

Managing patient flow using time buffers

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Abstract

Purpose

The purpose of this paper is to determine how and why Theory of Constraints (TOC) based time buffer management has contributed to improved patient flow in health and social care applications.

Methodology

The focus of the research is on the application and implementation of time buffer management by QFI consulting. Four UK hospital implementations of the QFI Jonah software and methodology were investigated to establish how buffer management was being applied and why the reported benefits were being achieved. This involved collecting service delivery data together with semi-structured interviews. To support this evaluation, four control functions of time buffer management have been identified as a basis for evaluation of the application designs and their implementation.

Findings

Case research evidence shows significant and rapid improvement in length of stay following implementation of the approach, amounting to a reduction in length of stay of over 20% and significantly improved Accident & Emergency performance. Sustainability issues were evident however and were traced, at least in part, to lack of adherence to one or more of the functional elements of the system.

Research limitations/implications

This case research has considered four applications that represent some of the more successful implementations. This research is, therefore, limited by the range of applications considered and is also limited in its ability to evaluate the sustainability of the implementations in the longer term.

Practical implications

This paper provides clearer theoretical understanding of the improvements experienced by these hospitals, which is critical to expanding the use of traditional manufacturing approaches into complex service environments.

Originality/value

This research has helped conceptualise how time buffer management control functions can be structured to evaluate the design and implementation of novel applications.

Keywords: Theory of constraints, buffer management, health and social care, patient

flow, case research

1.0 The operations challenge in healthcare and social care

With an aging population it is increasingly important to view health care delivery systems holistically, acknowledging that the wider delivery system encompasses both health and social care. Therefore, effective and efficient acute health care must also ensure strategic alignment of the social care system. This fact further demonstrates the complexity of this wider system, as many different organisations need to be synchronised in order to ensure improvements in efficiency and timeliness associated with improved patient flow. However, the silo mentality, driven by separate organisational targets, often results in dysfunctional behaviour. In England the government drive to improve performance in the National Health Service (NHS) has had to address many examples of such behaviour, especially at the silo interface, between social and medical care services.

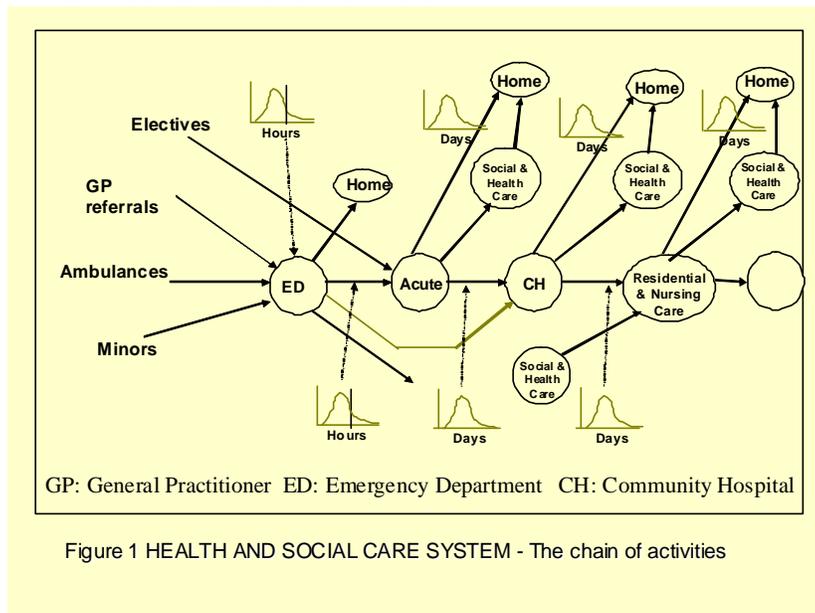


Figure 1 HEALTH AND SOCIAL CARE SYSTEM - The chain of activities

Figure 1 illustrates the macro flow routes into and through the health care system, together with the interface between health and social care. This Figure, in addition to the major flows, illustrates the variation and uncertainty associated with demand, together with process and recovery times. In the UK, such times, together with budgetary control, are used to drive improvement and there are now emergency and planned treatment targets. The Emergency Department (ED) performance is measured against a government target for England that states 98% of patients are to be treated within 4 hours. The more recent referral to treatment target states that 95% of patients are to have started treatment within 18 weeks of referral by a General Practitioner (GP).

In England the government sets the waiting targets and the local hospital management are empowered to find appropriate means of achieving these targets, whilst remaining within budget. Agencies, such as the NHS Institute for Innovation and Improvement support this process and over the years a wide mix approaches have been used that originated in manufacturing.

2.0 Meeting the operations challenge

The health care environment can be closely allied to non-standard manufacture where the flow complexity is characterised by dependent events and statistical fluctuations. In healthcare the need for tailored pathways and highly variable procedures, as well as recovery times, adds considerably to this complexity. Over the years manufacturing based theory has been increasingly applied to this area. This includes the adoption of clinical pathways (Herck et al., 2004) to help standardise procedures and the use of Shewhart's (1931;39) continuous improvement cycles (PDSA) (Walley and Growland, 2004). The use of run charts and control charts are now common and this has more recently been expanded to explore the Six-Sigma methodology (Proudlove et al., 2008). Over recent years, with the UK Government's emphasis on service delivery, the focus has moved to improving patient flow, with significant interest in manufacturing parallels. The two most prominent approach being kanban control, which is closely associated with lean manufacturing (Bhasin and Burcher, 2006) and time buffer management, which is closely associated with the Theory of Constraints. Although both these approaches are concerned with managing flow they come from very different environments.

Kanban is a control system closely associated with the origins of the Toyota Production system (Ohno, 1988), hence originally allied to the volume production of standard parts. Whereas, TOC based time buffer management originated at the other end of the operations spectrum, which is characterised by the manufacture of a wide variety of products on a make to order basis.

The variable and uncertain nature of patients and their treatments has much in common with the complexity of a make to order environment and, therefore, it is not so surprising that the time buffer management approach has proved effective (Umble and Umble, 2006); however, the question we are attempting to address here is how and why. To address this question it is important to outline the traditional TOC applications of time buffer management and the associated control functions they satisfied, before relating this to the health and social care applications.

3.0 Time buffer management – manufacturing origins and traditional applications

TOC based time buffer management is applied differently in manufacturing and project environments. The manufacturing approach, entitled Drum Buffer Rope, emerging in the late 1980s with the project management approach, entitled Critical Chain, emerging in the later 1990s. These traditional applications are briefly outlined in turn, before identifying common functional control elements. These functional elements will subsequently be used to both explain and evaluate the healthcare applications.

3.1 Manufacturing based time buffer management

The manufacturing application is termed Drum - Buffer - Rope (DBR). This approach is well documented and has been developed as a practical approach in the manufacturing environment (Goldratt, 1990; Umble and Srikanth, 1997; Schragenheim and Detmer,

2001; Stratton et al., 2008) as outlined below.

- **Drum:** The drum can be set by a resource constraint or market demand and we will assume here that it is the market demand. It may be interesting to note that DBR applications are now rarely associated with bottleneck management as any growth strategy will look to ensure market demand remains the constraint, as is the case in healthcare.
- **Rope:** This is the planning mechanism for releasing work and effectively choking material release in line with customer demand. This is the DBR mechanism for preventing over production where the rope represents the time offset that releases material in line with demand.
- **Buffer:** Once material is released the time remaining is termed buffer time, which is based on the assumption that the actual processing time (touch time) is negligible. To support the management of this buffer it is conceptually divided into three equal time zones (See Figure 2).

3.1.1 *The four control functions of DBR buffer management*

The associated control functions are related below.

- *Prioritise the flow of work according to buffer consumption.*

Work is release based on the choked release date set by the rope. Work is progressed with reference to the buffer consumption, indicated coarsely by the colour coding or more precisely, percentage buffer penetration..

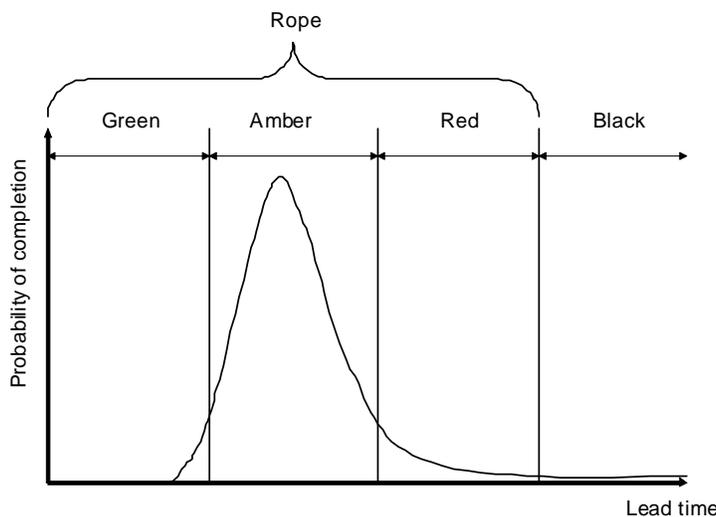


Figure 2: Buffer management in an operations environment showing buffer zoning of lead time distribution

- *Identify when to expedite potentially late arrivals.*

The red zone should effectively represent the tail of the distribution with relatively few orders entering this zone (see Figure 2). Having parts in the red zone indicates the need to act, i.e. expedite where necessary to ensure it is delivered within the remaining buffer

time. As has already been stated, even though the red zone represents only one third of the lead time, there is still time to complete the order, even if processing has not started. This, however, assumes there are few orders in the red zone at any one time.

- *Signals when the whole production system is starting to become unstable.*

The system is acknowledged to have the capability to expedite only a limited number of parts but if this rises above a certain level (Goldratt (1990) suggests over 10%) the system is at risk of going out of control. In such cases, urgent action is required to bring the system back into control, typically by limiting order intake or increasing capacity in some way.

- *Identify main sources of delay in order to target improvement.*

Continuous improvement is about reducing variation (Deming, 1986) and in the flow context, targeting sources of variation that threaten delivery. This is illustrated well by the exposure of rocks in the river and rocks analogy commonly associated with lean manufacturing. The equivalent, in buffer management terms, is associated with the reasons for red zone penetration of the buffer, therefore, it is necessary to record what is the source of delay at this time.. This information is periodically analysed using Pareto analysis and used to target improvement..

3.2 Project based buffer management

In the project environment, where the processing time (touch time) is a significant part of the overall lead time, the DBR assumption that process time is insignificant is no longer valid. In these situations the time buffer element of the lead time needs separating from the process time.

If we consider traditional project management, a network of tasks are logically linked by dependencies and the longest path is referred to as the critical path (see Figure 3 – left side). The TOC approach to buffer management in projects is called Critical Chain Project Management (CCPM) (Goldratt, 1997; Steyn, 2000; Stratton 2009) and, as with DBR, it emphasises the need to manage the time buffer.

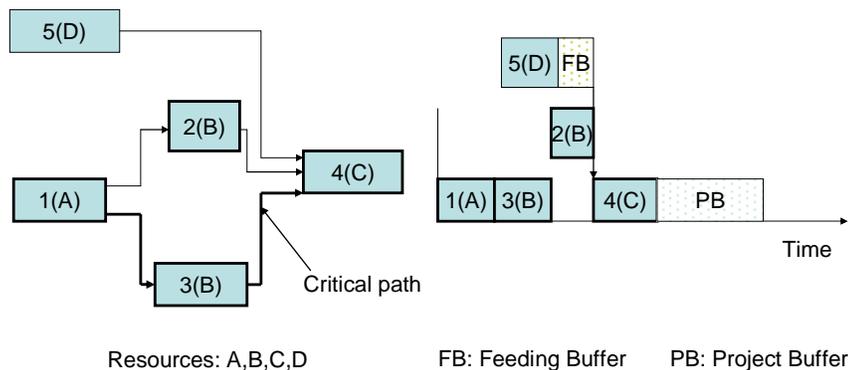


Figure 3 Traditional Network diagram (left)
Critical Chain showing schedule with time buffers (right)

In CCPM the time is extracted to make it visible simply halving the task time and placing half of the time removed into a time buffer which is conceptually located at the end. As can be seen in Figure 3, resource dependency is also acknowledged (the scheduling of resource B is staggered) and the project buffer protects the critical chain, with feeder buffers protecting activities with float from becoming critical. Goldratt (2007) advocates the project buffer and associated feeder buffers should be set at one third of the lead time.

3.2.1 The four control functions of CCPM buffer management

Again we can identify four prime functions of CCPM buffer management.

- *Provide a priority mechanism*

Priority is not just set by the time remaining, as in DBR, but by a simple ratio of project buffer remaining to critical chain remaining. This enables a resource provider to prioritise different tasks within and across projects.

- *Provide a mechanism for expediting tasks consuming the project buffer.*

Unlike with DBR, where action is only taken in the red zone, it is important to reduce buffer consumption that can occur in any activity. As there is effectively only one activity consuming the project buffer at any time the improved visibility of buffer consumption creates awareness and opportunity to support the resource concerned and minimise wastage of the buffer at the activity level.

- *Escalate action when buffer consumption threatens delivery*

At the project and programme level the monitoring of the ratio of buffer consumption to completion of the critical chain is used to trigger escalation procedures.

- *Target ongoing improvement activity by tracking causes of buffer consumption.*

As with DBR there is a need to track the reasons for delay to focus improvement

activity.

3.3 Summary

Traditional time buffer management has been shown to embrace four control functions that may be summarised as Prioritise, Expedite, Escalate and Improve. These functions will be used in the case study research that follows to provide a framework for comparison and evaluation of these health and social care applications of time buffer management.

4.0 Research method

This research has been initiated to help explain the basis of the improvement in patient flow claimed by QFI consulting and numerous hospitals that have adopted their approach and software. Two buffer management applications were chosen for investigation due to the fact that they were in common use and embraced both planned and emergency care:

- 1) Emergency Department Buffer Management (termed A&E Jonah)
- 2) Discharge Buffer Management (termed Discharge Jonah)

It should also be noted that although these two buffer management applications operate at different points in the health and social care system they are not independent of each other. For example, one of the main reasons for breaching the Emergency Department (A&E) access target is lack of beds due to delayed discharge. Hence, reducing length of stay impacts bed availability and this in turn impacts ED performance.

The research question set is:

How and why has time buffer management contributed to improved patient flow?

The inductive nature of this research question clearly fits the case method, but it was necessary to develop a conceptual framework on which to base the comparison and evaluation. This has been provided through identifying the underlying control functions represented in the two generic time buffer management applications DBR and Critical Chain.

This research involved access to the buffer management application software design, the implementation process and users of the system. Four hospitals were visited where the systems were seen in operation, archival data and reports were accessed and semi-structured interviews were conducted, in line with the good practice advocated by Yin (1994) and Eisenhardt (1989). In one case the unit of analysis was extended to include social care and cross buffer meetings at a regional level were attended. This research was conducted over a period of 20 months. In all four cases the discharge buffer management application was implemented and in three cases the Emergency Department buffer management application. In all cases the implementations were less than 3 years old.

The research findings are presented below, with chapter 5 describing the applications and how they are designed to operate. Specific reference has been made to the conceptual framework, in the form of the four underlying control functions. Chapter 6 discusses the evidence concerning the merits of the approach, before exploring the hows and whys further, through discussion of the issues and observations of the users. This

culminates with discussion of the findings regarding the broader research question.

5.0 Emergency and planned care buffer management application design

The two health care buffer management systems investigated in this section provide an explanation of the system and recommended method of use together with an explanation of how the control functions relate to the time buffer management applications.

5.1 Emergency Department buffer management application

The Emergency Department application is closely allied to the DBR buffer management approach as outlined below.

- **Drum:** The pace of the system is set by the drum and in this environment it is determined by demand with no prior warning apart from the ability to forecast as the Emergency Department is expected to manage capacity in line with demand.
- **Rope:** The rope would normally be used to control release of work into the system, but in this environment there is no attempt to control release as all patients are considered to be in the 4 hour buffer on arrival.
- **Buffer:** The buffer time of 4 hours commences on patient entry and as with standard buffer management practice this time is equally divided into three zones (see Figure 2) of 80 minutes each. The application is supported by software that tracks the patient buffer consumption with the priority being set by the time of entry. The buffer changes colour as time progresses and at each transition (80,120 and 240 minutes) the system is designed to record what the patient is waiting for. This is selected from a drop down menu and used in Pareto analysis. This typically includes waiting for - consultant, waiting for X-ray, etc. The protocol is that this drop down menu is updated by the nurse responsible for the patient and on discharge, or admission, the patient is removed from the screen.

5.1.2 Buffer management functions

The practical representation of the four control functions are as follows:

- *Prioritise* - the order of priority regarding the discharge target is simply the order of presentation, however, this clearly does not acknowledge clinical priorities that are expected to override this default priority sequence.
- *Expedite* - patients entering the red zone are within 80 minutes of breaching the 4 hour target and the computer networked screen is used across the hospital to communicate the need to expedite action by the resource currently causing the delay. The resource causing the delay of a patient is also informed separately from this screen.
- *Escalate* - on a regular basis (hourly is recommended) a buffer meeting analyses delay reasons and escalates as necessary. This escalation is deemed to be an essential part of the synchronisation of resources to enable flow. The overall stability of the Emergency Department performance is monitored by the number of red zone penetrations and middle and senior management have visibility of this screen. This effectively acts as an escalation signal and protocols can be established to assess the situation. Additional resource may need to be provided to avoid the Emergency Department becoming unstable, resulting in breaches of

the 4 hours which have to be reported by the hospital centrally.

- *Improve* - the reasons for delay are subsequently analysed by charting the main causes of delay on entering the yellow, red and back zones. This data (produced in Pareto format) is used in buffer management meetings (typically weekly) aimed at focused continuous improvement effort. Although the Pareto graph is produced to present the main reasons for delay the data is also used to identify causal links with any common causes becoming a focus for rapid improvement.

5.2 *Patient discharge buffer management application*

The need for timely patient discharge relates to acute and community hospitals, as well as social care homes, and can be viewed as key to managing patient flow through the health and social care system. This application aims to shorten the length of stay (LOS) by subordinating all support activities to the medical needs of the patient, with the aim that the patient's position within the health and social care pathway is determined by medical needs alone.

A first step in this discharge planning process is to set a Planned Discharge Date (PDD) when the patient first arrives. This is followed by identifying the care plan and associated activities that need to be completed before this date. In reality the PDD is initially indicative but can be updated as knowledge and circumstances dictate. The concept of a PDD is new to many hospitals but is an essential part of any planning and control system. As with CCPM task management, the emphasis is on updating the PDD if it significantly changes, to ensure priorities reflect the medical need.

With the time to discharge based on medical judgement alone it is necessary to ensure subordination (alignment) of the support activities. In this environment activity durations are more characteristic of a project where the touch time is significant, as illustrated in Figure 4. Therefore, the projected buffer time remaining comprises the time to the planned discharge date (PDD) minus the longest activity duration yet to be completed.

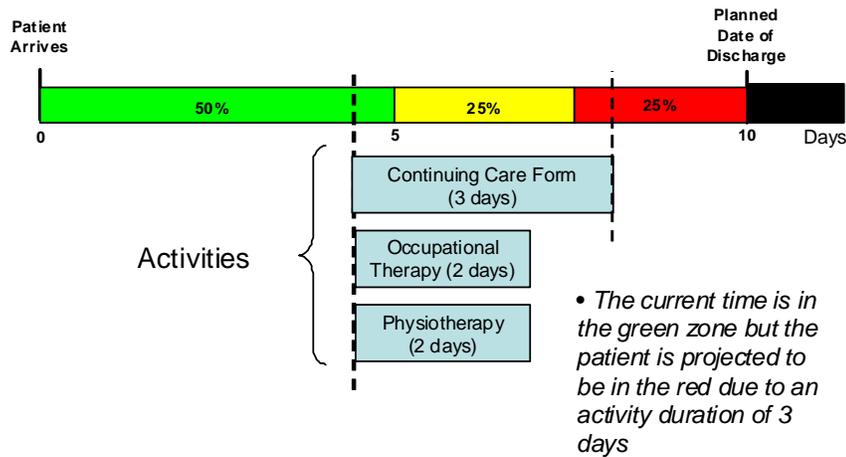


Figure 4 Discharge Buffer Management

Accounting for the duration of activities has been simplified with the assumption that there is no activity dependency. Therefore, the longest activity duration, together with the time now and PDD, enables the projected buffer penetration to be determined (see Figure 4). This application is effectively a hybrid of the Critical Chain and DBR buffering approaches. That is, the duration to PDD effectively acts as a buffer as in DBR, but the longest activity duration is acknowledged in determining the buffer penetration. Finally, the buffer regions have been adjusted (see Figure 4) to make allowance for the activity duration offset. The software can provide priority lists for the different specialists (eg occupational therapists) showing buffer penetration.

5.2.1 Buffer management control functions

The practical representation of these four control functions are as follows:

- *Prioritise* - the priority status for the patient is determined by the time to planned discharge minus the longest remaining activity to complete. Unlike in the Emergency Department this may change. As the planned discharge dates can change in both directions the relative priority of different patient activities may change. Each patient is displayed on a computer screen, a line for each patient, in priority order, coded green, yellow, red and black. The software enables a subset of patients waiting for a resource, such as an occupational therapy, to be listed as a priority coded work to list.
- *Expedite* - patients that are projected to stay beyond the planned discharge date are shown in the black, therefore urgent, but as this predicts a future situation there is still time for recovery. Reasons for delay are recorded on entry into the yellow/red/black zone and where it remains in the black zone the entry is repeated every three days to capture data for analysis purposes. The delay reasons are typically: waiting for – medical review, care package, community hospital, continuing care decision, etc. The 'reasons for delay' data is circulated

daily at a ward based buffer meeting and the main reason for delay communicated as part of the escalation process.

- *Escalation* - the stability of the overall system is signified by the overall number of red and black buffer penetrations which provide advanced warning of the pending instability and the need to escalate recovery action. Lack of beds is a major cause of Emergency Department breaches and increases in delayed patient days is a leading indicator that bed shortages across the hospital will follow. Typical delays can be due to - a need for medical review, shortage of a particular resource provider, lack of community hospital beds, etc. To be effective this escalation process needs to be activated before the system destabilises, which in the final instance may mean temporarily opening additional beds.
- *Improve* – with the reasons for delay recorded it is important to regularly identify and act on common causes, Regular buffer management meetings are encouraged at different levels of frequency locally and regionally. Figure 5 illustrates the Pareto format of the delay reasons analysis used at the regional level with other care providers.

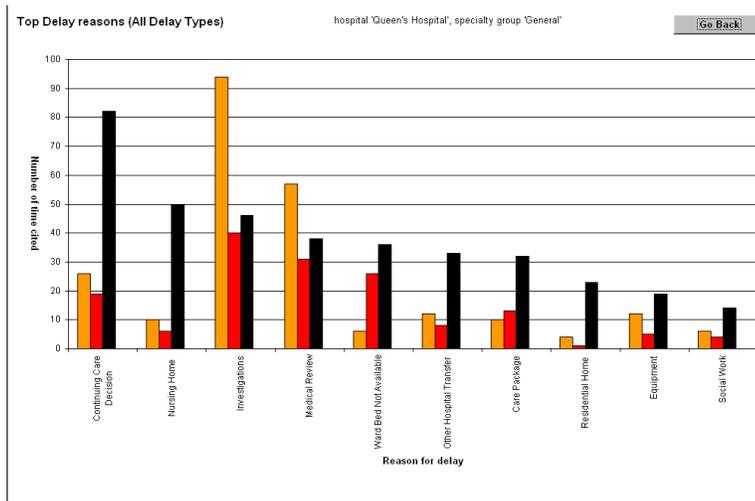


Figure 5 Discharge QFI Jonah top delay reasons by region presented to cross-buffer meetings

6.0 Implementation Findings and Discussion

This section focuses on the implementation of the applications. Firstly, establishing the overall benefit, before identifying observations and issues concerning the control functions, and then finally addressing the research question directly.

Interviews with senior management regarding both applications were very positive as evidenced by the following quotes.

‘TOC has been applied to improved patient flow in A&E, Assessment Units, and

discharge planning. This has resulted in a sustained reduction in medical length of stay from 8.6 to 6.3 days (>25%). Released bed capacity supported the achievement of the 18 week GP referral to treatment target, a year ahead of schedule.'

(Director of Governance and Nursing)

'With the help of Theory of Constraint we have been able to move Barnet & Chase Farm Hospitals NHS Trust from one of the worst performing trusts in England to one of the top performing. In Q4 (2007-2008) we were the top performing trust in London for the 4 hour target and 6th across England. Also, by applying the Theory of Constraints to our discharge process we have been able to reduce our length of stay by 27% and we know we can improve further on this.'

(Chief Executive Officer)

'The application of TOC has helped us to reduce our length of stay by up to 23% in one of our hospitals, but the real benefits from QFI Jonah are around improving how we deliver care to our patients through better planning and co-ordination of their care - ultimately it's about recognising that patients should go home as quickly and safely as possible.'

(Chief Executive Officer)

The numerical data supports the wider claims of the CEOs, particularly in the early stages of implementation as illustrated in Figure 6. In this case the improvement in ED performance was rapid (4 months) following the implementation of both the Discharge and ED buffer management systems.

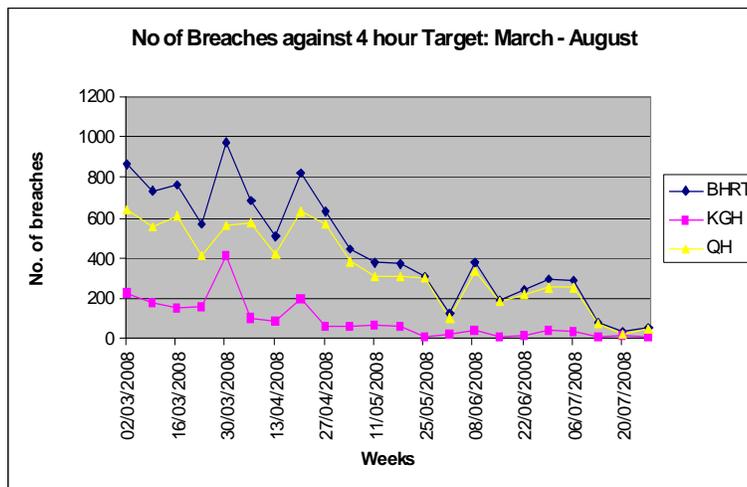


Figure 6: Improvement in emergency breaches following discharge and emergency buffer management implementations introduced from March to July 08.

In all the implementations there was a clear link between discharge management and delayed admissions in the Emergency Department as indicated in Figure 6. Therefore, the normal practice is to introduce discharge buffer management first, before implementing the emergency buffer management system. The marked improvement in ED performance resulting from the implementation of Discharge Jonah, clearly indicates that the main reason for breaching is bed availability. In one hospital the improvement in ED performance was such that they delayed the introduction of A&E Jonah. That was until they realised that the ED performance profile clearly showed the poor stability of the system as a large proportion of the patients were there over 3.5 hours.

The ED is where chaos reigns when the system is out of control and in another hospital the Operations Director explained how the introduction of A&E Jonah had completely transformed their Emergency Department from a place of chaos where no one wanted to work to a relatively stress free stable environment.

What follows are specific observations and issues that illustrate the four control functions used in the evaluation.

6.1 Observations and Issues Allied to the Four Control Functions *Prioritise*

Introducing Discharge Jonah requires key care plan activities to be promptly set together with a planned discharge date for each patient. In all cases these dates were not formally kept prior to the implementation but this practice is critical to providing priority control based on patient need. Adherence to the discipline of promptly setting these dates and plans varied between hospitals and across wards, especially when under pressure. It was evident that unless they were effectively maintained the system would quickly lose its value to the organisation.

Expedite

It was also evident that the discipline of holding daily and weekly buffer meetings on the wards was necessary to both expedite specific patients and deal with common causes of delayed patient discharge. Practice varied between wards and it was evident there was correlation between reduced length of stay and the ward discipline in updating the system and holding buffer meetings. However, these buffer management meetings need to avoid any sense of blame, as there was evidence that this had resulted in discharge dates being extended in some wards to avoid the perceived pressure in such meetings.

Escalate

In one hospital the improvement resulted in a ward closure which was negatively viewed by some ward staff as the remaining beds were more intensively utilised and management were reluctant to open extra beds when the system was under pressure. Some hospitals had started to formalise the escalation procedure and one had recently set up a fast response ward of 20 beds. The ward was fully kitted out and ready to use at less than two hours notice. A team of staff were trained to open the ward in response to

previously agreed escalation signals, which include ED buffer signals and other leading indicators. Prior to this, there was no formal preparation for opening extra beds and management only reluctantly approved the opening of a ward because of the cost, and particularly the difficulty in closing it back down again. It was, therefore, necessary to establish clear procedures that manage the closing of wards as well as the opening. This contrasted with the previous practice of cobbling together a mothballed and ill equipped ward and staffing it at short notice with all the patient risks that entailed. The consequence of not escalating in a timely way typically resulted in patient outliers (patients not being placed on the correct wards) which makes the ongoing length of stay worse and, therefore, the additional beds are needed for longer.

Another illustration of less formal escalation is where an Operations Manager kept the A&E Jonah screen constantly running in the background on his computer and if he saw the red zone growing he would go down without being requested to lend a hand and escalate if necessary.

Improve

When the PDD is exceeded the system captures reasons for delayed discharge every three days and these are analysed periodically in buffer meetings held at the hospital and regional level with other health and social care partners. The regional cross buffer meetings were not in regular use in all the hospitals, but they provide a regional forum to discuss the external causes of delay. In one instance these included waiting for clinical review in an outlying community hospital, but more commonly waiting for care packages. In another situation at a cross buffer meeting the main cause of delayed discharge was 'awaiting the continuing care decision' which often meant the family had yet to decide on a nursing home. One of the actions that followed resulted in a communication campaign aimed at encouraging family members to start planning ahead and keeping them informed of the planned discharge date.

A more fundamental result of the cross buffer meetings was a change in attitude of a Social Services manager. Following several of these meetings he admitted to previously not viewing the wider system needs but focusing on protecting his budget.

6.2 How and why has buffer management contributed to improved patient flow?

Having illustrated and discussed how these time buffer management applications have worked in theory and practice let us consider the wider theoretical basis for its success.

In volume manufacturing environments that have embodied lean it is now readily accepted that control of quality and product flow embrace the concepts of priority, escalation and continuous improvement. However, this is not so apparent in the complex environment of make to order and particularly healthcare,, where simpler signalling systems such as kanban are more difficult to apply. It is, therefore, important to clarify the control functions involved and find simple and workable means of employing them. The essence of the control functions outlined here (prioritise, expedite, escalate and improve) can be related back to Shewhart (1939)/ Deming's (1986) control concepts. For example the buffer zoning, as with SPC, provides a simple means of interpreting the instability signals and in a flow environment focusing timely expediting, escalation and continuous improvement effort. Buffer management also has the

potential of providing a timely signal to ensure growing capacity issues are acknowledged as the number of red zone penetrations are seen to increase. The authors consider these control functions to be evident in all successful flow control systems but, as in the case of kanban (Ohno, 1988), the simplicity of the system can mean that important functional elements are taken for granted. It is interesting to note that the growing adoption of lean healthcare has resulted in improvements through activities such as waste walking and the adoption of 5S. However, understanding how to manage patient flow is proving more elusive (Jones, 2008) and the direct kanban equivalent is proving difficult to establish. (Jones and Mitchell, 2006; Zidel, 2006; Fillingham, 2008; Graban, 2009; Baker et al., 2009).

7.0 Conclusions

There is increasing pressure worldwide to improve health and social care services and growing interest in how manufacturing developments can be applied. The UK NHS is being driven to improve access through targets, with market competition driving the need to reduce length of stay within the system. One such approach is time buffer management which has been developed and implemented across many hospitals within the UK and internationally. This paper has used case study evidence to explore how and why emergency and planned time buffer management applications have proved successful at improving patient flow. This commenced, by firstly understanding logic and control elements present in the established manufacturing based applications of Drum Buffer Rope and Critical Chain. To support this evaluation, four common control functions were identified (prioritise, expedite, elevate and improve) to provide a framework for evaluation. All these control functions were present in both the buffer management application designs. The implantation evidence also supported the importance of these functions in the effective use of the system. It is apparent that the success of time buffer management is due, in the main, to providing a simple and workable system that embraces these control functions. This naturally raises the question as to how these control functions reflect the lean kanban approach to control and under what circumstances alternatives to time buffers should be considered in the healthcare environment.

Lastly, it must be stressed that the software use in these applications is simply a means of applying the theoretical understanding that underpins these systems.

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