

## Hospital capacity planning: from measuring stocks to modelling flows

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**Abstract** The metric of “bed numbers” is commonly used in hospital planning, but it fails to capture key aspects of how hospital services are delivered. Drawing on a study of innovative hospital projects in Europe, we argue that hospital capacity planning should not be based on beds, but rather on the ability to deliver processes. We propose using approaches that are based on manufacturing theory such as “lean thinking” that focuses on the value that different processes add for the primary customer, i.e. the patient. We argue that it is beneficial to look at the hospital, not from the perspective of beds or specialties, but rather from the path taken by the patients who are treated in them, the respective processes delivered by health professionals and the facilities appropriate to those processes. Systematized care pathways seem to offer one avenue for achieving these goals. However, they need to be underpinned by a better understanding of the flows of patients, work and goods within a hospital, the bottlenecks that occur, and translation of this understanding into new capacity planning tools.

Une traduction en français de ce résumé figure à la fin de l'article. Al final del artículo se facilita una traducción al español. الترجمة العربية لهذه الخلاصة في نهاية النص الكامل لهذه المقالة.

### Introduction

Although revenue for hospital services in many developed countries is increasingly based on measures of activity such as diagnosis-related groups, hospital capacity planning remains dominated by “bed numbers”.<sup>1</sup> A review of international practice found that bed capacity continues to be the preferred unit for planning hospital care in Finland, Germany, Italy, New Zealand and most Canadian provinces. Of the countries included in the review, only England and France were moving towards planning based on service volume and activity.<sup>2,3</sup> Bed occupancy and the ratio of beds per population remain predominant metrics in hospital capacity planning.<sup>4–6</sup>

There are several problems associated with this approach. Most importantly, bed numbers or bed occupancy do not provide a good measure of the services provided inside hospitals, given the wide variation in case mix and thus treatment costs of those occupying the beds,<sup>4</sup> nor are they suitable for predicting future demand.<sup>7</sup> The measure implies that the bed is the core piece of capital stock in the hospital, constraining the performance of the other assets around it. The near universal trend towards growing numbers of day cases and shorter lengths of hospital stay further invalidates beds as a measure of capacity. The continued use of “bed numbers” also fails to consider the trade-offs and complementarities from investing in different types of health capital. Thus, while bed numbers have the benefit of convenience, as they are one of the few indices of hospital capacity that are routinely collected, there is a growing recognition of the intrinsic limits of this measure.

Neither are diagnosis-related groups an appropriate methodology for capacity planning. They are simply a way of categorizing admissions, derived from retrospective micro-costing data and combining diagnosis and any interventions.<sup>8</sup> This means that they can be used for calculating prices but they say little about the mix of resources that is needed.<sup>9</sup>

There seems to be a clear need to employ other metrics and, in some places, this is happening. However, so far, this process has been poorly documented. This paper responds to a call for a focus on care pathways when designing and constructing health-care facilities.<sup>10</sup> We review the case for new approaches to planning hospital capacity and describe some experiences with alternative approaches by drawing on insights gained in a recent study of health capital investment in Europe undertaken by the European Observatory on Health Systems and Policies and the European Health Property Network.<sup>11,12</sup> The project involved a review of the literature around core themes, including capacity planning and how to translate services into assets, and analysis of a series of case studies from across Europe, including the Coxa hospital in Finland, the Rhön Klinikum Group in Germany, the Orbis and Groningen hospitals in the Netherlands, the Trondheim hospital in Norway, the John Paul II hospital in Poland, the Alzira franchise in Spain, the Karolinska hospital in Sweden, as well as regional planning in Tuscany (Italy) and Northern Ireland.

### Need for innovation

Traditionally, hospitals were designed around specialties and departments rather than around the needs of patients. Patients often spend most of their time in hospitals waiting for something to happen, with large areas provided for this inactivity. The situation is often exacerbated by the inefficient management of admission and discharge. In the United Kingdom of Great Britain and Northern Ireland, a patient admitted on a Friday night may have a length of stay that is 25% longer than a patient admitted on a Tuesday.<sup>13</sup> To accommodate this phenomenon, beds and wards in effect become holding areas for “work in progress” and have, in the past, been planned accordingly. A consequence is that in many hospitals the flow of patients is inefficient, dislocated and disorganized.<sup>14</sup> Yet poor patient flow impairs patient and staff satisfaction, and the effective utilization of resources.<sup>15</sup> It

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(Submitted: 15 October 2009 – Revised version received: 19 December 2009 – Accepted: 5 January 2010)

also compromises the quality of care and patient safety, with evidence that patients admitted at weekends have worse outcomes,<sup>15,16</sup> although this is not inevitable if services are organized appropriately.<sup>17–19</sup> Several factors, including the growing complexity of treatment and a willingness to see the care process from the patient's perspective, have rendered this situation unacceptable, leading to demands for care models based on syndromes, care processes and patient pathways.

## Care pathways

Considerations of both quality and efficiency point to the need to systematize processes where possible.<sup>20</sup> Of particular importance, in this regard, are care pathways that are grounded in the concept of flow across the whole system.<sup>21</sup> These began to be conceptualized in the 1980s, based on the recognition that, for many complaints, many patients have similar needs. Although patient pathways have been defined in various ways,<sup>22</sup> and there is debate over the scope of what is included in a pathway, they seek to describe optimal packages for particular syndromes and, ideally, encapsulate measurable inputs and outcomes. In this context, it is important to recognize that processes do not stop at the hospital door. Care is not an isolated event, but usually a short episode in a longer patient journey. Integrated pathways that are developed by multidisciplinary teams and plan for pre- and post-hospital care can inform strategies that avoid unnecessary hospitalizations.<sup>23,24</sup>

Care pathways seem to provide a basis for using health-care demand, derived from demographic and epidemiological data, to plan capital investment in the health sector. In three of our case studies (Coxa, Rhön Klinikum and Orbis), new hospitals have been designed around care pathways, with particular attention being paid to systematization of work processes. Interestingly, these are hospitals operating in competitive market environments, and are thus forced to pay more attention to long-term sustainability and performance, even if this means higher initial capital costs.

## Lessons from supply chain re-engineering

In addition to the use of care pathways, “lean thinking” and operations research provide important insights on how hospi-

tal capacity planning could be improved. While they largely focus on re-engineering of internal processes, they also involve different understandings of capacity that are relevant to hospital planning.

The concept of lean thinking is most commonly associated with Japanese manufacturing and was pioneered by Toyota Motor Corporation in the 1950s.<sup>25</sup> Lean thinking principles have been used increasingly in manufacturing companies, to the extent that they are now virtually universal in the automobile industry.<sup>20</sup> They have also been applied in service industries, including air transport, where the perishable and intangible nature of the service bears some similarities to health care.

Several lessons from lean thinking are relevant to health care. A key principle is that each step in production must produce “value” for the customer and that all sources of “waste” should be eliminated. The concept of “waste” is far-reaching, and includes unnecessary inventory, waiting, mistakes, unplanned re-admissions and inappropriate procedures or processes.<sup>13,20,26</sup> The lean concept of “pull”, whereby something is not started until the customer wants it, may also be relevant where delivery of care involves a predictable process.

A related concept that comes from operations research is “queuing theory”, which aims to improve the efficiency of processes by targeting bottlenecks that cause queues. One cause of bottlenecks in hospitals is semi-autonomous departments seeking to optimize their own functioning without considering how this affects the performance of others.<sup>27</sup> However, such bottlenecks are not always recognized, resulting in long delays for patients.<sup>28</sup> Common settings for bottlenecks include emergency departments, operating theatres and central diagnostic facilities, such as imaging.<sup>29</sup>

Anything that eases throughput by releasing the bottleneck potentially adds value to the system. However, improving the efficiency of only one part of the system may not improve overall efficiency. Reducing crowding in emergency departments, for example, requires strategies that go far beyond the department.<sup>30</sup> It is therefore necessary to consider the extended supply chain as a whole, acknowledging the way change in one part of the process impacts on the rest of the health and social-care system.

## Applying these principles

Can these insights from industrial environments really be translated into hospital capacity planning and design? While lean thinking is not a new concept, until recently it has only been applied to health care to a limited extent.<sup>31,32</sup> We believe that health care does have many features in common with the production of goods. The traditional layout and workflow of hospitals to some extent resemble the batch-and-queue organization of a “pre-lean” factory, with equipment and activities arranged by type rather than in the sequence needed to deliver a final outcome. Patients are processed in batches before being moved on, often to wait in a queue for the next stage. This results in long lead times for processing and high costs in terms of space and capacity, and for patients in terms of their time.

Rather than seeing them as “warehouses” through the “bed number” approaches to planning, we need to see hospitals as immensely complicated processing plants, with thousands of parallel, often complex and interlocking, processes. In health care, waste – in terms of time, money, supplies and goodwill – is a common problem.<sup>20</sup> One major reason for this is that internal “customers” (such as physicians, hospitals, insurers, governments, payers) have often driven these processes. Lean thinking sees the value as defined in terms of the primary customer, the patient.<sup>20</sup> Overall, the objective is to deliver high levels of value via a flexible and “mass-customized” approach, where individualized service is provided by tailoring a standardized set of processes. There are several ways of achieving this, each with implications for the design of the supply chain. All require predictability and the consistent interchangeability of processes.<sup>33</sup>

## Improving patient flow

A major implication of applying management theory to health care is the need to separate different flows of patients, work and goods, enabling each to move according to its own logic and pace. For hospitals, this means that the focus should not be on similar clinical conditions but rather on similar processes.<sup>34</sup> In an emergency department in a teaching hospital in Australia, patients were separated into two streams on the basis of complexity rather than urgency, creating a fast-track

patient stream for patients who can be treated and discharged more or less immediately. The new system led to significant improvements in several key performance indicators, including mean waiting and treatment time.<sup>35</sup> The *Unscheduled Care Collaborative Programme* in Scotland introduced five flows, including an out-of-hospital flow designed to improve processes in the wider health and social-care systems before and after discharge from the emergency department.<sup>36</sup>

A key to improving patient flow is the smoothing of peaks and troughs in workload.<sup>29</sup> This may be achieved by reconfiguring services. Thus, advances in medical imaging increasingly allow decentralization, which can facilitate high-velocity flow.<sup>37</sup> Non-random variability is common in elective care, but this can easily be remedied, for example by spreading surgery evenly among the days of the week.<sup>38</sup> This example indicates how hours can be a more appropriate planning unit than days.

It is critical to recognize whether one is dealing with continuous (“fast track”) or batch processes. A failure to distinguish between the two can lead to the view that queuing is due simply to a lack of capacity (in terms of beds, facilities, diagnostics, nurses or doctors).<sup>39</sup> This can be illustrated by the use of escalators and elevators in department stores. The elevators are more likely to cause queues in a surge situation, such as when the stores need to be evacuated, whereas escalators are more forgiving in such circumstances.

As these examples show, while insufficient supply may well be a problem, it can only be understood as a function of the way that the service is configured.<sup>13</sup> Thus, an imaging department in Amsterdam’s Academic Medical Centre removed a bottleneck in computerized tomography scanning by inserting intravenous access lines in a preparation room, increasing utilization from 44% to 51%.<sup>29</sup> This illustrates how the seemingly almost random progress of patients conceals hidden bottlenecks, feedback loops and lines moving at different speeds.<sup>40</sup> Investments in “capacity” often fail to increase overall output because they are not systematically directed at the real bottlenecks.<sup>13</sup> By contrast, a childrens’ hospital in Stanford, California, was able to admit 7% more children per year and improve patient satisfaction by use of improved patient flow systems.<sup>41</sup>

## A new understanding of capacity

Improving patient flow has major implications for our understanding of hospital capacity. Rather than counting beds, a new definition of capacity could start from a description of the pathways travelled by patients, whether in batches or as flows, followed by identification of those elements that can constrain them (the bottlenecks). In some cases, this could be the number of beds but in others it will be operating theatres, diagnostic equipment or particular specialist staff – in each case, these depend on the particular site and its relation to the local health-care economy. It is necessary to examine how these elements are configured within and outside hospitals, recognizing that many pathways will join together at bottlenecks, such as in operating theatres, before going their separate ways. The key to successful capacity planning is then to ensure that each patient travels along the shortest (or least costly) path possible within the network, encountering as few delays at bottlenecks as possible. This approach has major implications for hospital planning. By differentiating those processes that are best undertaken in batches and those that should be continuous flows, it is possible to develop appropriate simulation models that integrate the demands on the hospital and the capacity to meet them. When combined with the opportunities provided by advances in technology, such as “near-patient” or point-of-care testing and telemedicine, there is scope for significant improvement in understanding the options for how and where care is provided.

## Discussion

Many of the challenges we have described will be familiar to hospital physicians, managers and planners, who will recognize the application of management principles in health care even if they are not always identified as such. Furthermore, these principles are mainly concerned with optimizing processes and not with capacity planning. Why are hospitals still predominantly planned on the basis of bed numbers?

Several factors are at play. Hospital planners may be well aware of the limits of using beds as a measure for future capacity, but may use it as a shorthand for the physical space (in terms of square

metres) needed by different departments. Furthermore, as mentioned previously, most systems of capacity planning still focus on hospitals and do not include primary health care or social care. As care pathways are likely to have the biggest impact when applied across settings of care, they assume particular importance in integrated systems of planning. In addition, the development of care pathways across health systems is only beginning in many countries and, usually concerned with chronic diseases, they do not yet cover a sufficient number of medical conditions. In effect, the “bed” implies that capacity is the inventory of patients, rather than the much more intense processing of patients that is more characteristic of the functioning of modern hospitals.

The way capital has been financed historically is also important. Traditionally, capital was essentially “free” for health-care providers in Europe. New facilities were financed from elsewhere, such as government funds, with no incremental risk to health-care providers.<sup>42</sup> However, this is changing in many countries and the costs of capital are increasingly being charged to the costs of outputs. We believe that it may not be a coincidence that those hospitals in our sample with the greatest exposure to risk have used care pathways to plan hospitals. This does not mean we advocate that hospitals should be run by commercial firms, but rather that hospital planning needs to ensure the long-term viability of new or refurbished facilities; in a sense, the match between the clinical and financial functioning of the hospital. The increasing use of public-private partnerships for managing hospitals, including in developing countries, may provide a powerful incentive for better hospital planning and performance,<sup>43</sup> but only if they avoid the pitfalls of some existing schemes.<sup>44</sup>

Care pathways seem to be a promising way of conceptualizing hospital capacity in planning exercises, but they are a methodology that needs to be developed further. Challenges include the systematization of care pathways, their large number and propensity to change, the integration of health-care demand and supply, and the linking of resources to care pathways.

Concepts such as “lean thinking” offer insights for designing improved hospital capacity planning by drawing attention to patient flows. However, we

caution against overly rigid interpretation and implementation of these concepts in health care. The focus is often efficiency-oriented, relies heavily on certainty to ensure cost minimization and seeks to engineer stability into the system to avoid costs resulting from disturbances occurring in the supply chain. Lean principles should not be over-zealously applied at the expense of responsiveness – indeed, building in modest spare capacity can have disproportionate benefits on the effectiveness of the delivery process.<sup>45</sup> The use of management theory in hospital capacity planning needs more rigorous testing.

Finally, although systems thinking can help explain the wider inter-relationships between health-care processes, care needs to be taken at each level in the system when considering problems or solutions. For example, when planning to improve the flexibility and adaptability of a local health-care economy, should this be targeted at the level of the ward, department, hospital or local health system as a whole?

Although health care is increasingly being shifted away from expensive hospital facilities, the demand for new hospitals remains high across the world. Finding

better ways of planning and operating hospital capacity is essential for delivering sufficient capacity at the right price to meet future health-care needs. ■

**Funding:** The paper forms part of a wider study of health capital investment in Europe that has been undertaken by the European Observatory on Health Systems and Policies and the European Health Property Network. It also draws on work carried out within the EPSRC Health and Care Infrastructure Research and Innovation Centre (HaCIRIC).

**Competing interests:** None declared.

## الملخص

### تخطيط قدرات المستشفيات: من قياس القدرة الاستيعابية إلى سريان النماذج المثالية

المستشفى ليس بمنظور عدد الأسرة أو التخصصات، ولكن من خلال المسار الذي يسلكه المريض الذي يعالج في المستشفى، والإجراءات التي يقدمها المهنيون الصحيون، ومدى ملائمة المرافق لتقديم هذه الإجراءات. ويبدو أن المسارات المنهجية للرعاية تسمح بتقديم نهج لتحقيق هذه المرامي، غير أنها تحتاج إلى التعزيز من خلال الإدراك الأعمق لتدفق المرضى، وسريان العمل والبضائع في المستشفى، والاختناقات التي تحدث، ثم ترجمة هذا الإدراك إلى أدوات جديدة لتخطيط القدرات.

يشيع استخدام مقياس "عدد الأسرة" في عملية تخطيط المستشفيات، لكنه يفشل في تعريف السمات الرئيسية لكيفية تقديم المستشفى للخدمات. وبناء على دراسة أجريت في أوروبا حول مشاريع مبتكرة للمستشفيات، يرى الباحثون أن تخطيط قدرات المستشفى لا ينبغي له أن يتم وفقاً لعدد الأسرة، بل وفقاً لمقدرة المستشفى على تقديم الإجراءات. واقترح الباحثون استخدام أساليب تعتمد على نظرية التصنيع مثل "عدم الترهل الفكري" والذي يركز على القيمة المضافة من مختلف الإجراءات إلى العميل الأول، وهو في هذه الحالة، المريض. ويرى الباحثون أنه من الأجدى النظر إلى

## Résumé

### Planification des capacités hospitalières : de la mesure des stocks à la modélisation des flux

L'unité de mesure « nombre de lits » est habituellement utilisée dans la planification hospitalière, mais elle ne rend pas compte des principaux aspects caractéristiques de la façon dont les services hospitaliers sont fournis. Mettant à profit l'expérience de projets hospitaliers innovants en Europe, nous affirmons que la planification de la capacité hospitalière doit être basée non sur le nombre de lits, mais plutôt sur la capacité à fournir les services. Nous proposons d'utiliser des approches basées sur la théorie de construction, telle la « pensée LEAN » qui met en évidence les avantages que différents processus ajoutent pour le client primaire, c.-à-d. le patient. Nous soutenons qu'il est avantageux d'évaluer l'hôpital,

non en fonction du nombre de lits ou de spécialités, mais plutôt au travers du parcours entrepris par les patients qui y sont traités, les services fournis respectivement par les professionnels de santé et les structures adaptées à ces services. Les parcours de soins systématisés semblent offrir une voie prioritaire pour parvenir à ces buts. Ils nécessitent toutefois d'être soutenus par une meilleure compréhension des flux de patients, de travail et de marchandises au sein de la structure hospitalière, des goulots d'étranglement qui surviennent et d'une traduction de ces connaissances en nouveaux outils de planification.

## Resumen

### Planificación de la capacidad hospitalaria: desde la medición de existencias hasta el modelado de flujos

El parámetro del «número de camas» se suele utilizar en la planificación hospitalaria, si bien no logra captar los aspectos clave sobre cómo se ofrecen los servicios hospitalarios. En base a un estudio sobre proyectos hospitalarios innovadores llevado a cabo en Europa, argumentamos que la planificación de los recursos hospitalarios no se debe basar en el número de camas, sino en la capacidad de ofrecer procesos. Proponemos el uso de enfoques basados en un modelo de producción como el «pensamiento Lean» que se centra en el valor sumativo de los diferentes procesos para el principal cliente, es decir, el paciente. Sostenemos que es beneficioso considerar el hospital, no desde la perspectiva de las camas o de las

especialidades, sino de la trayectoria que siguen los pacientes tratados en ellos, los correspondientes procesos ofrecidos por los profesionales sanitarios y la adecuación de las instalaciones a dichos procesos. Las trayectorias asistenciales sistematizadas parecen ofrecer una vía para la consecución de estos objetivos. Sin embargo, tienen que estar respaldadas por una mejor interpretación de los flujos de pacientes, el trabajo y los productos de un hospital, los obstáculos que se producen y la traducción de esta interpretación en nuevas herramientas de planificación de los recursos.

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