NICE National Institute for Health and Care Excellence

Safe Midwife Staffing for Maternity Settings

Evidence Review 3 – Economic evidence review

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Economic evidence review

1.1.1 Overview

The National Institute for Health and Care Excellence (NICE) was asked by the Department of Health and NHS England to develop an evidence based guideline on safe midwife staffing of maternity settings.

A scope was developed which defines what the guideline will and will not consider. It also outlines the 7 review questions that will be addressed to inform the development of the guideline.

This report is one of a series of evidence reviews that cover the review questions outlined in the scope. This report systematically reviews the economic evidence for all the questions outlined in the scope.

1.1.2 Acknowledgements and disclaimer

We thank Sandall J, Murrells T, Dodwell M, Gibson R, Bewley S, Coxon K et al. (2014) for early use of the report “The efficient use of the maternity workforce and the implications for safety & quality in maternity care. Health Service and Delivery Research 2014”

The Sandall et al project was funded by the Health Service and Delivery Research Programme (10/1011/94) and will be published in full in the Health Service and Delivery Research journal. Further information available at: http://www.nets.nihr.ac.uk/projects/hsdr/10101194

This evidence review was quality assured by Sarah Richards – Technical Analyst (economics) at NICE.

1.2 Introduction

Determining midwife staffing requirements can be challenging. This is because the number and skill mix of midwives required to provide care to women and neonates is influenced by a multitude of factors. These can include: the number of women and neonates requiring care, the type of care needed, and the amount of time taken to provide the required care; the knowledge and experience of the midwife as well as many other factors. The challenge facing providers of midwifery care is ensuring that the right staff, with the right skill mix is available in the right place and at the right time.

There are different options of organising and planning midwife staffing levels or skill mix. Therefore, choosing an option will result in an 'opportunity cost' of a change to the number and skill mix of midwives required to provide care in maternity settings. This 'opportunity cost' is the cost and effects of any alternative foregone, that is, the benefits and costs that could have been achieved by choosing a different option.

This review aims to identify primary economic studies which examine different options in terms of their expected net benefits (health and non-health) and their expected costs – their 'cost-effectiveness'. This review does not examine non-comparative costs of an option, or the cost-impact of interventions; as outlined in the NICE's 'Principles for the development of NICE guidance' – Social Value Judgements.

1.3 Review questions

The aim of this report is to systematically review the economic evidence addressing the following review questions:

1. What maternal and neonatal activities and outcomes are associated with midwife staffing at a local level?
    a. Is there evidence that demonstrates a minimum staffing threshold of safe midwifery care at a local level?

2. What maternal and neonatal factors affect safe midwife staffing requirements, at any point in time, at a local level? These include:
    a. Number of women pregnant or in labour
    b. Maternal risk factors including medical and social complexity and safeguarding
    c. Neonatal needs
    d. Stage of the maternity care pathway (e.g. antenatal, intra-partum, postnatal)

3. What environmental factors affect safe midwife staffing requirements? These include:
    a. Local geography and demography
    b. Birth settings and unit size and physical layout

4. What staffing factors affect safe midwife staffing requirements at a local level? These include:
    a. Midwifery skill mix
    b. Availability of and care provided by other healthcare staff (e.g. maternity support workers, obstetricians, anaesthetists, paediatricians and specialist midwives)
    c. Division of tasks between midwives and maternity support workers
    d. Requirements to provide additional services (e.g. high dependency care, public health roles, vaccinations)

5. What local level management factors affect safe midwife staffing requirements? These include:
    a. Maternity team management and administration approaches (e.g. shift patterns)
    b. Models of midwifery care (e.g. caseloading/named midwife/social enterprises)
    c. Staff and student supervision and the supernumerary arrangements

6. What organisational factors influence safe midwife staffing at a local level? These include:
    a. Management structures and approaches
    b. Organisational culture
    c. Organisational policies and procedures, including staff training

7. What approaches for identifying midwife staffing requirements and skill mix at a local level, including tool kits, are effective and how frequently should they be used?
    a. What evidence is available on the reliability and/or validity of any identified toolkits?

1.4 Methods

1.4.1 Overview

This systematic review was conducted in accordance with the draft 'Developing NICE guidelines - the manual' (Consultation in 2014).

The main process of the systematic review for the economic evidence is:

- Databases searched using a search strategy (Appendix A)
- Identifying potentially relevant primary economic studies by reviewing titles and abstract using the pre-specified inclusion and exclusion criteria outlined in the protocol (Appendix B). Retrieving full text papers for all references assessed to be potentially relevant.
- Appraising full text papers against the pre-specified inclusion and exclusion criteria outlined in the protocol (Appendix C)
- Critical appraisal of economic evidence table using appropriate checklist as specified in 'Developing NICE guidelines - the manual'.
- Extracting study methods and results into evidence tables (Appendix D).
- Summarise the evidence into Economic evidence profiles and generate evidence statements.

1.4.2 Search strategy

A search strategy and review protocol were developed to identify primary economic studies comparing the use of a particular approach to another approach, or maximise outcomes in relation to resources related to the number of midwife staffing and skill mix (see Appendix A and B). Databases searched include Medline, Medline in-process, Health Management Information Consortium, Cumulative Index to Nursing and Allied Health using an economic filter. Separate searches were carried out on the NHS Economic Evaluations Database, Econlit, Health Economic Evaluations Database, Tufts Cost Effectiveness Analysis Registry.

A date restriction was imposed on all the systematic reviews that were conducted for the midwife staffing guideline, including this review, as it was deemed inappropriate to include all

evidence. This is because midwifery practices have advanced over the years, making older studies of limited relevance to midwifery practice today. A cut-off date of 1998 was chosen following advice from a topic expert, and studies published before this date or which used data from before this date were excluded. Studies published after June 2014 was not considered in this review.

For more information on the search strategy, see Appendix A.

The systematic search identified 621 references. An additional 16 references were identified through screening the searches for other review questions included in the related evidence reviews.

1.4.3 Inclusion and exclusion criteria

The inclusion and exclusion criteria are specified in the protocol, see Appendix B. The protocol mirrors the inclusion and exclusion criteria used for the other evidence reviews produced for this guideline.

All common types of economic study design were considered. The 'Developing NICE guidelines - the manual' outlines a preference for cost-utility analysis. This systematic review considered a wider range of types of analysis and included cost utility analysis, cost consequences analysis, cost effectiveness analysis, cost benefit analysis, cost minimisation analysis and any cost-comparative analysis which were specific to midwife staffing numbers or skill-mix. Any intervention which considered midwife staffing levels or skill mix was included.

English language studies are included, all non-English language were excluded due to a lack of capacity to translate into English. All midwife staffing in non-maternity settings or obstetric settings were excluded as these were outside of the scope of the guideline. All studies from non-OECD countries were excluded due to limited applicability to the UK NHS.

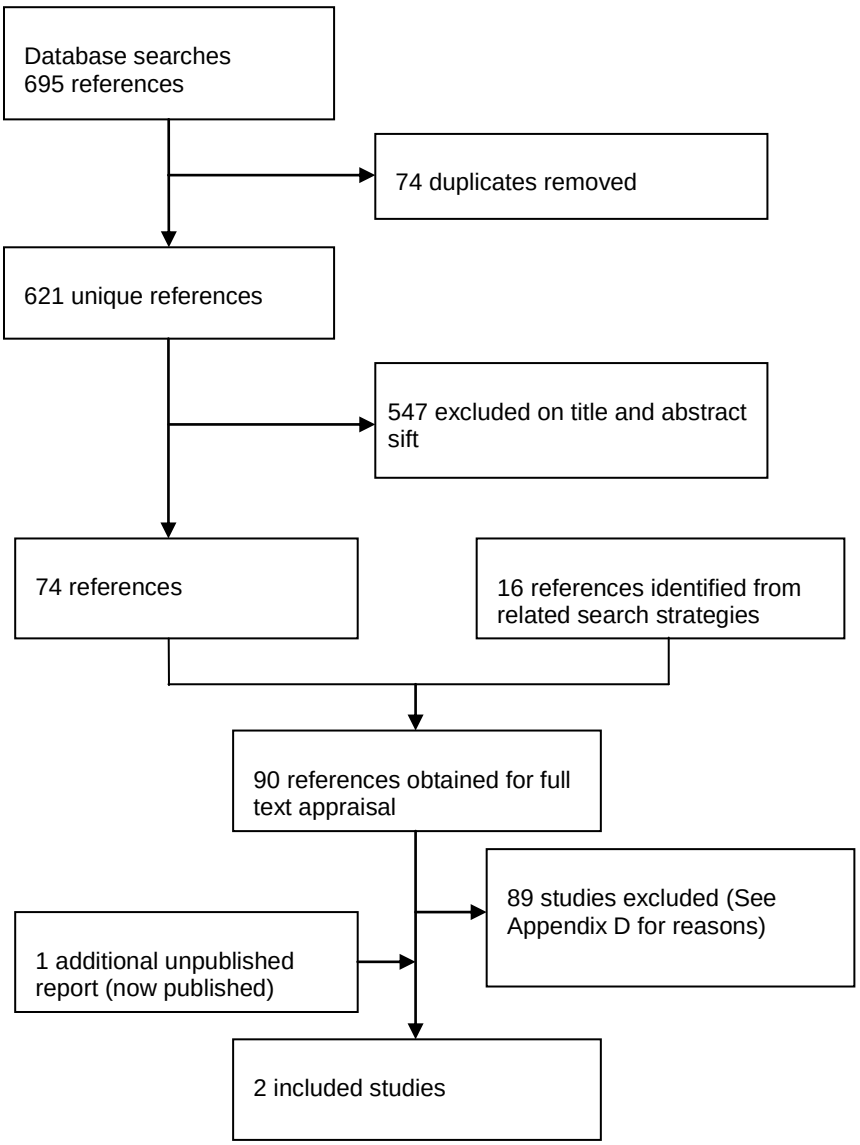
All 637 titles and abstracts identified from the search strategy were independently assessed by two reviewers. All abstracts considered to potentially meet the inclusion and exclusion criteria by either reviewer were obtained in full.

90 full-texts of studies were assessed by one reviewer using the pre-defined inclusion and exclusion criteria in Appendix B. A second reviewer assessed full-texts when the first reviewer could not make a clear decision on inclusion. One study (Allen and Thronton, 2013) was identified that met the criteria for inclusion in this evidence review. One additional unpublished study (at time of the search) (Sandall et al, 2014) was identified and assessed as relevant to the evidence review.

A total of 89 references were excluded. Most studies (n=40) were not economic evaluations and did not contained economic or cost outcomes. Many studies (n=37) contained economic outcomes in the study but the study was not specific to midwife staffing numbers or skill mix, or did not have midwife staffing numbers (non-segregated), ratio or hours as outcomes. Three references were for systematic reviews which included economic studies or outcomes. The reviews were excluded; however, reference details of the included primary studies were cross-checked with the database search to identify any further primary studies. The midwifery caseload (i.e. number of mothers or babies) was unknown in 3 economic studies and so were excluded. An economic study (n=1) was excluded because it investigated service delivery changes of maternity services as a whole and did not investigate staffing numbers or skill mix separately. Some studies (n=2) contained economic outcomes in the study but were excluded because it investigated non-OECD maternity services. A small number of studies (n=3) could not be obtained through British Library or Internet sources and thus excluded due to non-retrieval. A full list of excluded studies and reasons for exclusion is provided in appendix D.

Figure one presents a summary of the search and selection process flow.

Figure 1: Review flow chart



1.4.4 Critical appraisal and quality assessment

The two included studies were critically appraised using the appropriate checklist for the study type as outlined in the draft 'Developing NICE guidelines - the manual'. On completion of the checklist, two overall ratings are given for the economic study 'applicability' and 'limitations'. The 'applicability' criteria give an overall rating of the economic studies applicability to the NICE reference case (the perspective taken in this review is 'health outcomes in NHS settings'). A study can be given one of three possible ratings:

- Directly applicable – the study meets all applicability criteria, or fails to meet 1 or more applicability criteria but this is unlikely to change the conclusions about cost effectiveness.

- Partially applicable – the study fails to meet 1 or more of the applicability criteria, and this would change the conclusions about cost effectiveness.
- Not applicable – the study fails to meet 1 or more of the applicability criteria, and this is likely to change the conclusions about cost effectiveness. Such studies would usually be excluded from further consideration and there is no need to continue with the rest of the checklist.

The 'limitations' criteria outlines the methodological quality of the study. A study can be given one of three possible ratings:

- The Minor limitations – the study meets all quality criteria, or fails to meet 1 or more quality criteria but this is unlikely to change the conclusions about cost effectiveness.
- Potentially serious limitations – the study fails to meet 1 or more quality criteria, and this could change the conclusions about cost effectiveness.
- Very serious limitations – the study fails to meet 1 or more quality criteria, and this is highly likely to change the conclusions about cost effectiveness. Such studies should usually be excluded from further consideration.

1.4.5 Economic evidence profile

The two included studies are summarised in an economic evidence profile. The profile summarises the key finding from many studies into one table. It includes information on the incremental benefits (both health and non-health) and incremental costs of an option compared to another option, and the cost-effectiveness estimate (incremental cost-effectiveness ratio, or net benefit) of an option compared to another It also gives an overview of the applicability and limitations of each economic study (with reasons). The economic evidence profile will describe any information on the certainty (or uncertainty) of the results.

1.4.6 Evidence statements

Evidence statements are brief summary statements which outline key findings from the economic evidence review. The evidence statement includes the number of studies identified, the overall quality of the economic evidence (the applicability and limitations of the study) and the direction and certainty of the results.

1.5 Results

Two studies were included in the evidence review:

1.5.1 Allen and Thornton (2013)

This study used a simulation model based on 6,000 deliveries per annum from a single English hospital maternity unit. The model compared calculation using birth rate plus (BR+) to simulated scenarios. The main outcome used in the study was the occurrence of overload: the number of women or the BR+ Workload Index exceeds the scheduled midwife availability to deliver one to one care. Further background information on this study is presented in the Evidence Review 2 'Decision support approaches and toolkits for identifying midwife staffing requirements'.

The study was rated as 'partially applicable' as it used scenario modelling which may not be an appropriate realistic comparator. In addition, it did not follow any of the possible NICE reference cases outlined in the draft 'Developing NICE guidelines - the manual'. The study was considered to have 'very serious limitations' for multiple reasons. The study did not describe the simulation model in detail, the cost perspective, resource estimates, unit cost estimates and sources were not stated. The study also used evidence for one ward in England and may not be generalisable to other wards. The analysis was not a fully incremental analysis and no sensitivity analysis was undertaken to investigate uncertainty.

The results of the study limitations suggested a 25% reduction in midwifery overload (the number of women exceed the scheduled workload) could be achieved with a 4% increase in budget and a lower 15% reduction in midwifery overload (the number of women exceed the scheduled workload) could be achieved by reducing staffing on Saturday night and all of Sunday and reapplied at peak weekday times with no increase in cost.

The economic profile is presented below, and the evidence table is available in Appendix D.

1.5.2 Sandall et al (2014)

The study was a large correlation study on 143 NHS trusts in England on 665,969 births using Health Episode Statistic (HES) data from 2010/11. Two approaches were used to examine economic consequences, a costing analysis (using Reference Cost and Electronic Staff Records 2010, and economic modelling analysis (a production function analysis). The study examined changes to inputs such full time equivalent (FTE) of midwives, Support Staff , Doctors and Consultants and examined outputs in terms of total annual deliveries per trust, and total cost-weighted annual deliveries (weighted by relative cost, to take into account differences in cost between vaginal and caesarean deliveries)

The study was rated as 'partially applicable' because it did not follow any of the possible NICE reference cases outlined in the draft 'Developing NICE guidelines - the manual'. In addition, the analyses were at trust and not ward level. The study was considered to have potentially serious limitations because it was unclear if all relevant long terms costs and consequences were considered (i.e. long term implications of mother and baby safety concerns). The analysis was not a fully incremental analysis. The time spent between roles in obstetric versus gynaecology could not be separated, and there was no consideration of bank and agency staff. Multicolinearity (a strong correlation between explanatory variables used in the model) between many variables was identified. Endogeneity (the error term and the explanatory variables are correlated) was also a potential concern. The combination of

both multicolinearity and endogeneity could result in potentially biased results, or incorrectly accepting or rejecting a null hypothesis.

The costing analysis showed higher midwife staffing levels were associated with higher costs of each delivery taking account of trust size, risk, parity, age and IMD[a]. However, only 17% of the variability in delivery costs could be accounted for by the model specification.

The production function analysis showed that that an additional midwife would increase the number of deliveries possible in a trust between 18 and 94 deliveries in a year. The study also showed that midwifes and other doctors are complements (should be used together) and midwives are consultants are complements. However, it was unclear if midwives and support staff might be complements or substitutes (can replace each other).

The economic profile is presented below, and the evidence table is available in Appendix D.

[a] Index of Multiple Deprivation (IMD)

1.5.3 Economic profiles

Study	*Limitations*	*Applicability*	*Other comments*	*Incremental*			*Uncertainty*
				Costs	*Effects*	*Cost effectiveness*	
Allen and Thornton 2013 Compared Birth Rate plus (BR+) to Simulated data Scenario 1: Additional resource Scenario 2: Reduced staffing on Saturday night and all of Sunday and re-applied at peak load during weekdays.	Very serious limitations[a]	Partially applicable[b]	Occurrence of workload (the number of women or the BR+ Workload Index exceeds the scheduled midwife availability)	Scenario 1: 4% increase in budget Scenario 2: 0% increase in budget	Scenario 1: 25% reduction in occurrence of overload Scenario 2: 15% reduction in occurrence of overload	NA[c]	None

Study	*Limitations*	*Applicability*	*Other comments*	*Cost-effectiveness*	*Uncertainty*
Sandall et al 2014 Costing Analysis Econometric analysis	Potentially serious limitations[d]	Partially applicable[e]	142 NHS trust, Health Episode Statistics (HES) data from 2011/11	**Costing analysis** Higher midwife staffing levels associated with higher costs of each delivery (relationship not strong)	**Costing analysis:** Relationship strengthened when antenatal expenditure included as an explanatory variable

[a] Simulation model structure was not clearly defined. There was an unclear cost perspective; resource use, unit costs and sources of unit costs were not specified. Use of one ward in the UK may not be generalisable other wards. No fully incremental analysis undertaken. No sensitivity analyses undertaken to investigate uncertainty
[b] Investigated birth rate plus compared to a computer simulation model: unclear if comparator is realistic or appropriate. Does not reflect any NICE reference case.
[c] Cannot be calculated
[d] No NICE reference case was followed; a QALY approach was not taken. Trust level perspective taken and not ward level.
[e] Unclear if all relevant long terms costs and consequences were considered (i.e. long term implications of mother and baby safety concerns). Not a fully incremental analysis. No account of time spent between roles in obstetric versus gynaecology, no consideration of bank and agency staff. Multicollinearity between variables. Potential endogeneity between variables and error term.

Study	*Limitations*	*Applicability*	*Other comments*	*Cost-effectiveness*	*Uncertainty*
(production function) Comparing the following: Midwives (FTE) Support Staff (FTE) Doctors (FTE) Consultants (FTE)			NHS Workforce statistics 2010/11 CQC Maternity Survey of Maternity Provider Trusts 2007 and 2010 ONS Birth Registrations 2000/01 – 2010/11 BirthChoiceUK database Reference cost data – NHS reference costs 2010/11 Population Total of 665,969 delivery babies	**Econometric analysis** Marginal productivity *(change in output that results in the change of 1 unit of input. Keeping all other inputs constant)* Total deliveries (standard errors): 1 additional midwife is associated with +17.93 deliveries 1 additional support staff is associated with +10.47 deliveries 1 additional consultant is associated with 32.31 deliveries 1 additional other doctor is associated with 42.81 deliveries Cost weighted deliveries[a] 1 additional midwife is associated with +93.85 deliveries 1 additional support staff is associated with +50.15 deliveries 1 additional consultant is associated with +58.72 deliveries 1 additional doctor is associated with +51.01 deliveries Hicks elasticity of substitution*: (degree to which two inputs can be substituted for one another)* Total deliveries: If the number of support staff increased by 1% change in the number of midwives needed would be -0.03% (substitutes) If the number of consultants increased y by 1%, change in the number of midwives needed would be 0.30% (complements)	17% of variation between trust' delivery costs are accounted for in model, rising to 23% when antenatal expenditure is included. **Econometric analysis** Adjusted R^2 (total deliveries) = 0.885 Adjusted R^2 (cost weighted deliveries) = 0.878 Model suffers from multicollinearity – investigated by Variance inflation Factor (VIF) which was high for multiple variables.

[a] Weighted by relative cost, to take into account differences in cost between vaginal and caesarean deliveries

Study	*Limitations*	*Applicability*	*Other comments*	*Cost-effectiveness*	*Uncertainty*
				If the numbers of other doctors required rose by 1%, change in the number of midwives needed would be 0.70% (complements) Cost-weighted deliveries: If the number of support staff increased by 1%, change in the number of midwives needed would be 0.05% (complements) If number of consultants increased by 1%, change in the number of midwives needed would be 0.14% (complements) If numbers of other doctors increased by 1%, change in the number of midwives needed would be 0.97% (complements)	

1.5.4 Evidence statements

One partially applicable study (Allen and Thornton, 2013) with very serious limitations suggested a 25% reduction in midwifery overload (the number of women exceed the scheduled workload) could be achieved with a 4% increase in budget. A 15% reduction in midwifery overload could be achieved by reducing staffing on Saturday night and all of Sunday and reapplied at peak weekday times with no increase in costs.

One partially applicable study with potentially serious limitations (Sandall et al, 2014) showed higher midwife staffing levels were associated with higher costs of each delivery. An additional midwife would increase the number of deliveries possible in a trust between 18 and 94 deliveries in a year. The study also showed that midwifes and other doctors are complements (should be used together) and midwives are consultants are complements. However, it was unclear if midwives and support staff might be complements or substitutes (can replace each other).

2 Gaps in the evidence

This evidence review identified important evidence reviews. There is limited economic evidence examining the impact of midwife staffing levels (the number of women to each midwife) in different models of care at different stages for the care pathway. Limited high quality evidence related to outcomes and midwife staffing levels may also limit the extent to which economic evidence is available in the future.

Further research could include:

- A cost utility analysis examining the impact of different midwife staffing levels at the antenatal, intrapartum and postnatal care stages in different models of care settings (such as alongside midwifery units, or midwifery led units, home birth).
- A cost utility analysis examining the use of different support approached and toolkits (such as birth-rate plus) compared to each other and professional judgement for identifying midwife staffing requirements.

3 References

Allen M, Thornton S (2013) Providing one-to-one care in labour. Analysis of 'Birthrate Plus' labour ward staffing in real and simulated labour ward environments BJOG: An International Journal of Obstetrics & Gynaecology 120 (1) 100-107

Sandall J, Murrells T, Dodwell M, Gibson R, Bewley S, Coxon K et al. (2014) The efficient use of the maternity workforce and the implications for safety & quality in maternity care. Health Service and Delivery Research 2014

National Institute for Health and Clinical Excellence (2009) Principles for the development of NICE guidance. http://www.nice.org.uk/media/default/About/what-we-do/Research-and-development/Social-Value-Judgements-principles-for-the-development-of-NICE-guidance.pdf (Second Edition)

National Institute for Health and Care Excellence (2014) Developing NICE guidelines - the manual. https://www.nice.org.uk/Guidance/InConsultation/GID-INCONSULTATION/html/p/developing-nice-guidelines--the-manual?id=wdztd54otwzih6g5y3erlqysx4 (Consultation Version)

4 Appendices

4.1 Appendix A Search strategy

This appendix outlines the searches carried out for this review, in order to inform NICE's safe staffing guidance for midwife staffinging services. It should be read in conjunction with the protocol for this review, and with the appendices for the associated reviews.

The Medline; Medline in-process; Embase; HMIC and CINAHL searches for the economics review are sub-sets of those carried out for the associated reviews (henceforth the *base searches*). In each instance, only the search terms used to identify the economics sub-set have been given below. The final line of each of these search strings was combined with the final line of the respective base searches using the Boolean operator, 'AND'.

References which were identified during each of the three midwife staffing reviews were shared with the other (midwife staffing) review groups if they were thought to be relevant to other review questions. No additional citation searching or website searching was carried out specifically for this review.

4.1.1 Database search strategies

4.1.2 Medline and Medline in-process

Platform: Ovid
Search date: As for base searches.

1 Economics/ or exp "Costs and Cost Analysis"/ or Economics, Dental/ or exp Economics, Hospital/ or exp Economics, Medical/ or Economics, Nursing/ or Economics, Pharmaceutical/ or Budgets/ or exp Models, Economic/ or Markov Chains/ or Monte Carlo Method/ or Decision Trees/
2 (Economic* or cost or costs or costly or costing or costed or price or prices or pricing or pharmacoeconomic* or pharmaco economic* or budget*).ti.
3 ((monte adj carlo) or markov or (decision adj2 (tree$ or analys$))).ti,ab.
4 Quality of Life/ or Health Status Indicators/ or Quality-Adjusted Life Years/ or Value of Life/
5 (quality of life or quality adjusted life or qaly* or qald* or qale* or qtime* or quality of wellbeing or quality of well-being or willingness to pay or standard gamble* or time trade off* or time tradeoff*).ti.
6 (disability adjusted life or daly).ti.
7 (value adj2 (money or monetary)).ti.
8 health* year* equivalent*.ti.
9 (sf36 or sf 36 or short form 36 or shortform 36 or sf thirtysix or sf thirty six or shortform thirtysix or shortform thirty six or short form thirtysix or short form thirty six).ti.
10 (sf6 or sf 6 or short form 6 or shortform 6 or sf six or sfsix or shortform six or short form six).ti.
11 (sf12 or sf 12 or short form 12 or shortform 12 or sf twelve or sftwelve or shortform twelve or short form twelve).ti.

12 (sf16 or sf 16 or short form 16 or shortform 16 or sf sixteen or sfsixteen or shortform sixteen or short form sixteen).ti.
13 (sf20 or sf 20 or short form 20 or shortform 20 or sf twenty or sftwenty or shortform twenty or short form twenty).ti.
14 (euroqol or euro qol or eq5d or eq 5d).ti.
15 Computer Simulation/
16 simulation*.ti.
17 (dynamic adj model*).ti.
18 Operations Research/
19 "operation* research".ti.
20 (efficiency adj3 maximi*).ti.
21 stochastic.ti.
22 (efficiency adj3 maximi*).ti.
23 stochastic.ti.
24 Stochastic Processes/
25 data envelopment.ti.
26 Efficiency, Organizational/
27 or/1-26
28 (((energy or oxygen) adj cost*) or (metabolic adj cost*) or ((energy or oxygen) adj expenditure*)).ti,ab.
29 27 not 28

4.1.3 Embase

Platform: Ovid
Search date: As for base searches.

The Embase search for the economics review was derived by combing the last line of the search string below with each of the base searches using the Boolean 'AND' operator.

1 Computer Simulation/
2 simulation*.ti.
3 exp mathematical model/
4 system analysis/
5 (dynamic adj model*).ti.
6 system analysis/
7 "operation* research".ti.
8 (efficiency adj3 maximi*).ti.
9 stochastic.ti.
10 (efficiency adj3 maximi*).ti.
11 stochastic.ti.
12 data envelopment.ti.
13 organizational efficiency/
14 economic evaluation/ or economics/
15 *health-economics/ or exp *economic-evaluation/ or exp *health-care-cost/ or *pharmacoeconomics/ or *Monte Carlo Method/ or *Decision Tree/
16 (Economic* or cost or costs or costly or costing or costed or price or prices or pricing or pharmacoeconomic* or pharmaco economic* or budget*).ti.
17 ((monte adj carlo) or markov or (decision adj2 (tree$ or analys$))).ti.
18 (value adj2 (money or monetary)).ti.
19 *Quality of Life/ or *Quality Adjusted Life Year/ or *Quality of Life Index/ or *Short Form 36/ or *Health Status/
20 (quality of life or quality adjusted life or qaly* or qald* or qale* or qtime* or quality of wellbeing or quality of well-being or willingness to pay or standard gamble* or time trade off* or time tradeoff*).ti.
21 (disability adjusted life or daly).ti.
22 Health* year* equivalent*.ti.
23 (sf36 or sf 36 or short form 36 or shortform 36 or sf thirtysix or sf thirty six or shortform thirtysix or shortform thirty six or short form thirtysix or short form thirty six or sf6 or sf 6 or short form 6 or shortform 6 or sf six or sfsix or shortform six or short form six or sf12 or sf 12 or short form 12 or shortform 12 or sf twelve or sftwelve or shortform twelve or short form twelve or sf16 or sf 16 or short form 16 or shortform 16 or sf sixteen or sfsixteen or shortform sixteen or short form sixteen or sf20 or sf 20 or short form 20 or shortform 20 or sf twenty or sftwenty or shortform twenty or short form twenty or euroqol or euro qol or eq5d or eq 5d).ti.
24 or/1-23

4.1.4 Health Management Information Consortium

Platform: Ovid

Search date: As for base searches.

The HMIC search for the economics review was derived by combing the last line of the search string below with each of the base searches using the Boolean ‘AND’ operator.

1 exp health economics/ or exp costs/ or cost effectiveness/ or exp economic analysis/ or economic models/ or exp models/ or quality adjusted life years/ or quality of life/ or exp health indicators/ or exp operational research/ or exp efficiency/
2 (Economic* or cost or costs or costly or costing or costed or price or prices or pricing or pharmacoeconomic* or pharmaco economic* or budget*).ti.
3 ((monte adj carlo) or markov or (decision adj2 (tree$ or analys$))).ti,ab.
4 (quality of life or quality adjusted life or qaly* or qald* or qale* or qtime* or quality of wellbeing or quality of well-being or willingness to pay or standard gamble* or time trade off* or time tradeoff*).ti.
5 (disability adjusted life or daly).ti.
6 (value adj2 (money or monetary)).ti.
7 health* year* equivalent*.ti.
8 (sf36 or sf 36 or short form 36 or shortform 36 or sf thirtysix or sf thirty six or shortform thirtysix or shortform thirty six or short form thirtysix or short form thirty six).ti.
9 (sf6 or sf 6 or short form 6 or shortform 6 or sf six or sfsix or shortform six or short form six).ti.
10 (sf12 or sf 12 or short form 12 or shortform 12 or sf twelve or sftwelve or shortform twelve or short form twelve).ti.
11 (sf16 or sf 16 or short form 16 or shortform 16 or sf sixteen or sfsixteen or shortform sixteen or short form sixteen).ti.
12 (sf20 or sf 20 or short form 20 or shortform 20 or sf twenty or sftwenty or shortform twenty or short form twenty).ti.
13 (euroqol or euro qol or eq5d or eq 5d).ti.
14 simulation*.ti.
15 (dynamic adj model*).ti.
16 "operation* research".ti.
17 (efficiency adj3 maximi*).ti.
18 stochastic.ti.
19 (efficiency adj3 maximi*).ti.
20 stochastic.ti.
21 data envelopment.ti.
22 or/1-21
23 (((energy or oxygen) adj cost*) or (metabolic adj cost*) or ((energy or oxygen) adj expenditure*)).ti,ab.
24 22 not 23

4.1.5 Cumulative Index to Nursing and Allied Health (CINAHL)

Platform: Ovid

Search date: As for base searches.

#	Query	Limiters/Expanders
S24	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23	Search modes - Boolean/Phrase
S23	TI (data AND envelopment)	Search modes - Boolean/Phrase
S22	TI stochastic	Search modes - Boolean/Phrase
S21	TI (efficiency N3 maximi*)	Search modes - Boolean/Phrase
S20	TI "operation* research"	Search modes - Boolean/Phrase
S19	TI (dynamic N1 model*)	Search modes - Boolean/Phrase
S18	TI simulation*	Search modes - Boolean/Phrase
S17	TI (euroqol OR euro AND qol OR eq5d OR eq AND 5d)	Search modes - Boolean/Phrase
S16	TI (sf20 OR sf AND 20 OR short AND form AND 20 OR shortform AND 20 OR sf AND twenty OR sftwenty OR shortform AND twenty OR short AND form AND twenty)	Search modes - Boolean/Phrase
S15	TI (sf16 OR sf AND 16 OR short AND form AND 16 OR shortform AND 16 OR sf AND sixteen OR sfsixteen OR shortform AND sixteen OR short AND form AND sixteen)	Search modes - Boolean/Phrase
S14	TI (sf12 OR sf AND 12 OR short AND form AND 12 OR shortform AND 12 OR sf AND twelve OR sftwelve OR shortform AND twelve OR short AND form AND twelve)	Search modes - Boolean/Phrase
S13	TI (sf6 OR sf AND 6 OR short AND form AND 6 OR shortform AND 6 OR sf AND six OR sfsix OR shortform AND six OR short AND form AND six)	Search modes - Boolean/Phrase
S12	TI (sf36 OR (sf AND 36) OR (short AND form AND 36) OR (shortform AND 36) OR (sf AND thirtysix) OR (sf AND thirty AND six) OR (shortform AND thirtysix) OR (shortform AND	Search modes - Boolean/Phrase

	thirty AND six) OR (short AND form AND thirtysix) OR (short AND form AND thirty AND six))	
S11	TI (health* AND year* AND equivalent*)	Search modes - Boolean/Phrase
S10	(value N2 (money OR monetary))	Search modes - Boolean/Phrase
S9	TI (disability adjusted life OR daly)	Search modes - Boolean/Phrase
S8	TI ((quality of life OR quality adjusted life OR qaly* OR qald* OR qale* OR qtime* OR quality of wellbeing OR quality of well-being OR willingness to pay OR standard gamble* OR time trade off* OR time tradeoff*))	Search modes - Boolean/Phrase
S7	TI (((monte ADJ carlo) OR markov OR (decision N2 (tree* OR analys*))))	Search modes - Boolean/Phrase
S6	TI (Economic* OR cost OR costs OR costly OR costing OR costed OR price OR prices OR pricing OR pharmacoeconomic* OR (pharmaco AND economic*) OR budget*)	Search modes - Boolean/Phrase
S5	MH "ORGANIZATIONAL EFFICIENCY+"	Search modes - Boolean/Phrase
S4	MH "QUALITY-ADJUSTED LIFE YEARS"	Search modes - Boolean/Phrase
S3	MH BUDGETS	Search modes - Boolean/Phrase
S2	MH "DECISION TREES"	Search modes - Boolean/Phrase
S1	MH "ECONOMICS+"	Search modes - Boolean/Phrase

4.1.6 NHS Economic Evaluations Database

Platform: Wiley
Search date: 13/6/2014

Strategies and search dates: see Cochrane database strategies for “influences and outcomes” and “toolkits” reviews**.**

4.1.7 Econlit

Platform: Ovid
Search date: 20/6/2014

See Medline database strategies for “influences and outcomes” and “toolkits” reviews. No additional filters applied.

Note that thesaurus terms are not recognised in Econlit on the Ovid platform.

4.1.8 Health Economic Evaluations Database (HEED)

Platform: Wiley
Search date: 20/6/2014

Title search for: maternity OR midwife OR midwifery OR midwives OR MSW OR MSWs

Note: database crashed for any more complex searches.

4.1.9 Tufts Cost Effectiveness Analysis Registry

Basic interface
Search date: 20/6/2014

Searched for the following words individually: maternity; midwife; midwifery; midwives; MSW; MSWs.

Note: limited search functionality. Zero results for Boolean searches.

4.2 Appendix B Review protocol

	Details
Objectives	To identify economic evidence on midwife staffing approaches
Language	English
Study design	Cost-utility analysis Cost-consequences analysis Cost-effectiveness analysis Cost-benefit analysis Cost- minimization analysis Any comparative cost analysis Econometric studies which include cost Costs outcomes reported in included studies from non-economic evidence review.
Status	Published papers (full papers only)
Setting	Maternity settings
Perspective	NA
Intervention	Any approach or process identified in the non-economic evidence review (midwife staffing number or skill-mix)
Comparator	No assessment Comparison to each other approach
Evaluation	- Cost per outcome (incremental cost-effectiveness ratios) if available - Total and Incremental Costs - Total and Incremental Benefits (including process outcomes) - Any cost-effectiveness data
Other criteria for inclusion/ exclusion of studies	**Include:** • English language • Cost/productivity outcomes reported in included studies from non-economic evidence review **Exclude:** • Obstetric settings • Studies conducted before 1998 • Any evaluations in non-maternity settings • Studies in non-OECD countries (due to limited applicability to the UK)
Review strategies	• The appropriate NICE methodology checklist will be used as a guide to appraise the quality of individual studies • Data on all included studies will be extracted into evidence tables • Data will be placed into NICE economic evidence profiles

4.3 Appendix C Excluded studies

Reason for exclusion: not an economic evaluation:

Studies: (Asaduzzaman 2011; Ashcroft et al. 2003; Baldo 2001; Buchan and Seccombe 2012; Burton 2008; Campbell et al. 2006; Carman et al. 2004; Dagustun 2013; Donnellan-Fernandez 2011; Dorling 2005; Fagerlund and Germano 2009; Flynn et al. 2010; Gifford et al. 2002; Haxton and Fahy 2009; Hodnett et al. 2008; King et al. 2012; Leinweber and Rowe 2010; Leversidge 2013; Loper and Hom 2000; Murphy and Fullerton 2006; O'Brien-Pallas et al. 2001; Ogburn et al. 2012; Page et al. 1999; Petrou and Henderson 2003; Ransom et al. 1998; Rosser 2001; Sandall 1999; Sandall 1998; Simpson 2009; Smith et al. 2013; Stone 1998; Symon et al. 2007; Tate 2007; Tillett 2009; Toohill et al. 2012; Tracy et al. 2013; Tracy et al. 2014; Turnbull et al. 2013; van, V et al. 2010; Walsh 1999);

Reason for exclusion: Not specific to midwife staffing numbers; Cannot calculate economic outcomes specifically for midwife staffing numbers (non-segregated), ratio or hours

Studies: (Bellanger and Or 2008; Bernitz et al. 2012; Bones 2005; Byrne et al. 2000; Dexter and Macario 2001; Gillespie 2013; Harris et al. 2004; Henderson and Petrou 2008; Hendrix et al. 2009; Homer et al. 2001; Ickovics et al. 2007; Isken et al. 2011; James et al. 2001; McIntosh et al. 2012; Mistry 2007; Morrell et al. 2000; Newhouse et al. 251; O'Brien et al. 2010; Oluboyede et al. 2010; Palmer et al. 2010; Petrou et al. 2000; Petrou 2003; Petrou et al. 2004; Petrou and Glazener 2002; Ratcliffe et al. 1998; Reinharz et al. 2000; Richardson 1999; Stanziano 2008; Stevens et al. 2006; Stone et al. 2000; Toohill et al. 2011; Townsend et al. 2004; Tracy et al. 2011; Tracy et al. 2012; Vincent et al. 2000; Wall et al. 2004; Watson 1998)

Reason for exclusion: Systematic review including studies excluded in protocol (included studies were checked)

Studies: (Dawson et al. 1999; Ryan et al. 2013; Sandall et al. 2013)

Reason for exclusion: Midwifery caseload unknown

Studies: (Schroeder et al. 2012; Simpson 2010)

Reason for exclusion: Service delivery – outside scope

Studies: (Draper et al. 2004)

Reason for exclusion: non OECD country

Studies: (Hutton 2004; Manasyan et al. 2011)

Reason for exclusion: unable to source

Studies: (Chamberlain et al. 1998; Geitona 2007; O'Brien-Pallas et al. 2001)

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4.4 Appendix D Evidence tables

Study details	Population and setting	Intervention / comparator	Outcomes and methods of analysis	Results	Notes
Authors: Allen and Thornton, **Year:** 2013 **Type of economic analysis:** Unclear[a] **Applicability** Partially applicable[b] **Limitations:** Very serious limitations[c]	**Source population:** A total of 5800 births (1 year). **Setting:** A labour ward of a city hospital **Data sources:** Whether through primary research, published studies or sources, meta-analyses or decision-analytic techniques.	**Interventions:** Birth Rate Plus **Comparator:** Simulated data **Sample sizes:** • Total N=5800	**Outcomes:** Occurrence of workload (the number of women or the BR+ Workload Index exceeds the scheduled midwife availability) Budget[d] **Time horizon:** 1 year **Discount rates:** NA **Perspective:** Unclear[e] **Measures of uncertainty:** None **Modelling method:** Retrospective simulation model	**Primary results:** 25% reduction in occurrence of overload achieved with 4% increase in budget. **Secondary analysis:** Reduced staffing on Saturday night and all of Sunday and re-applied at peak load during weekdays. 15% reduction in occurrence of overload achieve	**Source of funding:** National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care (CLAHRC) for the South West Peninsula

[a] Simulation undertaken, type of economic evaluation is unclear; does not produce a cost-effectiveness ratio.
[b] Investigated birth rate plus compared to a computer simulation model: unclear if comparator is realistic or appropriate. Does not reflect any NICE reference case.
[c] Simulation model structure not clearly defined. Unclear cost perspective; resource use, unit costs and sources of unit costs were not specified. Use of one ward in the UK may not be generalisable to other wards. No fully incremental analysis. No sensitivity analysis undertake to investigate uncertainty
[d] Budget not defined in study
[e] Unclear cost perspective assumed to be NHS only

				with 0% increase in budget.	

Study details	Population and setting	Intervention / comparator	Outcomes and methods of analysis	Results	Notes
Authors: Sandall et al **Year:** 2014 **Type of economic analysis:** 1. Costing analysis 2. Econometric analysis **Applicability** Partially applicable[a] **Limitations:** Potentially serious limitation[b]	**Setting:** UK NHS **Data sources:** See evidence review (for more information) 142 NHS trust, Health Episode Statistics (HES) data from 2011/11[c] NHS Workforce statistics 2010/11 CQC Maternity Survey of Maternity Provider Trusts 2007 and 2010 ONS Birth Registrations	Midwives (FTE) Support Staff (FTE) Doctors (FTE) Consultants (FTE) Relationships between above and number of births	**Outcomes:** Descriptive statistics, regression analysis coefficients, Marginal productivity, Hicks elasticity **Time horizon:** 1 year **Discount rates:** NA **Perspective:** NHS **Measures of uncertainty:** Sensitivity analyses undertaken **Modelling method** Production function analysis (Econometric analysis)	**Costing analysis** Higher midwife staffing levels associated with higher costs of each delivery (relationship not strong) **Econometric analysis** Descriptive aggregate results per trust: Mean (SD) Midwives 135 (6.45) FTE Support workers 42 (3.55) FTE Other Doctors 24 (1.46)	**Costing analysis:** Relationship strengthened when antenatal expenditure included as an explanatory variable 17% of variation between trust' delivery costs are accounted for in model, rising to 23% when antenatal expenditure is included. **Econometric analysis** Adjusted R^2 (total deliveries = 0.88 or higher Model suffers for

[a] No NICE reference case was followed, a QALY approach was not taken. Trust level perspective taken, and not ward level.
[b] Unclear if all relevant long terms costs and consequences were considered (i.e. long term implications of mother and baby safety concerns). Not a fully incremental analysis. No account of time spent between roles in obstetric versus gynaecology, no consideration of bank and agency staff. Multicollinearity between variables. Potential endogeneity between variables and error term.
[c] Aggregated at a trust level.

	2000/01 – 2010/11 BirthChoiceUK database Reference cost data – NHS reference costs 2010/11[a] Population Total of 665,969 delivery babies Sample mean number of total deliveries per trust (sd) Total deliveries: 4,600 (1991) Cost weighted deliveries[b] 5,740 (2,491)		**Costing analysis** Takes into account of trust size, risk, parity, age and IMD[c] **Econometric analysis** Controlled for case-mix of patients. Included variables on maternal age, parity, proportion of mothers considered high risk	Consultants 11 (0.60) 50.35% of patients considered High Risk using NICE criteria Mean maternal age 29.47 (1.18) Mean Parity 1.02 (0.30) % High Risk (NICE) 50.35% (6.36%) *Marginal productivity (change in output that results in the change of 1 unit of input. Keeping all other inputs constant)* *Total deliveries (standard errors):* *1 additional midwife is associated with +17.93 deliveries* *1 additional support staff is associated with +10.47 deliveries* *1 additional*	multicollinearity – investigated by Variance inflation Factor (VIF) which was high for multiple variables. **Source of funding:** National Institute for Health Research (NIHR)

[a] Costs converted to costs per delivery, and adjusted for geographical variations in labour and capital using Market Forces Factor (MFF)
[b] Weighted by relative cost, to take into account differences in cost between vaginal and caesarean deliveries based on HRG tariff
[c] Index of Multiple Deprivation (IMD)

				consultant is associated with 32.31 deliveries *1 additional other doctor is associated with 42.81 deliveries* *Cost weighted deliveries* *1 additional midwife is associated with +93.85 deliveries* *1 additional support staff is associated with +50.15 deliveries* *1 additional consultant is associated with +58.72 deliveries* *1 additional doctor is associated with +51.01 deliveries* *Hicks elasticity of substitution: (degree to which two inputs can be substituted for one another)* *Total deliveries:* *If the number of support staff increased by 1%*	

				change in the number of midwives needed would be -0.03% (substitutes) *If the number of consultants increased y by 1%, change in the number of midwives needed would be 0.30% (complements)* *If the numbers of other doctors required rose by 1%, change in the number of midwives needed would be 0.70% (complements)* *Cost-weighted deliveries:* *If the number of support staff increased by 1%, change in the number of midwives needed would be 0.05% (complements)* *If number of consultants increased by 1%, change in the number of midwives needed would be*	

				0.14% (complements) *If numbers of other doctors increased by 1%, change in the number of midwives needed would be 0.97% (complements)*	