**Institution: University of Reading**

**Unit of Assessment:** 17, Business and Management Studies

**Title of case study:** Improving the Quality of Health Care Through an Integrated Clinical Pathway Management Approach and a Digital Platform

**Period when the underpinning research was undertaken:** 2012–19

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s): | Role(s) (e.g. job title): | Period(s) employed by submitting HEI: |
|---|---|---|
| Dr Weizi (Vicky) Li | Research Fellow<br>Lecturer<br>Associate Professor | 2012 - present |
| Professor Kecheng Liu | Professor of Applied Informatics | 2002 - present |

**Period when the claimed impact occurred:** 2014–20

**Is this case study continued from a case study submitted in 2014?** No

## 1. Summary of the impact

Whilst an ageing population is seen as a global phenomenon, in China this population is rising more rapidly than in many other countries. As a consequence, demand for health care has increased, and delivering a good-quality service is a challenge for providers. Research from the University of Reading on an integrated clinical pathway management approach and a digital platform has been used by over 1,000 major public hospitals (over 400 Grade A hospitals) and 1,400 suburban hospitals, covering 31 provinces and 200 cities in China. Informing the decision-making of over 1,500,000 doctors, the integrated pathway management approach has improved the quality of hospital service and increased capacity, with reduced medical error, reduced patient waiting time, shorter hospital stays, and fewer unnecessary tests. The successful adoption of this research also led to the growth of the Chinese company, Sinldo Information Technology (Beijing) Co. Ltd, where Li is the Scientific Advisor and which is now listed on a Chinese Stock Exchange.

## 2. Underpinning research

In addition to China's large (1,400,000,000) and ageing population, shortages in critical health and care workers have compounded the demand for health care, in a country where major hospitals can have over 4,000 beds, with outpatient volumes of 4,000,000 patients per year. Within this context, research at the University of Reading has addressed how the quality, efficiency and safety of hospital services can be significantly improved through the effective use of information, data and clinical pathway knowledge. Prior to this, there was limited research on integrating best-practice clinical pathways with local hospital practices and existing technical information systems. Although digital systems are increasingly used in hospitals, they form information silos; thus, their effectiveness has been limited, owing to a lack of alignment with clinical pathways. By developing an integrated clinical pathway platform, the research has addressed the lack of connection between best practice clinical pathways, local hospital practices and existing hospital information systems.

Funded by the National Natural Science Foundation of China (NSFC), this research first developed a theoretical underpinning and a co-designed research methodology for integrated pathway management by drawing on organisational semiotics. Led by Li (Ref 1), the integrated clinical pathway management approach was piloted by working closely with key hospital staff in selected hospitals (Hospitals 301 and 309, China), including the hospital's Director of Information. It built on research understanding and encoding the complex clinical pathway knowledge into a knowledge-based management system (Ref 2). The first pilot in Hospital 301

was with 70 staff participants; the second pilot, funded by the hospital R&D fund, was implemented in Hospital 309 and a total of 342 patient pathways were analysed. The findings since the second pilot (in 2014) show that the integrated clinical pathway management approach and the digital platform can significantly reduce medical errors, costs and waiting times (Ref 1).

The introduction of the co-designed integrated pathway management approach through agent technology differentiates this work from other clinical decision systems; it generates a personalised patient support pathway, whereby best-practice clinical pathways are integrated with existing hospital processes and information systems. Further work on the integrated digital platform has incorporated cloud and mobile technology for wider adoption (Ref 3). Having received funding from Sinldo Information Technology, ESRC, and NSFC, the innovative approach is now enabling further collaborative research, with data generated from the integrated hospital data platforms informing medical science and the pharmaceutical industry on differing medication patterns for different patient groups (Ref 4).

**3. References to the research**


1. Li, W., Liu, K., Yang, H. and Yu, C. (2014) 'Integrated clinical pathway management for medical quality improvement – Based on a semiotically inspired systems architecture'. *European journal of Information Systems*, 23 (4). pp. 400–417. doi: https://doi.org/10.1057/ejis.2013.9
2. Li, W. (2014) 'Clinical pathway enhanced by knowledge management: A critical step towards medical quality improvement'. In: Michell, V., Rosenorn-Lanng, D.J., Gulliver, S.R. and Currie, W. (eds) *Handbook of Research on Patient Safety and Quality Care Through Health Informatics*. IGI Global.
3. Li, W. and Yang, G. (2016) 'Best practice of "Internet+" hospital: seamless medical services across whole process'. *China Digital Medicine*, 2016 (5). pp. 31–33. doi: https://doi.org/10.3969/j.issn.1673-7571.2016.05.009
4. Huang, H., Shang, X., Zhao, H., Wu, N., Li, W., Xu, Y., Zhou, Y. and Lei, F. (2019) 'Discovering medication patterns for high-complexity drug-using diseases through electronic medical records'. *IEEE Access*, 7. pp. 125280–125299. doi: https://doi.org/10.1109/ACCESS.2019.2937892


The underpinning research for this case study comprises four journal articles (one of which is published in a blind-refereed journal rated at 3* by the AJG/ABS list, while one is rated at 2*), and one book chapter. The research meets or exceeds 2* quality definitions, and uses large databases of patient records to develop important new knowledge on integrated clinical pathway management systems.

**4. Details of the impact**

***Improving hospital practices and patient experience***

Responding to the challenge of rapidly increasing health-care demand in China, research at the University of Reading has underpinned a major change in hospital practice across the country. In addition to improving clinical outcomes, it has brought significant benefit to the quality of the patient experience prior to, during and after a hospital visit. Through the development of a digital integrated clinical pathway management approach, and a digital platform linked to existing hospital information systems, the research has enabled up-to-date clinical pathway knowledge and healthcare data to be readily accessible through mobile technology by the patient, clinician and hospital management. In so doing, it has considerably improved hospital service capacity, and reduced medical error, patient waiting time, length of hospital stay, and unnecessary tests. At the same time, it has increased patient surgery and patient referrals. The integrated clinical pathway approach has also been responsible for improved diagnoses, resulting in the saving of lives [sources 5 to 7].

Through successful pilots in collaboration with Chinese hospitals, the novel approach was developed and demonstrated by the Reading team. On the basis of this approach, and

informatic tools derived from the research, the Sinldo Information Technology company was set up, with Li acting as the Scientific Advisor (see below). By 2018, research at Reading had underpinned the delivery of bespoke digital platforms and integrated clinical pathway management systems across 2,400 hospitals in China [source 1]; this includes 1,000 major public hospitals (over 400 Grade A hospitals) and 1,400 suburban hospitals, covering 31 provinces and 200 cities in China [source 4]. In summary, the research outcome has been translated into products and services including the following:

1) A digital platform
   - a knowledge-based platform to facilitate decision making based on best-practice clinical pathways, integrated with existing hospital systems
   - front-end applications for doctor workstations (providing integrated information on patient pathway activities, treatment progression and patient condition), and nurse workstations (providing integrated information on care activities and patient condition every day along the pathway)
   - patient applications (integrating hospital service information along a patient's journey).

2) A consulting tool to map best-practice clinical pathways to local hospital processes (outpatient and inpatient processes, and doctors' working processes) with the support of the digital platform.

The research has enabled better utilisation of health-care resources and improved service quality, despite the dramatically increasing demand for health care. It supports 1,500,000 doctors and helps 600,000,000 outpatients and 25,000,000 inpatients each year by enabling the right information to be available at the right time on the clinical pathway. Moreover, it supports hospital services for 480,000,000 patients with hypertension, 350,000,000 patients with cardiovascular disease, 270,000,000 patients with diabetes and 120,000,000 patients with cancer [source 9] every year.

According to statistics from 100 major hospitals that applied this research, it has on average reduced medical error by 30% (from an average of 252 adverse events and prescribing errors on six disease pathways during six months before implementation to 168 adverse events and prescribing errors after implementation), and reduced waiting times by 50%, patient record and treatment data accessing times by 90%, and admission/discharge/referral times by 85%, with a total reduction of average length of stay from 12 days to 10 days [source 6]. Specifically, 23 hospitals were assessed for detailed impact (31 pieces of evidence collected).

For example, Wuhan Central Hospital adopted the mobile health application for integrated care service in September 2014. By December 2015, 98% of patients felt the process had been improved; there was a 55–83% reduction in medical errors; a 27% reduction in unnecessary tests and an 80% reduction in waiting times. The average time for patient record updating (including in ICU) was reduced by 24.4 hours. Due to the significant reduction in waiting time, the overall outpatient time was reduced from 260 to 170 minutes, while the average inpatient stay was reduced by 176.8 hours [source 6 and ref 4].

A further example is that of the Second Affiliated Hospital of Xi'an Jiaotong University, which adopted a hospital-wide information integration platform in 2015. This has significantly improved the hospital's service capacity: completed outpatient cases increased by 62%, completed inpatient cases increased by 49%, completed surgery cases increased by 99%, outpatient cost reduced by 9% and patient referrals increased by 40% [source 6]. This has benefited patients by improving their experience of hospital (through reduced waiting times and fewer medical errors), benefited doctors by providing them with more efficient workplaces, benefited hospital chief executives by giving them an improved overview of performance supported by an integrated data platform, and benefited hospitals by improving their use of resources and the quality of the service they offer.

Professor Xijing He, the former dean of the hospital, confirms that "the integrated clinical

pathway platform enabled seamless access to various systems linking to doctors' mobile applications, where they can get the most up-to-date information at the point of care. Furthermore, with the best practice clinical pathway knowledge incorporated in the digital platform, doctors will be warned of abnormal values (in patient test results) … for timely interventions, which ensures patient safety and service quality" [source 6].

***Adoption and commercialisation of the research***

As a result of the Reading team's research, a system was developed with Sinldo which embraced the integrated clinical pathway management approach. In order to maximise care provision, it bridged the gap between healthcare best practices and the patient journey. Through Li's continued engagement with these hospitals, she was instrumental in demonstrating more broadly to the Chinese health-care sector the added value of the informatics tools developed. She also successfully pitched the potential of these artificial-intelligence-based systems to investors [source 1]. The number of employees in the company grew from 89 in 2014 to 171 in 2017, and it has received four rounds of financing/investment (attracting GBP14,568,598 in total) since 2013 [sources 2–4]. In April 2017, Sinldo was listed on the National Equities Exchange and Quotations (NEEQ) stock market [source 2]. It was recognised as China's first digital health company listed on that market since China's national strategy of "Internet + Health" was introduced in 2015. This has also given Sinldo a means to make an eventual transition to being listed on the main stock exchanges in the future and competing with larger firms.

Hongqiao Yang, Chairman of Sinldo Information Technology (Beijing) Co. Ltd. confirms that "Sinldo became a leading technology company providing a data integration platform and Weizi [Li] has been playing a key role in research and development before and after Sinldo's establishment. The successful pilots of her research outcome led to the start of the company and she has been working continuously with the company team and hospital staff to develop applications in different hospitals. Weizi's research has brought inspiration and innovation in our products and our partnership development with hospitals and investors." (source 1)

This research from the University of Reading, which was a winner in the 2018 ESRC Excellence in Impact Awards [source 8], has made a highly significant contribution to addressing the challenge of providing high-quality health care to the whole of the Chinese population, considered to be the fastest-growing elderly population globally. Through the design, implementation and subsequent commercialisation of appropriate informatics technology, it has improved patient health outcomes through increased efficiency and efficacy of hospital service delivery, reaching 600 million outpatients and 25 million inpatients each year. Critical to this has been the encoding of the complex clinical pathway information into a knowledge-based management system. For the Chinese nation, this has been highly significant, with both social and economic benefits in terms of increased efficiency and improved health outcomes. For individuals, it has meant not just a decrease in inconvenience (for example, through shorter waiting times, referral times and length of hospital stay), but for many patients, it has provided more fundamental benefits, such as reduced medical errors, with lifesaving ramifications.

**5. Sources to corroborate the impact**


[S1] Letter from the Chairman of Sinldo Information Technology.

[S2] Company information on Sinldo Information Technology (annual reports, investors and investments, listing on NEEQ stock market).

[S3] Sinldo Pioneer Award for hospital data integration platform.

[S4] Data integration platform implemented in 400 major hospitals and 2,000 medium hospitals.

[S5] Assessment of the impact of the integrated data platform on services and management in 100 hospitals in China.

[S6] Hospital case studies reported by *Outlook Weekly* (Xinhua News Agency) – Internet

+ hospital special issue March 2016.

[S7] 'Data quality improvement in Haikou Hospital, before and after the use of the system'. *Hainan Medicine Journal*, Jul. 2017, Vol. 28, No. 14.

[S8] ESRC Excellence in Impact Awards 2018.

[S9] Updated data about the adoption of the integrated clinical pathway digital platform in China with number of doctor and patient users (in different disease groups)