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Applying Lean principles to the design of healthcare facilities

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Abstract

The National Health Service (NHS) in England has a capital budget of approximately £4bn per year to spend on the construction and refurbishment of new and existing buildings. The majority of capital costs are committed by early stage design decisions, which have a large impact on operations, costs and performance. It is necessary to incorporate a sociotechnical approach to design as healthcare is a service environment in which patients are part of the system. The design of facilities determines the allocation of space and the interacting flows including: patients, clinicians, visitors, medication, supplies, equipment, and information. The design requires many trade-offs and has a major impact on the patient experience and the quality and efficiency of care. This paper evaluates the application of the Lean 3P (production, preparation, process) participative design method as part of a pilot project to design a new endoscopy unit at Gateshead Health NHS Foundation Trust. The research, which was funded by the Health Foundation, used participant observation, and an analysis of the layout drawings and the 7 flows of medicine to appraise 3P. The existing and proposed designs were compared. The results show that 3P is an effective tool that can develop designs that meet the requirements of multiple stakeholders. A framework was developed that positions 3P within the overall design process. The seven flows of medicine classification was extended to include subcategories and to identify interrelationships between the flows. This will help inform the design of healthcare facilities.

Keywords: Healthcare, Facilities Design, Participatory Design, 3P, Endoscopy

1 Introduction

National Health Service (NHS) England has an allocation of £95.6bn for the financial year 2013/4 (www.england.nhs.uk). However, it is required to realise £20bn of efficiency savings by 2014/15, which will be reinvested to support improvements in outcomes and quality (Department of Health, 2010a). In 2010/11 the NHS estate was valued at £40bn, making it the largest property holder in the UK public sector. The annual estates running cost was £7bn (Department of Health, 2013c). However, the need to reduce estate running costs and carbon emissions was identified in the 2010/11 operating framework (Department of Health, 2009). The total capital budget is approximately £4bn, which is spent on improvements to premises or the development of new premises. Staff costs comprise around 65% of expenditure for a typical hospital, with premises accounting for approximately 5% (see for example, GHNFT, 2013, p.29). Thus, the majority of expenditure is on staff, with premises representing a relatively small cost in comparison.

However, the design of facilities can have a large impact on efficiency and outcomes. A study conducted in 36 US hospitals found that nurses spent 19.3% of their time on patient care activities; whilst the median walking distance covered by a nurse on dayshift was 3 miles (Hendrich et al., 2008). In terms of health outcomes, PWC (2004, appendix 1) provided a comprehensive review of research that investigated improvements that could be achieved through good hospital design. These related to hospital acquired infections; medication errors; medical errors; nutrition levels; occupancy rates and length of stay; pain levels; patient comfort/satisfaction; patient falls; threatening behaviour; sleep; staff absenteeism; stress levels; and verbal outbursts. Stock et al. (2007) noted that the redesign of the work environment could help prevent medical errors and improve patient safety.

The design of healthcare facilities is a complex multivariate problem in which medical, technical and social issues have to be considered simultaneously. This is in contrast to many

studies in manufacturing, which have optimised some technical criteria, for example minimising the distance travelled by parts. ‘Nightingale’ wards, in which beds are positioned in rows in a large room were efficient in terms of flow and staffing (as the matron and nurses could be positioned at the end of a ward and could observe many patients without obstruction). Florence Nightingale (1863) provided early guidance on the construction of hospitals that recognised the importance of avoiding excessive patient densities in wards, circulation of fresh air and adequate light. However, this configuration would be unacceptable in a modern hospital due to the risk of infection and the lack of privacy for patients. Solutions that segregate patients and clinical pathways for reasons of privacy and infection control tend to be more dispersed, which can give rise to higher costs and longer travel distances.

Many organisations in the manufacturing and service sectors have improved their competitiveness through the application of Lean philosophy and tools. The Virginia Mason Hospital in Seattle used the Production Preparation Process (3P) method together with the seven flows of medicine for facilities design (Bohmer & Ferlins, 2005; Coletta, 2012). The 3P design process is part of the Lean design process that takes into account people, products and processes. It is a participative approach that generates a collective design by including inputs from a wide range of stakeholders and involves them in decision making relating to potential designs (Coletta, 2012). 3P has been adopted by other American hospitals, including Loyola University Hospital, which reduced the distance walked by nurses by 71%, reduced the space required by 1,900 square feet and saved an estimated \$380,000 in construction costs (Nicholas, 2012). Likewise, Pelly et al. (2013) reported that a paediatric surgical centre in Seattle was completed three and half months ahead of schedule and saved \$30m in project costs due to the use of 3P.

The National Health Service in the UK is a public service that is managed by the Department of Health, is free at the point of delivery and funded through taxation. It has well-established processes for managing its estates, capital expenditure and facilities design. There has been no research published on the application of 3P in the NHS or other publically funded systems.

The purposes of this paper are to:

- Briefly outline the context within which hospital facilities are designed;
- Discuss the design process and how it is applied in the NHS;
- Briefly review the literature on Lean in healthcare and the application of Lean 3P design;
- Present a case study that evaluated the application of 3P for designing an endoscopy unit at Gateshead Health NHS Foundation Trust through participant observation and through the analysis of primary and secondary data;
- Extend the Royal Institute of British Architects plan of work framework to show how 3P contributes to the overall design process;
- Propose a classification that further develops the principles of 3P, which takes into account flows and their interrelationships from a multiple stakeholder perspective.

The next section briefly reviews the literature on healthcare systems and their characteristics, the design process, Lean, 3P design and their application in healthcare. This is followed by a description of the research methods and a brief explanation of endoscopy. Section 5 evaluates the application of Lean 3P Lean for designing the endoscopy ward at the Queen Elizabeth Hospital in Gateshead. Section 6 develops a model of the design process and outlines the proposed classification that provides further insight into flows, their interrelationships and the

requirements of stakeholders. This is followed by conclusions and suggestions for future work.

2 Literature review

The literature on healthcare operations and supply chain management has increased significantly over recent years. This has particularly related to: information technology and new technology in services; general aspects of strategy and objectives of operations and services; the selection and design of the service delivery system; strategic quality issues in services; and capacity planning, scheduling and control (Dobrzykowski et al., 2014). However, limited attention has been paid to design of healthcare facilities in these fields.

The demand for healthcare is increasing due to aging populations, new technologies and life style factors (Bloom et al., 2010). However, economic austerity is imposing significant resource constraints. In healthcare there are many stakeholders, including patients, staff, families and carers, funders (government or insurance companies), members of the public and managers/decision makers. The requirements and values of these stakeholders are different and vary over time. There is often a lack of consensus on which values should guide decisions, which makes priority setting difficult (Holm, 1998). Sibbald et al. (2009, p.7) defined stakeholder engagement as “an organisation’s efforts to identify the relevant internal and external stakeholders and to involve these stakeholders effectively in the decision-making process”. Holm (1998) noted that the overall goal of healthcare systems includes a complex combination of goals (some fuzzy) and that there is no natural way to balance them. He commented that it is impossible to use a simple maximising algorithm because such approaches require a single objective or some systematic way of balancing objectives.

The key themes for NHS England include: putting patients at the centre of decision making; increasing the delivery of quality, innovation, productivity and prevention (QIPP); and maintaining strong control of financial resources and service delivery (Department of Health, 2011). However, these objectives include many potential trade-offs and difficult choices. The QIPP challenge was seen as being central to achieving savings of £20bn/year (Department of Health, 2010a).

Healthcare systems are complex adaptive systems in which many individuals interact in ways that are not always predictable. They are highly interconnected so that the action of one agent can change the context for others (Plsek, 2006). Healthcare is a service environment in which patients are part of the system. It is therefore necessary to incorporate a sociotechnical approach to design (Cherns, 1976, 1978). The sociotechnical system approach considers that “organisational objectives are best met not by the optimisation of the technical system and the adoption of a social system to it, but by the joint optimisation of the technical and social system” (Cherns, 1978, p.63). Caixeta (2013) noted that it is important to consider the design of healthcare buildings and services simultaneously, as poor connections may lead to problems with service delivery. The design of healthcare facilities is complex because there are multiple stakeholders, many outcomes and flows that interact including: patients, clinicians, visitors, medication, supplies, equipment and information. Hospitals are operating at very high utilisation meaning that layout and flow become very important (Dowdeswell et al., 2004). Although the healthcare literature considers flow and value generation, there is poor clarity on their relationship to the built environment (Tzortzopoulos et al., 2009).

2.1 *The design process*

The Royal Institute of British Architects (RIBA) developed a plan of work that has been the definitive UK model for building design and construction (RIBA, 2013). It comprises eight phases: (0) strategic definition; (1) preparation - identifying the project objectives, the client's business case and other parameters or constraints required to develop an initial project brief; (2) concept design - the development of an outline specification and design proposals; (3) developed design that updates design proposals and specifications for planning approval submission; (4) technical design, which produces the detailed design; (5) specialist design performed by specialist subcontractors; (6) construction; and (7) use and aftercare.

The majority of costs have been committed by the end of the conceptual design process, although the incurred cost is low. Errors at this stage can commit substantial costs, which are realised subsequently. Approximately, 75–80% of avoidable total costs are controllable at the design stage (Burt & Doyle, 1993). Likewise, the early stage of the design process has a large impact on the performance and utility of the final design. Thus, it is particularly important that the users' requirements are fully taken into account by the specification and conceptual design processes (McGovern & Hicks, 2006).

The National Health System (NHS) in the United Kingdom has an estates process that is followed when building new facilities or redeveloping existing sites. The first phase is strategic and considers healthcare planning, which takes into account the needs of the population and the availability of finance. This is followed by a project phase that manages construction activities, then an operational phase that considers commissioning and operational use (NHS, 2013, accessed 19th February). Building in the United Kingdom is regulated by national building regulations (DCLG, 2013). In addition, the Ministry of Health developed a series of Hospital Building Notes (HBNs) in 1961, which set additional standards for existing and new developments. Health Building Notes provide 'best practice' guidance relating to the design and planning of new healthcare buildings and on the redevelopment of existing facilities. They are based upon ergonomic research and the professional opinion of experts from the fields of architecture, ergonomics and nursing (Department of Health, 2013a). These are complemented by Health Technical Memoranda that give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology that is used in the delivery of healthcare (Department of Health, 2013b). Standardisation, which initially aimed to ensure that buildings were of high quality, became used as a mechanism for applying centralised control and ensuring the efficient use of resources (Francis et al., 1999). The allocation of resources is managed through a business case approval process, which seeks to prioritise investments in order to achieve a fair, effective and sustainable use of finite resources (NHS England, 2013).

Bate & Robert (2006) identified three aspects of healthcare facility design: (i) the design of pathways that are derived from evidence-based best practice and processes that are fast efficient and have no bottlenecks; ii) taking into account clinical governance, standards and safeguards for patients; and (iii) designing human experiences as distinct from designing processes. There has generally been a focus on the first two aspects, which are technical, and a lack of attention to the third, which relates to social factors, emotion and perceptions.

Designers are taking more account of the requirements of future users. There have been various terms used to describe collective creativity including co-creation, co-design and participatory design (Sanders & Stappers, 2008). User-centred design involves an 'expert' observing or interviewing largely passive users (i.e. 'user' as subject). Co-creation refers to

any act of collective creativity; with co-design this is applied throughout the design process. The participatory design approach, which originated in Scandinavia gives users more influence in the conceptual activities that take place in the early phase of design (Sanders & Stappers, 2008). With participative design “the people destined to use the system play a crucial role in designing it” (Gregory, 2003, p.62). The process involves the co-construction of knowledge through collaborative partnerships that take into account social practices. User participation improves the knowledge that is used for building systems. It helps reduce resistance to change by helping participants develop realistic expectations and it increases workplace democracy. A range of methods may be used including ‘design by doing’, mock-ups and organisational games (Gregory, 2003). There are examples of the use of experience-based design in healthcare, which is “a user-focused design process with the goal of making user experience accessible to the designers, to the, to conceive of designing experiences rather than services” (Bate & Robert, 2006, p.308). Here, users are not regarded as passive recipients of services, rather their experiences are part of a participatory design process.

Learning in a participatory context has often focused on the learning of the participants. Learning is a two-way process in which the participants learn more about the design, its purpose and constraints; whilst the designers learn about the stakeholders, their requirements and perspectives. “Expert facilitation can appear to be a seamless conversation where the users quickly understand the subject being discussed, its relevance to their lives” (Luck, 2007, p.233). The facilitators of events learn through experience and from observing the behaviours of other participants (Luck, 2007). High quality facilitation is necessary to give the participants the ‘voice’ to fully engage in the process.

2.2 *Lean and its application in healthcare*

Lean production stemmed from the Toyota Production System (TPS), which is based upon two concepts: the reduction of costs through the elimination of all forms of waste (those things that do not add value to the product) and the full utilisation of workers’ capabilities (Sugimori et al., 1977). There are seven types of waste, which are: overproduction, inventory, waiting, transportation, defects, movement and unnecessary processing (Bicheno & Holweg, 2009). Lean adopts a process-based view that focuses upon value streams (Burgess & Radnor, 2013). The principles of Lean are: (i) identify value from the customer’s perspective; (ii) identify the value stream for each product or service and address all wasteful steps; (iii) make the product or service flow continuously and standardise processes around best practice; (iv) introduce ‘pull’ between all steps where continuous flow is impossible; (v) manage towards perfection (Womack et al., 1990).

Lean has been adopted widely in healthcare. Healthcare quality and costs depend on delivery processes, which often include unnecessary or inappropriate steps that lead to cost and the risk of mistakes, but do not contribute to the value of patient care (Nicholas, 2012). Radnor, Holweg, and Waring (2012) investigated the introduction of Lean in four UK NHS hospital trusts. They found a widespread use of Lean tools that led to small scale and localised productivity gains. They highlighted significant contextual differences between healthcare and manufacturing that made it difficult to move towards a more system-wide approach. In particular, some of the principles proposed by Womack et al. (1990) did not apply. ‘Customer value’ in healthcare is different to manufacturing because the patient is normally a recipient of treatment and usually does not commission or pay for the service. The provision of healthcare is often subject to budgetary constraints that make it capacity-led; there is limited ability to influence demand or make use of freed up resources (Radnor et al., 2012).

Fillingham (2007) described the use of the Toyota Production System for improving patient care at the Royal Bolton Hospital in the UK, which has been widely considered to be an exemplar case. He reported a 42% reduction in paperwork, better multidisciplinary team working, a reduction in length of stay by 33% and a reduction in mortality of 36% per cent. Ballé and Régnier (2007) reported on the use of Lean to reduce medication distribution errors, nosocomial infection rates, and catheter infections in a French hospital. Although the initiative was deemed successful, the authors identified resistance to the standardisation of clinical and nursing practices. This indicates that Lean is no panacea, but it can significantly reduce waste. In healthcare, wastes include: defects – wrong medication; transportation; waiting; unnecessary motion; and unused human potential (Nicholas, 2012). Thus, constructing business cases for the redevelopment of facilities could be justified by a range of factors including improved outcomes and the more effective and efficient use of staff. This could be achieved, for example, by improvements in flow that reduce waste.

2.3 Lean design and its application in healthcare

3P (production, preparation, process) is a Lean design process that encourages collaboration between all of the key stakeholders early in the design process. 3P is sometimes alternatively known as product, process and people (Coletta, 2012). As it is used during the conceptual design stage, it can have a large impact on committed costs and the overall performance of the solution. It utilises the Lean toolkit to help maximise quality, minimise costs and avoid future problems. However, it is common for 3P interventions to consider a subset of issues relating to a specific design problem. “When product development and change are very limited the process is referred to as 2P (Production, Preparation)” (Coletta, 2012, p.5).

Grunden and Hagood (2012, p.54) suggested that participants should be aware of constraints and variables that can be changed. These were categorised as: (i) key assumptions – the available space and budget, building codes, regulatory requirements, site selection and vertical circulation; (ii) design criteria – ‘voice of the customer’, space utilisation, staff work flow, patient accessibility, patient flow, ergonomics and safety; and (iii) organisational criteria – mission, vision, values and the criteria against which the facility will be assessed.

Fishbone diagrams (Ishikawa, 1986) (sometimes known as cause-and-effect or Ishikawa diagrams) can be used to represent the relationship between quality problems with causes shown as lines radiating from category branches (Greasley, 2009, p.183). They can also be used to represent processes and sub-processes, or to capture existing issues and improvement opportunities; thus they can become a ‘lessons learned’ document that helps the team avoid repeating existing problems. The seven wastes can also be considered at this stage (Bicheno & Holweg, 2009; Coletta, 2012, p.139). The stakeholders involved in a 3P workshop develop physical models (typically created with cardboard and sticky tape). Flows in the system are represented by coloured string. A spaghetti diagram is produced that represents the movement of materials and people. These enable participants to visualise design options and work together to produce improvements (Coletta, 2012, p.141). Seven or more alternatives are considered initially, but this is reduced to three prototypes, typically on the second day of the workshop. The alternative solutions are rated against pre-specified criteria by which the participants select the final solution (Coletta, 2012, p.156).

The Lean design of hospitals systematically concentrates on defining, developing and integrating safe, efficient, waste-free operational processes in order to create a more patient focused physical environment (Grunden & Hagood, 2012). Grunden and Hagood (2012) proposed steps for Lean design: i) analyse the activities involved in the work; ii) identify the

connections between the customer and suppliers; iii) identify the pathways that connect activities in the path of care; and iv) identify improvements. Miller (2006) identified ten principles for the application of 3P in healthcare: 1) make production and preparation fast; 2) make the process adaptable; 3) aim for smooth work flow and motion; 4) build-in quick setup and changeover; 5) make everything easy to move; 6) use technology only when needed and use simple machines that perform one function well; 7) use only the space necessary; 8) create small, fast focused lines rather than multipurpose workstations; 9) use single-piece flow with no batching; and 10) build in right first time quality with line stopping when abnormal conditions occur. Grunden and Hagood (2012) provided a description and examples of how 5S, visual management, standardisation, value stream mapping, TAKT time (the average process time required to meet demand) and Failure Modes Effects Analysis (FMEA) can be applied in healthcare settings.

The Virginia Mason Hospital in Seattle used the Production Preparation Process (3P) for facilities design (Bohmer & Ferlins, 2005; Kenney, 2010). It identified seven flows of medicine which are represented using standard colours: patients (red), family and carers (brown), staff (yellow), medications (orange), supplies (blue), equipment (black) and information (green) (Bohmer & Ferlins, 2005). There are different objectives and constraints for the various flows and interactions. For example, it is desirable to minimise the distance travelled by patients and staff as this helps to maximise the speed of treatment and the efficiency of operations. However, it is important to minimise the possibility of hospital acquired infections, which can be caused by interactions between individuals and a lack of hygiene. The risk can be minimised by reducing patient-to-patient interactions and by ensuring that patients only come into contact with their own visitors. There are inherent trade-offs, for example single rooms increase privacy and reduce infectious disease, yet this may cause flow to deteriorate and increase the number of staff required (Dowdeswell et al., 2004). The movement of patients is also influenced by their mobility. For example, if the movement of patients require wheel chairs or trolleys, this can impact on vertical circulation (e.g. necessitating the use of lifts) and horizontal circulation (e.g. door sizes).

3 Methods

Research on change, such as the application of 3P, benefits from a sociotechnical perspective (Cherns, 1976, 1978) that takes into account organisation and social systems as well as technical aspects of the system. The Lean Design of Space (LDoS) project is based on a case study approach (Eisenhardt, 1989; Yin, 2009). As part of the LDoS Project, the North East Transformation System (NETS) redesigned an endoscopy department as a pilot. The 3P approach was used with different units of analysis. At the macro-level it was used to determine the overall design configuration using 2½D models. At the micro level it was used to evaluate flow and ergonomics in a treatment room using 3D models.

Change initiatives may be viewed in terms of context, content, process and outcomes (Armenakis & Bedeian, 1999). This led to the application of mixed methods (Bryman & Bell, 2007) that included participant observation, observation and the analysis of secondary data. The evaluators participated in the NETS's LDoS Project activities including: the LDoS Project Group Meetings; the week-long endoscopy 3P event and report-out. Extensive secondary data were collected prior, during and after the 3P workshop.

This case study focused on the endoscopy department at the Queen Elizabeth Hospital, which was the site where the approach was developed, tested and evaluated. The quantitative aspects of the analysis were based upon measurements taken from AutoCad drawings of the existing

and proposed layouts. The seven flows of medicine were placed on separate layers and represented as polylines, which were measured in AutoCad. This approach enabled the existing and proposed layouts to be evaluated on a like-for-like basis.

4 Endoscopy

The NETS Lean Design of Space Project Group carefully considered the criteria for selecting pilot sites. A wide range of ‘hard’ and ‘soft’ issues were considered, including project characteristics, executive support, receptiveness to change, timing and funding. From this analysis, the endoscopy ward at the Queen Elizabeth Hospital became an early candidate. An endoscope is a thin, long, flexible tube that has a light source and a video camera at one end. Endoscopy is a procedure where the body is examined internally using an endoscope. Endoscopes can be inserted into the body through a natural opening or through a small surgical cut made in the skin. It can also be used to help perform keyhole surgery (NHS Choices, 2013).

Endoscopy services are accredited by the Joint Advisory Group (JAG) on gastrointestinal (GI) Endoscopy (<https://www.jagaccreditation.org/>), which audits provision to verify compliance with the Global Rating Scale (GRS) Standards. This scale is based upon the following factors: (i) clinical quality (information/consent, safety, comfort, quality, appropriateness and results); (ii) quality of the patient experience (equality of access, timeliness, choose and book, privacy and dignity, aftercare and patient feedback); (iii) workforce (skill mix, review and recruitment; orientation and training; assessment and appraisal; care of staff; and communication with staff); and (iv) training (environment and opportunity; endoscopy trainers, assessment and appraisal; and equipment and materials). This accreditation of endoscopy services takes a holistic approach and is a patient centred and workforce focused scheme.

In the UK the design of endoscopy facilities should comply with Health Building Note 52 part 2 (Department of Health, 1994), which provides comprehensive guidance on the design of day care endoscopy units which include: (i) general service considerations (including classification of hospital patients, patients with special needs, children, sizing a unit, functional relationships, clinical and other services); (ii) general function and design requirements (including signposting, location, planning considerations, environment, phasing, environmental engineering and finishes); (iii) specific functional and design requirements (for example, including entrances, reception, preparation and treatment rooms, offices, cleaning rooms etc.); and (iv) engineering service (safety, fire safety, noise, mechanical services, electrical services etc.). There is also considerable extra guidance on the design of endoscopy wards provided by the Joint Advisory Group on GI Endoscopy (JAG, 2011), which is also responsible for the accreditation of endoscopy facilities. These guidelines include: (i) a wide range of general principles (such as disabled access, gender separation etc.); (ii) reception and waiting arrangements; (iii) patient assessment and preparation areas; (iv) the endoscopy room (access, floor space, drug storage etc.); (v) recovery and discharge; (vi) decontamination environment; (vii) staff changing rooms and other facilities. There is also a summary of essential and desirable features for each of these headings.

The design of endoscopy facilities requires a wide range of factors to be taken into account. Facilities should be designed so that they can provide an effective service that meets the requirements of independent accreditation and a wide range of stakeholders.

5 3P applied to Endoscopy

The pilot of the 3P method was at the endoscopy ward at the Queen Elizabeth hospital in Gateshead. This will be considered in terms of data collection and other actions that took place before the workshop; the workshop itself and activities and actions that took place after the workshop.

5.1 Design objectives

A primary requirement was to develop a new endoscopy facility on an existing site that fully complied with the JAG requirements (JAG, 2011) and would be likely to score highly in terms of the GRS standards (<https://www.jagaccreditation.org/>). The UK Department of Health has also placed increased emphasis on the prevention and early detection of cancer (Department of Health, 2010c) which will increase the demand for endoscopy services. The unit had approximately 60 patients per day with 60% requiring recovery. The new facility was required to satisfy an expected increase in demand of 10% per annum between 2014 and 2016. The proposed design aimed to meet the requirements of a range of stakeholders and had to comply with building regulations, hospital building notes, JAG guidelines and other regulatory standards.

The requirements in terms of the flows of medicine were (Bohmer & Ferlins, 2005):

- patients (red) – the distance travelled and backtracking should be minimised. There should be segregation in the flows of males and females to ensure dignity at all times. There needed to be sufficient capacity/circulation space to accommodate bariatric patients (with a body weight of over 25 stones (159Kg)). It was desirable to locate patients in a single location for pre-assessment and recovery so that their clothes and personal possessions could be located in a single place. It was also necessary to have separate entrances for inpatients and outpatients, which was a requirement of the JAG guidelines;
- family and carers (brown) - should be able to accompany vulnerable patients or those with special needs throughout the process. As far as possible they should be isolated from other patients to ensure dignity and to prevent the risk of infection that could arise through contact;
- staff (yellow) – the distance travelled should be minimised to ensure the efficient use of time;
- medications (orange) – the aim was to bring medications as close as possible to the point of use and minimise delays in patients waiting for medications (such as anaesthesia or analgesics). Medication safety checks should be made explicit within the process;
- supplies (blue) – ideally, supplies will be located at the point of use and presented in sequence of use. This should use visual pull strategies (such as min/max levels or twin-bin approaches) for restocking and managing inventory from upstream suppliers;
- equipment (black) – the distance travelled should be minimised. The supply of endoscopes should be synchronised with the decontamination process that processes 8 endoscopes at a time, with a cycle time of 40 minutes. The endoscopes should be used within 3 hours of cleaning. The design should also accommodate sufficient circulation space for resuscitation equipment and oversized trolleys and lifting equipment for bariatric patients;
- information (green) – patient information should be positioned so that confidentiality is maintained at all times. Work should be scheduled so that demand and capacity are appropriately matched and so that variations in cycle times are minimised (which can cause queuing and/or reduce resource utilisation and efficiency).

5.2 *Data collection and analysis prior to the 3P workshop*

The data collection prior to the workshop was comprehensive and was managed through a series of six planning meetings. The data included a breakdown of the number of procedures and control charts for procedure cycle times, procedures by day and procedures conducted over the previous 200 days. The overall process included administration and check-in, pre-assessment; change and wait; procedure; first stage recovery; and second stage recovery. Value stream maps (see for example, Insert Figure 1) were produced using standard notation (Rother & Shook, 2003, p.28). Engineering drawings were obtained for the existing facility; some adjacent space was also made available to increase the floor space available for the new facility. A photographic library was produced that included images of: flip charts produced during the planning of the events; the existing endoscopy ward; and its equipment. The 7 flows of medicine were measured. These were superimposed onto a layout drawing of the existing facility (see

Insert Figure 2). The existing facility required staff and supplies to travel long distances. The staff flows were associated with three main loops: i) the patient loop, that included collecting patients from reception, then to pre-assessment, a changing room, endoscopy in a treatment room, recovery and finally back to reception; ii) the equipment loop – transporting endoscopes between the decontamination room and the treatment room; and iii) the waste disposal loop, which involved taking clinical waste to disposal.

Feedback from patients in the workshop identified that it was important to segregate patient flows by gender to improve dignity (this was also a requirement of the JAG guidelines). It was necessary to separate inpatient and outpatient flows as the flow of seriously ill inpatients could cause anxiety in outpatients waiting for treatment. Patients also expressed a desire to be located in a specific room where they could keep their possessions.

Insert Figure 1 Example of value stream map

Insert Figure 2 Endoscopy ward; 7 flows

5.3 *3P workshop*

There were 26 workshop participants, which included two architects, one consultant, one junior doctor, two patient representatives, a JAG consultant, a nurse endoscopist, a line manager, nurse manager, nurses, nurse assistants, quality improvement professionals, administrative staff (including an appointment scheduler) and two academic evaluators. Participants from the endoscopy unit were selected to reflect the range of staff in the care pathway, so that they could share their detailed knowledge and contribute to the design. The role of the patient was to provide an insight into their experience of the endoscopy service. The Architects contributed to the event as participants, but they were subsequently responsible for developing the detailed design and will be responsible for managing the construction process. The JAG Consultant provided detailed expertise on the accreditation requirements and shared their experience of best practice. The Trust's quality improvement professionals were also present to learn from the event so that they could subsequently disseminate 3P through share and spread. The participants were split into three groups which were broadly representative of the functional areas and the levels within the organisation as recommended by Coletta (2012, p.166). The academic evaluators acted as participant observers who took notes and photographs.

The workshop carefully took the social and organisational dynamics within groups into account and included ‘ice breakers’ at the beginning of the workshop which aimed to break down the influence of normal hierarchical relationships. The participants identified the details of the endoscopy processes through the development of a detailed fishbone diagram which comprised 7 high level processes, 31 sub-processes with 127 components in total. This analysis informed the subsequent development of the 3P designs.

Based on the principle of having 7 or more alternatives (Coletta, 2012) each team within the 3P process moved progressively through 2D and 3D scale model representations of the proposed layouts (see Insert Figure 3 and Insert Figure 4). The workshops considered the flow of patients first, then the flow of staff and equipment. This was a logical approach. In this particular case the location of the decontamination facility was fixed as the cost of moving it would have been prohibitive. The space available was also a constraint. The consequence was that it was not possible to achieve an ideal flow of equipment or staff. The 3P workshop therefore considered how best to manage the flow to minimise the number of journeys made. This highlights the fact that the solutions are context dependent, taking into account constraints, stakeholders, the nature of the clinical processes and the availability of capital.

The emergent designs were selected using a voting system that utilised a weighted factor approach. The high level criteria considered were: staff and patient flows; separate inpatient and outpatient entrances; staff facilities; a quiet room for private discussions and the ongoing requirement to carry out all types of procedure including physiology. This process incrementally revealed preferable configurations, which caused convergence in the emerging designs. Finally, one team was given the task of developing a full scale model of a procedure room (see Insert Figure 5) that was 25% smaller than the current size of 6m x 4m.

Insert Figure 3 Example of a 2D design

Insert Figure 4 A final 3D scale model

Insert Figure 5 Full scale procedure room model

5.4 Revised layout

An independent report by a JAG Consultant confirmed that the proposed design complied with the JAG requirements at a ‘high level’. The proposed design included 17 ensuite rooms, which was an increase of 5, compared to the existing design. It increased the number of treatment rooms from 4 to 5, which would accommodate the anticipated increase in demand for endoscopy services. It was also possible to provide two entry/exit points, which would help isolate inpatient and outpatient flow. Thus, the design satisfied the objectives outlined in section 5.1.

The analysis of the seven flows was a static analysis. The measurement of distances from AutoCad drawings was based on straight lines between points for typical routings (taking into account constraints and the movement in/out of rooms). This inevitably missed the variations, queuing and back tracking that would occur in practice, but it compared the existing and proposed layouts on a like-for-like basis. The actual flows could not be measured until the facility is built and is in operation. Therefore, it was necessary to use estimates based on the

drawings. Insert Table 1 provides a comparison of other metrics. The facility was designed to accommodate an increase in demand of 38%. The number of treatment rooms was increased from 4 to 5. The number of beds increased from 10 in two open wards to 17 within separate ensuite rooms. The number of toilets increased from 9 to 20, which would help reduce infection risk and queuing. The distance travelled by patients was typically reduced by 25.82%, with a corresponding reduction in staff walking distance of 27.1%. The number of process steps was reduced by 35%. The workshops revealed that the number of times that a patient was relocated was a particular concern rather than the distance travelled per se. In the existing design the patients had two stages of recovery in different areas; in the new design this was reduced on one, although this particular change did not have a large impact on the distance travelled.

Insert Table 1 A comparison of existing and revised layout.

The 3P workshops had many other advantages. For example, the Architect commented that he obtained a much better brief in a shorter period of time. The specification process was considerably improved as it took into account flows and embedded Lean principles. The workshops provided a forum for developing a functional specification that met the needs of a wide range of stakeholders. It also introduced the stakeholders to the design process and made them aware of some of the constraints and design issues that needed to be taken into account in the technical specification and the detailed design. The decision makers involved in evaluating the business case benefitted from a more comprehensive and inclusive solution that was shaped by multiple stakeholders. The Director of Estates was so impressed by the process that he announced that 3P would become part of the standard estates process within the Trust. To date, there have been two further applications of 3P, the first related to a maternity ward at the Queen Elizabeth Hospital, the second was another endoscopy ward at a different hospital.

6 Discussion and contribution to theory

The design of healthcare facilities can have a large impact on efficiency and outcomes. Although capital expenditure on buildings is around 4% of turnover, the efficient design of space can have a large impact on the efficiency and effectiveness of the whole system. The RIBA plan of work provides a model of the overall design process, which provides a framework for integrating tasks including design, procurement and planning. However, the RIBA framework does not specifically consider flow. Previous research on 3P has focused upon the method and has not placed it within the context of the overall design process. At stage 1, preparation and brief, the 3P process allowed a wide range of stakeholders to specify their requirements and influence the evaluation criteria. An improved specification is likely to enhance the functionality of facilities and reduce costs due to errors. At stage 2, the 3P participants contributed to the conceptual design in terms of defining the configuration in terms of layout and flow. At stage 3, developed design, 3P contributed to the outline specification through an iterative process that selected the preferred special configuration. The remaining stages of the RIBA plan of work (technical design, specialist design, construction and use/aftercare) were not directly addressed by 3P, although the Architects managing the process were informed by their attendance at the 3P workshop.

With 3P the stakeholders were engaged through a facilitated workshop. Although this was a good example of participatory design, participation did not continue throughout the design process. Therefore, it could not be considered to be co-design as defined by Sanders & Stappers (2008).

Healthcare systems are complex service environments in which patients are part of the system. A healthcare system is not a factory; it is a sociotechnical system in which the technical system is closely interrelated to a social system of people and organisation. The design of facilities is further complicated because there are multiple stakeholders that interact and give rise to several types of flow. 3P provides a framework for optimising the design of sociotechnical systems, taking into account flow and other issues through stakeholder participation. The construction of physical models helps participants visualise solutions, which leads to rich discussions about the various design configurations.

3P involves the analysis of seven flows of medicine. However, the nature and interrelationships between these flows has not been addressed by the literature. Individual flows have different characteristics. In the analysis it became clear that patient flow was the dominant flow, because it largely determined the other flows. The seven flows can be categorised in several ways:

- Patients – gender, weight (bariatric/non-bariatric), mobility (walking/wheel chair/trolley bed); state (conscious/unconscious); age (paediatric, geriatric etc.), inpatients/outpatients and vulnerability. Improving patient flow improved satisfaction. It was important to separate the flow of males from females to increase dignity. Bariatric patients need larger rooms, beds and trolleys; staff require lifting equipment to move them; the facility needs sufficient space for this additional equipment. Some patients may be able to move independently, whereas others may require assistance throughout the process. There are also implications in terms of physical access. It is desirable to separate the flow of inpatients from outpatients to reduce anxiety in outpatients caused by them seeing seriously ill inpatients. Patient flows could also be categorised as being related to the clinical process (e.g. endoscopy) or nonclinical activities (e.g. visiting the toilet);
- Staff may be categorised according to their role (nurse, doctor, manager, porter, ancillaries etc.); their specialism (anaesthetist, endoscopist etc.); and task. The flow of staff has an impact on costs, efficiency and potentially the level of service that can be offered to patients if the capacity is fixed. The staff flow was linked to the patient flow for most of the patient journey, as staff accompanied patients from reception to pre-assessment, then to the changing room, treatment room and recovery. Patient satisfaction could be improved by having the same nurse care for them throughout the process. Other staff flows were linked to equipment flows, waste flows, medication, information and supplies;
- The flow of families and friends were linked to part of the patient journey, typically from the waiting room, through pre-assessment and changing. Families and friends are a possible source of infection, therefore it is beneficial to limit their contact with other patients;
- The flow of equipment (clean/dirty) was linked to the flow of patients through the treatment room, but the clean equipment needed to arrive before the patient and the dirty equipment was removed after the patient had left. The flow of equipment impacted on staff, which could increase costs. If the equipment flow was poor, it could lead to delays or batching, which might make it necessary to buy more equipment;
- The flow of medication, which can be categorised as being related to personal medication (e.g. blood pressure tablets) or related to the specific clinical operation being performed;
- The information flowed with the patients, as hard copy notes in folders, however visual management boards needed to be in staff areas that could not be seen by visitors or patients.

The design complexity arises from the relationship between these flows, rather than from combinatorial complexity caused by long and complex routings, which is common in manufacturing. The 3P process forms a general approach for designing healthcare facilities that takes into account multiple stakeholders and flows.

7 Conclusions

The design of facilities has a significant impact on the efficiency and effectiveness of healthcare systems. The demand for healthcare is increasing due to aging populations, new technologies and life style factors. However, healthcare budgets have come under increasing pressure due to economic austerity. Healthcare providers have well established processes for appraising capital investment proposals. However, the development of the design brief and subsequent decisions are made by a limited range of stakeholders. The case study has demonstrated that 3P provides an effective process for engaging with a wide range of stakeholders which improves the quality of the design brief. The analysis of flows, taking into account Lean principles leads to configurations that facilitate efficient and effective operations.

This paper has provided a framework that identified how 3P fits within the overall design process. It has also contributed to the deeper understanding of the seven flows of medicine by identifying important subcategories of flow and explaining interactions between the flows. In terms of design, patient flow is the dominant flow and needs to be considered first, as it partially determines the other flows.

The successful results of the pilot described in this paper has led to 3P being made a standard part of the estates process at Gateshead Health NHS Foundation Trust where it has since been applied for designing a maternity unit. 3P has also been applied for designing another endoscopy facility at a different hospital trust. This demonstrates that the results have practical application and can be generalised.

There is considerable scope for further work that analyses the facilities in use after they have been constructed.

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