Industry 4.0 Tool Application: Integration of TAM and TTF Model Perspective

Surajit Bag* and Arnesh Telukdarie
Faculty of Engineering and Built Environment
University of Johannesburg
Johannesburg, South Africa
*Corresponding author

Abstract

The fourth industrial revolution, also known as Industry 4.0 drives industrial automation of plant's processes to enhance productivity. The fast pace growth of technology and maturity of plant's processing technology have actually triggered the fourth industrial revolution. Advanced systems under Industry 4.0 architecture comprises of hardware, software, electronics, machines and equipments, all working together in a synchronised manner to meet the common organisation goals. Industry 4.0 affirms the ability to build dynamic capabilities in an organisation and beat market competition. The use of Industry 4.0 tool application is complex and requires additional knowledge and special skill sets, thus lowering the interest of companies towards adoption of Industry 4.0 projects. There is hardly any evidence in existing literature on the technology maturity level of Industry 4.0 tool. Also there is limited literature on smart factory task and Industry 4.0 technology fit. The current study aims to eliminate the void in existing literature by integrating Industry 4.0 Technology Acceptance Model (TAM) and Industry 4.0 Task-Technology Fit (TTF) model. Using samples drawn from South African companies the theoretical framework can further be statistically validated and new insights can be generated.

Keywords: Industry 4.0, South Africa, Technology acceptance model, Task-Technology fit model, Tool

1. Introduction

The fourth industrial revolution has advanced manufacturing systems and use cyber physical systems to drive automated industrial process (Sung, 2018). Industry 4.0 is a relatively new concept which evolved in Germany and gradually gaining popularity globally (Bag et al., 2018). The opportunity to apply industry 4.0 technological subsets for business logistics optimization is the focus of most organisations worldwide. Van Looy *et al.* (2011) opined that logistics practitioners frequently neglect the difference between maturity and capability. Business logistics cannot achieve excellence without gradually improving the maturity and capability of processes (Telukdarie et al., 2018). Industry 4.0 technological maturity is still unknown and is the main focus of this research study. The current study aims to use integrated Industry 4.0 Technology Acceptance Model (TAM) and Industry 4.0 Task-Technology Fit (TTF) model as the theoretical lens to understand the Industry 4.0 underlying mechanism and assess the current maturity level.

2. Research Propositions

The research propositions of the current study are derived from review of extant literature and discussion with industry experts. Smart factory task involves automation and digitisation enabling end to end business integration. Executing these tasks require high end technologies which must perfectly fit in the current organisation system. Therefore selection of right technology set would depend upon the nature of tasks and further lead to successful adoption of Industry 4.0 projects. Therefore, research team hypothesize:
H1: Smart factory task characteristics have a positive influence on Smart factory task- Industry 4.0 technology fit

Smart factory tasks in a manufacturing setting would involve developing a plant control network to operate the machines automatically, manage flexible production lines, optimize resource usage, and use RFID tags for packaging and dispatching. There are multiple Industry 4.0 tools including Real time yield optimization; Routing flexibility; Machine flexibility; Remote monitoring and control; Predictive maintenance; Augmented reality for MRO; Human-robot collaboration; Digital performance management; Automation of knowledge work; In-situ 3D printing; Real time supply chain optimization; Batch size; Statistical process control; Advanced process control; Digital quality management; Data driven demand prediction; Open innovation; Concurrent engineering; Rapid experimentation and simulation; Remote maintenance; Virtually guided self service; Smart energy consumption and Intelligent lots. Successful accomplishment of smart factory tasks requires right selection of Industry 4.0 tools and proper application in the business environment. Therefore, research team hypothesize:

H2: Smart factory task characteristics have a positive influence on Actual Industry 4.0 tool application

Industry 4.0 tools are of various types and yield diverse benefits. Smart factory task-Industry 4.0 technologies fit calls for application of correct Industry 4.0 tool sets to unlock the potential benefits. Therefore, research team hypothesize:

H3: Industry 4.0 tool functionality has a positive influence on Smart factory task-Industry 4.0 technology fit

Industry 4.0 tool functionality influences the perception of users' in terms of degree of easiness in Industry 4.0 tool application. When detailed guidelines of Industry 4.0 tool functionality are available to the users, then they find it easy to apply and obtain the desired results. Therefore, research team hypothesize:

H4: Industry 4.0 tool functionality has a positive influence on Perceived ease of Industry 4.0 tool application

Users having many years of experience in dealing with Industry 4.0 tools generally feel comfortable to use such tools on a daily basis. Usage of such tools on a regular basis creates a perception on the mind of the users that tools are easy to apply. This is developed over years of continuous usage and practice. Therefore, research team hypothesize:

H5: Industry 4.0 tool use experience has a positive influence on Perceived ease of Industry 4.0 tool application

Experience of using Industry 4.0 tools come from performing various trial and error experiments and ultimately achieving the desired results. Such trials provide countless key information on the usefulness of the Industry 4.0 tool which is helpful in long term for successful adoption of Industry 4.0 projects. Therefore, research team hypothesize:

H6: Industry 4.0 tool use experience has a positive influence on Perceived usefulness of Industry 4.0 tool

Smart factory task and Industry 4.0 technology fit creates an environment compatible for users to implement Industry 4.0 projects through overcoming the technological challenges. This provides an opportunity for users to use the right Industry 4.0 tool and optimize business processes. It becomes easier to do the selection of right tool and eradicates the technological complexity. Therefore, research team hypothesize:

H7: Smart factory task-Industry 4.0 technology fit has a positive influence on Perceived ease of Industry 4.0 tool application

Organisations having fitted smart factory task and Industry 4.0 technology perfectly have basically won half of the battle by overcoming the hurdles in the initial phase of Industry 4.0 project implementation. Post fitment stage the directives and guidelines to use Industry 4.0 tools are shared with key members in the project team. Effective communication and transparency creates a positive mindset on usefulness of such tools which is beneficial in change management. Therefore, research team hypothesize:

H8: Smart factory task-Industry 4.0 technology fit has a positive influence on Perceived usefulness of Industry 4.0 tool

Smart factory tasks execution using appropriate technology subsets makes a perfect fit in Industry 4.0 environment and can avoid losses. These create a technological friendly environment and enhanced efficiency for actual Industry 4.0 tool application. Therefore, research team hypothesize:

H9: Smart factory task-Industry 4.0 technology fit has a positive influence on Actual Industry 4.0 tool application

The perception of simplicity of Industry 4.0 tool application on the mind of workers creates a positive image of Industry 4.0 tools in terms of benefits and usefulness. This will make them inclined towards usage of Industry 4.0 tools in driving Industry 4.0 projects. Therefore, research team hypothesize:

H10: Perceived ease of Industry 4.0 tool application has a positive influence on Perceived usefulness of Industry 4.0 tool

Employees show positive attitude towards adoption of Industry 4.0 tool when they fully understand the benefits of such tools and find it easy to apply in real environment. This also helps in managing changes in Industry 4.0 projects. Therefore, research team hypothesize:

H11: Perceived usefulness of Industry 4.0 tool has a positive influence on Attitude towards Industry 4.0 tool application

Employees having knowledge about Industry 4.0 tools and are aware of the usefulness always shows interest towards application of Industry 4.0 tool. Perceived usefulness basically creates an intention to apply these tools practically. Therefore, research team hypothesize:

H12: Perceived usefulness of Industry 4.0 tool has a positive influence on Intention to apply Industry 4.0 tool

Continuous education and training on Industry 4.0 tools along with long years of practical experience provides an understanding on the real benefits of such tools which drive employees to apply these tools on real cases. Therefore, research team hypothesize:

H13: Perceived usefulness of Industry 4.0 tool has a positive influence on Actual Industry 4.0 tool application

Intention to apply Industry 4.0 tools are driven through positive attitude of employees to apply these Industry 4.0 tools on real ground. If employees are scared of new technological tools, then they may not intend to use such tools. Awareness can drive away such fears from their minds and can trigger a positive intention towards adoption of new technological tools which is critical to success in Industry 4.0 projects. Therefore, research team hypothesize:

H14: Attitude towards Industry 4.0 tool application has a positive influence on Intention to apply Industry 4.0 tool

Industry 4.0 actual tool usage depends upon the intention of employees to apply such tools on real ground scenarios without restricting it to theoretical levels. Therefore, research team hypothesize:

H15: Intention to apply Industry 4.0 tool has a positive influence on Actual Industry 4.0 tool application

Based on the preceding discussion the Integrated TAM-TTF Industry 4.0 model has been proposed and further presented in Figure 1.

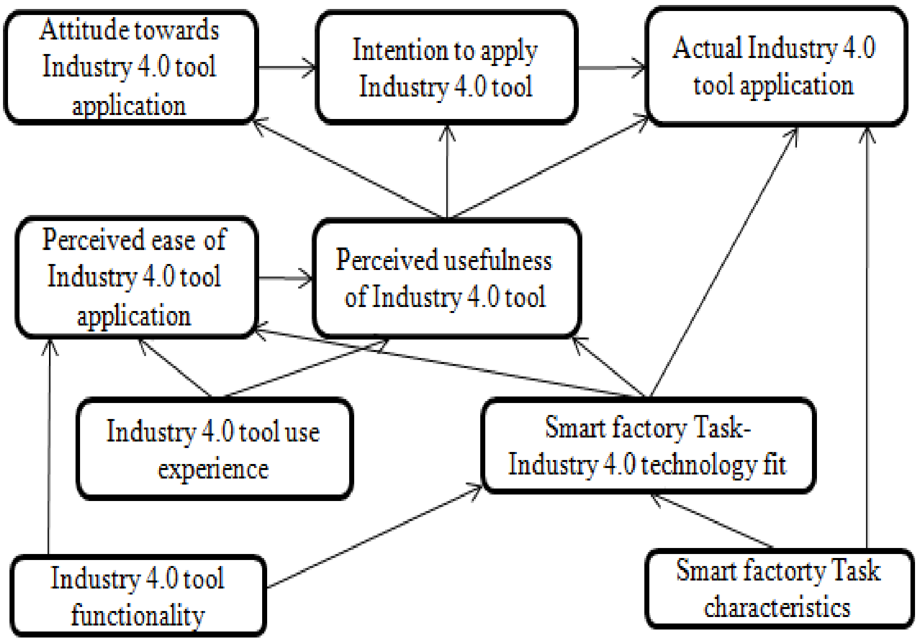

Figure 1. Integrated TAM-TTF Industry 4.0 model

3. Data Analysis

This section presents the methods adopted for conducting the empirical survey and the results of survey.

3.1 Operationalization of constructs

A rigorous process was used to develop the survey items; they were based on the systematic literature review, feedback from twenty industry executives (in the automotive, mining, steel, and engineering industries). The scales are drawn from established research and were selected to have high levels of reliability and validity. A multiple-item, 5-point Likert-type scale (1 = 'strongly disagree'; 2= 'disagree'; 3 = 'neutral'; 4= 'agree'; 5 = 'strongly agree') was used; the 5-point scale was used. The scales, consisting of 54 measurement items and no controls were used in the study.

3.2 Sampling and data collection

The research design involves sampling from the population of supply chain managers from the South African manufacturing sector. We used the manufacturing sector as this has been more extensively studied in terms of I4.0 applications and the items we used in the survey have been validated in this sector. The sample from South Africa is important as this is an emerging economy where digital transformation is a priority for most CEOs of industrial companies; of the firms surveyed, 27% rated their level of digitisation as high, and this value is expected to rise to 64% within the next five years (PWC South Africa n.d.). The digitalisation is based on essential functions and vertical operations process, gaining revenue growth and operational efficiencies from I4.0 applications while around 90% of the firms expect to expand their product portfolio with digital offerings (PWC South Africa n.d.). Therefore, this population will be well aware of the benefits derived from I4.0 applications in supply chains and able to answer the survey questions with authority. A random sampling approach was used from a list compiled from the association databases of the National Association of Automobile Manufacturers of South Africa (NAAMSA); The National Association of Automotive Component and Allied Manufacturers (NAACAM) and Steel and Engineering Industries Federation of Southern Africa (SEIFSA).

A pilot of the survey was provided to forty industry experts, each with over ten years' work experience. Based on the expert feedback, several items were re-worded to provide clarity to respondents and five items were removed to reduce redundancy and confusion. A five-point, likert-type scale was used to collect the data, where 1 would mean "strongly disagree"; 2 means "disagree"; 3 means "neutral"; 4 means "agree" and 5 means "strongly agree". Initially, the link for the online survey was emailed to 500 working professionals having professional membership of NAAMSA/NAACAM/SEIFSA and finally we received 360 useful responses. WarpPLS software was used to conduct the path analysis. The model fit and quality indices are within standard ranges.

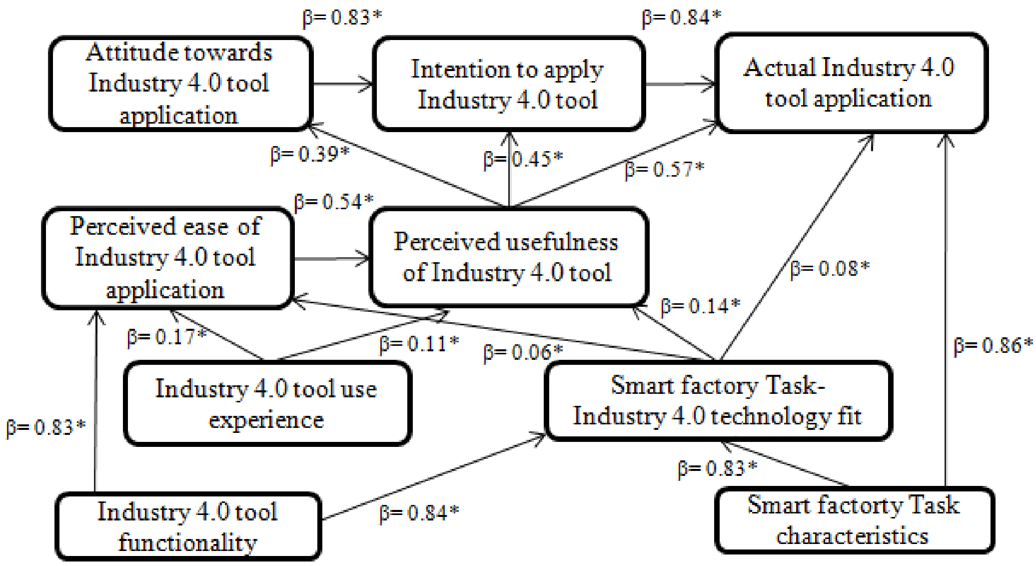

Figure 2. Tested Model

The research team presented the tested model obtained from analysis of structural equation modelling (Figure 2). P-value is considered there to establish the basis of acceptance or rejection of the null hypothesis. The results of hypothesis testing shows that all the fifteen hypotheses are supported based on the sample data used in this study.

4. Conclusion

In this era of globalization and heightened competition every organization aims to optimize business activities not only to meet customer commitments but also resources optimization, costs reductions and business sustainability. The fourth industry revolution, popularly known as Industry 4.0 drives digitalization and smart systems. Industry 4.0 has the potential to optimize the protracted and complex global business logistics chains. The current study basically aims to eliminate the void in existing literature by integrating Industry 4.0 Technology Acceptance Model (TAM) and Industry 4.0 Task-Technology Fit (TTF) model. All fifteen hypotheses are supported based on the sampling done in South African context. Managers need to understand I4.0 tool functionality and smart factory task characteristics to develop the I4.0 implementation strategy and fit smart factory task-. Understanding I4.0 tool functionality will help managers to change the attitude of fellow workers towards actual application of I4.0 tools.

4.2 Unique contributions

The scientific contribution of this research study is the proposed theoretical framework and its statistical validation in context to the South African manufacturing context. The study is grounded upon TAM-TTF theory and the findings can be helpful for practitioners and policy makers.

4.3 Future research directions

Future research directions can focus in the following areas:-

- Impact of I4.0 enabled technologies on the global manufacturing networks
- Managing supply chain risks using I4.0 technologies in VUCA business environment
- Using I4.0 technologies for business logistics optimization in a circular economy
- Integrating I4.0 and Circular economy concept to do facility planning
- Building global supply chain network using I4.0 technologies in remanufacturing context
- Managing talents and building HR capabilities to fit I4.0 in the organisation

References

Bag. S., Telukdarie, A. Pretorius, JHC and Gupta.S. (accepted, in press). Industry 4.0 and Supply Chain Sustainability: Framework and Future Research Directions, *Benchmarking: An International Journal.*

Dishaw, M. T., & Strong, D. M. (1999). Extending the technology acceptance model with task–technology fit constructs. *Information & Management*, *36*(1), 9-21.

PWC South Africa. n.d.. "Industry 4.0: South African Perspective." Retrieved October 25, 2018, from https://www.pwc.co.za/en/publications/industry-40.html

Sung, T. K. (2018). Industry 4.0: A Korea perspective. *Technological Forecasting and Social Change*, *132*, 40-45.

Telukdarie, A., Buhulaiga, E.A, Bag, S., Gupta, S., Luo, Z. (2018). Industry 4.0 implementation for multinationals, *Process Safety and Environment Protection*, DOI: 10.1016/j.psep.2018.06.030.

Van Looy, A., De Backer, M. and Poels, G. (2011). Defining business process maturity. A journey towards excellence. *Total Quality Management & Business Excellence*, *22*(11), 1119-1137.

Biographies

Dr. Surajit Bag
Post Graduate School of Engineering Management
Faculty of Engineering and the Built Environment
University of Johannesburg
E-mail: surajit.bag@gmail.com

Surajit Bag is a Sr. Research Associate at the Faculty of Engineering and Built Environment, University of Johannesburg, South Africa. He completed his PhD in 2014 in the domain of Logistics and Supply Chain Management from University of Petroleum & Energy Studies, India. His areas of research interest are Industrial supply chain automation, Buyer-supplier relationship, Sustainable supply chain management, Humanitarian logistics strategy and Business excellence. He has attended several National and International conferences and has published more than 20 papers in top tier O&SCM journals ranked in ABDC and ABS. His articles are in the spotlight with 280 citations, h-index 10 and i10-index 6 (Source: Google scholar). He is the recipient of "AIMS-IRMA Young Management Researcher Award 2016" for his significant contribution towards management research. He is an Editorial board member of International Journal of Applied Logistics (IJAL). He is also serving as the International Advisory Board Member of International Journal of Social Ecology and Sustainable

Development (IJSESD) and International Journal of E-Entrepreneurship and Innovation (IJEEI). He is a member of professional bodies such as IEOM and IEEE.

Dr Arnesh Telukdarie
Post Graduate School of Engineering Management
Faculty of Engineering and the Built Environment
University of Johannesburg
E-mail: arnesht@uj.ac.za

Dr. Arnesh is an Associate Professor in the domain of Engineering Management under University of Johannesburg, South Africa. His publication appears in reputed journals like *Journal of Cleaner Production, International Journal of Sustainable Engineering, Benchmarking, Process Safety and Environment Protection and Industrial and Engineering Chemistry Research*. His areas of research interest are Manufacturing systems, Systems Engineering, Enterprise Optimisation and Industry 4.0 IIoT.