Identifying nurse-staffing requirements using the Safer Nursing Care Tool. Modelling the costs and consequences of real world application to address variation in patient need on hospital ward

Protocol HS&DR 14/194/21

IRAS project ID is 190548

Version Number	Author	Effective Date	Reason for Change
1.0	PG	Jan 13 2016	Protocol as submitted for final funding approval with minor edits to correct typo, layout and removing content not required in a protocol
	Last opened	22/08/2016 12:19:11	
Original version and subsequent amendments produced by the study team © University of Southampton 2016			

Study team

University of Southampton

Peter Griffiths

Jane Ball

Tom Monks

Alejandro Recio Saucedo

NIHR CLAHRC Wessex, University of Southampton

Jeremy Jones

Antonello Maruotti

Poole Hospital NHS Foundation Trust

Yvonne Jeffrey

Portsmouth NHS Trust

Nicky Sinden

Royal Marsden HHS Foundation Trust

Andrew Dimech

Natalie Pattison

University Hospital Southampton NHS Trust

Rosemary Chable

Claire Aspden

Summary of Research

The quality of nursing care and the potential for inadequate nursing to harm patients has emerged as a factor in many reports on failings in NHS hospitals. [1, 2] Reports often cite inadequate nurse staffing as a causal factor in these failures. NICE has recently issued guidance on determining safe staffing for hospital wards[3] which endorsed using the Safer Nursing Care Tool (SNCT) to indicate the number of nurses required on a ward to meet patient need, based on a patient acuity/dependency measure. [4, 5]

Our review for NICE found little evidence about the costs or consequences of tools used to determine staffing levels based on assessed patient need, or the extent to which different staffing policies, based on using the tools are affordable, effective or feasible. [6] Our proposed study examines how patients' needs for nursing care, as measured by the SNCT, vary from day to day. This will allow us to determine how often staffing shortfalls occur, whether there may be excess staff on other wards who could make up a shortfall, and to model the costs and consequences of different strategies for using the tool and deploying nursing staff to meet varying need.

We will collect data on ward nurse staffing, validated nurse reported measures of staffing adequacy, and SNCT measures of patient acuity/dependency from all adult medical / surgical wards of three general and one specialist hospitals daily over a period of 1 year. We will compare daily nursing hours (RN, HCA, all nurses) available per patient to:

- the required nursing hours (derived from daily SNCT acuity/ dependency assessment)
- planned staffing for that day and
- professional judgment of staffing adequacy.

We will assess the association between periods of understaffing identified by the tool and nurse reported staffing adequacy and use computer modelling techniques that account for variability in patient acuity, length of stay, admissions and workforce availability, to compare the recommended strategy (staffing based on mean patient acuity/dependency) with:

- a maximum staffing strategy (staffing set to meet maximum patient acuity dependency)
- a flexible staffing strategy (regular staffing set to meet minimum patient acuity/dependency with shortfall met by redeployment from other wards or bank/agency staffing)
- other staffing policies, as determined by an expert reference group.

For each strategy, we will assess the proportion of shifts with a critical shortfall of nurses using criteria derived from NICE guidance. We will model the staffing costs and consequences of each strategy with varying approaches to filling critical shortfalls. Costs will include costs of any ward nursing staff and bank / agency staff deployed to meet shortfalls. Consequences will be modelled using regression coefficients from robust studies showing the association between nurse staffing and outcomes. Feasibility of flexible strategies will be assessed by examining data to identify when staffing shortfalls can be met by surplus on other wards and the required availability of bank/agency staff.

The study will provide evidence for the usefulness and accuracy of the SNCT, which is widely used in the NHS. The results of the study will give guidance on the feasibility and relative costs and consequences of a variety of staffing policies aimed at addressing fluctuations in demand, including flexible staffing. To our knowledge this will be the first substantial study conducted using the SNCT other than those by its developers and the only study to have modelled the costs and consequences of using it to guide flexible staffing policies.

Background and Rationale

What is the problem being addressed?

NICE guidance "safe staffing for nursing in adult inpatient wards in acute hospitals" (SG 1) recommends a systematic approach to determining the staffing requirements of hospital wards. [3] The recommended approach to setting a staffing establishment, that is the number of nurses employed in order to meet patient needs 24 hours per day, seven days per week, is based on the use of an endorsed toolkit to assess average patient needs on a particular ward. The only toolkit currently endorsed by NICE is the Safer Nursing Care Tool (SNCT). [4, 5] This tool is widely used within the NHS. [7] In our proposed research we aim to determine the feasibility, likely costs and consequences of using the SNCT to setting safe nurse staff levels.

Using the SNCT to establish staffing requirements, the acuity and dependency of every patient on the ward is assessed over a baseline period. The tool provides 'multipliers' to translate patient acuity and dependency (assigned to one of 5 categories) into a staffing requirement.[4, 5] The ward establishment is then set, based upon staff required to meet the average care requirements, with allowances for sick leave, holidays and study leave. However, we do not know whether this approach gives an efficient or effective solution to ward staffing, given fluctuations in need. It is unclear how often the average staffing levels match daily requirements or how often wards are over or under staffed when these averages are used to plan staffing. International studies indicate considerable daily variation in workload intensity for nurses. [8] Modelling studies suggest that staffing based on average requirements can lead to critical shortfalls in the face of variable need. [9] and empirical evidence suggests that substantial mismatches between workload and available staff are common [8] even where formal staffing methodologies are in use. [10] However, we have no equivalent data from the UK.

In 2010, as part of the RN4CAST study of nursing workforce, we undertook a survey of a stratified random sample of 31 English acute hospital Trusts. We found that a majority (59%) of these Trusts used a formal acuity/dependency system to guide nurse-staffing decisions. Most identified the tool used as the SNCT or its precursor. [7] Although the SNCT is designed to set nursing establishments based on periodic review, thirty-six percent of Trusts reported that they monitor acuity/dependency daily, making a responsive, flexible staffing policy potentially feasible. In this study we will assess a range of options for using the SNCT and model the costs and consequences of various ward staffing policies based on dependency/acuity assessments derived from it.

Why is this important?

The Francis inquiries and the Keogh review into care provided by 14 hospital trusts with persistently high mortality rates identified inadequate nurse staffing as a significant factor associated with poor patient outcomes, including death. [1, 2] These reports are consistent with a large body of evidence linking low nurse staffing level to higher hospital mortality rates. [6, 11] Recently, our RN4CAST study in 300 hospitals across nine European countries showed a 7% increase in the odds of death among surgical patients for every additional patient per registered nurse. [12] However, beyond emphasising the vital importance of nurse staffing levels, these studies do little to help determine the correct level of staffing, as we identified in the evidence we reviewed for the NICE safe nurse staffing committee. [3] More usefully, Needleman's recent study identified that risk of death for a hospital patient was

significantly increased by exposure to nursing shifts where staffing fell below what was planned (hazard ratio 1.02 per shift of 8 hours or more below target staffing). This identified the crucial importance of methods to plan staffing and meet fluctuation in demand.

NICE recommended a systematic approach at ward level to ensure that patients receive the nursing care they need, regardless of the ward to which they are allocated, the time of the day, or the day of the week. [3] In response to the NICE guidance, NHS England has mandated the publication of data regarding the proportion of daily planned nursing hours that are actually filled. The published data shows substantial variation between Trusts (http://www.nhs.uk/). However, despite outlining guiding principles of staff planning in the NQB/NHS England document '"How to ensure the right people, with the right skills, are in the right place at the right time"', [13] neither NHS England nor Needleman's study is explicit about how planned staffing should be arrived at, in terms of the recommended "evidence based" tools, or how they should be used.

If deviation between planned staffing and that deployed is to be a useful indicator of safety, more evidence is required about the systematic approaches to be taken to determine staffing requirements in the first place. Furthermore, evidence is needed to understand how best to plan staffing to meet variations in patient need between wards and over time. NICE is assessing and endorsing tools that are broadly compliant with its guidance. To date only one tool, the Safer Nursing Care Tool, [4] has been endorsed by NICE. This tool is the most widely used in the NHS.[7]

The NHS faces pressure to maintain the quality and safety of care in hospitals at the same or less cost than previously. However, there remains a dearth of evidence on the effectiveness of tools, including the SNCT, or how best to translate estimates of patients' average requirements for nursing care into daily staffing plans. [14, 15] While the published evidence on the SNCT shows variation in average patient need from one quarter to another, emphasising the need for periodic review of establishments, [5] we are aware of no published data indicating the extent of variation from day to day as measured by the tool. Such information is necessary in order to understand the implications of planning staffing based on average requirements and the feasibility of flexible responses to daily variation. [9] We have undertaken small scale pilot work in one Trust, that found that the required daily nursing hours measured by the SNCT varied by approximately +/- 30% (SD 15%) from the mean, whilst the number of staff deployed varied much less (RN staffing approx. +/-10%). There was little correlation ($r<-0.01$ to 0.16) between staffing deployed and the SNCT measure (unpublished doctoral work).

Although the SNCT guidance focusses on setting ward establishments (that is the number of nurses employed) 36% of Trusts that reported using it in in our RN4CAST survey monitor acuity and dependency daily, making a responsive / flexible staffing policy using the tool possible. But the feasibility, costs and consequences of different approaches to responding to varying patient needs are unknown.

Why is it needed now?

In our review of evidence to inform the NICE safe staffing guidance for nursing in adult inpatient wards we found no evidence for the effectiveness of any tools or systems designed to guide decisions about staffing levels on hospital wards. [6] There are many such systems. A review undertaken for the then DHSS in 1982 identified over 400. [16] A more recent review of 58 studies concluded that there is little objective and validated information regarding systems to determine staffing requirements, and that current evidence provides insufficient accuracy for resource allocation or for decision making.[15] The field is dominated by descriptive reports of locally developed studies with limited or weak evidence for validity even for widely used and commercially supported approaches. [14, 15]

Systems based on assessments of dependency/acuity are the most widely used [17] and this is confirmed by our recent RN4CAST survey. [7] The SNCT falls into this category. Patients are allocated to one of five acuity dependency categories. These categories indicate requirements for nursing care based on an estimate of the time taken to care for patients in each category. [5] It is distinctive because its care 'multipliers', used to estimate staffing requirements from patient dependency/acuity categories, have been derived from observations on approximately 1000 NHS wards and was most recently applied to 40,000 patient care episodes, making it a strong candidate for the NHS. [5, 18] However, in the face of rapidly changing care needs, it is not clear how long even such relatively extensive validation can be relied upon. Furthermore, even if average nurse staffing requirements are accurately estimated, the costs and consequences of basing daily staffing on an average using the tool are unknown. Alternative approaches to setting required staffing levels, including flexible approaches, have not been explored.

Because some form of systematic planning process is present in most Trusts, trials are no longer feasible. However, our modelling approach will provide robust estimates of the costs and consequences (in terms of adverse outcomes) of different approaches to using tools and workforce deployment policies based upon the results. We focus on the SNCT because it is currently the only tool endorsed by NICE and appears to be the most widely used tool in England. However, the lessons learned from this study would have implications for the use of any similar tool and flexible staffing policies based upon assessments made using them. Furthermore, our design would be adaptable should any of the participating Trusts choose to adopt an alternative tool following (e.g. future NICE endorsement) prior to study commencement.

This research aims to fill a number of significant gaps relating to safe and effective nurse staffing in hospital wards. It aims to determine the feasibility and likely costs and consequences of a number of approaches to dealing with fluctuations in workload, as assessed by the only tool that is currently endorsed by the National Institute for Health and Care Excellence (NICE). This study has the potential to tackle several key knowledge gaps in this field and the results will support local managers and decision makers to achieve safe nurse staffing consistently on NHS hospital wards.

We will consider options for flexible staffing policies using different baseline staffing and model the feasibility and costs / consequences of each staffing strategy including:

- Opportunities to redeploy staff from 'over-staffed' wards to 'under-staffed' wards
- Costs of bank / agency staff to be employed to fill critical staffing deficits

- The relative efficiencies of different staffing groups to meet patient need
- Adverse outcomes associated with under-staffing

Aims and objectives

In this study on acute medical surgical wards in 4 hospitals we aim to assess a range of options for using the Safer Nursing Care Tool and model the costs and consequences of various ward staffing 'policies' based on dependency/acuity assessments derived from the tool. We will assess:

- The required nursing establishment (daily staff equivalent), as measured by the tool using the recommended approach (based on average acuity/dependency of every patient on the ward over a minimum of 20 days).
- Daily variation in acuity / dependency of the patients as measured by the tool.
- The number of observations required to determine a reliable baseline.
- How current staffing on the wards matches staffing requirements measured by the tool.
- Whether a mismatch between staffing requirements measured by the tool and available staff is associated with nurse perceptions of staffing adequacy.
- The influence of non-patient factors such as admission/discharge rate.
- Develop computer based mathematical simulation models to explore scenarios with different approaches to using the tool and flexible staffing policies
- model the costs/consequences of each staffing policy including costs of bank/agency staff to be employed to fill critical staffing deficits, opportunities to deploy staff from overstaffed wards to understaffed wards and potential adverse outcomes associated with understaffing.

The study will provide evidence for the usefulness and accuracy of the SNCT, which is widely used in the NHS. The results of the study will give guidance on the feasibility and relative costs and consequences of a variety of staffing policies aimed at addressing fluctuations in demand, including flexible staffing.

Research Plan / Methods

In this study we will use the SNCT tool to assess acuity / dependency for all patients in each ward daily, over a period of 1 year. In a sub-sample we will undertake multiple daily observations periodically in order to assess variation throughout the day. For each shift we will also ask the nurse in charge to complete a brief report of perceived staffing adequacy based on a single item from our RN4CAST survey [19], reports of significant delayed or missed care [20], estimated staffing requirement (professional judgement) and reasons for any mismatch between available and required staffing. These nurse-reported assessments of staffing adequacy provide an external criteria for assessing SNCT accuracy and have been validated by relationships with patient care outcomes. [12, 21, 22]

From these data we address a number of questions. SNCT scores are designed to identify the required nursing establishment (employed workforce in WTE). From this, the daily staffing requirement can be inferred in nursing hours per day (NHPD). We will compare the establishment and daily NHPD as predicted using the SNCT scores with the actual establishment and staffing deployed on the ward. In order to assess whether the tool accurately predicts required staffing we will assess associations between deviations from planned staffing and measures of staffing adequacy. Using mathematical

models (e.g. [9, 23]) we will attempt to identify if there is an optimal approach to planning ward staffing using the tool and whether this varies across settings.

Using a range of criteria, we will determine the proportion of days that wards are critically under / over staffed if staffing / establishment were based on a range of policies for using the SNCT results. The policies to be considered will include:

- setting staffing to meet the mean patient acuity/dependency determined from 20 days observation (the SNCT standard approach);
- staffing to meet the maximum commonly observed acuity/dependency observed during baseline observation (maximum staffing approach) and
- a flexible staffing approach with ward establishments set to meet the minimum commonly observed dependency from baseline (and deficits filled by temporary staffing)
- other staffing policies, as determined by an expert / PPI reference group

We will assess the extent to which adding allowances for factors not incorporated into the tool (e.g. variability in admissions / discharge rates) changes daily staffing requirements.

Critical understaffing will be defined as 25% or 8 nursing hours per shift below the required level or a patient to nurse ratio exceeding 8:1 (whichever is reached first), as described in NICE safe staffing guidance. Needleman's study showed an increase in the risk of death for patients exposed to shifts when available nurse staffing was 8 hours or more below target. [3, 10, 24]

Using evidence on potential adverse outcomes associated with understaffing derived from robust observational studies, e.g. [10-12], we will create dynamic models of the costs and consequences of the staffing policies for meeting the fluctuations in demand considering:

- establishment costs
- availability and costs of bank / agency staff to be employed to fill critical staffing deficits
- opportunities to redeploy staff from overstaffed wards to understaffed wards
- relative efficiency of permanent vs temporary staff
- adverse outcomes associated with residual staffing variation

Setting

This is an observational study in medical / surgical wards in 1 university hospital, 2 district general hospitals and one specialist (oncology) hospital based in London, South East and South West England. The Trusts serve diverse populations including rural areas, deprived inner city populations and specialist national referrals. Across the four Trusts there are approximately 75 adult medical / surgical wards (excluding ICU and highly specialised areas) with over 1700 beds. Currently, staffing is reviewed periodically (up to three times per year). Two of the four trusts currently use the SNCT combined with professional judgement to review nursing establishments, as recommended by NICE. The remaining Trusts use other approaches but both plan to move to using the SNCT prior to study commencement. This range of settings is typical of those in which the SNCT is currently deployed and will allow us to explore the extent to which results might vary across settings or be generally applicable (as per the intention of the tool).

Sample / data sources

Eligibility criteria for inclusion in the study are:

- Ward provides inpatient care for 7 days per week.
- Adult somatic health population / medical or surgical
- Appropriate for SNCT according to the SNCT resource pack [4]

Exclusion criteria

- Wards that are assessed as providing highly specialised services (such as maternity) with atypical staffing requirements (as determined by local chief investigator, with documented reason)
- Day case / weekday wards
- ICU

For each hospital and ward we will develop a profile detailing current ward establishments (and any subsequent changes during the study), specialities, approaches to setting ward establishment and review of staffing adequacy including methods to identify and rectify staffing shortfalls on a given shift. In addition, we will determine basic ward layouts and the proportion of beds in bays / single rooms, factors that may influence staffing requirements. [25, 26] These data will be gathered from Trust reports and interview with staff responsible for setting and monitoring nursing establishments.

We will gather anonymised data on patient flow (admission, discharge and length of stay) and case mix (age, admission method, main specialty, HRG) from the each hospitals' patient administration system.

Staffing requirements / dependency acuity

Daily SNCT assessments on patients will be undertaken by nurses in charge of the shift. Using the supporting material developed for the SNCT, all nurses making assessments will be trained in the tool's use. [4] Published data indicates high reliability between raters [5] confirmed by our pilot testing. An overall agreement of 92% was reported at the level of the individual patient rating, and all disagreements being between categorisations of lower dependency patients, where differentials between staffing requirements (according to the tool's multipliers) are relatively small. Consequent impact on calculated ward staffing levels is generally negligible. Data will be collected over a one year period in order to ensure that seasonal variation is fully accounted for. Three of the four trusts in the study will have installed systems for inputting data into local databases via ward-based computers. In the remaining Trust we will deploy a bespoke spreadsheet for gathering data. While this generates a substantial requirement for data collection we are aware that this practice is routine in many Trusts and our own piloting indicates that it is feasible, taking only a few minutes to complete. Furthermore, although we might be able to undertake the study with a sample from across the year, the volume of data required would still be large and we judge it more feasible to establish the practice as a normal part of ward routine than to undertake frequent intermittent assessments. Co-applicants in all participating Trusts are confident that the systems can be implemented. In order to support the implementation of data collection and maximize response rates we will organize a programme of training and induction into data collection starting 2 months prior to the main study data collection period We will include a run-in period for data collection to assess feasibility and monitor compliance. and offer monthly feedback on compliance to investigators in Trusts and to individual wards throughout the study

with additional tailored training and support offered to wards whose compliance falls substantially below average compliance. Wards where overall compliance (response rates) falls below 50% will be targeted for immediate support.

The recommended approach to assessing the SNCT is to gather data at 15.00. [4] This will be undertaken on all participating wards every day for 1 year – 356 ward level assessments per ward. Based on our piloting we estimate that the assessments will take approximately 6 minutes per ward per day. In order to assess additional variation throughout the day we will undertake additional data collection. For one week (7 days) during the study period, ratings will also be undertaken after morning and evening shift handovers (approx. 8pm and 8/10 pm depending on shift patterns) on a stratified sample of wards.

Data will be collected at the level of the patient (anonymised) so any future changes in the recommended SNCT multipliers can be accommodated. Currently the SNCT multipliers generate an establishment (whole time equivalent nurses to be employed). Daily staffing requirements (Nursing Hours per day - NHPD) will be calculated from the SNCT establishment, which includes an 'uplift' of 22% for study and sick leave and a 20% WTE allowance for senior staff administrative duties by removing these 'uplifts' and dividing all staff hours across the year.

$$NHPD = \frac{(Establishment\ WTE - .2)}{122 * 365}\% * weekly\ working\ hours\ (37.5) * weeks\ worked\ (45)$$

This gives an indication of the nursing hours required on a given day, given the patient acuity level according to the SNCT tool. As the SNCT gives no indication of how staff are to be deployed across shifts we will make initial shift level estimates of staffing requirements by allocating hours to shifts based on planned deployment patterns for each ward. For example, if a ward runs two 12-hour shifts and typically has four staff at night and six during the day we will allocate calculated staffing requirements in proportion (40% night, 60% day). As the SNCT does not indicate the required staff skill mix we will take this same approach, using current ward rosters, to estimate ratios of qualified to unqualified staff per shift.

Deployed staffing

Data on deployed nurse staffing will be derived from Trusts e-rostering systems, which record nursing hours / grades and times, actually worked per ward per day. Depending on the trust, bank and agency staff employed are recorded on separate systems. These will also be interrogated.

Outcomes

In order to assess the validity of SNCT staffing predictions, we will measure the perception of staffing adequacy using a 'micro survey' for the nurse in charge on each shift to assess professional judgement. Professional judgement remains a leading alternative approach to determining nurse staffing requirements [5, 17] and is seen as an essential adjunct to measurement systems, as recognised by NICE. [3] The nurse in charge will report staffing adequacy, based on a single item from our RN4CAST survey [19] ("on this shift, do you have enough nurses to provide quality patient care"); reports of significant delayed or missed care [20] ("on this shift was necessary nursing care left undone because staff lacked time to complete it"); and estimated staffing requirement (estimated number of RNs and

HCSW required). These nurse-reported assessments of staffing adequacy provide an external criteria for assessing SNCT accuracy and have been validated by relationships with patient care outcomes. [21, 27, 28] To assess within day variation we will also assess these measures three times per day over one week (see above).

Analysis

For the purposes of descriptive analysis, we will form groupings of wards based on a-priori criteria (e.g. named specialty) and / or empirically derived criteria (e.g. high turnover, high acuity). Identification of relevant grouping will be informed by consultation with a reference group of clinical experts recruited from individuals with responsibility for setting staffing establishments in participating Trusts and additional experts in staffing methodologies.

We will undertake descriptive analyses to identify central tendency (mean, median) and variation (SD, range and interquartile range) in SNCT acuity/dependency ratings. We will explore variation over time by looking at trends throughout the year although depending on any observed pattern it may not be possible to distinguish secular variation from recurring seasonal variation. We will also explore variation by day of week. From the sub-sample of three times daily observations we will also calculate the magnitude of variation within a day by calculating intracluster correlation coefficients between observations taken within a single ward on one day. We will describe actual staffing patterns in a similar manner

We will identify indicative daily staffing requirements from the SNCT, using the methods outlined above. The indicative staffing requirement will be based on the first 20 days of data. We will consider the appropriateness of the 20 day sample window of the SCNT and its impact on establishment. Areas of investigation will include the timing of the sampling and length of the sampling period, for example, a comparative analysis between establishment based on 20 and 60 day measures and a comparison of the estimate obtained from months with high and low average scores.

In order to give an indication of the validity of SNCT predicted staffing requirements (professional judgement), we will calculate the deviation between predicted staffing requirements from the SNCT (per shift and per day) and the actual staffing deployed. Using multi-level modelling approaches appropriate to the type of data we will assess the relationship between deviation from predicted staffing requirement and nurse reported measures of perceived staffing adequacy (including staffing levels and skill mix). We will derive three outcome measures: 1) binary measure of staffing being perceived as adequate 2) deviation between nurse reported requirement and available staffing (all RN+HCSW) and 3 deviation between nurse reported skill mix requirement and actual skill mix (RN/RN+HCSW). Beginning with a simple model of the association between deviation from staffing required and the measure of staffing adequacy we will add (multi-level) effects for ward type (ward clustered in ward type) and hospital (ward clustered in hospital). We will test models with both random slopes and random intercepts. Reduction in the Bayesian information criterion (BIC) and Akaike information criterion (AIK) will be used as the criterion for model selection. We will also assess whether inclusion of daily patient turnover (admissions, discharges) and ward layout improves model fit and whether there is interaction between

these terms and staffing deviation. All statistical modelling will be undertaken using the analysis software STATA.

If the SNCT provides an accurate prediction of staffing requirements, there should be a significant inverse association between deviation from the required staffing and reported staffing adequacy (professional judgement). If the overall results indicate that the SNCT gives a good estimate of required staffing levels and skill mix then the current approach to using the tool is validated. If the degree of relationship varies according to the other factors included in the model (indicated by including random slopes in the multi-level model and significant interaction between staffing adequacy and turnover / ward types / hospital) this will indicate that the accuracy of the SNCT prediction may vary according to these factors, because the relationship between deviation and staffing adequacy differs, and thus that additional information is required to estimate the staffing required. In particular, we will explore whether there is specific evidence indicating that the specialist cancer hospital may differ from other offering more 'general' services and whether traditional ways of categorising wards (e.g medical, surgical, older people) for benchmarking staffing requirements are, in fact, useful discriminators. We will also assess specifically whether perceived adequacy of skill mix varies according to ward type and assess whether results give any indication of the necessary skill mix on particular wards.

Operational Research Modelling

Model parameterisation & conceptualisation

The SNCT and ward data collected will be used as the empirical basis for an analysis of staffing policies by simulation. Stochastic simulation models consist of a number of continuous and discrete random variables used to mimic the variability seen in a real ward and hospital. A stochastic simulation is the appropriate methodology as wards are subject to variation in patient admission rates, patient length of treatment, patient acuity and are subject to capacity constraints. In particular, we will make use of a discrete-event simulation framework to model each ward within the hospital.

We will construct a model of a hospital with a finite number of beds and wards. Parameters in the model will be derived from observations of wards within each of the 4 hospitals. We will select and fit appropriate probability distributions using maximum likelihood estimates of parameters. The model will run to simulate data for a period of one year for each hospital and for each comparative analysis.

As admissions are conceptualised as a random variable, there will be instances where the model generates a number of patients whom cannot be immediately admitted to the ward. In these instances we will assume the patient is admitted as an outlier to an alternative ward. Although we expect the acuity of patients to vary during their stay in hospital, it is not feasible to track how the SNCT estimate of acuity/dependency varies in an individual patient during data collection. The model will therefore treat acuity as an independent random variable from patients, but will still incorporate transient effects, such as acuity by time of day.

Comparative analysis

We will model and compare a range of staffing strategies

- Standard staffing – Staffing levels based on a 20 day SNCT average
- Maximum staffing – Staffing based on the maximum requirement seen in 20 days of SNCT data

- Minimum / flexible staffing (base staffing set to meet minimum need observed in 20 days of SNCT data)
- Any alternative scenario suggested by the clinical expert / PPI reference group

Assuming a normal distribution model applies, base staffing levels for maximum and flexible staffing levels will be set using mean + (or minus) 1.65 SD in order to have staffing that is sufficient 95% of the time (or a staffing level set based on the lowest that is commonly observed). We will investigate the feasibility of further comparative scenarios using measures of sample error and variation, such as the standard deviation, and methodology from statistical process control.

For flexible and standard models, we will assess the feasibility of flexible staffing by calculating a hospital level estimate of staffing required and comparing this to the number of nurses deployed according to the model. For flexible staffing policies and the standard staffing model we will determine the feasibility of filling staffing shortfalls from redeployment within the hospital firstly and bank and agency staff secondly. We will work with our expert reference group to determine triggers and priority rules for the point at which more resource is needed and why one ward might get the resource over another if there are insufficient resources. Any residual difference would be an estimate of requirements for bank / agency nurses. We will use hospital level estimates for proportion of bank and agency shifts required vs those filled to model the likelihood of filling a shift from bank / agency. We will assess the implications of lower efficiency for temporary staff on wards by using varying assumptions about the relative efficiency of temporary staff (e.g. 1 temporary staff WTE = .8 permanent staff WTE)

Primary model outcomes

- No. (proportion) of days that are below the required nurse staffing level (NHPD)
- No. (proportion) of shifts that ward is below 8 hours or more of required nurse staffing
- No. (proportion) of shifts that ward is below 8 hours or more of required registered nurse staffing
- No. (proportion) of Day shifts where Registered nurse staffing is below 8 patients per nurse
- Number / proportion of shifts associated with reports of inadequate staffing
- Mortality at 30 days due to insufficient staffing
- Other adverse outcomes

In order to model shifts where professional judgement identifies staffing levels to be inadequate we will use coefficients from our regression models for the association between staffing shortfalls and the likelihood of reports of inadequate staffing. In order to estimate effects on outcomes we will scrutinise evidence for robust studies that estimate adverse effects in the face of nurse staffing below that required. Currently the only study we are aware of that provides estimates in this form is a US study by Needleman and colleagues. [10] This gives a hazard ratio of 1.02 for the effect of exposure to a shift with 8 hours or less below target staffing on 30 day mortality. Using hospital level mortality rates as a baseline we will use this to estimate the effects of understaffing in each ward. Because overall risk of mortality will not be uniformly spread across wards, we will also aggregate these estimates at a hospital level. Although wards included in the study will not cover all patients they are likely to include the majority of those at higher risk of mortality. Excluded areas will be have relatively few patients and / or be at relatively low risk of mortality (e.g. day surgery, paediatrics, maternity). While we exclude ICU, the majority of patients with an ICU stay will also experience a ward stay.

As we are collecting actual staffing levels over a period of one year we will be in a position to compare the modelled results based on SNCT establishment with actual understaffing. This will allow us to evaluate if improvement is achieved using the SNCT relative to the success of the staffing policies currently deployed in the Trust.

Bias handling in model estimates

As the model will begin with no patients in it, we will use standard methodology for handling initialisation bias to run the model to a representative starting state. We will also investigate the feasibility of using representative initial conditions, such as the average ward occupancy, instead or in addition to a run in period, as this will greatly reduce the runtime and manageability of the models. We will use standard methodology (multiple replications or non-overlapping/spaced batch means) to ensure that sufficient data is generated by the model to provide point estimates that are accurate assessments of model performance. We will investigate the feasibility of more advanced batched means methods such as overlapping batch means in reducing model runtime.

Parameter Uncertainty

We will investigate the impact of parameter uncertainty at both the individual ward level and the aggregate hospital level results level using a combination of one-way and multiple-way sensitivity analyses.

Economic modelling

Nurse staff costs will be estimated for each shift, for each ward, based on the number of staff (at each band) and the length of shift (or time working on each shift for those nurses working across shifts) to derive total whole-time equivalents. We propose reporting an overall breakdown of registered vs unregistered nurses. Each of these broad groups will be costed based on each ward's existing grade/ skill mix of staff, within these broad categories. These definitions are aligned with nationally representative unit costs [29], which will be used as the basis of costing the nursing staff on all included wards (see Table). The Unit Costs will be applied to agency and bank staff. However additional charges will be included to account for additional costs associated with employing agency staff. If the published unit costs are considered inappropriate for any of the staff categories included in the study, new estimates will be calculated by the study team using consistent methodology. Ward costs will also be calculated using Trust-level WTE costs to determine the robustness of the costing approach to local variations in estimating staff costs.

Category of nursing staff	Salary	On-costs†	Overheads			Total
			Staff ‡	Non-staff*	Capital #	
Mean FTE basic salary for Agenda for Change band 7	38,345	9,598	9,257	20,121	2,752	80,073
Mean FTE basic salary for Agenda for Change band 6	31,943	7,818	7,677	16,687	2,752	66,877
Mean FTE basic salary for Agenda for Change band 5	25,847	6,123	6,173	13,417	2,752	54,312
Mean FTE basic salary for Agenda for Change band 4	21,120	4,493	4,945	10,749	2,173	43,480
Mean FTE basic salary for Agenda for Change band 3	18,433	3,922	4,316	9,382	1,896	37,949

Mean FTE basic salary for Agenda for Change band 2	16,282	3,464	3,812	8,287	1,675	33,520

Notes
† employer NI contribution plus 14% salary for employer's contribution to superannuation
‡ Management, administration and estates staff at 19.31% of direct salary costs
* Costs for office travel/ transport and telephone, education and training, supplies and services, plus utilities, at 41.97% of direct salary costs
# based on new-build and land requirements of NHS hospital facilities, adjusted to reflect shared use. Treatment space not included. Annuitised over 60 years at discount rate of 3.5%

We will assume that projected staffing requirements (whole time equivalent across all nurse staff on the ward) will keep the same skill mix (in terms of registered and unregistered nurses and seniority of registered nurses). We may consider alternative assumptions, such as meeting all staffing shortfalls with registered nurses (since studies of safety of care suggest patient outcomes are most closely associated with levels of registered nurse staffing), as sensitivity analyses.

For the economic modelling, we will consider four main scenarios:

- Assume that staffing deficits will be met by employing bank/ agency staff, both registered and unregistered nurses. A sensitivity analysis will be conducted adjusting this scenario so that all staffing deficits will be met by registered bank/ agency nurses;
- Assume that staffing deficits will initially be met by redeployment from over-staffed wards (both registered and unregistered nurses) with bank/ agency staff used only when no further re-deployment is possible. A sensitivity analysis will be conducted adjusting this scenario so that all staffing deficits will be met by registered nurses.
- Assume that staffing deficits are not met
- Assume staffing deficits are partially met, assuming limited availability of bank and agency staff

The preceding analyses assume that bank/agency staff will be equally able to work on the ward as established staff. This may be the case for staff attached to a given ward for a period of time, or who are regularly employed on a given ward, but may not apply for staff deployed to a ward for a relatively short period of time (including staff who are temporarily redeployed within a single Trust). Sensitivity analyses will be conducted to consider the potential variation in relative efficiency of permanent versus temporary staff (by adjusting the multipliers when employing agency, bank or re-deployed staff). Because costs of flexible staffing policies can be shared across wards (the "cost" of a staff member moving from one ward to another could be attributed to either ward, depending on local accounting practices) and occur within a single organisation, we will aggregate staffing cost estimates at the hospital level.

Where feasible, we will model the cost of adverse consequences of deviations from predicted staffing requirements, although this will be dependent on identifying robust quantitative measures of association between staffing levels and outcomes. We have already identified the study by Needleman and colleagues [10] as potential basis for modelling mortality consequences of inadequate nurse staffing levels. Where such quantitative estimates exist, and where these can be combined with appropriate measures of baseline risk, an estimate of the impact of staffing levels on patient outcomes can be estimated. We will search for similar estimates relating to any adverse consequences (for example, falls) of nurse staffing levels falling below a defined required level. In order to cost these outcomes we will identify/ develop unit cost estimates that capture the additional costs (in terms of patient care) of the adverse outcomes.

We will consider and compare costs and consequences of each staffing strategy, including the current (actual) staffing, which will be taken as representing the strategy described in the trust profile as enacted in the real world.

Data management

SNCT acuity data will be electronically recorded initially at sites within a Microsoft Excel spreadsheet or within local e-rostering databases. These data will be anonymised, but will provide detail of time of day, shift, the site and ward. A sample of workforce, SNCT, ward admissions and discharge data will be extracted from each sites patient administration system (PAS) and e-rostering systems. It is envisaged that these data will be in a similar format across the research sites, although some cleaning of the data may be appropriate. An initial sample will be extracted from each site to explore differences. All data will be collected in a database (see below). Data will be checked for invalid and anomalous values (e.g. out of range values) and cleaned. Should overall response rates fall below 80%, we will assess data for evidence that missing data is related to workload. Specifically we will determine whether shifts with missed ratings are more likely to occur during periods of higher acuity / dependency (as assessed by previous / subsequent ratings) and develop strategies for dealing with missing data accordingly. Rules for dealing with missing data will be established in consultation with the SSC, according to data types and observed distributions. With careful data collection, we expect that missing data may be minimized, and the missing data mechanism may be carefully reconstructed to some extent. As any model fit to incomplete data extrapolates the missing data under some set of untestable assumptions, a sensitivity analysis to assumptions about the missing data mechanism is will be undertaken. We will review imputation methods, e.g. last observation carried forward and multiple imputation, parametric modelling under missing at random assumptions, and random effects modelling to deal with possible missing not at random mechanisms. If a missing not at random mechanism is plausible, we will explore the application of cutting-edge approaches in a likelihood-based framework.

Data storage and transfer

All raw SNCT and patient administration will be stored on secure encrypted servers at the University of Southampton with access restricted to the project team. The data will transferred to the project team by the University of Southampton's encrypted file transfer facility. All data will be anonymised at source. The volume of SNCT data collected is estimated to be large 365 days X 75 wards X 30 SNCT ratings per day, but its structure will not be complex. The same is true for all ward admission and discharge data, although this will require some processing to structure the data in a format suitable for analysis. The data will be imported to a relational database management system such as SQL Server Express 2014 installed locally on the SRF's encrypted University of Southampton computer system. All import and manipulation of data will be handled through T-SQL and stored procedures that will be backed up and stored on University servers. These procedures will be developed early in the project based on an initial sample of primary and routinely collected ward data.

Dissemination and projected outputs

A range of dissemination approaches will be used to target different audiences for the research. We will produce a final research report for the NIHR journals library detailing all the work undertaken and

including supporting technical appendices, an abstract and an executive summary focused on results/findings and suitable for use separately from the report as a briefing for NHS managers.

We will also prepare a set of 10 PowerPoint slides presenting the main findings from the research, designed for use by the research team or others in disseminating the research findings to the NHS. The slides will be made available alongside the report on the HS&DR programme website and, where possible, as additional material linked to any other publications.

We will submit abstracts for oral presentation for at least one national conference and one international conference focussing on nursing workforce / patient safety. We will disseminate summaries of findings and implications via journals such as the HSJ, Nursing Standard and Nursing Times; networks such as the Health Services Research Network and NHS employers and via networks of key stakeholders. Our PPI and service representatives on the project steering group will guide us in developing a dissemination strategy for these audiences as findings emerge. We will work closely with the University media team and ensure that members of the project team are given full support and training in dealing with media enquiries.

We will prepare at least three academic papers and publish these open access, in high impact journals. The focus of these will be:

1. Variation in SNCT acuity dependency by time of day and day of week
2. Variation in staffing / staffing adequacy between wards / specialities and over time
3. The costs / consequences of different staffing policies.

We aim to publish as early as possible and within the project life span with publications contributing to (rahter than deriving from) the final report. In particular, we aim to publish paper 1. above shortly after data collection is complete. We will also run one workshop for NHS nurse / workforce leaders to disseminate findings and to further consider the implications of the research.

We will use our established social media networks which include organisational (e.g. @Wessexclahrc) and personal professional (e.g. @workforcesoton) twitter accounts with substantial following to promote all project outputs.

Outputs

The study will provide data that can identify the relative feasibility and the costs / consequences of a variety of different staffing policies. This study will provide more direct evidence than is currently available to inform decisions about staffing levels and flexible staffing policies in an NHS context, and so can contribute significantly to future revisions of such guidance.

The research has the potential to have a number of impacts. The findings have wide utility throughout the acute hospital sector of the NHS. Nurse staffing is a vital issue as nursing staff account for a substantial proportion of the wage bill and the significance of nurse staffing in maintaining patient safety and quality experience has been established in many studies. However, the NICE safe staffing guidance noted a lack of directly relevant evidence to guide safe staffing. To our knowledge this will be the first study in the world conducted using the SNCT other than those by its developers and the only study to have modelled the costs and consequences of using it to guide flexible staffing policies. Our

study will also provide an independent assessment of the validity of this widely used tool and guidance on how its use might be adapted to deliver optimal staffing solutions.

Our Steering group / reference panel will include senior stakeholders including senior nurses from the large acute NHS Trusts and a representative from the Shelford group's chief nurses' subgroup (who have supported the SNCT). Through the established networks of these members we will share our findings with those leading national and local implementation of NICE safe staffing guidance and action area 5 of NHS England's compassion in practice strategy for nursing "ensuring we have the right staff, with the right skills in the right place".

We anticipate developing these lines of research by means of a future NIHR programme grant and through our extensive networks of international collaboration in this area, linking to other planned research that will allow us to estimate directly consequences for patients by using local clinical data. Immediate project outputs will include the workshop and other dissemination material identified under our dissemination strategy, which will form the core of a toolkit for NHS managers.

Plan of investigation and timetable

Month	Pre project (Year -1)	Year 1	Year 2	Year 3
1		Project start up meet. Project Steering Group meet Literature review / background for papers (to month 6)	Project Steering Group meet OR modelling	Project Steering Group meet Draft modelling / economics papers
2		Initiate R&D approval	OR modelling continues	Review and finalise drafts / submit papers
3		Specification for local data extraction	OR modelling continues	Prepare final report to NIHR
4		Develop local context profiles	OR modelling continues	Prepare final report to NIHR / revise papers
5		Pilot data extraction (PAS, staffing) Build database (2 months) Pilot data collection / run in	OR modelling continues	Prepare final report to NIHR / revise papers
6		Project Steering Group meet Preliminary modelling Pilot data collection / run in	Data collection ends OR modelling continues	Stakeholder event Final report NIHR
7	Initiate ethics application	Data collection begins / data extraction (12 Mo)	Project Steering Group meet Final data extract OR modelling parameterisation / testing Economic modelling begins	
8		Data collection continues	Modelling /analysis continues	
9		Data collection continues	Descriptive analysis	
10		Data collection continues	Modelling /analysis continues	
11	Initiate appointments (if required)	Annual report prep Data collection continues	Modelling /analysis continues	
12		NIHR annual report Data collection continues Data extract	Modelling /analysis continues Draft modelling / economics papers	

Project management

The project will be overseen and managed by PG with day-to-day project management provided by a senior RF with admin support. JJ or TM will deputise in the case of unforeseen periods of absence. The work of the project will be organised into 6 work streams with senior leads. Project management (PG), data acquisition (ARS), data management (TM), Stats modelling (AM) economic modelling (JJ) and OR modelling (TM). Leads will hold monthly research management group meetings to review and coordinate progress on each work stream. A specific liaison group including the lead investigator in each trust, will work to establish and oversee mechanisms of data acquisition and transfer. Project progress will be monitored monthly against key milestones. Because of the complexities of the modelling and associated analyses, we have allowed significant time for analysis and for write up following the building of the database. This timescale also gives some degree of contingency should we experience delays in accessing data or building the database.

Strategic oversight and advice will be provided by a study steering committee (SSC), with a wider reference panel also recruited to provide specific advice including a PPI perspective. The SSC will meet twice per year during the project.

Approval by ethics committees

We have registered with IRAS (project ID is 190548). Our self-assessment using the tool provided by NRES indicates that this study will not require formal ethical approval by that body because no data is collected directly from patients and reports of patient acuity / dependency ratings are entirely anonymous. We see no substantial ethical issues arising from the research. While results of the SNCT staffing tool may indicate staffing shortages and staff reports may also indicate concerns Trusts already have established mechanisms for dealing with these issues. However, in order to get external assurance and to remove any potential barriers to publication we will seek scrutiny from the University Ethics committee.

Patient and Public Involvement

Safe staffing in hospitals is a major area of public concern following the Francis Inquiry and other reports. This proposal has been developed with this concern in mind but it addresses specific questions that arise from the commissioning brief which in turn follow from gaps in the evidence identified by (among others) the National Institute of Health and Care Excellence (NICE) in their guidance of safe staffing in hospital wards. The developing proposal was discussed with Claire Ballinger (Patient and Public Involvement [PPI] lead for the NIHR CLAHRC Wessex) and Anya de Iongh (PPI champion for the 'fundamental care in hospital' theme of the CLAHRC). Following their guidance we sought no further direct patient / public involvement in prioritising or shaping the questions as these arise from the brief and need for technical assessment of the tool, we have focussed on considering how the public could be involved in the proposed research, its governance and dissemination.

Based on this advice, we have sought a lay member of our Steering group with specific interest and expertise. To this end, we have worked with Stephen Habgood, a lay member of the NICE safe staffing advisory committee for the development of guidelines in mental health, who has agreed to participate in the project Steering group. Stephen also has experience of staffing methodologies used in other sectors

from his past work as a prison governor and is currently chair of a charity concerned with young people's suicide. These combined experiences means that he is actively interested in the specific topics and can fully participate in the Steering group based on prior expertise. We will recruit a second lay member of the Steering group via networks established through the NIHR CLAHRC and the Wessex Involvement in Service Research and Delivery (WISeRD) group – which includes both patients and members of the public. We will also recruit additional members to our reference panel with a particular focus on giving insights into issues that arise from models to be tested and aiding the selection of models that we consider. Training requirements will be assessed and support provided as required, drawing on expertise and facilities provided by the local RDS and NIHR CLAHRC Wessex. We will ensure that these lay members are enable to be full and active members of the Steering group, giving insight and expertise across all aspects of the study. We anticipate in particular that they will orient the team to wider (industry, public, service user) perspectives on safe staffing and advise on public facing dissemination activities.

Expertise

The team brings strengths in health services research, workforce, NHS workforce management operational research and health economics from the University of Southampton, NIHR CLAHRC (Wessex) and partner NHS Trusts. This team provides the expertise to deliver this project, which draws on a unique set of linked data. The PI (PG) has extensive experience of managing large research teams undertaking complex secondary data analysis (including multi-level modelling) in the field of nurse staffing. JEB is an expert on nurse staffing and large scale workforce surveys. She will provide advice and expertise in relation to relevant factors that will shape the modelling and will design and oversee the survey elements of the study. PG and JEB were leads in the "RN4CAST" study, one of the largest nursing workforce studies ever undertaken. JJ is an experienced senior health economist with considerable experience in undertaking economic modelling for NICE technology appraisals. He will oversee the work of research fellows / associates undertaking the economic aspects of the study. This core team recently undertook evidence reviews for the NICE safe staffing guidance. AM is a statistician and health economist with specific expertise in time-varying clustering of multivariate longitudinal data and current expertise on another HSDR funded nurse staffing study. These will be joined by TM, an operational researcher whose research interests include applied healthcare modelling within the NHS, the role modelling plays in decision making in organisations and statistical issues in simulation, ARS, who is currently working with the CLAHRC to link data across trusts in Wessex and NS, RC, YJ, AD & NP who are senior nursing leads with responsibility for implementing staffing policies, including the use of the SNCT. These latter will provide access to staffing data, expertise on its interpretation and be involved in shaping the scenarios for models. TM will supervise the OR modelling and ARS coordinate routine data returns across trusts.

References

1. The Mid Staffordshire NHS Foundation Trust Inquiry and Chaired by Robert Francis QC, *Independent Inquiry into care provided by Mid Staffordshire NHS Foundation Trust January 2005 – March 2009*. 2010, London: The Stationary Office.
2. Keogh, B., *Review into the quality of care and treatment provided by 14 hospital trusts in England: overview report*. 2013, NHS.
3. National Institute for Health and Care Excellence (NICE), *Safe Staffing for Nursing in Adult Inpatient wards in Acute Hospitals (Guidance)*. 2014, National Institute for Health and Care Excellence London.
4. *Safer Nursing Care Tool Implementation Resource Pack*. 2014, The Shelford Group.
5. Smith, S., et al., *Developing, testing and applying instruments for measuring rising dependency‐acuity's impact on ward staffing and quality.* International Journal of Health Care Quality Assurance, 2009. **22**(1): p. 30-39.
6. Griffiths, P., et al., *The association between patient safety outcomes and nurse/healthcare assistant skill mix and staffing levels and factors that may influence staffing requirements (NICE evidence review)*. 2014, University of Southampton Centre for innovation and Leadership in Health Sciences.
7. RN4CAST survey, *unpublished data.*
8. Gabbay, U. and M. Bukchin, *Does daily nurse staffing match ward workload variability? Three hospitals' experiences.* Int J Health Care Qual Assur, 2009. **22**(6): p. 625-41.
9. Allen, M. and S. Thornton, *Providing one-to-one care in labour. Analysis of 'Birthrate Plus' labour ward staffing in real and simulated labour ward environments.* BJOG, 2013. **120**(1): p. 100-7.
10. Needleman, J., et al., *Nurse staffing and inpatient hospital mortality.* N Engl J Med, 2011. **364**(11): p. 1037-45.
11. Kane, R.L., et al., *The Association of Registered Nurse Staffing Levels and Patient Outcomes: Systematic Review and Meta-Analysis.* Medical Care, 2007. **45**(12): p. 1195-1204 10.1097/MLR.0b013e3181468ca3.
12. Aiken, L.H., et al., *Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study.* Lancet, 2014. **383**(9931): p. 1824-30.
13. National Quality Board, *How to ensure the right people, with the right skills, are in the right place. A guide to nursing midwifery and care staffing capacity and capability'*. 2013: http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-how-to-guid.pdf.
14. Edwardson, S.R. and P.B. Giovannetti, *Nursing Workload Measurement Systems.* Annual Review of Nursing Research, 1994. **12**(1): p. 95-123.
15. Fasoli, D.R. and K.S. Haddock, *Results of an integrative review of patient classification systems.* Annual Review of Nursing Research, 2010. **28**: p. 295-316.
16. DHSS Operational Research Service, *Nurse Manpower Planning: Approaches and Techniques*. 1982, DHSS: London:.
17. Harper, P.R., N.H. Powell, and J.E. Williams, *Modelling the size and skill-mix of hospital nursing teams.* Journal of the Operational Research Society, 2009. **61**(5): p. 768-779.
18. National Institute for Health and Clinical Excellence, *Safer Nursing Care Tool (SNCT): statement of endorsement*. 2014.
19. Sermeus, W., et al., *Nurse forecasting in Europe (RN4CAST): Rationale, design and methodology.* BMC Nurs, 2011. **10**(6): p. 6.
20. Ball, J.E., et al., *'Care left undone' during nursing shifts: associations with workload and perceived quality of care.* BMJ Qual Saf, 2014. **23**(2): p. 116-25.
21. Smeds Alenius, L., et al., *Staffing and resource adequacy strongly related to RNs' assessment of patient safety: a national study of RNs working in acute-care hospitals in Sweden.* BMJ Quality & Safety, 2014. **23**(3): p. 242-249.
22. Aiken, L.H., et al., *Patient safety, satisfaction, and quality of hospital care: cross sectional surveys of nurses and patients in 12 countries in Europe and the United States.* BMJ, 2012. **344**(7851): p. e1717.
23. Kortbeek, N., et al., *Flexible nurse staffing based on hourly bed census predictions.* Memorandum 1996, Department of Applied Mathematics, University of Twente, Enschede, The Netherlands, 2012., 2012. **http://eprints.eemcs.utwente.nl/22408/01/memo1996.pdf**.
24. Fagerstrom, L. and A. Rauhala, *Benchmarking in nursing care by the RAFAELA patient classification system - a possibility for nurse managers.* J Nurs Manag, 2007. **15**(7): p. 683-92.
25. Hurst, K., *UK ward design: Patient dependency, nursing workload, staffing and quality--An observational study.* International Journal of Nursing Studies, 2008. **45**(3): p. 370-381.
26. Maben, J., et al., *Evaluating a major innovation in hospital design: workforce implications and impact on patient and staff experiences of all single room hospital accommodation.* Health Serv Deliv Res, 2015. **3**(3): p. 254.
27. Gunnarsdóttir, S., et al., *Front-line management, staffing and nurse–doctor relationships as predictors of nurse and patient outcomes. A survey of Icelandic hospital nurses.* International Journal of Nursing Studies, 2009. **46**(7): p. 920-927.
28. Schubert, M., et al., *Associations between rationing of nursing care and inpatient mortality in Swiss hospitals.* International Journal for Quality in Health Care, 2012. **24**(3): p. 230-238.
29. Curtis, L., *Unit Costs of Health and Social Care 2014*. 2012, Canterbury: PSSRU, University of Kent.