trend of using alternative energy sources to aid operators in tasks requiring significant energy. The third phase introduces automation for repetitive tasks, allowing operators to focus on higher-value functions while tools handle repetitive assembly processes [46]. Programming languages, actuators, sensors, and electronic control systems facilitate automation. The fourth and final phase achieves full automation, surpassing human capabilities with robotics, high-speed systems, precise sensors, advanced programming, and data-driven AI support [47].

TRIZ TESE proves valuable in guiding technological and process intervention for the Industrial Revolution, offering a systematic approach to elevating organisational value and attaining intervention goals [48]. Using TRIZ tools, notably the ideality and contradictions matrix, has a transformative impact on identifying environmentally sustainable materials. This methodology achieves a synergistic equilibrium among cost-effectiveness, mechanical properties, and manufacturability, thereby optimising Field's material selection process [49]. The infusion of 4IR (Fourth Industrial Revolution) technology into these approaches further enhances the sustainability of material choices. By incorporating these tools into feasibility assessments, we ensure optimal material selection and align with the core tenets of sustainability.

2.6 Consultation of Patent Analysis

A comprehensive review of patents, research papers, and industry reports was done to gauge the hydrogen and hydrogen fuel cell technology's potential for disruption throughout the Industrial Revolution. Malaysia is one of many countries studying hydrogen as a sustainable energy option to replace fossil fuels as part of the global energy shift [50]. Hydrogen fuel cell integration in automotive systems is also investigated, with an S-curve analysis developed using the TRIZ methodology. The objective is to discover places in the automobile industry where intervention and innovation are needed. These analyses inform a practical intervention framework for Malaysian businesses to fully capitalise on the revolutionary potential of hydrogen technologies as they undergo the 4IR transition [51,52].

2.7 Evidence-Focused Review

Malaysia's industrial revolution program is called Industry4WRD readiness assessment, as shown in Figure 5. Industry4WRD manufacturers have various subsectors. Three sectors—rubber & plastics, food products, and fabricated metal products—accounted for 210 participants, about half the total manufacturing enterprises. The lowest participation was in Other Transport Equipment, Coke, and Refined Petroleum Products.

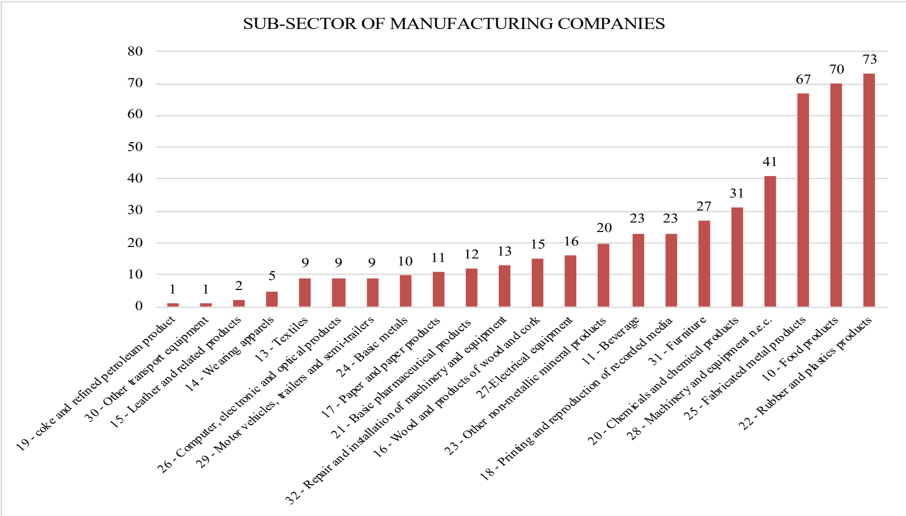

Fig. 5. The manufacturing sectors for the Industry4WRD program in Malaysia

The Industry4WRD profile firms suggest that roughly 90% of newcomers are interested in 4IR, as seen in Figure 6. With 30, conventional profile enterprises are second, followed by learner profile companies (27). Since the ratio of Newcomers is higher than in other groups, it's crucial to analyse and support their needs to embrace Industry 4.0 successfully. Considering the contributions of each participating company to the 28 sub-sectors, we found numerous comparable patterns that were categorised as indicated below:

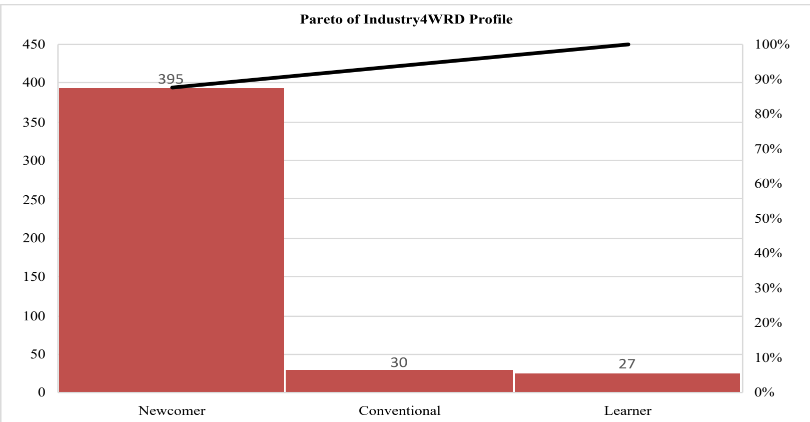

Fig. 6. The Industry4WRD readiness profile for Malaysia manufacturing sectors

2.8 The Conceptual Intervention Framework for the Industrial Revolution Intervention Program

The IDT, ToC, and TRIZ TESE offer a structured approach for planning, implementing, and evaluating interventions in the transition to the 4IR. This process comprises three key stages: pre-intervention, intervention, and post-intervention, with financial support available through mechanisms like a 70%-30% matching grant [53]. The pre-intervention phase involves assessing the organisation's readiness for the 4IR initiative and its desired outcomes, using tools like S-curve analysis to gauge technological maturity [53]. The next step is designing and executing the intervention plan, prioritising resources based on timeframes and project types, with TRIZ TESE aiding in innovative action identification [53]. Funding sources, including government grants, are considered to facilitate the transition [54]. Finally, the post-intervention phase evaluates progress at project and program levels, enabling management to gauge the effectiveness of their 4IR intervention strategy [53]. As depicted in Figure 7, this comprehensive framework supports Malaysia's industrial transformation [55].

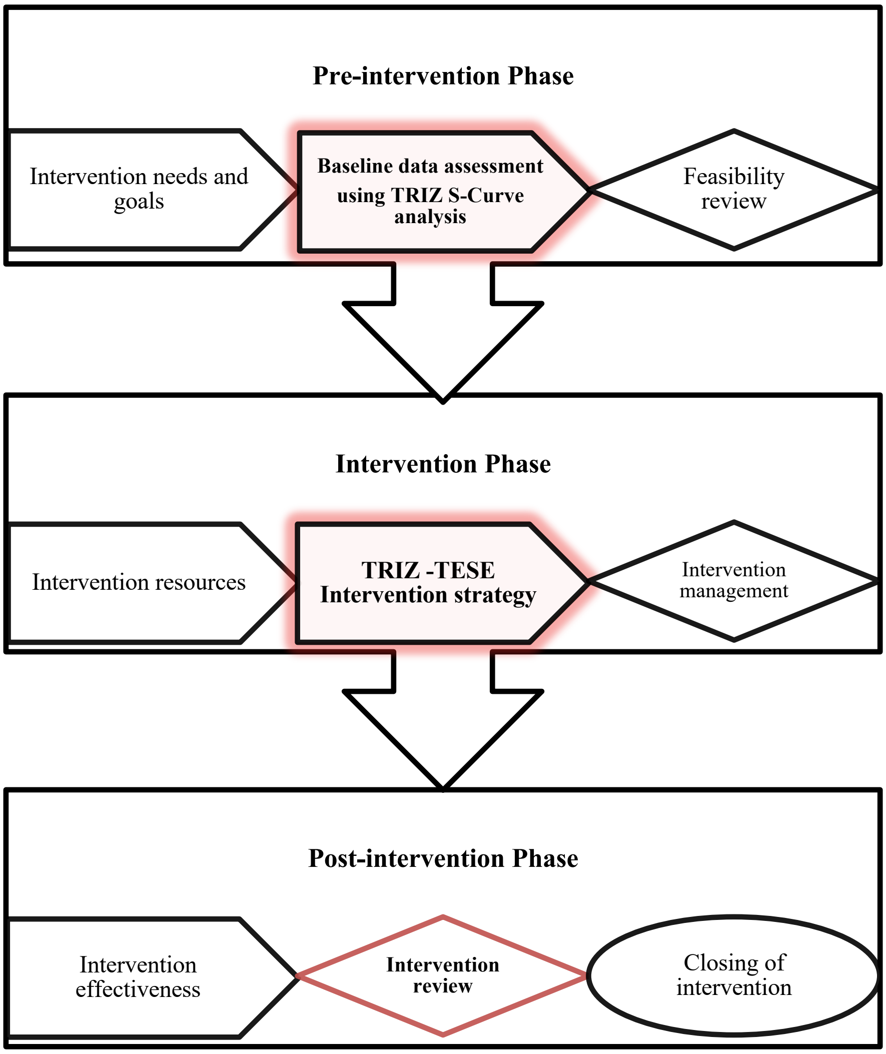

Fig. 7. Conceptual framework intervention for the industrial revolution

3. Methodology

This qualitative study employs an exploratory research approach to develop and validate an intervention framework for Malaysian SMEs transitioning to the 4IR. The research design includes a systematic literature review, patent analysis, evidence-focused review, document review, and a rigorous Delphi technique. The Delphi technique, a systematic and iterative method for gathering expert opinions, is central to this research [56]. It enables the convergence of views on complex 4IR issues, ensuring anonymity for experts and fostering unbiased responses. Kendall's coefficient is utilised for consensus measurement within the Delphi process [57], enhancing the reliability and credibility of the research outcomes.

A rigorous, systematic methodology guided the development and validation of this study's Comprehensive 4IR Adoption Framework. We extensively reviewed the literature using scholarly databases like Scopus, Web of Science, and EBSCOhost to methodologically search and identify relevant studies on themes like technology adoption models, innovation diffusion theory, organisational change management and Industry 4.0 readiness using inclusion criteria. For this search strategy, we used a set of predetermined keywords drawn from our study topic and area of interest (e.g., "TRIZ," "industrial intervention," "Industry4RWD," "Malaysia," and "Fourth Industrial Revolution" to narrow the results. Researchers used these keywords to find publications and papers about the overlap of TRIZ, industrial intervention, Industry4RWD, Malaysia, and the 4IR.

To identify and analyse TRIZ trends that can guide the industrial intervention, the approach also comprises consultation of patent analysis, which enriches the thematic and conceptual framework of the 4IR intervention. Using patent data, the researcher can analyse and classify relevant discoveries [58] that correspond to or are relevant to established TRIZ patterns. Researchers were able to achieve this through comprehensive studies. Results and studies were presented through the following three different publications [50-52]. This literature study will also examine the evolution of the TRIZ ideal system framework and the practical significance of intervention within the setting of the 4IR. In this work, we conduct an evidence-focused literature analysis of pertinent research questions to identify developing trends in intervention components that may be matched with TRIZ [59]. After establishing a thorough intervention framework, it will be validated using the Delphi method. The scientific process can only proceed by selecting a foundation for the intervention [60]

A panel of manufacturing and TRIZ specialists evaluated the framework using three iterations of the Delphi technique. The committee, which was carefully selected, consisted of experts in the field of 4IR intervention, with each member having at least ten years of pertinent expertise. By the eligibility criteria, participants must possess at least five years of professional experience in a government-related corporation, have actively participated and completed the Industry4WRD Readiness Assessment, and be offered constructive expert feedback regarding the proposed intervention framework. The process of participant selection was conducted using a purposive sampling approach. Six participants were divided evenly between the two groups. Three TRIZ experts and three MRS experts were included in each group. All three groups finally settled on a course of action after much discussion. Questionnaires included structured questions on Framework topics to get insights into the pre-intervention, intervention, and post-intervention phases. The organised framework was reviewed using Kendall's W coefficient correlations between expert viewpoints, which were determined through many iterative questionnaire rounds that enabled deeper interaction with specialists. Part of the approach will include the selection of the expert panel, creating the questionnaire, scoring processes (Table 1), rounds of iteration, and data analysis. It will be necessary to validate the framework after Delphi analysis. Data was summarised or analysed using a condition and a respondent feedback form. The multi-stage procedure of the Delphi method encourages a group of responders to reach an agreement. To improve the framework, we will employ the results of the Delphi analysis. There can only be three rounds of a Delphi until there is 70% agreement. Consensus analytics and conclusions are born out of each Delphi cycle.

Table 1
Interpretation of Kendall’s W

W	*Interpretation*	*Rank Confidence*
0.5	Low agreement	Low
0.7	Moderate agreement	Moderate
0.9	Robust agreement	High
1.0	Complete Agreement	Very High

All participants met the above criteria. There were three male and three female participants. All participants received a post-secondary education; three reported significant business experiences in the MRS industry, while the others were academic experts with at least a TRIZ level 2 practitioner background. Delphi methods—respondent feedback and data summary and analysis—are used in the study. The research seeks key data patterns, subjects, and trends. Kendall's coefficient works with Delphi expert rankings. Quantifying subjective evaluations simplifies comparison and analysis. W coefficients define a set of scores agreed-upon rank [57]. Kendall's coefficient shows expert opinions on consensus or divergence over numerous iterations. Find commonalities and differences to converge. Kendall measures non-parametric rank data column relationships. The rank correlation coefficient is in Table 2. No ties at 0.5, highly significant at 1.

Using Kendall’s W, a statistical measure of rank correlation, alongside validation strategies such as Observational Field Notes, Triangulation, and Document Reviews, enhances the research findings' robustness, validity, and precision. Kendall’s W is particularly suitable for this study due to its proficiency in analysing ordinal data or data that does not necessarily need continuous [57]. These methodological choices, including using Kendall’s W to effectively determine the degree of agreement between two ranks, are crucial in enhancing this work's academic rigour and significance [61,62].

The study will employ member checking, peer debriefing, and data triangulation techniques to validate the research outcomes. Implementing these measures can enhance the precision and reliability of research outcomes, thereby bolstering its credibility.

4. Results and Analysis

This chapter presents the outcomes of the Delphi technique employed to validate the Comprehensive Intervention Framework developed for Malaysian SMEs in the context of the 4IR. The Delphi process involved three rounds of expert feedback, emphasising the iterative nature of intervention required in the 4IR landscape. A panel of six experts participated in this process, including three specialists in TRIZ and three in MRS. The results and analysis showcase the convergence of expert opinions and the consensus on various aspects of the intervention framework. Additionally, this chapter elucidates the refinements and modifications made to the framework based on the feedback received from the expert panel. The Delphi results underscore the practical applicability and robustness of the Comprehensive Intervention Framework and provide valuable insights for organisations venturing into 4IR initiatives. See Table 2 for the results.

Table 2
Results from the Delphi Technique

Dimensions	Critical success factors	IQR Score Round 1	IQR Score Round 2	IQR Score Round 3	Degree of Consensus
Pre-Intervention Phase	How familiar are you with the S-curve analysis as a tool for assessing technological progress and application maturity in organisations?	0.5	0.7	0.9	=>70 % Accepted
	How valuable is the S-curve analysis for organisations in understanding their technological progress and maturity level in the application?	0.7	0.9	0.9	=>70 % Accepted
	Do you believe collecting new information on an organisation's position in the industrial revolution is crucial for its future course?	0.9	1.0	1.0	=>70 % Accepted
Intervention Phase	How important do you consider evaluating the viability of technical and financial factors before implementing intervention strategies, especially in the context of a refined framework?	0.5	0.7	0.9	=>70 % Accepted
	Does TRIZ - TESE Intervention Strategy outline the innovative approach and actions required to enhance the value of the organisation's technological system?	0.7	1.0	1.0	=>70 % Accepted
	How likely do you think the methodology and actions outlined in the TRIZ - TESE Intervention Strategy, as aligned with the refined framework, can serve as a blueprint for administering intervention activities for the Industrial Revolution program?	0.7	0.9	0.9	=>70 % Accepted
Post- Intervention Phase	During this phase, can organisations monitor and evaluate the efficacy of the intervention endeavour at the project and programme levels since all data and information are made accessible in a systematic flow?	1.0	1.0	1.0	=>70 % Accepted
	Does this last stage in the post-intervention phase provide input to the organization's management about the effectiveness of the Industrial Revolution intervention programme?	1.0	1.0	1.0	=>70 % Accepted
	In your opinion, should organizations consider discontinuing interventions after achieving the targeted outcomes?	0.7	0.9	0.9	=>70 % Accepted

4.1 Validated Comprehensive Intervention Framework

The Delphi validation process has refined and endorsed the Comprehensive Intervention Framework. This paradigm offers a systematic and strategic approach to planning, implementing, and evaluating 4IR interventions in the MRS sector, grounded in the Theory of Constraints (ToC) and TRIZ TESE.

The framework comprises three key phases:

4.1.1 Pre-intervention phase

This phase assesses the prerequisites for initiating a 4IR initiative, including:

i. Organisational readiness for 4IR technology adoption.
ii. Conducting S-curve analysis to gauge technological maturity.

iii. Collecting data on current and desired 4IR states.
iv. Analysing 4IR potential through technical and financial assessments.

4.1.2 Intervention phase

Once the baseline is set and a 4IR strategy is developed, this phase focuses on designing and implementing the intervention plan. Key considerations include:

i. Leveraging TRIZ methodologies, especially TESE, for creative 4IR actions.
ii. Ensuring alignment between intervention actions and the 4IR strategy.
iii. Exploring government subsidies and support for funding 4IR initiatives.

4.1.3 The post-intervention phase

Involves ongoing monitoring of the project and program progress. Continuous assessment and evaluation are crucial for achieving intended outcomes. Key objectives include:

i. Providing senior management with valuable data for evaluating the intervention plan.
ii. I am supporting decision-making during the implementation of 4IR intervention programs.
iii. Assessments conducted before, during, and after intervention identify areas for improvement.

The Comprehensive Intervention Framework, validated through Delphi consensus by a diverse panel of experts, strikes a balance between theoretical robustness, as emphasised by TRIZ experts, and practical application, valued by industry stakeholders. It equips MRS industries to navigate the complexities of the 4IR and intervene effectively in their industrial revolution projects. Figure 8 illustrates the validated framework.

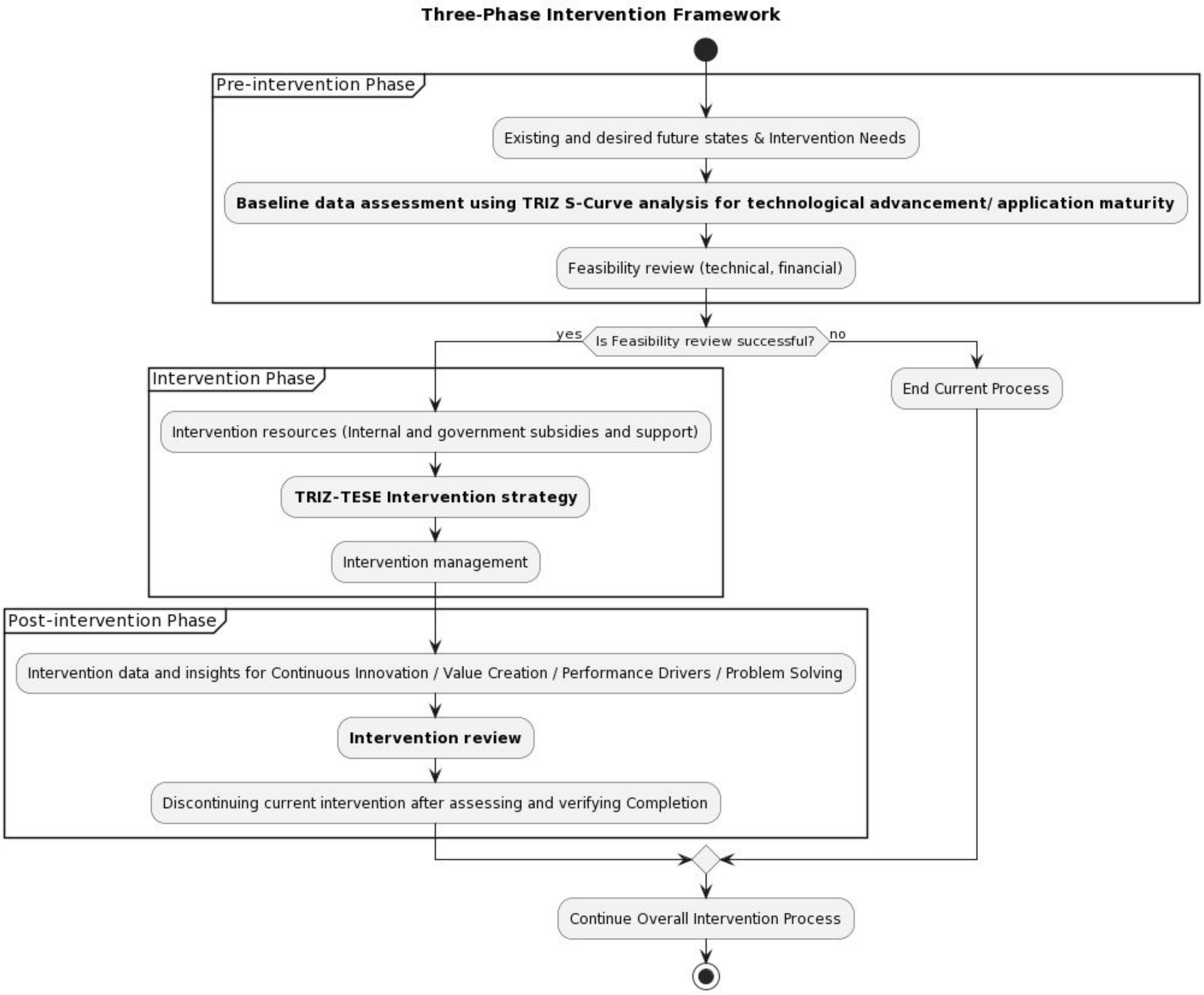

Fig. 8. Validated, comprehensive framework intervention for the Industrial Revolution

5. Graphical Abstract

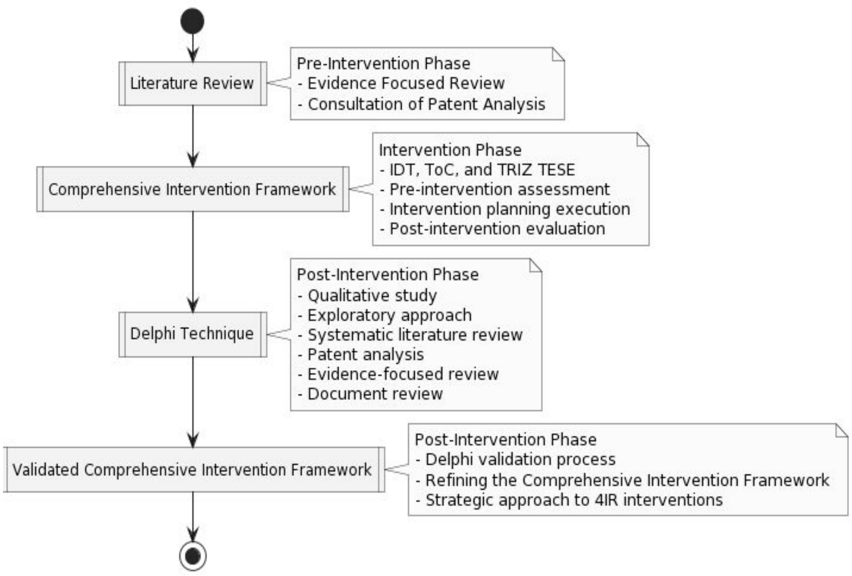

Fig. 9. Comprehensive Framework for 4IR Intervention

6. Conclusion

This study explores the impact of the 4IR on Malaysia's MRS industry, where digitalisation and automation present challenges and opportunities for employment, economic growth, and industrial progress. In response to this paradigm shift, Malaysia established Industry4WRD as a pioneer in 4IR. This research bridges theory and practice by introducing a TRIZ-based Comprehensive Intervention Framework. This framework, grounded in the study of engineering system evolution tendencies, assists MRS firms in embracing 4IR technologies while mitigating risks.

The research methodology involved a thorough review of 4IR, TRIZ, and industrial transformation literature, followed by data collection through evidence-based reviews and patent consultations. The resilience and applicability of the framework were validated through an iterative Delphi process involving a broad panel of experts. The significant findings highlight the alignment of theory and practice within the framework and the diagnostic value of S-curve analysis in understanding technological progress. The research underscores firms' need to adopt data-driven agility in the dynamic 4IR landscape.

The relevance of this study lies in its potential to increase technological capabilities and adoption, enhance competitiveness, and promote sustainable growth for firms adopting this framework. However, the work has limitations, including focusing on the Malaysian context and relying on qualitative Delphi approaches. Future research can validate the framework's effectiveness through case studies, expand the industrial scope, and integrate computational tools for intervention design. This would address the limitations and further the developments in this field. This conclusion underscores the critical role of TRIZ and 4IR technology in driving sustainable industrial transformation, making it a cornerstone of our research topic.

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