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Understanding patient flow in hospitals

Briefing

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The aim that 95% of patients attending A&E should be admitted, discharged or transferred within four hours is one of the highest profile NHS targets, yet it is being consistently missed across England. Although the target can be over-emphasised, struggles in meeting it are associated with deeper problems in the capacity to move patients into hospital wards. This briefing draws on theories about congestion to look at why this has become more difficult in the hospital setting, and what can be done about it. It looks at ongoing changes driving pressure on bed space, including mortality, the squeeze on bed space during years of austerity, rising numbers of patients with multiple conditions, and delayed discharges. It also looks at the solutions available short of actually building enough beds to restore free space, and suggests managers should focus in particular on the minority of long-staying patients who account for a majority of bed use. Given the variation during the day, and with an increasing number of patients leaving in a matter of hours, it urges the NHS to invest in IT and management systems that can track and deal with the need for beds and patient movement in real time.

Acknowledgements

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Many of the themes that this report explored were triggered by conversations on the frontline of hospitals that the author has worked in. In particular, we thank Laura Allen, Bob Gregory, Paul Younge and Jude French for their valuable insights, and Phil Martin for extracting the data that has illustrated them.

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The different sections of this report will be of interest to different people – those managing beds, those looking at local health services as a whole, and those thinking about the resources needed by the NHS nationally. Click the links below to jump straight to a specific section.

Executive summary

Previous work on the A&E 'crisis' has identified that hospital bed space and the ability to move people through it lie at the heart of the problem. This report looks at the dynamics of flow and applies this to the English NHS. We compare areas that achieved the four-hour standard with those furthest from it to understand the differences and consider what is needed to restore flow. Our analysis looks at bed use and flow day by day and hour by hour, and shows that ideas based around counting patients at midnight and managing the proportion of beds occupied fail to recognise the need for resources to move people in and out of beds, which peaks at different times to the actual occupancy. In recent years the need for beds has risen as the number available has flatlined, bringing the problem to crisis points. We look at drivers of demand, including mortality, where a historic increase from 600,000 each year to 800,000 each year is projected, and conclude that pressure is only likely to grow. We outline a number of considerations that are key to understanding patient flow, then provide a number of possible solutions and recommendations for resolving this complex issue.

Key findings

Understanding how flow affects performance

Some basic principles of flow remain the same whether we are looking at cars on a motorway, or patients in bed. **Faster movement requires more space**, and when space runs short, movement will slow down. Our comparison of hospital trusts that do meet the four-hour target with those that do not illustrates the reality of this in the NHS: the hospitals with the least free space struggle the most. Getting patients through hospital as quickly as we want means we need to have a certain amount of space set aside to do so.

Important questions arise from this regarding how much space is needed, how we can identify when and where it is needed, and how it be freed up. We endeavour to answer these as best we can.

Identifying the space needed in a more effective way

Current bed modelling techniques are often based on counting occupied beds at midnight and do not provide enough information to plan and manage the space for patient flow. Simple rules like keeping the proportion of beds occupied at 85% or 92% are misleading. Management needs to accommodate both the number of patients in beds, *and* the number moving in and out of them. These peak at different times. We therefore need a more complex understanding:

- **Peak occupancy** is when the most beds are full. It normally occurs around 8am, after overnight admissions and before patient discharge starts. **Peak flow** is when the most patients are being moved in and out of beds. It normally occurs in the late afternoon, as emergency arrivals and elective discharges peak.
- Flow needs space: every patient transfer requires sufficient resources for the process to happen without delay. After discharging the previous patient, this includes time

for cleaning, patient transfer, handover and communication. Unless each of these is in place, the process will take longer than necessary, potentially leading to poor patient experience as queues build up. Furthermore, increasing amounts of staff time will be wasted waiting for patients and rescheduling work.

- When queues build up, work-around solutions such as 'boarding' patients on wards or providing care in the emergency department or assessment areas are used, often increasing delays.
- The amount of space needed to manage peak flow is dependent on the numbers of admissions and discharges and the time each takes. We estimate that between 2% and 4% of bed capacity is likely to be needed for this activity in most hospitals.

Understanding why the problem is growing

A number of ongoing trends have resulted in more pressure on bed space, and the current system is not well calibrated to see when and how constrained space has the most serious implications for patient flow. Consider the following issues:

- Bed use has increased but bed supply has not. With 105,000 acute beds in use, occupancy increased from 98,000 in 2011 to 102,000 in 2014 (NHS England, 2016b).
- The volume of patients treated has increased. Most notably, there was a 17% increase in zero-day patients between 2009/10 and 2014/15 (Monitor and NHS England, 2013; Hospital Episode Statistics, 2016).
- Continued increases in day surgery, short stay, and admission on the day of surgery reduce midnight occupancy (when occupancy is typically measured) but increase daytime pressure. We estimate that this has increased demand for day time beds by 1,200 over the last six years (Hospital Episode Statistics, 2016).
- Co-morbidity, which is associated with a need for longer stays in hospital, has increased. Using changes in the Charlson index of comorbidity, we estimate that it has led to a demand for 6,500 more beds over the last six years.
- There has been an increase in discharges to nursing and residential care (Hospital Episode Statistics, 2016), which may be more susceptible to delays when the services are not ready to receive a patient leaving hospital. Although there have been improvements, the length of stay in hospital of people being discharged to these services remains almost double what would be expected based on the diagnosis and demographic profile of the patients. Data on discharges home with home care are not included in routine hospital data, but are likely to be at least as significant.
- Changing working practices (both in and out of hospital) create a late afternoon and early evening 'rush hour' effect, creating further pressure owing to concentration of demand and changes in work schedules.

Addressing the problem: solutions and recommendations

Keeping the above key considerations in mind, we now assess the range of possible actions available to those making decisions regarding the reorganisation of care. We make a number of suggestions that be useful for resolving issues with patient flow.

Solutions

Simply building more beds in existing hospitals is unlikely to provide a solution. The current Spending Review provides for minimal investment in new buildings before 2020 and the number of people required to staff additional hospitals do not exist today and are not being trained. Given that doing nothing is not a viable option, there appear to be three possible strategies:

- **Reduce the volume of patients by redesigning assessment, diagnosis and short-stay care**. Most activity growth is for short-stay patients. Redesigning the 'front' of the hospital may improve care, but this is unlikely to be sufficient to solve flow problems.
- **Reduce the time spent in hospital by redesigning rehabilitation and discharge processes.** Only 10% of patients stay in hospital over 7 days, but these patients use 65% of beds and generate 32% of income (Hospital Episode Statistics, 2016). Redesigning this phase of care appears to offer very large system benefits.
- **Improve control systems to provide real-time workflow information to improve both individual patient care, system management and support process improvement**. Around 90% of patients spend less than 6 days in hospital and use only 35% of hospital space with an average stay of 1.1 days (Hospital Episode Statistics, 2016). Very small changes in length of stay (measured in minutes) and small changes in the time taken to prepare beds can cause significant disruption. Hospitals need systems that reduce non-value-adding time and provide real-time operational data to support real-time decision making and service planning.

Our assessment of risk and opportunity suggests that the latter two approaches are most likely to be successful. However, it is clear that bold action is needed to create capacity and improve IT and management. A problem that has taken this long to solve also implies that the way we look for answers is not working. We argue for a more open approach that seeks to learn from the experience that exists on the frontline.

Recommendations

Successfully restoring patient flow is dependent on achieving an accurate diagnosis and putting in place actions that are scaled to meet the identified challenges. Simply optimising present systems will not be sufficient.

Drawing on our own analysis, a seminar in 2015 drawing together key stakeholders on winter pressures, and discussions across England, we make four key recommendations:

1. **Systems (probably Sustainability and Transformation Plan areas) should develop capacity plans based on medium-to-long-term demand estimates** to ensure the scale of the challenge that they face is understood beyond the current STP timescale in order to ensure that short-term plans are aligned with medium- and long-term requirements.
    - Plans that focus on short-term bed reduction should demonstrate how future demand pressures will be accommodated, particularly if they are difficult or impossible to reverse.
    - Medium-to-long-term workforce and capital plans should be aligned with capacity and demand plans.

2. **Setting an appropriate target for flow capacity and establishing plans to achieve it should be a key objective** for Strategic Resilience Groups (to be A&E Delivery Boards). STP areas should ensure this capacity is built into planning and performance processes as a key operational performance target.
3. **By providing a focus on ways of achieving the four-hour standard, there should be a greater understanding of delivery risk, leading to more timely and effective responses.** We identify three main approaches for achieving this later.
4. **The approach to resolving complex performance problems should be reviewed to accelerate learning and improvement.** Better use could be made of the knowledge and skills available to the NHS to solve complex problems faster, thereby minimising the impact of poor service for patients.

Glossary of key terms

Spell – A spell is the full time a patient spends in hospital, including if they are passed between different wards and consultants.

Bed – When we refer to beds, we mean not just the physical location but the staff and other resources that go with it to make an NHS hospital bed a safe and effective place for unwell people receiving care.

Midnight census – National data on how many beds are occupied is based on whether they are occupied at midnight. Trusts use the same measure, although some augment this by counting patients at other times as well. In this report, we argue that all trusts need to come closer to knowing what occupancy is at all times.

Day case – A day case is a patient admitted to hospital who is specifically not expected to need an overnight bed – for example, for a non-urgent operation or test.

Zero-day patient – A zero-day patient is one who is admitted without the specific expectation that they will leave within the day, but who ends up not having to stay overnight.

Introduction

In recent years, despite enormous effort at every level, the NHS has repeatedly missed its highest-profile target – to admit or transfer 95% of people from A&E within four hours (NHS England, 2016a). This suggests that the diagnosis of the underlying reasons for this target being missed is incorrect.

Previous work undertaken by the Nuffield Trust (2015), Monitor (2016) and others suggests that the major constraint in the system as it stands is the availability of beds and the capacity to pass patients through them – or 'flow' as it is referred to hereafter. In this report we explore this problem in detail.

Over the last three years, bed occupancy has increased (NHS England, 2016b), principally due to underlying demographic pressures. As congestion has risen, there is growing evidence that crowding has added to length of stay, making flow even more difficult. Speeding the passage of patients through the hospital in this situation is hard because there is insufficient space to allow flexibility: pace is dictated by the crowd and not the needs of the individual. Creating sufficient space for flow has to be the immediate priority.

This is not easy to achieve in the face of ongoing demographic pressure and resource constraints. But it is not impossible: Sustainability and Transformation Plan (STP) teams have the best chance for some time to make some of the necessary changes to achieve this. We make some suggestions regarding suitable areas for focus based on the findings in this report.

This report is intended to be useful to managers in hospitals who deal with patient flow directly and need to understand how much space it requires. It will also be relevant to commissioners and policymakers who set goals and targets, and influence the bed space available to meet them.

About the ideas in this report

The author has a long-standing interest in patient flow and has considerable experience as a practitioner and researcher on the topic. This piece of work emerged by identifying gaps in the current literature, through ideas generated from a conference and seminar hosted by the Nuffield Trust, and through several useful conversations with colleagues.

Much of the data has been collected in response to stories told by frontline staff and patients regarding their actual experiences and insights. Through careful observation and enumeration, a sufficient amount of information has come together to provide a 'good enough' understanding of what seems to be happening. It is hoped that the report will provide readers with additional insights and ideas for improving their own local systems.

The approach used closely follows the clinical model: good practice starts with a history of the present complaint. This is put in context with a review of past history, then the differential diagnosis is tested with investigations to inform the final diagnosis and treatment plan.

We highlight that inadequate flow capacity is the major system constraint affecting the system and provide ideas about how this might be solved.

We recognise that we are commenting on a complex adaptive system and its current constraints. Once these are resolved, new constraints will emerge in other parts of the system. It is important that we remember this. Each new problem solved will take us to the next step on the journey. Hopefully the system will be better, but the journey will not end.

We have found this to be a difficult story to tell. We hope it triggers new ideas and action, and we welcome ideas for further development and research.

Understanding how flow affects performance

Everybody who travels experiences, and is part of, flow on every journey they make. But heavy traffic, with managed motorways in place to maximise the number of vehicles that can use a stretch of road, are commonplace. This is a long way from the design vision of open stretches of motorway and free-flowing traffic.

We might imagine that the vision of an uncrowded road where travel at full speed was possible was initially the case. But, over time, people adapted to the opportunity the new roads offered by using them more. More people go to work that way, new factories and warehouses are built close to junctions and, as a result, traffic increases.

With the limiting factor of the size of the road itself, this eventually leads to reduced speeds. The way in which this happens rests on the concepts of complex adaptive systems and the theory of constraints – which are vital for understanding flow.

We now introduce a simple model to illustrate this theory.

A simple guide to congestion

On a free-flowing motorway, typically the right-hand lane will be occupied by cars travelling faster than the left and middle lanes. To travel safely at 70 mph, a car needs about 100 metres of road. At slower speeds, less space is needed.

The maximum capacity of a kilometre of road, assuming safe distances are maintained, is around 43 cars. The fastest cars will cover a kilometre in 32 seconds.

If more cars join the road, traffic will have to slow down to maintain a safe distance. In the managed motorway example, this allows 51 cars (20% more) to fit in a kilometre of road. The average journey time increases by only 4 seconds but total time for all road users jumps by 32% (28 to 37 minutes) (Transportation Research Board, 2008).

Once more traffic joins the road, speeds must reduce further. At 30 mph, all of the lanes travel at the same speed, and three times as many vehicles can fit in a kilometre of road (see Table 1 for a breakdown of this). However, the average time taken to travel 1 km has almost doubled and the total time for all users has increased almost six times.

The fact that more congestion in a confined space means less speed, and less flow once a certain level of occupancy is reached, is well established in modelling of road traffic. Heavy congestion cannot be solved by asking people to drive faster. In fact, speed can only be increased by reducing congestion first.

Table 1: Car speeds and time on free flowing, managed, and heavy congestion motorways

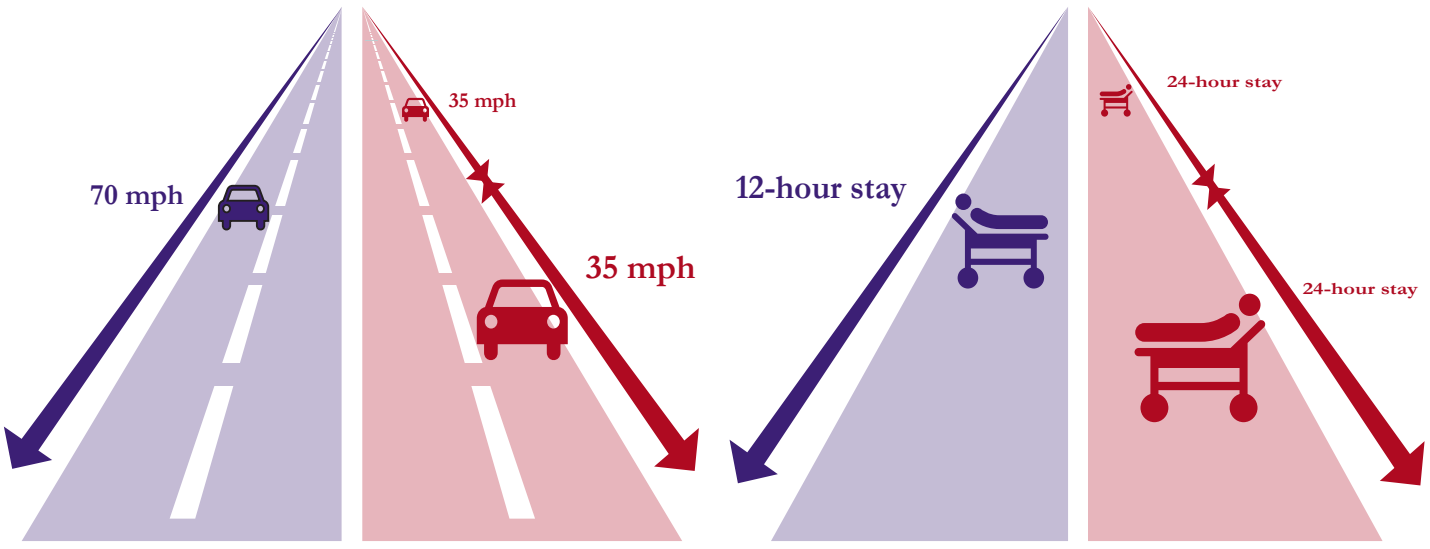
	Free flow	Managed motorway	Heavy congestion
Lane 1	50	50	30
Lane 2	60	50	30
Lane 3	70	60	30
Standard deviation	10	5.8	0
Capacity of 1 km of road	43	51	130
Total time for all users to cover 1 km (mins)	28	37	163
Time for fastest user to cover 1 km (seconds)	32	37.5	75
Average time per user (seconds)	39	43	75

Source: Transportation Research Board (2008)

Flow and congestion in the NHS

The flow of patients through beds in a hospital reflects the same dynamics as the flow of traffic on a road. Just as cars moving more quickly require more road, patients who are moving through the hospital system more quickly use more bed space and resources at any one time.

This is because, relative to the amount of time they spend in a bed, more time must be spent preparing the bed for them, preparing it for the next patient, and carrying out processes for admission or transfer. As wards fill, this becomes less feasible. Just as with a full road, the speed of passage becomes limited (see illustration below).



Fast and slow passages through hospital

In hospitals, the range of relative speed (measured by length of stay) varies much more than would be typical of speed on a motorway. This makes the use of average data for analysing flow highly misleading.

This is illustrated in Table 2. Assuming a length of stay of 12 hours for day cases and zero-day patients (an overestimate in most cases, but actual data is not recorded nationally) means 2,000 patients can be treated in 1,000 bed days.

Table 2: Length of patient stay versus overall hospital capacity

Length of patient stay	Average length of stay	Inpatients per 1,000 bed days	% of admissions	% of bed days
Zero-day and day cases	0.5	2,000	58%	10%
1-6 days	2.2	446	32%	25%
Over 7 days	18.8	53	10%	65%

Source: HES (2016)

This 58% of patients use only 10% of occupied beds. These beds generate a significant proportion of a hospital's income.

In comparison, patients staying over 7 days had an average length of stay of 18.8 days meaning only 53 patients can be treated in 1,000 bed days.

After 7 days, the average income per bed drops to £79,411 per year, only 18% of that for short-stay work (Monitor and NHS England, 2013; Hospital Episode Statistics, 2016). Clearly, delayed discharge for these patients carries a huge opportunity cost if short-stay patients cannot get in to the hospital.

Because there are so many of them, small variations in length of stay for short-stay patients can have a big impact on the capacity required to treat them. If this does not exist, queues develop very quickly. As care is usually concentrated close to the core of the hospital it is very difficult to add capacity and maintain operational processes, so change is a significant undertaking. Thus, small changes in speed from the fastest cars on the motorway play a major role in determining congestion.

Comparing trusts achieving the four-hour standard with those furthest from the target

So, how do the pressures associated with flow drive performance in the NHS?

To understand this, we compared 12 non-specialist trusts that achieved the four-hour standard against the 12 performing least well against the standard. On balance, trusts meeting the standard are smaller and have lower occupancy – that is, a lower proportion of all their beds, on average, are occupied (see Table 4).

Table 3: Length of patient stay versus income			
Length of patient stay	Income per day (£)	Income per spell	Income per bed
Zero-day and day cases	1,246	623	454,827
1-6 days	718	1,610	262,046
Over 7 days	218	4,088	79,411
Source: HES (2016); Monitor and NHS England (2013)			

Table 4: Comparing trusts achieving the four-hour standard with those furthest from the target		
	Achieved target	Furthest from target
Four-hour standard	4.2%	18.1%
Beds	566	1,010
Occupancy	94.5%	105.8%
Bed days per 1,000	760	715
Admission rate per 1,000	283	253
Average length of stay (days)	4.1	4.4
High comorbidity	4.4%	4.7
Time between patients at midnight (hours)	4.5	–1.1
Source: HES (2016)		

They also have a slightly a lower length of stay than those furthest from the target. However, the length of stay difference (after allowing for differences in comorbidity) amounts to only 3 hours per patient. Removing this difference does not create sufficient flow capacity to meet the four-hour standard.

Surprisingly, lead CCGs for hospitals meeting the standard have higher admission rates and bed use per citizen than those furthest from the target. Further work is needed to understand whether this difference is the result of planned strategic changes or the evolution of custom and practice.

As the table shows, hospitals meeting the four-hour standard have an average of 4.5 hours' space between each patient, as measured at midnight. This appears to be close to the minimum necessary to meet the standard. Those not achieving the standard actually have a negative space between patients – who are overlapping as beds cannot be cleared for them.

Identifying the space needed for flow

We now move on to consider the space needed for flow, and how this tends to be understood – and misunderstood. Bearing in mind the increase in patients not staying overnight, we look at the problems inherent in using midnight censuses to judge occupancy, the 'rush hour' effect of short-stay and day patients, and the importance of housekeeping. We also introduce the concepts of **peak occupancy** and **peak flow** and consider how much capacity is needed to manage flow.

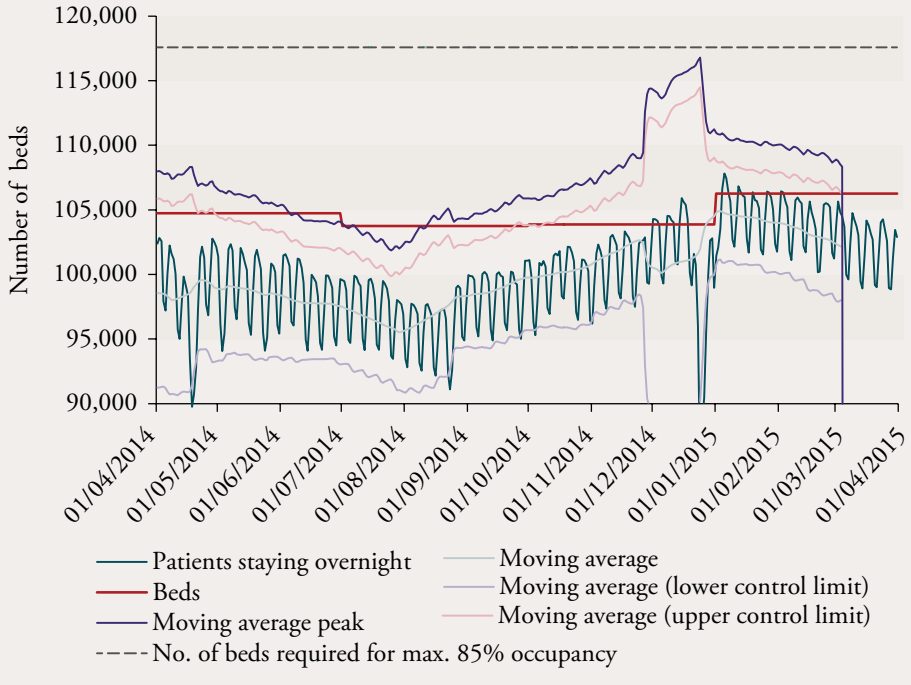
We show that more space is needed for patients to travel through the system faster. We estimate the impact of not providing this space on the emergency department and the four-hour target. We deal with the following issues in turn:

- Impact of peak occupancy and peak flow
- The challenge of achieving early discharge
- The consequences of not providing flow capacity.

How much space do we have? The annual activity cycle

Figure 1 shows the number of beds used at midnight each day over 2014/15 in England, in teal.

Figure 1: Number of beds used at midnight each day, England, 2014/15



Source: HES (2016)

The moving average is shown in light green (on a rolling 28-day basis), showing how underlying trends are moving. The rate of occupancy reached on the most heavily occupied 2.5% of days in each 28-day period is shown by the upper control limit in pink. The rate on the lowest occupied 2.5% of days is shown by the lower control limit in lilac.

The actual number of beds is shown in red. The figure shows that this is below the number needed to provide sufficient capacity to meet demand on many days during the year.

For comparison, the number of beds needed to achieve the lower target of 85% occupancy – a commonly used management figure – is indicated by the dotted grey line. This is 12,000 beds more than current availability.

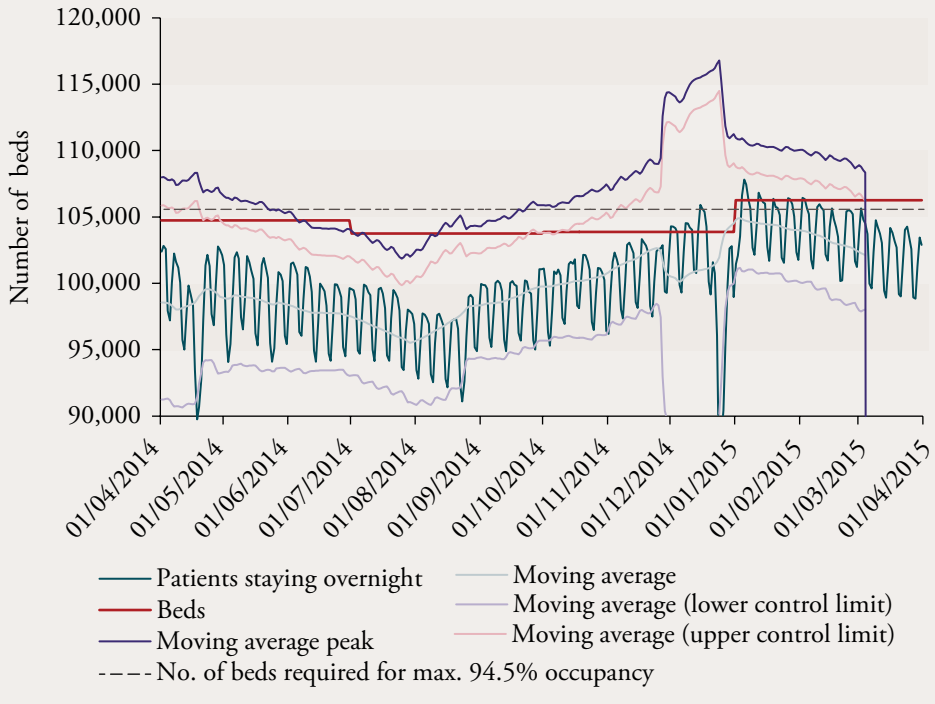
The figure shows that bed availability and demand are poorly matched. More thought needs to be given to aligning supply and demand. This will need more sophisticated systems to manage staff and beds, which we discuss below.

This also gives us an insight into why the NHS faces such serious winter pressures. For many years, bed use fell in the NHS. Each winter peak was lower than the previous one, giving an appearance of lower peak demand. This trend has now stopped, and each winter is likely to present greater demand than the previous one. Unless this is planned for, winter performance will continue to deteriorate.

What happens when capacity is constrained?

The NHS currently operates at a high occupancy level of around 94.5%, rather than 85%. Figure 2 shows the 94.5% level as a dashed grey line to illustrate what this means over the course of the year, and to look at some of the signs of pressure created.

Figure 2: Number of beds used at midnight each day, England, 2014/15, with 94.5% occupancy level



Source: HES (2016)

The number of patients staying overnight, which is measured at midnight, is how hospitals measure occupancy. Measured occupancy, shown in teal in the figure, only actually exceeds the number of beds at a few points in the year. However, the upper control limit level, showing the level of occupancy on the 2.5% of days with most bed use, is often above this level. This indicates a high level of risk with minimal system resilience.

As the system becomes saturated in winter, variation reduces in bed use from day to day. This is because the maximum number of beds cannot be exceeded. A 'one in, one out' dynamic takes hold as patients queue for the next available bed, which is filled very quickly.

Tracking the level of variation may provide an early warning of system performance. As a benchmark, the hospitals achieving the four-hour standard had a standard deviation of around 5% of average beds used. In theory, larger hospitals should be able to manage with less variation, but they will need more flow capacity owing to the increased volume of patients being treated. This is explained in more detail in the next section.

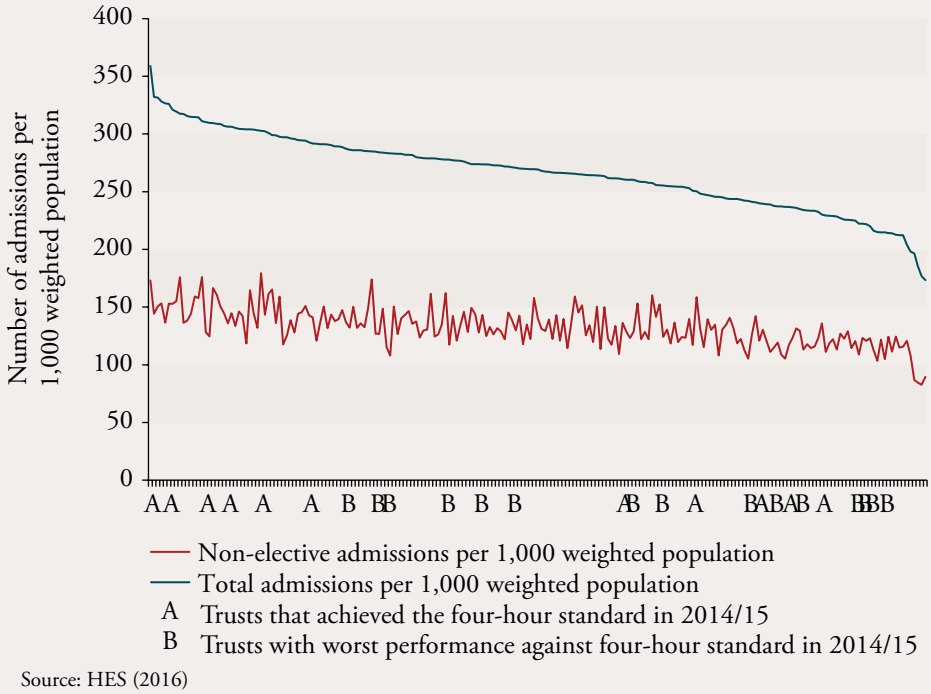
The moving average peak line, shown in dark purple, shows the capacity needed based on peak occupancy compared with calculations based on the midnight census.

Admission rates

Trusts that meet the four-hour standard predominantly have higher rates of non-elective and total admissions to hospital per citizen. The result runs counter to advice to reduce admissions to resolve flow problems. Provided the expected volume of patients is planned for, the extra space appears to create more flexibility to deal with demand surges.

Typically, elective occupancy peaks at different times of the day and week to non-elective activity. This means that the space created for planned procedures can probably often serve as a buffer to surges in demand for urgent care (see Figure 3). We explore this in more detail later in the report.

Figure 3: Number of admissions per 1,000 weighted population, by individual trust



Source: HES (2016)

How important is the turnover interval?

The turnover interval is the period between a patient being discharged or transferred from a bed, and the next one being admitted. As outlined earlier, in hospitals achieving the four-hour standard, this is about four hours.

But how long does the actual process take? We have not been able to identify any routinely available data that answers this question.

Table 5 shows the impact on the total length of stay of turnover processes lasting one, two and three hours.

Table 5: Turnover intervals as a percentage of length of stay

		Turnover interval as percentage of length of stay		
Band	Length of stay (hours)	1	2	3
0	12	8.3%	16.7%	25.0%
1-6	54	1.9%	3.7%	5.6%
7-13	223	0.4%	0.9%	1.3%
14-20	397	0.3%	0.5%	0.8%
21-27	567	0.2%	0.4%	0.5%
28+	1,322	0.1%	0.2%	0.2%

Source: HES (2016)

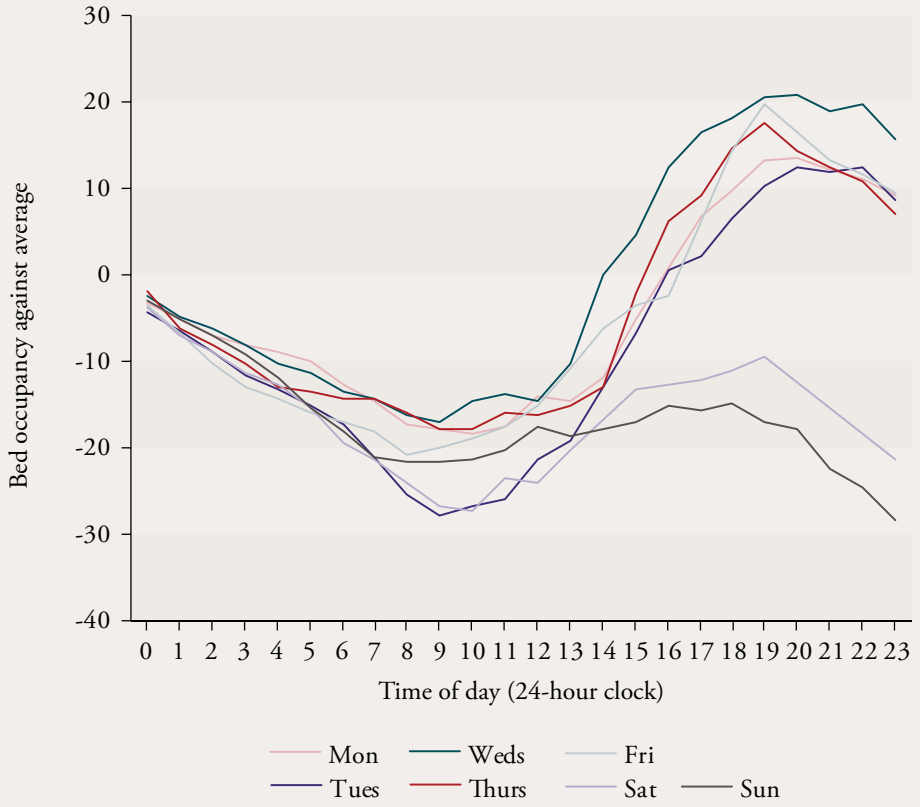
For patients with shorter lengths of stay, a higher proportion of their total bed use is accounted for by the turnover interval. With very high volumes of admissions, discharges and transfers in assessment and short-stay areas of the hospital, controlling the process of turning over a bed is critical to freeing up space.

Yet most hospitals do not track this in real time. Improving the transfer process to the point of having precisely timed information appears to be a significant opportunity for most hospitals.

Box 1: How Great Western Railway prepare a train

Trains often spend less than 20 minutes at Paddington Station. In this time, up to 600 people have to get off; the train has to be cleaned, seat reservations need to be set out – all while allowing sufficient time for the next passengers to board. By having a team of eight people each responsible for one coach, this can be reliably achieved. Being clear about each stage of the process, the time necessary and the time available allows a process that works to be implemented and managed.

Figure 4: The daily and weekly cycle of bed occupancy



Negative numbers indicate higher bed use. Source: HES (2016)

The weekly and daily activity cycle

Every hospital has a typical weekly activity cycle that has developed over many years. This cycle represents the output from complex timetabling decisions that have developed incrementally as teams seek to optimise their work.

In an example hospital, demand for bed space increases steadily during the night: patients continue to be admitted, but it is not good practice to discharge them. By 8am, around 20 more beds are needed compared with the average. This is shown as a negative number in Figure 4. This represents **peak occupancy**.

Through the day, from 9am to 9pm, the trend reverses. More patients are discharged than admitted, and the lowest occupancy of the day typically occurs around 7pm.

There is also a pattern over the course of the week. Capacity builds up over the weekend, then recovers by about 10 beds per day during the week.

The steepness of the curve represents the rate of flow. The rate is greatest between 2pm and 6pm, when approximately 25% of the day's moves take place. This represents **peak flow**.

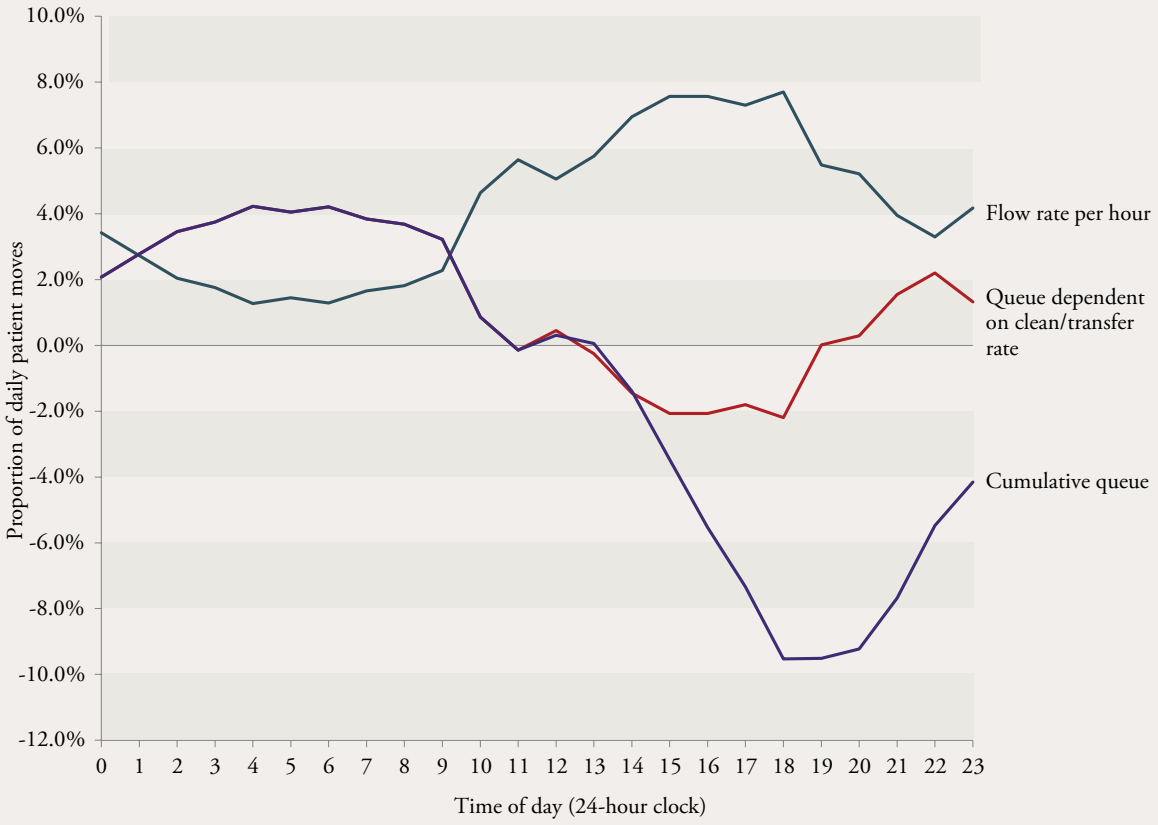
As we can see, occupancy at midnight is well below the peak number of beds needed on every day of the week. This highlights the serious limitations of a midnight census as a basis for understanding the real demand for beds: IT systems, and managers who

use them, should track bed use in real time in order to understand the long-term need for space, and to manage it effectively day by day.

Flow over the course of the day

The model in Figure 5 shows how the need to admit or discharge patients can be mismatched with the capacity of services to do so over the course of the day. The hourly data comes from the weekly cycle shown in Figure 4.

Figure 5: Example flow scenario over the course of a day



Queuing is occurring where numbers are negative. Source: HES (2016)

The teal line shows what proportion of flow (i.e. admissions and discharges) happens during each hour. Overnight, the rate drops below 2% of daily patient moves. It peaks at around 8% between 3pm and 7pm.

If services do not match this, queues will build up. The scenario shown in the figure, (which is Scenario A in Table 6), shows what happens when the maximum amount of flow that services can actually deliver in an hour is 5.5%. The cumulative impact is shown by the purple line. Overnight, there is excess capacity. A queue starts to develop at 11am and peaks at around 7pm with a backlog of about 10% of the day's work – equivalent to almost 2 hours. In a hospital admitting 300 patients per day, this means that 30 patients will be queuing.

Table 6 shows five scenarios with different peaks for the amount of flow that can be handled ('movement rate'), and different waiting times for a decision to transfer or admit in A&E. It also shows the calculated impact on A&E indicators and

Table 6: Five flow scenarios and impact on A&E performance

Scenario	A	B	C	D	E
Peak flow	7.7%	7.7%	7.7%	7.7%	7.7%
Time	18:00	18:00	18:00	18:00	18:00
Movement rate	5.5%	5.5%	6%	6%	7%
A&E decision to admit time (minutes)	150	180	150	180	180
Time when flow adds time to A&E	11:00	11:00	14:00	14:00	14:00
Maximum time added (minutes)	105	105	71	71	18
Peak waiting time in the A&E	18:00	18:00	18:00	18:00	18:00
First breach	18:00	16:00	N/A	18:00	N/A
Breach rate	9.2%	20.3%	0%	6.6%	0%
Excess trolley space occupancy	29%	35%	21%	20%	5%
Hours per day with delayed patients in A&E	12	12	9	9	5
Peak trolley spaces blocked	12	12	8	8	2

performance. This can mean serious breaches of the four-hour target, with many trolley spaces blocked as patients who require admission have to queue to enter. The projected time of the first four-hour breach, and the peak time for A&E waits, are shown.

Housekeeping matters

It is important to recognise that this type of queue can happen regardless of whether beds are available or not – the constraint is the ability to actually move patients in and out of them. Figure 6 shows that lowest occupancy actually occurs at the same time as the peak queue.

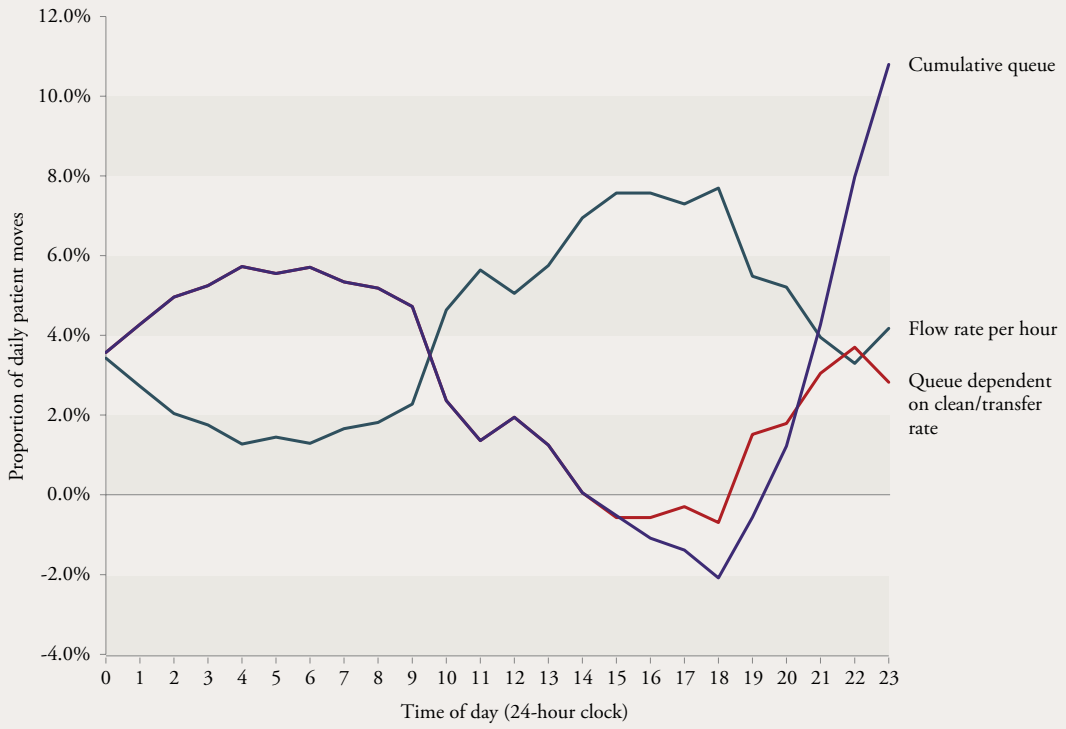
This suggests that earlier discharge alone will not solve problems with flow – unless it is matched with sufficient service capacity to maintain flow. Adding additional beds provides a workaround solution that enables a patient to use a free bed while a queue builds up of beds to be cleaned and prepared and patients transferred. The more direct solution is simply to improve the capacity of the housekeeping system – increasing the speed at which patients can move in and out of beds.

Internal transfer processes are likely to make a significant contribution to flow problems. Scenario E, as shown in Figure 6, shows what happens when a maximum of 7.7% of daily flow can be achieved in an hour. Although a small queue occurs around 7pm, a maximum of 18 minutes' delay is added to the patient journey and no breaches occur. By midnight, 10% of beds are freed up – enough to cover overnight admissions.

Recognising the pattern of breaches enables the underlying causes to be explored in order to identify the best actions to take.

Concentration of demand occurs due to changes in working practice, such as the shift to day surgery and surgery on the day of admission for elective care, and the increasing trend to non-elective admissions later in the day. Supply pressures include pressure on

Figure 6: Example flow scenario over the course of a day



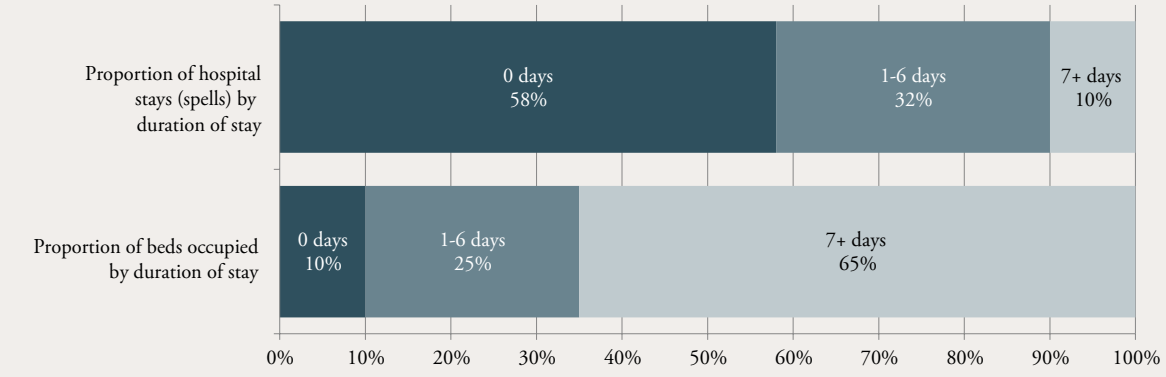
Queuing is occurring where numbers are negative. Source: HES (2016)

hotel services budgets, moves to 12-hour shifts and an underinvestment in logistics support to deal with higher patient volumes.

The challenge of achieving early discharge

In theory, discharging patients early in the day makes sense: it ought to be possible to plan discharge between 8am and 12 noon with some reliability. In practice, however, it is much harder to achieve, as shown by Figure 7. One reason for this is that only 10% of patients stay more than 7 days – but that same 10% use 65% of the beds. The average length of stay for patients staying over 7 days was 18.8 days in 2014/15. In a 32-bed ward caring only for this group of patients, this translates in to less than two discharges per day.

Figure 7: The challenge of achieving early discharge



Source: HES (2016)

In contrast, 90% of patients spend less than 7 days in hospital. This group uses 35% of the beds and these patients have an average length of stay of 1.12 days. A 32-bed ward focusing on this group might discharge 20–25 patients per day. It would clearly be very difficult to achieve discharge by 12 noon for all of these patients, and small variations in patient numbers or length of stay will have a large impact on flow.

These data suggest most flow difficulties arise from the challenge of needing to manage care pathways for 90% of patients in minutes and hours in order to maintain flow. In contrast, halving the number of long-stay patients would release 30% of existing beds, but moving to real-time management is probably also necessary to minimise delays for the increasing volume of patients.

How much capacity is needed?

The amount of capacity needed for flow should be calculated according to the operational requirements of the local system. While it is true that 85% occupancy would deliver much better flow, it is also true that this builds in a level of spare capacity that cannot be justified in the current environment.

Empirically, our look at trusts meeting the four-hour standard suggests smaller hospitals appear to be able to achieve it with an occupancy of 94.5%. This is probably the ceiling above which system resilience cannot be assured.

We have identified four key factors to take in to account in order to arrive at a reasonable local estimate of the space required. These are listed below. Note that the space needed for flow should always be set aside and should not be reduced during seasonal peaks of activity – this would have the same impact as increasing roadworks over key holiday periods, for example.

Overnight admissions

It is poor practice to discharge patients overnight, so there need to be sufficient beds available to manage expected admissions.

Increases in zero-day admissions and day cases

Although zero-day and day case patients will not count in the midnight census, they do require space. Given the 17% increase in these categories of patients over the last 6 years, it is likely that counting based on the midnight census underestimates the total space required, which will impede flow.

Protected beds

Keeping beds for the next stroke, fractured neck of femur, burn or critical care patient effectively reduces bed capacity during the time the beds are empty, and the impact needs to be assessed. In an 800-bed hospital, protecting eight beds for an average of half a day reduces capacity by 0.5%, adding pressure to the system during peak flow rates.

Peak flow rates

In a hospital admitting 200 patients per day with a peak flow rate of 8% and a turnover process lasting 1 hour, 16 beds are needed. The hospitals furthest from the four-hour target admit an average of 368 patients per day and therefore need 30 beds free to manage flow.

Why is the pressure growing?

Having shown the complexity of the problem of flow, it is important to understand that the issue is becoming increasingly intractable due to four key issues:

- Trends in bed use
- Rising age, rising co-morbidity, rising death rates
- Delayed discharge
- Trends in length of stay.

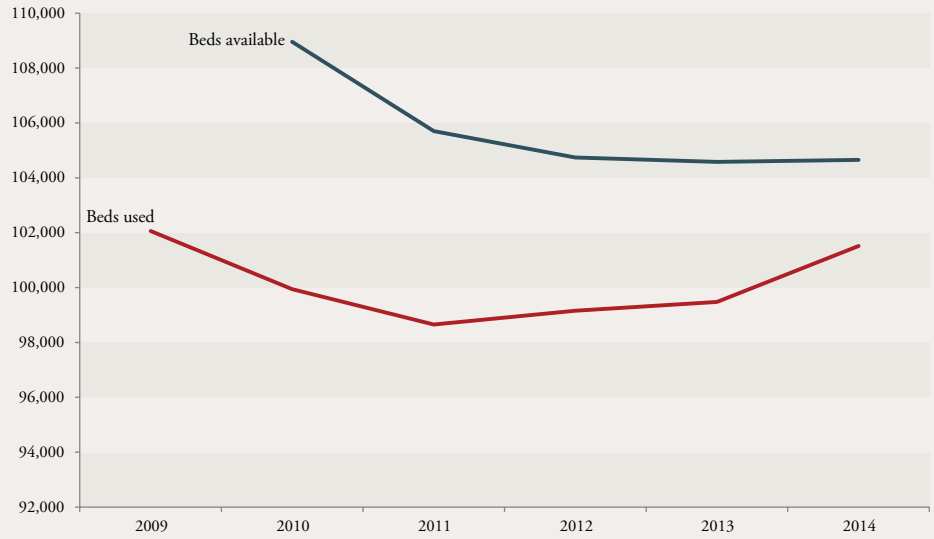
In this section we show how demand for hospital beds is increasing and changing, leading to increased congestion in the system. We deal with each of the above issues in turn.

Trends in bed use

As Figure 8 shows, the number of beds available has reduced to around 105,000 nationally over the last 6 years. Meanwhile, the number of beds used has increased to almost 102,000. The impact of this can be seen in the number of breaches of the four-hour A&E target that have occurred in recent years.

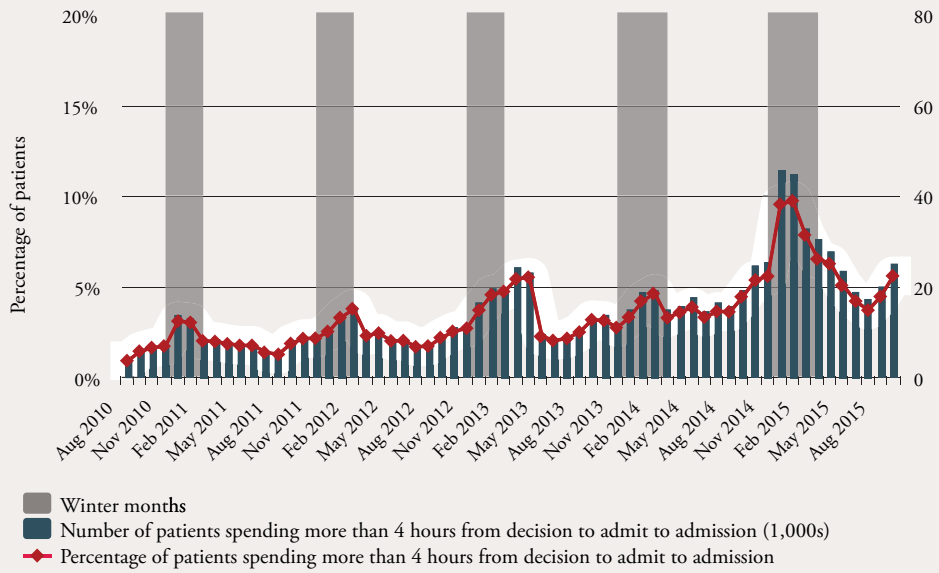
As we saw earlier, when looking at the performance of trusts meeting the four-hour standard in 2014/15, occupancy levels of below 94% appear to be a precondition for success. It should be noted that this is not a blanket rule – the space required for flow must be planned for and should take account of local circumstances. But, ultimately, space is needed to enable flow, and as the space available falls below the level required, congestion occurs and increasingly large queues build up.

Figure 8: Number of available beds versus number of beds used, 2009–2014



Source: NHS England (2016b)

Figure 9: Patients waiting longer than four hours from decision to admit to admission, 2010–2015



Source: QualityWatch (2016)

Figure 9 shows how the number of patients waiting longer than four hours has risen as space has become more scarce. It also demonstrates a seasonal pattern with supply and demand not appropriately matched throughout the year, resulting in the much-discussed winter pressures.

Increasing admission rates and bed use

Due to the tendency for activity to increase with age, the overall admission rate is increasing nationally. An additional 2.5 million spells per year are possible by 2030 (see Table 7). The average admission rate is likely to increase by 6% but, because of the increasing population, total activity could increase by 17%.

Table 7: Increasing admission rates and bed use

Year	Spells	Adm. per 1,000*	Rate change	Volume change	Beds per 1,000**	Beds per 1,000 % change	No. of beds	No. of beds % change	Weighted average length of stay
2015	14,903,382	273	–	–	2.0	–	109,897	–	2.7
2020	15,653,407	277	101.4%	105.4%	2.1	104%	118,976	108%	2.8
2030	17,450,227	290	106.4%	117.1%	2.4	119%	143,568	131%	3.0

* There is a trend of increasing intervention rates beyond 65 so rates are likely to be higher

** There are reductions in length of stay so bed use may be less, but this will be countered by increasing intervention rates

Source: HES (2016)

As most of the growth relates to older patients with more complex conditions, bed use increases at a greater rate with growth of about 31% by 2030. This drives an increase in expected average length of stay and beds per 1,000 population.

Past models based on extrapolated data have overpredicted demand and underestimated improvement. However, many of these models were generated during a period of declining death rates. Now this long-term trend has reversed, we caution against assuming outcomes will be better than expected unless there are credible plans in place for delivering this. OECD (2015) data demonstrate that the UK already has low bed availability and high occupancy in comparison with comparator countries.

Changes in admission profile and bed use from 2009/10 to 2014/15

Overall, there has been a 10.4% increase in spells and a 1% increase in bed use over the last 6 years.

Table 8 shows that the biggest change in activity has occurred in patients who stay less than a single day, with a 17% increase. Meanwhile, there has been a reduction in patients and bed use for patients staying over 28 days. This suggests that although delayed discharge is an issue, the reduction in the supply of beds has put more pressure on the system than the increase in demand.

Table 8: Percentage changes in bed use from 2009/10 to 2014/15

Length of stay	Spells	Bed days
0	17.1%	17.1%
1-6	3.0%	2.6%
7-13	1.1%	1.4%
14-20	2.7%	2.8%
21-27	1.4%	1.4%
28+	-4.1%	-5.9%
Total	10.4%	1.0%

Source: Monitor and NHS England (2013); HES (2016)

The major problem with these data is that they represent a snapshot view based on the midnight census. As discussed previously, this gives an incomplete view of real levels of bed use. This is also true over time. Although overall bed use as measured at midnight has increased by 1%, some 10% more patients are being treated. And as shown using the motorway example, once capacity is exceeded, speed reduces to maintain safety, with the biggest impact occurring during peak periods.

Flow in hospitals is concentrated in late afternoon, and additional work at this time of day is likely to create a 'rush hour' effect, with large reductions in speed leading to large increases in breach rates.

Bed use increases with age

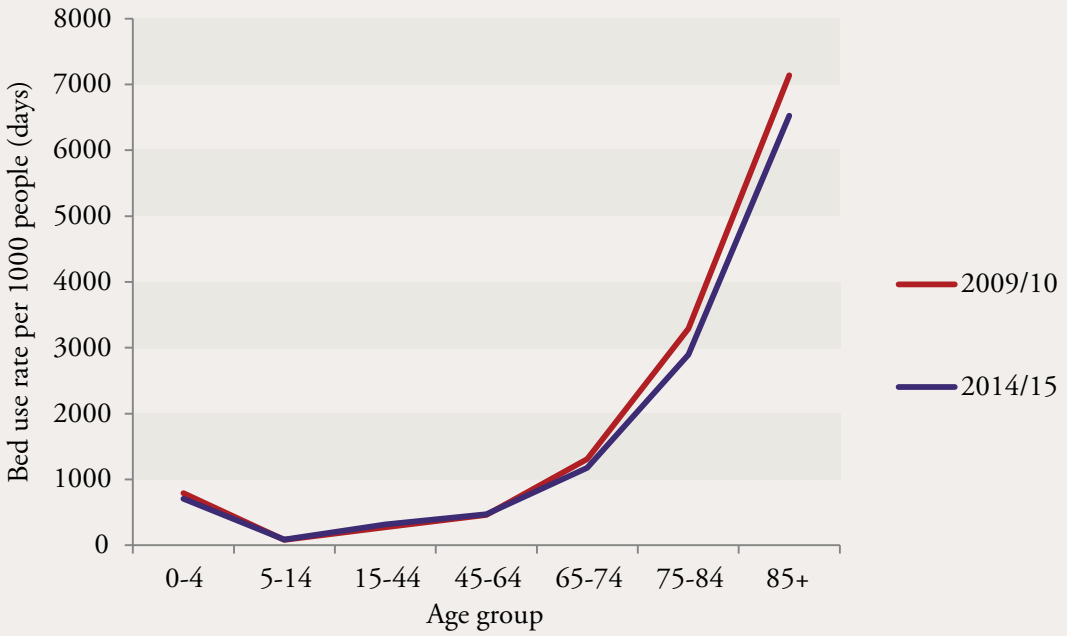
England's changing population underpins all of these trends, which implies that the trends will occur for the foreseeable future. Hospital activity and bed use increase with age. Although progress is being made to reduce length of stay, it is not sufficient to balance the demand of an increasingly ageing population.

Figure 10 shows bed use per 1,000 people by age band. While a 45–64 year-old spends half a day in hospital per year on average, an 85-year-old will spend almost a week in hospital. Figure 11 on the next page shows the impact of this on beds by projecting current patterns of activity on to the projected population in 2020 and 2030.

By 2020 additional demand for 9,500 beds is expected. This increases to 35,000 by 2030. This is on top of the current shortfall needed to restore flow.

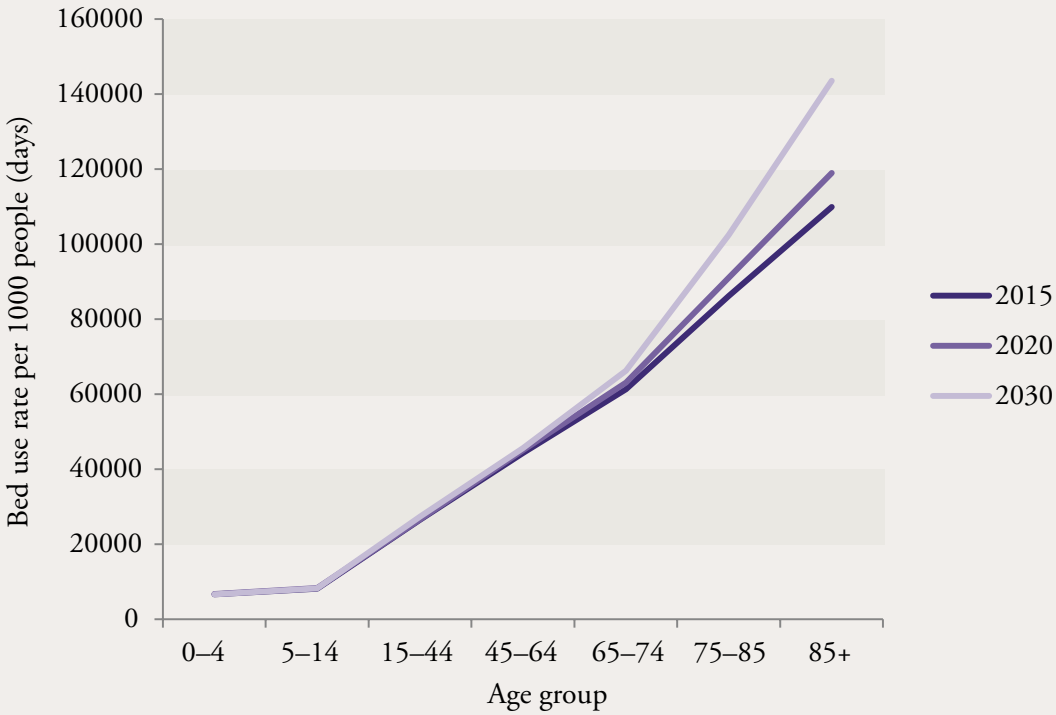
It is unlikely that a gap of this size can be closed solely through operational improvement inside hospitals. This can and should continue to improve, but not quickly enough to keep up with the factors which increase demand such as increasing comorbidity, increasing intervention rates and higher death rates.

Figure 10: Bed use per 1,000 people, 2009/10 and 2014/2015



Source: HES (2016)

Figure 11: Cumulative beds by age band, 2015–2030



Source: HES (2016)

Increasing comorbidity

It will not be news to clinicans or managers that patients are presenting with increased comorbidity. The data confirm this. Figure 12 shows the percentage of patients scoring from 0 points (i.e. no comorbidity) through to 20–49 points (i.e. multi-system disease) on the Charlson Index of Comorbidity. The percentage of patients in the highly comorbid groups has grown over the last 6 years.

Figure 13 shows that there have been length of stay reductions in each age bracket. However, the most complex patients spend almost three times as long in hospital as those admitted with no comorbidity, and the increasing number of these patients outweighs the improvements across the board. The net result is equivalent to a 6,500-bed increase in demand over the last 6 years. It is unlikely that a peak has yet been reached, and it therefore it seems reasonable to plan for the impact of further increases in comorbidity.

Increasing illness is a precursor of death. Population projections suggest that, having reduced over the last 40 years, death rates are now expected to increase every year for the next 40–50 years. This will drive ongoing increases in clinical workload and demand. The capacity required to manage this needs to be planned for.

Figure 12: Patient scores on Charlson Index of Cormorbitity, by age group

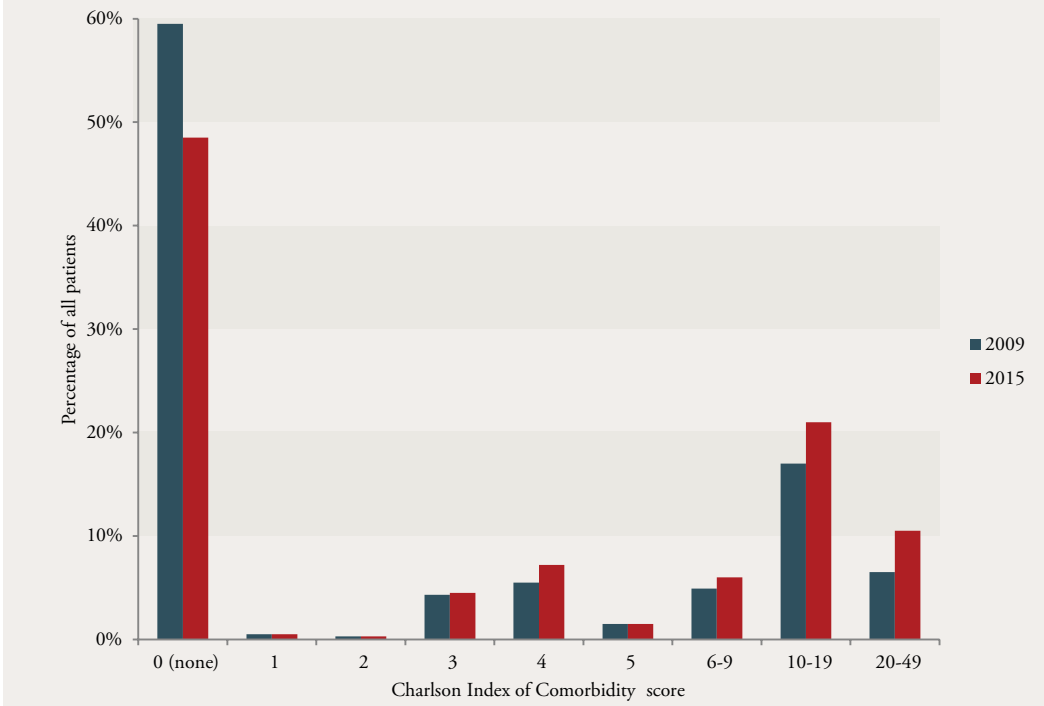
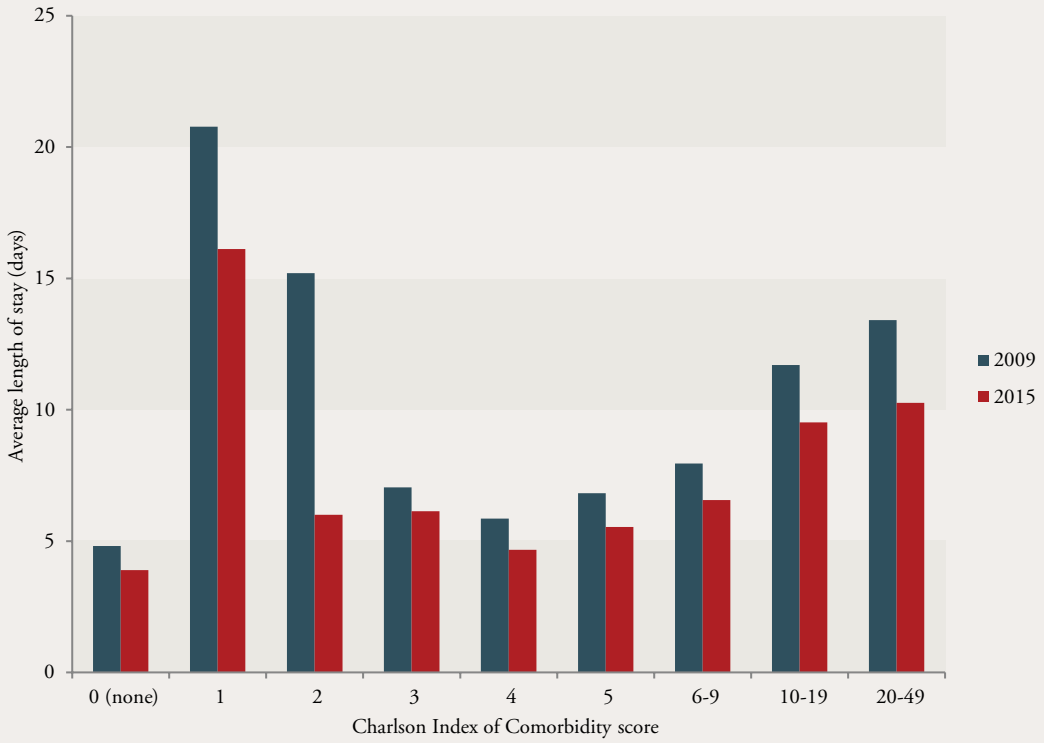


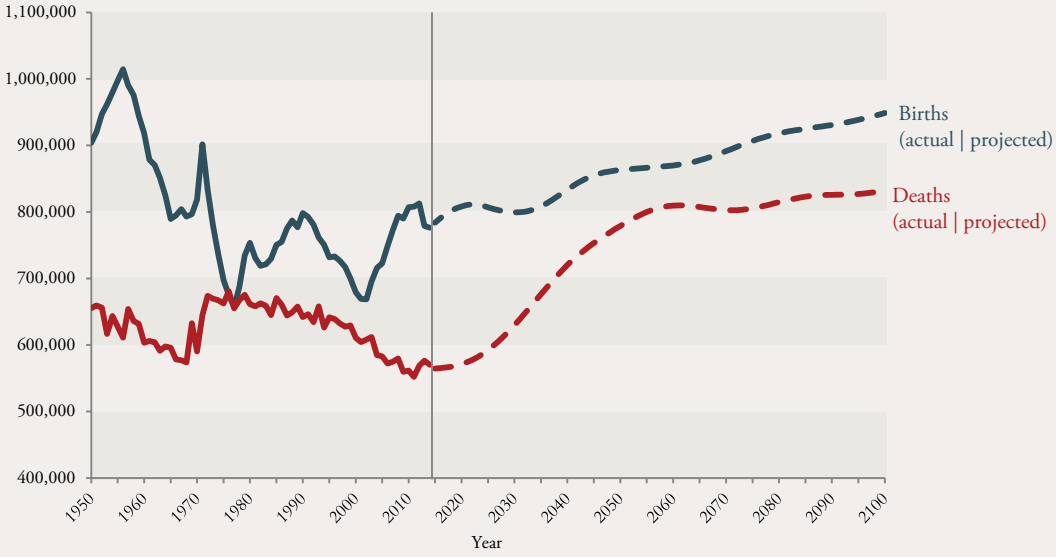
Figure 13: Length of stay in 2009 and 2015, by age group



Increasing death rates

The projected number of births and deaths is shown in Figure 14. Death rates are projected to rise from their current, relatively low level of around 600,000 to around 800,000 over the course of this decade, with important implications for NHS capacity. A substantial percentage of health activity and expenditure occurs in the last two years of life. The ability to provide enough effective, safe care at this stage of life will have a material impact on system performance over the next three decades.

Figure 14: Birth and death rates, historical and projected, 1950 to 2100



Source: Office for National Statistics (2015)

The data show that there are a range of changes contributing to increasing demand for beds. These increases are impinging on flow capacity and, as a result, queues are building up in many hospitals. The data also show that systems should expect continued increases in demand over the long term. Expecting the system to perform to standard without creating the conditions for this to happen is doomed to failure.

Delayed discharge

It is widely believed that difficulties experienced by patients leaving hospital and moving into nursing and residential care are the main reason for delays. Our data suggest that this is part of the problem but that it actually only contributes as much as increases in zero-day and day case activity to current bed pressures.

Table 9 shows that the number of patients discharged to nursing and residential care has increased by 30% over the last 6 years, but bed use has increased by only 18%. This suggests there have been some process improvements over the period.

Table 9: Average length of stay versus total beds in 2010 and 2015

Year	Spells	Expected length of stay	Length of stay	Difference	Total beds	Beds lost
2010	159,124	10.8	21.6	10.8	8,886	4,426
2015	206,216	10.2	19.7	9.5	10,488	5,071
Difference	47,092	–0.7	–1.9	–1.2	1,602	645
Percentage	30%	–6%	–9%	–11%	18%	15%

Source: HES (2016)

However, the length of stay is almost double what would be expected based on diagnosis and demographic predictions. This means that the potential improvement opportunity has increased by 645 beds to 5,071 beds over the 6-year period.

The care planning process appears to be an important component of delay. If supply of homes was the main issue, it is likely that length of stay would have increased given the large increase in the volume of patients being treated.

Trends in length of stay

Total bed use is a product of the number of patients treated and their length of stay. Table 10 shows the average length of stay for all patients, and for only those patients who stay for at least one night.

It also shows the marginal change from year to year – the increase in length of stay created by the average additional patient that year. Marginal changes are useful for

Table 10: Average length of stay and percentage change, all patients, 2010–2014

Year	Average length of stay	Marginal change in average length of stay	Average length of stay	Marginal change in average length of stay
2010	3.05	–2.51	6.85	–14.94
2011	2.99	–2.63	6.81	13.69
2012	2.98	2.01	6.82	7.53
2013	2.92	0.78	6.84	12.60
2014	2.89	2.10	6.92	13.15

Source: HES (2016)

understanding the difference between periods. For example, between 2013 and 2014 the average length of stay fell from 2.92 days to 2.89 days. For every additional patient, the marginal change was 2.1 days. This means the additional patients were using less space than average, showing an apparently improving position.

Between 2010 and 2011 the marginal change was negative, meaning that the overall improvement was so great each additional patient required no new space.

However, the all-patient average is misleading. When we only look at patients who stayed overnight, the average length of stay is essentially stable. Over the last year, each additional patient added 13.15 days – about twice the average stay. This suggests that system delays are increasingly significant, although increasing complexity leading to longer stays may also play a role.

These data suggest that, despite improvement efforts, length of stay is stable and is showing signs of increasing. Many plans have been targeting 5–10% reductions in length of stay, but there were clearly significant challenges to delivering this in reality. Planning may be subject to optimism bias.

The reasons for this gap between past ambitions and reality therefore need to be considered when looking at future plans that rely on reducing length of stay as a solution to flow or financial problems.

Future trends

Sustainable improvements in performance will only be achieved if health and care systems develop effective plans to deal with changing demography. There is increasing diversity across the country with population growth in London almost five times higher than the north east of England. Increasing age and proximity to death and the conditions associated with it are the largest drivers of growth.

The UK has low levels of beds and high occupancy compared with other OECD countries (OECD, 2015). This suggests caution is needed in developing a strategy dependent on bed reduction without putting clear alternatives in place, given that:

- Based on current patterns of activity, the number of hospital spells is expected to increase by 17% by 2030 (Hospital Episode Statistics, 2016)
- Demand for beds is expected to increase at almost double this rate as most growth is for relatively long-stay work. Some 9,500 additional beds are likely to be needed by 2020, increasing to 35,000 by 2030 (Hospital Episode Statistics, 2016)
- Virtually all of this increase is accounted for by the over-65 population
- Unless this demand is met (through increased supply or innovation), gridlock is likely to occur in many areas of the country
- Capacity and demand will also be influenced by changes in the social care sector. Our recent work with The King's Fund (Humphries and others, 2016) underlines how an increasingly uneven system risks making social care unavailable to growing numbers of people who need it. In some cases, hospital bed space may end up as a substitute, while discharging people with ongoing needs will become more difficult. This is likely already to be one factor behind the increase in delayed transfers of care.

How to free up flow: possible solutions

This report has identified that generating enough **flow capacity** is the key problem to be solved. This is largely invisible in snapshot or census reports. Returning to our motorway analogy, it is the space between cars that enables them to travel safely at the appropriate speed for the conditions. The amount of space needed depends on the volume and intensity of demand and needs to be calculated locally. In 2014/15, the maximum occupancy commensurate with hitting the four-hour standard was around 94.5%, so this serves as a starting point for discussion.

The obvious solution might be to simply **build more beds.** But in the current environment, this is not feasible. Neither the people nor the funds exist, and development would not be achieved fast enough to mitigate the demand pressures we have identified. Alternative solutions are needed, which we look at below in the following order:

- The problem to be solved
- Better measurement and management
- Reducing short-stay admissions
- Earlier discharge.

When looking at all of these possible ways to improve, having a receptive environment is critical – a point that emerged very strongly from workshops on the subject of system flow held by the Nuffield Trust. We heard many stories regarding poor behaviour at many levels of the system. The key to creating the right environment is to recognise that the system has changed, and that what has worked in the past is not necessarily relevant today. Leaders need to recognise the skill and commitment of frontline staff, to be ready to learn from them, and to provide conditions conducive to effective teamwork and problem-solving.

Better measurement and management

Improving control systems

Experiences described at the Nuffield Trust workshop and seen in different hospitals across England suggest that better control systems can help to improve flow. By this we take to mean both the management systems that govern patients moving in and out of beds, and the IT systems that enable this by monitoring and recording moves.

Most hospitals rely on a significant number of manual processes to coordinate the use of beds, including face-to-face conversations, paper filing, and reporting into central teams. But with increasing complexity comes a greater risk of communication failure, confusion and delay in these processes. At busy times, central teams will become overloaded, and this compromises the performance of the whole system.

Evidence from other sectors suggests a number of potential improvements:

- A **decentralised framework** that provides control at a number of levels is needed to manage complex operations reliably. In a hospital, this would enable more decisions at ward and directorate level. It rarely makes sense to integrate information from many different processes through complex interfaces. The role of the centre should be a 'command centre' model that brings together information from different processes with people able to understand the information and make appropriate decisions on a wider scale where this is needed.
- Ideally, the information used is available real-time, reflecting how patient flow and occupancy change in important ways from hour to hour, as we showed above.
- It should also be generated automatically by staff doing their core jobs, rather than requiring extra data entry tasks. Real time, automatically generated data should reduce the time staff need to spend in activities that do not add value to patients, and assist in scheduling and identification of bottlenecks.

There is growing evidence of a market in IT systems with these characteristics for hospitals. Although they are relatively expensive, these solutions are a lot cheaper than building additional facilities or recruiting additional staff.

Reducing short-stay admissions

One way of directly freeing up more bed space for flow is to simply reduce the number of patients attending. This is likely to apply mostly to people who would have relatively short stays in hospital: people who stay for a long time tend to have serious enough needs that it would be difficult to find an alternative to inpatient care.

But reducing short-stay admissions is not easy. It would rely on general practice and community services, which are in many cases themselves under intense strain (Baird and others, 2016). The Nuffield Trust has evaluated a large number of initiatives aimed at reducing emergency admissions to hospital in particular (Bardsley and others, 2013), and most do not have a significant impact in the short term. Success will depend on having a clear understanding of why patients are presenting – and this is often for specialist opinion, diagnosis or treatment. Replicating these functions is potentially very expensive and runs the risk of spreading resources over an even greater number of locations. This could impede plans to deliver seven-day services.

Additionally, the impact of this on the space available may be fairly limited. Removing half of the patients would only release 5% of beds – much less than the capacity needed to restore flow. Hospital income would reduce by 14%, creating additional financial pressures. There is also some evidence that keeping patients with less serious needs within the hospital sector creates additional space, which helps with system resilience. Remember, as discussed above, that hospitals meeting the four-hour standard tend to have relatively higher admission rates and greater access to beds.

Achieving earlier discharge

The other direct way to free up bed space is to find ways to move patients out of hospital more quickly. This means very different things depending on the patient pathway concerned. For 90% of patients staying under 7 days, the average stay is only 1.12 days, or 29 hours. A 10% reduction in length of stay means reliably delivering the patient treatment pathway in about 180 minutes less than is currently the case. If delivery is dependent on systems that measure length of stay in days at midnight but it is necessary to wait until the next day to see what has happened, it seems unlikely that the environment is conducive to achieving this.

In contrast, 10% of patients stay over 7 days, have an average stay of 18.8 days, use 65% of the beds and generate 32% of hospital inpatient revenue. A significant number of these patients are likely to need, and would benefit from, rehabilitation. It is probable that designing at-scale systems to provide this outside hospital could enable earlier discharge in a way that frees up significant space. Even if only 3% of patients were cared for in a different way, 20% of acute beds could be released.

This would have a dramatic impact on flow and is likely to eliminate the need for escalation beds, significant amounts of temporary staffing and the constant pressure to manage beds and capacity rather than provide care for patients. The bed space freed up could also be used, in some cases, to bring elective work that has been subcontracted out back into the hospital, providing a useful financial contribution.

Conclusion

If the NHS is to treat patients more quickly and meet major commitments like the four-hour target for A&E, allowing patients to flow freely through hospital is essential. Yet after years of flat or falling bed numbers and growing need for care, this is all too often not possible. It appears that at least 5.5% of beds need to be free to create the space for cleaning and preparing beds that makes successful flow possible. Yet many trusts now struggle much of the time to provide this.

With a rising death rate, and increasing numbers of patients with multiple conditions, these pressures are only likely to intensify. More capacity is one answer, but at best it can only provide a small part of the solution given the current financial situation. Counting patients at midnight no longer gives a useful national or local picture in a world where so many are treated within a matter of hours. Managers should improve IT and governance systems that track bed use and flow so that they can see where problems and pressures exist. Meanwhile, quicker discharge for the longest staying patients is probably where the most potential exists to free up space. Above all of this, the NHS culture of problem-solving needs to be more open to ideas, including from the front line.

The findings in this report do not change the fact that addressing this situation is complex and difficult. But after years of failing to address the A&E crisis through narrow measures, we hope they at least show how looking at the right parts of the broader system might provide answers.

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About the author

Sasha Karakusevic joined the Nuffield Trust in October 2015 as a Visiting Senior Fellow to work on health systems, with a particular interest in new technology, diagnostics and system design. Sasha started his career in dentistry and maxillofacial surgery. Early in his career he became very interested in service improvement and health system design, focusing on the systems and processes that drive innovation and improvement. He played a major role in shaping the South Devon Integrated Care Network. He has operated at Director level in the NHS since 2001 and has wide experience of using information to drive improvement and on aspects of patient flow. Sasha has worked with colleagues in a wide variety of countries exploring how to make health systems work better. Sasha has a BSc and BDS from the University of Manchester and an MBA from Imperial College.

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