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Strategic workforce planning in health and social care – an international perspective: A scoping review

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ABSTRACT

Effective strategic workforce planning for integrated and co-ordinated health and social care is essential if future services are to be resourced such that skill mix, clinical practice and productivity meet population health and social care needs in timely, safe and accessible ways globally.

This review presents international literature to illustrate how strategic workforce planning in health and social care has been undertaken around the world with examples of planning frameworks, models and modelling approaches.

The databases Business Source Premier, CINAHL, Embase, Health Management Information Consortium, Medline and Scopus were searched for full texts, from 2005 to 2022, detailing empirical research, models or methodologies to explain how strategic workforce planning (with at least a one-year horizon) in health and/or social care has been undertaken, yielding ultimately 101 included references.

The supply/demand of a differentiated medical workforce was discussed in 25 references. Nursing and midwifery were characterised as undifferentiated labour, requiring urgent growth to meet demand. Unregistered workers were poorly represented as was the social care workforce. One reference considered planning for health and social care workers. Workforce modelling was illustrated in 66 references with predilection for quantifiable projections. Increasingly needs-based approaches were called for to better consider demography and epidemiological impacts.

This review's findings advocate for whole-system needs-based approaches that consider the ecology of a co-produced health and social care workforce.

1. Introduction

1.1. What is strategic workforce planning in health and social care?

Strategic workforce planning in health and social care has been described as a technical process to predict demands for care, and the staff required to provide it [1,2]. Kroezen et al. [3: 87] stated health workforce planning ensures `the right number of people, with the right skills, are at the right place, at the right time to deliver the right services to those in need of them.' In the past strategic health workforce planning has been outlined as a composite of horizon scanning to identify future drivers of care needs; scenario generation or modelling to simulate possible future outcomes and their impacts; workforce modelling to frame the future workforce demand and supply; and policy analysis to forecast policy implications [4,5]. Willis et al. [6] noted the healthcare workforce is complex and planning approaches need to capture such complexity not only in terms of the myriad of factors at play within systems, but also to account for the uncertainty of factors and extended timeframes over which planning needs to occurs. Strategic planning is co-ordinated with the organisation's longer-term plans and typically

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occurs over a two-to-five-year period with a focus on the quality and size of the workforce [7].

Increasingly integration within and between health and social care has been identified as essential for future health and social care provision around the world [8,9]. However, the progress towards such proposed integration of health and social care has been debated. In the United Kingdom (UK) for example, work of the Nuffield Trust [10] and Miller et al. [11] both noted limited evidence to support such policy ambition in terms of improvements in patient health outcomes or service integration. Moreover Anderson et al. [12] noted the historical exclusion of social care from workforce planning in health and care in the United Kingdom as well as identifying data limitations and lack of strategic planning as debars to integration in health and social care workforce planning. Definitions of strategic workforce planning in health and social care must account not only for its technicality and complexity, multi-factorial elements including their combinations, and timeframes but also for a sustainable workforce of integrated services uniting health and social care. Whilst the World Health Organization [13: 9] advised its member nations `have inclusive institutional mechanisms in place to coordinate an intersectoral health workforce agenda', it is questionable how well health workforce planning has effectively incorporated social care to achieve this ambition.

1.2. Why is strategic workforce planning in health and social care of global importance?

Strategic workforce planning in health and social care is essential to ensure the provision of sustainable, safe, accessible health and social care services that meet the needs of and are utilised by populations around the world with a health workforce that is universally available, accessible, acceptable and of high quality [13,3,14]. Freer [15: 1] predicted increasing the supply of the health workforce to meet current demand would not be adequate, calling for a paradigm shift to `identify, train, allocate and retain health workers.' Szabo et al. [16] noted the global shortage of healthcare workers impacts ambitions for Universal Health Coverage (UHC) calling for closer consideration of the health worker demography with an especial focus on inequities identifiable by gender, migration and ageing. Szabo et al. [16] noted scrutiny of the health workforce demography is essential if UHC and the Sustainable Development Goals (SDGs) are to be achieved.

The World Health Organization [17: 2] identifies four key parameters within `a policy matrix', denoted within their toolkit for a sustainable health workforce targeted toward policy makers around the world. The toolkit focuses on health workforce supply concerns, including education and performance, planning and investment, capacity-building, analysis and monitoring, noting policies must address the production of the health workforce, inflows and outflows, maldistribution and inefficiencies. Figueroa et al.'s [18] review examines the roles of health leaders and workforce managers, from a global perspective, tasked often to deliver on such policy and strategy ambitions, noting ongoing prioritisation for reforms of cost, consolidation of hospitals and reconfiguration of primary healthcare for efficiencies.

The Organisation for Economic Cooperation and Development (OECD) [19: 15] identified that health and social sectors employ 10% of the workforce in OECD countries with concerns not only for global shortages of workers but also for `the right mix of health workers, with the right skills, … providing services in the right places, to better respond to changing population health needs.' The OECD [19] noted increasingly aged populations with chronic morbidities effect additional health and care needs that would require policy initiatives to drive innovative service delivery utilising technologies and new health and care worker roles. Long et al. [20] noted urgency for low- and middle-income countries to embrace digital innovations to support health worker development and support service provision in remote settings. More recent OECD working papers [21,22] have promulgated global attention towards policy that drives the health workforce towards people-centred care and welcomes digital innovations to aid service efficiency. Bronsoler et al.'s [23] discussion paper advocated for improved patient outcomes and heightened health worker productivity resultant from implementation of health information technologies.

Increasingly health workforce planning shifts from simple approaches that utilise professional to population ratios and health worker density statistics, prizing single parameters such as supply/demand of a single professional group or service, to more complex and comprehensive approaches that engage population health needs [24,14]. Needs-based workforce planning strengthens health systems (responding to population health requirements) yet depends on capacity building to provide the services people need [25].

Whilst service configuration and capacity may more easily be predicted during times of endemic disease, pandemic requirements, such as those experienced during COVID-19 are unique and specifically challenging for health workforce planners to forecast and incorporate into planning approaches [26]. Kunjumen et al. [14] encourage health policy planners to be responsive to evolving emergency situations such as national and international responses to establish surge capacities within health services. Strategic workforce planning in health and social care must also include levels of resilience to manage unprecedented health and care needs [13].

1.3. What does this article contribute?

This article presents an international academic literature review depicting how strategic workforce planning has been undertaken around the world in a variety of health and care settings over the past seventeen years (2005–2021). It also describes illustrative frameworks, models and tools to support strategic workforce planning. To the authors' knowledge this is the first review that has sought to aggregate strategic health and social care workforce planning approaches, as well as identify gaps in approaches such as backtesting. The review reinforces the literature about supply/demand deficits in specific workforces as well as the drivers for needs-based planning approaches. It illustrates international collaborations to share intelligence regarding health workforce planning globally.

Increasingly, there is an interest in the provision of integrated health and social care, and improving access to and use of, safe, quality care to achieve the ambition of integrated health and care services aligned to the World Health Organization's SDGs. Whilst there have been international collaborations [3] and global efforts [14] to share intelligence with respect to planning the health workforce, there has been very limited consideration globally to plan for an integrated health and social care workforce; a `whole' workforce for integrated care. Strategic workforce planning, regardless of analytical approach, needs to integrate health and social care through whole system thinking, if accessible, utilised, care for all, across the lifespan, is to be provided.

2. Materials and methods

2.1. Study design and rationale

Scoping reviews are noted as suitable for evidence synthesis, clarification of concepts and identifying opportunities for and approaches to further research [27]. A scoping review was identified as an appropriate approach to determine a range of available evidence on the ways strategic health and social care workforce planning is undertaken globally. The five-stage framework proposed by Arksey and O'Malley [28] was utilised to scaffold the review. The Open Science Framework (https://osf.io/) and Figshare (https://figshare.com/) were searched for registered scoping reviews on strategic workforce planning in health and social care with none identified.

Table 1
Inclusion and exclusion criteria for full text screening.

Criterion category	Inclusion criteria	Exclusion criteria
Type of source	Published qualitative, quantitative, mixed methods studies, policy, strategy, guidance and framework documents	Reviews, case reports, letters, book chapters, books, guidelines, comments, discussions, editorials, conference abstracts, study protocols, master or doctoral dissertation or theses
Source availability	Full texts available from Google, University of Bradford library or inter-library loan requests	Abstracts for which a full text was not available via Google, University of Bradford library or inter-library loan request
Language	English	Any other language besides English
Area of enquiry	Area 1: Accounts of how strategic workforce planning has been undertaken for service provision at least one year in advance with strategic workforce planning defined as `a technical task – using data to develop projections of expected demand for care and of how that demand can be met with a sufficient number of trained and appropriately skilled staff' (The King's Fund 2018: 2). Area 2: Models and/or methodologies that may be characterised as `judgemental, mathematical and a mix (of these)' (6:251). May include technologies and tools. Area 3: Evaluations of models and/or methodologies.	Area 1: Focus on operational or short-term planning (less than one year); staff scheduling; does not anticipate future requirements or preparations for future requirements. Area 2: Models and/or methodologies that are 'operational' and/or 'tactical'[6]. Do not describe a particular model and/or methodology. Area 3: Do not evaluate models and/or methodologies.

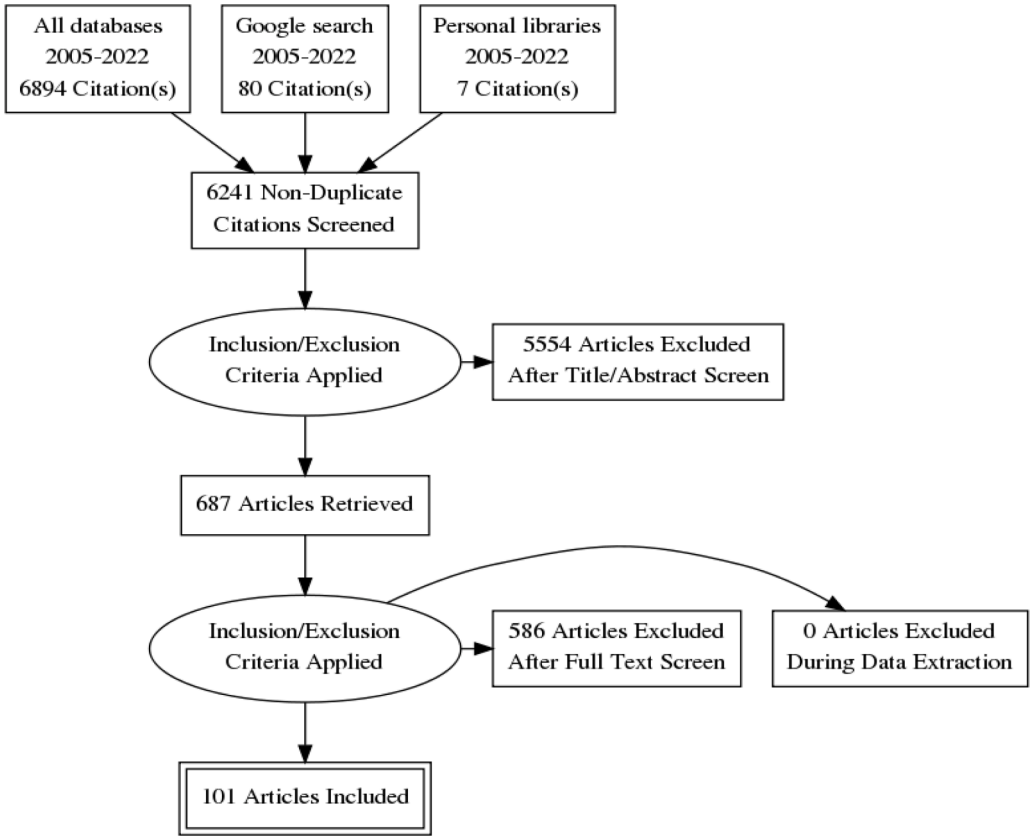


Diagram 1. The selection processes for the included literature of the review.

2.2. Search strategy

Searches of the international literature, using the search strings (#1 AND #2) presented below, were run in Business Source Premier, CINAHL, Embase, Health Management Information Consortium, Medline and Scopus with the following date range: 2005 to 2021 for English language items with at least an abstract available. EndNote® was used to manage the review's bibliography. An information specialist provided guidance in carrying out the literature searches.

#1 ("workforce" OR "human resource*" OR "personnel" OR "staff*" OR "manpower" OR "labour") N3 ("planning" OR "demand" OR "supply" OR "modelling") AND #2 "healthcare" OR "social care" OR "domiciliary care" OR "community care" OR "residential care" OR "primary care" OR "secondary care" OR "tertiary care" OR "hospital*" OR "general practi*" OR "ambulance service*"

In addition to the literature identified in academic databases, supplementary literature was identified from two Google searches (#a; #b)

Table 2
Summary of findings from included literature (drawing on details presented in Appendix 2)

Surname of Lead/Sole Author/s (Date of Publication)	Method/Framework for Strategic Workforce Planning	Region and Time Frame of Prediction (where available)	Workforce Implicated
Abel (2018)	Predictive risk modelling for supply/demand	United Kingdom	General practice
Ahern (2019)	Needs-based workforce planning; simulation model using scenario analyses	Europe	Oral health
Amorim-Lopes (2021)	Enhancing workforce modelling (mathematical) by embedding scenario building	Portugal	Health
Ansah (2015)	'Singapore Eye Care Workforce Model'	Singapore, 2017 – 2040	Ophthalmologists
Asamani (2021)	Needs-based workforce planning including training requirements	Ghana, 2020 – 2035	Primary health
Ball (2010)	'Birthrate Plus' - framework	United Kingdom, 2001 onwards	Midwifery
Ball (2020)	Safe-staffing policies' impacts	United Kingdom, 2009 - 2017	Nursing
Bam (2021)	Workload-based framework	International/South Africa	Diagnostic radiography
Batenburg (2015)	Health workforce planning characteristics (supply and demand modelling)	Europe	Health
Baumann (2016)	Policy impact assessment	Canada	Health
Birch (2021)	Integrated needs-based framework	International/United Kingdom	Health
Blank (2017)	Productivity modelling	The Netherlands	Hospital care
Centre for Workforce Intelligence (2014)	Workforce planning framework	United Kingdom	Health
Cowards (2016)	Systems dynamic modelling	South East England	Primary care
Chung (2021)	Prediction modelling	Taiwan	Nursing
Dejaco (2018)	Requirements in workforce planning	European	Rheumatology
Department of Health and Social Care (2016)	Policy	United Kingdom, 2012 - 2017	Health and social care
Department of Health and Social Care (2021)	Policy mandate to Health Education England	United Kingdom	Health and social care
Department of Health and Social Care (2022)	Policy	United Kingdom	Health and social care
Dol (2020)	Needs-based framework	Tanzania	Mothers as health workforce
Gallagher (2010)	Modelling using skill mix, supply and demand data	United Kingdom	Dental
Gupta (2015)	Interactive dynamic modelling tool	United States	Pathology
Health Education England (2018)	'WRaPT', planning tool using capabilities, trends and case studies	United Kingdom	Health
Health Resources and Services Administration (2019)	'Technical Documentation for Health Resources Service', modelling tool for specific professions	United States	Health
Hu (2016)	Planning model using linear programming	United States	Health
Kanagaratnam (2019)	Illustration of 'WRaPT'	United Kingdom	Health
KPMG (2021)	'Health and care transformation: how to get workforce planning right', range of bespoke workforce planning solutions	International	Health and care
Koichubekov (2021)	System dynamic model (using Any Logic) using workforce flow, demography and disease prevalence	Serbia, 2018 - 2030	General practitioners
Laurence (2016)	Simulation model for supply and need for general practitioners	Australia	General practitioners
Laurence (2017)	Needs-based model	Australia	General practitioners
Laurence (2018)	Needs-based model using scenarios	Australia, 2013 - 2033	General practitioners
Lavieri (2009)	Linear programming	Canada, 20-year planning horizon	Nurses
Leerapan (2021)	System dynamics simulation modelling to supply/demand balance	Thailand	Health
Looi (2021)	Practitioner-to-population ratios; call for needs-based workforce planning	Australia	Psychiatrists
Lopes (2018)	Agent-based simulation modelling	Portugal	Physicians
Mabunda (2021)	Implementation of Workload Indicators of Staff Need (WHO)	South Africa and Peru	Primary care
Maenhout (2013)	Modelling nursing staff structures for scheduling	Belgium	Nursing
Maier (2018)	Effects of new roles in workforce planning	International	Nurse practitioners and physician assistants
McCarty (2013)	Composite modelling in health workforce planning	Australia	Health
Monitor (2014)	Strategic workforce planning guidance	United Kingdom	Health
National Audit Office, Department of Health and Social Care (2017)	Workforce strategy	United Kingdom	Health
National Health Service (2020)	Workforce plan	United Kingdom	Health
National Health Service (2021)	Workforce plan	United Kingdom	Health
Northern Ireland Assembly (2016)	Workforce strategy	Northern Ireland	Health
Organisation for Economic Cooperation and development (OECD) (2013)	Workforce projection models	International (OECD countries)	Heath
OECD (2016)	Workforce policies	International (OECD countries)	Health
Panzera (2016)	Four stage workforce planning: needs assessment, remodelling of health services, workforce redesign, innovations and training	Australia	Health
Penny (2016)	Four step workforce planning methodology: scoping the workforce planning strategy, alignment, profiling the workforce, developing strategies to address gaps	Australia	Health
Pepler (2019)	Indigenous models of care for planning population health and social care workforce; whole system approach	Canada	Health and social care

(*continued on next page*)

Table 2 (*continued*)

Surname of Lead/Sole Author/s (Date of Publication)	Method/Framework for Strategic Workforce Planning	Region and Time Frame of Prediction (where available)	Workforce Implicated
Pittman (2016)	Management of workforce changes; whole system perspective	United States	Health
Queensland Health (2020)	Regional strategy for health workforce	Australia	Health
Ranta (2015)	Project modelling	New Zealand	Neurologists
Reulen (2009)	Supply/demand projections	Europe	Neurosurgery
Robboy (2015)	Dynamic modelling to forecast demand	United States	Pathology
Roberts (2013)	Service analysis: staffing level, service quality and cost	United Kingdom	Palliative care
Russo (2020)	Integrated workforce modelling: socioeconomic and epidemiological factors	United States	Hepatology
Santric Milicevic (2018)	Supply/demand projections	Serbia	Public health
Scheffer (2020)	Workforce profiling using medical school places and physician densities	Brazil and Spain, 1998 - 2017	Physicians
Schofield (2006)	Demand for hospital bed-days: demographic change model	Australia, to 2050	Health
Scottish Government (2019)	Workforce plan	Scotland	Health
Segal (2011)	Needs-based workforce planning framework to skill mix and hours; Workforce Evidence-Based (WEB) model	Australia	Health
Segal (2018)	Needs-based workforce model	Australia	Community mental health care for infants, children and adolescents
Simkin (2021)	Integrated needs-based workforce planning toolkit; patient use of services	Canada	Primary care
Skills for Care (2022)	A practical guide for workforce planning	England	Social care
Skills for Care (No date)	Web-based data for workforce description, analysis and planning	England	Social care
Skills for Health (2022)	'Six Steps Methodology to Integrated Workforce Planning' considering workforce size, skills, demand, demography and budget	England	Health
Smith (2009)	Service analysis: patient dependency, flow and skill mix	United Kingdom	Nursing
Somerville (2015)	'Victorian Assistant Workforce Model'; developing workforce capacity	Australia	Allied health professions
South West Yorkshire Partnership NHS Foundation Trust (No date)	Excel based regional health workforce planning tool	England	Health
Spetz (2015)	Forecasting model for use of long-term care	United States	Workforce involved in care of the older adult (over 65 years)
Stordeur (2010)	Supply impacts of *numerus clausus*	Belgium	Physicians
Streeter (2017)	Application of 'Health Workforce Simulation Model'	United States	Primary care
Taghavi (2021)	Population-need workforce planning model to forecast staff need; linear programming	Canada	Palliative care
Teljeur (2010)	Stochastic modelling using policy interventions	Ireland	General practitioners
Teusner (2016)	Workforce modelling: productivity, skill mix, workforce composition and task shifting	Australia	Dental services
The Health Foundation (2019)	'Think-tank' report on key areas for action in health and social care workforce planning	United Kingdom	Health and social care
The King's Fund (2018)	'Think-tank' report on roundtable discussion: strategy for health and care workforce in England	United Kingdom	Health and social care
Theppanya (2016)	Workforce modelling: situation analysis, project of staff requirements and solutions	Lao	Health
Thongsukdee (2020)	Agent-based modelling	Thailand	Physicians
Tomblin Murphy (2011)	Service analysis; conceptual framework	Canada	Nursing – hospital care
Tomblin Murphy (2012)	Needs-based planning	Canada	Nursing
Tomblin Murphy (2013)	Service-based planning framework	Canada	Staff for domiciliary and residential care of older adults
Van Greuningen (2012)	Evaluation of workforce planning model	The Netherlands	General practitioners
Van Greuningen (2013)	Workforce projection modelling accuracy – back testing (1998 – 2011)	The Netherlands	General practitioners
Vanderby (2014)	Simulation using system dynamics	United States	Cardiac surgeons
Vigersky (2014)	Supply/demand projections	United States, to 2025	Endocrinology workforce
Vile (2016)	Demand forecasting and labour scheduling modelling	Wales	Emergency medical services
Von Eitzen-Strassel (2014)	Skill mix analysis	The Netherlands	General practitioners
Welsh Parliament (2020)	Workforce strategy	Wales	Health and social care
West Yorkshire Health and Care Partnership	Regional workforce strategy	England	Health and social care
Whitehouse (2020)	Supply/demand projections	United Kingdom	Neurosurgery
Whole Systems Partnership (2022)	Strategic workforce planning framework: 'SWiPe'	United Kingdom	Health
World Health Organization (2010)	Supply-focused workforce planning models and tools	International	Health
World Health Organization (2010)	'Workload Indicators of Staffing Needs' (WISN) – supply focused workforce planning tool	International	Health
Wranik (2008)	Typology of health human resourcing strategies: micro- to macro-levels	International	Health
Yao (2016)	'Birthrate Plus' – application of model	China	Midwifery
Yasutake (2012)	Four-point plan to augment workforce	Hawaii, to 2020	Health

detailed below, and hand searching references lists from previously identified literature as well as reviewers' personal libraries.

#a "strategic workforce planning" health; #b "strategic workforce planning" "social"

2.3. Initial screening

In total 6894 references were identified from six academic databases. Following de-duplication, the title/abstract of 6105 references were divided among a team of nine reviewers and screened once using the algorithm presented in Appendix 1. This yielded 654 references that were subsequently divided between two reviewers for full text retrieval and screening utilising inclusion/exclusion criteria (presented in Table 1 below).

The first 80 items of the two Google searches [29] were screened by one reviewer with a total of 26 items identified for full text review using the inclusion/exclusion criteria in the subsequent section. Seven items from reviewers' personal libraries were also included.

2.4. Inclusion and exclusion criteria for full text screening and data extraction

Inclusion and exclusion criteria for full text screening are presented in Table 1. Inclusion criteria privileged empirical research, for example studies. Owing to the volume of included literature, reviews were excluded. Three areas of enquiry were identified. These areas of enquiry were also used to categorise broadly and extract data from the literature of this review. Data extraction was undertaken as an iterative process. All full text screening and data extraction was carried out by two reviewers contemporaneously.

3. Results

3.1. Overview of the literature

A simple diagram to show the selection process of included items is presented below (Diagram 1). Table 2, below, presents a summary of findings from included literature drawing on details presented in Appendix 2. Appendix 3 offers named examples of workforce models. The results of the review are presented to reflect the key areas of enquiry as denoted in the above table with the exception of Area 3, for which there was very limited evidence.

3.1.1. Date range and type of literature

The distribution of literature across the date range of this review is presented in Bar chart 1 (below). Most included literature was published in either 2016 or 2021 (13 items each), with more limited literature published before 2010. Most empirical research of this review provides workforce modelling illustrations with 58 of the 101 references (see Bar chart 2 below). Most of the 12 policy and strategy documents are from nations of the United Kingdom with one document only from elsewhere (Queensland, Australia).

3.1.2. Groups of health and social care workers represented

The medical and dental workforces are most heavily represented within the review's literature with 28 items. Gallagher et al. [30], Ahern et al. [31] and Birch et al. [32] discussed the oral health workforce including dentists. Several references denoted the supply/demand for physicians [33–36] or medical workforce [37] with others focused on individual specialities including psychiatry [38], neurosurgery [39,40], public health [29], endocrinology [41], cardiac surgery [42], neurology [43], pathology [44], hepatology [45], ophthalmology [46] and rheumatology [47].

There is notable concern for the supply and demand for general practitioners and the general practice workforce in the UK [48], Ireland [49], the Netherlands [50–52] Kazakhstan [53] and Australia [54–56].

The shortage of registered nurses is noted from generic and specific perspectives in the literature. For example, there is an enduring deficit of nurses in the UK [57] and a commitment to 50 000 more nurses in the UK's National Health Service (NHS) by 2025 [58]. Unlike the literature regarding the medical workforce, which can be differentiated by specialty, the literature about the nursing workforce has given nurses a homogenous identity with the nursing workforce differentiating the nursing workforce by patient outcomes [59,60], patient dependency-acuity [61,62], the importance of needs-based planning [63], organisation of nursing staff [64] and safe staffing [65]. Penny and Fennah [66] identified a lack of specific methodologies for strategic workforce planning in community nursing, noting strategic planning is essential for long term workforce solutions.

Birthrate Plus®, a key methodology to plan the midwifery workforce in the UK [67,68] and in China [69], dominates the literature about midwives. Both Ball and Washbrook [67] and Yao et al. [69] noted an imbalance in the midwifery workforce supply to provide current levels of care, advising patient acuity and the contribution of support workers are essential components in planning the midwifery workforce. Allied health professionals have minimal representation within the literature [70,71]. Unregistered health workers are under-represented within the literature and as contributors to specific disciplines only [72,73].

The adult social care workforce is a marginal presence within the literature as required workforce to meet the increasing demand for long-term care manifest through a growing aged population [74,75].

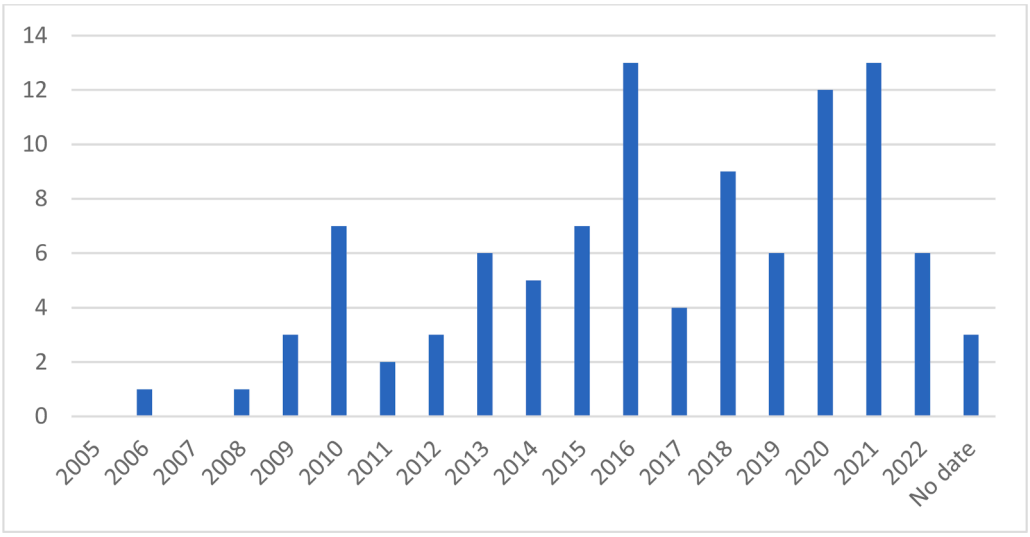
3.1.3. Health and social care services and needs

Health services are addressed by a range of references (subsequently discussed). By contrast social care needs are discussed in the work of two articles. Spetz et al. [74] discussed the long-term care needs of older adults and the differential use of such services by ethnicity whilst Pepler and Martell [76] advocated for the importance of planning for and providing health and social care that is responsive to the needs of indigenous peoples.

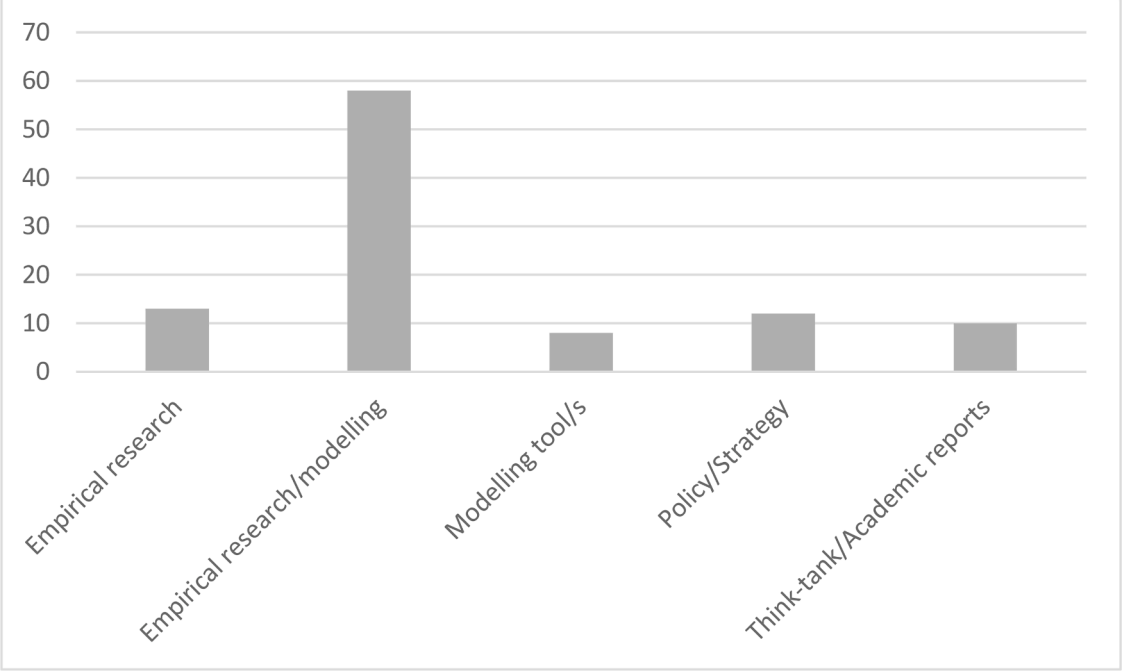
In-patient health workforce demand within the literature has been planned for variably but includes the use of estimates of bed-days [77], patient dependency-acuity [61], workforce productivity [78], accessible and safe care [65].

Community-based care is represented within the literature with illustrations of specialist services and denoted current deficits [79,66,80]. Segal et al. [79] utilised a needs-based model to identify a deficit of 947 personnel and AU$126 million, five times the current provision, for tertiary-level community mental health care for infants, children and adolescents in South Australia. In response to an identified lack of approaches suitable to plan the future nursing workforce for a child and youth community health service in Queensland, Australia, Penny and Fennah [66] designed their own four stage approach. Similarly, Taghavi et al. [80] designed, implemented and reported a population-need workforce planning model, utilising linear programming within an operations research approach, for a community-based palliative care multidisciplinary team to predict staffing to 2038.

The increased need for care services for older adults and those with chronic disease globally is noted [81] but there are limited specific illustrations within the literature regarding how the workforce for such need is planned. Tomblin Murphy et al. [82] examined home and long-term care provision in Nova Scotia, calling on policy makers to consider the type of service required by service users. Segal and Leach [83] identified the importance of the multidisciplinary team to provide optimal care for those with chronic disease yet a lack of literature to explain and plan for the skill mix required to deliver it. Segal and Leach [83] advocated for the use of needs-based workforce planning to meet the complex needs of those with chronic disease noting three tiers of consideration: 1. population needs assessment aligned with best-practice care competencies, 2. regional service requirement as full-time equivalent competencies aligned with occupations required to



Bar chart 1. Number of references by year.



Bar chart 2. Number of references by categories of literature

deliver such competencies, and 3. policy implications including supply/demand comparisons, resource, education and training implications.

3.2. *Approaches to strategic workforce planning in health and social care*

Projection approaches, which the World Health Organization [84] have grouped into those using workforce-to-population ratios, health needs, service demands and service targets, have been often used for health workforce planning yet identified by the OECD [81] as limited.

3.2.1. *Workforce supply and demand approaches*

Historically, workforce supply and demand have founded workforce projections, where `supply' can be described as the number of staff or skills to provide care, and `demand' can be described as the required (number of) staff or skills to provide care [84]. More recently Ahern et al. [31: 2] defined provider supply by: `existing stock, flow and newly trained'.

Birch et al.'s [85] more contemporary work noted reliance on provider (supply/demand) projections by singular profession, a lack of integration in health workforce planning with service provision and funding, a lack of consideration for the requisite skill mix to best meet population needs, a lack of consideration of the contribution of new roles and task substitution to improve service capacity and efficiency and lack of consideration for productivity. Despite the challenges of workforce supply/demand projections there are a variety of illustrations within the literature which have demonstrated supply/demand approaches often culminating in supply/demand growth predictions from scenario generation.

Reulen et al. [39: 719] presented data on the characteristics of the neurosurgical workforce from 27 European countries, with the aim of identifying the demand for neurosurgeons ('real needs of neurosurgeon

per population') and number of neurosurgeons in training. Reulen et al. [39] collated primary survey data to identify the number of neurosurgeons of each country, the number of neurosurgical operations per million population per year, the nature of the neurosurgical case load, implementation of a numerus clausus (capped trainee number), average annual intake of new trainees, the annual loss rate, annual intake against annual loss rate and total number of neurosurgeons. Reulen et al. [39] noted there was considerable variation in neurosurgeon-to-population ratio, those countries with fewer neurosurgeons undertook fewer neurosurgical operations, a numerus clausus was used in 13 of 27 countries and annual attrition rates owing to retirement for instance, range from 2.3% to 3.36%. Whitehouse et al.'s [40] later UK based neurosurgical workforce projection research again utilised primary survey data with the aim of identifying changes in the number of consultant neurosurgeons over a five-year period (2014–2018) and those who had achieved a Completion of Certificate of Training. Whitehouse et al. [40] went on to develop neurosurgeon workforce projections with five alternative scenarios based on changes in consultant retirement numbers, consultant post increases and non-trainees appointed. They concluded current trends in the UK neurosurgical workforce projected a deficit in supply.

Vigersky et al. [41] developed supply/demand projections for the endocrinology workforce of the United States utilising primary survey data on endocrinologist demographics and non/clinical practice with secondary data from national medical associations and boards. Supply was derived from endocrinologists in training and those who had completed training. Attrition rate was defined by emigration, change in professional activity, leave, retirement or death data. Algebraic formulae were derived to generate supply figures by full time equivalents and demand by number of visits as well as full time equivalents. Three scenarios were generated to project supply/demand possibilities. The first two scenarios considered factors affecting the workforce environment such as increased training positions, whilst the third scenario sought to identify the number of training positions required to address the supply/demand imbalance in five and ten years respectively.

Ranta et al. [43] similarly gathered primary survey data on New Zealand's neurology workforce in public hospitals for workload and productivity analyses by full time equivalents and patient contact equivalents (PCEs) for supply/demand projections. They noted anticipating future supply/demand balance was challenging owing to confounding factors and practice variation. Scenario modelling was also used to understand the impacts of increased training opportunities, new roles, novel technologies and service delivery changes for efficiency. Ranta et al. [43] concluded a supply/demand imbalance for the New Zealand neurology workforce yet advocated for the use of PCEs to better quantify productivity for service demand projections.

Teljeur et al. [49] described a supply/demand analysis using general practitioner visits as indicators of demand with supply enhancement projections based on four potential policy directives: increasing training places, international recruitment, incentivising later retirement and the upskilling of practice nurses to substitute for general practitioners for some tasks. Scheffer et al.'s [36] comparative analysis of the supply of physicians and specialist trainees in Brazil and Spain examined the impact of increased training places, notably via private medical schools, to augment supply growth rate. They found the policy initiative of limited efficacy and called for service-use appraisal, multidisciplinary care and the better consideration of demographic and epidemiological factors in workforce planning.

Whilst supply/demand projections are traditional and embedded approaches in workforce planning, needs-based approaches including service level and utilisation have gained increased attention around the world [2,38,47,85–87].

3.2.2. Health and social care needs-based planning approaches

Population health needs approaches to health and social care workforce planning have been used increasingly over the last decade [63,83,85,87]. Of note there are multiple illustrations within the literature of needs-based approaches in workforce planning in community [79,80] and primary care settings [55,56,88,89]. Health and social care services' access, utilisation and configuration for efficacy, as well as efficiency, notably cost efficiency, are dependent on population needs [85] and as such workforce planning models are recommended to consider demographic and epidemiological perspectives [88]. The King's Fund [2: 4], in relation to the UK's health and social care workforce planning ambitions noted that prioritising `standards of care, targets or what patients … want … will provide a different picture of workforce requirements.'

Facets of population demography and epidemiology in needs-based workforce planning approaches are variably considered within the literature. Segal and Leach's [83] workforce modelling for primary and community care, espousing a needs-based approach, organised their workforce planning framework by population health status and best-practice care to provide for population health, regional service requirements by full time equivalent requirement and occupations required to deliver best-practice care and policy implications. Segal et al.'s [79] later work, in modelling for a tertiary-level community mental health service for young people, framed a needs-based workforce within regional planning and workforce, needs analysis, the regional workforce, clinical workforce costs and service delivery implications.

Panzera et al.'s [90] action research to inform health services commissioning in Northern Queensland, Australia, utilised a four staged approach starting with a health needs assessment phase including identification of essential services, remodelling to facilitate prioritisation to meet needs, workforce redesign and development to identify and project requisite skill sets and lastly a training plan to effect workforce reconfiguration and training pathways. Within Ahern et al.'s [31: 3] modelling, `need' is categorised by `population', `health status' and `level of service'. Dejaco et al.'s [47] points to consider in rheumatology workforce requirements noted the importance of identifying need for care based on prevalence and referral rates of diseases managed by rheumatologists, current and future demographics, sociocultural characteristics and disease trends.

National and regional health needs and priorities are frequently identified and driven by governmental policy ambitions. For example, the recent paper from the UK's Department of Health and Social Care [91]: Section 1.8 identified the importance of integration between health and social care services to provide `co-ordinated' services that provide `the right care, in the right place, at the right time' through a `shift to prevention … to address people's needs … .' Queensland Health [92: 4] noted health services are increasingly in demand, and this demand must be delivered through a `networked' approach that is sustainable, provided at `whole-of-system' level and is responsive. Queensland Health [92] outlined a strategic planning approach to provide such health services that considers workforce capacity, capability (skills), sustainability and diversity, design (including strategic and organisational) and the culture of the health work environment for wellbeing and performance.

Local and regional approaches for delivering on such governmental ambitions for population health and social care needs identify nuanced considerations. Pepler and Martell [76] pointed to the importance of planning a health and social care workforce that is sensitive and competent to provide care that befits indigenous peoples calling notably for increases in indigenous professionals to better represent as well as provide for, First Nations, Inuit and Metis peoples and their needs. Pepler and Martell [76] noted a disproportionate burden of chronic disease among indigenous peoples noting their late utilisation of services.

There has been a similar interest in geographic variation in specialist health services. For example, Russo et al. [45] noted a need to encourage hepatologists to areas outwith specialist centres. Ranta et al.'s [43] analysis of the New Zealand neurology workforce noted access to specialist neurologist/s in rural parts of the country is especially limited.

Appendix 2
Included literature.

Lead author (Country/ies or continent to which workforce planning pertains)	Date of publication	Headline of workforce planning approach *(May include document title in italics)*	Sourced from	Type of literature
Abel, G. (United Kingdom)	2018	Predictive risk modelling for general practice; supply/demand imbalance	Database	Empirical research/ modelling
Ahern, S. (Europe)	2019	Needs-based workforce planning model (in Microsoft Excel) for oral health workforce; simulation model based on framework of Birch et al. (2007); scenario analyses	Database	Empirical research/ modelling
Amorim-Lopes, M. (Portugal)	2021	Enhancing workforce modelling by embedding scenario building within mathematical planning models	Database	Empirical research/ modelling
Ansah, J. (Singapore)	2015	Singapore Eye Care Workforce Model to forecast ophthalmologists (2017 to 2040); workforce stocks; system dynamics; three components: eye disease; demand and workforce requirements; four scenarios	Database	Empirical research/ modelling
Asamani, J. (Ghana)	2021	Needs-based health planning framework (in Excel); fifteen-year projection (2020 to 2035) of health workforce supply, needs, gaps and training requirements in primary health care in Ghana	Database	Empirical research/ modelling
Ball, J. (United Kingdom)	2010	Overview of theoretical framework of Birthrate Plus® (BR+) and subsequent studies (since 2001) of BR+ implementation	Database	Empirical research/ modelling
Ball, J. (United Kingdom)	2010	Birthrate Plus®, ratios of births to midwives to plan for additional staffing needs from `out-of-area' deliveries and follow-up postnatal care	Database	Empirical research
Ball, J. (United Kingdom)	2020	Nursing workforce staffing description (2009 to 2017); impact of safe staffing policies	Database	Empirical research
Bam, L. (International/South Africa)	2021	Diagnostic radiographer staffing requirements by workload-based framework	Database	Empirical research/ modelling
Batenburg, R. (Europe)	2015	Score European countries by health workforce planning characteristics: data infrastructure; workforce planning mechanism; use of health workforce modelling (focus on supply and demand modelling)	Database	Empirical research
Baumann, A. (Canada)	2016	Description of policy impact	Google	Empirical research
Birch, S. (Europe)	2020	Apply integrated needs-based framework (based on Birch et al. (2007) to re-configure care delivery; re-allocation of treatment tasks; impacts on care costs by pay, productivity and practice style	Database	Empirical research/ modelling
Birch, S. (International/United Kingdom)	2021	Design of `fit for purpose' workforce planning model for oral health workforce: model including changes in demography, epidemiology, care pathways and productivity	Database	Empirical research/ modelling
Blank, T. (The Netherlands)	2017	Modelling productivity growth using factor technical change (FTC) for a Dutch hospital (2003 to 2011); improve forecasting for demand	Database	Empirical research/ modelling
Centre for Workforce Intelligence (United Kingdom)	2014	*Robust workforce planning framework, An introduction*; framework to include horizon scanning, scenario generation, workforce modelling, policy analysis; supply and demand (workforce modelling) orientated	Reviewer's personal library	Think-tank/ Academic report
Coward, M. (England)	2016	Project report for primary care strategic workforce planning in South East of England; system dynamics modelling	Google	Think-tank/ Academic report
Chung, M. (Taiwan)	2021	Prediction model for nursing staff in cancer care using fuzzy sets to account for uncertainties to improve flexibility of results	Database	Empirical research/ modelling
Dejaco et al. C. (Europe)	2018	Ten points to consider in Europe rheumatology workforce requirement studies	Database	Empirical research/ modelling
Department of Health and Social Care (United Kindgom)	2016	Workforce planning for health, public health and social care; webpage providing links to a collection of policy paper (2012 to 2017) each relation to individual medical specialties	Google	Policy/Strategy
Department of Health and Social Care (United Kingdom)	2021	DoHSC mandate to Health Education England (HEE), requirement of the Care Act 2014; HEE's responsibility for workforce planning, education and training; policy paper	Reviewer's personal library	Policy/Strategy
Department of Health and Social Care (United Kingdom)	2022	*Joining up care for people, places and populations*; policy paper	Reviewer's personal library	Policy/Strategy
Dol, J. (Tanzania)	2020	Needs-based framework examining contribution of mothers as health workforce resource; conceptual framework (as in Tomblin Murphy 2011 and in Birch 2007)	Database	Empirical research/ modelling
Gallagher, J. (United Kingdom)	2010	Modelling dental workforce skill mix using supply and demand data and scenario planning to assess impacts of variation in staff competencies (2005 to 2028)	Database	Empirical research/ modelling
Gupta, S. (United States)	2015	Interactive dynamic modelling tool; scenario-based; for analysis of United States pathologist workforce to forecast supply and demand	Database	Empirical research/ modelling
Health Education England (England, United Kingdom)	No date	Webpage of *HEE Star*; solution-focused workforce planning framework	Reviewer's personal library	Modelling tool/s
Health Education England (England, United Kingdom)	2018	*WRaPT*, website: health workforce planning intelligence sub-categorised into capabilities, trends and case studies	Google	Modelling tool/s

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Appendix 2 (*continued*)

Lead author (Country/ies or continent to which workforce planning pertains)	Date of publication	Headline of workforce planning approach *(May include document title in italics)*	Sourced from	Type of literature
Health Resources and Services Administration (United States)	2019	*Technical Documentation for Health Resources Service*; guide to modelling health workforce focus on specific health professions	Google	Modelling tool/s
Hu, W. (United States)	2016	Health workforce planning model using linear programming methodology; test lookahead policy using model	Google	Empirical research/ modelling
Kanagaratnam, S. (United Kingdom)	2019	Description and illustrations of workforce planning framework (Workforce Repository and Planning Tool (WRaPT)) from Health Education England	Google	Empirical research/ modelling
KPMG	2021	*Health and care transformation: how to get workforce planning right*; website advertising a range of workforce planning resource	Reviewer's personal library	Modelling tool/s
Koichubekov, B. (Serbia)	2021	System dynamic model (using Any Logic) including general practitioner flow, demography and disease prevalence (2018 to 2030); three scenarios for forecasting	Database	Empirical research/ modelling
Laurence, C. (Australia)	2016	Simulation model to estimate supply and need for general practitioners	Database	Empirical research/ modelling
Laurence, C. (Australia)	2017	Needs-based model for general practitioner requirement (2013 to 2033); simulation model; scenario modelling (policy/non-policy)	Database	Empirical research/ modelling
Laurence, C. (Australia)	2018	Needs-based model to estimate general practitioner requirements (2013 to 2033) using five scenarios	Database	Empirical research/ modelling
Lavieri, M. (Canada)	2009	Linear programming hierarchical planning model to determine number of nurses to train and recruit over a 20 year planning horizon	Database	Empirical research/ modelling
Leerapan, B. (Thailand)	2021	System dynamics simulation modelling of health care workforce by group model building to understand supply/demand im/balance	Database	Empirical research/ modelling
Looi, J. (Australia)	2021	Psychiatrist-to-population ratio projections; call for needs-based workforce planning	Database	Empirical research/ modelling
Lopes, M. (Portugal)	2018	Agent-based simulation modelling for medical workforce; `physician' as agent	Database	Empirical research/ modelling
Mabunda, S. (India, South Africa and Peru)	2021	Implementation of WISN for primary care in India, South Africa and Peru	Database	Empirical research
Maenhout, B. (Belgium)	2013	Modelling nursing staff organisational structure for scheduling	Database	Empirical research/ modelling
Maier, C. (Eight countries)	2018	Inclusion and effects of new roles (nurse practitioner and physician assistants) in workforce planning	Database	Empirical research
McCarty, M. (Australia)	2013	Overview of key elements in Australia's health workforce planning: composite modelling	Database	Empirical research
Monitor (United Kingdom)	2014	Strategic workforce planning tool/guidance for health workforce	Google	Modelling tool/s
National Audit Office, Department of Health and Social Care (United Kingdom)	2020	National report (description and strategy) on the United Kingdom's nursing workforce; challenges to workforce planning: understanding future need; performance of current and future supply; workforce plan; information/ data; integrating workforce, finance and performance; coverage of all types of staff in planning	Google	Policy/Strategy
National Health Service (England, United Kingdom)	2017	*Facing the Facts, Shaping the Future, A draft health and care workforce strategy for England*	Google	Policy/Strategy
National Health Service (United Kingdom)	2020	*WE ARE THE NHS: People Plan for 2020/2021 – action for all*	Google	Policy/Strategy
National Health Service (United Kingdom)	2021	*The future of NHS human resources and organisational development*; vision and actions for four pillars of `We are the NHS: People Plan for 2020/2021′	Google	Policy/Strategy
Northern Ireland Assembly (Northern Ireland, United Kingdom)	2016	*Health and Social Care Workforce Strategy 2026, Delivering for Our People*	Google	Policy/Strategy
Organisation for Economic Cooperation and Development (International)	2013	*Health Workforce Planning in OECD Countries, A Review of 26 Projection Models from 18 Countries*	Google	Think-tank/ Academic report
Organisation for Economic Cooperation and Development (International)	2016	*Health Workforce Policies in OECD Countries*	Google	Think-tank/ Academic report
Panzera, A. (Australia)	2016	Four stage workforce planning approach: needs assessment, remodelling of health services, workforce redesign, innovations and training	Database	Empirical research/ modelling
Penny, R. (Australia)	2020	Four-step workforce planning methodology: scope the workforce planning strategy; alignment; profile the workforce; develop strategies to address gaps	Database	Empirical research/ modelling
Pepler, E. (Canada)	2019	Use of indigenous models of care for population health; health and social care workforce; systems thinking; scenario planning; population health simulation; whole system approach	Database	Empirical research/ modelling
Pittman, P. (United States)	2016	Management of workforce changes; whole system perspective rather than single professions	Database	Empirical research
Queensland Health (Australia)	2020	Regional strategy; frameworks and associated tools for health workforce planning in Queensland, Australia	Google	Policy/Strategy

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Appendix 2 (*continued*)

Lead author (Country/ies or continent to which workforce planning pertains)	Date of publication	Headline of workforce planning approach *(May include document title in italics)*	Sourced from	Type of literature
Ranta, A. (New Zealand)	2015	Supply/demand projection modelling for neurologist workforce	Database	Empirical research/ modelling
Reulen, H. (Europe)	2009	Supply/demand projections for neurosurgical workforce	Database	Empirical research/ modelling
Robboy, S. (United States)	2015	Dynamic modelling/interactive system of algebraic formulations to forecast demand for pathologist services	Database	Empirical research/ modelling
Roberts, D. (United Kingdom)	2013	Service analysis: palliative care; staffing level; service quality and cost	Database	Empirical research
Russo, M. (United States)	2020	Integrate workforce framework model of hepatology workforce: socioeconomic factors; epidemiological factors	Database	Empirical research/ modelling
Santric Milicevic, M. (Serbia)	2018	Supply/demand projections (to 2025) for public health workforce; use of Microsoft Excel	Database	Empirical research/ modelling
Scheffer, M. (Brazil and Spain)	2020	Physician workforce description using longitudinal data 1998 to 2017; association medical school places and physician densities in Brazil and Spain	Database	Empirical research/ modelling
Schofield, D. (Australia)	2006	Future demand for hospital bed-days (to 2050); demographic change model	Database	Empirical research/ modelling
Scottish Government (Scotland, United Kingdom)	2019	*An Integrated Health and Social Care Workforce Plan for Scotland*	Google	Policy/Strategy
Segal, L. (Australia)	2011	Application of needs-based workforce planning framework to predict health workforce team's skill mix and hours; Workforce Evidence-Based (WEB) planning model	Database	Empirical research/ modelling
Segal, L. (Australia)	2018	Needs-based workforce model for community mental health care of infants, children and adolescents	Database	Empirical research/ modelling
Simkin, S. (Canada)	2021	Integrated needs-based primary care workforce planning toolkit; patient use of services	Database	Empirical research/ modelling
Skills for Care (England, United Kingdom)	2022	*A practical guide for strategic workforce planning, shaping and commissioning*; Key consideration for local authorities in planning for the social care workforce; manual	Google	Think-tank/ Academic report
Skills for Care (England, United Kingdom)	No date	*Workforce intelligence*; Website providing data and publications regarding workforce data, description, analysis and planning	Google	Think-tank/ Academic report
Skills for Health (United Kingdom)	2022	*Six Steps Methodology to Integrated Workforce Planning*; approach for `workforce of right size … right skills … taking into account … demand … local demographic situation … to the budget …'	Google	Modelling tool/s
Smith, S. (United Kingdom)	2009	Service analysis: nursing workforce requirement based on patient dependency-acuity, patient flow, skill mix	Database	Empirical research
Somerville, L. (Australia)	2015	Developing workforce capacity: allied health professions; Victorian Assistant Workforce Model – Allied Health	Database	Empirical research/ modelling
South West Yorkshire Partnership NHS Foundation Trust (England, United Kingdom)	No date	*Workforce & Success Planning Round 2021–22*; Excel based regional health workforce planning tool	Reviewer's personal library	Modelling tool/s
Spetz, J. (United States)	2015	Forecasting model for use of long term care by people aged 65 years and over	Database	Empirical research/ modelling
Stordeur , S. (Belgium)	2010	Supply impacts of numerus clausus for physicians	Database	Empirical research/ modelling
Streeter, R. (United States)	2017	Application of Health Workforce Simulation Model to examine the geography of primary care	Database	Empirical research/ modelling
Taghavi, M. (Canada)	2021	Population-need (community based palliative care specialist teams) workforce planning model to forecast staff need for next 20 years; operations research; linear programming	Database	Empirical research/ modelling
Teljeur, C. (Ireland)	2010	Stochastic modelling for probable future supply of general practitioner based on four policy interventions	Database	Empirical research/ modelling
Teusner, D. (Australia)	2016	Dental service provision and capacity analysis by workforce modelling: productivity, skill mix, workforce composition, task shifting	Database	Empirical research/ modelling
The Health Foundation (United Kingdom)	2019	'Think-tank' report on key areas for action in the health and social care workforce of the United Kingdom	Google	Think-tank/ Academic report
The King's Fund (United Kingdom)	2018	'Think-tank' report on roundtable discussion about strategy for health and care workforce in England: supply/demand scenarios, productivity, workforce planning, modelling, data	Google	Think-tank/ Academic report

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Appendix 2 (*continued*)

Lead author (Country/ies or continent to which workforce planning pertains)	Date of publication	Headline of workforce planning approach *(May include document title in italics)*	Sourced from	Type of literature
Theppanya, K. (Lao)	2016	Provincial workforce planning: situation analysis; projection of staff requirement; solutions	Database	Empirical research/ modelling
Thongsukdee, P. (Thailand)	2020	Physician supply; agent-based modelling; systematic approach; sensitivity analysis	Database	Empirical research/ modelling
Tomblin Murphy, G. (Canada)	2011	Service analysis: nursing inputs and outcomes of hospital care; conceptual framework of health-care system	Database	Empirical research
Tomblin Murphy, G. (Canada)	2012	Needs-based planning to reduce nursing workforce shortage	Database	Empirical research/ modelling
Tomblin Murphy, G. (Canada)	2013	Service-based planning framework for older adults in home and long term care	Database	Empirical research/ modelling
Van Greuningen, M. (The Netherlands)	2012	Evaluation of Dutch health workforce planning model when applied to general practitioner workforce	Database	Empirical research/ modelling
Van Greuningen, M. (The Netherlands)	2013	Workforce projection modelling accuracy; backtesting; general practitioner workforce 1998 to 2011	Database	Empirical research/ modelling
Vanderby, S. (Canada)	2014	Cardiac surgeon workforce modelling/simulation using system dynamics; includes demand and supply components; feedback loops; facilitates scenario exploration	Database	Empirical research/ modelling
Vigersky, R. (United States)	2014	Supply/demand projections for endocrinology workforce (to 2025)	Database	Empirical research/ modelling
Vile, J. (Wales)	2016	Emergency services management; demand forecasting; labour scheduling modelling	Database	Empirical research/ modelling
Von Eitzen-Strassel, J. (The Netherlands)	2014	Skill mix analysis of Dutch general practitioners	Database	Empirical research/ modelling
Welsh Parliament (Wales, United Kingdom)	2020	*A Healthier Wales: Our Workforce Strategy for Health and Social Care*	Google	Policy/Strategy
West Yorkshire Health and Care Partnership (England, United Kingdom)	2022	*People Plan, Workforce Strategy 2021–2025*; regional strategy	Reviewer's personal library	Policy/Strategy
Whitehouse, K. (United Kingdom)	2020	Supply/projections of neurosurgical workforce	Google	Empirical research/ modelling
Whole Systems Partnership (United Kingdom)	2022	Population health led strategic workforce planning framework; *Strategic Workforce Planning (SWiPe®)*	Reviewer's personal library	Modelling tool/s
World Health Organization (International)	2010	*Models and tools for health workforce planning and projections*; overview of supply-focused health workforce planning models and tools	Google	Think-tank/ Academic report
World Health Organization (International)	2010	Webpage with link to *Workload Indicators of Staffing Need (WISN)*; supply-focused health workforce planning tool initial iteration Shipp (1998)	Google	Modelling tool/s
Wranik, D. (Canada)	2008	Typology of health human resourcing strategies by micro (individual) and macro (regional/national) levels	Database	Empirical research
Yao, J. (China)	2016	Implementation of Birthrate Plus® in China for midwifery workforce demand	Database	Empirical research/ modelling
Yasutake, J. (Hawaii, United States)	2012	Four-point plan to increased primary care workforce by 20% by 2020: early warning system for impending workforce shortages, fill gaps in education and training, strengthen pipeline into health careers, additional resourcing to maximise benefit of health care provision	Database	Empirical research/ modelling

Theppanya et al. [93] highlighted the importance of provincial engagement of Bolikhamxay, Laos, to ensure health services can respond to increasing demand, despite diminished staffing supply in provincial areas.

Level of service standard and service targets are impacted by and impact on level of need. Smith et al. [61] utilised generic categories of patient dependency-acuity (from acute hospital wards in the UK) and staffing levels (aligned to patient dependency-acuity) to comment on service quality. They called for additional patient dependency-acuity categories to better reflect specific needs of particular population groups such as those utilising primary care, mental health and learning disability services. Roberts and Hurst [62] similarly evaluated service quality by patient dependency and staff activity but also included cost considerations in their planning approach. Tomblin Murphy et al. [82] advised service-based health human resource planning, based on how often a service is required against how often a service is performed, to predict service level aids prediction of capacity. Birch et al. [85] advocated for a needs-based approach to planning that incorporates service elements, such as skill mix or competency requirements, productivity levels and task or provider substitution, to improve service efficiency notably cost savings as well as move to inter- and multi-disciplinary models of care provision that align to service targets.

3.2.3. *Descriptive and predictive workforce modelling*

Modelling of the health and social care workforce is often utilised to provide a quantitative forecast of future staffing supply and demand as well as population needs [47,94]. Modelling is frequently mathematical to generate numerical predictions, given uncertainty within multiple input parameters for health and social workforce planning [94]. However, frameworks [85] or toolkits [89] incorporating mathematical elements may also be utilised. Increasingly it is noted supply/demand considerations must be considered alongside population needs if comprehensive modelling approaches are to be designed and used [88,95]. Dejaco et al. [47] advised workforce modelling needs to account for technological advancements and enhancements upon service supply and demand.

Simulation approaches to modelling may be defined as `useful … for assessing the potential impact of various changes on future health workforce resources' [76: 34]. Simulation approaches continue to be commonly applied within health and social care workforce modelling approaches [50,54,56,86,96] and may be categorised into discrete event simulation, system dynamics and agent-based modelling [94]. There are multiple illustrations of system dynamics modelling within the literature and several references to agent-based modelling. These are discussed in more detail below.

Vanderby et al.'s [42: 1325] modelling for future Canadian cardiac surgeons described system dynamics as `a continuous time modelling approach, which simulates the flow of cohorts through various stages.' Koichubekov et al.'s [53] model to predict the general practitioner workforce in Kazakhstan utilised mathematical statements that captured supply as stock from inflow and outflow, and demand from population size, health needs and level of use of general practice services. Leerapan et al. [97] used system dynamics modelling to inform policy decision-making to plan the health workforce (for 2018–2037) to provide UHC. Leerapan et al.'s [97] model included three sub-modules: population, healthcare delivery and education/labour market. All examples of system dynamics models cited used causal loops to demonstrate the interdependent nature of the models' multiple parameters.

Whilst system-based modelling focuses on the activity/behaviour of the system, agent-based modelling focuses on the activity of the individual or agent [35,37]. Lopes et al. [37] utilised an agent-based modelling approach to forecast the physician workforce in Portugal noting an agent-based approach enabled consideration of geographic distribution and migration of physicians and the interactions between physicians across a range of medical specialities and other healthcare professionals. Thongsukdee and Weerat [35] also reported the benefit of modelling at the level of the individual physician offered policy and operational insights with an especial interest in modelling the geographical imbalance between urban and rural physician densities.

Managing uncertainty within modelling is challenging and complex [94]. The means by which uncertainty is managed within modelling is often dependent on the nature of the uncertainty and outcomes sought [94,59]. Stochastic, robust programming and sensitivity analysis model uncertainty variably [94]. Stochastic programming, akin to robust programming, processes unknown parameter values using random parameters and/or uncertainty sets, usually from a probability function and provide a worst-case guarantee. Vile et al. [70] utilised stochastic modelling to forecast demand for emergency medical services and generate efficient staffing estimates to match changeable demand. Lopes et al. [37] applied Monte Carlo simulation to ascertain the impact of input parameter variation in their agent-based modelling of physician supply in Portugal. Chung et al. [59] used fuzzy sets to substitute known values in a dynamic model to forecast nursing personnel requirements for cancer care over a ten-year planning horizon. Robust programming is criticised for its conservativeness, whilst stochastic approaches are criticised because it is difficult to understand how they generate optimal solutions [94]. Sensitivity analysis attempts to harness the contribution of inputs to the variation of optimal solutions [86]. However, it does not consider data uncertainty at the modelling stage [94]. Sensitivity analysis does not capture inter-relationships between input parameters [94]. Asamani et al. [24,88] advised sensitivity analyses utilised a full range of input values, as well as structural uncertainty or policy scenarios to capture key assumptions implicated in analyses.

Scenario generation, application and analysis are commonly utilised within health workforce modelling both within supply/demand projections [29,40,42,43,98] and within needs-based approaches [30,31,34,56,88,89,94,99] to make predictions about challenging futures [4,5] defined through changing one or more input parameters [94]. Whilst policy analysis has been categorised separately from scenario generation by the Centre for Workforce Intelligence [5], it can be seen in the literature how policy closely impacts scenario generation, notably effects on supply [49,55,100].

Both qualitative and quantitative data are utilised in health and social care workforce modelling [50,89] with qualitative data more often used to contextualise modelling approaches and outcomes [89]. Data quality is commented on as a significant constraint on the accuracy of modelling [86,43,47,89]. McCarty and Fenech [86] noted the value of national data sets for national modelling in comparison with regional datasets that may better reflect regional variation across both health needs as well as workforce supply distribution. Simkin et al. [89: 4] evaluated the quality of the data sets they utilised in the production of their primary care workforce planning toolkit. They categorised data `quality' by source, strengths and limitations, best `availability' data being those `readily' available, for example, those data in the public domain such as census data, whilst the most `comprehensive' data are those that accommodate a broad range of scenario analyses. Simkin et al. [89] noted the most challenging data to harness being those that illustrated productivity and practice activities.

Ranta et al. [43: 42] noted several limitations regarding the data used in their projections for the neurologist workforce of New Zealand advising `the neuro-epidemiological and neurologic case mix data in New Zealand are insufficient … the contribution of non-neurologists to neurological service provision could be greater than estimated.' They add that the lack of data from private neurologists as well as lack of adjustment for ageing and ethnic variation within the population across the planning horizons may have increased the prevalence of some neurological conditions. Dejaco et al.'s [47] recommendations on modelling the rheumatology workforce from a European perspective encouraged the use of multiple data sources and uncertainty analyses.

Whilst projection horizons are variably represented within the literature from five- to 45-year periods, extended projection horizons are noted as less accurate than those of shorter periods [51]. Dejaco et al.'s

[47] points to consider in European rheumatology workforce studies advocated for models that provide five- to 15-year projection periods. This chimes with for example the projection periods utilised in Van Greuningen et al.'s [51] evaluation of the Dutch workforce projection model for the general practitioner workforce and the work of Russo et al. [45] modelling the hepatology workforce of the United States (US). Dejaco et al. [47: 3] also noted the importance of regular `prediction validity' work to evaluate accuracy of modelling performance.

Workforce modelling is undertaken and contributed to by a range of health and social care workforce stakeholders including clinicians/practitioners, administrators/managers, public and private partners/providers, policy-makers, educators, representatives of regulatory bodies and researchers. There is also an increasing market contribution by commercial modelling consultants [45,87,95].

4. Discussion

The SDGs agreed in September 2015 highlighted a global emphasis on health care access for all [101]. The World Health Organisation's [12] strategy is clear on the need to ameliorate the deficits of the global health workforce, notably in low-income countries [102], to resource resilient, sufficient health services that provide accessible, safe health care. National Health Workforce Accounts (NHWA) of the WHO [103], a system of online datasets pertaining to the health workforce, has facilitated the WHO's commitment to develop data-driven health workforce planning [12].

This review has identified a growth in strategic workforce planning literature in health, particularly over the last five years (2017–2022), with a preceding peak in 2016 that may have been aided in part by the World Health Organization's global health policy and strategy publications of 2015 and 2016. Approximately half of the literature identified by this review illustrates empirical research, much of which is focused on descriptive and predictive health workforce modelling for quantifiable workforce projections. No literature explicated optimal periodicity of strategic workforce planning in health and social care. However, all literature referenced the imperative requirement, globally, of the workforce for health and care services for today and the future. As workforce planning shifts internationally towards demographic and needs-based approaches, there is increased consideration, albeit implicitly, for services' design and development in planning their requisite workforce.

Whilst there are notable authors, for example Asamani et al. [24,88,104] who provide African/Ghanian perspectives and advocate for needs-based health workforce planning [24,104], most literature (86 of 101 references) of this review is from high-income countries notably North America, Australia, Europe and the UK. Workload Indicators of Staff Needs (WISN) is used worldwide to identify health workforce staffing requirements notably in low and middle-income countries. Whilst the universality of WHO's WISN commends its accessibility, low-income countries particularly have struggled to implement it. Mabunda et al. [105] noted challenges in relation to lack of data to meet the model's requirements, technology to run the software and the lack of workforce supply to meet the recommended number of staff needed that the model generate. Higher income countries have generated an additional range of health workforce planning models and frameworks as bespoke solutions to health workforce planning challenges. Literature from Europe has demonstrated multi-national collaborations for health workforce planning [106,47,85].

The supply of the medical workforce is predominant in the literature. Whilst pockets of over-supply are forecast by particular scenarios run in the context of specific medical specialities, for example, Whitehouse et al. [40] on the UK's neurosurgical workforce, overall, the medical workforce deficit is clearly communicated within the literature. The concern over the past decade and more for the supply/demand of general practitioners is noted globally [49,52,56,53]. There is increasing use of advanced practitioners, (registered non-medical health professionals who have undertaken advanced training), to address shortages within the medical workforce, as highlighted by Streeter et al.'s [96] geography of primary care. However, there is limited strategic workforce planning literature, and an opportunity for further research, about the potential for task substitution by `new' roles like these to address the supply/demand imbalance.

Current and future deficits within the nursing and midwifery workforce are evident in the literature from analyses of service level [61,67,68,63,82,69,59], patient outcomes [60] and safety [65]. The notable lack of literature within this review about the global social care workforce calls for additional research into workforce planning of social care. There is also a minimal presence within the literature regarding lower paid, unregistered, and voluntary roles within health settings. In the UK, given many social care roles are undertaken by the lower paid [75] the lack of research from social care settings is not surprising from this perspective but concerning.

Traditionally supply/demand approaches have been utilised for strategic workforce planning [81]. Yet increasingly there is call for needs-based approaches that better consider demography, epidemiology and service requirements [19,85]. Whilst life expectancy has increased over the past two decades, healthy life expectancy has not kept pace [107]. Increasing demands for health personnel and health services, are generated by increasingly aged populations living with chronic co-morbidities. Whilst increased appreciation of needs-based health workforce planning may aid its utility, this is within a context of limited health expenditure [19,85]. Increasingly service configuration has been incorporated into needs-based health workforce planning approaches, often based on patient dependency-acuity and service standards [61,62] and safety [65]. Birch et al. [85] called for increased attention to pay, productivity and practice variation in planning for efficient health services, where competency requirements rather than role/profession defined demand and supply. Whilst Dejaco et al. [47] identified the importance of factoring in the contribution of technologies on workforce demand and supply, this recommendation has limited representation [63] within the health and social care workforce planning literature.

The World Health Organization [99] identified the importance of integration to transform services for people-centred care, provided by multi-disciplinary teams, that better met the increasing needs of the aged, chronically ill and those multimorbid. Braithwaite et al. [108] have promulgated changing models of health care to accommodate population needs in more streamlined, flexible and digitised ways however strategic health and social care workforce planning to meet the objectives of health systems remains tacit within this narrative.

Health workforce modelling is commonly illustrated within the literature of this review to describe and predict personnel supply and demand, population needs and service provision (66 of 101 items). Workforce models are often mathematical to provide quantitative forecasts of future staffing requirements. However conceptual frameworks as illustrated by Tomblin Murphy et al. [60: 130], Organisation of Economic Cooperation and Development [19: 33] and Asamani et al. [88: 4] are also utilised to provide qualitative context to planning approaches. Simulation modelling is often used [37] and may be categorised by the level of focus: individual (agent-based), system (system dynamics) or event (discrete event) [94] or combination of foci such as in hybrid modelling [89]. Managing uncertainty within mathematical modelling is complex and variably illustrated within the health workforce planning literature of this review. Stochastic approaches are noted within the work of Vile et al. [70] and Lopes et al. [37]. Amorim-Lopes et al. [94] compare the contribution of stochastic approaches, robust programming and sensitivity analyses to manage uncertainty. No one approach is necessarily preferable although running uncertainty analyses is advised [47,94,88]. Scenario modelling in comparison with forecasting based on a single current set of circumstances, offers multiple hypothetical projections and potentiates a range of solutions for `wicked problems' according to Amorim-Lopes et al. [94: 2]. Data quality, availability and comprehensiveness are key in modelling

accuracy [89].

There is a limited, dated, literature of backtesting/evaluation of health and social care workforce models and/or approaches [50,51,82]. The Organisation for Economic Cooperation and Development [81] noted use and accuracy as key evaluative measures. Whilst these measures would recommend the strength of WISN, given its extensive use around the world, the need to evaluate health and social care workforce planning approaches and models remains.

4.1. Limitations of the review

This review does not present an exhaustive literature on strategic workforce planning in health and social care, but it does strive to capture key characteristics of a reasonably comprehensive though limited literature from around the world on strategic workforce planning in health and social care. Single reviewer screening of titles/abstracts and the contribution of a large (nine) number of reviewers at this stage may also have negatively impacted the consistency in the application of the initial title/abstract screening algorithm. Only English language texts were consulted. Literature was retrieved from 2005 to 2021 to include the policy document `Our health, our care, our way: a new direction for community services' [109], identified as one of the first policy documents to propose better health and social care integration in the UK; however, in essence an arbitrary date range. The paucity of literature retrieved and included within the review on social care workforce planning is noticeable. The reasons for this deficit are unclear. Finally, the contribution of literature from reviewers' personal libraries is by chance and for convenience, to compliment the majority literature of this review retrieved through systematised search means.

5. Conclusion

Strategic workforce planning in health and social care around the world for the next five to 20 years is essential if the growing imbalance between the supply of the health and social care workforce and its demand is to be addressed adequately to ensure safe, accessible and utilised care services that meet the needs of the world's populations. Whilst the World Health Organization's SDGs are aspirational, meeting the health and social care elements will rely on robust strategy and planning for the workforce to deliver them.

The current and future medical workforce is more commonly considered within the literature than any other professional group with the supply/demand of a variety of specialty medical practitioners represented. The nursing and midwifery workforce is represented by literature that examines the need for undifferentiated nursing care. Allied health professionals are poorly represented with single references. Similarly lower paid, unregistered workers and volunteers within health have minimal representation. The social care workforce is notable by its sparse literature. Whilst this may be a limitation of the method of this review, it may also point to a lack consideration for this undervalued workforce, the importance of which to the overall health and care system has not been recognised.

Multiple frameworks and models are used for strategic workforce planning in health and social care around the world. However, access and use tend to be the privilege of high-income countries with middle and low-income countries reliant on the World Health Organization's [110] WISN model. Increasingly, countries across Europe collaborate to share resources and mutual knowledge. Supply/demand approaches to health and social care workforce planning are often utilised within the literature of this review but needs-based frameworks and models, considerate of demographic and epidemiological factors, are also adopted to plan for services with an appropriate skill mix and level of productivity to deliver for people's health and social care requirements.

Descriptive and predictive modelling dominates the review's literature. Mathematical modelling proffers not only the possibility to predict potential futures of the health and social care workforce but also to provide quantifiable forecasts which are likely to have value in estimating health and social care expenditure. The accuracy of predictive modelling is limited often by data quality and availability as well as the duration of planning horizon. Whilst conceptual frameworks and models are common within the literature on strategic workforce planning in health and social care, their evaluations are not. This remains an enduring limitation.

The lack of integration within health services is noted, alongside the integration of health and social care services beyond policy ambitions. It is essential that strategic workforce planning for sustainable, responsive, targeted health and social care moves from aggregations of health and social care workforce projections for individual professions, or services towards whole-system approaches that consider the ecology of practitioners, their patients, people and environments.

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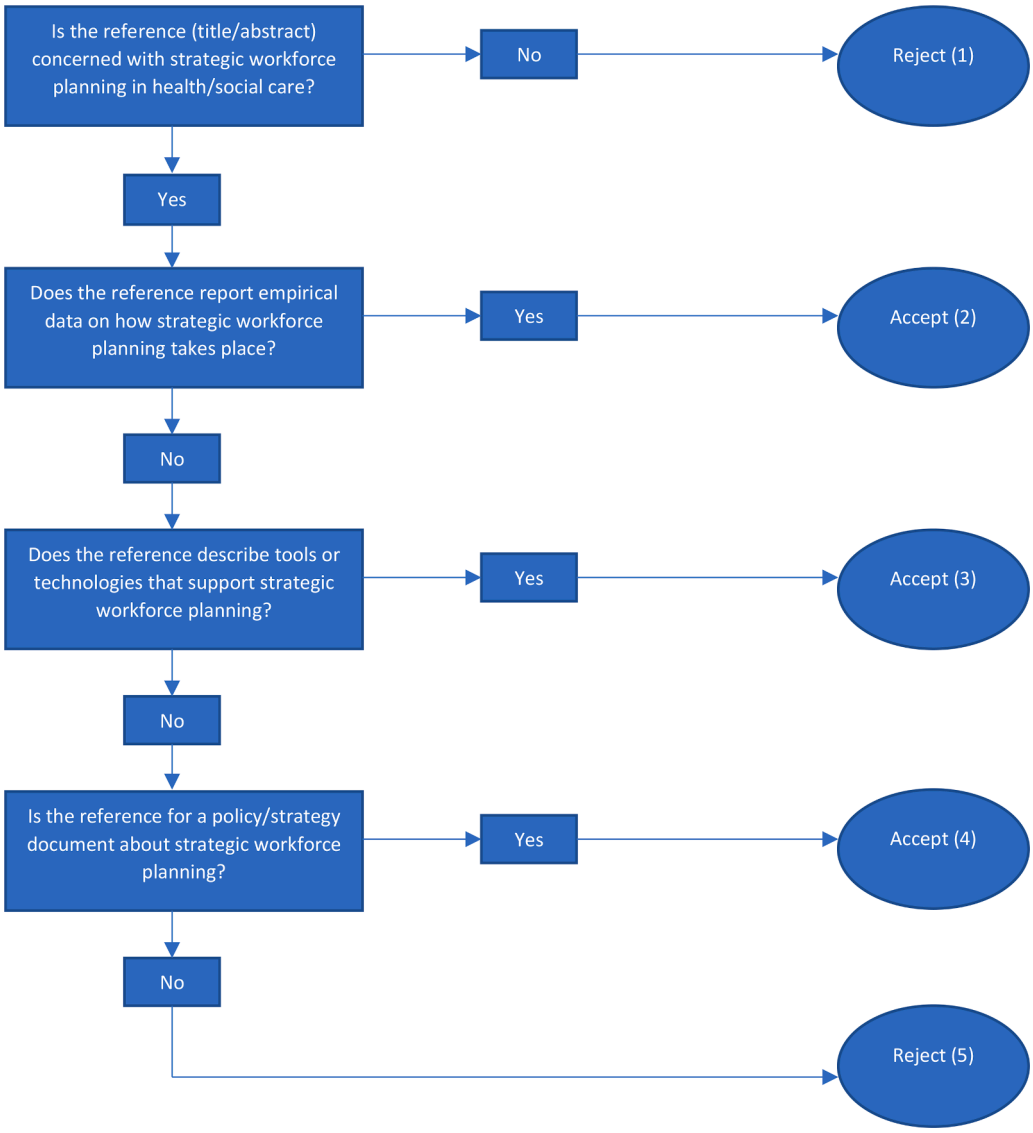
Appendix 1. Initial literature title and abstract screening algorithm



Appendix 3. Named examples of strategic health and social care workforce planning models, methodologies and frameworks

Lead author/s and date/s of publication that make/s reference to named model, methodology, framework	Title (if available) and brief description of model, methodology or framework
Asamani, J. (2021)	Population needs-based simulation model
Ball, J. (2010a); Ball, J. (2010b); Yao, J. (2016)	Birthrate Plus®: number of midwives to provide all women with a minimum of one-to-one care during labour
Centre for Workforce Intelligence (2014)	*Robust workforce planning framework, An introduction*; framework to include horizon scanning, scenario generation, workforce modelling, policy analysis; supply and demand (workforce modelling) orientated
Health Education England (No date)	*HEE Star*; solution-focused workforce planning framework
Health Education England (2018)	*WRaPT* repository of health workforce planning tools sub-categorised into capabilities, trends and case studies
Health Resources and Services Administration (2019)	*Technical Documentation for Health Resources Service*; modelling approach for health workforce focus on specific health professions
KPMG (2021)	Bespoke software solutions according to commissioner requirements; utilised by Northern Care Alliance NHS Foundation Trust (UK NHS Trust)
Organisation for Economic Cooperation and Development (2013)	A range[26] health workforce projection models from 18 countries around the world
Organization for Economic Cooperation and Development (2016)	Framework for the supply and demand of health workers
Shipp, P. (1998); World Health Organization (2010)	*Workload Indicators of Staffing Needs*: international staff supply/demand approach
Skills for Health (2022)	*Six Steps Methodology to Integrated Workforce Planning*; approach for `workforce of right size … right skills … taking into account … demand … local demographic situation … to the budget …'

(*continued on next page*)

(*continued*)

Lead author/s and date/s of publication that make/s reference to named model, methodology, framework	Title (if available) and brief description of model, methodology or framework
Tomblin Murphy, G. (2011)	Health human resources conceptual framework: identifies key factors of health workforce planning and the ways they relate; developed within Birch et al. (2007)
Van Greuningen (2012)	Simulation model to estimate required and available capacity of health professionals in the Netherlands. Initially developed in 2000
Whole Systems Partnership (2022)	SWiPe®: Population health led strategic workforce planning frameworks and models; illustrative examples of models commissioned by regional UK NHS Trusts
World Health Organization (2010)	*Western Pacific Workforce Projection Tool (WWPT)*: projecting workforce needs of a country or area
World Health Organization (2010)	*iHRIS*: workforce planning toolkit based on health provider-to-population ratios

References

[1] Lopes M, Almeida A, Almada-Lobo B. Handling healthcare workforce planning with care: where do we stand? Hum Resour Health 2015;13(38). https://doi.org/10.1186/s12960-015-0028-0.

[2] The King's Fund. Developing a strategy for the health and care workforce in England, summary of a roundtable discussion. 2018. https://www.kingsfund.org.uk/sites/default/files/2019-03/developing-strategy-health-care-workforce-england_0.pdf. Accessed 03 April 2022.

[3] Kroezen M, Van Hoegaerden M, Batenburg R. The joint action on health workforce planning and forecasting: results of a European programme to improve health workforce policies. Health Policy (New York) 2018;122:87–93. https://doi.org/10.1016/j.healthpol.2017.12.002.

[4] Centre for Workforce Intelligence. Robust workforce planning framework, an introduction. 2014. http://www.wales.nhs.uk/sitesplus/documents/1096/Technical%20Paper%20No%201%20Robust%20workforce%20planning%20framework1.pdf. Accessed 25 April 2022.

[5] Centre for Workforce Intelligence. Robust workforce planning framework: update from practice. 2014. https://recipeforworkforceplanning.hee.nhs.uk/Portals/0/HEWM_LinksAndResources/3RWP%20TP%2010%20-%20Framework%20update%20Aug%202014.pdf?ver=2016-04-13-130227-440. Accessed 11 April 2022.

[6] Willis G, Cave S, Kunc M. Strategic workforce planning in healthcare: a multi-methodology approach. Eur J Oper Res 2018;267:250–63. https://doi.org/10.1016/j.ejor.2017.11.008.

[7] Monitor. Strategic workforce planning tool. 2014. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/365275/Strategy_development_toolkit_Strategic_workforce_planning_tool_20102014.pdf. Accessed 03 April 2022.

[8] National Academies of Sciences, Engineering and Medicine. Integrating social care into the delivery of health care: moving upstream to improve the nation's health. 2019. https://nap.nationalacademies.org/read/25467/chapter/1. Accessed 13 April 2022.

[9] The Commonwealth Fund. How are countries innovating the delivery of integrated health and social care?. 2020. https://www.commonwealthfund.org/publications/journal-article/2020/apr/how-are-countries-innovating-delivery-integrated-health-social-care. Accessed 11 April 2022.

[10] Nuffield Trust, Accessed 22 September 2022. Integrating health and social care, a comparison of policy and progress across the four countries of the UK. 2021. https://www.nuffieldtrust.org.uk/files/2021-12/integrated-care-web.pdf.

[11] Miller R, Glasby J, Dickinson H. Integrated health and social care in England: ten years on. Int J Integr Care 2021;21(4). https://doi.org/10.5334/ijic.5666.

[12] Anderson M, O'Neill C, Clark J, Street A, Woods M, Johnston-Webber C, Charlesworth A, Whyte M, Foster M, Majeed A, Pitchforth E, Mossialos E, Asaria M, McGuire A. Securing a sustainable and fit-for-purpose UK health and care workforce. The Lancet 2021;397(10288):1992–2011. https://doi.org/10.1016/S0140-6736(21)00231-2.

[13] World Health Organization. Global strategy on human resources for health: workforce 2030. 2016. https://interprofessional.global/wp-content/uploads/2019/11/WHO-2016-Global-Strategy-on-Human-Resource-for-Health-Workforce-2030.pdf. Accessed 12 April 2022.

[14] Kunjumen T, Okech M, Diallo K, Mcquide P, Zapata T, Campbell J. Global experiences in health policy, planning and management using the Workload Indicators of Staff Need (WISN) method, and way forward. Hum Resour Health 2022;19(Suppl1). https://doi.org/10.1186/s12960-021-00695-9.

[15] Freer J. Sustainable development goals and the human resources crisis. Int Health 2017;9(1):1–2. https://doi.org/10.1093/inthealt/ihw042.

[16] Szabo S, Nove A, Matthews Z, Bajracharya A, Dhillon I, Singh D, et al. Health workforce demography: a framework to improve understanding of the health workforce and support achievement of the Sustainable Development Goals. Hum Resour Health 2020;18(7). https://doi.org/10.1186/s12960-020-0445-6.

[17] World Health Organization. The toolkit for a sustainable health workforce in the who European region. 2018. https://www.euro.who.int/_data/assets/pdf_file/0004/375547/WH11_TK_text_AW-2.pdf. Accessed 12 April 2022.

[18] Figueroa C, Harrison R, Chauhan A, Meyer L. Priorities and challenges for health leadership and workforce management: a rapid review. BMC Health Serv Res 2019;19(239). https://doi.org/10.1186/s12913-019-4080-7.

[19] Organisation for Economic Cooperation and Development. Health workforce policies in OECD countries, right jobs, right skills, right places. 2016. https://read.oecd-ilibrary.org/social-issues-migration-health/health-workforce-policies-in-oecd-countries_9789264239517-en#page1. Accessed 03 April 2022.

[20] Long L-A, Pariyo G, Kallander K. Digital technologies for health workforce development in low- and middle-income countries: a scoping review. Global Health Sci Pract 2018;6(1):S41–SS48. https://doi.org/10.9745/GHSP-D-18-00167.

[21] Organisation for Economic Cooperation and Development. Skills for the future health workforce: preparing health professionals for people-centred care. 2021. https://www.oecd-ilibrary.org/docserver/68fb5f08-en.pdf?expires=1649767897&id=id&accname=guest&checksum=1CA2654BD9CEA783816A400783C91206. Accessed 12 April 2022.

[22] Organisation for Economic Cooperation and Development. Empowering the health workforce to make the most of the digital revolution. 2021. https://www.oecd-ilibrary.org/docserver/37ff0eaa-en.pdf?expires=1649768195&id=id&accname=guest&checksum=DA5B29C4D7AF91477ED476D08C6DFE47. Accessed 12 April 2022.

[23] Bronsoler A, Doyle J, Van Reenen J. The impact of health it on clinical quality, productivity and workers. 2021. https://cep.lse.ac.uk/pubs/download/dp1801.pdf. Accessed 12 April 2022.

[24] Asamani J, Christmals C, Reitsma G. Advancing the population needs-based health workforce planning methodology: a simulation tool for country application. Int J Environ Res Public Health 2021;18:2113. https://doi.org/10.3390/ijerph18042113.

[25] Tomblin Murphy G, Gilbert J, Rigby J. Integrating interprofessional education with needs-based health workforce planning to strengthen health systems. J Interprof Care 2019;33(4):343–6. https://doi.org/10.1080/13561820.2019.1638758.

[26] Buchan J, Williams G, Zapata T. Governing health workforce responses during COVID-19. Eurohealth (Lond) 2021;27(1). https://apps.who.int/iris/bitstream/handle/10665/344948/Eurohealth-27-1-41-48-eng.pdf?sequence=1&isAllowed=y. Accessed 12 April 2022.

[27] Pollock D, Davies E, Peters M, Tricco A, Alexander L, McInerney P, et al. Understanding a scoping review: a practical guide for nursing and midwifery students, clinicians, researchers, and academics. J Adv Nurs 2021;77:2102–13. https://doi.org/10.1111/jan.14743.

[28] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol 2005;8(1):19–32.

[29] Santric Milicevic M, Vasic M, Edwards M, Sanchez C, Fellows J. Strengthening the public health workforce: an estimation of the long-term requirements for public health specialists in Serbia. Health Policy (New York) 2018;122:674–80. https://doi.org/10.1016/j.healthpol.2018.03.012.

[30] Gallagher J, Kleinman E, Harper P. Modelling workforce skill-mix: how can dental professionals meet the needs and demands of older people in England. Br Dent J 2010:E6. https://doi.org/10.1038/sj.bdj.2010.106.

[31] Ahern S, Woods N, Kalmus O, Birch S, Listl S. Needs-based planning for the oral health workforce – development and application of a simulation model. Hum Resour Health 2019;17(55). https://doi.org/10.1186/s12960-019-0394-0.

[32] Birch S, Ahern S, Brocklehurst P, Chikte U, Gallagher J, Listl S, et al. Planning the oral heath workforce: time for innovation. Community Dent Oral Epidemiol 2021;49:17–22. https://doi.org/10.1111/cdoe.12604.

[33] Stordeur S, Leonard C. Challenges of physician supply planning: the case of Belgium. Hum Resour Health 2010;8(28). http://www.human-resources-health.com/content/8/1/28.

[34] Gupta S, Black-Schaffer S, Crawford J, Gross D, Karcher S, Kaufman J, Knapman D, Prystowsky M, Wheeler T, Bean S, Kumar P, Sharma R, Chamoli V, Ghai V, Gogia V, Weintaub S, Cohen M, Robboy S. An innovative interactive modelling tool to analyze scenario-based physician workforce = supply and demand. Acad Pathol 2015;2(4). https://doi.org/10.1177/2374289515606730.

[35] Thongsukdee P, Weerawat W. Physician workforce planning and allocation model using agent-based modelling: a case study in Thailand. Int J Health Plann Manage 2019;35:1384–97. https://doi.org/10.1002/hpm.3041.

[36] Scheffer M, Pastor-Valero M, Cassenote A, Rosique A. How many and which physicians? A comparative study of the evolution of the supply of physicians and specialist training in Brazil and Spain. Hum Resour Health 2020;18(30). https://doi.org/10.1186/s12960-020-00472-0.

[37] Lopes A, Santos Almeida A, Almada-Lobo B. Forecasting the medical workforce: a stochastic agent-based simulation approach. Health Care Manage 2018;21:52–75. https://doi.org/10.1007/s10729-016-9379-x.

[38] Looi J, Bastiampillai T, Allison S. Psychiatrist workforce planning: contexts, considerations and recommendations. Aust Psychiatry 2021:1–4. https://doi.org/10.1177/10398562211042367.

[39] Reulen H-J, Hide R, Bettag M, Bodosi M, Cunha e Sa M. A report on neurosurgical workforce in the countries of the EU and associated states. Acta Neurochir (Wien) 2009;151:715–21. https://doi.org/10.1007/s00701-009-0396-0.

[40] Whitehouse K, Bodiabaduge A, Jayasekera P, Nelsonon R. UK neurosurgical workforce planning. What changes have occurred in the consultant body 2014–2018? Br J Neurosurg 2020;34(4):402–7. https://doi.org/10.1080/02688697.2020.1749986.

[41] Vigersky R, Fish L, Hogan P, Stewart A, Kutler S, Ladenson P, et al. The clinical endocrinology workforce: current status and future projections of supply and demand. J. Clin. Endocrinol. Metab. 2014;99(9):3112–21. https://doi.org/10.1210/jc.2014-2257.

[42] Vanderby S, Carter M, Lather T, Feindel C. Modellling the future of the Canadian cardiac surgery workforce using system dynamics. J Oper Res Soc 2014;65(9):1325–35. https://doi.org/10.1057/jors.2013.77.

[43] Ranta A, Tiwari P, Mottershead J, Abernethy D, Simpson M, Brickell K, et al. New Zealand's neurologist workforce: a pragmatic analysis of demand, supply and future projections. New Zealand Med J 2015;128(1419):35–44.

[44] Robboy S, Gupta S, Crawford J, Cohen M, Karcher D, Leonard D, Magnani B, Novis D, Prystowsky M, Powell S, Gross D, Black-Schaffer S. The pathologist workforce in the United States. Arch Pathol Lab Med 2015;139(11):1413–30. https://doi.org/10.5858/arpa.2014-0559-OA.

[45] Russo M, Fix O, Koteish A, Duggan K, Ditmyer M, Fuchs M, et al. Modeling the hepatology workforce in the United States: a predicted critical shortage. Hepatology 2020;72(4):1444–54.

[46] Ansah J, De Korne D, Bayer S, Pan C, Jayabaskar T, Matchar D, et al. Future requirements for and supply of ophthalmologists for an aging population in Singapore. Hum Resour Health 2015;13(86). https://doi.org/10.1186/s12960-015-0085-4.

[47] Dejaco C, Putrik P, Unger J, Aletaha D, Bianchi G, Bijilsma J, Boonen A, Cikes N, Finckh A, Gossec L, Kvien T, Madruga J, Matteson E, Sivera F, Stamm T, Szekanecz Z, Wiek D, Zink A, Ramiro S, Buttgereit F. `EULAR' points to consider for the conduction of workforce requirements in rheumatology. Rheumatic Musculoskeletal Dis 2018;4. https://doi.org/10.1136/rmdopen-2018-00780.

[48] Abel G, Gomez-Cano M, Mustafee N, Smart A, Fletcher E, Salisbury C, Chilvers R, Gerard Dean S, Richards S, Warren F, Campbell J. Workforce predictive risk modelling: development of a model to identify general practices at risk of a supply-demand imbalance. BMJOpen 2020;10:e027934. https://doi.org/10.1136/bmjopen-2018-027934.

[49] Teljeur C, Thomas S, O'Kelly F, O'Dowd T. General practitioner workforce planning: assessment of four policy directions. Health Serv Res 2010;10(148). http://www.biomedicalcentral.com/1472-6963/10/148.

[50] van Greuningen M, Batenburg R, Van der Velden L. Ten years of health workforce planning in the Netherlands: a tentative evaluation of GP planning as an example. Hum Resour Health 2012;10:21. http://www.human-resources-health.com/content/10/1/21.

[51] van Greuningen M, Batenburg R, Van der Velden L. The accuracy of general practitioner workforce projections. Hum Resour Health 2013;11:31. http://www.human-resources-health.com/content/11/1/31.

[52] von Eitzen-Strassel J, Vrijhoef H, Derckx E, Bakker D. Personnel planning in general practice: development and testing of a skill mix analysis method. Hum Resour Health 2014;12(53). http://www.human-resources-health.com/content/12/1/53.

[53] Koichubekov B, Kharin A, Sorokina M, Korshukov I, Omarkulov B. System dynamics modelling for general practitioner workforce forecasting in Kazakhstan. Annali di igiene: medicina preventive e di comunita 2021;33(3):242–53. https://doi.org/10.7416/ai.2020.2391.

[54] Laurence C, Karnon J. Improving the planning of the GP workforce in Australia: a simulation model incorporating work transitions, health need and service usage. Hum Resour Health 2016;14(13). https://doi.org/10.1186/s12960-016-0110-2.

[55] Laurence C, Karnon J. What will make a difference? Assessing the impact of policy and non-policy scenarios on estimations of the future GP workforce. Hum Resour Health 2017;15(43). https://doi.org/10.1186/s12960-017-0216-1.

[56] Laurence C, Heywood T, Bell J, Atkinson K, Karnon J. The never ending road: improving, adapting and refining a needs-based model to estimate future general practitioner requirements in two Australian states. Fam Pract 2018;35(2):193–8. https://doi.org/10.1093/fampr/cmx087.

[57] National Audit Office, Department of Health and Social Care. The NHS nursing workforce. 2020. https://www.nao.org.uk/wp-content/uploads/2020/03/The-NHS-nursing-workforce.pdf. Accessed 03 April 2022.

[58] Department of Health and Social Care. The department of health and social care mandate to health education England: April 2021 to March 2022. 2021. https://www.gov.uk/government/publications/health-education-england-mandate-2021-to-2022/the-department-of-health-and-social-care-mandate-to-health-education-england-april-2021-to-march-2022. Accessed 03 April 2022.

[59] Chung M, Hung K, Chiou J, Fang H, Chiu C. Nursing manpower forecast for cancer patients. Comput Methods Program Biomed 2021;201. https://doi.org/10.1016/j.cmpb.2021.105967.

[60] Tomblin Murphy G, Birch S, O-Brien-Pallas L, Kephart G, MacKenzie A. Nursing inputs and outcomes of hospital care: an empirical analysis of Ontario's acute-care hospitals. CJNR 2011;43(1):126–46.

[61] Smith S, Casey A, Hurst K, Fenton K, Scholefield H. Developing, testing and applying instruments for measuring rising dependency-acuity's impact on ward staffing and quality. Int J Health Care Qual Assur 2009;22(1):30–9. https://doi.org/10.1108/09526860910927934.

[62] Roberts D, Hurst K. Evaluating palliative care staffing using bed occupancy, patient dependency, staff activity, service quality and cost data. Palliat Med 2013;27(2):123–30. https://doi.org/10.1177/0269216312447593.

[63] Tomblin Murphy G, Birch S, MacKenzie A, Alder R, Lethbridge L, Little L. Eliminating the shortage of registered nurses in Canada: an exercise in applied needs-based planning. Health Policy (New York) 2012;105:192–202. https://doi.org/10.1016/j.healthpol.2011.11.009.

[64] Maenhout B, Vanhoucke M. Analyzing the nursing organizational structure and process from a scheduling perspective. Health Care Manage 2013;16:177–96. https://doi.org/10.1007/s10129-013-9222-6.

[65] Ball J. Analysing the implementation and effects of safe staffing policies in acute hospitals. Nurs Manage 2020;27(3):35–40. https://doi.org/10.7748/nm.2020.e1904.

[66] Penny R, Fennah W. Comm2Work: developing a nursing workforce plan for a child and youth community health service. Collegian 2020;27:375–80. https://doi.org/10.1016/j.coleg.2019.12.002.

[67] Ball J, Washbrook M. Birthrate Plus: using ratios for maternity workforce planning. Br J Midwifery 2010;18(8):724–30.

[68] Ball J, Washbrook M. Workforce planning in midwifery: an overview of 8 years. Br J Midwifery 2010;18(8):527–32.

[69] Yao J, Zhu X, Hu H. Assessing the midwifery workforce: utilising Birthrate Plus in China. Midwifery 2016;42:61–6. https://doi.org/10.1016/j.midw.2016.09.007.

[70] Vile J, Gillard J, Harper P, Knight V. Time-dependent stochastic methods for managing and scheduling emergency medical services. Oper Res Health Care 2016;8:42–52. https://doi.org/10.1016/j.orhc.2015.07.002.

[71] Bam M, Cloete C, de Kock I. Determining diagnostic radiographer staffing requirements: a workload-based approach. Radiography 2021. https://doi.org/10.1016/j.radi.2021.09.014.

[72] Somerville L, Davis A, Elliott A, Desiree T, Austin N, Philip K. Building allied health workforce capacity: a strategic approach to workforce innovation. Aust Health Rev 2015;39:264–70. https://doi.org/10.1071/AH14211.

[73] Teusner D, Amarasena N, Satur J, Chrisopoulos S, Brennan D. Dental service provision by oral health therapists, dental hygienists and dental therapists in Australia: implications for workforce modelling. Community Dent Health 2016;33:15–22. https://doi.org/10.1922/CDH_3848Teusner08.

[74] Spetz J, Trupin L, Bates T, Coffman J. Future demand for long-term care workers will be influenced by demographic and utilization changes. Health Aff 2015;34(6):936–45. https://doi.org/10.1377/hlthaff.2015.0005.

[75] Skills for Care. The state of the adult social care sector and workforce in England. 2021. https://www.skillsforcare.org.uk/Adult-Social-Care-Workforce-Data/Workforce-intelligence/documents/State-of-the-adult-social-care-sector/The-State-of-the-Adult-Social-Care-Sector-and-Workforce-2021.pdf. Accessed 04 April 2022.

[76] Pepler E, Martell R. Indigenous model of care to health and social care workforce planning. Healthcare Manage Forum 2019;32(1):32–9. https://doi.org/10.1177/08404704188090105.

[77] Schofield D, Earnest A. Demographic change and the future demand for public hospital care in Australia, 2005 to 2050. Aust Health Rev 2006;30(4):507–15.

[78] Blank J, van Hulst B. Balancing the health workforce: breaking down overall technical change into factor technical change for labour – an empirical application to the Dutch hospital industry. Hum Resour Health 2017;15:1–14. https://doi.org/10.1186/s12960-017-0184-5.

[79] Segal L, Leach M, Groves A, Turnbull, Furber G. A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: a mixed-methods study. Lancet Public Health 2018;3:e296–303.

[80] Taghavi M, Johnston G, Urquhart R, Henderson D, Tschupruk C, Tupala B. Workforce planning for community-based palliative specialist teams using operations research. J Pain Symptom Manage 2021;61(5). https://doi.org/10.1016/j.jpainsymman.2020.09.009.

[81] Organisation for Economic Cooperation and Development. Health workforce planning in OECD countries, a review of 26 projection models from 18 countries. 2013. https://read.oecd-ilibrary.org/social-issues-migration-health/health-workforce-planning-in-oecd-countries_5k44t787zcwb-en#page1. Accessed 03 April 2022.

[82] Tomblin Murphy G, MacKenzie A, Rigby J, Rockwood K, Gough A, Greeley G, et al. Service-based health human resources planning for older adults. J Am Med Dir Assoc 2013;14:611–5. https://doi.org/10.1016/j.jamda.2013.03.018.

[83] Segal L, Leach M. An evidence-based health workforce model for primary and community care. Implementation Sci. 2011;6(93). http://www.implementationscience.com/contents/6/1/93.

[84] World Health Organization. Models and tools for health workforce planning and projections. 2010. https://apps.who.int/iris/bitstream/handle/10665/44263/9789241599016_eng.pdf?sequence=1&isAllowed=y. Accessed 13 April 2022.

[85] Birch S, Gibson J, McBride A, Munros team. Opportunities for, and implications of skills mix changes in health care pathways: pay, productivity and practice variations in needs-based planning framework. Soc Sci Med 2020;250. https://doi.org/10.1016/j.socscimed.2020.112863.

[86] McCarty M, Fenech B. Towards best practice in national health workforce planning. Med J Aust 2013;199(5):S10–3. https://doi.org/10.5694/mjao12.10309.

[87] Whole Systems Partnership. Strategic workforce planning (SWiPe®). 2022. https://www.thewholesystem.co.uk/workforce-modelling/swipe/. Accessed 03 April 2022.
[88] Asamani J, Christmals C, Reitsma G. Modelling the supply and need for health professionals for primary health care in Ghana: implications for health professions education and employment planning. PLoS ONE 2021;16(9): e0257957. https://doi.org/10.1371/journal.pone.0257957.
[89] Simkin S, Chamberland-Rowe C, Bourgeault I. An integrated primary care workforce planning toolkit at regional level (part 2): quantitative tools compiled for decision-makers in Toronto. Canada. Hum Resour Health 2021;19(86). https://doi.org/10.1186/s12960-021-00595-y.
[90] Panzera A, Murray R, Stewart R, Mills J, Beaton N, Larkins S. Regional workforce planning through action research: lessons for commissioning health services from a case study in Far North Queensland. Aust J Prim Health 2016;22:63068. https://doi.org/10.1071/PY15149.
[91] Department of Health and Social Care. Health and social care integration: joining up care for people, places and populations. 2022. https://www.gov.uk/government/publications/health-and-social-care-integration-joining-up-care-for-people-places-and-populations/health-and-social-care-integration-joining-up-care-for-people-places-and-populations. Accessed 04 April 2022.
[92] Queensland Health. Strategic health workforce planning framework. 2020. https://www.health.qld.gov.au/_data/assets/pdf_file/0034/986614/shwpf-guide-20200623.pdf. Accessed 03 April 2022.
[93] Theppanya K, Phathammavong O, Rotem A. Strengthening the engagement of provinces in health workforce planning and management: a case study from Lao PDR. J Epidemiol 2016;26(7):337–47. https://doi.org/10.2188/jea.JE20160094.
[94] Amorim-Lopes M, Oliveira M, Raposo M, Cardoso-Grilo T, Alvarenga A, Barbas M, et al. Enhancing optimization planning models for health human resources management with foresight. Omega (Westport) 2021;103. https://doi.org/10.1016/j.omega.2020.102384.
[95] Skills for Health. Six step methodology, effective and robust workforce planning support that improves patient care. 2022. https://www.skillsforhealth.org.uk/integrated-solutions/workforce-development/six-step-methodology/. Accessed 13 April 2022.
[96] Streeter R, Zangaro G, Chattopadhyay A. Perspectives: using results from HRSA's health workforce simulation model to examine the geography of primary care. Health Serv Res 2017;52:481–507. https://doi.org/10.1111/1475-6773.12663.
[97] Leerapan B, Teekasap P, Urwannachotima N, Jaichuen W, Chiangchaisakulthai K, Udomaksorn K, et al. System dynamics modelling of health workforce planning to address future challenges of Thailand's University Health Coverage. Hum Resour Health 2021;19(31). https://doi.org/10.1186/s12960-021-00572-5.
[98] Hu W, Lavieri M, Toriello A, Liu X. Strategic health workforce planning. IIE Trans 2016;48(12):1127–38. https://doi.org/10.1080/0740817X.2016.1204488.
[99] World Health Organization. Integrated care models: an overview. 2016. https://www.euro.who.int/_data/assets/pdf_file/0005/322475/Integrated-care-models-overview.pdf. Accessed 03 April 2023.
[100] Baumann A, Crea-Arsenio M, Akhtar-Danesh N, Fleming-Carroll B, Hunsberger M, Keatings M, et al. Strategic workforce planning for health human resources: a nursing case analysis. Can J Nurs Res 2016;48(3–4):93–9. https://doi.org/10.1177/0844562116680715.
[101] Asma S, Lozano R, Chatterji S, Swaminathan S, Marinho M, Yamamoto N, Varavikova E, Misganaw A, Ryan M, Dandona L, Minghui R, Murray C. Monitoring the health-related sustainable development goals: lessons learned and recommendations for improvement measurement. The Lancet 2020;395(10219): 240–6. https://doi.org/10.1016/S0140-6736(19)32523-1.
[102] World Health Organization. Global health workforce statistics database (The global health observatory). 2022. https://www.who.int/data/gho/data/themes/topics/health-workforce. Accessed 21 April 2022.
[103] World Health Organization. National health workforce accounts, a handbook. 2017. https://apps.who.int/iris/bitstream/handle/10665/259360/9789241513111-eng.pdf. Accessed 18 March 2023.
[104] Asamani J, Christmals C, Reitsma G. The needs-based health workforce planning method: a systematic scoping review of analytical applications. Health Policy Plan 2021;36:1325–43. https://doi.org/10.1093/healpol/czab022.
[105] Mabunda S, Gupta M, Chitha W, Mtshali N, Ugarte C, Echegaray C, et al. Lessons learnt during the implementation of WISN for comprehensive primary health care in India, South Africa and Peru. Int J Environ Res Public Health 2021;18:12541. https://doi.org/10.3390/ijerph182312541.
[106] Batenburg R. Health workforce planning in Europe: creating learning country clusters. Health Policy (New York) 2015;119:1538–44. https://doi.org/10.1016/j/healthpol.2015.10.001.
[107] World Health Organization. GHE: life expectancy and healthy life expectancy. 2022. https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-life-expectancy-and-healthy-life-expectancy. Accessed 13 May 2022.
[108] Braithwaite J, Mannion R, Matsuyama Y, Shekelle P, Whittaker S, Al-Adawi S, Ludlow K, James W, Ting H, Herkes J, McPherson E, Churruca K, Lamprell G, Ellis L, Boyling C, Warwick M, Pomare C, Nicklin W, Hughes C. The future of health systems to 2030: a roadmap for global progress and sustainability. Int J Qual Health Care 2018;30(10):823–31. https://doi.org/10.1093/intqhc/mzy242.
[109] Department of Health. Our health, our care, our say: a new direction for community services, health and social care working together in partnership. 2006. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/272238/6737.pdf. Accessed 11 October 2022.
[110] World Health Organization. Workload indicators of staffing need, user's manual. 2010. file:///C:/Users/cesutto1/Downloads/9789241500197_users_eng.pdf. Accessed 13 April 2022.