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Does the ageing population correctly predict the need for medical beds? Part 2: Wider Implications

Dr Rodney P Jones
hcaf_rod@yahoo.co.uk

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Part of a far wider series on bed numbers and optimum occupancy available at: http://www.hcaf.biz/2010/Publications_Full.pdf

Abstract

Part 1 demonstrated that the World War II baby boom coupled with increasing life expectancy implies that a surge in deaths will continue for the next 40 years. The last year of life represents a high intensity part of lifetime use of a hospital bed with up to 55% of lifetime occupancy. Not only does the number of deaths encapsulate hospital use in the last year of life it is also a key indicator of the wider morbidity/mortality pyramid. Part 2 investigates the wider implications of these findings. First and foremost is that the NHS funding formula completely omits to include the nearness-to-death (NTD) effect in the calculated CCG allocations. As a result, the formula becomes unduly dependent on the year in which it is primed, leading to gross over- and under-funding in subsequent years. These same forces also have profound implications to the minimum size for CCG financial stability which needs to be around 20,000 to 25,000 deaths per annum, only allowing for 20 large commissioners in England. A pragmatic overview is given regarding how to modify current bed models so that they give answers which reflect real world demand rather than being manipulated to give 'policy correct' answers.

Key Points

- A new method for forecasting medical bed demand suggests high growth in demand due to death of the World War II birth cohort over the next 40 years.
- Age-based forecasting is highly unreliable and always underestimates future demand.
- The nearness to death (NTD) effect must be incorporated in demand forecasts.
- The absolute number of deaths not only reflects the NTD effect but also reflects a component of non-end-of-life acute admission for the wider morbidity due to environmental challenges, i.e., Covid-19, influenza, respiratory syncytial virus (RSV), respiratory bacteria, etc which also cause death.
- The NHS funding formula contains a serious flaw and must be amended to include the NTD-effect and associated wider death-related morbidity.
- The minimum size for commissioner long-term financial stability is around 20,000 to 25,000 deaths per annum suggesting only 20 large commissioners are required for the population of England.

Key Words: Hospital Bed Numbers, Demand Forecasting, APC models, Funding Formula, Age-based forecasting, Nearness to Death, Financial Risk

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Introduction

In the world of mathematical models, it is widely known that the omission of a critical variable will cause the model to distort itself to fit the parameters fed into the model. While the NTD effect has been understood and used by economists for over 40 years it has never been incorporated into bed models or the NHS formula for resource allocation. This is a hugely serious omission which will lead to catastrophic failure of the models. The implications to bed modelling will first be discussed followed by the financial and policy implications.

Alternative models for bed demand

No one model can be assumed to give the correct answer and alternative models and scenarios should always be considered. Scenarios should never be cherry picked to force the model outputs to give the 'right' answer. Alas such cherry picking is forced upon the NHS by virtue that forecast budgets should never be overspent. The CCG STP process was an unfortunate example of cherry picking (Jones 2020) with consequent totally unrealistic outcomes. (). Some promising modelling approaches will now be discussed. While conducting an age-based forecast is relatively simple the added complexity of running better models implies that this may better be done centrally by (impartial) subject matter experts.

Modification of the current method

An excellent example of a modification of the current method, which ignores the NTD effect, can be seen in the work of Nowossadeck et al (2020). This approach uses decomposition techniques to extract the changing admission rate in each age band (thereby avoiding the constant risk fallacy, also approximating the NTD effect) and changing LOS. They approximate declining LOS as a logarithmic function over time, i.e., the rate of reduction in LOS diminishes with time which can reach an asymptote (as seen in Figure 1 Part 1). Various extrapolation techniques with different scenarios then attempt to model the range in future bed demand. Hence in Germany between 2015 and 2040 they predicted somewhere between a -3.7% to a +18.4% change in bed occupancy for women and between 0% to +22% for men. My suspicion is that they over-estimated the reduction in LOS and therefore alternate scenarios and models are needed for the change in LOS over time. Other studies show that changes in morbidity and the prevalence of chronic disease have a bigger impact over age and NTD (Nowossadeck 2012, Kramer and Schreyogg 2019).

A bed forecasting study in the Republic of Ireland used the HIPPOCRATES macrosimulation which incorporates the effects of population growth, ageing, healthy ageing, length of stay, avoidable hospitalizations and demand diverted to community care. NTD was not incorporated in this model. This study forecast the need for between 26% to 41% more beds by 2030 (Keegan et al 2018).

Models which do not directly include allowance for the NTD effect are perhaps better employed in those locations where there is only a modest increase in deaths over time. Such areas were highlighted in Table 2 of Part 1 and will need to use a more sophisticated approach. To develop such models is far beyond the capacity of most hospitals and commissioning groups. Public Health England and NHS England could easily develop a planning tool for wider use in the NHS using these methods.

Age-period-cohort models

Age-period-cohort (APC) models are widely used in the life insurance industry, in epidemiology and in wider non-life situations (Harnau 2018, Xiao et al 2020). Age refers to chronological age, period refers to the relevant period for example the 2020 Covid-19 outbreak, while cohort refers to the birth cohort, i.e., the year in which the person was born, i.e., during the 2019 Spanish flu pandemic, etc. APC models have been effectively used to model acute and social care demand in England (Wittenberg et al 2015, 2018, Chalkey et al 2017). Unfortunately, these studies ignored the NTD effect, however, the APC model approximates NTD effects but could be subject to bias at smaller areas. Interestingly these studies were funded by NHS England but the implications to local area demand forecasting have been seemingly overlooked.

Two compartment models

Two compartment models basically reflect the reality of the NTD effect. In one compartment APC or other models account for age-based demand while in the second compartment the NTD effect is modelled. An excellent example of this approach has been employed to model prescription costs in Ireland where age, NTD and morbidity are all considered (Moore et al 2017).

A method to sense check model outputs

A new method for international bed comparison was first introduced in BJHCM in 2018 (Jones 2018). This method plots the ratio of beds per 1,000 deaths versus the ratio of deaths per 1,000 population. The ratio of beds per 1,000 deaths encapsulates the role of NTD in bed demand while the ratio of deaths per 1,000 population is a measure of the age structure of the population. Bed numbers in England were concluded to lie among the upper edge of beds available in *less developed* countries. The method was then used to investigate beds in the states of Australia where a known deficit of beds in the state of Tasmania was correctly quantified (Jones 2019a). A study of bed numbers in US states then revealed gross differences with some states having bed numbers equivalent to less developed countries. Bed numbers in US states followed relative wealth rather than need (Jones 2020b).

A further study relating to occupied beds in English CCGs shows that after adjustment for deprivation most CCGs are using roughly the same number of beds expected from their ratio of deaths per 1,000 population (Jones 2021a). This study investigated if deaths per 1,000 population as a simple measure of age structure (from the perspective of deaths) could be improved by age-adjustment. No improvement could be discerned.

The method has also been used to analyse the levels of *occupied acute* beds in US states and if the availability of nursing home beds influences acute bed utilization (Jones 2021b). An ongoing study of occupied acute beds in the Northern Territory (Australia), where there is a 9-times higher number of indigenous people in this state, indicates an extremely high demand for occupied beds which is seemingly not funded by the capital allocation methods used in Australia. The role of ethnicity is an important point since South Asians and black African/Caribbean are known to have a higher incidence of diabetes (Diabetes UK 2020) and South Asians also have a greater incidence of cardiovascular disease (American College of Cardiology 2019).

After adjustment for deprivation and ethnic/indigenous groups with high service demand the method seems both simple and reliable and should be used to sense-check the outputs from the other models discussed above. New Zealand and Singapore remain the benchmarks for minimum bed numbers after long-term investment in integrated care.

Strategy, perverse incentives, and other issues

This section summarises several diverse issues relevant to the need for robust bed modelling.

Perverse incentives

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NHS commissioners are required to submit balanced budgets to NHS England. In a three-decade career I have never seen a realistic demand forecast by an NHS commissioner. Hospital managers echo this observation. Curiously, CCG calculated demand is always equal to that which is affordable.

Those analysts which I have spoken to indicate that they are making sensible demand forecasts which management send back to be 'reworked'. Indeed, any CCG submitting a real cost scenario to NHS England will be politely told to go away and 'rework' the figures.

During the Blair/Brown administration the need for accurate demand forecasts was avoided by 8 years of high funding growth at +9.3% per annum from 2003/04 to 2007/08 and +5.5% per annum between 2008/09 and 2010/11 (The Health Foundation 2017). However, during the austerity years, and now in the post-Covid-19 era accurate demand forecasting is vital.

Is it possible that commissioners (or NHS England) cannot be trusted to forecast their own demand? Should an independent forecast be prepared against which commissioners can detail how they intend to bridge the gap, and be held accountable for such plans?

Integrated care

It is far too easy to jump to the conclusion that acute care delivered to persons in the last year of life is largely futile. However, as mentioned in Part 1 there are no current methods which can accurately predict who is or is not in the last year of life. Various frailty scores are being evaluated and refined (Leahy et al 2021), however, hospital admission cannot be eliminated. Indeed, it could be argued that primary legislation will be required to enable all the supporting data sharing, compulsory DNR orders, and allowing doctors to administer palliative rather than aggressive acute interventions. It is assumed that the NHS in England will increasingly implement integrated care to move end-of-life related inpatient care into community-based alternatives. Clearly some areas have a higher mountain to climb than others (as per Table 1 in Part 1). The implications of this were discussed in the previous medical beds paper and a paper relating to CCG bed utilization (Jones 2020a, 2021a).

The key points relevant to this study are that England generally has a low number of nursing home beds compared to other countries, and that nursing home care is itself expensive. Palliative care is mainly run by charitably funded hospices and is in limited supply. Acute bed supply in England is already remarkably close to the two most efficient health care systems in the world, namely, New Zealand and Singapore – yet without all the years of dedicated legislation and investment in integrated care. You cannot expect the benefits of integrated care without fully integrated health and social care policy and budgets. The fact that the gap between England and these countries is so small implies that there are not huge benefits to be reaped from integrated care and that any benefits will be fully offset by the need to restore a safe and functional occupancy margin to allow optimum flow in hospitals (next section).

The bed occupancy rate

Hospital bed occupancy is a poorly understood area, and the 85% occupancy target has no valid basis even though it is widely believed to be true. The occupancy margin is largely a function of size not perceived efficiency (Green 2002, Jones 2011a, Kakad et al 2019, Proudlove 2020). It must also be stressed that the occupancy margin applies to individual bed pools, i.e., paediatrics, gynaecology, trauma and orthopaedics, etc, and cannot be applied as a whole hospital average (Jones 2011a). It must also be stressed that x% more available beds do not equate to x% more staff. The aim is to flex the staff in response to seasonal and other factors (Beeknoo and Jones 2016). In addition, hospital bed occupancy fluctuates due to the wider environment (as demonstrated for LOS in Figure 1, Part

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1). For example, areas with higher population density show higher volatility, seemingly due to enhanced spread of pathogens (Jones 2021a-e). Higher volatility implies a more generous occupancy margin. Far from achieving cost savings, a high bed occupancy rate is the source of all manner of increased costs, poor performance and patient harm (Beeknoo and Jones 2016). Intense financial pressure has led the NHS in England down the misplaced road to ever higher occupancy rates (NHS England 2020b). Consequently, the NHS in England requires an additional 10,000 acute beds just to restore an efficient and safe bed occupancy rate (authors calculation). These additional beds involve no additional staff since they are merely to restore flow and avoid the hidden costs of bed management, cancelled operations, delays in the emergency department, and other hidden queues. The huge backlog of elective patients on the waiting list in the post COVID-19 era implies that additional surge beds will be required to clear the backlog.

Does London have too many beds?

One of the interesting features of Table 2, Part 1 is the surprising number of London boroughs in the top 40 list. The increase in deaths between 2019 and 2043 for the whole of London is 39%, the median for the boroughs is 40% (ONS 2020d). Lowest increases are 10% in Barking and Dagenham and 17% in Havering. See Table A1 in the Appendix for details of all London boroughs.

Also note from Table 1 Part 1 that we have entered a period when the growth in deaths is outstripping both births and population growth, i.e., age-based forecasting becomes increasingly unreliable.

A recent study investigating occupied hospital beds in English CCGs (acute + maternity + mental health) concluded that there was little evidence that London CCGs were utilizing more beds than anywhere else in the country (Jones 2021a). This was after adjustment for deprivation and deaths per thousand population. Plans by London CCGs to reduce bed numbers are highly likely to be an artefact of poor modelling, and cherry picking of assumptions, rather than reality.

Covid-19

The future impact of Covid-19 on healthcare demand depends entirely on the dynamics of adaptive immunity (Saad-Roy et al 2020) and the success of immunisation against an increasing number of variants. Hence immunological characterisation studies need to be initiated. The modelled outcomes range between eventual near absence to continued seasonal peaks. In the latter case Covid-19 then becomes a permanent feature of additional medical bed demand. Persons suffering from the immune disturbance known as long-Covid (NICE 2020, Wang et al 2020), will presumably be more susceptible to infection and inflammatory diseases and this will add further demand into the NHS.

We will now turn to the financial and policy implications of the NTD effect.

NTD and flaws in the funding formula

The current NHS funding formula for English CCGs is based on the person-based statistical model developed by the Nuffield Trust (Dixon et al 2011). Despite its apparent huge sophistication this model completely ignores the NTD effect. The sensitivity of the Nuffield Trust model to environmental factors was first highlighted in a 2013 study (Jones 2013), and the specific implications of the NTD effect on the funding formula was highlighted in 2018 (Jones and Kellet 2018). Unfortunately, these studies seem to have been ignored by NHS England. Hence the initial Nuffield Trust study which was conducted using 2006/07 data to predict 2007/08 costs led the authors to conclude that “we would expect about a third of (GP) practices to exceed or undershoot predicted costs by more than 10%” (Dixon et al 2011).

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This observation leads to a discussion of the role of chance and other risk factors and the role of size on CCG funding and financial stability. It is widely known that age is associated with the risk of dying, usually as a logarithmic function. If this is so why the emphasis on the NTD effect? The role of age in the risk of dying is very much about large number averages – assuming that there are no other risk factors, i.e., the effect of ethnicity highlighted above.

For example, epidemics show both age and gender specificity (Yang et al 2015). Respiratory pathogens show different sensitivities to metrological variables which can facilitate or inhibit transmission and viral survival (Paynter 2015). The risk of dying therefore varies in space and time, called spatiotemporal granularity and this has a profound effect on local capacity and cost pressures (Jones 2021c,d). Figures 1a and 1b illustrates the fatal flaw in the person-based model, namely, that the model is susceptible to the high volatility in deaths demonstrated in Figure 4 of Part 1 which is amplified in smaller populations due to chance. The data in Figures 1a and 1b covers local authority and regions across the entire UK (National Records of Scotland 2020, Northern Ireland Statistics and Research Agency 2020, Office for National Statistics 2020b). Monthly data has been summed to give financial year totals. Hence, the original model used 2006/07 data to prime the model, but by 2007/08 deaths in each location had already changed. Figure 1a also shows the ± 95% confidence interval (CI) for Poisson-based chance (Koehrsen 2019). The wide scatter in the data indicates a mix of chance-based and environment-based risk. If you are 'lucky' 2006/07 was a high year for deaths in your location or place, and so your funding is thereby set high for years to come. No funding formula should ever depend on 'luck' to drive future funding.

Figure 1a: Difference in deaths between 2006/07 and 2007/08, and the effect of size

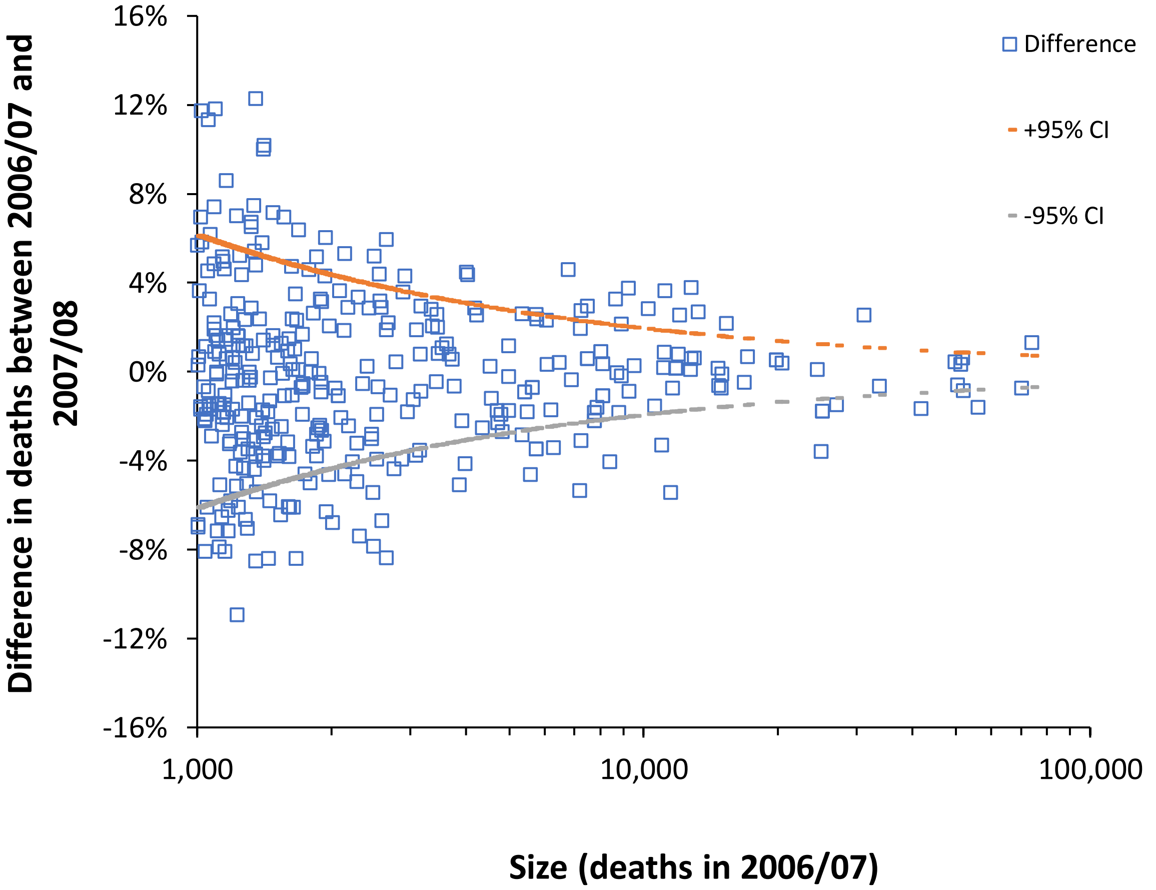

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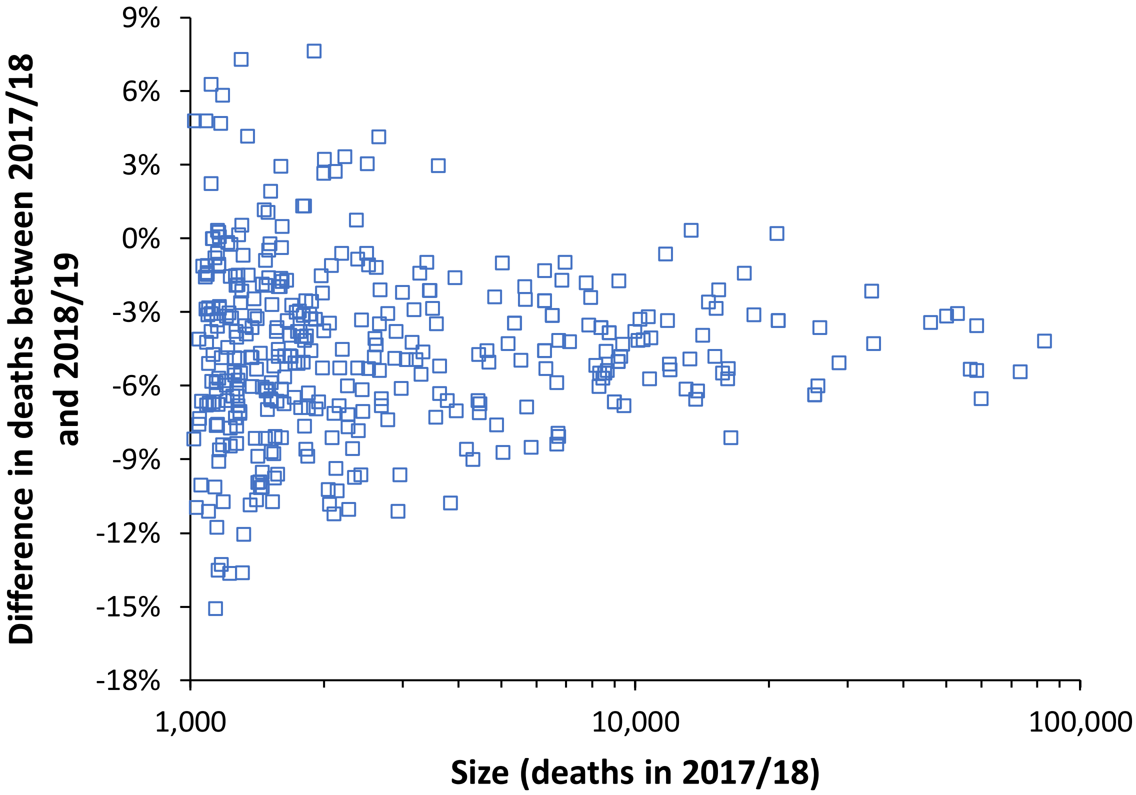
Figure 1b: Difference in deaths between 2017/18 and 2018/19, and the effect of size



However, Figure 1b demonstrates a completely different outcome if 2017/18 data were to be used as the base year to prime the resource allocation formula. As opposed to the 2006/07 and 2007/08 years, in which by pure coincidence the national average is close to a 0% difference, the 2017/18 and 2018/19 years show largely lower deaths in 2018/19 compared to 2017/18. On this occasion the majority receive a higher funding base, while the 'unlucky' few do not. This tendency to over/under fund then accumulates over time leading to cumulative large financial discrepancies depending on the trajectory of deaths over time in each area. A careful comparison between Figures 1a and 1b shows that Figure 1b seems to have more locations away from the average, i.e., the effects of spatiotemporal granularity creating higher dispersion.

These year-to-year fluctuations in deaths has been called the calendar (or financial) year fallacy (Jones 2019c) and represents a serious limitation to any budgeting or planning for services dependant on the NTD effect and associated morbidity (as discussed in Part 1).

Size and NTD costs

Figures 1a and 5b clearly illustrate the role of size in chance-based risk. The average local authority has around 1,000 deaths per annum, the whole of Northern Ireland has around 15,000 deaths per annum, while the largest STP footprint (Greater Manchester) has around 25,000 deaths. The smallest STP Footprints, Frimley Health and Gloucestershire only have around 5,000 deaths per annum. Data at the far right of Figures 1a and 1b is for larger regions such as the South East of England, etc. So even for STP footprints the size of Greater Manchester year-to-year volatility in deaths is around ± 1.2% just from chance alone, which then manifests in volatile end-of-life costs plus additional volatility due to associated wider morbidity (Jones 2021f). All other STP footprints

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have higher volatility. The formula has obviously been recalculated several times since the initial study; however, this inherent and serious flaw remains.

It should be clear that using the 2020/21 financial year (the Covid-19 epidemic) as a base year to prime the funding formula would likewise generate gross over/under funding.

Most importantly even the most recent version of the person-based funding formula then concatenates all demand back to age bands and forecasts future CCG funding based on age-related growth (NHS England 2020a). CCGs containing local authorities in Table 1 (and London in particular) therefore suffer from serious underfunding as time progresses. CCGs with low deaths, in whatever year is used to prime the formula, likewise suffer continuous underfunding until the formula is recalculated.

This is not an infallible or fair way to set CCG financial allocations! The funding formula is therefore in urgent need of a retrospective element to account for the unavoidable costs of NTD and the associated morbidity reflected by deaths (Jones and Kellet 2018).

Death and commissioning financial risk

As has been demonstrated in Figure 4, Part 1 and Figures 1a and 5b deaths are highly volatile and this has profound knock-on effects to financial risk in health and social care costs (Jones 2012b, 2019b). While the smooth trend line for anticipated future deaths in Figure 2 of Part 1 is helpful for planning it is always the volatility that imposes unavoidable capacity and cost risk (Jones 2021b). Indeed, a consideration of Figures 1a and 1b suggests that CCG Footprints with fewer than 20,000 to 25,000 deaths per annum are likely to be long-term financially unstable. The volatility in deaths, and hence medical costs, is almost certainly the primary cause of volatile commissioner costs (Jones 2010). This implies that there should only be 20 large commissioners covering the population of England. The size boundary of 20,000 to 25,000 deaths reflects similar conclusions of an earlier study (Jones 2012b) and of a more recent large international study (Jones 2021e).

Implications to policy

Poor modelling of demand is never an asset to any project. Implementing the multitude of schemes to mitigate the rising medical demand such as those recommended by the National Institute for Health and Care Excellence in 2018 (NICE 2018), plus others, will require up-front investment and years of combined hard work and dedicated supporting policy. Recall that in just 8 years' time the NHS will be experiencing 2020/21 total levels of deaths as the norm.

Overnight surgical bed capacity will come under increasing pressure as medical outliers in surgical wards become more and more commonplace. This is at a time when the government is attempting to deal with a huge waiting list backlog which had been rising before Covid-19 but ballooned from the considerable medical capacity pressures during the epidemic (NHS England 2020e). Temporary surgical beds will be required to address this growing elective waiting list, which in November 2020 stood at some 4.5 million persons waiting for an operation (NHS England 2020f). This represents around 33% of total elective capacity available in 2019/20 (NHS Digital 2020). An astonishingly high mountain to climb, equivalent to 7% more elective capacity required to deal with the waiting list spread over a 5-year period, plus any underlying growth in demand, at >1.5% per annum.

It would seem wise for organisations such as NHS England to (somewhat belatedly) insist on robust modelling rather than repeat the fiasco of the STP process when CCG Footprints were claiming large reductions in bed numbers and/or demand (Boyle et al 2017, Lister 2017, Nuffield Trust 2017, Quilter-Pinner 2017, The Kings Fund 2017, Jones 2021a). Clearly acute trusts should discuss the implications of this study with their CCG colleagues and likewise insist on robust joint demand forecasts. There is never any point in attempting to deny reality and blindly walk into the future hoping that it will all work out. The Department of Health and Social Care (including NHS England) needs to decide if this is truly a National Health Service or just a collection of fiefdoms all trying to replicate the same core functions which are best centrally administered.

The issues behind the funding formula have far wider ramifications to the size of CCGs and the management of financial risk (Jones 2021b-d) – vital issues which have been repeatedly ignored.

Conclusions

The absolute number of deaths serves as a dual proxy for both the NTD effect and wider morbidity from infectious outbreaks and other environmental challenges – although with necessary adjustment for cause of death, and higher multi-morbidity in more deprived areas. Current models of activity and costs completely neglect these contributions. Models which do not incorporate NTD can also be used provided the admission rate in each age band is allowed to change over time (a proxy for NTD). Such models can be used in those locations where growth in deaths is minimal. Supporting technology needs to be made available to the whole NHS to enable predictive staffing. This is an absolute must as it allows costs to be minimised and benefits to be maximized. Models need to be jointly provided by NHS England and Public Health England which give realistic local forecasts with the facility for multiple scenarios involving the role of ethnicity and deprivation. The bed occupancy margin needs to be restored to allow optimum patient flow. The funding formula requires urgent revision to account for the skewing effect of NTD. The way in which the NHS is managed tends to facilitate a culture of denial regarding future demand which hinders open discussion of the magnitude of the task ahead.

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Appendix 1: Change in deaths, births and population for London boroughs and larger regions in England, 2019 to 2043

Area	Deaths	Births	Population
Barking and Dagenham	10%	5%	7%
Havering	17%	13%	14%
City of London	18%	-23%	10%
Bromley	20%	9%	9%
Bexley	24%	9%	10%
Sutton	25%	3%	7%
Waltham Forest	25%	5%	8%
Merton	29%	1%	3%
Redbridge	32%	-1%	6%
Islington	33%	12%	12%
Lewisham	33%	10%	12%
Harrow	34%	-1%	2%
Enfield	35%	-3%	3%
Greenwich	36%	11%	16%
Hillingdon	37%	3%	7%
Lambeth	39%	6%	8%
London	**39%**	**5%**	**9%**
Croydon	40%	3%	6%
Wandsworth	40%	6%	10%
Kingston upon Thames	41%	-2%	6%
Hounslow	41%	-2%	3%
Ealing	42%	-3%	-1%
Haringey	46%	0%	5%
Richmond upon Thames	46%	1%	6%
Barnet	47%	3%	12%
Kensington and Chelsea	50%	-5%	1%
Southwark	52%	10%	13%
Hackney	52%	12%	16%
Brent	55%	3%	8%
Hammersmith and Fulham	55%	3%	10%
Newham	60%	3%	11%
Camden	64%	6%	18%
Westminster	64%	3%	16%
Tower Hamlets	76%	12%	27%
North West	26%	10%	8%
North East	27%	5%	4%
Yorkshire and The Humber	29%	9%	7%
West Midlands	29%	17%	13%
England	**34%**	**10%**	**10%**
East	36%	8%	10%
South East	38%	8%	8%
London	39%	5%	9%
East Midlands	39%	14%	13%
South West	41%	14%	13%