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New additions



Annotated Bibliography on Lean in Healthcare Organizations

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Overview

This annotated bibliography update compiles summaries and findings of systematic reviews and primary research articles focused on lean management's application in healthcare settings, with the majority of summarized articles published within the last 3 years. All papers were published between 2000 and 2017. Primary research articles were restricted to those that focused on lean or lean-Six Sigma in healthcare. Articles are organized by whether they addressed 1) health, process, satisfaction, and cost outcomes; 2) components, methods, barriers, and facilitators of lean healthcare interventions; or 3) lean tool development, testing, and validation in healthcare. For primary articles, papers are further sub-categorized by the organizational unit (e.g. ER, surgery, laboratory) in which lean was implemented.

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Systematic Reviews

Systematic reviews assessing health, process, satisfaction, and cost outcomes of Lean in healthcare organizations

Acute Care

Deblois, S. & Lepanto, L. (2015). 'Lean and Six Sigma in acute care: a systematic review of reviews' *International Journal of Health Care Quality Assurance*, 29 (2), pp. 192-208.

This paper was a systematic review of literature reviews summarizing lean and Six Sigma management techniques and outcomes in acute care settings. The authors searched 8 databases and assessed methodological quality of included reviews using AMSTAR. A narrative synthesis was then performed, and data reported according to PRISMA standards. There were 149 articles published between 1999 and January 2015 that were identified and reviewed, with 7 publications ultimately being included in the systematic review. Quality of evidence ranged from poor to fair.

The most consistent finding was that lean and Six Sigma seem to be better suited for processes involving a linear sequence of events. The review also found that tracked outcomes were most often related to processes and quality, and acute settings most often described were operating suites, ICUs, and EDs. Lean and Six Sigma were found to be valuable process optimization approaches in the acute care setting. The authors stated that more studies of high methodological quality were needed to better understand components and barriers to lean and Six Sigma implementation. Field studies comparing the effects of lean and Six Sigma to other quality improvement initiatives were suggested as an area of future research.

Geriatrics

Butler, M. (2016). *Introduction of the Productive Ward: Releasing Time to Care to Programme. Introducing the Programme to a Care of the Older Person Unit*. [MSc Thesis]. Dublin: Royal College of Surgeons in Ireland.

This broad literature review sought out key themes in papers on the introduction of the Productive Ward Programme, which began in the UK National Health System and was based on lean principles. The author states that the Productive Ward Programme was developed with the aim of empowering staff to identify areas for improvement by providing information, time, and skills to teams while allowing them to take ownership of the quality of care in their ward. Databases searched included Cinahl, Pubmed, Emerald, and Google Scholar. Results were limited to articles published in English between 2006 and 2016. Key terms used were 'productive ward,' 'productive community hospital,' and 'releasing time to care.' The search was then refined to review articles examining the benefits of introduction, implementation, and adoption of the program within the healthcare setting.

Key themes found were the importance of communication with stakeholders, need for positive leadership at multiple levels, alignment of the initiative with organizational goals, and support from senior leadership. The literature also noted that the Productive Ward emphasized different key points of the program depending on the audience, and that the program could bridge gaps between executive leadership and frontline staff through a shared language helping to foster shared interests and values. Open communication was repeatedly stated as a vital part of successful implementation.

Systematic reviews identifying components, methods, barriers and facilitators for implementing Lean in healthcare organizations

General

Curatolo N., Lamouri S., Huet J., & Rieutord A. (2014). 'A critical analysis of Lean approach structuring in hospitals,' *Business Process Management Journal*, 20 (3), pp. 433-454.

This literature review analyzed published lean literature in the hospital setting. A methodological maturity-level framework was used as well as 11 activities defined by the authors as characteristic of business process improvement (BPI). The maturity-level framework defined levels from 0-6 to indicate how much methodological support an article had to allow other practitioners to replicate its results. Researchers defined 0 as "Lean approach not described or poorly described" and 6 as "Lean approach structured with a procedure model, techniques, results, role defined for each activity, and information model." A total of 142 articles reporting lean process improvement in hospitals were selected, all of which sought to transform an existing process into an improved future process.

Most articles identified did not provide any description of the lean approach (level 0), preventing other practitioners from reproducing results. The authors focused the rest of their analysis only on articles with at least a procedure model described (\geq level 2). Only 17 out of 142 articles were found to be at least a level 2, and none were level 5 or 6. All 17 were case studies: ten were categorized as 'manufacturing like,' six as 'patient flow,' and one as 'organizational'.

Each of the 11 BPI activities were quoted in at least half of the 17 articles. These activities were 1) understand the environment of the organization, 2) select a process to improve, 3) establish top management support, 4) organize a project team, 5) understand the selected process, 6) measure process performance, 7) analyze the process, 8) improve the process, 9) manage change through communication and training, 10) implement the new process, and 11) monitor performance indicators.

The authors recommend that hospitals introduce a lean approach starting at the micro-level by acting on one or more operational processes using a 'system-driven' approach. They also suggested use of the 11 BPI activities as a procedure model for lean approaches.

Published Primary Research Articles

Primary research articles assessing health, process, satisfaction, and cost outcomes of Lean in healthcare organizations

Acute Care (Medical/Surgical)

McConnell J.K., Lindrooth R.C., Wholey D.R., Maddox T.M., & Bloom N. (2015). 'Modern Management Practices and Hospital Admissions', *Health Economics*, 25(4), pp. 470-485.

This study assessed whether modern management practices such as lean and publicly reported performance measures were associated with hospital choice for acute myocardial infarction (AMI) patients. 18 cardiac care management practices were defined and measured in a survey, with 6 out of those 18 being lean practices. These practices were included in a national survey of US cardiac units with a response rate of 46% (n = 581). The authors used a "method of multiple imputation" to account for potential non-response bias; however they noted that they could not completely rule out correlation of response with unmeasured characteristics. The American Hospital Association (AHA) Guide and Medicare's 2009 Hospital Cost Reporting and Information System file were used to acquire hospital characteristics information.

The 2010 Medicare Provider Analysis and Review file was used to identify a sample of AMI patients over 65, who were admitted to a hospital with at least 1 other competitor within 50 miles and at least 24 annual discharges. The percentage of patients who reported "YES, they would definitely recommend the hospital" was used as a global measure for patient satisfaction. To calculate predicted AMI admissions compared to actual admissions and predicted Herfindahl-Hirschman Index, Medicare Provider Analysis and Review data were also used. Additionally, management scores were calculated by taking hospital managers' survey scores on a 1 – 5 Likert scale and converting them into z-scores. A more positive z-score indicated better performance in that particular practice (e.g. admitting patients, measuring performance). An adjusted management score averaging the z-scores of all 18 practices was then used as the primary measure of overall management practice.

Analysis of adjusted management scores and patient admissions found that a 1 standard deviation higher management score correlated with an 8.31% higher number of AMI admissions. The largest change in admissions was positively correlated with the percentage of patients who would “definitely recommend the hospital.” Higher admission rates compared to other hospitals within the patient’s vicinity were identified as a proxy for a patient’s hospital preference. The researchers interpreted this positive association between management scores and number of admissions as follows: Management practices were correlated directly with admissions through reputational effects and indirectly through improved performance on publicly reported measures. Overall, analysis found that management scores had a statistically significant positive relationship with both AMI processes (e.g. provision of percutaneous coronary intervention within 90 minutes of arrival) and percentage of patients who would recommend the hospital.

Community Health Clinics (CHCs) & Rural Facilities

Bailey, R. (2016). *Exploring the Process of Lean Training in the Healthcare Industry*. [DBA thesis]. Walden University.

This dissertation was a qualitative single case study that sought to explore how healthcare managers successfully implemented lean training strategies to combat costs. Participants were 8 healthcare managers at a single rural care hospital in Tennessee who had implemented strategies to train staff in lean principles. For data collection, a semi-structured interview was conducted with each manager, and public hospital data and quality reports were reviewed. Yin’s 5-phase qualitative data analysis process was used: Compiling the data, disassembling the data, reassembling the data, interpreting the data, and concluding the data. Themes that emerged from the author’s analysis were improving quality of patient care, teamwork and collaboration, hands-on learning, and training the trainers.

Emergency Department (ED)

Claret P. G., Bobbia X., Olive S., Demattei C., Yan J., Cohendy R., ... & de la Coussaye J. E. (2016). ‘The impact of emergency department segmentation and nursing staffing increase on inpatient mortality and management times’, *BMC Health Services Research*, 16(1), pp.279-286.

This before-after study aimed to investigate the impact of a lean-based ED segmentation on patient mortality and management delays in a French university hospital. ED segmentation consisted of the development of a new patient care geographical layout on a pre-existing site and changing the organization of patient flow. Data were collected through the hospital's electronic medical record system and compared to matching seasons from the previous year to adjust for seasonal differences in mortality. A total of 83,322 patient visits were analyzed, with 61,118 before and 22,204 after segmentation. Overall, there was a significant decrease in inpatient mortality after segmentation, from 1.5% during summer 2011 to 1.3% during summer 2012 (OR = 0.85, 95% CI: 0.72,0.99).

Kane M., Chui K., Rimicci J., Callagy P., Hereford J., Shen S., Norris R., & Pickham D. (2015). 'Lean Manufacturing Improves Emergency Department Throughput and Patient Satisfaction', *Journal of Nursing Administration*, 45 (9), pp. 429-434.

This study involved a multidisciplinary team led by nurses and physicians who developed a plan to meet increasing demand and improve patient experience in the ED without expanding the ED's resources. An assessment and planning phase consisting of 3 meetings was conducted. Meetings were standardized and goals and objectives established to maximize effectiveness. A current state map was created that identified wait times and left-without-being-seen (LWBS) rates as key metrics to improve upon. The multidisciplinary team conducted value stream mapping, two 5S organization initiatives, three rapid process improvement workshops, and active daily management (gemba) to improve these key metrics.

The lean implementation was performed with 20 clinical staff over approximately 350 person-hours. It resulted in a 17% reduction in median length of stay (282 minutes to 243 minutes) and a 73% reduction in door-to-doctor time (49 minutes to 13 minutes). LWBS rates fell from 2% to 0.65%. The results were achieved during a period of 7% growth in throughput without increasing the size of the ED, at only a 1% growth in cost. Patient satisfaction metrics were also improved according to the Council of Teaching Hospitals' peer group percentile rankings, with "likelihood to recommend" increasing from the 12th percentile to the 75th percentile and "waiting time to see doctor" improving from the 7th percentile to the 75th percentile. The authors concluded that lean implementation significantly decreased patient wait times and length of stay, while improving patient throughput and satisfaction.

Laboratory

Damato C. & Rickard D. (2015). 'Using Lean-Six Sigma to Reduce Hemolysis in the Emergency Care Center in a Collaborative Quality Improvement Project with the Hospital Laboratory', *Joint Commission Journal on Quality and Patient Safety*, 41 (3), pp. 99-107.

This before-after study conducted value stream mapping (VSM) in the emergency care center (ECC) of a health care system in a large US town. The goal was to reduce hemolysis from 9.8% to 2% in the ECC. In the VSM process, a project team of 3 laboratory managers and 2 lean-Six Sigma experts identified hemolysis as one of seven non-value-added activities in the blood collection and pre-analytical processes. They identified potential root causes of hemolysis and verified these against healthcare best practices. After identification, the team then developed a system-wide protocol involving standardized collection processes, implemented competency-based training, and improved ECC hiring practices.

Baseline hemolysis data was collected from July 2009 to December 2009, with a mean hemolysis percentage of 9.8%. Post-implementation data was collected from June 2010-September 2010, and showed a 64% reduction from baseline to 3.5%. This did not meet the hospital's goal of 2%.

After the post-implementation data collection, a collaborative pilot project was launched using PDSA cycles to confirm or negate the validity of setting a 2% goal in the ECC. A range of hemolysis levels (from a low of 0.9% to a high of 5.8%) was shown in five non-pilot pods. The two pods with full-time phlebotomists reduced hemolysis to 0.5%. From this data the team concluded that a 2% goal was attainable. As it was not economically feasible to permanently hire full-time ECC phlebotomists in all the pods, the team had phlebotomists transfer their knowledge and skills by training ECC staff (nurses and technicians) through shadowing of the phlebotomists, teach-back, and real-time practice with immediate feedback. New hiring practices were also integrated into the ECC, requiring that multi-skilled technologists have phlebotomy training before hire and have one day of compulsory laboratory education during their orientations. Over 4 after the changes in training and hiring practices, the mean ECC hemolysis percentage was consistently <.50%.

Quetz J.S., Dantas I.F., Hirth C.G., Brasil C.G., & Juaçaba, S.F. (2015). 'Preliminary results of Lean method implementation in a pathology lab from Northeastern Brazil', *Brazilian Journal of Pathology and Laboratory Medicine*, 51 (1), pp. 33-38.

This case study utilized lean tools in a Brazilian medical center to improve processes in a pathology laboratory. Lean training was conducted by a team of facilitators comprised of 2 pathologists, a pharmacist, an administrator, and a receptionist. Trainings sometimes included the CEO and the entire body of employees. Value stream mapping (VSM) was then conducted, as well as spaghetti diagrams and an A3 report. After VSM, the team implemented 'first in, first out', standardization, and continuous flow to reduce lead time from 8 – 10 days to 5 days.

It was noted that the laboratory was able to easily support an increase in number of exams in 2014 under the new system; continuous flow contributed to this by evening out demand. The authors stated that the lean implementation created a more collaborative work environment and increased worker autonomy. They noted that lean efforts depended on the CEO's support and the involvement of multidisciplinary, multi-hierarchical teams. Plan-Do-Study-Act (PDSA) cycles and visual management will be continuously used to improve processes in this laboratory.

Sinnott P.L., Breckenridge J.S., Helgerson P., & Arch S. (2015). 'Using Lean Management to Reduce Blood Culture Contamination', *Joint Commission Journal on Quality and Patient Safety*, 41 (1), pp.26-34.

In this pre-post study, a lean quality improvement initiative was undertaken by a US Veterans Affairs (VA) medical center to reduce its blood culture contamination (BCC) rate. A 40-hour, 1 week rapid process improvement workshop (RPIW) was conducted by representatives from hospital medicine, ED, nursing, phlebotomy, clinical microbiology, and others. The RPIW identified root causes of variation in blood culture procedures and potential improvement strategies. Changes in BCC rates were tracked over 5.25 years (2009 - 2014, including 1.5 years before the RPIW). Additionally, results from the primary medical center were compared to data from a similar VA medical center during the same time period.

Four root causes of BCC were identified through the RPIW and refined over a 90-day period. The following countermeasures were then developed: Standardized training, certification, and

recertification procedures for nurses; redesigned blood culture kit; modified order templates to default to a peripheral blood draw; wall posters with simple and clear instructions for blood draws; modified specimen labels to include standard data elements; monthly tracking and feedback of contaminated culture rates; and discontinued low-value speciation.

At baseline, annual average BCC rate at the medical center was 4.2%. In Year 1 post-RPIW, BCC rate fell to 3.4%, then to 2.8% in Year 2, and 2.4% in Year 3. BCC rate increased to 3.0% in Year 4. Each year exhibited a significant BCC reduction compared to baseline, with $p \leq .0010$ for all years. At the comparison VA site, baseline BCC rate was 4.2% and BCC change was only significant in Year 2. However, using a difference-in-difference estimation to find the effect of the lean intervention on BCC rates *independent* of the underlying BCC rate, the underlying BCC rate was 3.6%. Only Year 3's BCC rate was significantly different from the baseline underlying rate ($p=.004$, 95% CI:-0.259,-.0051). While the authors recognized that these results were disappointing, they noted that the project did reduce annual BCC rates by nearly 30% during the study period.

Sunyong M. (2004) 'Lean Management and Six Sigma yield big gains in hospitals immediate response laboratory: Quality improvement techniques save more than \$400,000', *Clinical Leadership and Management Review*, 18(5), pp.255-258.

This pre-post study evaluated a hospital laboratory's efforts to implement lean with the assistance of outside consultants. The stated goal was to reduce lab sample turn-around time with fewer staff resources. After noting that collecting all hospital samples from patients in a two-hour period created a daily bottleneck, the lab transitioned to three separate rounds of sampling, with phlebotomists required to deliver each sample to the lab directly after it was drawn. This change reportedly allowed the lab to reassign six phlebotomists, realizing savings of \$160,000 per year. Addressing the layout of the lab itself, devices were reorganized according to the measured usage by lab staff. Finally, visual management strategies were implemented to address stock and inventory difficulties. Cabinet doors were removed and standards for automatic supply reordering were established. A reduction of 4.5 technologists resulted in savings of \$250,000 per year. In the first year of implementation overtime spending fell from \$130,000 to \$52,000, a 60% decrease. Overall savings in the first year totaled more

than \$400,000. Furthermore, the authors attributed an improvement in patient satisfaction scores to the intervention (which resulted in less need to wake patients in the middle of the night).

Outpatient Care

Aij K.H., Widdershoven G., & Visse M. (2014). 'Lean Process Mapping Techniques: Improving the Care Process for Patients with Oesophageal Cancer', *Global Journal of Management and Business Research*, 14 (2), pp.81 – 98.

This case study tested the hypothesis that Lean value-stream mapping (VSM) could help streamline care for patients with esophageal cancer. The study took place in one of the largest tertiary referral center for esophageal cancer in the Netherlands. The researchers began the project by evaluating the care pathway, revealing that it was unsystematic and could lead to medical errors. Researchers then cut the number of steps needed to begin treatment from 128 to 103 and applied standardization to reduce variability. This implementation reduced the time it took for patients to start treatment from 13.5 to 10.5 weeks.

Baril C., Gascon V., Miller J., & Côté N. (2015). 'Use of a discrete-event simulation in a Kaizen event: A case study in healthcare', *European Journal of Operational Research*, 249, pp. 327-339.

The authors of this paper used a business game and discrete event simulation during a Kaizen event to simulate scenarios defined by team members in an outpatient hematology-oncology clinic. The goal was to allow a rapid and successful implementation of solutions to reduce patient lead time from registration to treatment preparation. The study began with the formation of a project team (including clinicians, managers, and academics), a project launch, and employee interviews to ensure group alignment of objectives. Process mapping of the patient pathway was then carried out for 4 different care pathways: 1) Blood sample, meet with doctor, schedule appointment, and treatment, 2) blood sample and treatment only, 3) treatment only, and 4) meet with doctor and schedule appointment only. After more data was gathered about clinic processes, a study was conducted to gather data on the time it took for patients to reach each step in a pathway. Total lead time from registration to meeting with a doctor could only be calculated for 2 pathways: For pathway 1 total wait time was 69.31 minutes (93% of total lead time), and for pathway 4 total wait time was 48.50 minutes (97% of

total lead time). These wait times were both considered too high, and reducing lead time by 45% was identified as the main objective of the Kaizen event.

Next, a business game was developed that randomly placed participants into the role of patients with differing needs (e.g., treatment type, name of doctor to meet) and had them schedule an appointment based on the patient's need. A simulation model was used that modified patient arrival rates based on the schedules generated. This allowed researchers to measure with the discrete event simulation how scheduling impacted patient wait times. The Kaizen event lasted 3 days and resulted in an action plan to implement changes, ideally in 20 working days.

The authors stated that because pathways 1 and 2 were divided over 2 days, it wasn't possible to compare results before and after testing improving propositions. Therefore only data on lead times for pathway 3 were collected 19 weeks after implementing the changes. The researchers found that patient delays before receiving treatment were reduced by 74% from 61 to 16 minutes, which was less than the simulated result of 90% reduction during Kaizen. The authors hypothesized that this gap could be explained by limits of the model not accounting for factors like patient lateness and treatments being late. The authors concluded from their findings that participants' involvement is crucial for the success of an ambitious project. They noted that use of simulation and business games can encourage participation from all members, as well as measure potential impacts of changes before implementation.

Kamiya Y., Ishijima H., Hagiwara A., Takahashi S., Ngonyani H.A.M., & Samky E. (2016). 'Evaluating the impact of continuous quality improvement methods at hospitals in Tanzania: a cluster-randomized trial', *International Journal for Quality in Health Care*. Advance online publication.

This cluster-randomized trial evaluated the impact of lean 5S on patient satisfaction in outpatient care units of 16 district-level hospitals in Tanzania. Eight district-level hospitals were randomly allocated to the intervention group and 8 hospitals to the control group. Outpatient exit surveys were conducted at all 16 hospitals at 3 time points (baseline, midpoint, and follow-up) between September 2011 and 2012: they measured cleanliness, wait times, various aspects of patient experience, and overall patient satisfaction on a Likert scale.

At baseline, no statistical difference was found for cleanliness between the intervention and control hospitals; at follow-up the intervention hospitals had higher scores than the controls with $p < 0.1$ for 4 out of 5 cleanliness variables. Waiting time also decreased significantly at midpoint and follow-up for 2 out of 4 locations (consulting room and pharmacy) within the intervention hospitals, compared to control hospitals. Waiting time differences were not significant in the outpatient department and laboratory, suggesting to the authors that it is easier to reduce lead-time in the consulting room and pharmacy. Patient experience scores were significantly higher for the intervention hospitals at midpoint, but this difference diminished at follow-up, suggesting that hospital personnel did not maintain initial improvements. Patient satisfaction scores were significantly higher for the intervention hospitals at midpoint but this difference was not significant at follow-up. The authors hypothesized that this could be due to the development of patients' higher expectations for the intervention hospitals over time, given that the exit survey asked "if the main reason a patient came to the hospital was dealt with to their satisfaction." The authors concluded that 5S implementation successfully improved hospital cleanliness, waiting time, and overall rating in the outpatient department, but that the effects on patient satisfaction were not strong. They suggested that this could be the result of the intervention's 'training of trainers' approach, whereby the success of 5S was dependent on the motivation and ability of the 'trainers.'

Pharmacy

Furukawa P.O., Cunha I.C.K.O., & Pedreira M.L.G. (2016). 'Evaluation of environmentally sustainable actions in the medication process', *Revista Brasileira de Enfermagem*, 69(1), pp.16-22.

This pre-post study analyzed the ability of lean-Six Sigma to reduce waste in the medication process, by following the process from reception to pharmacy to disposal. The study was conducted at a large 446-bed hospital in Sao Paulo, Brazil from February to September 2010. An interdisciplinary team of 6 professionals from nursing, pharmacy, and environmental management participated in all stages of the project: definition, measurement, analysis, implementation, and control process.

The team began by conducting process mapping of the medication process. Problems were identified related to irrational use of resources, many medications returned and discarded at the pharmacy, and incorrect discard of waste. These problems were then ranked in terms of priority based on a *cause*

effect matrix and *effort impact matrix* to determine which issues would result in the greatest reduction of waste using the least resources. Root causes of these problems were analyzed using the 5 Why's. Then an action plan was developed based on root causes, including clear delegation of tasks and explicit deadlines.

The lean-Six Sigma intervention resulted in a 74.8% reduction in chemical, infectious, and sharps waste, a 33.3% increase in common recyclable waste, and a 20% increase in common non-recyclable waste. Based on the results, the authors concluded that the development of environmentally sustainable actions is possible in hospital settings, thereby reducing use of resources and volume of waste.

Radiology

Simons P., Benders J., Bergs J., Marneffe W., & Vandijck D. (2016). 'Has Lean improved organizational decision making?', *International Journal of Health Care Quality Assurance*, 29(5), pp.536-549.

This study investigated whether a lean program changed an organization's decision-making context and made it more amenable to quality improvement initiatives. Two 25-question surveys, one in 2011 and one in 2014, were conducted with 12 professionals from a Dutch radiotherapy institute to assess their perceptions of lean in their organization and the perceived ambiguous objectives and uncertain cause-effect relations in their clinical processes. Structured interviews were analyzed using a deductive approach.

Interviewees expressed improved shared vision and decreased number of uncertain cause-effect relations. 99 positive lean effects and 18 negative lean effects were shared. Positive effects included reduced ambiguity of objectives and decreased information asymmetry in clinical process. Negative effects included conflicting objectives between research and clinical practice and unrealistic objectives. Overall, the authors found that lean implementation led to greater transparency and shared visions.

Surgery

Filho M.G., Boschi A., Rentes A.F., Thurer M., & Bertani T.M. (2015). 'Improving Hospital Performance by Use of Lean Techniques: An Action Research Project in Brazil', *Quality Engineering*, 27(2), pp.196-211.

This action research study presented the implementation of lean methods in the surgery department of a Brazilian hospital. The researchers first began by defining the scope of the project and forming an internal team with the hospital's superintendent director as the project lead. The Material and Sterilization Center (MSC) was identified by the director as a key area of focus as it was one of the main contributors to disrupted flow and higher cost. The project's objective was to reduce cost, increase sterilization capacity, and reduce surgery delays due to lack of MSC surgical supplies. Value stream mapping was conducted and flowcharts developed for typical patient movements throughout all steps of the surgery process, beginning when the patient leaves for the hospital.

In order to reach the MSC's desired future state, 5S and visual management were used to increase efficiency, simplify processes, and reduce waste. A pull system was also used to meet demand more efficiently.

The researchers found that the lean intervention resulted in a reduction in changeover time between MSC autoclave cycles from 34 minutes to 4 minutes (88% reduction). Autoclave cycle time overall was reduced from 2 hours to 1.5 hours, resulting in a 64% capacity increase. This generated a direct cost reduction of 78%. Lastly, the pull system and increased MSC efficiency resulted in a significant 94% reduction in surgery delays.

Karvonen S., Nordback I., Elo J., Havulinna J., & Laine H.J. (2016). 'The Elimination of Transfer Distances Is an Important Part of Hospital Design', *Health Environments Research & Design Journal*. Advance online publication.

This case study used a patient flow analysis with from-to charts to influence new hospital design and layout planning at a university hospital's musculoskeletal surgery unit. The authors began by determining the main activities of the surgery unit, then studying the routes and physical movement of all patients treated in the unit over 1 year. From this data, an ideal layout of the new hospital was generated to minimize transfer distances. This was done by placing related activities near one another, based on patient flow analysis. The hospital's architectural design was then created based on the developed layout. Lastly, the authors compared current transfer distances to the distances they estimated patients would move in the new hospital.

The authors estimated that the new design would result in a 50% reduction in transfer distances for inpatients and a 30% reduction for outpatients. They concluded that a detailed patient flow analysis with from-to charts can substantially shorten transfer distances, thereby minimizing patient transfers (a non value-adding activity). This reduction supported productivity improvement, cross-functional teamwork, and patient safety through placement of patient flow activities close to each other.

Mazur L. M., Johnson K., Pooya P., Chadwick J., & McCreery J. (2016). 'Integrating Lean Exploration Loops Into Healthcare Facility Design: Programming Phase', *Health Environments Research & Design Journal*. Advance online publication.

This case study sought to explore what, when, and how lean can add value during the programming phase of design in a large academic hospital. The study took place during the design efforts of a surgical tower to house 19 operating rooms (ORs) as well as support spaces (e.g., pre- and post-op, central processing and distribution, materials management). Lean exploration loops (LELs) were conducted to generate evidence to support decision-making, primarily in comparing the benefits of a large footprint with few floors versus a smaller footprint with more floors and support spaces not adjacent to ORs on the same floor.

LELs quantified key operational and design features, which created opportunities to gain buy-in from stakeholders through active participation in many analyses. The authors concluded that lean was most valuable during programming when it focused on high-level operational and design issues to help establish consensus among stakeholders.

Paim R., Costa A., de Carvalho J., & Costa Lima I.A. (2016). 'Lean healthcare application in a surgical procedures appointment scheduling center in a maternity', *Brazilian Journal of Operations & Production Management*, 13(4), pp.452-461.

This action research study applied lean healthcare concepts and tools in the surgical scheduling process at a network of maternity hospitals in Rio de Janeiro, Brazil. The authors conducted benchmarking visits of other Rio de Janeiro maternity wards to identify best practices, analyzed current working conditions, and compared indicators before and after the intervention. Qualitative data focused on understanding the work process was collected by observing hospital professionals and having them

describe internal procedures and documents. After lean implementation, results were analyzed to identify strengths and considerations for future improvement. After implementation, the number of surgeries performed increased 15-17% in two different surgical centers. The authors concluded that better management of patient demand resulted in increased capacity utilization. Results also showed that adherence to surgery safety protocol increased by 13%, average length of stay decreased by 52%, and patient satisfaction with reception service increased by 32%.

Valsangkar N.P., Eppstein A.C., Lawson A.R., & Taylor A.N. (2017). 'Effect of Lean Processes on Surgical Wait Times and in a Tertiary Care Veterans Affairs Medical Center', *Journal of the American Medical Association Surgery*, 152(1), pp.42-47.

This study examined the effect of lean processes (e.g., value stream mapping) on wait times for surgical procedures at a tertiary care Veterans Affairs (VA) medical center. Key outcome measures were wait time, clinic and telehealth volume, number of no-shows, and operative volume. The researchers utilized VA databases to assess these changes in elective general surgeries before, during, and after lean implementation. Analyses were based on paired t-tests and the total timeframe of the study was 3 fiscal years. Multidisciplinary teams participated in rapid process improvement (RPI) workshops to identify systemic inefficiencies and strategies to reduce canceled consultations, diagnostic re-work, and no-shows. High-priority triage with enhanced operating room flexibility was instituted to reduce scheduling wait times. After rollout of RPI projects, mean patient wait times decreased from 33.4 days (SD 8.3) in 2012 to 26.0 days (SD 9.5; $p = .07$) in 2013. In 2014, wait times decreased further to 12 days (SD 2.1; $p = .07$ compared to 2013). Operative volume increased from 931 patients in 2012 to 1,072 in 2014. Combined clinic, telehealth, and e-consultation encounters also increased from 3,131 in 2012 to 3,517 in 2014, while no-shows decreased from 366 in 2012 to 227 in 2014 ($p=.02$). The authors concluded based on these findings that multidisciplinary collaboration among systems can reduce systemic inefficiencies and improve patient experience.

General

Al-Hyari K., Abu Hammour S., Abu Zaid M.K., & Haffar M. (2016). 'The impact of Lean bundles on hospital performance: does size matter?', *International Journal of Health Care Quality Assurance*, 29(8), pp.877-894.

This paper studied the effect of implementing lean tools (e.g., just-in-time, total quality management) on hospital performance in private hospitals in Jordan, and evaluated how much organization size could affect the relationship between lean tool implementation and hospital performance. The researchers analyzed the impact of lean on quality, cost, patient and staff satisfaction, and overall healthcare performance. Main lean tools (just-in-time, human resource management, and total quality management) were found to be effective in large, small, and medium-sized private hospitals without significant differences in advantages that depend on size.

Da Silva I.B., Seraphim E.C. & Agostinho O.L., Lima Jr. O.F., & Batalha G.F. (2015). 'Lean office in health organization in the Brazilian Army', *International Journal of Lean Six Sigma*, 6(1), pp.2-16.

This case study evaluated the effectiveness of lean in healthcare at a Brazilian military medical center. A hired multidisciplinary management group by the name of G5 held meetings with staff, doctors, and management to teach them lean concepts. They also conducted value stream mapping (VSM) to identify waste within the medical center. Lean techniques were conducted to achieve the waste reduction goal: future VSM, continuous flow, 5S, time reduction, and standardized work. For example, it was found that communication failures in the center's laboratory were leading to longer patient care. Non-value adding activities like these were then subject to root cause analysis and future VSM.

After conducting a climate survey of employees, the researchers found that employees' personal satisfaction increased from 30% before lean implementation to 70% after lean implementation. The authors also found that after lean implementation, the medical center's rank rose to 2nd place out of 21 medical centers in Brazil.

Ferguson A., Aaronson B., & Anuradhika A. (2016). 'Inbox Messaging: an effective tool for minimizing non-urgent paging related interruptions in hospital medicine provider workflow', *BMJ Quality Improvement Reports*, 5(1), pp.1-5.

This study used lean to reduce pages for non-urgent communication, in order to minimize workflow interruptions at Virginia Mason Hospital. To facilitate the implementation, a workgroup was formed consisting of unit-based leaders, nurses, providers, administrators, and IT staff. A baseline measurement of paging data was conducted over a 2-week period, facilitated by an RN project

manager and hospital leader. Inbox messaging was then identified by the workgroup as a tool that could provide back-and-forth messaging without audible interruptive alerts. This method was chosen due to its success as a tool in Virginia Mason's ambulatory setting. Multiple PDSA cycles were then implemented to fine tune the messaging intervention. Immediately after implementation, inbox messages increased from 0 to 80, and non-urgent pages decreased from 103 to 38 ($p < .001$). The total number of communications also increased after the intervention from 116 to 131 ($p < .001$). The authors concluded that the inbox messaging tool was successful in reducing the number of non-urgent, interruptive pages from hospital RNs to hospital medicine providers.

Kanamori S., Castro M.C., Sow S., Matsuno R., Cissokho A., & Jimba M. (2016). 'Impact of the Japanese 5S management method on patients' and caretakers' satisfaction: a quasi-experimental study in Senegal', *Global Health Action*. Advance online publication.

This pre-post controlled study implemented 5S in 10 health centers in Senegal and analyzed its impact on client (patient and caretaker) satisfaction. A 5S 'pretest' was first conducted at a trial facility to establish a reference health center as well as test and validate 5S training instruments. Then pre-5S implementation data was collected at 4 facilities selected for implementation and 4 control facilities. From September – December 2012, this data was gathered in the form of questionnaires given to clients with 10 five-point Likert items to measure client satisfaction. From May – June 2013, data was collected again at all 8 facilities post-5S implementation and an impact assessment was conducted. After the second data collection, 5S intervention was also conducted at the 4 control facilities and 1 non-study facility.

In regression analysis, 5S implementation was associated with a significant increase in client satisfaction scores. At baseline, the mean overall client satisfaction score was 4.01 (SD = 0.51) in control facilities and 3.98 (SD = 0.59) in intervention facilities. At follow-up, satisfaction increased to 4.07 (SD = 0.51) in the control facilities and 4.20 (SD = 0.59) in the intervention facilities. The authors concluded that 5S has potential to improve satisfaction in resource-poor health facilities, although it does not directly address resource problems.

Khlie, K., Serrou, D. & Abouabdellah, A., (2016). 'The impact of Lean-logistics and the information system on the information flow management within the healthcare supply chain'. In *Intelligent Systems: Theories and Applications (SITA), 2016 11th International Conference*, pp.1-5.

This case study focused on the impact of lean on information management performance and cost within a 10-hospital system in Morocco. The case study consisted of 1) identification of waste, 2) evaluation of waste, and 3) performance measurement. To identify waste, interviews were conducted with various healthcare professionals (e.g., pharmacists, managers, physicians) in several departments. These interviews led to identification of problems in 3 main categories: organizational problems, lack of a sufficient relevant information system (e.g., inaccurate or lacking information), and lack of sufficient tools to track performance (e.g., in HR utilization rates). Focusing on the last two categories, the researchers implemented a healthcare information system (HIS) and developed a dashboard to measure the impact. A working group was formed with 4 coordinators, 3 industrial engineering researchers, 4 organizational science experts, and pharmacists. The team collected 6 months of historical data on waste identified by lean, and logistic costs associated with the lack of an HIS. Examples of waste were expiration costs, stock shortage costs, and HR underutilization. To evaluate the data on waste, the researchers compared the 6 months of data before HIS implementation to 6 months of data after HIS implementation. Lastly, in regards to performance measurement, the researchers used a balanced scorecard to develop a dashboard evaluating expiration costs, stock shortage costs, and HR underutilization costs before and after implementation of lean HIS. The authors found that on all 3 measures of costs (expiration, stock shortage, HR underutilization), costs were lower after HIS implementation. They concluded that integrating HIS infrastructure is one of the most important dimensions of improving information management, and that lean implementation within the HIS reduced costs for the hospital system.

Primary research articles identifying components, methods, barriers, and facilitators for implementing Lean in healthcare organizations

Intensive Care Unit (ICU)

Bastian N.D., Munoz D., & Ventura M. (2016). 'A Mixed-Methods Research Framework for Healthcare Process Improvement', *Journal of Pediatric Nursing*, 31, pp.39-51.

This paper applied a mixed-methods research framework incorporating lean thinking to a pediatric intensive care unit (PICU) at Penn State Hershey Children's Hospital. The researchers sought to identify if this methodology could lead to better healthcare process improvement implementation when assessing the current state of workflow in the PICU. The framework consisted of three phases: 1) stakeholder analysis, 2a) staff survey, 2b) time-motion study, and 3) process improvement. In phase 1 of the case study, researchers held two separate meetings: one with two physicians and the other with two nurses in the PICU. This allowed the PICU stakeholders to walk through various workflow elements they did not previously consider important. After interviews, the researchers observed nurses' and physicians' activities in the PICU as part of an observational study, to examine issues previously identified in the interviews as well as identify other causes of inefficiency.

In phase 2a, the researchers conducted a survey of physicians and nurses in the PICU focused on workflow efficiency and clinician satisfaction issues. This survey allowed the researchers to identify perceived critical to quality elements for measuring work performance, including satisfaction of patients' families, patient safety, efficient use of resources and time, and job satisfaction.

Phase 2b was a time-motion study during which clinicians collected data on time spent on daily workflow activities. This time-motion study assessed the appropriateness and time decomposition of workflow processes, while further identifying critical workflow activities.

Phase 3, process improvement, used the main findings from phase 2b to address four main categories impacting clinical efficiency and satisfaction: communication, layout, procedures/standards, and health information technology. Fishbone diagrams were used for both root cause analysis (RCA) and to generate recommendations for process improvement.

Overall, the study found that implementing the framework led to identification and categorization of different workflow tasks and activities into both value-added and non-value added in an effort to provide more valuable and higher quality patient care. The researchers emphasized that involvement of healthcare stakeholders, namely nurses and physicians, was critical to fully understanding PICU workflow and discovering root causes of inefficiencies.

Primary & Preventive Care

Hung D., Martinez M., Yakir M., & Gray C. (2015). 'Implementing a Lean Management System in Primary Care: Facilitators and Barriers From the Front Lines', *Quality Management in Healthcare Journal*, 24(3), pp.103-108.

This case study was conducted to highlight key facilitators and barriers to implementing lean among frontline primary care physicians (PCPs). It took place at a large California ambulatory care delivery system serving 1 million patients. In-depth interviews were conducted with PCPs, staff, and administrators to identify key factors affecting lean re-designs in primary care.

Aspects identified as critical when introducing lean were staff engagement and performance management, sensitivity to the professional values and culture of medicine, and perceived adequacy of organizational resources. Drivers of change were staff empowerment at all levels, visual display of performance metrics, and a culture of innovation and collaboration. Identified barriers were physician resistance to standardized work, difficulty transferring management responsibilities to non-physician staff, and time and staffing required to participate in improvement efforts. The authors concluded that understanding early facilitators and barriers can maximize lean's potential to improve health care delivery.

Surgery

van Rossum L., Aij K.H., Simons F.E., van der Eng N., & Ten Hav W.D. (2016). 'Lean healthcare from a change management perspective: the role of leadership and workforce flexibility in an operating theatre', *Journal of Health Organization and Management*, 30(3), pp.475-493.

This cross-sectional survey was conducted in the operating theatre (OT) of a Dutch University Medical Centre to evaluate the influence of organizational factors on a hospital's capacity for lean change.

Transformational leadership was expected to ensure top-down implementation of lean, while researchers hypothesized that team leadership would also influence the necessary bottom-up commitment of employees. Further, it was expected that greater workforce flexibility would result in increased lean implementation through adapting organizational elements and optimizing process flow.

The cross-sectional survey was conducted in the OT 18 months after lean implementation in the department. Employees (n = 380) were asked to complete a 69-item survey that was distributed by e-mail. After 2 weeks, a reminder to complete the survey was sent to those who had not responded/had responded incompletely. The overall response rate was 27% (103/380 employees). The authors stated that the respondents reflected the general OT 'population' as they were distributed evenly across functions.

Linear regression analysis was conducted to test the hypotheses; it was found that all three predictors together explain 53% of the difference in how lean healthcare implementation is perceived ($p < .0001$). Each individual predictor also had a significant positive relationship to its respective dependent variable. Workforce flexibility had the strongest relationship with lean implementation, though the strength of the association was similar for all three predictors. The authors concluded that transformational leadership, team leadership, and workforce flexibility were facilitators of lean transformation in an operating theatre.

General

Chiarini A. & Baccarani, C. (2016). 'TQM and lean strategy deployment in Italian hospitals,' *Leadership in Health Services*, 29(4), pp.377-391.

This article analyzed the deployment path of lean-TQM implementation in Italian public healthcare to assess benefits and pitfalls. 3 case studies were conducted in 3 large Italian hospitals with 500+ beds each. All 3 hospitals had embraced lean or TQM as part of their strategic objectives. The case studies were based on interviews with 4 managers across the 3 hospitals, who were chosen because they had managed several lean-TQM projects previously and were experienced with many different organizational problems. The research team developed an interview guide with open-ended questions that was used in a semi-structured interview format. Examples of questions were "what tools were

used [in lean implementation]?", "what did you think of these tools?", and "would you give me an example of what you think about it?" The authors then grouped interview responses based on patterns and repeated elements.

The researchers found that there was a specific deployment path for TQM-lean implementation, and that implementation was linked to increased patient satisfaction and organizational performance. Some barriers that could affect TQM-lean effectiveness were problems with senior management commitment, staff management, manufacturing culture, and tools adaptation.

Harrison M.I., Paez K., Carman K.L., Stephens J., Smeeding L., Devers K.J., & Garfinkel S. (2016). 'Effects of organizational context on Lean implementation in five hospital systems', *Health Care Management Review*, 41(2), pp.127-144.

This case study consisted of semi-structured interviews at 5 healthcare organizations to evaluate the effects of intra-organizational context on 12 lean rapid improvement projects at these organizations. All of the projects sought to improve clinical care delivery. A framework of factors likely to affect lean quality improvement (QI) was developed based on literature and utilized in developing interview questions. Interviews were then transcribed and given qualitative codes. Available documents, data, and observations were utilized as supplements to the interviews. Case studies were constructed for lean implementation in each organization; these case studies and the 12 projects were compared across organizations.

Based on data from the sources above, the researchers identified intra-organizational characteristics affecting organization-wide lean projects, and also often shaping project outcomes. Higher levels of these characteristics were associated with better project outcomes. The characteristics were listed as follows: 1) CEO's active support and commitment to lean, 2) prior organizational capacity for QI initiatives, 3) alignments of lean initiatives with organizational mission, 4) dedication of resources and experts to lean, 5) staff training before and during projects, 6) establishment of measurable and relevant project targets, 7) planning of project sequences that enhance staff capabilities and commitment without overburdening them, and 8) ensuring communication between project members

and other affected staff. The authors concluded that their study underscores the importance of ensuring that organizational infrastructure can support an improvement initiative.

Jorma T. & Tiirinki H. (2016). 'LEAN thinking in Finnish healthcare', *Leadership in Health Services*, 29(1), pp.9-36.

This study used a mixed-methods survey approach to evaluate the use and associated outcomes of lean in the Finnish public healthcare system. A 28-question survey with both qualitative and quantitative questions was sent to Finnish public healthcare workers between February and June 2014, and received a 44.4% response rate (110 out of 248). 79 respondents indicated that their organization had at least one ongoing lean initiative focused on patient or care processes. 100% of respondents ranked developing healthcare processes as either "very important" or "important." Only 3 out of 110 respondents indicated that they did not know what lean meant and were subsequently excluded from the rest of the survey. In general, there was high awareness of lean methods; for example, among respondents who had no ongoing lean initiatives focused on patient or care processes (n = 28), 84% reported that they had considered launching a lean project in their organization. While there was high awareness of lean, the authors found that lean was a new concept to Finnish healthcare and that it had not been implemented deeply. Lean was mostly used as a development tool for financial savings and improved efficiency. Implementations had not been systematic, data was lacking, and most lean initiatives documented were started less than five years ago. However, respondents' experiences with lean were encouraging, as 100% of those who had implemented lean initiatives defined them as successful.

Lee J.Y., McFadden K.L., & Gowen C.R. (2016). 'An exploratory analysis for Lean and Six Sigma implementation in hospitals: Together is better?', *Health Care Management Review*. Advance online publication.

This survey of U.S. hospitals sought to explore existing patterns of lean-Six Sigma implementation and compare performance of the different patterns. Survey questions included measurements developed from lean-Six Sigma healthcare research following a literature review. A geographically stratified sample of 307 hospitals was selected from an online hospital database, and a total of 215 responded to the survey (70%). The survey was completed by organizational managers most likely to have acute

knowledge of lean-Six Sigma: chief quality officers, patient safety directors, risk management officials, and nursing directors.

Using factor analysis, the authors identified 2 clusters based on type of lean implementation: a Moderate Six Sigma group (Cluster 1) and a lean-Six Sigma group (Cluster 2). Cluster 1 (n = 116) represented hospitals that implemented Six Sigma at a moderate level but used little to no lean implementation. The authors claimed that this might imply the use of project-based Six Sigma approaches without using lean to manage internal processes on a daily basis for continuous improvement. Cluster 2 (n = 99) represented hospitals that embraced both lean and Six Sigma activities for continuous improvement. Hospitals in this cluster exhibited a much higher level of lean and Six Sigma implementation, with lean's holistic, whole-system view appearing to result in higher performance in responsiveness capability and patient safety. The authors noted an interesting finding from this study that no cluster was obtained for hospitals using only lean. This indicated that implementing lean without Six Sigma was not a predominant implementation strategy in U.S. hospitals. Based on the higher performance in Cluster 2, the authors found there was justification to use more lean tools in combination with Six Sigma for better outcomes.

Primary Research on Lean Tool Development, Testing, and Validation in Healthcare

Intensive Care Unit (ICU)

Almoosa K.F., Luther K., Resar R., & Patel B. (2016). 'Applying the New Institute for Healthcare Improvement Inpatient Waste Tool to Identify 'Waste' in the Intensive Care Unit', *Journal for Healthcare Quality*, 38(5), pp.e29-e38.

The authors of this paper attempted to apply a new Institute for Healthcare Improvement (IHI) tool to measure the prevalence of and reason for inappropriate use of intensive care unit (ICU) beds. Unnecessary days (waste) in a 16-bed closed medical ICU (MICU) and a 10-bed semi-closed transplant surgical ICU (TSICU) were identified by physicians over a 3-month period. Data was collected on 513 patients admitted to both ICUs for a total of 1,631 patient-days. This data demonstrated that 15% of MICU days and 25.8% of TSICU days were unnecessary. Common causes of delays were transfer of patients out of the ICU, end-of-life decision-making, and delays in procedures. However, determination of waste varied widely among physicians, ranging from 4.5% to 27.7% in the MICU and 0% to 37.5% in the TSICU. Therefore, although limited by variations in physician perceptions, the tool may be helpful in identifying specific causes of delays in the ICU that could be the focus of improvement efforts. Based on their findings, the authors also suggested that waste is likely common in the ICU and warrants further attention.

Surgery

Lasorsa I., Liuzzi G., Calabrese R., & Accardo A. (2015). An Innovative Method for Standardizing Lean Management Approach in Hospitals. In *16th Nordic-Baltic Conference on Biomedical Engineering*, pp. 67-70. Springer International Publishing.

This case study tested a new method for standardizing lean healthcare management in the operating theatre (OT) of an Italian hospital; it specifically focused on improving the process of providing surgical tools for operations. Preliminary, informal interviews were first conducted with clinicians and nurses,

and some selected to be part of the lean team based on their personal interest. This team then set out to reduce seven forms of waste in the surgical tool value chain, as identified by Goal Question Metric (GQM), a data measurement and metric identification tool originally used in computer science. 15 questions and 17 metrics were defined to identify the root causes of waste in the process. A value stream map (VSM) was designed that separated activities into stages: Stage 1 – preparation of tools on the surgical cart in the OR, Stage 2 – utilization of surgical tools, Stage 3 – positioning of instruments in the surgical cart for transport to the Central Sterile Supply Department (CSSD), and Stage 4 – transport to the Central Sterile Supply Department. Data was collected on all 4 of these stages.

Based on data collected, it was found that 71.2% of activities in Stage 1 of the surgical tool process added value. In Stage 1 and Stage 3, percent of non-conformities to standard procedures was 47.8% and 75% of the process respectively. The team used these findings to create a future stream map, which was simulated and potential economic savings calculated. The potential economic savings was €229,421. The authors concluded that the teams' proposal of improved inventory of surgical tools and new classification of tools in containers could potentially increase the number of available surgical tools, reduce the number of tools that need to be transported to the CSSD, and generate economic savings.

General

Castle A. & Harvey R. (2009). 'Lean information management: the use of observational data in health care', *International Journal of Productivity and Performance Management*, 58(3), pp.280-299.

This paper compared traditional data collection methodologies in healthcare to observational methods closely aligned with lean thinking. The authors conducted case studies on the use of observational data in the UK National Health Service (NHS), and then used their evaluations to drive general principals regarding the application of observational data in healthcare.

One such case study was conducted in the sterile services department of a general hospital, which was perceived as responsible for delaying operations. The sterile services department felt that these problems were the result of insufficient staffing to meet demand. The authors worked with this

department and the hospital's surgery operating theatres over two months to examine processes and improve workflow, using video to record the process of packing several different sets of instruments. Analysis of video resulted in identification of waste (namely insufficient number of scanners/printers and inefficient location of said printers), which led to the development of solutions to eliminate waste (e.g., equipment purchase and workspace redesign). These solutions rendered the recruitment of 6 extra staff members unnecessary.

Overall, the authors stated that the case studies resulted in fundamental changes in processes by observing the current processes in a way that staff could relate to. They also found that having frontline staff in charge of collecting data made the need for change and urgency of the situation more apparent. In conclusion, the authors found that the observational data methodology was valid in a range of clinical settings for examining a process to identify opportunities for improvement.

Henrique D.B., Rentes A.F., Filho M.G., & Esposto K.F. (2016). 'A new value stream mapping approach for healthcare environments', *Production Planning & Control*, 27(1), pp.24-48.

This article presents a new lean value stream mapping (VSM) approach specifically geared toward healthcare environments, as opposed to current healthcare VSM models that adapt manufacturing-style VSM. The authors' proposed VSM model analyzes activities in relation to their effect on treatment time, with the intention of uniting the positive aspects of various mapping methodologies found in healthcare literature. The novel VSM model was implemented in a Brazilian hospital to observe its effect on processes and related patient lead times.

Results showed that the novel VSM model was able to identify some operational bottlenecks and waste that the authors stated could not be identified by other mapping models studied; they determined that these un-identified bottlenecks had a combined impact of 110 days, or 56%, of patients' waiting time. However, the researchers did not test these other mapping models against the novel VSM model directly. The authors concluded that through this novel VSM model, all flows that impact patient lead time can be shown on a single map, with clear visualization of patients' actions and support activities.

Wallace J. & Savitz L. (2007). 'Estimating waste in frontline health care worker activities', *Journal of Evaluation in Clinical Practice*, 14(1), pp.178-180.

As part of an AHRQ funded study intended to provide hospitals with estimates of waste, researchers at Intermountain Healthcare and Abbot Associates examined waste estimates for hospital frontline worker activity. Researchers used time-and-motion study design to observe staff activities for 72 hours at two tertiary referral centers and three community hospitals. The time-and-motion design records data on the length and location of actors' different actions using a stopwatch or video recording. 61 staff members were observed, with 69% classified as caregiver roles and 31% classified as technical. 43% of observed staff were nurses.

During 1-2 hour observation periods, observed group activity was classified into 1 of 6 classes. These classes were operations, defects/errors, classifying activities, processing activities, motion, and other. Classes were created using Toyota Production System, separating activities by value and non-value adding activities. Frequency of interruption, location changes, and problems identified by staff post-observation were documented in field notes. Statistically significant reliability estimates (intraclass correlations) were computed by comparing the principal observer's observation data with simultaneous, independently collected observations from 8 different observers, resulting in intraclass correlations between .67 and .88 ($p < .054$ to $.007$).

Operations, the class defined as having no waste, took up 41% of total observation time. Activities considered 100% waste (defects/errors & other) comprised only 3% of observed time. Clarifying, processing, motion, and other were assigned as low, medium, or high waste based on the observed proportion of recoverable waste time: 20% indicated Low, 50% indicated Medium, and 80% indicated High. Half of total documented waste was reported as part of the High range according to these parameters. Researchers used base salary and fringe benefits to calculate a cost of waste per hour ranging from \$7.40 to \$18.98. Interruptions and location changes occurred at average rates of 8 and 13 instances per hour, respectively, both with an SD of +/- 11 interruptions. The most common problems reported by staff during post-observation interviews were supply/equipment related problems (36%), missing information (22%), and redundant work (17%). The researchers concluded that their results indicate a need for increased attention to operational quality.