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# BMJ Open

## The adverse impact of increasing capacity to reduce admission times

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**TITLE PAGE****The adverse impact of increasing capacity to reduce admission times**

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# The adverse impact of capacity increases to reduce admission times

## ABSTRACT

**Objectives:** To investigate the consequences of increasing capacity to reduce admission times, and to explore how patient waiting times and use of physical capacity were influenced by variability.

**Design:** A retrospective case study that combines both primary and secondary data. Secondary data were retrieved from a hospital database in order to establish inflow and outflow of patients, utilisation of resources and available capacity, realised admission times and the weekly number of new patients seen over one year. Primary data consisted of field notes, on-site visits and observations, and semi-structured interviews.

**Setting:** A secondary care facility, i.e. a rheumatology department, in a large Dutch hospital.

**Participants:** Analyses are based on secondary patient data from the hospital database, and the responses of the interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.

**Results:** The study shows that artificial variability was increased by managerial decisions to add capacity and to allow an increased inflow of new patients. This, in turn, resulted in undesirable and significant fluctuations in admission times. Although the studied fluctuations have commonalities with the so-called service bullwhip effect, we argue that we witnessed a new multiplier effect that typifies the fluctuations.

**Conclusions:** Adding capacity resources to reduce admission times might appear an obvious and effective solution. However, the outcomes were less straightforward than expected, and even led to new artificial variability. The study reveals a phenomenon that is specific to service environments, and especially healthcare, and has detrimental consequences for admission times.

Keywords: patient waiting times; variability; buffers; bullwhip effect

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study provides knowledge as to the effectiveness of increasing capacity buffers in order to reduce hospital admission times.
- A particular strength of this study relates to the novel structured approach adopted to investigate hospital admission times that generates a thorough understanding of actions to reduce these and their consequences over a prolonged period.
- Another strength of this study is its combination of both objective performance data retrieved from the hospital database and subjective qualitative data to explain past occurrences.
- Although the dyadic structure of GPs and a small rheumatology department with new and returning patients is relatively simple and open to analysis, it does not represent the more complex networks with multiple interdependencies seen in many other situations.
- Another limitation relates to the adopted single case study approach which limits the generalisability of the findings, although the phenomena we identify are widely relevant and not unique to the setting.

## Introduction

It seems very logical that, when confronted with long admission times, one increases capacity to more quickly serve clients: an obvious solution to a clear problem, or so it appears. This study however shows the possible adverse consequences of adding physical capacity in order to reduce admission times. In addition, we provide a theoretical frame of reference to help understand the underlying mechanism that causes the adverse effects.

Patient flow is a topic of ongoing interest in healthcare research[1-3]. A smooth patient flow is characterised by short waiting times. In our study, we are especially interested in the admission time as a specific type of waiting time. Achieving short admission times is important for healthcare providers: reducing admission times can positively affect the patients' condition (e.g. by reducing pain), and can prevent further problems as medical conditions can deteriorate while waiting for treatment[4,5]. Despite this, consistently achieving short admission times is difficult. One of the main barriers to achieving short admission times, and short waiting times in general, is variability[6].

One can distinguish between natural and artificial variabilities[7]. Two patients responding differently to the same treatment is an example of natural variability. This type of variability is inevitable in healthcare and can only be controlled to a very limited extent: natural variability is a 'fact of life'. In contrast, artificial variability is caused by our own actions, routines or regulations. This type of variability can and should be controlled and reduced. A striking example of artificial variability was seen in a study where a case was discussed in which surgeons were late arriving for their 7.30 a.m. surgeries. Previously, the surgeons had encountered operating rooms that were not prepared and ready for punctual starts and, as a result, the surgeons became 'conditioned' by the system to arrive late to ensure the operating room was ready. Artificial variability is demonstrated in the routine of arriving late, which hindered patient flow and increased patient waiting times.

The mechanisms that allow an organisation, or more precisely a process, to cope with variability are termed buffers. Some form of buffer will be required to cope with variability in either supply or demand[8]. The available buffers in a healthcare environment consist of time buffers (waiting patients) and capacity buffers (idle resource capacity)[9]. Healthcare is thus faced with a trade-off between either waiting patients or idle capacity, both of which are unattractive. Buffers are the natural result of a system that has to cope with variability, but one should continuously attempt to minimise buffers and reduce their underlying causes.

Increasing capacity buffers seem to be the most effective solution if one wants to reduce the time buffers represented by hospital admission times. However, during a recent improvement project, we witnessed adverse outcomes from expanding capacity to cope with long admission times. This led us to the following research question: why does expanding capacity lead to variation in patient waiting times? This study aims to contribute to knowledge on the dynamic relationship between variability and patient waiting times, and to the understanding of fluctuations in hospital admission times.

In the remainder of this paper, we first introduce the methodology applied by explaining the hospital setting and the approaches used in obtaining and analysing the empirical data. Following this, we present the results of our analysis, and then a discussion reflecting on the interaction between variability and buffers. This interaction turned out to be less straightforward than expected. This paper then ends with the conclusions in which we highlight our main contributions.

## Methods

The research setting for this study was the rheumatology department of a Dutch teaching hospital. The hospital had embarked on an improvement programme with several projects focussing on improving flow performance. These projects allowed us to study the impact of actions aimed at reducing admission times. At the time of this study, the rheumatology department employed two specialists (physicians), a specialised nurse practitioner and a rheumatology patient advisor that together served 9,277 patients in 2013. As the admission time was rather long (up to 16 weeks) and the utilisation rate of the two physicians was high, the hospital board decided to initiate an improvement project.

The aim of this research was to understand the complex interaction between variability and buffers. To study a complex phenomenon in its natural setting we applied the single retrospective case study methodology[10]. The data gathered was used to study the interaction between variability and buffering and the fluctuations in admission times through an operations management lens, a perspective especially appropriate for issues related to patient flow.

### *Case description*

The typical patient pathway in our case setting is as follows. A patient experiences problems with their joints, and visits their general practitioner (GP). The GP will refer the patient to a rheumatologist, who will examine the patient at an outpatient clinic. If deemed necessary, the rheumatologist will request additional diagnostic tests (an ultrasound examination, X-ray, blood test etc.). The rheumatologist will then discuss a treatment plan with the patient and notify their GP. Alongside the rheumatologists, the nurse practitioner serves a small, predefined, group of new patients whose situations lack complexity.

The rheumatology department distinguishes three types of consultation requests determined by the perceived urgency of the problem: 1) regular, 2) semi-urgent and 3) urgent patients. Of the new patient arrivals, 7% are considered urgent and 6% semi-urgent. Standard admission times have been predetermined for urgent and semi-urgent patients (two weeks and four weeks respectively). No target admission time has been set for 'regular' patients who form the majority of new arrivals.

### *Data sources*

This study combines several secondary data sources from the hospital database: inflow and outflow (new arrivals and patients leaving the system), utilisation of resources and available capacity, realised admission times and the number of new patients per week over one year (2013). In addition to these secondary data sources, we acquired primary qualitative data through keeping field notes, onsite visits and observations, and semi-structured interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.

During the interviews, questions were focused on obtaining in-depth information on possible sources of variability. We used an interview protocol to enhance both the reliability and the validity of the research[10]. Combining objective quantitative and subjective qualitative data contributes to the accuracy and reliability of case study research[10]. In addition, the physicians, nurses and LSS project leaders had a crucial role during a focus group meeting in which we reflected on the outcomes of the analyses and attempted to build an understanding what had occurred.

### *Analysis approach*

This study required an in-depth exploration of admission time data, for which there is no standard approach. Therefore, the initial analysis involved calculating the median and

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4 mean admission times for each week. The median is often used in analyses of highly  
5 variable data because it is less sensitive to outliers than the mean.

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7 Next to median admission times, we calculated the 90<sup>th</sup> percentile of the admission  
8 times for each week to detect whether any apparent changes in admission times affected  
9 a large majority (i.e. at least 90%) of patients. We constructed diagrams that relate  
10 capacity and admission times over time, through which we provide insights into the  
11 dynamics of time and capacity buffers.

12  
13 To deepen the analysis of flow-related variables, we followed a previously used  
14 approach[11] making use of throughput diagrams that show both cumulative patient  
15 inflow and outflow curves over time. The vertical distance between the two curves  
16 reflects the number of waiting patients while the horizontal distance reflects the backlog  
17 in terms of time. The behaviour of these two variables can be analysed over time and at  
18 the same time be related to fluctuating patient inflow and outflow rates. As such it is  
19 particularly useful in dynamic situations where the averages change over time. Finally,  
20 the relative share of new and returning patients was analysed to detect any ratio changes  
21 over time.

22  
23 In the analyses, the weekly capacity in person-days is calculated based on the number  
24 of scheduled physicians and corrected for any absences. The capacity information is based  
25 on the available calendars of the physicians. This capacity is allocated to new and  
26 returning patients.

#### 27 28 *Patient and Public Involvement statement*

29 This research did not involve patients in the design, conduct and reporting of the research.  
30 The results of this work were presented and discussed during a focus group meeting with  
31 representatives of the hospital. Once the study has been published, the main findings will  
32 be used in the education of Master students.

#### 33 34 35 **Results**

36 Figure 1 depicts the capacity in person-days each week and the admission times (in  
37 weeks) for patients making an appointment in that week. The analysis shows that, up to  
38 week 31, the maximum capacity was 10 person-days, i.e. two full-time physicians.

39 In an attempt to reduce the admission times an intern (shown in red) provided  
40 additional capacity from week 31. In addition, in weeks 33 through 39, a resident provided  
41 a further temporary boost to capacity. Here, we note that the productivity of the resident  
42 was expected to be similar to that of the rheumatologists, whereas the intern would realise  
43 roughly one third of their output due to their relative lack of experience. The graph is  
44 adjusted to reflect this difference. In effect, by increasing staff, the department sought to  
45 replace time buffers (waiting patients) with capacity buffers (additional physicians).

46 The expansion in capacity resulted in an almost immediate drop in admission times  
47 from week 31 onwards. In terms of variability, Figure 1 shows that the actual capacity in  
48 just over half of the weeks of the first 6 months was below the notional 10 person-days,  
49 and often significantly so. That is, there were more weeks in which at least one  
50 rheumatologist was partly absent than weeks in which both were fully present. This  
51 illustrates that, in this case, capacity availability is a relevant source of artificial  
52 variability.

53 Furthermore, Figure 1 shows that, in week 28, more than half of the appointments  
54 made had an admission date at least 16 weeks in the future (the median value). Whereas,  
55 in week 32, half of the appointments made were for within one week. In other words,  
56 patients that sought an appointment in week 28 often had to wait a further 16 weeks for  
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4 their meeting with a physician, whereas patients that joined the list in week 32 would  
5 usually see their physician within a few days.  
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8 <insert Figure 1 about here>

9 Figure 1. Weekly capacities in person-days and median admission times  
10

11 When we look at the 90<sup>th</sup> percentile of recorded admission times (Figure 2), there is  
12 no equivalent and sustained immediate improvement after week 31, indicating that a  
13 substantial number of patients still experienced lengthy admission times. However, from  
14 week 46 on, there was a significant drop in the 90<sup>th</sup> percentile, indicating that the  
15 admission times for the majority of patients had decreased in the final weeks of the year.  
16  
17

18 <insert Figure 2 about here>

19 Figure 2. 90<sup>th</sup> percentile of admission times  
20  
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22 Influences on admission times can also be analysed using throughput diagrams (Figure  
23 3). The vertical axis shows cumulative numbers of patients. The upper (green) curve  
24 represents the cumulative inflow and the lower (blue) curve the cumulative outflow. To  
25 ensure data validity, the inflow curve is not shown after week 47 because some of the  
26 patients then applying for appointments might not be admitted until the first weeks of the  
27 following year, which would distort any conclusions.  
28

29 The horizontal distance between the two curves in Figure 3 is the backlog (in weeks)  
30 and can be interpreted as the projected admission time for a patient requesting an  
31 appointment at that point in time. A red curve, representing this horizontal distance, is  
32 included, with values indicated on the secondary vertical axis. For example, the 400<sup>th</sup>  
33 request for an appointment (inflow) was made in week 17, and the 400<sup>th</sup> appointment  
34 (outflow) was scheduled for week 29 (but not necessarily the same patient). This means  
35 that a patient joining the queue in week 17 could, on average, expect an admission time  
36 of 12 weeks, whereas by the 800<sup>th</sup> patient (arriving in week 38) the expected admission  
37 time was down to 2 weeks. Compared to the representations in Figures 1 and 2, this  
38 diagram has the advantage of being less sensitive to individual deviations from the typical  
39 admission times. It provides a global view of how admission times develop and how they  
40 can be related to surges or drops in patient inflow or outflow.  
41  
42

43 More specifically, Figure 3 shows how the decrease in mean admission times from  
44 week 31 onwards was indeed linked to a surge in outflow, rather than a drop in inflow.  
45 As such it was clearly the result of the capacity increase.  
46  
47

48 <insert Figure 3 about here>

49 Figure 3. Throughput diagram including derived mean admission times  
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52 Along with the sudden decrease in admission times due to the increase in capacity, the  
53 number of new patients being referred by their GPs increased significantly from week 31  
54 onwards (see Figure 4). For example, 30 new patients were referred in week 31 compared  
55 with just 10 in week 29.

56 From the interviews, we learnt that referrers (i.e. GPs) select those hospitals that have  
57 the shortest admission times. An unforeseen consequence of this was that the drastically  
58 reduced admission times in the studied unit had a pulling or magnetic effect. Once the  
59 extra capacity was added, extra slots became available which allowed the hospital to offer  
60 very short admission times. As such, the system responded quickly through a market



mechanism based on admission times. Being aware of the dramatically reduced admission times, GPs directly started to refer a greater proportion of their patients to this hospital.

<insert Figure 4 about here>

Figure 4. Weekly inflow of new patients

This sudden inflow had consequences for the ratio of new to returning patients, which also changed from week 31 onwards. In the first 30 weeks of the year, there were typically about 13 new patients per week (Figure 4) representing 15-20% of the patients seen (Figure 5). However, in weeks 31-49, the average number of new patients increased sharply to an average of 28 per week and the proportion of new patients correspondingly increased to 30-40% as of week 31 (Figures 4 and 5).

<insert Figure 5 about here>

Figure 5. Relative share of new (NP) and returning patients (RP) per week

These additional new patients continued to fill the system. However, the increased inflow had a multiplier effect as each new patient admitted would typically have four follow-up appointments in the year following their first admission. In the worst-case scenario, this could result in a situation where there would be insufficient capacity for returning patients.

When we reflect upon our findings, the actions of the department seem to have triggered a potential amplification of its backlog. First, by adding capacity, and second by then accepting more new patients than the department would be able to cope with in the longer term. While we do not have accurate database information for the following year, the interviews provided information that new capacity problems did emerge. These capacity problems were a consequence of the vicious cycle that was started by deliberately expanding capacity and occurred despite the best intentions to reduce waiting times and increase patient care quality and satisfaction.

## Discussion

In this case study, we have elaborated on an in-depth analysis of the admission times and the capacity management of a hospital's rheumatology department. We first revisit the research question before considering the general implications of our study.

The main research question focused on how patient waiting times vary following an expansion in capacity. Our analysis revealed that the local managerial decision to temporarily add extra capacity to reduce the backlog (i.e. shorten admission times) had a magnetic effect on GPs who then referred many more patients to this hospital rather than elsewhere. The increase in new patients and, as a consequence, the avalanche of follow-up appointments was disproportionate to the extra capacity.

Furthermore, the decision to allow a significant increase in the inflow of new patients once this new capacity was added resulted, at least in the short term, in a substantial change in the ratio of new to returning patients. This ratio changed from 20:80 during the first 30 weeks of the measurement period to 40:60 as of week 31. With a surge in new patients, most of whom would need four follow-up appointments; it was inevitable that the department would later become overwhelmed with these new patients requiring multiple returning appointments.

In hindsight, two local decisions, to increase capacity and to use this to accept many more new patients, were important sources of artificial variability. Further, it triggered a self-inflicted multiplier effect.

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4 This effect was initially considered as a potential example of a service bullwhip effect.  
5 Four characteristics identify a service bullwhip effect: 1) it has to occur in a supply chain,  
6 2) there should be a trigger event inducing the demand distortion, 3) there should be a  
7 lag, and 4) there should be an amplification effect[12]. We explored to what extent these  
8 characteristics were present in the studied case.  
9

10 The case study focussed on a rheumatology department that formed part of a three-  
11 stage serial supply chain of referring GPs followed by the rheumatology department  
12 treating newly admitted and then returning patients. This structure fulfils the first  
13 criterion: the amplification occurs in a supply chain context.  
14

15 The second characteristic is that there has to be a trigger that induces the distortion in  
16 demand. The trigger in this case was the decision to add temporary capacity combined  
17 with the associated decision to accept an increased inflow of new patients.  
18

19 The third criterion, that there should be lags, appeared plausible but the figures suggest  
20 otherwise. For example, although a time lag is possible between adding capacity and GPs  
21 referring additional new patients, the diagram combining capacity and admission times  
22 (Figure 1) shows virtually *no* lag, with admission times dropping and new patients being  
23 accepted almost immediately after the capacity increase. The ‘system’ appeared to fully  
24 allocate the new capacity to new and returning patients almost automatically.  
25 Nevertheless, if we consider the 90<sup>th</sup> percentile of the admission times, then we could  
26 argue that there was still a considerable number who experienced relatively long  
27 admission times shortly after the extra capacity was added.  
28

29 The fourth and final criterion is that there should be amplification. The amplification  
30 in this situation was caused by the new patients requiring follow-up appointments.  
31 Interestingly, this amplification was downstream rather than upstream, which is contrary  
32 to what is normally seen with a service bullwhip effect.  
33

34 Although the fluctuations in admission times witnessed in this case study have  
35 commonalities with a service bullwhip effect, there are fundamental differences. To  
36 discuss these differences we present the causal network of the rheumatology situation in  
37 Figure 6. The network shows that a sharp decrease in the department’s admission times  
38 (here referred to as hospital A) caused GPs to switch their demand by opting to refer  
39 patients to hospital A rather than elsewhere (hospital B). This was possible because GPs  
40 were aware of the improved admission time offered by hospital A, which distinguished it  
41 from hospital B. This resulted in a sharp increase in the inflow of new patients of whom  
42 an unlimited number were accepted (although one would expect the admission times to  
43 eventually increase as appointments fill up until a new equilibrium is reached with  
44 hospital B). This boosted the ratio of new to returning patients, and resulted in a massive  
45 increase in demand for follow-up appointments due to a multiplier effect with typically  
46 four returning visits in the year following first admission. The increase in follow-up  
47 appointments absorbed all the available capacity, which had a negative effect on the  
48 admission times offered to future new patients.  
49

50  
51 <insert Figure 6 about here>

52 Figure 6. Causal network of the rheumatology situation  
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55 It is striking to see that the increase in new patients has a self-reinforcing effect on the  
56 demand for physician capacity due to the multiplier effect of follow-up appointments.  
57 This amplification reveals itself in the next stage of the supply chain, rather than  
58 upstream, and so is fundamentally different from the bullwhip effect.  
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60 The amplification is not induced, as with a bullwhip effect, by a lack of information.  
On the contrary, it is the consequence of continuous and instantaneous information

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4 sharing between the hospital (and its rheumatology department) and GPs. Further, the  
5 amplification is not caused by a perceived change in overall demand but by GPs switching  
6 demand. The case stresses that it is insufficient to rely on a local or supply chain  
7 perspective. Here, a system awareness is necessary and this requires considering the  
8 referral behaviour of GPs and the delivery performance of other competing hospitals  
9 when addressing variability and buffers.  
10

11 In the situation we studied, it intuitively made sense to add local capacity to reduce  
12 admission times. However, the market mechanism, based on admission times, that this  
13 case study has revealed, clearly requires a system view to smooth the demand and keep  
14 long-term admission times at an acceptable level.  
15

16 The theoretical contributions of this study are threefold. First, we contribute to the  
17 theory on multiplier effects, which has so far been dominated by publications on bullwhip  
18 effects[12,13]. We have revealed a new multiplier effect, one that was self-inflicted and  
19 caused by decision-making being based on a local rather than a system perspective. Given  
20 the existence of a market mechanism based on admission times, supply chain partners  
21 need to make decisions based on an overview of available 'market information'.  
22

23 Second, we contribute to the 'theory of swift and even flow'[14] by positioning  
24 artificial variability as a managerial problem that negatively affects flow. Based on this  
25 study, and given the dynamics of the interaction between variability and buffers, we stress  
26 the need to apply a system view when pursuing flow improvements. Introducing poorly  
27 informed local policies can negatively affect flow.  
28

29 Third, we contribute to the growing knowledge base on process improvement, which  
30 includes approaches such as Six Sigma and lean thinking[15,16] by confirming the  
31 importance of variability and buffer reduction, an area that has recently received  
32 increasing attention in the literature on lean thinking. Lean is generally considered to  
33 include the concept of *mura*, which reflects unevenness or variability as can be found in  
34 the healthcare field[17]. Hopp [18(p.89)] considers the 'production of goods or services  
35 to be lean if it is accomplished with minimal buffering costs'. After an initial focus on  
36 direct waste, more mature lean approaches tend to focus on reducing variability and  
37 buffers[18]. This study contributes by revealing the interaction between variability and  
38 buffers within a hospital setting, and shows that these dynamics are less straightforward  
39 than often thought.  
40

41 As this study is the first to identify a new multiplier mechanism in practice, an obvious  
42 limitation of this research is that it is based on a single case study, which consequently  
43 limits the generalisability of the findings and conclusions. Another limitation relates to  
44 the fact that the service supply chain in this paper is a simple dyadic structure of GPs and  
45 a relatively small rheumatology department with new and returning patients. As such, it  
46 is not representative of very complex networks with many interdependencies needing to  
47 be understood. A strength of the study is its combination of objective quantitative and  
48 subjective qualitative data that contributes to the accuracy and reliability of the findings.  
49 We would encourage further research aimed at increasing the knowledge on multiplier  
50 effects and the dynamics between variability and buffers.  
51  
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53

## 54 **Conclusions**

55 This research has identified the variation in admission times that follows from adding  
56 capacity. We have seen that admission times are heavily influenced by sources of artificial  
57 variability such as managerial decisions about adding capacity and accepting new  
58 patients. This can cause undesirable dynamics in the variability-buffer interaction such as  
59 a new multiplier effect that has not been previously discussed in the literature. Our  
60

findings lead us to agree with earlier research[13] that concluded that synchronising service supply chains is ‘complex’ and ‘non-intuitive’.

### List of abbreviations

**GP:** General Practitioner

**LSS:** Lean Six Sigma

**NP:** New patients

**RP:** Returning patients

### Declarations

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**Contributors:** All authors contributed to the design of the research and to carrying it out. PW and FZ collected the data and analysed the results. OR, FZ and KA wrote the manuscript, and PW and ML provided comments on the manuscript and approved the final version.

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**Competing interests:** The authors declare that they have no competing interests.

**Ethics approval:** Study approval [reference number RDMPFEB-20180111-2835] was granted by the ethics committee of the Faculty of Economics and Business, University of Groningen, the Netherlands.

**Data sharing statement:** The datasets used and/or analysed during the current study are available from the *University of Groningen*. Data are available from the corresponding author on reasonable request.

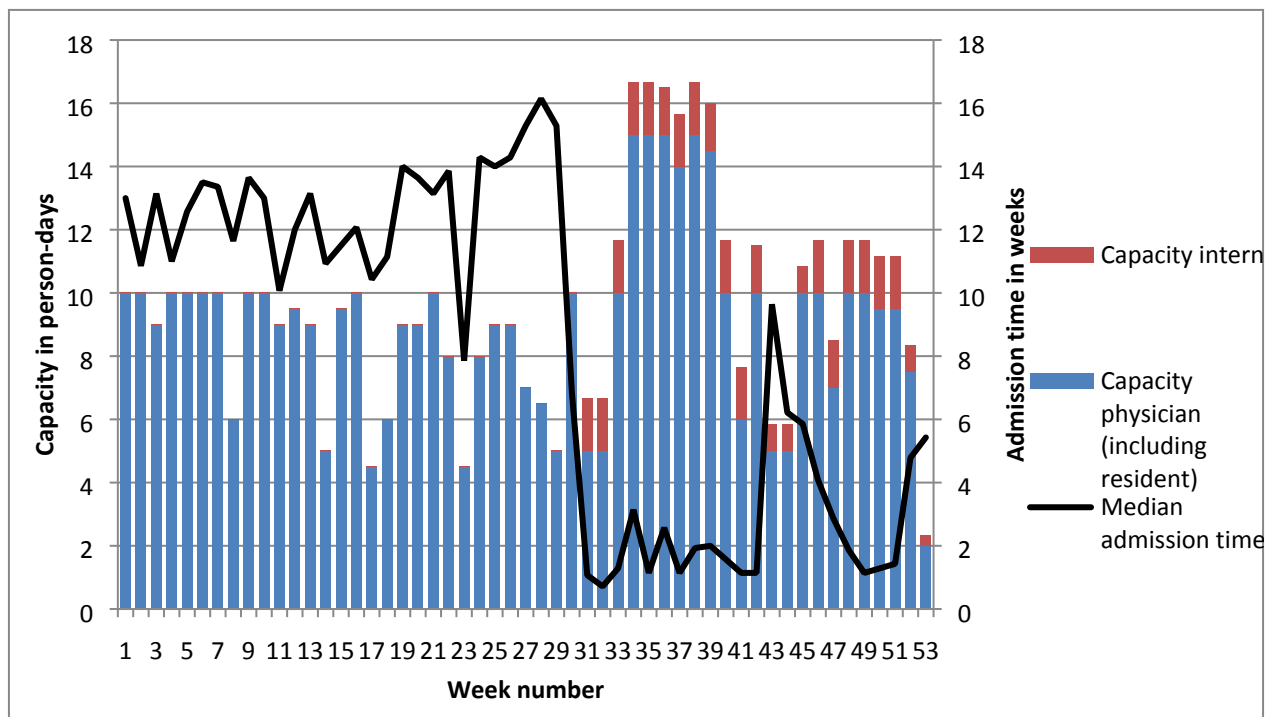
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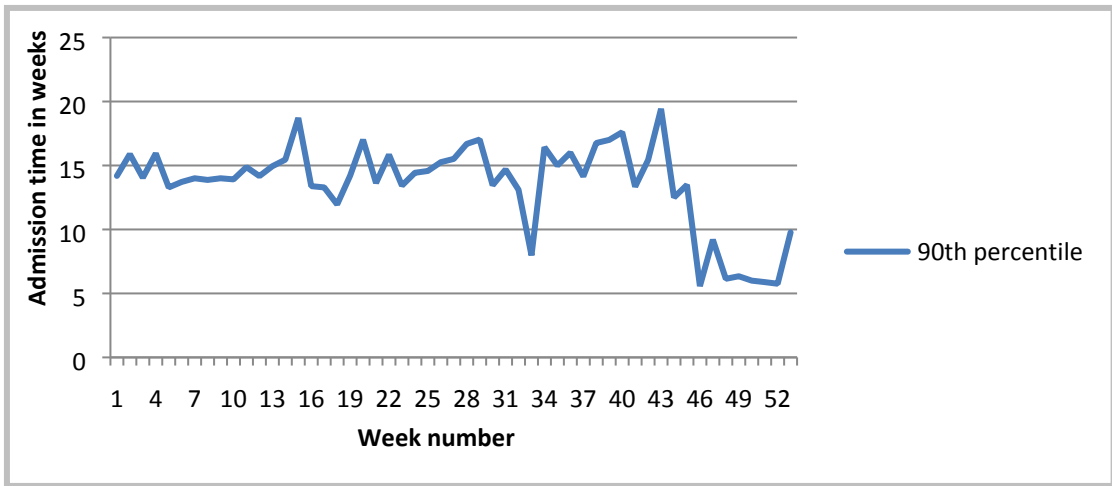
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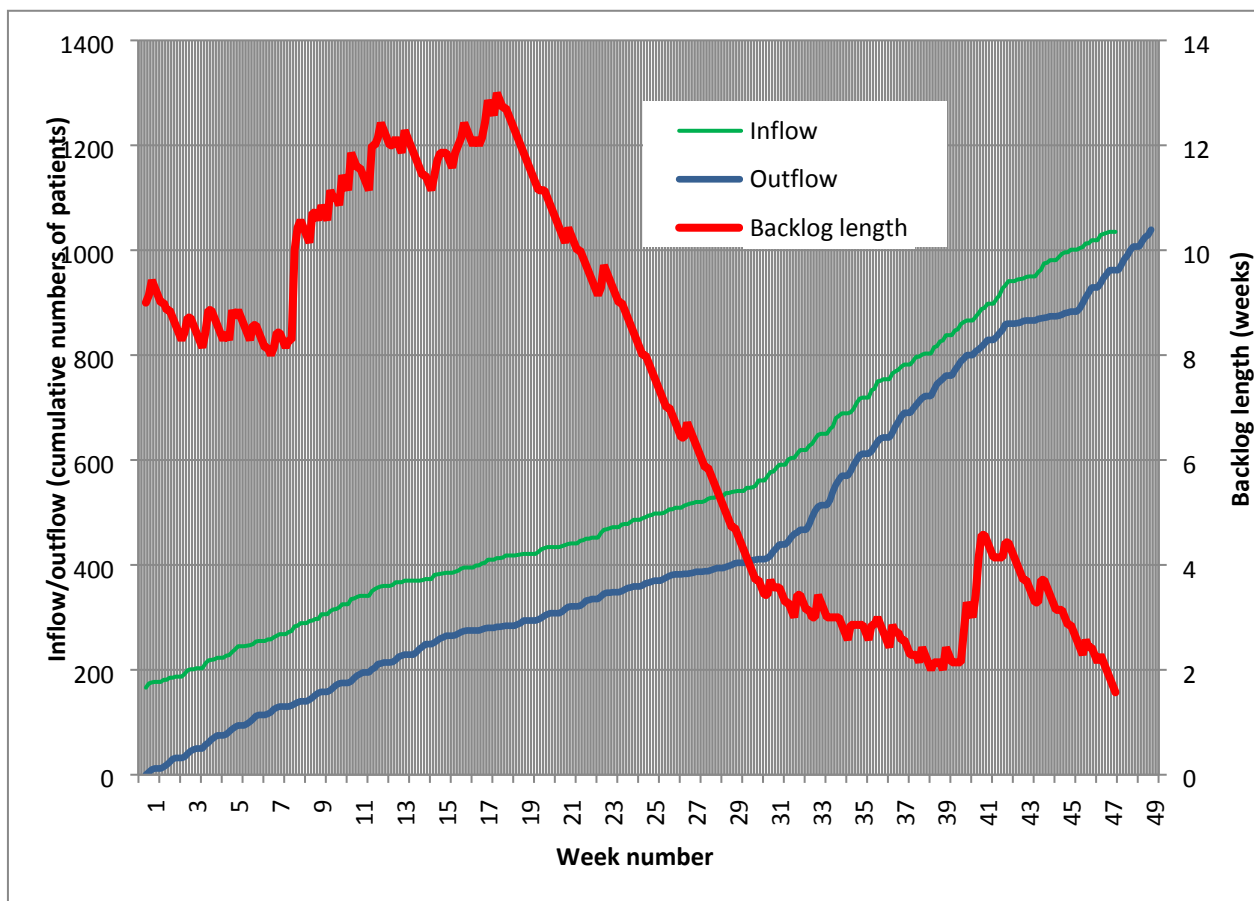


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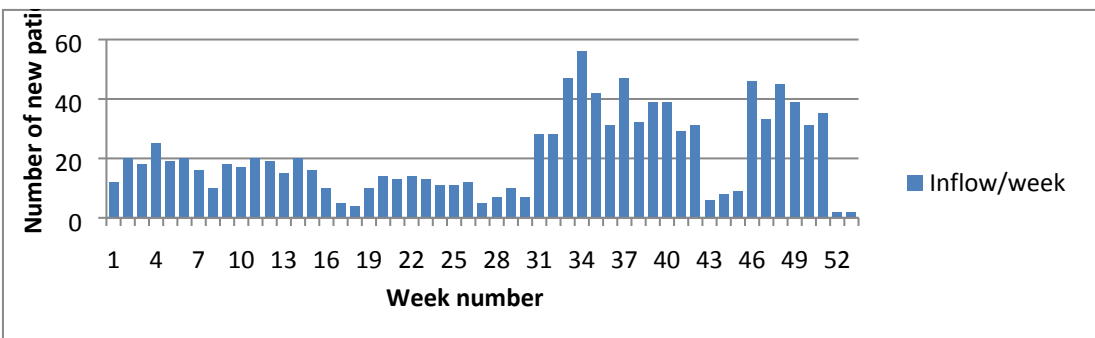
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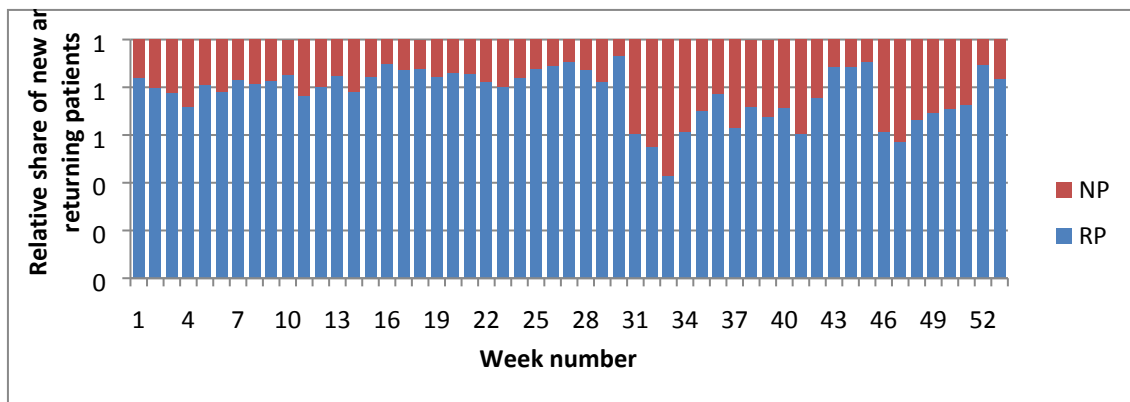
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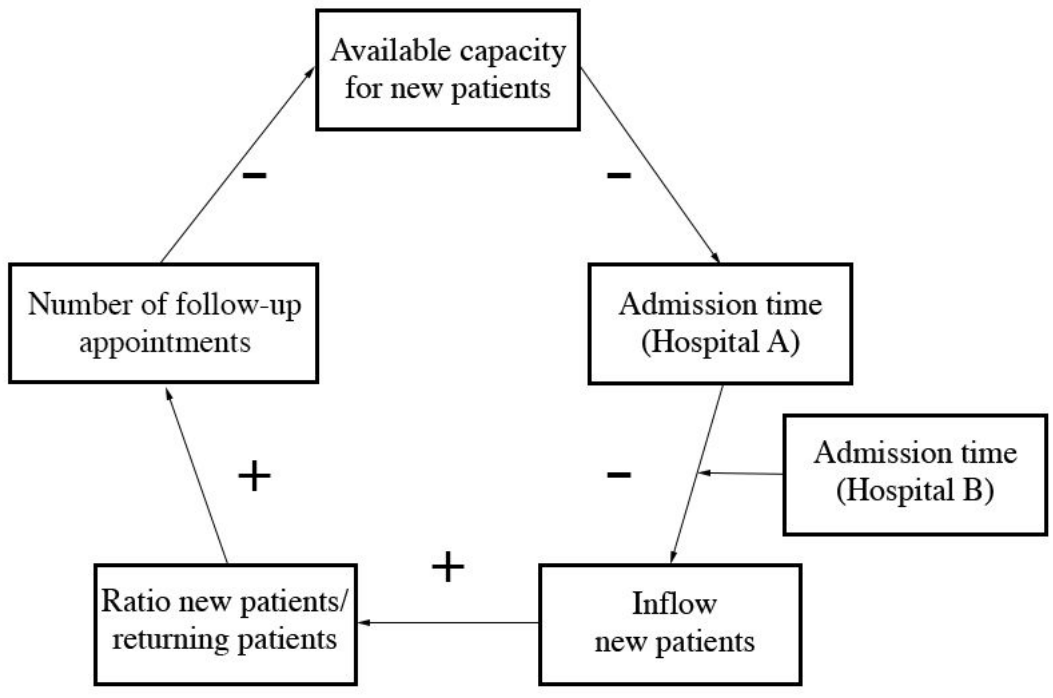


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## Standards for Reporting Qualitative Research (SRQR)

### Report for:

# The adverse impact of increasing capacity to reduce admission times

Note: page and line numbers are based on proof (pdf).

	Page/line no(s).
<b>Title and abstract</b>	
<b>Title</b> - Concise description of the nature and topic of the study Identifying the study as qualitative or indicating the approach (e.g., ethnography, grounded theory) or data collection methods (e.g., interview, focus group) is recommended	P1/L7, P2/L5
<b>Abstract</b> - Summary of key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results, and conclusions	P2/L9-35
<b>Introduction</b>	
<b>Problem formulation</b> - Description and significance of the problem/phenomenon studied; review of relevant theory and empirical work; problem statement	P3/L5-46
<b>Purpose or research question</b> - Purpose of the study and specific objectives or questions	P3/L47,48
<b>Methods</b>	
<b>Qualitative approach and research paradigm</b> - Qualitative approach (e.g., ethnography, grounded theory, case study, phenomenology, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g., postpositivist, constructivist/ interpretivist) is also recommended; rationale**	P4/L15-20
<b>Researcher characteristics and reflexivity</b> - Researchers' characteristics that may influence the research, including personal attributes, qualifications/experience, relationship with participants, assumptions, and/or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results, and/or transferability	P4/L41-47
<b>Context</b> - Setting/site and salient contextual factors; rationale**	P4/L24-38
<b>Sampling strategy</b> - How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g., sampling saturation); rationale**	P4/L5-13

1 2 3	<b>Ethical issues pertaining to human subjects</b> - Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues	P10/L25
4 5 6 7 8	<b>Data collection methods</b> - Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources/methods, and modification of procedures in response to evolving study findings; rationale**	P4/L40-55
9 10 11 12 13	<b>Data collection instruments and technologies</b> - Description of instruments (e.g., interview guides, questionnaires) and devices (e.g., audio recorders) used for data collection; if/how the instrument(s) changed over the course of the study	P4/L41-51
14 15 16 17	<b>Units of study</b> - Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results)	P4/L32-38
18 19 20 21	<b>Data processing</b> - Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymization/de-identification of excerpts	P4/L59-P5/L26
22 23 24 25	<b>Data analysis</b> - Process by which inferences, themes, etc., were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale**	P4/L59-P5/L26
26 27 28 29	<b>Techniques to enhance trustworthiness</b> - Techniques to enhance trustworthiness and credibility of data analysis (e.g., member checking, audit trail, triangulation); rationale**	P4/L41-55

### Results/findings

31 32 33 34 35	<b>Synthesis and interpretation</b> - Main findings (e.g., interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory	P5/L37-P7/L37
36 37 38 39	<b>Links to empirical data</b> - Evidence (e.g., quotes, field notes, text excerpts, photographs) to substantiate analytic findings	P6/L9,L20,L48 P7/L9,L20 (Figures)

### Discussion

40 41 42 43 44 45 46 47 48	<b>Integration with prior work, implications, transferability, and contribution(s) to the field</b> - Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application/generalizability; identification of unique contribution(s) to scholarship in a discipline or field	P7/L40-P9/L40
49	<b>Limitations</b> - Trustworthiness and limitations of findings	P9/L41-52

### Other

50 51 52 53	<b>Conflicts of interest</b> - Potential sources of influence or perceived influence on study conduct and conclusions; how these were managed	P10/L24
54 55 56	<b>Funding</b> - Sources of funding and other support; role of funders in data collection, interpretation, and reporting	P10/L23

1 \*The authors created the SRQR by searching the literature to identify guidelines, reporting  
2 standards, and critical appraisal criteria for qualitative research; reviewing the reference  
3 lists of retrieved sources; and contacting experts to gain feedback. The SRQR aims to  
4 improve the transparency of all aspects of qualitative research by providing clear standards  
5 for reporting qualitative research.  
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8 \*\*The rationale should briefly discuss the justification for choosing that theory, approach,  
9 method, or technique rather than other options available, the assumptions and limitations  
10 implicit in those choices, and how those choices influence study conclusions and  
11 transferability. As appropriate, the rationale for several items might be discussed together.  
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13  
14 **Reference:**

15 O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. **Standards for reporting qualitative**  
16 **research: a synthesis of recommendations.** *Academic Medicine*, Vol. 89, No. 9 / Sept 2014  
17 DOI: 10.1097/ACM.0000000000000388  
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# BMJ Open

## The adverse impact of increasing capacity to reduce access times

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**TITLE PAGE****The adverse impact of increasing capacity to reduce access times**

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# The adverse impact of capacity increases to reduce access times

## ABSTRACT

**Objectives:** To investigate the consequences of increasing capacity to reduce access times, and to explore how patient waiting times and use of physical capacity were influenced by variability.

**Design:** A retrospective case study that combines both primary and secondary data. Secondary data were retrieved from a hospital database in order to establish inflow and outflow of patients, utilisation of resources and available capacity, realised access times and the weekly number of new patients seen over one year. Primary data consisted of field notes, on-site visits and observations, and semi-structured interviews.

**Setting:** A secondary care facility, i.e. a rheumatology department, in a large Dutch hospital.

**Participants:** Analyses are based on secondary patient data from the hospital database, and the responses of the interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.

**Results:** The study shows that artificial variability was increased by managerial decisions to add capacity and to allow an increased inflow of new patients. This, in turn, resulted in undesirable and significant fluctuations in access times. We argue that we witnessed a new multiplier effect that typifies the fluctuations.

**Conclusions:** Adding capacity resources to reduce access times might appear an obvious and effective solution. However, the outcomes were less straightforward than expected, and even led to new artificial variability. The study reveals a phenomenon that is specific to service environments, and especially healthcare, and has detrimental consequences for access times.

Keywords: patient waiting times; variability; buffers; hospitals

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study provides knowledge as to the effectiveness of increasing capacity buffers in order to reduce hospital access times.
- A particular strength of this study relates to the novel structured approach adopted to investigate hospital access times that generates a thorough understanding of actions to reduce these and their consequences over a prolonged period.
- Another strength of this study is its combination of both objective performance data retrieved from the hospital database and subjective qualitative data to explain past occurrences.
- Although the dyadic structure of GPs and a small rheumatology department with new and returning patients is relatively simple and open to analysis, it does not represent the more complex networks with multiple interdependencies seen in many other situations.
- Another limitation relates to the adopted single case study approach which limits the generalisability of the findings, although the phenomena we identify are widely relevant and not unique to the setting.

## Introduction

It seems very logical that, when confronted with long access times, one increases capacity to more quickly serve clients: an obvious solution to a clear problem, or so it appears. However, this study shows the possible adverse consequences of adding physical capacity in order to reduce access times, which we define as the time between referral from the GP to the first visit of the patient to the rheumatology department. In addition, we provide a theoretical frame of reference to help understand the underlying mechanism that causes the adverse effects.

Patient flow is a topic of ongoing interest in healthcare research[1-4]. However, obtaining flow is not easy, and one has to be sensitive to barriers such as limited internal integration[5], paradoxes such as improvements that target parts of a system, but fail to address underlying system constraints[6], and strategies that do not address the linkages between process, population and capacity[7]. Especially, limited capacity can be a considerable bottleneck that impedes patient flow. Hence, it makes sense to increase capacity to alleviate this process constraint[8]. In turn, a smooth patient flow is obtained, characterised by short patient waiting times.

In our study, we are especially interested in the access time as a specific type of waiting time. Achieving short access times is important for healthcare providers: reducing access times can positively affect the patients' condition (e.g. by reducing pain), and can prevent further problems as medical conditions can deteriorate while waiting for treatment[9,10]. Despite this, consistently achieving short access times is difficult. One of the main barriers to achieving short access times, and short waiting times in general, is variability[11].

One can distinguish between natural and artificial variabilities[12-14]. Natural variability is inevitable in healthcare and can only be controlled to a very limited extent: natural variability is a 'fact of life', for example the different responses to similar treatment between patients. In contrast, artificial variability is caused by our own actions, routines or regulations. For example, variability stemming from providing inconsistent quality of referral information by GPs[15]. This type of variability can and should be controlled and reduced. (For a more elaborate discussion of artificial variability, and related examples please visit [16].)

The mechanisms that allow an organisation, or more precisely a process, to cope with variability are termed buffers. Some form of buffer will be required to cope with variability in either supply or demand[17]. The available buffers in a healthcare environment consist of time buffers (waiting patients) and capacity buffers (idle resource capacity)[18]. Healthcare is thus faced with a trade-off between either waiting patients or idle capacity, both of which are unattractive. Buffers are the natural result of a system that has to cope with variability, but one should continuously attempt to minimise buffers and reduce their underlying causes[19].

Increasing capacity buffers seem to be the most effective solution if one wants to reduce the time buffers represented by hospital access times. However, during a recent improvement project, we witnessed adverse outcomes from expanding capacity to cope with long access times. This led us to the following research question: why does expanding capacity lead to variation in patient waiting times? This study aims to contribute to knowledge on the dynamic relationship between variability and patient waiting times, and to the understanding of fluctuations in hospital access times.

In the remainder of this paper, we first introduce the methodology applied by explaining the hospital setting and the approaches used in obtaining and analysing the empirical data. Following this, we present the results of our analysis, and then a discussion reflecting on the interaction between variability and buffers. This interaction turned out

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4 to be less straightforward than expected. This paper then ends with the conclusions in  
5 which we highlight our main contributions.  
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## 8 **Methods**

9 The research setting for this study was the rheumatology department of a Dutch teaching  
10 hospital. The hospital had embarked on an improvement programme with several projects  
11 focussing on improving flow performance. These projects allowed us to study the impact  
12 of actions aimed at reducing access times defined as the time from the referral of the GP  
13 to the first visit of the rheumatology department. The rheumatology department employed  
14 two specialists (physicians), a specialised nurse practitioner and a rheumatology patient  
15 advisor that together served 9,277 patients in 2013. As the access time was rather long  
16 (up to 16 weeks) and the utilisation rate of the two physicians was high, the hospital board  
17 decided to initiate an improvement project.  
18

19 The aim of this research was to understand the complex interaction between variability  
20 and buffers. To study a complex phenomenon in its natural setting we applied the single  
21 retrospective case study methodology[20]. Whilst our study was quantitative in nature,  
22 we have added a qualitative component to explain past events, and strengthen our  
23 understanding of the identified phenomenon. The data gathered was used to study the  
24 interaction between variability and buffering and the fluctuations in access times through  
25 an operations management lens, a perspective especially appropriate for issues related to  
26 patient flow.  
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### 29 *Case description*

30 The typical patient pathway in our case setting is as follows. A patient experiences  
31 problems with their joints, and visits their general practitioner (GP). The GP will refer the  
32 patient to a rheumatologist, who will examine the patient at an outpatient clinic. If deemed  
33 necessary, the rheumatologist will request additional diagnostic tests (an ultrasound  
34 examination, X-ray, blood test etc.). The rheumatologist will then discuss a treatment plan  
35 with the patient and notify their GP. Alongside the rheumatologists, the nurse practitioner  
36 serves a small, predefined, group of new patients whose symptoms lack complexity.  
37

38 The rheumatology department distinguishes three types of consultation requests  
39 determined by the perceived urgency of the problem: 1) regular, 2) semi-urgent and 3)  
40 urgent patients. Of the new patient arrivals, 7% are considered urgent and 6% semi-  
41 urgent. Standard access times, have been predetermined for urgent and semi-urgent  
42 patients (two weeks and four weeks respectively). No target access time has been set for  
43 'regular' patients who form the majority of new arrivals. Before the improvement project  
44 was initiated, the average access time across patients was around 10 weeks with peaks up  
45 to 16 weeks.  
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### 49 *Data sources*

50 This study combines several secondary data sources from the hospital database: inflow  
51 and outflow (new arrivals and patients leaving the system), utilisation of resources and  
52 available capacity, realised access times and the number of new patients per week over  
53 one year (2013). In addition to these secondary data sources, we acquired primary  
54 qualitative data through keeping field notes, onsite visits and observations, and semi-  
55 structured interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.  
56

57 During the interviews, questions were focused on obtaining in-depth information on  
58 possible sources of variability. We used an interview protocol to enhance both the  
59 reliability and the validity of the research[20]. Combining objective quantitative and  
60 subjective qualitative data contributes to the accuracy and reliability of case study

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4 research[20]. In addition, the physicians, nurses and LSS project leaders had a crucial role  
5 during a focus group meeting in which we reflected on the outcomes of the analyses and  
6 attempted to build an understanding what had occurred.  
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### 10 *Analysis approach*

11 This study required an in-depth exploration of access time data, for which there is no  
12 standard approach. Therefore, the initial analysis involved calculating the median and  
13 mean access times for each week. The median is often used in analyses of highly variable  
14 data because it is less sensitive to outliers than the mean. In addition, we performed an  
15 independent sample t-test on the means of the access times to compare the pre- and post-  
16 intervention periods.  
17

18 Next to median access times, we calculated the 90<sup>th</sup> percentile of the access times for  
19 each week to detect whether any apparent changes in access times affected a large  
20 majority (i.e. at least 90%) of patients. We constructed diagrams that relate capacity and  
21 access times over time, through which we provide insights into the dynamics of time and  
22 capacity buffers.  
23

24 To deepen the analysis of flow-related variables, we followed a previously used  
25 approach[21] making use of throughput diagrams that show both cumulative patient  
26 inflow and outflow curves over time. The vertical distance between the two curves  
27 reflects the number of waiting patients while the horizontal distance reflects the backlog  
28 in terms of time. The behaviour of these two variables can be analysed over time and at  
29 the same time be related to fluctuating patient inflow and outflow rates. As such it is  
30 particularly useful in dynamic situations where the averages change over time. Finally,  
31 the relative share of new and returning patients was analysed to detect any ratio changes  
32 over time.  
33

34 In the analyses, the weekly capacity in person-days is calculated based on the number  
35 of scheduled physicians and corrected for any absences. The capacity information is based  
36 on the available calendars of the physicians. This capacity is allocated to new and  
37 returning patients.  
38  
39

### 40 *Patient and Public Involvement statement*

41 This research did not involve patients in the design, conduct and reporting of the research.  
42 The results of this work were presented and discussed during a focus group meeting with  
43 representatives of the hospital. Once the study has been published, the main findings will  
44 be used in the education of Master students.  
45  
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## 47 **Results**

48 Figure 1 depicts the capacity in person-days each week and the access times (in weeks)  
49 for patients being referred by their GP in that week. The analysis shows that, up to week  
50 31, the maximum capacity was 10 person-days, i.e. two full-time physicians.  
51

52 In an attempt to reduce the access times an intern (shown in red) provided additional  
53 capacity from week 31. In addition, in weeks 33 through 39, a resident provided a further  
54 temporary boost to capacity. Here, we note that the productivity of the resident was  
55 expected to be similar to that of the rheumatologists, whereas the intern would achieve  
56 roughly one third of their output due to a lack of experience. The graph is adjusted to  
57 reflect this difference. In effect, by increasing staff, the department sought to replace time  
58 buffers (waiting patients) with capacity buffers (additional physicians).  
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60 The expansion in capacity resulted in an almost immediate drop in access times from  
week 31 onwards. The reduction of access times, measured in days, for individual patients

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4 is significant at a level of  $p=0,000$  when comparing patients that arrived in weeks 1-29  
5 (M=72, SD=42) with patients that arrived in week 32-52 (M=29, SD=38). Weeks 30 and  
6 31 have been excluded as the transition period. In terms of variability, Figure 1 shows  
7 that the actual capacity in just over half of the weeks of the first 6 months was below the  
8 notional 10 person-days, and often significantly so. That is, there were more weeks in  
9 which at least one rheumatologist was partly absent than weeks in which both were fully  
10 present. This illustrates that, in this case, capacity availability is a relevant source of  
11 artificial variability.  
12

13 Furthermore, Figure 1 shows that, in week 28, more than half of the appointments  
14 made had an access time of at least 16 weeks in the future (the median value). Whereas,  
15 in week 32, half of the appointments made were for within one week. In other words,  
16 patients that sought an appointment in week 28 often had to wait a further 16 weeks for  
17 their meeting with a physician, whereas patients that joined the list in week 32 would  
18 usually see their physician within a few days.  
19

20  
21 <insert Figure 1 about here>  
22

23 Figure 1. Weekly capacities in person-days and median access times  
24

25 When we look at the 90<sup>th</sup> percentile of recorded access times (Figure 2), there is no  
26 equivalent and sustained immediate improvement after week 31, indicating that a  
27 substantial number of patients still experienced lengthy access times. However, from  
28 week 46 on, there was a significant drop in the 90<sup>th</sup> percentile, indicating that the access  
29 times for the majority of patients had decreased in the final weeks of the year.  
30

31  
32 <insert Figure 2 about here>  
33

34 Figure 2. 90<sup>th</sup> percentile of access times  
35

36 Influences on access times can also be analysed using throughput diagrams (Figure 3).  
37 The vertical axis shows cumulative numbers of patients. The upper (green) curve  
38 represents the cumulative inflow and the lower (blue) curve the cumulative outflow. To  
39 ensure data validity, the inflow curve is not shown after week 47 because some of the  
40 patients then applying for appointments might not have access until the first weeks of the  
41 following year, which would distort any conclusions.  
42

43 The horizontal distance between the two curves in Figure 3 is the backlog (in weeks)  
44 and can be interpreted as the projected access time for a patient requesting an appointment  
45 at that point in time. A red curve, representing this horizontal distance, is included, with  
46 values indicated on the secondary vertical axis. For example, the 400<sup>th</sup> request for an  
47 appointment (inflow) was made in week 17, and the 400<sup>th</sup> appointment (outflow) was  
48 scheduled for week 29 (but not necessarily the same patient). This means that a patient  
49 joining the queue in week 17 could, on average, expect an access time of 12 weeks,  
50 whereas by the 800<sup>th</sup> patient (arriving in week 38) the expected access time was down to  
51 2 weeks. Compared to the representations in Figures 1 and 2, this diagram has the  
52 advantage of being less sensitive to individual deviations from the typical access times.  
53 It provides a global view of how access times develop and how they can be related to  
54 surges or drops in patient inflow or outflow. More specifically, Figure 3 shows how the  
55 decrease in mean access times from week 31 onwards was indeed linked to a surge in  
56 outflow, rather than a drop in inflow. As such it was clearly the result of the capacity  
57 increase.  
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<insert Figure 3 about here>

Figure 3. Throughput diagram including derived mean access times

Along with the sudden decrease in access times due to the increase in capacity, the number of new patients being referred by their GPs increased significantly. For example, Figure 4 shows an increase from 10 new referrals in week 29 to 30 in week 31.

From the interviews, we learnt that referrers (i.e. GPs) select those hospitals that have the shortest access times. An unforeseen consequence of this was that the drastically reduced access times in the studied unit had a pulling or magnetic effect. Once the extra capacity was added, extra slots became available which allowed the hospital to offer very short access times. As such, the system responded quickly through a market mechanism based on access times. Being aware of the dramatically reduced access times, GPs directly started to refer a greater proportion of their patients to this hospital.

<insert Figure 4 about here>

Figure 4. Weekly inflow of new patients

This sudden inflow had consequences for the ratio of new to returning patients, which also changed from week 31 onwards. In the first 30 weeks of the year, there were typically about 13 new patients per week (Figure 4) representing 15-20% of the patients seen (Figure 5). However, in weeks 31-49, the average number of new patients increased sharply to an average of 28 per week, while the proportion of new patients correspondingly increased to 30-40% as of week 31 (Figures 4 and 5).

<insert Figure 5 about here>

Figure 5. Relative share of new (NP) and returning patients (RP) per week

These additional new patients continued to fill the system. However, the increased inflow had a multiplier effect as each new patient admitted would typically have four follow-up appointments in the year following their first visit. In the worst-case scenario, this could result in a situation where there would be insufficient capacity for returning patients.

When we reflect upon our findings, the actions of the department seem to have triggered a potential amplification of its backlog. First, by adding capacity, and second by then accepting more new patients than the department would be able to cope with in the longer term. While we do not have accurate database information for the following year, the interviews provided information that new capacity problems did emerge. These capacity problems were a consequence of the vicious cycle that was started by deliberately expanding capacity and occurred despite the best intentions to reduce waiting times and increase patient care quality and satisfaction.

## Discussion

In this case study, we focused on the access times and the capacity management of a hospital's rheumatology department. We first revisit the research question before considering the general implications of our study.

The main research question focused on how patient waiting times vary following an expansion in capacity. Our analysis revealed that the local managerial decision to temporarily add extra capacity to reduce the backlog (i.e. shorten access times) had a magnetic effect on GPs who then referred many more patients to this hospital rather than

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4 elsewhere. The increase in new patients and, as a consequence, the avalanche of follow-  
5 up appointments was disproportionate to the extra capacity.

6 Furthermore, the decision to allow a significant increase in the inflow of new patients  
7 once this new capacity was added resulted, at least in the short term, in a substantial  
8 change in the ratio of new to returning patients. With a surge in new patients, most of  
9 whom would need four follow-up appointments; it was inevitable that the department  
10 would later become overwhelmed with these new patients requiring multiple returning  
11 appointments.

12  
13 Reductions of waiting time result in increased inflow. However, in this case the  
14 temporary aspect of the waiting time reduction affects capacity supply in the short term,  
15 while creating even more demand for the same capacity in the longer term. A different  
16 approach towards waiting time reduction, such as process improvements, would arguably  
17 have had a smoother and more structural impact. Also these process improvements could  
18 have been expected to lead to increased inflow, but at a level that matched the structural  
19 capacity, such that a new equilibrium could be established based on shorter waiting times.

20  
21 In hindsight, two local decisions, to increase capacity and to use this to accept many  
22 more new patients, were important sources of artificial variability which triggered a self-  
23 inflicted multiplier effect. This effect was initially considered as a potential example of a  
24 service bullwhip effect. The service bullwhip effect also relates to a trigger event in a  
25 supply chain that induces demand distortion[22]. However, we argue for a simpler  
26 multiplier effect to have taken place. We have constructed a causal network of the  
27 rheumatology situation, Figure 6, to further explore this multiplier effect.

28  
29 The network shows that a sharp decrease in the department's access times (here  
30 referred to as hospital A) caused GPs to switch their demand by opting to refer patients  
31 to hospital A rather than elsewhere (hospital B). This was possible because GPs were  
32 aware of the improved access time offered by hospital A, which distinguished it from  
33 hospital B. This resulted in a sharp increase in the inflow of new patients of whom an  
34 unlimited number were accepted (although one would expect the access times to  
35 eventually increase as appointments fill up until a new equilibrium is reached with  
36 hospital B). This boosted the ratio of new to returning patients, and resulted in a massive  
37 increase in demand for follow-up appointments due to a multiplier effect with typically  
38 four returning visits in the year following first visit. The increase in follow-up  
39 appointments absorbed all the available capacity, which had a negative effect on the  
40 access times offered to future new patients.

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45 <insert Figure 6 about here>

46 Figure 6. Causal network of the rheumatology situation

47  
48 It is striking to see that the increase in new patients has a self-reinforcing effect on the  
49 demand for physician capacity due to the multiplier effect of follow-up appointments.  
50 This reinforcing effect reveals itself in the next stage of the supply chain and is typical  
51 for healthcare environments where follow-ups are common. The increase in inflow is the  
52 consequence of continuous and instantaneous information sharing between the hospital  
53 (and its rheumatology department) and GPs. Earlier, the GPs' ability to select hospitals  
54 based on their access times, acted as a variability absorbing or stabilizing mechanism in  
55 case of 'normal' variability and gradual changes in wait times. For example, as soon as  
56 one of the hospitals would tend to get to a higher inflow of patients and hence increased  
57 access times, the GPs' responded by selecting different hospitals in the system. In turn,  
58 this would bring the inflow level back to the original level, rebalancing the system load.  
59 However, in this case the temporary capacity change disturbed this self-stabilizing  
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4 mechanism. The case stresses that it is insufficient to rely on a local supply chain  
5 perspective. Here, system awareness is necessary and this requires considering the  
6 referral behaviour of GPs and the delivery performance of other competing hospitals  
7 when addressing variability and buffers. The market mechanism, based on access times,  
8 that this case study has highlighted, clearly requires a system view to smooth the demand  
9 and keep long-term access times at an acceptable level.  
10

11 The theoretical contributions of this study are threefold. First, we contribute to the  
12 knowledge on flow, and consequently the ‘theory of swift and even flow’[19] by  
13 positioning artificial variability as a managerial problem that negatively affects flow, and  
14 we show the possible negative effect of a common buffering approach. The addition of  
15 capacity would normally be a means to buffer against day-to-day variability. However, it  
16 now became a ‘disturbing’ factor or source of variability itself for longer term variability.  
17 Based on this study, and given the dynamics of the complex interaction between  
18 variability and buffers, we stress the need to apply a system view when pursuing flow  
19 improvements. Introducing poorly informed local policies can negatively affect flow[7].  
20

21 Second, we contribute to the knowledge base on the role of variability in healthcare  
22 environments[13,14,23]. The hospital’s well-intended actions caused inflow variability,  
23 here our study provides an example of unexpected outcomes related to improvement  
24 initiatives. We showed a multiplier effect, one that was self-inflicted and caused by  
25 decision-making being based on a local rather than a system perspective. Given the  
26 existence of a market mechanism based on access times, supply chain partners need to  
27 make decisions based on an overview of available ‘market information’, and be sensitive  
28 to regional effects. This decision to allow new patients has strong similarities with  
29 Roemer’s Law[24,25], which underlines that available capacity will be utilized.  
30

31 Third, we contribute to the growing knowledge base on process improvement, which  
32 includes approaches such as Six Sigma and lean thinking[26,27]. Earlier research  
33 identified three paradoxes in healthcare improvement initiatives: 1) improvement  
34 initiatives target parts of a system, but fail to address underlying system constraints, 2)  
35 local improvements do not account for regional integration, and 3) rules that improve the  
36 service organization for one department may create obstacles for other departments [6].  
37 Our results provide illustrations of these paradoxes. In addition, by confirming the  
38 importance of variability and buffer reduction, an area that has recently received  
39 increasing attention in the literature on lean thinking. Lean is generally considered to  
40 include the concept of *mura*, which reflects unevenness or variability as can be found in  
41 the healthcare field[28]. Hopp [29(p.89)] considers the ‘production of goods or services  
42 to be lean if it is accomplished with minimal buffering costs’. After an initial focus on  
43 direct waste, more mature lean approaches tend to focus on reducing variability and  
44 buffers[29]. This study contributes by providing an example of the interaction between  
45 variability and capacity buffers within a hospital setting.  
46

47 An obvious limitation of this research is that it is based on a single case study, which  
48 consequently limits the generalisability of the findings. Another limitation relates to the  
49 fact that the service supply chain in this paper is a simple dyadic structure of GPs and a  
50 relatively small rheumatology department with new and returning patients. As such, it is  
51 not representative of very complex networks with many interdependencies needing to be  
52 understood. A strength of the study is its combination of objective quantitative and  
53 subjective qualitative data that contributes to the accuracy and reliability of the findings.  
54

55 We would encourage further research aimed at increasing the knowledge on multiplier  
56 effects and the dynamics between variability and buffers. Where this study took a system  
57 perspective, a patient’s perspective on variability and buffers could add an extra  
58 dimension to this field of research.  
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## Conclusions

This research has identified the variation in access times that follows from adding capacity. We have seen that access times are heavily influenced by sources of artificial variability such as managerial decisions about adding capacity and accepting new patients. This can cause undesirable dynamics in the variability-buffer interaction. Our findings lead us to agree with earlier research[30] that concluded that synchronising service supply chains is ‘complex’ and ‘non-intuitive’.

## List of abbreviations

**GP:** General Practitioner

**LSS:** Lean Six Sigma

**NP:** New patients

**RP:** Returning patients

## Declarations

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**Data sharing statement:** The datasets used and/or analysed during the current study are available from the *University of Groningen*. Data are available from the corresponding author on reasonable request.

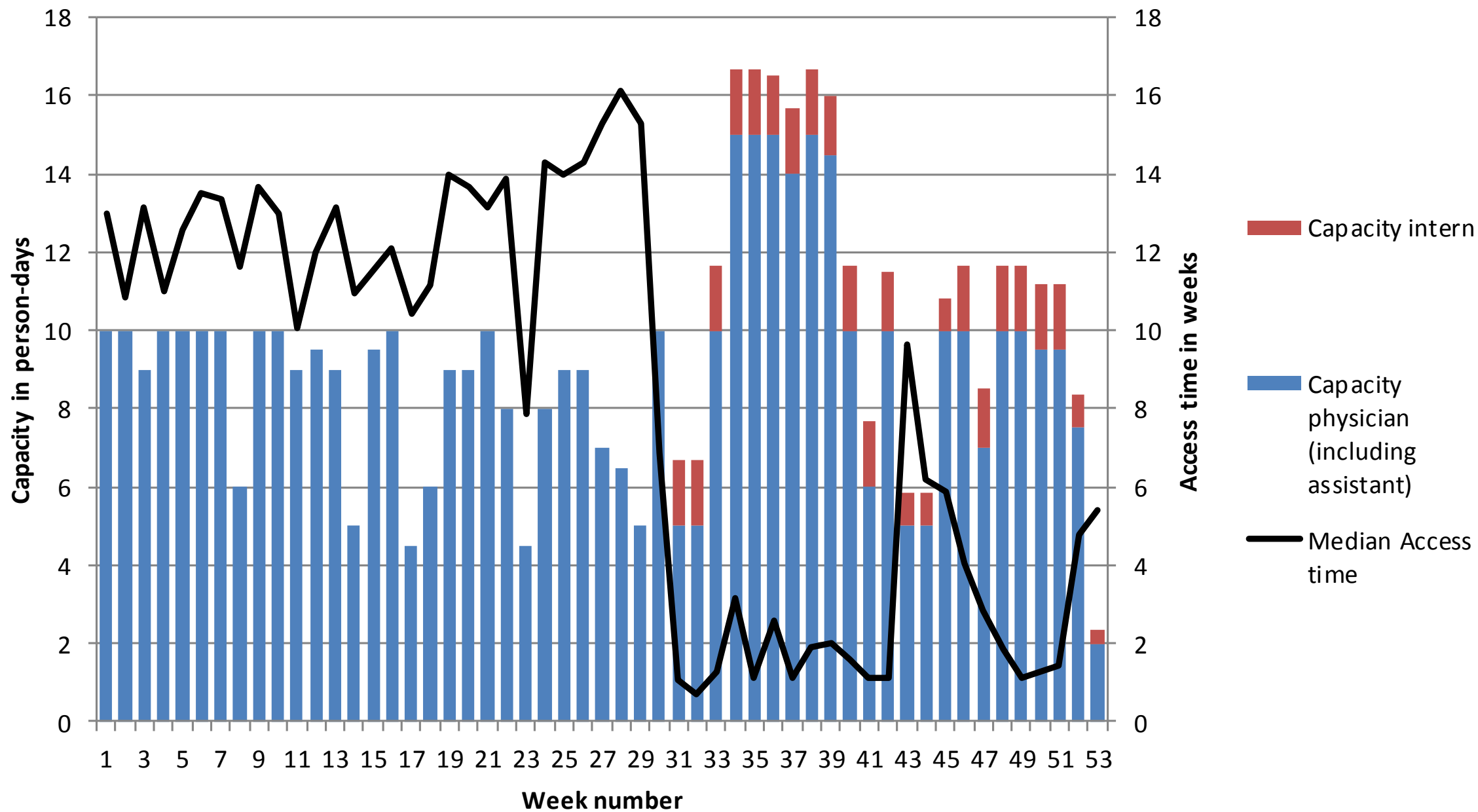
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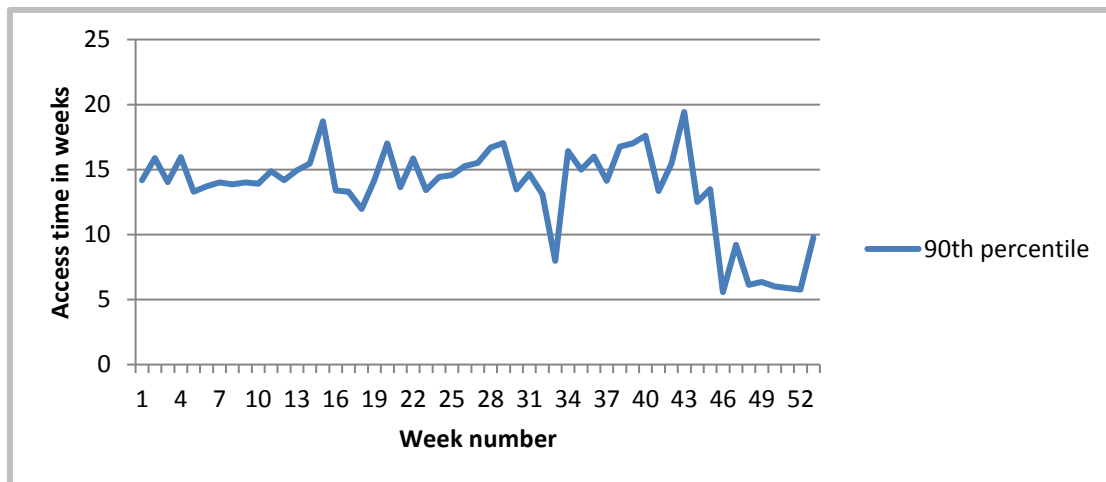
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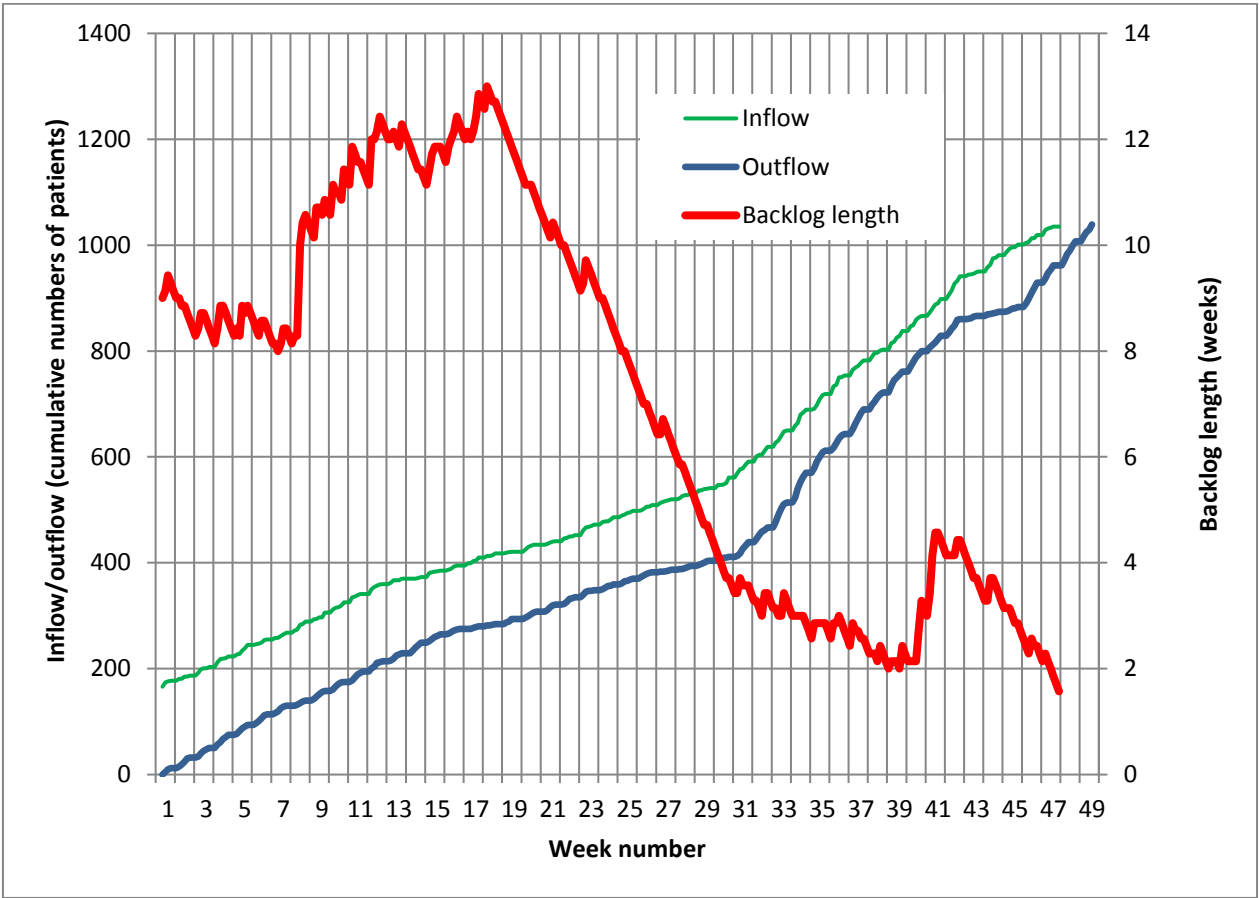
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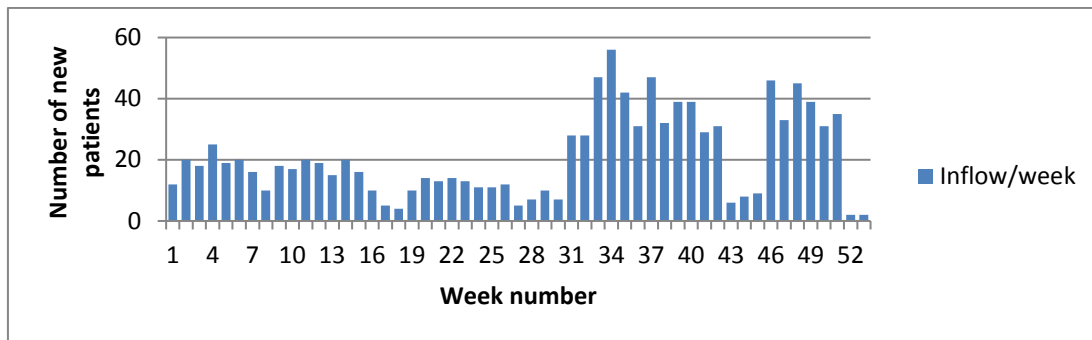


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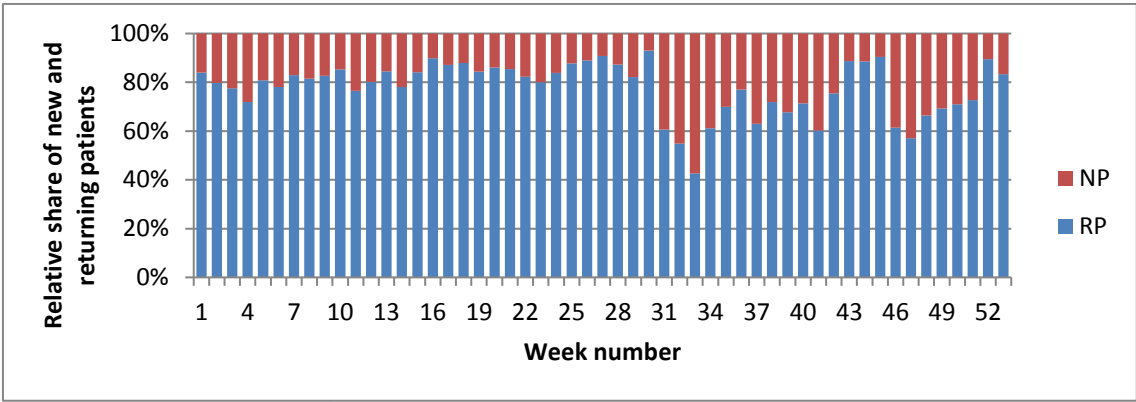
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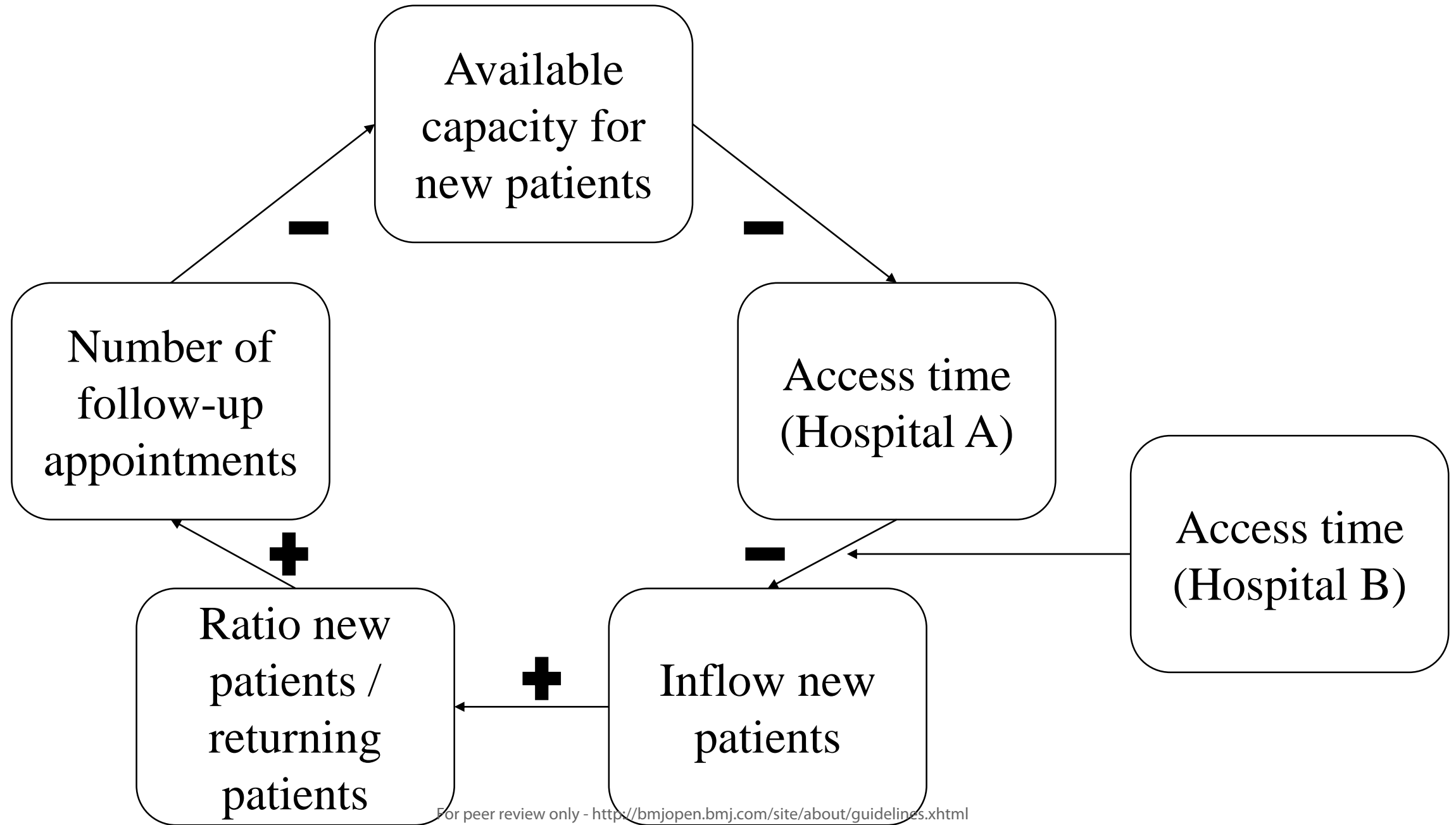
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## Standards for Reporting Qualitative Research (SRQR)

### Report for:

# The adverse impact of increasing capacity to reduce admission times

Note: page and line numbers are based on proof (pdf).

Title and abstract	Page/line no(s).
<b>Title</b> - Concise description of the nature and topic of the study Identifying the study as qualitative or indicating the approach (e.g., ethnography, grounded theory) or data collection methods (e.g., interview, focus group) is recommended	P1/L7, P2/L5
<b>Abstract</b> - Summary of key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results, and conclusions	P2/L9-35
<b>Introduction</b>	
<b>Problem formulation</b> - Description and significance of the problem/phenomenon studied; review of relevant theory and empirical work; problem statement	P3/L5-46
<b>Purpose or research question</b> - Purpose of the study and specific objectives or questions	P3/L47,48
<b>Methods</b>	
<b>Qualitative approach and research paradigm</b> - Qualitative approach (e.g., ethnography, grounded theory, case study, phenomenology, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g., postpositivist, constructivist/ interpretivist) is also recommended; rationale**	P4/L15-20
<b>Researcher characteristics and reflexivity</b> - Researchers' characteristics that may influence the research, including personal attributes, qualifications/experience, relationship with participants, assumptions, and/or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results, and/or transferability	P4/L41-47
<b>Context</b> - Setting/site and salient contextual factors; rationale**	P4/L24-38
<b>Sampling strategy</b> - How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g., sampling saturation); rationale**	P4/L5-13

1 2 3	<b>Ethical issues pertaining to human subjects</b> - Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues	P10/L25
4 5 6 7 8	<b>Data collection methods</b> - Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources/methods, and modification of procedures in response to evolving study findings; rationale**	P4/L40-55
9 10 11 12 13	<b>Data collection instruments and technologies</b> - Description of instruments (e.g., interview guides, questionnaires) and devices (e.g., audio recorders) used for data collection; if/how the instrument(s) changed over the course of the study	P4/L41-51
14 15 16 17	<b>Units of study</b> - Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results)	P4/L32-38
18 19 20 21	<b>Data processing</b> - Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymization/de-identification of excerpts	P4/L59-P5/L26
22 23 24 25	<b>Data analysis</b> - Process by which inferences, themes, etc., were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale**	P4/L59-P5/L26
26 27 28 29	<b>Techniques to enhance trustworthiness</b> - Techniques to enhance trustworthiness and credibility of data analysis (e.g., member checking, audit trail, triangulation); rationale**	P4/L41-55

### Results/findings

30 31 32 33 34 35	<b>Synthesis and interpretation</b> - Main findings (e.g., interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory	P5/L37-P7/L37
36 37 38 39	<b>Links to empirical data</b> - Evidence (e.g., quotes, field notes, text excerpts, photographs) to substantiate analytic findings	P6/L9,L20,L48 P7/L9,L20 (Figures)

### Discussion

40 41 42 43 44 45 46 47 48	<b>Integration with prior work, implications, transferability, and contribution(s) to the field</b> - Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application/generalizability; identification of unique contribution(s) to scholarship in a discipline or field	P7/L40-P9/L40
49	<b>Limitations</b> - Trustworthiness and limitations of findings	P9/L41-52

### Other

50 51 52 53	<b>Conflicts of interest</b> - Potential sources of influence or perceived influence on study conduct and conclusions; how these were managed	P10/L24
54 55 56	<b>Funding</b> - Sources of funding and other support; role of funders in data collection, interpretation, and reporting	P10/L23

1 \*The authors created the SRQR by searching the literature to identify guidelines, reporting  
2 standards, and critical appraisal criteria for qualitative research; reviewing the reference  
3 lists of retrieved sources; and contacting experts to gain feedback. The SRQR aims to  
4 improve the transparency of all aspects of qualitative research by providing clear standards  
5 for reporting qualitative research.  
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8 \*\*The rationale should briefly discuss the justification for choosing that theory, approach,  
9 method, or technique rather than other options available, the assumptions and limitations  
10 implicit in those choices, and how those choices influence study conclusions and  
11 transferability. As appropriate, the rationale for several items might be discussed together.  
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14 **Reference:**

15 O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. **Standards for reporting qualitative**  
16 **research: a synthesis of recommendations.** *Academic Medicine*, Vol. 89, No. 9 / Sept 2014  
17 DOI: 10.1097/ACM.0000000000000388  
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# BMJ Open

## How improving access times had unforeseen consequences: a case study in a Dutch Hospital

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<b>Primary Subject Heading</b>:	Health services research
Secondary Subject Heading:	Health services research, Health economics
Keywords:	patient waiting time, variability, buffers, hospitals

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**TITLE PAGE****How improving access times had unforeseen consequences: a case study in a Dutch Hospital**

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# The adverse impact of capacity increases to reduce access times

## ABSTRACT

**Objectives:** To investigate the consequences of increasing capacity to reduce access times, and to explore how patient waiting times and use of physical capacity were influenced by variability.

**Design:** A retrospective case study that combines both primary and secondary data. Secondary data were retrieved from a hospital database in order to establish inflow and outflow of patients, utilisation of resources and available capacity, realised access times and the weekly number of new patients seen over one year. Primary data consisted of field notes, on-site visits and observations, and semi-structured interviews.

**Setting:** A secondary care facility, i.e. a rheumatology department, in a large Dutch hospital.

**Participants:** Analyses are based on secondary patient data from the hospital database, and the responses of the interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.

**Results:** The study shows that artificial variability was increased by managerial decisions to add capacity and to allow an increased inflow of new patients. This, in turn, resulted in undesirable and significant fluctuations in access times. We argue that we witnessed a new multiplier effect that typifies the fluctuations.

**Conclusions:** Adding capacity resources to reduce access times might appear an obvious and effective solution. However, the outcomes were less straightforward than expected, and even led to new artificial variability. The study reveals a phenomenon that is specific to service environments, and especially healthcare, and has detrimental consequences for access times.

Keywords: patient waiting times; variability; buffers; hospitals

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study provides knowledge as to the effectiveness of increasing capacity buffers in order to reduce hospital access times.
- A particular strength of this study relates to the novel structured approach adopted to investigate hospital access times that generates a thorough understanding of actions to reduce these and their consequences over a prolonged period.
- Another strength of this study is its combination of both objective performance data retrieved from the hospital database and subjective qualitative data to explain past occurrences.
- Although the dyadic structure of GPs and a small rheumatology department with new and returning patients is relatively simple and open to analysis, it does not represent the more complex networks with multiple interdependencies seen in many other situations.
- Another limitation relates to the adopted single case study approach which limits the generalisability of the findings, although the phenomena we identify are widely relevant and not unique to the setting.



## Introduction

It seems very logical that, when confronted with long access times, one increases capacity to more quickly serve clients: an obvious solution to a clear problem, or so it appears. However, this study shows the possible adverse consequences of adding physical capacity in order to reduce access times, which we define as the time between referral from the GP to the first visit of the patient to the rheumatology department. In addition, we provide a theoretical frame of reference to help understand the underlying mechanism that causes the adverse effects.

Patient flow is a topic of ongoing interest in healthcare research[1-4]. However, obtaining flow is not easy, and one has to be sensitive to barriers such as limited internal integration[5], paradoxes such as improvements that target parts of a system, but fail to address underlying system constraints[6], and strategies that do not address the linkages between process, population and capacity[7]. Especially, limited capacity can be a considerable bottleneck that impedes patient flow. Hence, it makes sense to increase capacity to alleviate this process constraint[8]. In turn, a smooth patient flow is obtained, characterised by short patient waiting times.

In our study, we are especially interested in the access time as a specific type of waiting time. Achieving short access times is important for healthcare providers: reducing access times can positively affect the patients' condition (e.g. by reducing pain), and can prevent further problems as medical conditions can deteriorate while waiting for treatment[9,10]. Despite this, consistently achieving short access times is difficult. One of the main barriers to achieving short access times, and short waiting times in general, is variability[11].

One can distinguish between natural and artificial variabilities[12-14]. Natural variability is inevitable in healthcare and can only be controlled to a very limited extent: natural variability is a 'fact of life', for example the different responses to similar treatment between patients. In contrast, artificial variability is caused by our own actions, routines or regulations. For example, variability stemming from providing inconsistent quality of referral information by GPs[15]. This type of variability can and should be controlled and reduced. (For a more elaborate discussion of artificial variability, and related examples please visit [16].)

The mechanisms that allow an organisation, or more precisely a process, to cope with variability are termed buffers. Some form of buffer will be required to cope with variability in either supply or demand[17]. The available buffers in a healthcare environment consist of time buffers (waiting patients) and capacity buffers (idle resource capacity)[18]. Healthcare is thus faced with a trade-off between either waiting patients or idle capacity, both of which are unattractive. Buffers are the natural result of a system that has to cope with variability, but one should continuously attempt to minimise buffers and reduce their underlying causes[19].

Increasing capacity buffers seem to be the most effective solution if one wants to reduce the time buffers represented by hospital access times. However, during a recent improvement project, we witnessed adverse outcomes from expanding capacity to cope with long access times. This led us to the following research question: why does expanding capacity lead to variation in patient waiting times? This study aims to contribute to knowledge on the dynamic relationship between variability and patient waiting times, and to the understanding of fluctuations in hospital access times.

In the remainder of this paper, we first introduce the methodology applied by explaining the hospital setting and the approaches used in obtaining and analysing the empirical data. Following this, we present the results of our analysis, and then a discussion reflecting on the interaction between variability and buffers. This interaction turned out

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4 to be less straightforward than expected. This paper then ends with the conclusions in  
5 which we highlight our main contributions.  
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## 8 **Methods**

9 The research setting for this study was the rheumatology department of a Dutch teaching  
10 hospital. The hospital had embarked on an improvement programme with several projects  
11 focussing on improving flow performance. These projects allowed us to study the impact  
12 of actions aimed at reducing access times defined as the time from the referral of the GP  
13 to the first visit of the rheumatology department. The rheumatology department employed  
14 two specialists (physicians), a specialised nurse practitioner and a rheumatology patient  
15 advisor that together served 9,277 patients in 2013. As the access time was rather long  
16 (up to 16 weeks) and the utilisation rate of the two physicians was high, the hospital board  
17 decided to initiate an improvement project.  
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19 The aim of this research was to understand the complex interaction between variability  
20 and buffers. To study a complex phenomenon in its natural setting we applied the single  
21 retrospective case study methodology[20]. Whilst our study was quantitative in nature,  
22 we have added a qualitative component to explain past events, and strengthen our  
23 understanding of the identified phenomenon. The data gathered was used to study the  
24 interaction between variability and buffering and the fluctuations in access times through  
25 an operations management lens, a perspective especially appropriate for issues related to  
26 patient flow.  
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### 29 *Case description*

30 The typical patient pathway in our case setting is as follows. A patient experiences  
31 problems with their joints, and visits their general practitioner (GP). The GP will refer the  
32 patient to a rheumatologist, who will examine the patient at an outpatient clinic. If deemed  
33 necessary, the rheumatologist will request additional diagnostic tests (an ultrasound  
34 examination, X-ray, blood test etc.). The rheumatologist will then discuss a treatment plan  
35 with the patient and notify their GP. Alongside the rheumatologists, the nurse practitioner  
36 serves a small, predefined, group of new patients whose symptoms lack complexity.  
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38 The rheumatology department distinguishes three types of consultation requests  
39 determined by the perceived urgency of the problem: 1) regular, 2) semi-urgent and 3)  
40 urgent patients. Of the new patient arrivals, 7% are considered urgent and 6% semi-  
41 urgent. Standard access times, have been predetermined for urgent and semi-urgent  
42 patients (two weeks and four weeks respectively). No target access time has been set for  
43 'regular' patients who form the majority of new arrivals. Before the improvement project  
44 was initiated, the average access time across patients was around 10 weeks with peaks up  
45 to 16 weeks.  
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### 49 *Data sources*

50 This study combines several secondary data sources from the hospital database: inflow  
51 and outflow (new arrivals and patients leaving the system), utilisation of resources and  
52 available capacity, realised access times and the number of new patients per week over  
53 one year (2013). In addition to these secondary data sources, we acquired primary  
54 qualitative data through keeping field notes, onsite visits and observations, and semi-  
55 structured interviews with physicians, nurses and Lean Six Sigma (LSS) project leaders.  
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57 During the interviews, questions were focused on obtaining in-depth information on  
58 possible sources of variability. We used an interview protocol to enhance both the  
59 reliability and the validity of the research[20]. Combining objective quantitative and  
60 subjective qualitative data contributes to the accuracy and reliability of case study

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4 research[20]. In addition, the physicians, nurses and LSS project leaders had a crucial role  
5 during a focus group meeting in which we reflected on the outcomes of the analyses and  
6 attempted to build an understanding what had occurred.  
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### 10 *Analysis approach*

11 This study required an in-depth exploration of access time data, for which there is no  
12 standard approach. Therefore, the initial analysis involved calculating the median and  
13 mean access times for each week. The median is often used in analyses of highly variable  
14 data because it is less sensitive to outliers than the mean. In addition, we performed an  
15 independent sample t-test on the means of the access times to compare the pre- and post-  
16 intervention periods.  
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18 Next to median access times, we calculated the 90<sup>th</sup> percentile of the access times for  
19 each week to detect whether any apparent changes in access times affected a large  
20 majority (i.e. at least 90%) of patients. We constructed diagrams that relate capacity and  
21 access times over time, through which we provide insights into the dynamics of time and  
22 capacity buffers.  
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24 To deepen the analysis of flow-related variables, we followed a previously used  
25 approach[21] making use of throughput diagrams that show both cumulative patient  
26 inflow and outflow curves over time. The vertical distance between the two curves  
27 reflects the number of waiting patients while the horizontal distance reflects the backlog  
28 in terms of time. The behaviour of these two variables can be analysed over time and at  
29 the same time be related to fluctuating patient inflow and outflow rates. As such it is  
30 particularly useful in dynamic situations where the averages change over time. Finally,  
31 the relative share of new and returning patients was analysed to detect any ratio changes  
32 over time.  
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34 In the analyses, the weekly capacity in person-days is calculated based on the number  
35 of scheduled physicians and corrected for any absences. The capacity information is based  
36 on the available calendars of the physicians. This capacity is allocated to new and  
37 returning patients.  
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### 40 *Patient and Public Involvement statement*

41 This research did not involve patients in the design, conduct and reporting of the research.  
42 The results of this work were presented and discussed during a focus group meeting with  
43 representatives of the hospital. Once the study has been published, the main findings will  
44 be used in the education of Master students.  
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## 47 **Results**

48 Figure 1 depicts the capacity in person-days each week and the access times (in weeks)  
49 for patients being referred by their GP in that week. The analysis shows that, up to week  
50 31, the maximum capacity was 10 person-days, i.e. two full-time physicians.  
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52 In an attempt to reduce the access times an intern (shown in red) provided additional  
53 capacity from week 31. In addition, in weeks 33 through 39, a resident provided a further  
54 temporary boost to capacity. Here, we note that the productivity of the resident was  
55 expected to be similar to that of the rheumatologists, whereas the intern would achieve  
56 roughly one third of their output due to a lack of experience. The graph is adjusted to  
57 reflect this difference. In effect, by increasing staff, the department sought to replace time  
58 buffers (waiting patients) with capacity buffers (additional physicians).  
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60 The expansion in capacity resulted in an almost immediate drop in access times from  
week 31 onwards. The reduction of access times, measured in days, for individual patients

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4 is significant at a level of  $<p=0,001$  when comparing patients that arrived in weeks 1-29  
5 (M=72, SD=42) with patients that arrived in week 32-52 (M=29, SD=38). Weeks 30 and  
6 31 have been excluded as the transition period. In terms of variability, Figure 1 shows  
7 that the actual capacity in just over half of the weeks of the first 6 months was below the  
8 notional 10 person-days, and often significantly so. That is, there were more weeks in  
9 which at least one rheumatologist was partly absent than weeks in which both were fully  
10 present. This illustrates that, in this case, capacity availability is a relevant source of  
11 artificial variability.  
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13 Furthermore, Figure 1 shows that, in week 28, more than half of the appointments  
14 made had an access time of at least 16 weeks in the future (the median value). Whereas,  
15 in week 32, half of the appointments made were for within one week. In other words,  
16 patients that sought an appointment in week 28 often had to wait a further 16 weeks for  
17 their meeting with a physician, whereas patients that joined the list in week 32 would  
18 usually see their physician within a few days.  
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21 <insert Figure 1 about here>  
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23 Figure 1. Weekly capacities in person-days and median access times  
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25 When we look at the 90<sup>th</sup> percentile of recorded access times (Figure 2), there is no  
26 equivalent and sustained immediate improvement after week 31, indicating that a  
27 substantial number of patients still experienced lengthy access times. However, from  
28 week 46 on, there was a significant drop in the 90<sup>th</sup> percentile, indicating that the access  
29 times for the majority of patients had decreased in the final weeks of the year.  
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32 <insert Figure 2 about here>  
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34 Figure 2. 90<sup>th</sup> percentile of access times  
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36 Influences on access times can also be analysed using throughput diagrams (Figure 3).  
37 The vertical axis shows cumulative numbers of patients. The upper (green) curve  
38 represents the cumulative inflow and the lower (blue) curve the cumulative outflow. To  
39 ensure data validity, the inflow curve is not shown after week 47 because some of the  
40 patients then applying for appointments might not have access until the first weeks of the  
41 following year, which would distort any conclusions.  
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43 The horizontal distance between the two curves in Figure 3 is the backlog (in weeks)  
44 and can be interpreted as the projected access time for a patient requesting an appointment  
45 at that point in time. A red curve, representing this horizontal distance, is included, with  
46 values indicated on the secondary vertical axis. For example, the 400<sup>th</sup> request for an  
47 appointment (inflow) was made in week 17, and the 400<sup>th</sup> appointment (outflow) was  
48 scheduled for week 29 (but not necessarily the same patient). This means that a patient  
49 joining the queue in week 17 could, on average, expect an access time of 12 weeks,  
50 whereas by the 800<sup>th</sup> patient (arriving in week 38) the expected access time was down to  
51 2 weeks. Compared to the representations in Figures 1 and 2, this diagram has the  
52 advantage of being less sensitive to individual deviations from the typical access times.  
53 It provides a global view of how access times develop and how they can be related to  
54 surges or drops in patient inflow or outflow. More specifically, Figure 3 shows how the  
55 decrease in mean access times from week 31 onwards was indeed linked to a surge in  
56 outflow, rather than a drop in inflow. As such it was clearly the result of the capacity  
57 increase.  
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<insert Figure 3 about here>

Figure 3. Throughput diagram including derived mean access times

Along with the sudden decrease in access times due to the increase in capacity, the number of new patients being referred by their GPs increased significantly. For example, Figure 4 shows an increase from 10 new referrals in week 29 to 30 in week 31.

From the interviews, we learnt that referrers (i.e. GPs) select those hospitals that have the shortest access times. An unforeseen consequence of this was that the drastically reduced access times in the studied unit had a pulling or magnetic effect. Once the extra capacity was added, extra slots became available which allowed the hospital to offer very short access times. As such, the system responded quickly through a market mechanism based on access times. Being aware of the dramatically reduced access times, GPs directly started to refer a greater proportion of their patients to this hospital.

<insert Figure 4 about here>

Figure 4. Weekly inflow of new patients

This sudden inflow had consequences for the ratio of new to returning patients, which also changed from week 31 onwards. In the first 30 weeks of the year, there were typically about 13 new patients per week (Figure 4) representing 15-20% of the patients seen (Figure 5). However, in weeks 31-49, the average number of new patients increased sharply to an average of 28 per week, while the proportion of new patients correspondingly increased to 30-40% as of week 31 (Figures 4 and 5).

<insert Figure 5 about here>

Figure 5. Relative share of new (NP) and returning patients (RP) per week

These additional new patients continued to fill the system. However, the increased inflow had a multiplier effect as each new patient admitted would typically have four follow-up appointments in the year following their first visit. In the worst-case scenario, this could result in a situation where there would be insufficient capacity for returning patients.

When we reflect upon our findings, the actions of the department seem to have triggered a potential amplification of its backlog. First, by adding capacity, and second by then accepting more new patients than the department would be able to cope with in the longer term. While we do not have accurate database information for the following year, the interviews provided information that new capacity problems did emerge. These capacity problems were a consequence of the vicious cycle that was started by deliberately expanding capacity and occurred despite the best intentions to reduce waiting times and increase patient care quality and satisfaction.

## Discussion

In this case study, we focused on the access times and the capacity management of a hospital's rheumatology department. We first revisit the research question before considering the general implications of our study.

The main research question focused on how patient waiting times vary following an expansion in capacity. Our analysis revealed that the local managerial decision to temporarily add extra capacity to reduce the backlog (i.e. shorten access times) had a magnetic effect on GPs who then referred many more patients to this hospital rather than

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4 elsewhere. The increase in new patients and, as a consequence, the avalanche of follow-  
5 up appointments was disproportionate to the extra capacity.

6 Furthermore, the decision to allow a significant increase in the inflow of new patients  
7 once this new capacity was added resulted, at least in the short term, in a substantial  
8 change in the ratio of new to returning patients. With a surge in new patients, most of  
9 whom would need four follow-up appointments; it was inevitable that the department  
10 would later become overwhelmed with these new patients requiring multiple returning  
11 appointments.

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13 Reductions of waiting time result in increased inflow. However, in this case the  
14 temporary aspect of the waiting time reduction affects capacity supply in the short term,  
15 while creating even more demand for the same capacity in the longer term. A different  
16 approach towards waiting time reduction, such as process improvements, would arguably  
17 have had a smoother and more structural impact. Also these process improvements could  
18 have been expected to lead to increased inflow, but at a level that matched the structural  
19 capacity, such that a new equilibrium could be established based on shorter waiting times.

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21 In hindsight, two local decisions, to increase capacity and to use this to accept many  
22 more new patients, were important sources of artificial variability which triggered a self-  
23 inflicted multiplier effect. This effect was initially considered as a potential example of a  
24 service bullwhip effect. The service bullwhip effect also relates to a trigger event in a  
25 supply chain that induces demand distortion[22]. However, we argue for a simpler  
26 multiplier effect to have taken place. We have constructed a causal network of the  
27 rheumatology situation, Figure 6, to further explore this multiplier effect.

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29 The network shows that a sharp decrease in the department's access times (here  
30 referred to as hospital A) caused GPs to switch their demand by opting to refer patients  
31 to hospital A rather than elsewhere (hospital B). This was possible because GPs were  
32 aware of the improved access time offered by hospital A, which distinguished it from  
33 hospital B. This resulted in a sharp increase in the inflow of new patients of whom an  
34 unlimited number were accepted (although one would expect the access times to  
35 eventually increase as appointments fill up until a new equilibrium is reached with  
36 hospital B). This boosted the ratio of new to returning patients, and resulted in a massive  
37 increase in demand for follow-up appointments due to a multiplier effect with typically  
38 four returning visits in the year following first visit. The increase in follow-up  
39 appointments absorbed all the available capacity, which had a negative effect on the  
40 access times offered to future new patients.

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45 <insert Figure 6 about here>

46 Figure 6. Causal network of the rheumatology situation

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48 It is striking to see that the increase in new patients has a self-reinforcing effect on the  
49 demand for physician capacity due to the multiplier effect of follow-up appointments.  
50 This reinforcing effect reveals itself in the next stage of the supply chain and is typical  
51 for healthcare environments where follow-ups are common. The increase in inflow is the  
52 consequence of continuous and instantaneous information sharing between the hospital  
53 (and its rheumatology department) and GPs. Earlier, the GPs' ability to select hospitals  
54 based on their access times, acted as a variability absorbing or stabilizing mechanism in  
55 case of 'normal' variability and gradual changes in wait times. For example, as soon as  
56 one of the hospitals would tend to get to a higher inflow of patients and hence increased  
57 access times, the GPs' responded by selecting different hospitals in the system. In turn,  
58 this would bring the inflow level back to the original level, rebalancing the system load.  
59 However, in this case the temporary capacity change disturbed this self-stabilizing  
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4 mechanism. The case stresses that it is insufficient to rely on a local supply chain  
5 perspective. Here, system awareness is necessary and this requires considering the  
6 referral behaviour of GPs and the delivery performance of other competing hospitals  
7 when addressing variability and buffers. The market mechanism, based on access times,  
8 that this case study has highlighted, clearly requires a system view to smooth the demand  
9 and keep long-term access times at an acceptable level.  
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11 The theoretical contributions of this study are threefold. First, we contribute to the  
12 knowledge on flow, and consequently the ‘theory of swift and even flow’[19] by  
13 positioning artificial variability as a managerial problem that negatively affects flow, and  
14 we show the possible negative effect of a common buffering approach. The addition of  
15 capacity would normally be a means to buffer against day-to-day variability. However, it  
16 now became a ‘disturbing’ factor or source of variability itself for longer term variability.  
17 Based on this study, and given the dynamics of the complex interaction between  
18 variability and buffers, we stress the need to apply a system view when pursuing flow  
19 improvements. Introducing poorly informed local policies can negatively affect flow[7].  
20

21 Second, we contribute to the knowledge base on the role of variability in healthcare  
22 environments[13,14,23]. The hospital’s well-intended actions caused inflow variability,  
23 here our study provides an example of unexpected outcomes related to improvement  
24 initiatives. We showed a multiplier effect, one that was self-inflicted and caused by  
25 decision-making being based on a local rather than a system perspective. Given the  
26 existence of a market mechanism based on access times, supply chain partners need to  
27 make decisions based on an overview of available ‘market information’, and be sensitive  
28 to regional effects. This decision to allow new patients has strong similarities with  
29 Roemer’s Law[24,25], which underlines that available capacity will be utilized.  
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31 Third, we contribute to the growing knowledge base on process improvement, which  
32 includes approaches such as Six Sigma and lean thinking[26,27]. Earlier research  
33 identified three paradoxes in healthcare improvement initiatives: 1) improvement  
34 initiatives target parts of a system, but fail to address underlying system constraints, 2)  
35 local improvements do not account for regional integration, and 3) rules that improve the  
36 service organization for one department may create obstacles for other departments [6].  
37 Our results provide illustrations of these paradoxes. In addition, by confirming the  
38 importance of variability and buffer reduction, an area that has recently received  
39 increasing attention in the literature on lean thinking. Lean is generally considered to  
40 include the concept of *mura*, which reflects unevenness or variability as can be found in  
41 the healthcare field[28]. Hopp [29(p.89)] considers the ‘production of goods or services  
42 to be lean if it is accomplished with minimal buffering costs’. After an initial focus on  
43 direct waste, more mature lean approaches tend to focus on reducing variability and  
44 buffers[29]. This study contributes by providing an example of the interaction between  
45 variability and capacity buffers within a hospital setting.  
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47 An obvious limitation of this research is that it is based on a single case study, which  
48 consequently limits the generalisability of the findings. Another limitation relates to the  
49 fact that the service supply chain in this paper is a simple dyadic structure of GPs and a  
50 relatively small rheumatology department with new and returning patients. As such, it is  
51 not representative of very complex networks with many interdependencies needing to be  
52 understood. A strength of the study is its combination of objective quantitative and  
53 subjective qualitative data that contributes to the accuracy and reliability of the findings.  
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55 We would encourage further research aimed at increasing the knowledge on multiplier  
56 effects and the dynamics between variability and buffers. Where this study took a system  
57 perspective, a patient’s perspective on variability and buffers could add an extra  
58 dimension to this field of research.  
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## Conclusions

This research has identified the variation in access times that follows from adding capacity. We have seen that access times are heavily influenced by sources of artificial variability such as managerial decisions about adding capacity and accepting new patients. This can cause undesirable dynamics in the variability-buffer interaction. Our findings lead us to agree with earlier research[30] that concluded that synchronising service supply chains is ‘complex’ and ‘non-intuitive’.

## List of abbreviations

**GP:** General Practitioner

**LSS:** Lean Six Sigma

**NP:** New patients

**RP:** Returning patients

## Declarations

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**Ethics approval:** Study approval [reference number RDMPFEB-20180111-2835] was granted by the ethics committee of the Faculty of Economics and Business, University of Groningen, the Netherlands.

**Data sharing statement:** The datasets used and/or analysed during the current study are available from the *University of Groningen*. Data are available from the corresponding author on reasonable request.

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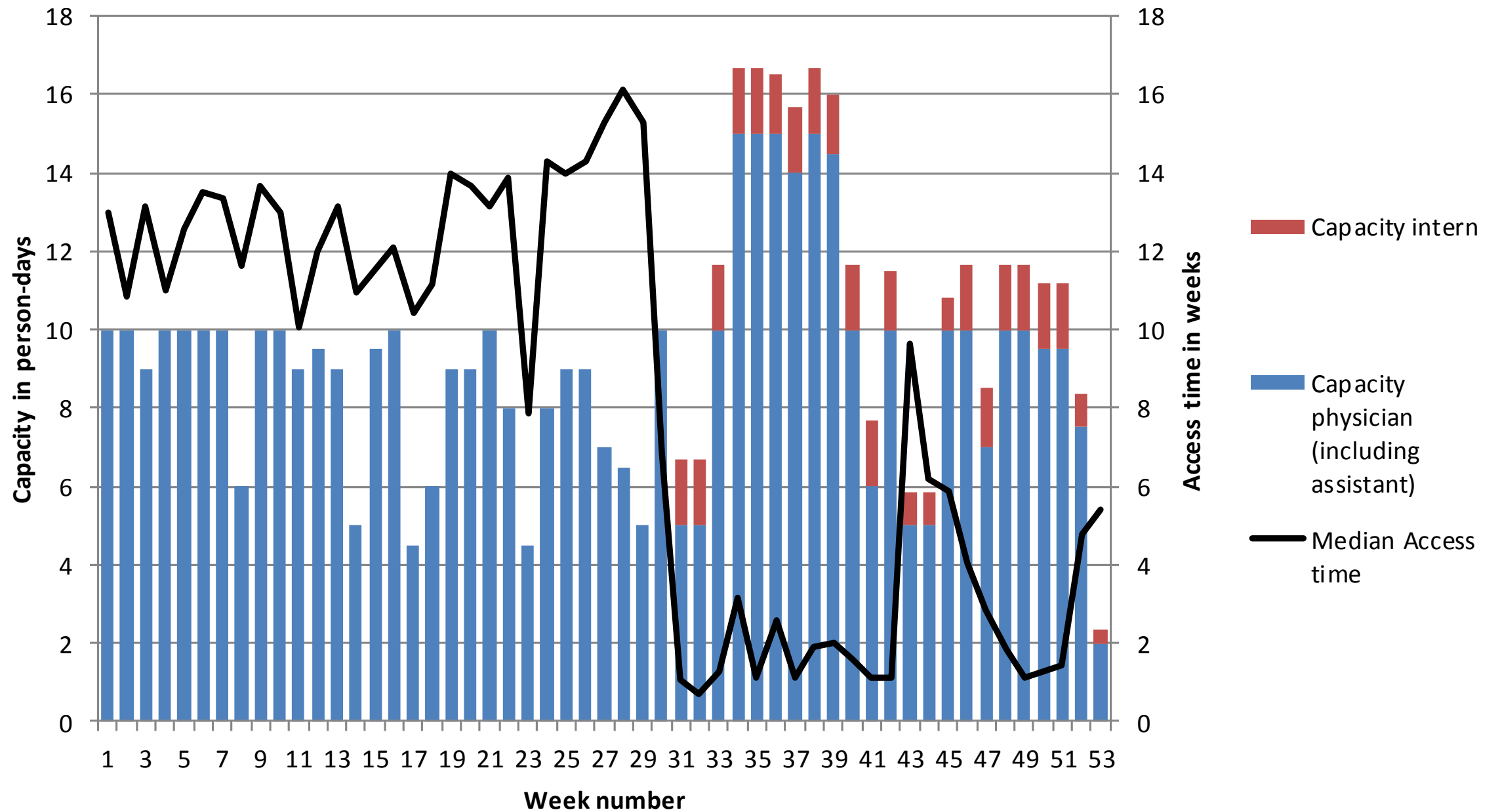
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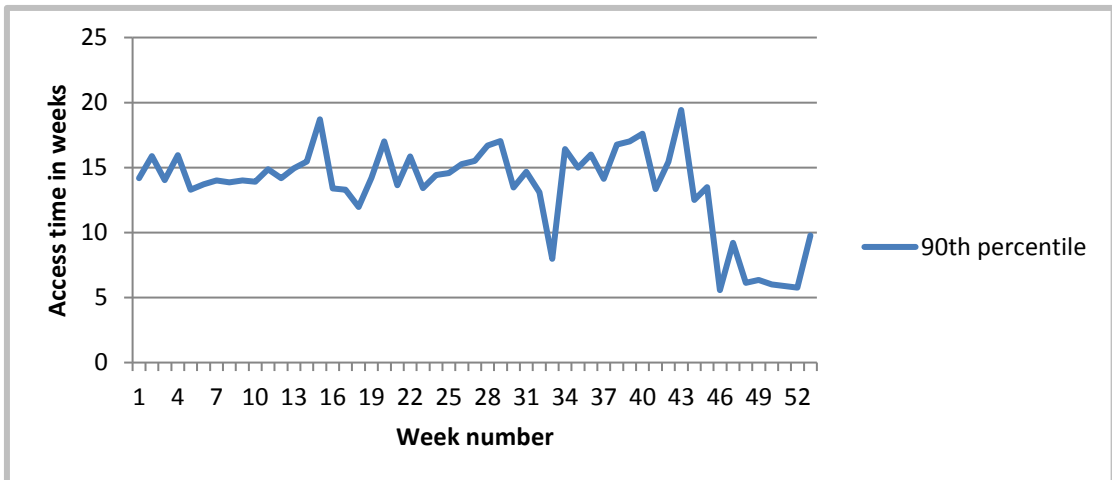
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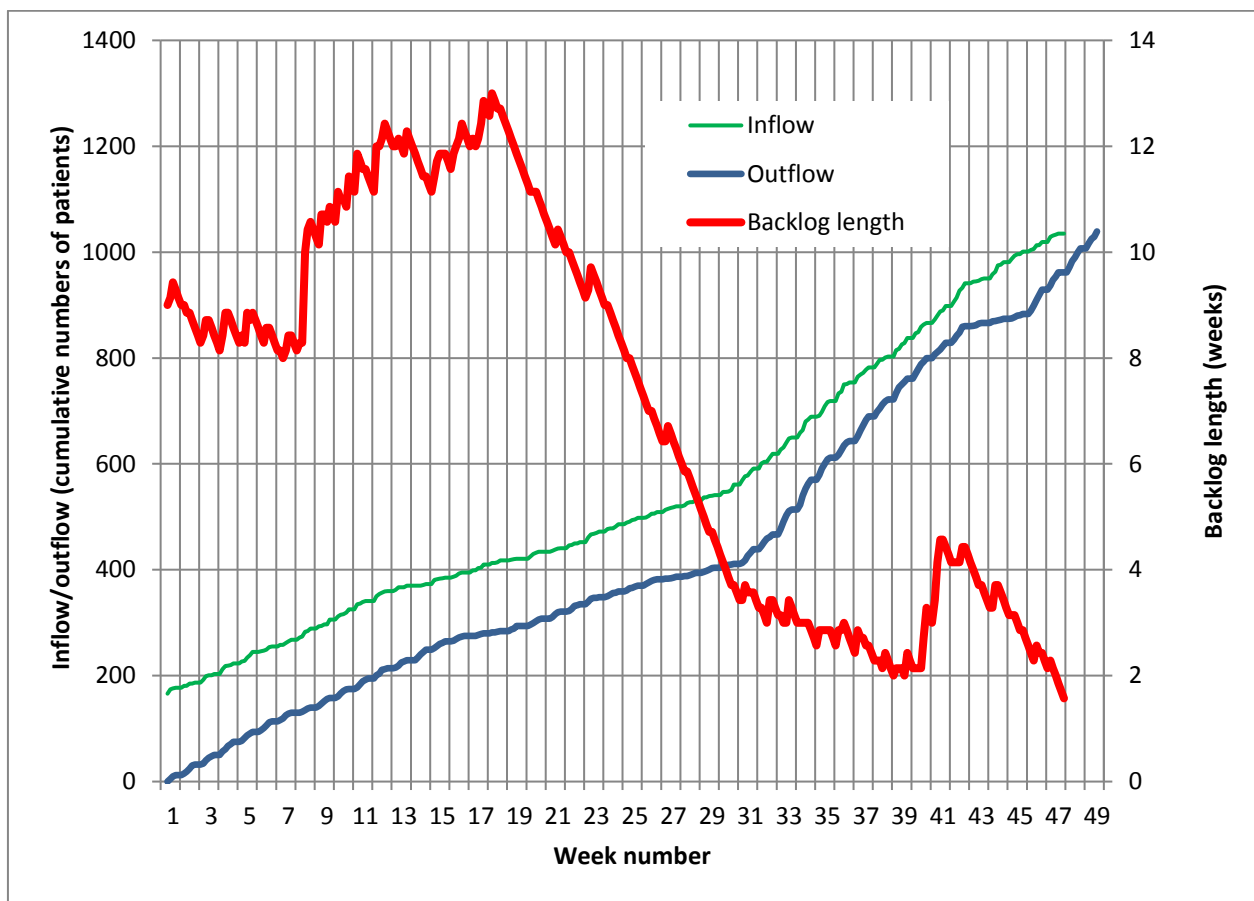
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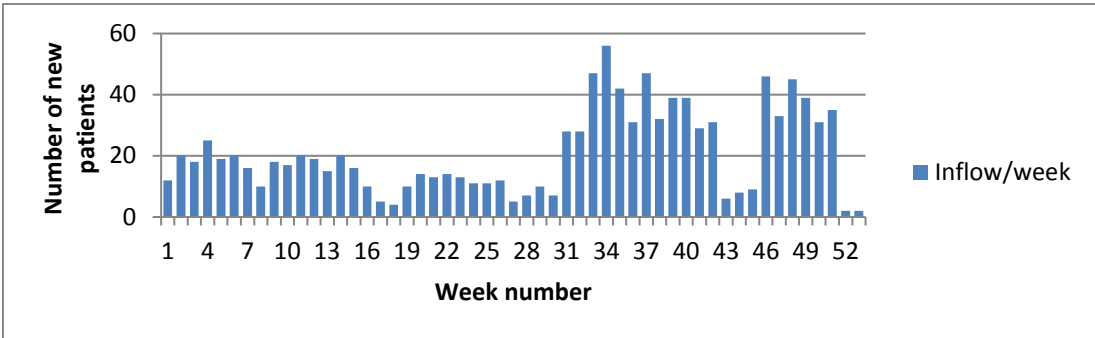
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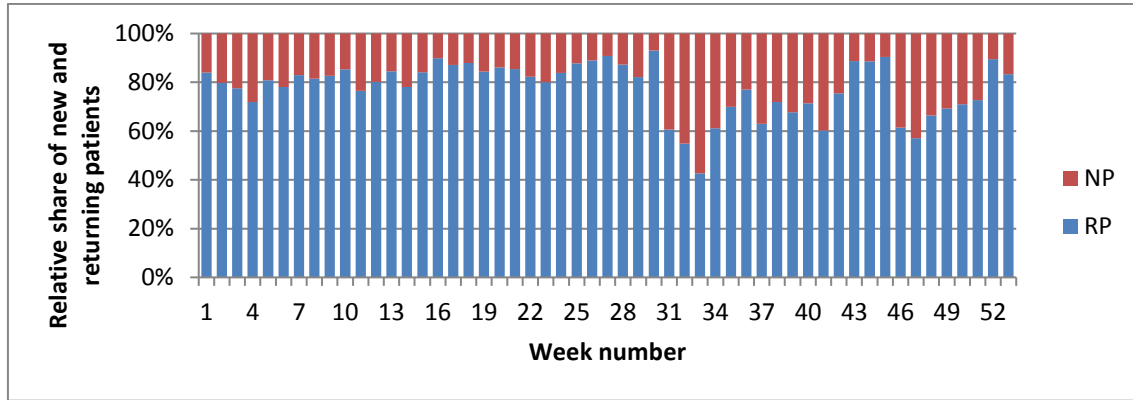
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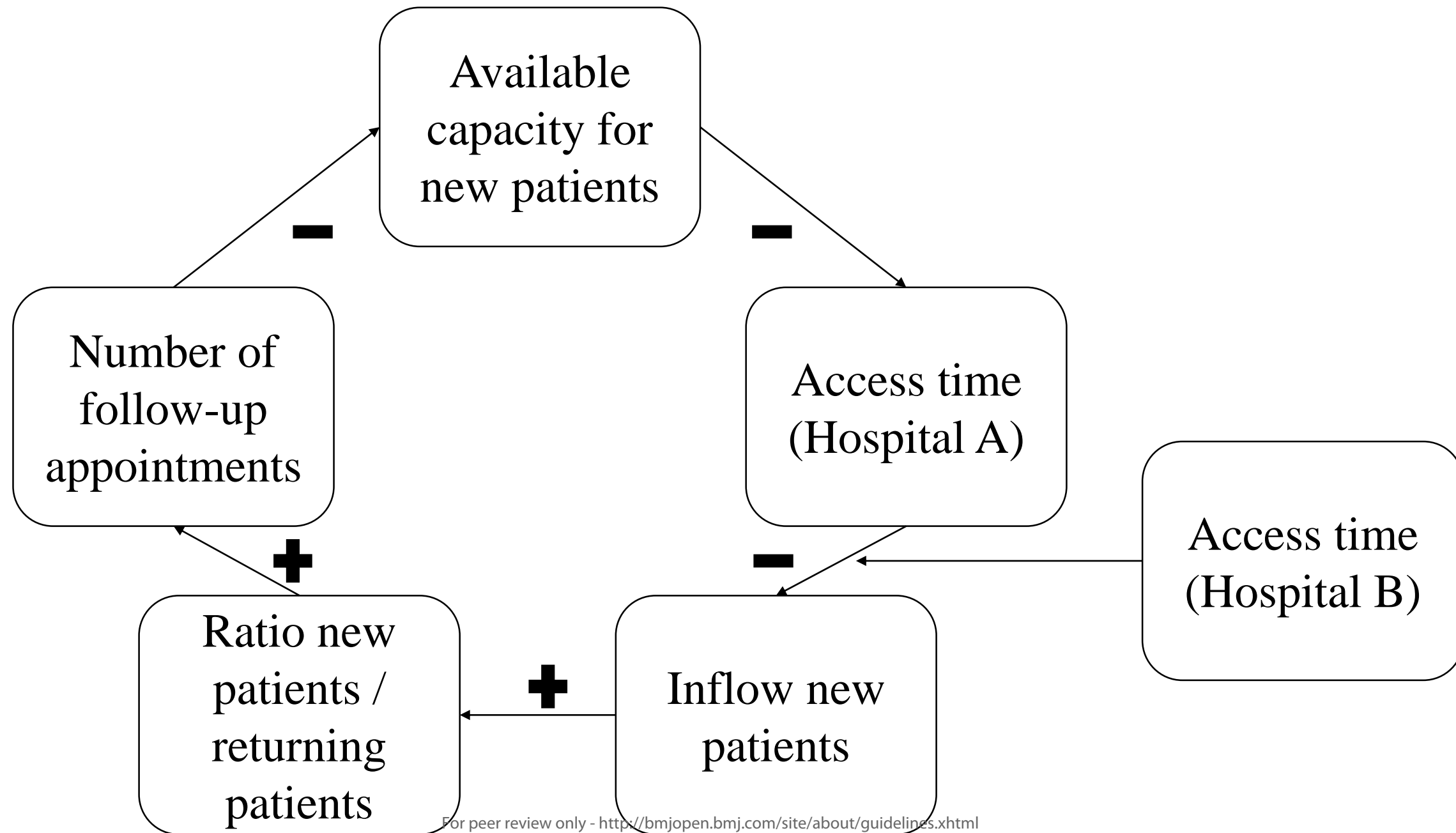
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## Standards for Reporting Qualitative Research (SRQR)

### Report for:

# The adverse impact of increasing capacity to reduce admission times

Note: page and line numbers are based on proof (pdf).

Title and abstract	Page/line no(s).
<b>Title</b> - Concise description of the nature and topic of the study Identifying the study as qualitative or indicating the approach (e.g., ethnography, grounded theory) or data collection methods (e.g., interview, focus group) is recommended	P1/L7, P2/L5
<b>Abstract</b> - Summary of key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results, and conclusions	P2/L9-35
<b>Introduction</b>	
<b>Problem formulation</b> - Description and significance of the problem/phenomenon studied; review of relevant theory and empirical work; problem statement	P3/L5-46
<b>Purpose or research question</b> - Purpose of the study and specific objectives or questions	P3/L47,48
<b>Methods</b>	
<b>Qualitative approach and research paradigm</b> - Qualitative approach (e.g., ethnography, grounded theory, case study, phenomenology, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g., postpositivist, constructivist/ interpretivist) is also recommended; rationale**	P4/L15-20
<b>Researcher characteristics and reflexivity</b> - Researchers' characteristics that may influence the research, including personal attributes, qualifications/experience, relationship with participants, assumptions, and/or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results, and/or transferability	P4/L41-47
<b>Context</b> - Setting/site and salient contextual factors; rationale**	P4/L24-38
<b>Sampling strategy</b> - How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g., sampling saturation); rationale**	P4/L5-13

1 2 3	<b>Ethical issues pertaining to human subjects</b> - Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues	P10/L25
4 5 6 7 8	<b>Data collection methods</b> - Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources/methods, and modification of procedures in response to evolving study findings; rationale**	P4/L40-55
9 10 11 12 13	<b>Data collection instruments and technologies</b> - Description of instruments (e.g., interview guides, questionnaires) and devices (e.g., audio recorders) used for data collection; if/how the instrument(s) changed over the course of the study	P4/L41-51
14 15 16 17	<b>Units of study</b> - Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results)	P4/L32-38
18 19 20 21	<b>Data processing</b> - Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymization/de-identification of excerpts	P4/L59-P5/L26
22 23 24 25	<b>Data analysis</b> - Process by which inferences, themes, etc., were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale**	P4/L59-P5/L26
26 27 28 29	<b>Techniques to enhance trustworthiness</b> - Techniques to enhance trustworthiness and credibility of data analysis (e.g., member checking, audit trail, triangulation); rationale**	P4/L41-55

### Results/findings

31 32 33 34 35	<b>Synthesis and interpretation</b> - Main findings (e.g., interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory	P5/L37-P7/L37
36 37 38 39	<b>Links to empirical data</b> - Evidence (e.g., quotes, field notes, text excerpts, photographs) to substantiate analytic findings	P6/L9,L20,L48 P7/L9,L20 (Figures)

### Discussion

40 41 42 43 44 45 46 47 48	<b>Integration with prior work, implications, transferability, and contribution(s) to the field</b> - Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application/generalizability; identification of unique contribution(s) to scholarship in a discipline or field	P7/L40-P9/L40
49	<b>Limitations</b> - Trustworthiness and limitations of findings	P9/L41-52

### Other

50 51 52 53	<b>Conflicts of interest</b> - Potential sources of influence or perceived influence on study conduct and conclusions; how these were managed	P10/L24
54 55 56	<b>Funding</b> - Sources of funding and other support; role of funders in data collection, interpretation, and reporting	P10/L23

1 \*The authors created the SRQR by searching the literature to identify guidelines, reporting  
2 standards, and critical appraisal criteria for qualitative research; reviewing the reference  
3 lists of retrieved sources; and contacting experts to gain feedback. The SRQR aims to  
4 improve the transparency of all aspects of qualitative research by providing clear standards  
5 for reporting qualitative research.  
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8 \*\*The rationale should briefly discuss the justification for choosing that theory, approach,  
9 method, or technique rather than other options available, the assumptions and limitations  
10 implicit in those choices, and how those choices influence study conclusions and  
11 transferability. As appropriate, the rationale for several items might be discussed together.  
12

13  
14 **Reference:**

15 O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. **Standards for reporting qualitative**  
16 **research: a synthesis of recommendations.** *Academic Medicine*, Vol. 89, No. 9 / Sept 2014  
17 DOI: 10.1097/ACM.0000000000000388  
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