Institution: LONDON BUSINESS SCHOOL		
Unit of Assessment: 17 – Business and Management studies		
Title of case study: Inventory management of essential drugs in Zambia		
Period when the underpinning research was undertaken: 2009-2010		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Jérémie Gallien	**Role(s) (e.g. job title):** Professor of Management Science and Operations; Associate Professor Management Science and Operations (2010-2017)	**Period(s) employed by submitting HEI:** From 01/07/2010
Period when the claimed impact occurred: 2014 onwards		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Improved access to essential medicine by under-privileged populations across eight districts in four provinces of Zambia was achieved by the launch in 2017 of a ground-breaking hi-tech inventory distribution system relying on special-purpose forecasting and inventory control algorithms and a distributed computer system with mobile devices adapted to sub-Saharan Africa's limited infrastructure. This system was designed, developed and deployed by an international partnership including the Zambian government, the World Bank, DfID, UNDP, Professor Gallien's research team and IBM. It **replaced the old, flawed** paper-based drug distribution system and **for the first time** allowed health officials to **track the supply and demand of dozens of medicines** in real-time, which allowed them to **better predict and cope** with both seasonal surges in demand and delays in shipping, and to secure the availability of drugs including life-saving antibiotics and malaria medicines for more patients in Zambia.

2. Underpinning research

The research addressed the **difficult and challenging issue** of how to distribute life-saving drugs in developing countries that lack the necessary systems and infrastructure. Working with the Zambian government and academic colleagues, Professor Gallien first used data from a supply-chain field pilot scheme that ran from April 2009 to April 2010 [3.4] along with his research on national procurement of medicines in African countries [3.3] to devise a computer model that could **accurately simulate the national distribution of anti-malarial medicines** based on artemether-lumefantrine (AL) [3.1]. Manufactured abroad, these drugs are imported to a national warehouse in the capital city Lusaka. Distributed to about 120 district stores, they are finally shipped to 1,500 health clinics across the country.

The model accounts for clinic orders, patient demand and the timing of deliveries. The results **closely mirrored** the situation on the ground. For example, while AL stocks in the clinics - from which the medicine is given to people who need it - were adequate at the end of 2009, the computer simulation **correctly predicted that many would run out** early in 2010 despite sufficient inventory in the Lusaka warehouse.

These results demonstrated that inventory control (formulas used to calculate specific shipment quantities of drugs to every destination on an ongoing basis) were a key reason why clinics ran out of AL. They were not adequately capturing peaks and troughs in both supply and demand, including changes caused by the seasonal nature of malaria and flooding. Existing methods also caused systematic inequalities in patient access to drugs across different geographic areas within Zambia.

Gallien used mathematical models to build better inventory control methods. Numerical experiments showed these would substantially improve patient access to drugs [3.2]. This rigorous and quantitative prediction of the substantial achievable reductions in patient-facing stock-outs provided the key motivation for the Government of Zambia and the World Bank to form an international partnership that would implement the system envisioned by Professor Gallien's research team and the algorithm it had developed. Professor Gallien contributed extensive technical support to that partnership, and his team shared the computer code implementing the algorithms he had developed so it could be used by IBM.

3. References to the research

[3.1] 2016. Leung N-HZ, Chen A, Yadav P, **Gallien J**. The Impact of Inventory Management on Stock-Outs of Essential Drugs in Sub-Saharan Africa: Secondary Analysis of a Field Experiment in Zambia. *PLOS ONE* 11(5): e0156026. DOI: 10.1371/journal.pone.0156026

[3.2] 2017. **Gallien J**, Leung Z, Yadav P. Inventory Policies for Public Pharmaceutical Distribution in Zambia: Improving Availability and Geographic Access Equity for Essential Medicines. Working paper. Available at SSRN: https://ssrn.com/abstract=3072362 or http://dx.doi.org/10.2139/ssrn.3072362

[3.3] 2017. **Gallien J**, Rashkova I, Atun R, Yadav P. National Drug Stockout Risks in Africa: Analysis of the Global Fund Disbursement Process for Procurement from 2002 to 2013. *Production and Operations Management* 26 (6), pp. 997-1014. DOI: 10.1111/poms.12662

[3.4] 2019. Vledder M, Friedman J, Sjöblom M, Brown T, Prashant Yadav P. Improving Supply Chain for Essential Drugs in Low-Income Countries: Results from a Large Scale Randomized Experiment in Zambia. *Health Systems and Reform* 5(2), pp. 158-177. DOI: 10.1080/23288604.2019.1596050

4. Details of the impact

The research described in section 2 has been **used to design and introduce a new drug distribution system in Zambia** called eZICS (Enhanced Zambia Inventory Control System). The goals of eZICS include improving drug availability for patients, creating real-time inventory and movement visibility through the supply-chain, digitising Zambia's distribution system and reducing inventory management labour.

Following system design recommendations outlined in [3.1], its main components include smart phones with barcode scanners at every storage location that are connected to a centralised application and database, enhanced demand and supply lead-times forecasting, and enhanced inventory control policies ([5.4] and [5.5]).

The initiative started in 2010 and was supported by a partnership that ultimately included the Zambian Ministry of Health, the World Bank, the UK Government's Department for International Development, UNICEF/UNDP, computer giant IBM and **Professor Gallien's research group** (see [5.1] and historical timeline in [5.5]).

The collaboration involved a transfer of the technical knowledge and computer code which Professor Gallien's group had developed for [3.1] and [3.2] to the IBM solution development team responsible for delivering the eZICS system to the Zambian Government for deployment by its central medical store (MSL).

Launched in 2016, the new tool **transformed the supply of medicines**. Dr. Bonface Fundafunda, Managing Director of MSL and advisor to the Zambian government at the time,

says it "allowed an officer at any health facility, to process all the requirements that were needed to enable an informed supply chain decision to be made." [5.2]

Professor's Gallien's **studies were pivotal in the tool's development**, he adds. "The studies provided decision-makers with the basis for planning the supply of health products to different health facilities per region of Zambia, taking into account parameters such as climatic impact. For example, facilities being cut off due to annual flooding events."

Positive impacts of the system included **improved stock accuracy**, **wider transparent access** to data on stock levels, orders and movements and **better national planning and budgeting** for medicines.

After **training workshops attended by more than 100 employees**, the system was **extended in 2018**, to cover the supply of 40 medicines across eight districts in four provinces of the country [5.3] and [5.4]. Staff at health facilities could use mobile devices with barcode scanners to record and transmit stock and usage details to a central inventory control system. Unlike the historic system, the eZICS was **fully transparent**, giving each district **real-time information on drug stock levels** at the clinics, and the ability to **coordinate the transfer of supplies** from one facility to another if required.

While the national deployment of eZICS has currently been paused due to funding issues among others, the system "continues to **receive high praise** in terms of simplicity, broad impact on management of supply chain for health products," Fundafunda says. "It can be deployed across different types or levels of the health sector, from the low village health centre or health post, to a major referral health facility with equally complex pharmaceutical and health product management infrastructure." Commenting on the impact of this work, he concludes "this approach enabled the Ministry and partners to start seeing assured healthcare service provision […]. By extension, the assured availability of health products made contribution to positive health outcomes for Zambia."

Finally, eZICS also served as a pioneering project and proof of concept beyond Zambia as it was the first inventory distribution system with decentralised real-time inventory visibility to be deployed in the public sector of any sub-Saharan African country. Other countries such as the Democratic Republic of Congo have since sent missions to Lusaka in order to benefit from MSL's experience with eZICS.

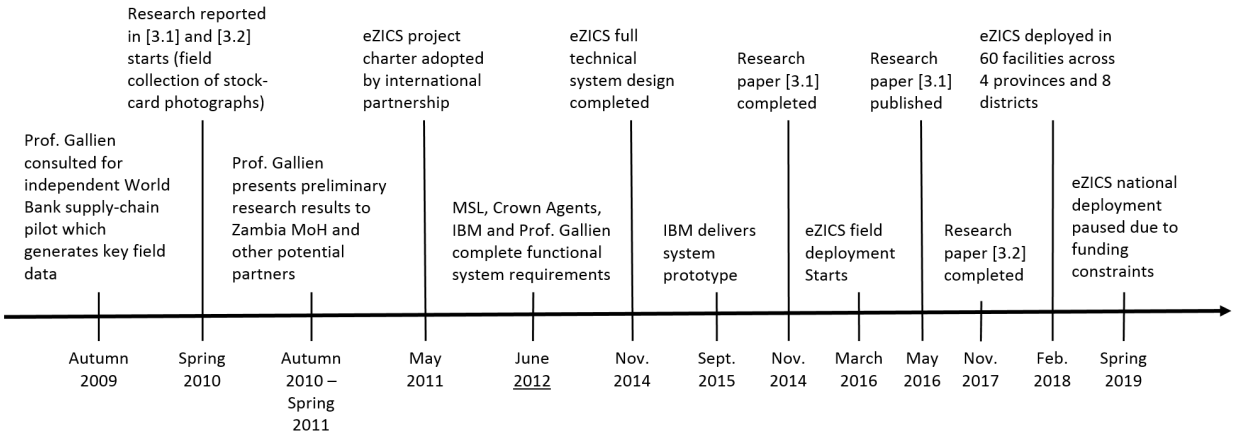


Figure 1. Research and Impact Timeline

5. Sources to corroborate the impact

[5.1] "Zambian Government and IBM Provide Improved Access to Life Saving Drugs. IBM Analytics and Mobile Solutions Will Ensure Medicine Availability", 22/05/2014;

https://newsroom.ibm.com/2014-05-22-Zambian-Government-and-IBM-Provide-Improved-Access-to-Life-Saving-Drugs

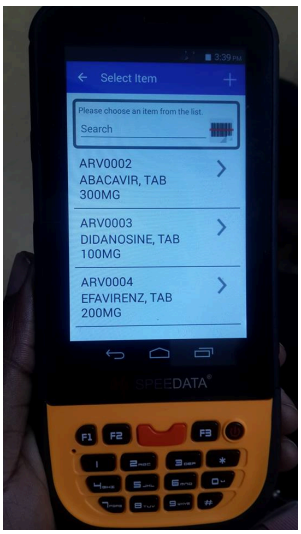
[5.2] Dr B Fundafunda, ZMSL: Beneficiary Statement

[5.3] EZICS – Rollout Plan for Zambia. Sachin Jagtap. Internal Planning Document. 05/02/2018

[5.4] Presentation: "Enhanced Zambia Inventory Control System (eZICS)", A MoH – MSL – UNDP - World Bank Initiative", 12/02/2018

[5.5] Presentation "New eZICS Platform Options", 30/08/2017

The eZICS system being used by a district pharmacist.
Credit: By permission of Medical Stores Limited.



Screenshot of the eZICS system mobile client application.
Credit: By permission of Medical Stores Limited.

A district pharmacist uses the barcode scanning function of the eZICS system mobile client application.
Credit: By permission of Medical Stores Limited.

eZICS system training session for district and health centre staff.
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