Research Assessment Exercise 2020
Impact Case Study

University: The Hong Kong Polytechnic University
Unit of Assessment (UoA): BUSINESS (22)

Title of Case Study: Improving Productivity and Performance through the Use of IoT, AI and Management Support Systems

(1) Summary of the Impact

Research into the Internet of Things (IoT), Artificial Intelligent (AI) and management support systems (MSS) conducted by the management information system (MIS) team at the Hong Kong Polytechnic University (PolyU) since 2010 has led to new knowledge, which, in turn, has been applied in companies. This has ranged from the development of theoretical models to conceptual IoT frameworks (e.g. radio frequency identification (RFID), sensors), implementation and licencing that design the processes and system architecture. The impact includes: (1) new insights and enhancements in the practices adopted in system design and development, (2) improved support for adoption of IoT and licencing by IT companies (e.g. Wavelane Technology Ltd. [B, C]) and (3) knowledge transfer leading through intermediaries such as the government research centres of the Logistics and Supply Chain MultiTech R&D Centre, Hong Kong Research Institute of Textiles and Apparel (HKRITA) and PolyU Technology & Consultancy Company Limited (PTeC).

(2) Research Underpinning the Theory

IoT is an important piece of technology that can bring many day-to-day objects into the digital fold to make them smarter. The developmental group research led by Prof. Eric W. T. Ngai at PolyU has largely been focused on IoT, AI and MSS. Since 2010, they have been elaborating and developing the theory of design in the MSSs integrated with IoT and AI settings, extended the field of decision support systems, and developed and tested IoT and AI as well as integrating them into the MSSs. The aim of the research conducted by Ngai and his team was to develop and apply implementation methodology and design theory and identify the critical success factors underpinning the implementation of intelligent IoT-based MSSs in different contexts.

Green manufacturing

To achieve the central tenet of green production as the global standard for the protection of the environment, Prof. Ngai and team have designed and developed an energy and utility management system (EUMS) (refs. 4, 5) to improve efficiency in monitoring energy consumption, obtain real-time data on energy usage (e.g. water and electricity) and facilitate analyses of energy consumption and production status while deriving production information for cost analysis.

With this system, we effectively control energy consumption and achieve energy conservation, cost reduction, technology improvement and environmental protection. By enabling real-time access to energy usage data and production status using the IoT and AI technologies, the system facilitates a comprehensive analysis of energy consumption and production conditions. The data are sent to a central source to be analysed so management can quickly determine whether costs in any particular area are threatening to spiral out of control. This work contributed to the development of the conceptual model of energy and utility management in textile processing, the energy and utility management maturity model for sustainable manufacturing processes and an implementation framework for RFID systems (refs 2, 5, 6).

Application of IoT and AI in the aircraft maintenance and logistics industry

Ngai and his team developed an RFID-based traceability system that effectively supports the tracking and tracing of aeroplane repairable items in a leading aircraft engineering company. We investigated the value of RFID in the maintenance of supply chains for aircraft parts, particularly in the proposed analytical model. The model helps us gain a better understanding of the relationships between various costs incurred and the RFID effect on the aircraft maintenance tracking process (refs. 1, 3).

Their further studies on IoT and AI in the logistics industry include a study of a monitoring system that tracks the movements of thousands of containers. Ngai and his team developed a smart, context-aware decision-support system that can monitor activity at container terminals in real time by employing a differential global positioning system. The system works and has quickly proven its effectiveness in supporting the real-time tracking of the activities of trucks, quay cranes and so on. Ngai and his team are working closely with terminal operators to ensure that it can significantly enhance the efficiency of port operations.

The significance of Ngai's research was recognised in April 2015 when their systems won a silver medal in the 43rd International Exhibition of Inventions in Geneva, Switzerland.

(3) References to the Research

(1) Ngai, E. W. T., Cheng, T. C. E., Kai, K. H., Chai, P. Y. F., Choi, Y. S., & Sin, R. K. Y. (2007). Development of an RFID-based traceability system: Experiences and lessons learned from an aircraft engineering company. *Production and Operations Management, 14*(4), 554–568.
(2) Ngai, E. W. T., To, C. K. M., Moon, K. K. L., Chan, T. L. K., Yeung, P. K. W., & Lee, M. C. M. (2010). RFID systems implementation: A comprehensive framework and a case study. *International Journal of Production Research, 48*(9), 2583–2612.
(3) Ngai, E. W. T., Cheung, B. K. S., Lam, S. S., & Ng, C. T. (2014). RFID value in aircraft parts supply chains: A case study. *International Journal of Production Economics, 147,* 330–339.
(4) Ngai, E. W. T., Chester, K. M., To, V. S. M., Ching, L. K., Chan, M. C. M., Lee, Y. S., & Choi, P. Y. F. C. (2012). Development of the conceptual model of energy and utility management in textile processing: A soft systems approach. *International Journal of Production Economics, 135*, 607–617.
(5) Ngai, E. W. T., Chau, D. C. K., Poon, J. K. L., & To, C. K. M. (2013). Energy and utility management maturity model for sustainable manufacturing process. *International Journal of Production Economics, 146*, 453–464.

Evidence showing the quality of research

The research has made significant contributions and had a major impact in the area of IoT implementation. The results have been published in high-level international journals, and the publications have received a large number of citations. According to Google Scholar, by 2019, the above-named papers have received (1) 141 citations, (2) 63 citations, (3) 39 citations, (4) 43 citations and (5) 85 citations.

Patents: An Internationally Recognised R&D Output Indicator

7) Ngai, E. W. T., Choi, Y. S., Sin, K. Y., & Chai, Y. F. 'Radio frequency identification (RFID)-based computation and its methodology' (Chinese Patent for Invention No. ZL200410045617.1, granted Feb. 6, 2008).

8) Ngai, E. W. T., Li, C.-L., Cheng, T. C. E., Lun, Venus, Y. H., Lai, K. H., & Choi, Y. S. 'Hierarchical positioning system (HPS)' (Chinese Patent for Invention No. ZL200810131046.1, granted Dec. 14, 2011).

(4) Details of the Impact

As evidenced above, an extensive body of research conducted by Ngai and his research team within PolyU resulted in the development of systems, design theory and implementation frameworks. In sum, Ngai's research has provided insights into IoT domain models (refs. 1–4) and how to design (refs. 2, 4) and evaluate IoT systems (refs. 3, 4).

The significance of this work's impact has been recognised in the nominations received for its benefits to the client organisations through its publication in journals (refs. 1–5). In particular, the IoT research, led by Prof. Ngai and team members Prof. Chung-lun Li, Prof. Edwin Cheng, Dr Venus Lun, Dr Kee-hung Lai and Mr Y. S. Choi has won an international innovation award, and they have obtained a patent for their invention (ref. 8).

Pathways to Impact

Pathways to impact have been both direct and indirect. They include the following: Key concepts and findings were shared, including methodology and models, in the workshop (date of workshop: August 22, 2014, held at PolyU) that was specifically designed for attendance by 21 public and private organisations from the textile industries. This event led to interest from workshop and event participants, leading in turn to further consultancy agreements (e.g. with Fang Brothers Knitting [FBK] Ltd. [E]) to embed the frameworks and associated systems. Ngai has undertaken consultancy research projects with, for example, FBK, which is a leader in the knitwear manufacturing industry. FBK offers production and sourcing clout within a long-standing manufacturing network in Hong Kong and Vietnam.

<u>Impact on the design and development of IoT systems in textile companies</u>

The IoT system design and implementation framework developed by Prof. Ngai and described in (refs. 2, 5, 7) has been licensed and implemented by Wavelane Technology Ltd. ([B] and [C]). The implementation of the IoT technologies through Ngai's EUMS and IoT system led to the following impacts (ref. 5, p. 462).

- The average energy consumption for each product and for the entire factory was decreased by 7.4% and 6.4%, respectively, in the case study company.

- The average water consumption for each product and for the entire factory was decreased by 17.9% and 15.1%, respectively, in the case study company.

From an environmental perspective, a reduction in the average energy and utility consumption implies a reduction in carbon emissions and volume of waste.

<u>Impact on reducing the costs of aircraft maintenance at the Hong Kong International Airport at Chek Lap Kok</u>

Ngai and his team's work in the field of IoT, in particular RFID and sensors, has transformed the aircraft parts maintenance tracking operations of one of the world's leading independent aircraft engineering and maintenance companies. The company is one of the largest maintenance, repair and overhaul service providers in terms of capacity. By 2014, the impact from applying the IoT technologies (i.e. RFID and sensors) on operational changes had been reported as follows (refs 1, 3,

4, pp. 335–336):

- The reduction of per-lead-time-period expected cost (Cr) for the avionic overhaul type component is $42.709 or 28.58% of Cr.
- The reduction of Cr for the component overhaul type component is $85.469 or 29.25% of Cr.

These computational results verify that, in the case of aircraft maintenance, the benefits of using an IoT system are ample. With the full visibility enabled by RFID, the risk of being severely penalised for failing to replace damaged components due to poor inventory control is reduced, whereas the abrupt interruption of the service due to mishandling of all sorts is almost eliminated.

(5) Sources to Corroborate the Impact

All sources are cross-referenced in section 4. Evidence such as letters to prove licensing agreements will be provided by PTeC, and evidence that Prof. Ngai has an influence on the external research community is provided by joint papers, as noted by the references. Specifically, Prof. Ngai has engaged in various consultancy projects with local companies via PTeC.

The University (PTeC)/HKRITA has granted a nonexclusive and nontransferrable licence of the patents/technologies to the following:

[A] FBK Ltd. (Agt. No. PTeC-10-3-1) – 'Advanced textile and garment manufacturing process technology'
[B] Wavelane Technology Ltd. (Agt. No. PTeC-10-3-9) – 'Innovative energy and utility management system in textile processing' RD/PR/001/09
[C] Wavelane Technology Ltd. (Agt. No. PTeC-10-3- 24) – 'Intelligent condition-based key machinery assets maintenance management platform for textile industry'
[D] ID-Tech (Hong Kong) Ltd. (PTeC LA07-114) – 'Supply of RFID middleware system and technical support for client's pilot project'
[E] Intellectual Ventures Holding 61 LLC (PTeC LA08-128_9) – 'Goods in-out navigation system and method base on RFID'

Consultancy services have been provided to the following as well:
[F] Consultancy on "RFID-enabled Knitting Warehouse Management" (P10-0384)" and Consultancy on "A 2D Barcode and RFID-enabled Mobile Warehouse" (P11-0329).