Research Issues in Industry 4.0 in relation to Quality 4.0 with Quality Engineering and Management

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22 October 2022

Organized by the Department of Engineering and Industrial Systems - Institut Teknologi Sepuluh Nopember (ITS) Summer Program theme "Aligning Industrial and System Engineering toward Industry 4.0 ".

What is research ?

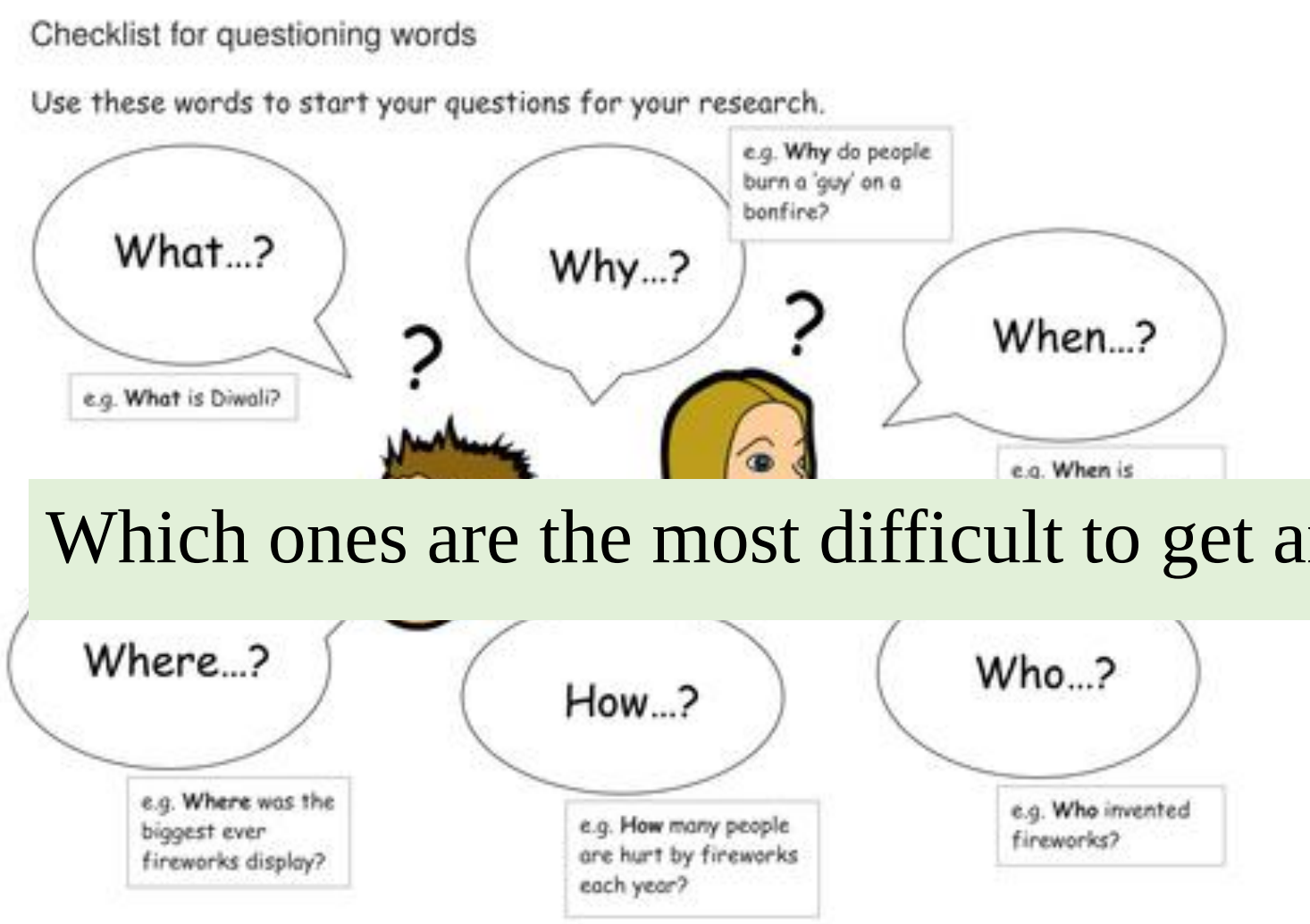
- A **logical and systematic search** for new and useful information on a particular topic
- An investigation of **finding solutions** to scientific and social problems through objective and systematic analysis
- **Search for knowledge**, that is, a discovery of hidden truths - knowledge means information about matters
- Information/data might be collected from many sources - experience, human beings, books, journals, nature, etc.
- Most importantly, research leads to **new contributions to the existing knowledge.**

What is main motives for doing research?

- To discover new facts
- Verify and test important facts
- Explore or develop new method/technology/system
- Analyze an event or process or phenomenon
- Identify the cause-and-effect relationship
- Develop new scientific tools, concepts and theories
- Solve and understand scientific and nonscientific problems
- Find solutions to scientific, nonscientific and social problems and
- Overcome or solve the problems occurring in our everyday life

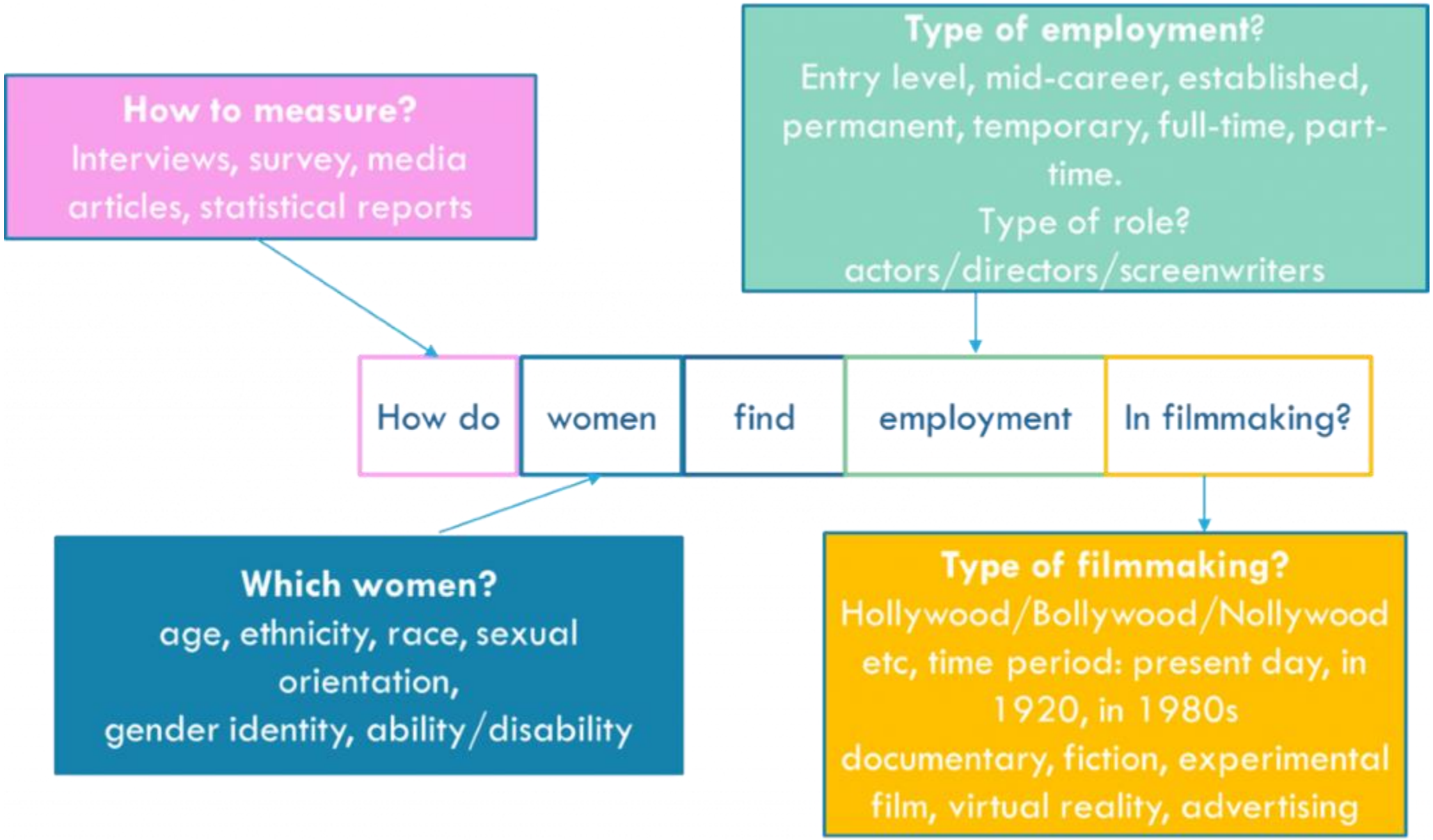
What do you think is most difficult type of research question?

What kinds of words you use when writing your research questions ?



Which ones are the most difficult to get answers?

Question word
How can / could
What are the
How do / does
Is /Are
What (other)
To what degree / extent
Why is / are / do / should
Do / Does
What is the benefit /effect / impact / value of
What economic / effect / factors / forms / future
How are / is
How may / might / will
When are / will / would
Has / Have
How feasible / economic / sustainable
What challenges / dangers
What impact does / did
How much of
In what ways does
What causes / determines


How to measure?
Interviews, survey, media articles, statistical reports
Type of employment?
Entry level, mid-career, established, permanent, temporary, full-time, part-time.
Type of role?
actors/directors/screenwriters
How do
women
find
employment
In filmmaking?
Which women?
age, ethnicity, race, sexual orientation,
gender identity, ability/disability
Type of filmmaking?
Hollywood/Bollywood/Nollywood etc, time period: present day, in 1920, in 1980s
documentary, fiction, experimental film, virtual reality, advertising

My Sharing Today

- What are the current topics in the area of Industry 4.0 and Quality 4.0?
- Method - reviewed papers – provide analysis and suggest possible areas (I believe) important in this field and relevant for your context of Indonesia – very fast moving with high expectations from current administrators/government
- How can Industrial Engineers stay relevant (higher quality, increased competitiveness, improved productivity, reduced costs, efficient processes in organizations) in VUCA (volatile, uncertain, complex and ambiguous) world we live in today – Post-Covid, Russia-Ukraine War, Oil/Food Prices Increases, Unstable monetary exchange, etc.

Some interesting **Topics** being published/researched in IR 4.0 recently

- **Industry 4.0 Implementation Cases/Framework**
- **Readiness Level of Industry 4.0**
- Challenges / Difficulties to Industry 4.0
- **Levels achieved in Industry 4.0**
- **Industry 4.0 relationship with TQM**
- **Managers reaction to Industry 4.0**
- **Barriers to Industry 4.0**
- ….. and many others

The road towards industry 4.0: a comparative study of the state-of-the-art in the Italian manufacturing industry

Ting Zheng, Marco Ardolino, Andrea Bacchetti and Marco Perona
Rise Laboratory, Department of Mechanical and Industrial Engineering, Universita degli Studi di Brescia, Brescia, Italy

Abstract

Purpose – This paper has two objectives: first, to investigate the state-of-the-art of Industry 4.0 (I4.0) adoption in Italian manufacturing firms and, second, to understand variations in technologies implemented and business functions involved, benefits perceived, and obstacles encountered in I4.0 implementation over a three-year period.

Benefits

- Significant strategic benefits leading to economic and financial performance – flexible, better decision-making
- Costs Reduction
- Quality Improvement
- Time Reduction
- Flexibility Improvement

Findings

Barriers

1. Top management awareness, champion change management
2. New skills and competency in IT Ind 4.0 Technologies, digitalization, Additive Mfg., Robotics, AR, VR, AI
3. Different maturity levels of organizations of enabling technologies – need integration of Technologies used with IT systems
4. Implementation costs especially manufacturing SMEs not having sufficient financial capacity to support investment

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Involvement of Business Functions

- Crucial for Integration and Successful Adoption
- Most involved – R&D, Production, IT
- Lowest involved – HR
- Unbalanced penetration of Ind 4.0 on the Business function
- After 3 years (2020) = quality and logistics more involved
- **(Comment : to be successful and sustainable more business functions need to be involved early in the process)**

Readiness Level

- Poor adoption in Italy - esp. AR, VR, AI -5%
- IIOT and AM = 20%
- Why low adoption?
- Technology adoption is a long-term evolutionary process – need company's Technology Strategy
- Implementing IR 4.0 = **need Technological and Organizational alteration** (adjustments, modifications, changes) – need to retrofit existing production system and equipment
- Firm size is a challenge – SMEs low adoption –costs issue, and skills/competencies

The mark of industry 4.0: how managers respond to key revolutionary changes

Erlinda N. Yunus
Sekolah Tinggi Manajemen PPM, DKI Jakarta, Indonesia

Purpose : to provide a framework of managerial responses to the Industry 4.0 phenomenon, which has impacted the productivity of Indonesian manufacturing companies (Large)

Findings : Indonesian manufacturers have engaged in Industry 4.0 initiatives: cyber-physical systems, the internet of things, Big Data and cloud computing. These initiatives require managers to adopt best practices, appoint champions as change agents, conduct training and even tailor the job qualifications of their subordinates to suit the current technology.

Recommendation : exploratory framework could guide managers in their strategic and operational decisions while embracing the Industry 4.0 transformation inside the organization

Interesting comment by author :-
"**human resources as their primary challenge** throughout the Industry 4.0 implementation. Some of their concerns were the limited knowledge of the operators and the resistance to change. The companies had to implement a systematic change management process that consisted of intensive communication, training, campaigns and appointed employees who served as **champions**"

The mark of industry 4.0: how managers respond to key revolutionary changes

Erlinda N. Yunus
Sekolah Tinggi Manajemen PPM, DKI Jakarta, Indonesia

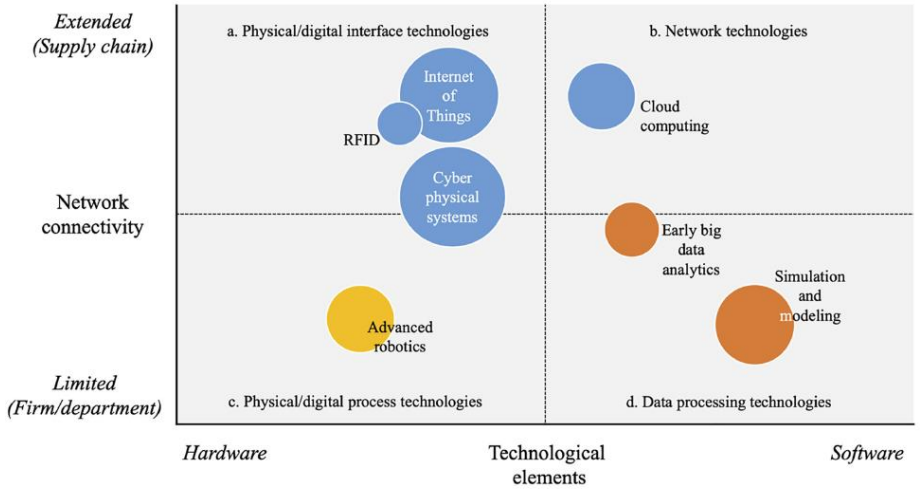

Figure 1.
The enabling technologies adopted by the companies of the current study

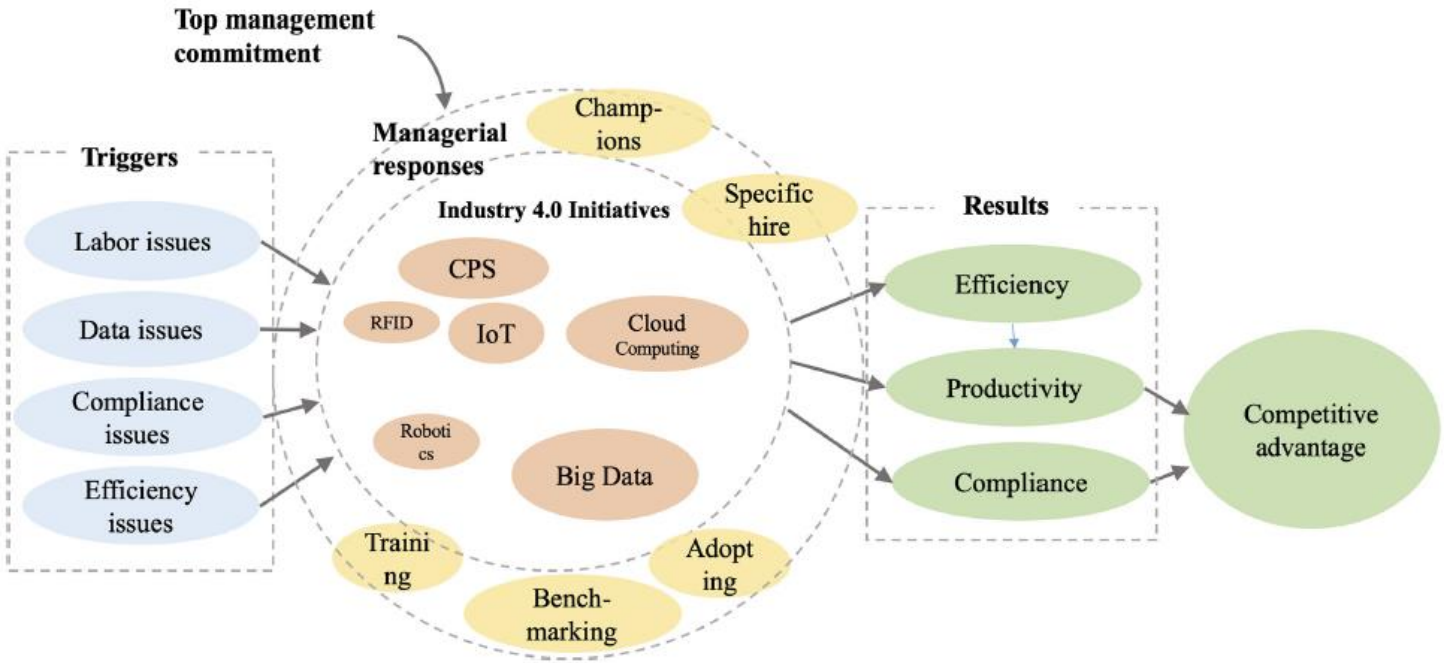

Figure 2.
Conceptual framework of managerial responses to industry 4.0 adoption

International Journal of Productivity and Performance Management ,Vol. 70 No. 5, 2021 pp. 1213-1231, Emerald Publishing Limited 1741-0401 DOI 10.1108/IJPPM-12-2019-0590

A mixed-method study on the barriers of industry 4.0 adoption in the Indonesian SMEs manufacturing supply chains

- Investigate the adoption barriers of Industry 4.0 in the Indonesian manufacturing supply chains.
- five main barriers - unclear Industry 4.0 policy, higher-risk investment, insecure data sharing, lack of expertise and lack of incentive
- Indonesia 4.0, which drives national owned manufacturing companies to transform their business process into the digital platform.
- Indonesia introduced roadmap of IR 4.0 - Making Indonesia 4.0 in 2018.
- Five industrial sectors (F&B, textile and clothing, automotive, chemistry, electrical and electronics)

- Infrastructure gaps, scattered location/island - difficulties deploying Industry 4.0 technologies
- Manufacturing companies located on Java island better opportunities to deploy Industry 4.0 - equipped with a better infrastructure and strategically located near the central government office - government can provide better guidance compared to other companies located quite far from Java island
- Government needs to empower the micro and small manufacturing firms to attract and assist in the Industry 4.0 deployment.

Fernando, Yudi & Sari, Ika & Gui, Anderes & Ikhsan, Ridho & Mergeresa, Fineke & Ganesan, Yuvaraj. (2022). A mixed-method study on the barriers of industry 4.0 adoption in the Indonesian SMEs manufacturing supply chains Indonesian SMEs manufacturing supply chains. Journal of Science and Technology Policy Management. 10.1108/JSTPM-10-2021-0155.

A mixed-method study on the barriers of industry 4.0 adoption in the Indonesian SMEs manufacturing supply chains

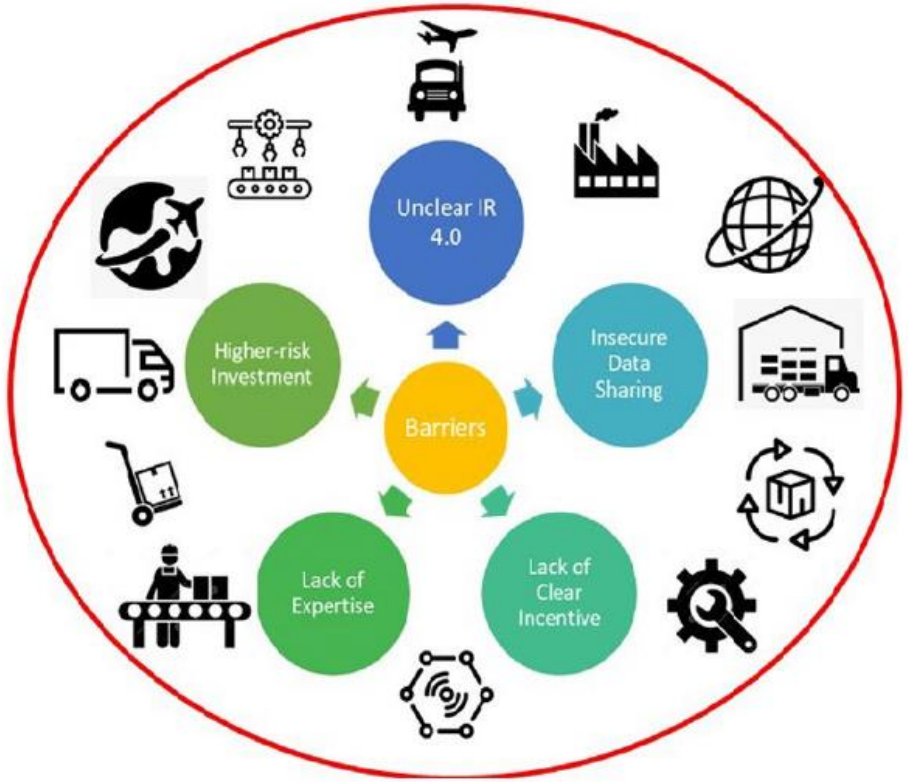

Figure 6.
Barriers of Industry 4.0 adoption in manufacturing supply chains

SUGGESTED FUTURE RESEARCH

"Understanding the barriers and enablers are the critical success factors on Industry 4.0 adoption in the manufacturing supply chain. It is worth suggesting that **future studies can replicate and incorporate** the strategic theory to extend the technological adoption framework."

Fernando, Yudi & Sari, Ika & Gui, Anderes & Ikhsan, Ridho & Mergeresa, Fineke & Ganesan, Yuvaraj. (2022). A mixed-method study on the barriers of industry 4.0 adoption in the Indonesian SMEs manufacturing supply chains Indonesian SMEs manufacturing supply chains. Journal of Science and Technology Policy Management. 10.1108/JSTPM-10-2021-0155.

Factors influencing Industry 4.0 adoption

Sabai Khin and Daisy Mui Hung Kee
School of Management, Universiti Sains Malaysia, Penang, Malaysia

Findings – Industry 4.0 Adoption

1.Driving Factors

2.Facilitating Factors

3.Impeding Factors

And the Expected Benefits and Opportunities given by the respondent

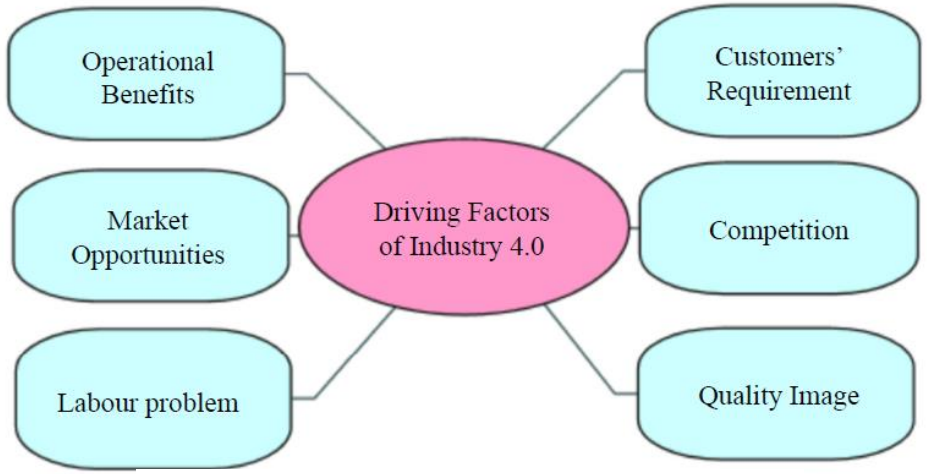

Figure 1.
Driving factors of I4.0 adoption

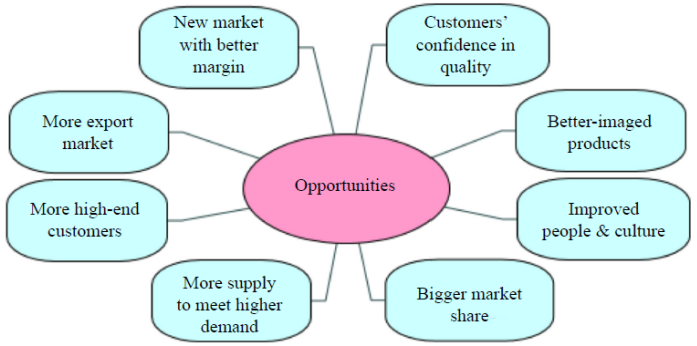

Figure 3.
Expected opportunities of I4.0 adoption

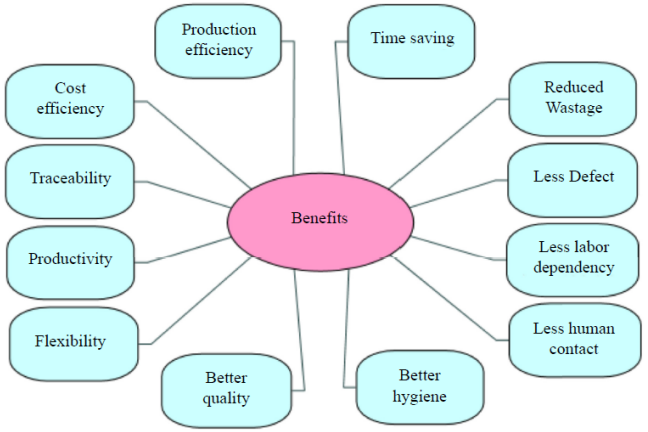

Figure 2.
Expected benefits of I4.0 adoption

Journal of Manufacturing Technology Management Vol. 33 No. 3, 2022 pp. 448-467, Emerald Publishing Limited , 1741-038X, DOI 10.1108/JMTM-03-2021-0111

Factors influencing Industry 4.0 adoption

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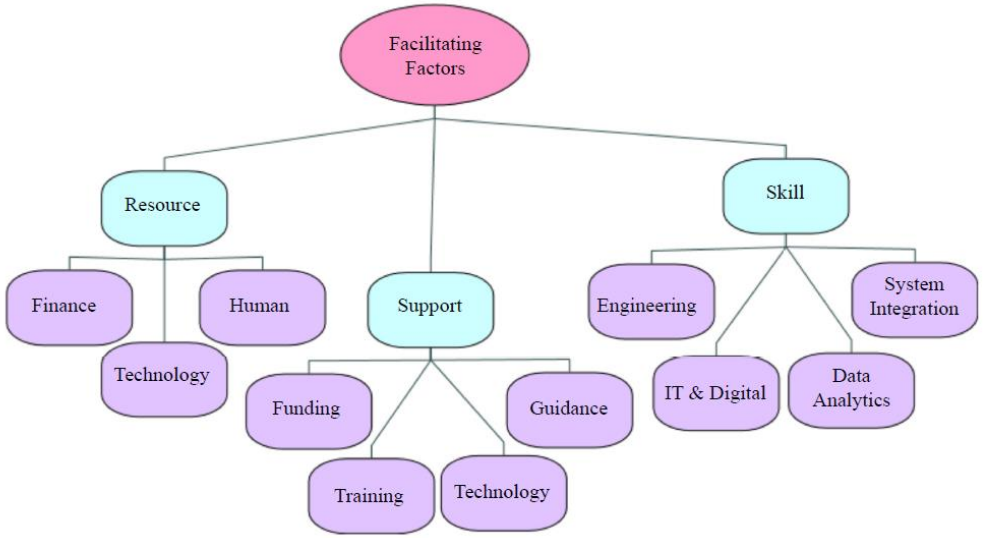


Figure 4.
Facilitating factors of I4.0 adoption

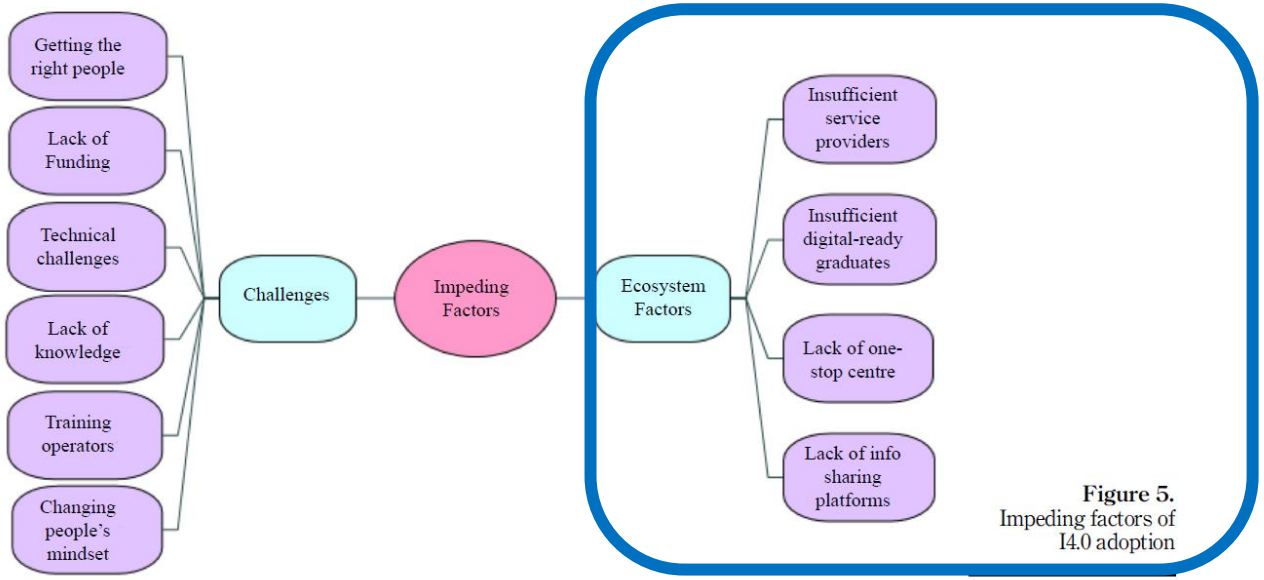


Figure 5.
Impeding factors of I4.0 adoption

Ecosystem for I4.0.

"These challenges include insufficient and inexperienced digital tech and service providers, an insufficient supply of **digital-ready graduates**, lack of **one-stop centres** and lack of **info-sharing avenues or platforms**:"

INDUSTRY4WRD READINESS ASSESSMENT (RA)

A **comprehensive programme** to help firms **assess their capabilities and readiness** to adopt Industry 4.0 technologies and processes, using a pre-determined set of indicators to understand their present capabilities and gaps

Government Incentives (2021 - 2025)

- Government-funded Industry*4WRD* RA
- Tax deduction on expenditure of Industry4WRD RA fee : up to RM27,000

Outcome

- Identify the gaps and areas of improvement for Industry 4.0 adoption
- Develop feasible strategies and plans for intervention projects

INDUSTRY4WRD RA CRITERIA MODEL
*Manufacturing Sector

Focuses on people and the entire organisation.

Emphasis on strategies towards having a right set of workforce

Focuses on management system in running business operations, supply chain and product lifecycle.

Emphasis on smart and strategic public-private partnerships, security, sustainability and product co-creation.

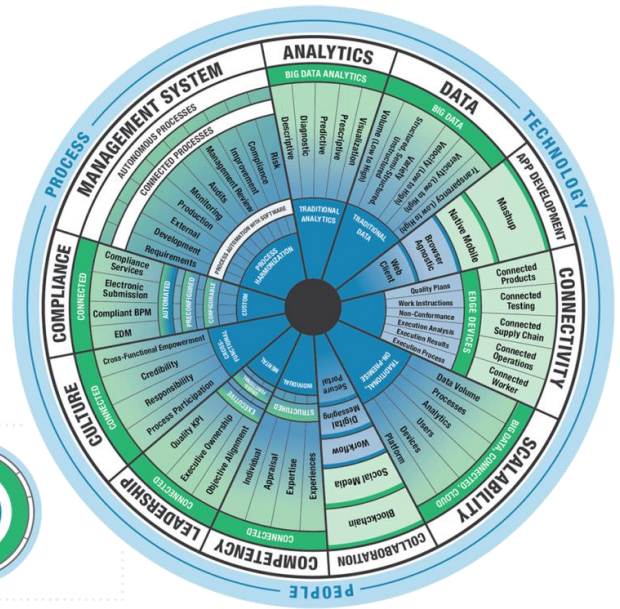
Focuses on the application of intelligent, connected and automated technologies.

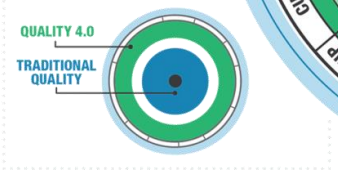
Measured at three different layers of the business: Shop floor, enterprise and facility

*MRS Sector – Additional dimension

1. Technology (Work area)
2. Process (Resource Management, Service lifecycle management, service customisation)

Next Part
Quality 4.0





Quality 4.0 – Research Issues

- How is Quality 4.0 being understood?
- What are the CSFs for Quality 4.0?
- How to adopt Quality 4.0 technologies?
- How to measure success of Quality 4.0?

- Competencies of quality professional specific for Quality 4.0
- Enablers to Quality 4.0

Quality 4.0 Definitions

Author(s)	Definition
Jacob (2017)	"Quality 4.0 certainly includes the digitalization of quality management" (p. 8) "Quality 4.0 does not replace traditional quality methods, but rather builds and improves upon them" (p. 8)
Radziwill (2018)	"Quality 4.0 is the name given to the pursuit of performance excellence during these times of potentially disruptive digital transformation" (p. 24)
Salimova *et al.* (2020)	". . .an adaptive ability of an object at all stages of the life cycle to meet the needs of a particular consumer on the basis of partnership with stakeholders and digital management of the value chain" (p. 486)
Zonnenshain and Kenett (2020)	". . .a framework for a quality discipline supporting the fourth industrial revolution. We propose to call it Quality 4.0" (p. 1)
Ramezani and Jassbi (2020)	"Quality "4.0" is a branch of the industry 4.0 (I4.0) movement associated with the digital transformation process connected with emerging technologies" (p. 5)
Sony *et al.* (2020)	"Quality 4.0 as such is so much more than technology. It is a new method by which digital tools can be used so that organizations' ability to consistently deliver high-quality products can be improved" (p. 781)
Escobar *et al.* (2021)	"Quality 4.0 is founded on a new paradigm based on empirical learning, empirical knowledge discovery, and real-time data generation, collection, and analysis to enable smart decisions" (p. 2320)

Table 6. Definitions for quality 4.0

Broday, E.E., (2022), The evolution of quality: from inspection to quality 4.0, International Journal of Quality and Service Sciences Vol. 14 No. 3, pp. 368-382, Emerald Publishing Limited 1756-669X DOI 10.1108/IJQSS-09-2021-0121

Quality 4.0 Concepts

The term “Quality 4.0” refers to the future of quality within the context of Industry 4.0 (ASQ, Quality 4.0).

The three aspects of quality “(a) quality of design, (b) quality of conformance and (c) quality of performance” needs are increasingly met **using improved technologies** such as “cyber physical systems (CPS), Internet of Things (IoT),robotic process automation (RPA), big data, artificial intelligence (AI) and cloud computing”.

Antony, J, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions, International Journal of Quality & Reliability Management, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

Quality 4.0 Concepts

The Quality 4.0 definition is evolving, and recent qualitative studies have defined Quality 4.0 as “the use of advanced technologies such as IoT, CPS, Cloud computing to design, operate and maintain adaptive, predictive, self-corrective, automated quality systems along with improved human interaction through quality planning, quality assurance, quality control and quality improvement to achieve new optimums in performance, operational excellence, and innovation to meet the vision, mission and goals of an organization.” (Antony et al., 2021).

Antony, J, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions, International Journal of Quality & Reliability Management, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

Quality 4.0 conceptualisation and theoretical understanding: a **global exploratory** qualitative study

FINDINGS - provides theoretical base for Quality 4.0 body of knowledge in terms of an organisation's adoption, implementation challenges, and examples of Quality 4.0 application.

- the benefits and motivating factors for implementing, the Critical Success Factors, challenges, the organisational readiness factors
- the role of leadership in a Quality 4.0 deployment
- the skills required by future Quality 4.0 professionals in terms of hard skills, soft skills and a curriculum for educating future quality management professionals
- respondents cited predictive analytics, sensors and tracking, and electronic feedback loops the most critical technologies for driving Quality 4.0

Antony, J., McDermott, O. and Sony, M. (2021), "Quality 4.0 conceptualisation and theoretical understanding: a global exploratory qualitative study", The TQM Journal, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/TQM-07-2021-0215

An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions (Antony, et al, 2021)

Readiness factor	Mean scores	Normalization
Top management support	4.00	1.00
Leadership	3.94	0.91
Organizational culture towards Quality 4.0	3.86	0.80
Customer readiness	3.83	0.74
Knowledge and awareness on Quality 4.0	3.80	0.70
Quality 4.0 vision and strategy	3.73	0.61
Supplier readiness	3.59	0.41
Trainings and rewards	3.30	0.00

Table 8. Overall readiness factors

Readiness factor	Mean scores	Normalization
Top management support	4.18	1.00
Leadership	4.08	0.87
Organizational culture towards Quality 4.0	3.97	0.72
Customer readiness	3.96	0.70
Quality 4.0 vision and strategy	3.93	0.67
Knowledge and awareness on Quality 4.0	3.87	0.58
Supplier readiness	3.68	0.32
Trainings and rewards	3.45	0.00

Table 9. Readiness factors for large enterprises

Antony, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions International Journal of Quality & Reliability Management, Emerald, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

Table 10. Readiness factors for small enterprises

Readiness factor	Mean scores	Normalization
Knowledge and awareness on Quality 4.0	3.56	1.00
Organizational culture towards Quality 4.0	3.50	0.92
Leadership	3.49	0.91
Top management support	3.44	0.83
Customer readiness	3.39	0.76
Supplier readiness	3.32	0.67
Quality 4.0 vision and strategy	3.05	0.30
Trainings and rewards	2.83	0.00

Table 11. Readiness factors difference between large and SMEs

Readiness factor	LE	SME	*t*-test	*p*-value
Top management support	4.18	3.44	2.490	0.014
Quality 4.0 vision and strategy	3.93	3.05	3.091	0.002
Leadership	4.08	3.49	2.097	0.038
Trainings and rewards	3.45	2.83	2.278	0.024
Knowledge and awareness on Quality 4.0	3.87	3.56	1.053	0.294
Organizational culture towards Quality 4.0	3.97	3.50	1.627	0.106
Customer readiness	3.96	3.39	1.936	0.055
Supplier readiness	3.68	3.32	1.181	0.240

Table 12. Critical readiness factor in manufacturing sector

Readiness factor	Mean scores	Normalization
Top management support	3.91	1.00
Leadership	3.79	0.85
Organizational culture towards Quality 4.0	3.73	0.78
Knowledge and awareness on Quality 4.0	3.69	0.72
Customer readiness	3.68	0.70
Quality 4.0 vision and strategy	3.60	0.61
Supplier readiness	3.54	0.53
Trainings and rewards	3.12	0.00

Table 13. Critical readiness factor in service sector

Readiness factor	Mean scores	Normalization
Leadership	4.33	1.00
Top management support	4.24	0.84
Customer readiness	4.20	0.78
Organizational culture towards Quality 4.0	4.19	0.76
Knowledge and awareness on Quality 4.0	4.06	0.54
Quality 4.0 vision and strategy	4.05	0.53
Trainings and rewards	3.77	0.06
Supplier readiness	3.74	0.00

- Importance of organizational readiness factors for the successful adoption of Q4.0,
- Can be used as indicators to understand readiness of an organization to implement Q4.0
- Organizations not ready will have tough time implementing Q4.0
- Readiness factors highly beneficial to senior quality professionals - both manufacturing and service who would like to embark on the journey of Q4.0.

Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research

Topic	Issue
Creating value within the company through quality (big) data, analytics and AI	Automated collection and sharing of the right data (where, what, how, to whom) Using analytics, predictive software and AI for problem-solving and decision-making process
Developing Quality 4.0 skills and culture for quality people	Acquiring expertise to collect, analyse and interpret (big) data, taking actions, for both employees and professionals Sustaining and promoting Quality 4.0 culture
Customer value co-creation	Digital servitization Automatically streaming (big) data from the customer to design and production Improving customer relations and experience through CPS, CRM, AI, social media
CPS and ERP for quality assurance and control	Monitoring product state and route Automatically collecting data and information concerning inspections and audits results, non-conforming product, calibration results Managing data through PLM and MES software Automating document control process

Table 5.
Relevant Quality 4.0 topics and issues emerging from the SLR

Main Issues
1. Digitalization of Quality Management Processes and Activities
2. Competencies for Quality Personnel in digitalization technologies

Chiarini,A., (2020) Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research, The TQM Journal, Vol. 32 No. 4, pp. 603-616, Emerald Publishing Limited DOI 10.1108/TQM-04-2020-0082

Critical success factors for the effective implementation of Quality 4.0 in more expansive organisations (Large companies)

1. Handling big data
2. Improving prescriptive analytics
3. Using Quality 4.0 for an effective vertical, horizontal and end-to-end integration
4. Using Quality 4.0 for strategic advantage
5. Leadership in Quality 4.0
6. Training in Quality 4.0
7. Organisational culture for Quality 4.0
8. Top management support for Quality 4.0

Sony, M., Antony, J. and Douglas, J.A. (2020), “Essential ingredients for the implementation of quality 4.0: a narrative review of literature and future directions for research”, The TQM Journal. DOI: 10.1108/TQM-12-2019-0275.

Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia

- Investigates the competencies required for quality management professionals to meet needs of industry 4.0
- Conducted case study at an electronics manufacturer in southern Malaysia - to adapt their role to be relevant in the industry 4.0 environment

64 quality professionals with a response rate of 96.88%. Interview to 3 decision-makers from critical areas in the electronics manufacturer
- finance, operations and talent development

4 RQ

(1) How are the changing technological trends expected to impact the future role of quality in industry 4.0?

(2) What are the competencies gap between current and future roles of quality professionals?

(3) What are the views and practices related to quality roles?

(4) How can the gaps identified be closed to meet the quality challenges of industry 4.0?

Findings –

- Quality professionals will require technical competencies to interpret large amounts of data from processes to make strategic decisions, the use of new AR tools and be aware of data security risks
- Methodological competencies will be required to use data to identify source of problems, to access reliable sources of learning and the ability to use new tools for solving complex problems efficiently
- Social competencies in communications across multi-sites, suppliers and customers in new collaborative virtual platforms, ability to retain tacit and explicit knowledge, in a decentralized environment - require leadership ability to make decisions
- Personal competencies required will be the ability to work in a flexible workplace and time and more frequent work-related changes.

Conclusion = quality professionals lack awareness of new roles in industry 4.0 - new technology is not implemented by (local) quality professionals but by the innovation team based in Singapore headquarters

Difficulty when you are a foreign subsidiary level – dependent on headquarter decision

Table 2.
Recommendation for the competency gap solutions

Competence	What is required	Suggested actions to be taken	Responsibility
Technical skills			
1. Increased job knowledge due to automated processes	Require knowledge of the automated processes	Awareness training, exposure to new technology by attending exhibitions, supplier demo, etc.	Top management and Innovation team
2. Strategic role as change agent and to identify value creation opportunities	Require knowledge from processes to align with business goals and objectives	Audit with new big data capability to have access to enterprise level data Corbin (n.d.)	Quality department/IT department
3. Higher technical and media skills for new technologies	Require knowledge of media tools	Machine/equipment suppliers to conduct on-site training Benešová and Tupa (2017, p. 2198)	Supplier
4. Awareness of data security	Require knowledge of IT and how data security is breached	Training on cyber security and data integrity and risk management Tupa *et al.* (2017, p. 1224)	IT department/ Quality department
Methodological skills			
1. Ability to solve complex problems by examining large amounts of data	Require knowledge to analyse big data in order to interpret and solve	Training in big data analysis using new tools Benešová and Tupa (2017, p. 2198)	Supplier
2. Reliable sources for continuous learning	Require access to the new knowledge	Have a personal assistant/ mobile device to retrieve relevant information and/or AR Gorecky *et al.* (2014, p. 292) and Gaskil (2017, p. 11)	Quality department/ Innovation team
3. Ability to solve complex problems efficiently, with new tools	Require capability for efficient problem-solving, with new advanced tools (analytics and algorithms)	Training to maximize value using new tools and software, by supplier Benešová and Tupa (2017, p. 2198) and Sung (2018, p. 41)	Supplier/Training department

Table 2.
Recommendation for the competency gap solutions

Competence	What is required	Suggested actions to be taken	Responsibility
Personal skills			
1. Ability to be flexible in work and time due to virtual work environment	Require work regulation to have work–life balance	Drafting of work regulation for industry 4.0 environment Hecklau *et al.* (2016, p. 3)	Human Resource
2. Be motivated to adapt to frequent work related changes	Require quality managers to motivate their teams and manage diverse employees, even virtually	Training for managers to change management style from power-driven to value-driven Erol *et al.* (2016, p. 14)	Training department
Social skills			
1. Increased virtual communication capabilities	May require knowledge of new virtual tools across platforms and value chains	Training in new virtual tools and platforms Benešová and Tupa (2017, p. 2198)	Training department/ supplier
2. Effective knowledge retention	Require effective knowledge sharing and storage	Centralizing data from all components of a smart factory in a quality intelligence solutions Lyle (2017, p. 8)	IT department
3. Ability to make decisions as leaders in decentralized environment	Require to read and understand process information from machines	Machine/equipment suppliers to conduct on-site training Benešová and Tupa (2017, p. 2198)	Supplier

Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda

Purpose – Quality 4.0 (Q4.0) is related to quality management in the era of Industry 4.0 (I4.0). It concentrates on digital techniques used to improve organizational capabilities and ensure the delivery of the best quality products and services to its customer.
Aim of this research : to examine the vital elements for the Q4.0 implementation.
Design/methodology/approach – Literature review carried out to analyze past studies in this emerging research field

Ramadas Thekkoote, (2022), Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda, International Journal of Quality & Reliability Management Vol. 39 No. 6, pp. 1368-1384, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-07-2021-0206

Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda

Findings

Identified ten factors that contribute to the successful implementation of Q4.0.

(1) Data
(2) Analytics
(3) Connectivity
(4) Collaboration
(5) Development of apps
(6) Scalability,
(7) Compliance,
(8) Organization culture
(9) Leadership and
(10) Training for Q4.0.

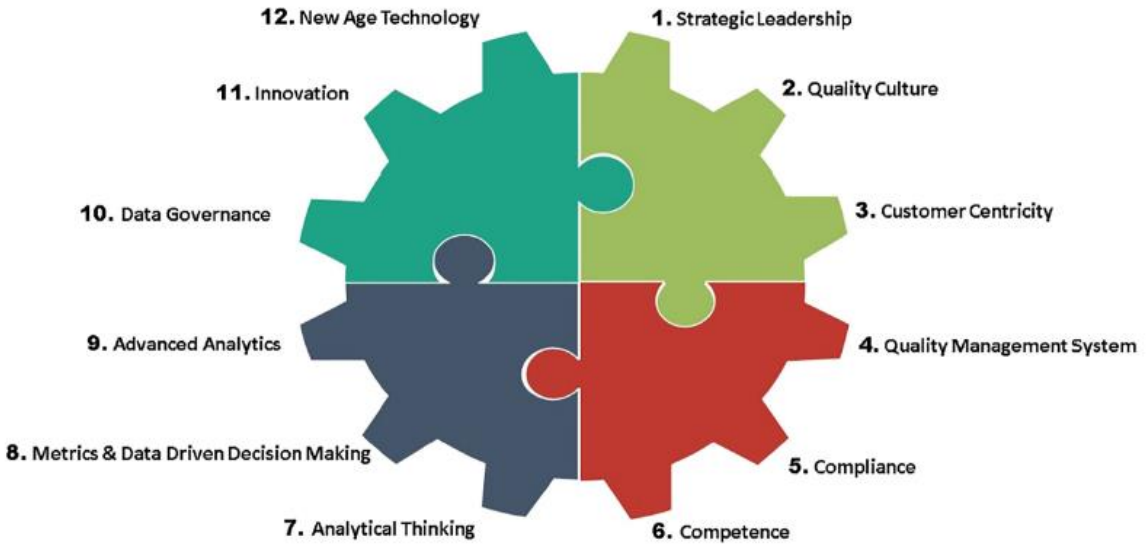
Originality/value

= a new understanding of factors of successful implementation of Q4.0 in the digital transformation era can assist firms in developing new ways to implement Q4.0.

Ramadas Thekkoote, (2022), Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda, International Journal of Quality & Reliability Management Vol. 39 No. 6, pp. 1368-1384, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-07-2021-0206

Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique

Quality 4.0 refers to the digitalization of quality work in the context of Industry 4.0.



Findings

- 12 dimensions contribute to outcome indicators such as organizational performance, agility and sustainability
- Although technology vital for Quality 4.0, elements of traditional quality such as leadership, quality culture, customer focus, quality systems, compliance, competence, analytical thinking, data-driven decision making, etc. are mandatory for the transformation journey

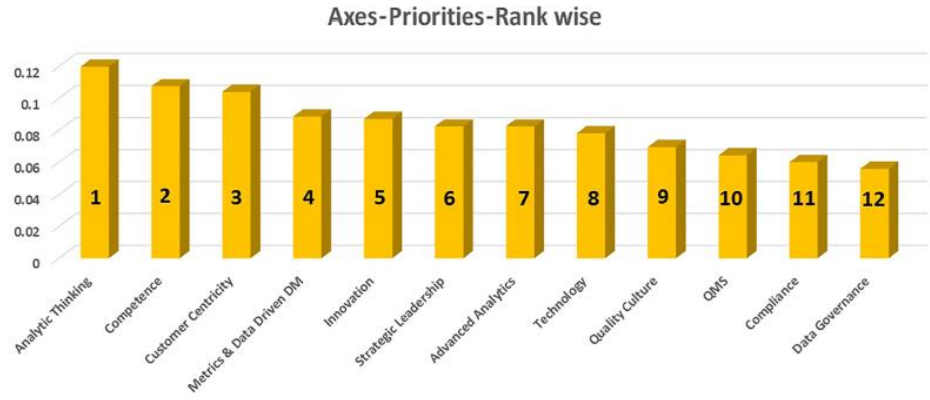


Figure 10.
AHP results – axes priorities – rank wise

G.S. Sureshchandar, (2022), Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique
International Journal of Quality & Reliability Management, Vol. 39 No. 6, pp. 1336-1367 © Emerald Publishing Limited 0265-671X DOI 10.1108/IJQRM-06-2021-0159

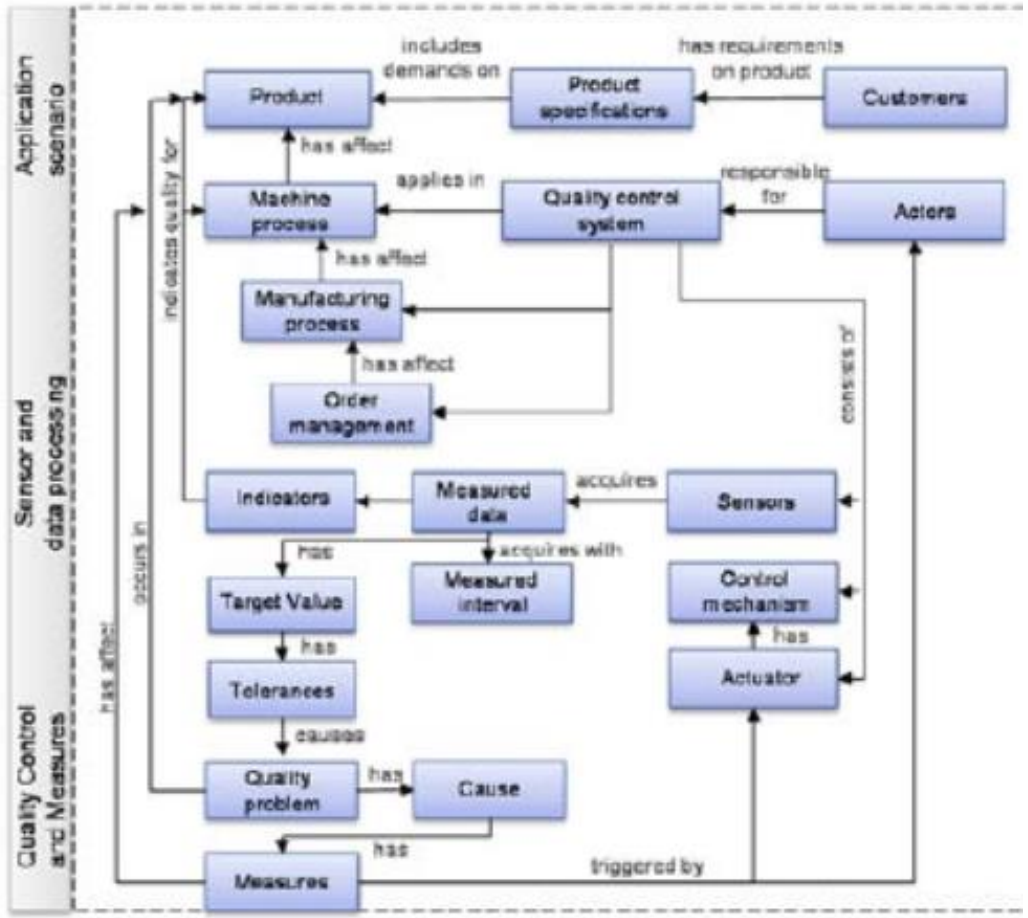


Figure 6: Ontology of the descriptive model for the manufacturer

Intelligent quality control systems

Industry 4.0 impacts on digitalizing (making it intelligent) quality control activities in smart factory environment -

Context : Germany – where IR4.0 started – advanced level

Albers, A.; Gladysz, B.; Pinner, T.; Butenko, V.; Stürmlinger, T. Procedure for defining the system of objectives in the initial phase of an industry 4.0 project focusing on intelligent quality control systems. Procedia CIRP 2016, 52, 262–267.

Note:

- Given the **specific and complex nature of Industry 4.0**, enterprises need to undertake appropriate implementation strategies tailored to the individual design of their institutional and process organization structure (Müller, Buliga and Voigt, 2018)

Must clearly define and decide context of research - size of organization, type of industry, even differences between manufacturing – food different from automotive, electrical, electronics, oil and gas, service industries ➔ cannot generalize
Use of technologies also differ between and intra industry. Compare between country – MUST CAREFULLY DESIGN THE RESEARCH

Some Suggested Further Research Areas

- What is a better definition of Quality 4.0?
- What are the elements, activities, practices and systems in Quality 4.0?
- How to implement Quality 4.0 that supports Industry 4.0 for specific industry/product categories?
- What is the readiness level of companies – compare between industries or between size of companies, or between countries?
- What are the performance measures of a Quality 4.0 level companies?
- Can we develop Quality 4.0 Maturity Matrix ?
- How to modify Excellence Framework such as MBNQA, EFQM, Deming award that include Quality 4.0 (digitalization integration and digital penetration)

Centre for Advancement of Quality 4.0

- Skills identification – digital design, analytics, smart inspection systems real-time experts, etc.
- Learning and Competency Upgrading
- Creation of Local Platforms for Sharing Best Practices and Implementation Method (especially Small Medium Enterprise)
- Incentives and Financial Support to SMEs
- University Graduate Digital Knowledge Upgrade
- New Curriculum Digital Industrial Engineering

Ecosystem for I4.0. "These challenges include insufficient and inexperienced digital tech and service providers, an insufficient supply of **digital-ready graduates**, lack of **one-stop centres** and lack of **info-sharing avenues or platforms**:"

Thank you and terima kasih

Domo arigato gozaimshita.