Planning for adaptability in healthcare infrastructure

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As part of an integrated system, healthcare infrastructure should be planned and evaluated in conjunction with the services it supports. However, this is challenging because of uncertainty about future requirements due to technological, demographic, medical and policy change. Long lasting infrastructure needs to support healthcare processes that change rapidly.

In the UK public private partnership models provide additional challenges for the National Heath Service. Contractual agreements between public sector providers of care services and the organisations responsible for the provision and maintenance of the built infrastructure typically last 30 years or more. Over this period both the demands for care services and the technologies used to deliver them are likely to change considerably. Infrastructure needs to be able to adapt to these changes, and planning tools need to recognise the interdependencies within the care service and care infrastructure system.

System dynamics modelling offers the potential to plan for these challenges. It can help to guide the planning process of new healthcare infrastructure under conditions of uncertainty, so that the services it enables can meet present and future needs. The stylised model presented considers care service delivery over time depending on infrastructure flexibility options (e.g. to increase capacity) under different scenarios in order to support infrastructure planning.

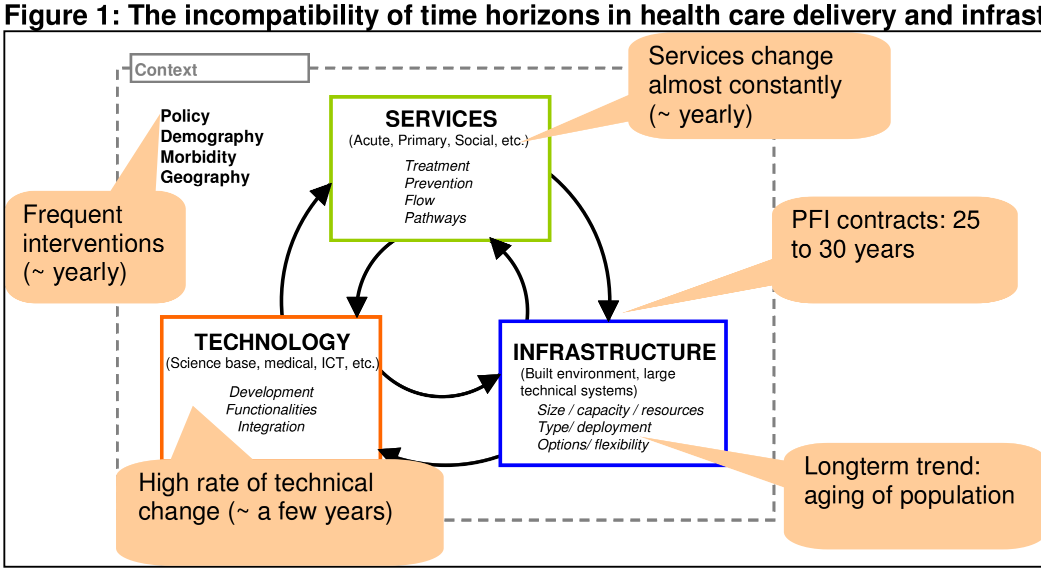
Introduction

In England there is currently a major investment programme in healthcare infrastructure undertaken. This programme includes a major overhaul of acute hospital provision throughout the country. The total investment in the acute hospital sector is estimated to range up to £45billion once fees and interest payments have been taken into account. At the same time other investment programmes for primary care facilities and new community hospitals are estimated to add another £4 billion to the volume of healthcare infrastructure investment. The renewal of the built infrastructure for healthcare is complemented by investment in the IT infrastructure for healthcare (Connecting for Health contract value (£6.2bn) plus local IT spending to support implementation (c. £10bn)).

The government has promoted new funding and contractual models, involving the use of private finance which it hopes will maximise this investment and inject innovation into infrastructure programmes. However, choices made today will determine the built infrastructure for healthcare for decades to come. Most investment in new hospitals is carried out using the “Private Finance Initiative” (PFI) procurement model. This has two main implications for the execution of projects in the healthcare sector. First, under the PFI, the National Health Service (NHS) procures a capital asset and services from the private sector on a long-term contract, typically at least thirty years. In hospital development a PFI arrangement typically involves design, construction, facilities management and often the provision of non-core services such as cleaning and catering for which fees have to be paid over the duration of the contract. The NHS maintains responsibility for all clinical services.

There is concern that the 25 to 30 year contractual arrangements and underlying performance criteria for buildings and non-clinical services adopted under PFI are not compatible with the rapidly changing healthcare system. Over the time-horizon of the contract the demand for care services is very likely to change considerably; the contractual arrangements make the adaptation of the buildings and non-clinical services to this change difficult. The context in which healthcare infrastructure is planned is characterised by continual change and high levels of uncertainty. The overall health and social care system in which the infrastructure is deployed is complex with multiple stakeholders involved in planning and delivering care. These stakeholders have differing institutional and funding arrangements and often very distinct cultures. A physical infrastructure with long-term contractual relationships fixed by the current investment programme may prove to be an obstacle to future innovation, without the adaptability required to accommodate the radical changes to the nature of care delivery that are expected over the coming years.

Figure 1: The incompatibility of time horizons in health care delivery and infrastructure



The timescales with which different elements of the service, infrastructure and technology system change are mismatched (figure 1). While demographic change and the increasing demand of healthcare services by an elderly population is a long-term and relative predictable trend, other contextual factors have shorter cycle times. These include medical innovations (such as new drugs, the possibilities to perform minimally-invasive surgery or advances in medical imaging) and changes in health policy due to the imposition of targets, changes in resource allocation, the political mandate for services or the introduction of new types of healthcare providers. The supporting built and technical (e.g. ICT) is frequently long-lived and expensive to modify. Because of the uncertainty about future requirements and high switching costs (in terms of time, money and disruption), it has long been seen as desirable to plan for a degree of flexibility and adaptability in hospitals and other types of healthcare infrastructure.

As we have indicated, the contractual structure of PFI contracts requires the NHS trusts as health provider organisations to commit to pay charges for a period of about 30 years for a building whose performance has been specified in advance during the project planning phase and which therefore might be over 35 years out of date towards the end of the contractual period. Any modifications of the building which will inevitably be required during the lifetime of the contract will incur additional costs. Several of the initial PFI projects have run into early problems as the capacity and specification was inappropriate soon after opening. This can be seen as an indication that over the lifetime of the contract further modifications will be required in order for the infrastructure to be appropriate for the services the NHS wants to provide.

Research Approach

The research reported in this paper has adopted a qualitative, case study approach to investigate the relationship between healthcare infrastructure delivery mechanisms and the potential to accommodate future changing healthcare needs. These findings have then informed the development of a system dynamics simulation model to examine the impact on care services of different flexibility options.

Qualitative research

We are using a qualitative, case study approach comparing six PFI acute hospital projects and 6 projects carried out in the 1960s and 1970s under the previous funding schemes where central government funded hospitals were owned and operated by the NHS.

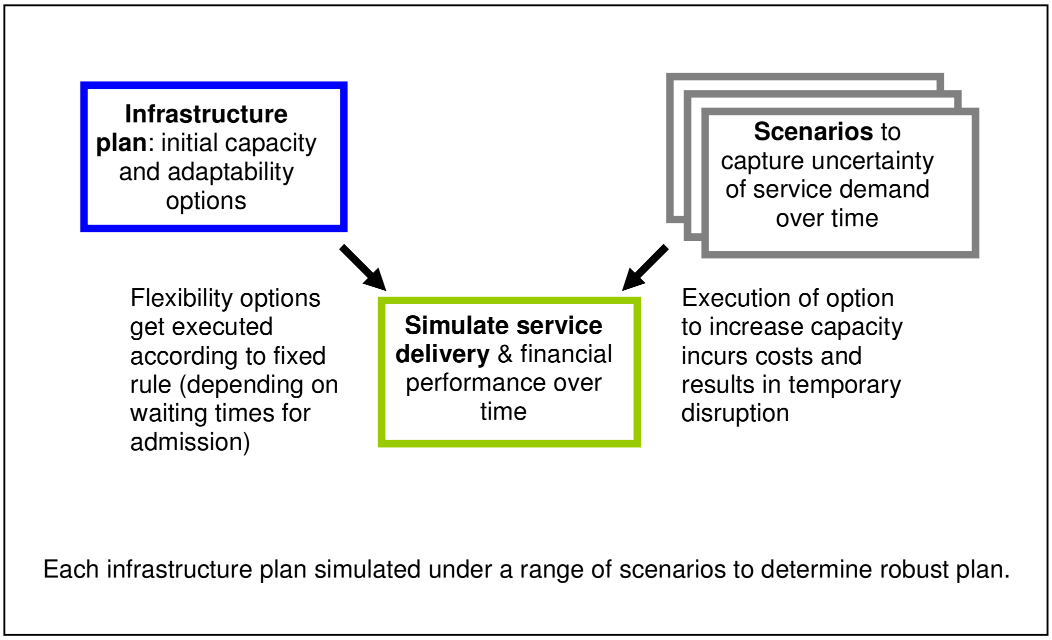
This work has highlighted particular challenges of the PFI approach compared to the pre-PFI model brought about by the increased complexity at the interface between infrastructure provision and clinical operation compared to pre-PFI model. These challenges have resulted both in difficulties in the process of project delivery as well as in less adaptable facilities.

System dynamics modeling

The modelling work builds on the insights of the qualitative work and aims to develop tools to help to guide the planning process of new healthcare infrastructure under conditions of uncertainty, so that the services it enables can meet present and future needs at a foreseeable cost. The initial modelling work concentrated on building a stylised system dynamics model considering the impact of infrastructure flexibility options (i.e. to increase capacity) on care service delivery over time under different scenarios.

The modelling work (see figure 2) examines the relationship between infrastructure and services on the project level: infrastructure enables services and service activity triggers the modification of the infrastructure (e.g. by exercising adaptability options). The ultimate aim of this work is to develop guidance for the planning process of the (initial) infrastructure investment.

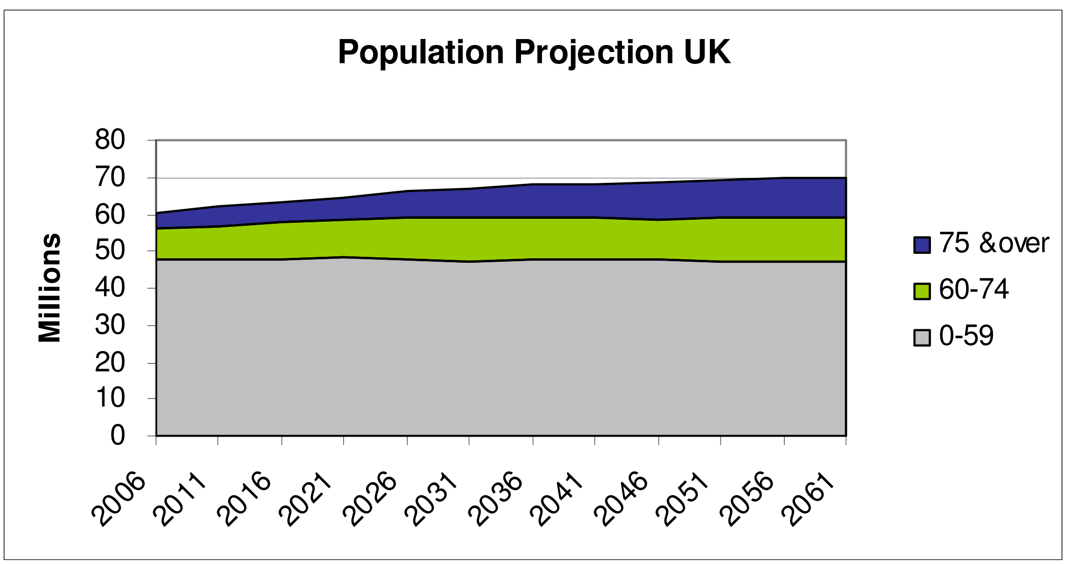
Figure 2: Simulation logic



The demand for hospital care

The demand for hospital care depends on basic demographic factors, i.e. the size of different age groups in the population as well as admissions rates for these age groups as well as the fraction of emergency admissions, the share of day cases and the average length of inpatient stay (see figure 3).

Figure 3: Population projection UK



An aging society leads to increased demand for health and social care services. Thus demographic change will (in absence of other changes) lead to increase in demand for scheduled inpatient outstripping current capacity. While demographic change can be predicted with a relatively high degree of confidence over the time horizon of the model (the biggest uncertainty lying in immigration patterns) the uncertainty related to the other factors is considerable. The age-specific hospital admissions rates are unlikely to remain static. It is very likely, that over the next decades these admissions rate to acute care as well as the share of day surgery on all surgical admission and the average length of stay will change. All these factors will impact the demand for acute hospital beds. The factors driving these changes are manifold: changing pattern of diseases, medical advances allowing the treatment of new conditions, new diagnostic techniques allowing the detection of early stage diseases, new surgery techniques allowing the wider adoption of minimally invasive surgery are some examples. Moreover, policy and funding decisions influence the range and scope of treatments performed in acute care. The precise impact of these changes on the demand for acute is difficult to predict – some of the changes might increase while other might reduce demand. As a first, preliminary step to dealing with this uncertainty we use in our current work a set of scenarios which consist of combinations of annual increases and decreases of age specific admissions rate, share of day surgery and length of stay by +/- 1%. Future work will investigate how these scenarios can be refined drawing on the insights of experts in health care and health planning.

Model structure

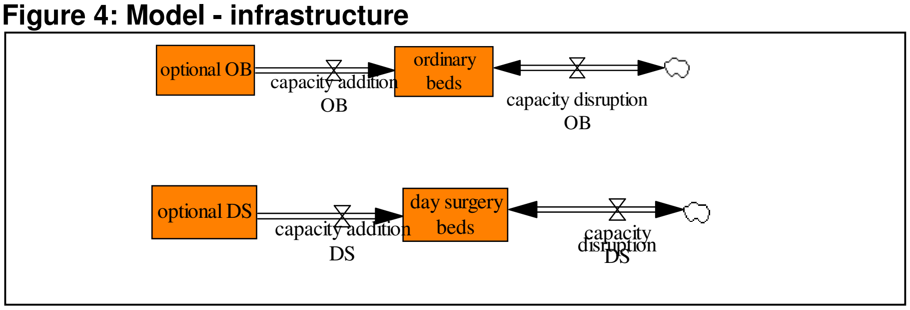
In the model both infrastructure (in this case a hospital) and the services enabled by the infrastructure are included (see appendix).

Infrastructure

The model represents infrastructure and the option to expand capacity in a very simplified way. The initial bed capacity can be expanded by exercising an option. This option can be exercised only once. Exercising this option leads to a short period of reduced capacity before the increased capacity becomes available. This reduction in capacity represents the disruption to other parts of the hospital while the construction activity required to exercise the option is carried out. If the option is, for example, exercised by adding an additional floor on top of the hospital, the disruption of the building activity might temporarily lead to the loss of the capacity in the floor below. In this stylised model it is assumed that the temporary disruption equals the size of the additional capacity added. In the model ordinary beds and day surgery beds are distinguished, both using a very similar structure. As the dynamics governing both types of beds do not interact in the current version of the model, the discussion in this paper focuses solely on ordinary inpatient beds (see figure 4).

The adaptability option considered here is executed as waiting time for non-urgent admissions (smoothed over three months) exceeds a predetermined threshold.

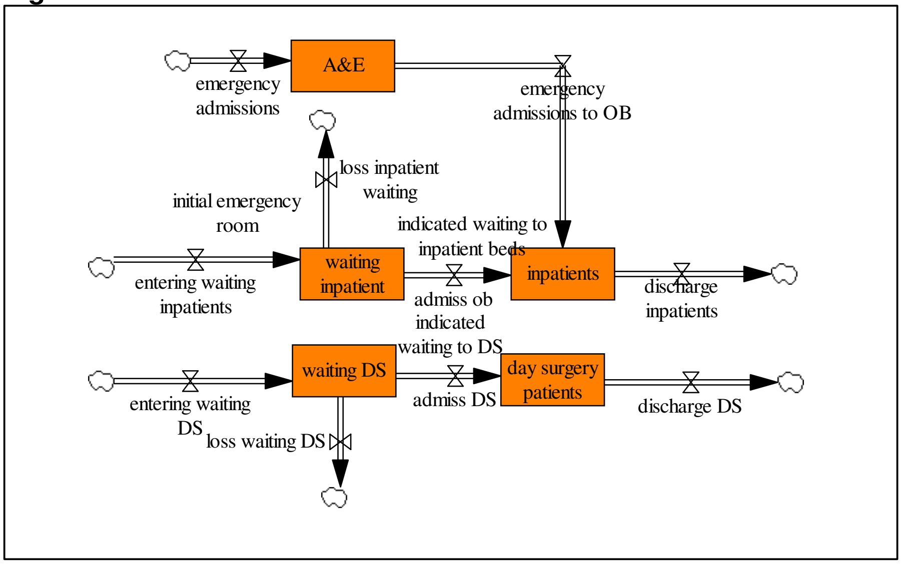
Figure 4: Model - infrastructure



Service delivery

Service delivery is modelled by distinguishing day surgery and ordinary inpatients. Inpatients enter the hospital either as scheduled patients from a waiting list or as unscheduled, emergency patients via A&E. Admissions are restricted by the available bed capacity. Admissions via A&E always have priority over admissions from the waiting list. There is a loss of patients from the waiting list; this represents patients who might go for treatment elsewhere, die or for other reasons do not require treatment any more (see figure 5).

Figure 5: Model - services



Simulation experiments

Simulating the base case

The following figures demonstrate the exercise of the option in the base case when demand is only influenced by demographic change and all other factors are kept constant. As the threshold for the impatient waiting time (figure 6) is reached (around month 130), capacity (figure 7) is – after a temporary disruption - increased, allowing more of the demand to be met. Subsequently waiting time drops. However, in the long run waiting time increases again as demand increases to outstrip hospital capacity (see figure 8) driven by demographic change.

Figure 6: Waiting time for elective hospital admission in base case

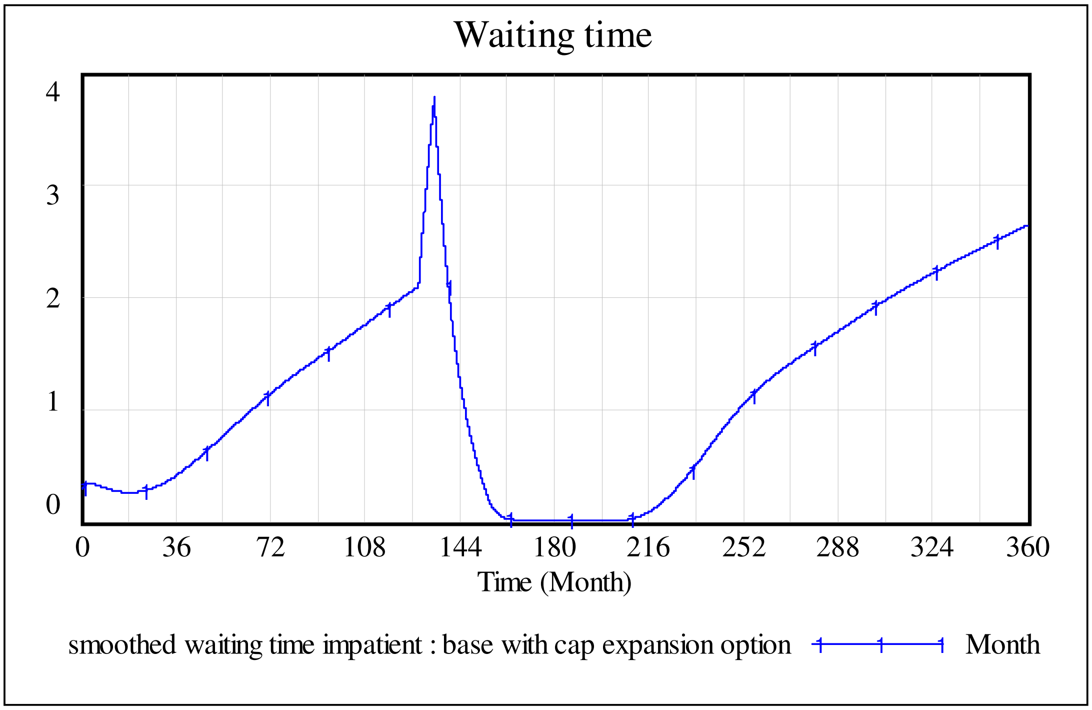


Figure 7: Inpatient bed capacity in base case

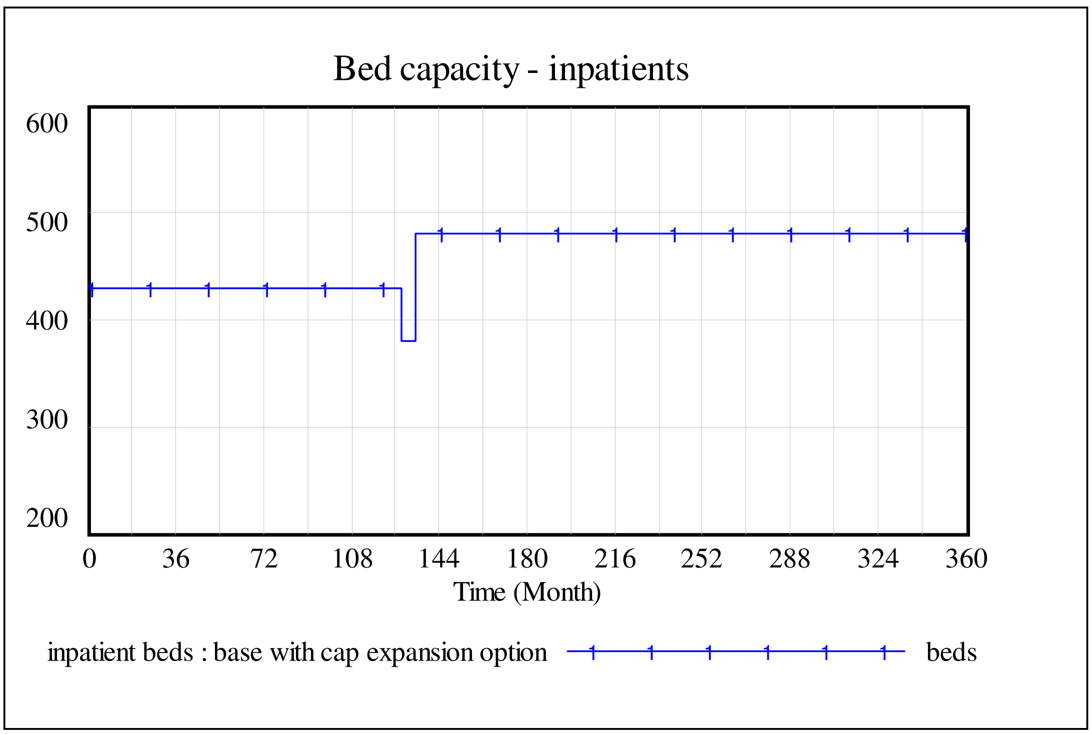
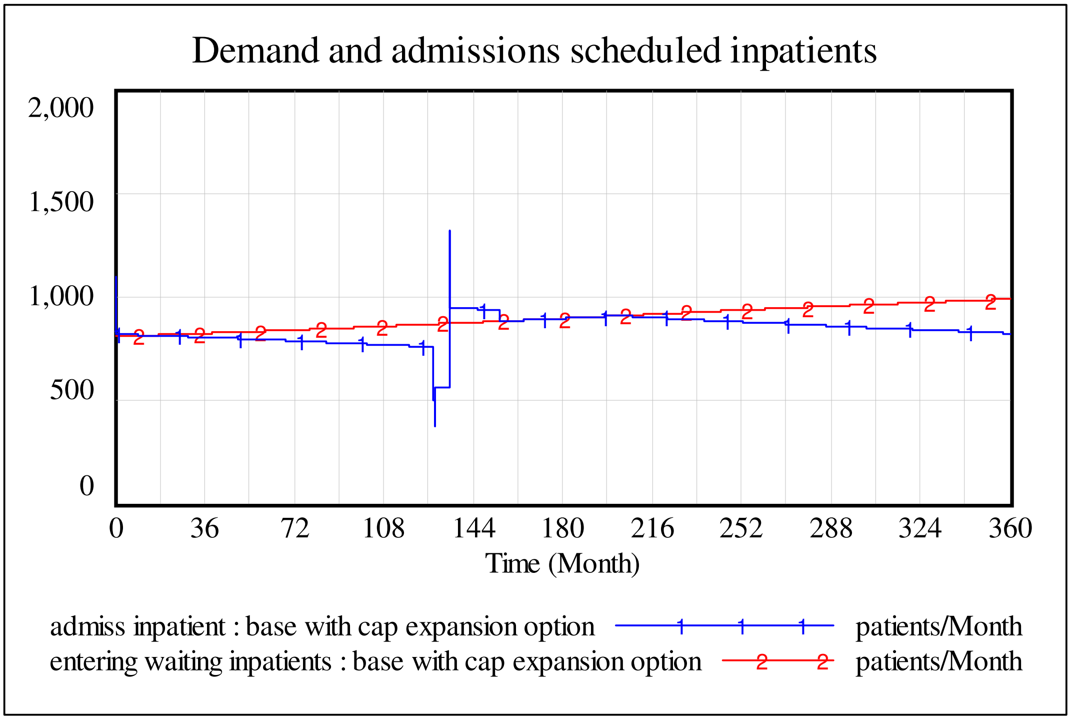


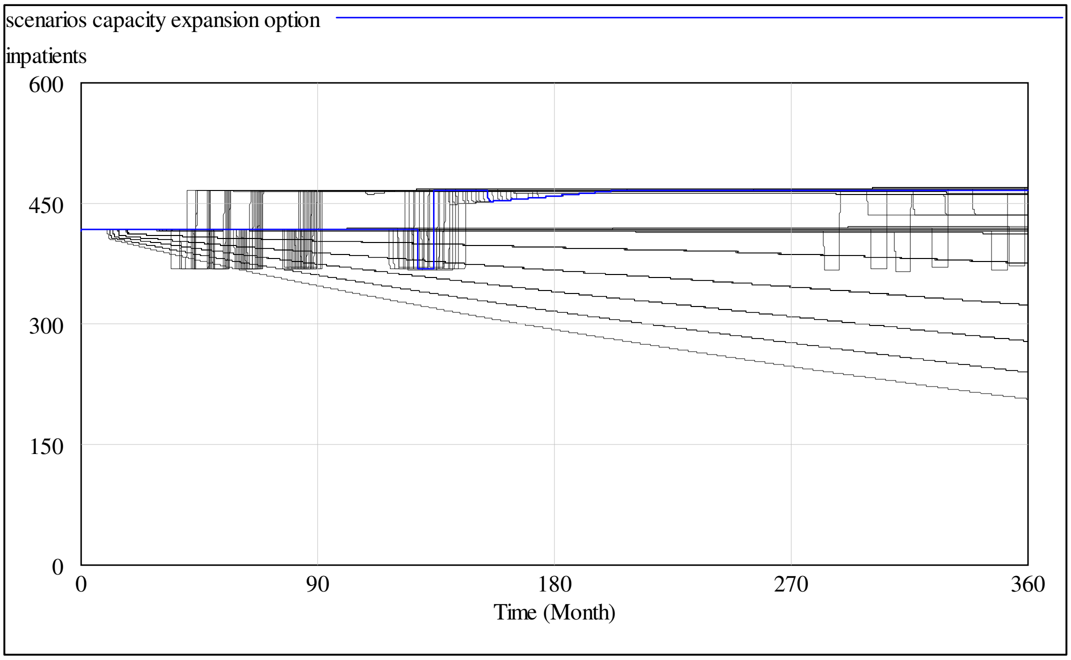
Figure 8: Hospital capacity vs demand for admissions in base case



Simulation of infrastructure plan under multiple scenarios

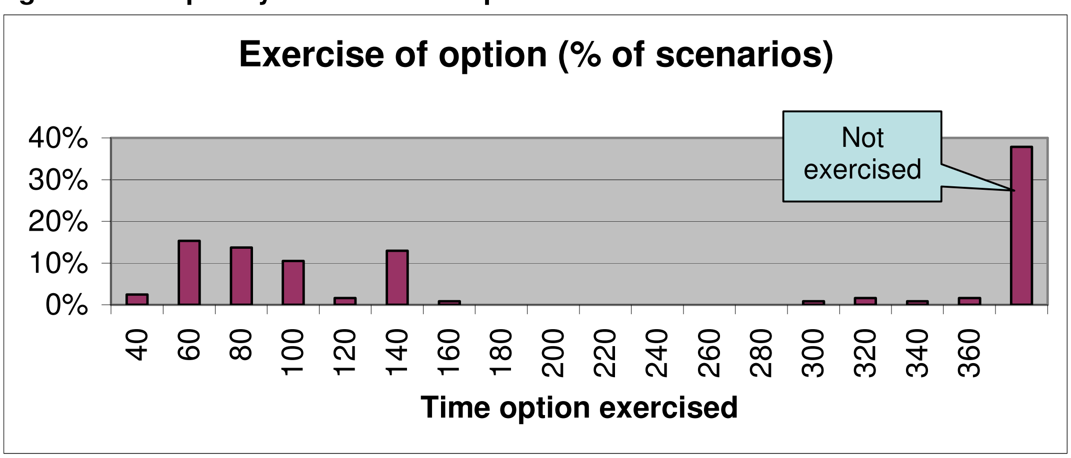
As a next step we have simulated the infrastructure plan (initial bed capacity and option for expansion) under our range of scenarios; each line in the graph below (figure 9) represents the number of in-patients over time in a different scenario. The number of inpatients under some scenarios falls as demand drops. Under other scenarios the hospital is filled to the initial capacity. In slightly less than two thirds of scenarios the option is exercised, and capacity increases after a temporary drop (due to disruption).

Figure 9: Performance of infrastructure with fixed capacity expansion option under different scenarios



In slightly more than one third of the scenarios (37%) the option to expand capacity will not be exercised, as inpatient waiting time never exceeds the required threshold to do so. In most of the remaining scenarios the option will be exercised during the first 14 years of the lifetime of the building and only rarely afterwards (see figure 10).

Figure 10: Frequency of exercise of option across scenarios



Comparisons of different infrastructure plans

The model allows comparison of the performance of different infrastructure plans under a range of the future scenarios as part of the planning process. As an example (see table 1), we contrast three different infrastructure plans (430+50, 400+80, 460+80 beds). Doing this allows us to compare the percentage of scenarios in which providing the option will have been exercised. It also allows us to look at the number of patients being treated and discharged, as well as the demand which cannot be met by the hospital. These simulated results can then form the basis of a cost-benefit assessment for making the initial investment in the provision of the option. The approach allows investigating whether (and under which circumstances) an adaptability option is likely to be valuable and whether the infrastructure is likely to enable the desired services to be provided. In a real life planning process a multitude of considerations will need to inform this assessment: not only are the costs of providing and exercising the option as well as the revenues and cost related to service provision important, but also more specific considerations such as the scarcity of capital or alternative options if service demand can not be met. A model has the potential to focus the attention of the discussion between the various stakeholders involved in the planning process, support the evaluation of the available options and can thereby help to make choices about the most suitable infrastructure plan.

Table 1: Comparison of infrastructure plans with different expansion options

Infrastructure Plan		Percentage scenarios options exercised	Inpatients discharged per month (avg. over simulation period and scenarios)	Patients not treated per month (avg. over simulation period and scenarios)	Inpatient beds (avg. over simulation period and scenarios)
Initial beds	Option to increase the number of beds by				
430	50	62%	1697 +/- 173	168 +/- 214	452 +/- 19
400	80	72%	1698 +/- 179	167 +/- 211	453 +/- 33
460	80	58%	1767 +/- 202	98 +/- 161	486 +/- 25

Conclusions

This work provides an early indication that modelling can have a role in meeting the challenges of infrastructure planning. A simulation approach can help to examine the effect of changing healthcare demand (due to demographics, pattern of diseases, raised patient expectations, etc.) on the requirements for the built environment supporting care delivery. It can also form an input into infrastructure planning for facilities that are able to adapt to innovation and rapid change in healthcare services. Simulation modelling can therefore have a role in addressing the challenge posed by short technology lifecycles and evolving service models mismatched to the long lifetime of physical structures and long-term contractual arrangements.

The paper reports work in progress serving to stimulate considerations and discussions about future scenarios and potential adaptability options in a structured manner. At the time of writing further work is underway to extend the model, ground it more firmly in empirical data, to develop more refined scenarios and explore the possibility to apply it as a planning tool in real life settings. Further areas to be addressed include the development of a more sophisticated understanding of infrastructure options, the distinction between different types of facilities and services and consideration of a range of performance measures. At a later stage, more thought will need to be given to consideration of technical change more explicitly in the model. We also plan to develop the connection of this modelling approach with real options theory.

Appendix: Model structure