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Economic investment required to scale-up bariatric surgery capacity in England

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Complete List of Authors:	Baker-Knight, James; Novo Nordisk A/S Pournaras, Dimitri J; North Bristol NHS Trust Southmead Hospital Mahawar, Kamal; South Tyneside and Sunderland NHS Foundation Trust, Bariatric Unit ; University of Sunderland Welbourn, Richard; Musgrove Park Hospital, Department of Upper Gastro-intestinal and Bariatric Surgery; University of Bristol Medical School Li, Yuxin; IQVIA Ltd Sharma, Yuvraj; IQVIA Ltd Guerra, Ines; IQVIA Ltd Tahrani, Abd; Novo Nordisk A/S; University of Birmingham
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TITLE

Economic investment required to scale-up bariatric surgery capacity in England

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AUTHOR LIST

James Baker-Knight¹, Dimitri J Pournaras², Kamal Mahawar^{3,4}, Richard Welbourn^{5,6}, Yuxin Li⁷, Yuvraj Sharma⁷, Ines Guerra⁷, Abd Tahrani¹

Author affiliations

1. Novo Nordisk A/S, Denmark; 2. North Bristol NHS Trust, Southmead Hospital, UK; 3. South Tyneside and Sunderland NHS Foundation Trust, UK; 4. University of Sunderland, UK; 5. Musgrove Park Hospital, Somerset NHS Foundation Trust, UK; 6. Bristol Medical School, Population Health Sciences, University of Bristol, UK; 7. IQVIA Ltd., UK

CORRESPONDING AUTHOR

James Baker-Knight; JMKG@novonordisk.com

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None declared.

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Bariatric surgery; COVID-19; Cost-effectiveness analysis; Metabolic surgery; Obesity.

ABSTRACT

Objectives

To quantify the economic investment required to increase bariatric surgery (BaS) capacity in National Health Service (NHS) England considering the growing obesity prevalence, and low provision of BaS in England despite its high clinical effectiveness.

Design

We used a decision-tree approach including four distinct steps of the patient pathway to capture all associated resource use.

Setting

BaS centres based in NHS and private sector hospitals in England.

Participants

Patients with obesity who are eligible for BaS.

Interventions

We estimated total costs according to the current capacity (current scenario) and three BaS scaling up strategies over a time horizon of 20 years (projected scenario): maximising NHS capacity (strategy 1), maximising NHS and private sector capacity (strategy 2), and adding infrastructure to NHS capacity to cover the entire prevalent and incident obesity populations (strategy 3).

Main outcome measures

Number of BaS procedures (including revision surgery), cost (GBP) and resource utilisation over 20 years.

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Results

At current capacity, the number of BaS procedures and total cost over 20 years were estimated to be 140,220 and £1.4 billion, respectively. For strategy 1, these values were projected to increase to 157,760 and £1.7 billion, respectively. For strategy 2, the values were projected to increase to 232,760 and £2.5 billion. Strategy 3 showed the highest increase to 564,784 and £6.4 billion, respectively, with an additional 4,081 personnel and 49 facilities required over 20 years.

Conclusions

The expansion of BaS capacity in England beyond a small proportion of the eligible population will likely be challenging given the significant upfront economic investment and additional requirement of personnel and infrastructure.

Trial registration

Clinical trial registration is not applicable.

INTRODUCTION

Effective obesity treatment can improve the health of the population and reduce the economic impact across health systems globally, including in the United Kingdom (UK) (1-4). Obesity is associated with reduced life expectancy and multiple long-term complications (5). The Health Survey of England 2019 indicated that 28% of adults had obesity (body mass index [BMI] ≥ 30 kg/m²) and 3.3% had severe obesity (BMI ≥ 40 kg/m²) (6). By 2060, the projected prevalence of UK adults who are overweight or have obesity will be 84.8% (7). The current cost of obesity and associated complications for the National Health Service (NHS) is £6.1 billion (around 4% of the total NHS spending on health services in 2022/23 (8)), and for society, £27 billion, which is projected to increase 4-5-fold by 2050 (1). The NHS has established policies that address the growing challenges to obesity treatment provision and access in England (5).

The UK National Institute for Health and Care Excellence (NICE) recommend bariatric surgery (BaS) as the most effective treatment option for the management of severe obesity (9). That includes people with BMI above 40 kg/m², or BMI above 35 kg/m² with obesity-related complications [ORCs], or BMI above 30 kg/m² with recent onset T2DM in specific situations (9). BaS results in significant sustained long-term weight loss (10, 11), improved health (10), and decreased cardiovascular disease, cancer (12-15) and mortality (9, 14, 16). It is the most clinically effective and cost-effective intervention for weight management when compared with no intervention or lifestyle interventions (17-20). The immediate cost of BaS in the UK was estimated to be £9.16 million per 1,000 operated population in 2008-2013, with an additional discounted lifetime healthcare cost of £15.26 million (18). However, only an estimated 0.2% of the annual eligible population in England receive BaS, and the number also includes revision operations for complications, poor weight loss, and weight regain (21). Reasons for the low

penetration of BaS in the NHS are multifactorial including factors related to the funding and physician preference or attitude towards BaS, or patient preference (24-26). In those accepted for surgery, there remain prolonged waiting times (18, 27, 28) due to limited NHS capacity and prioritisation of other surgical procedures instead (29).

There is a need to understand the feasibility of scaling up BaS, particularly with the increasing prevalence of obesity (6) and its complications. While there is awareness of the limited capacity of the NHS to address the need for BaS, data on the economic investment required to scale-up BaS are sparse. In line with NHS expansion plans (5), this study aims to estimate the investment and resources required to scale-up NHS capacity for BaS capacity in England. These results will guide healthcare systems and health technology assessment bodies in making informed decisions on scaling up BaS and efficient management of resources to treat obesity.

METHODS

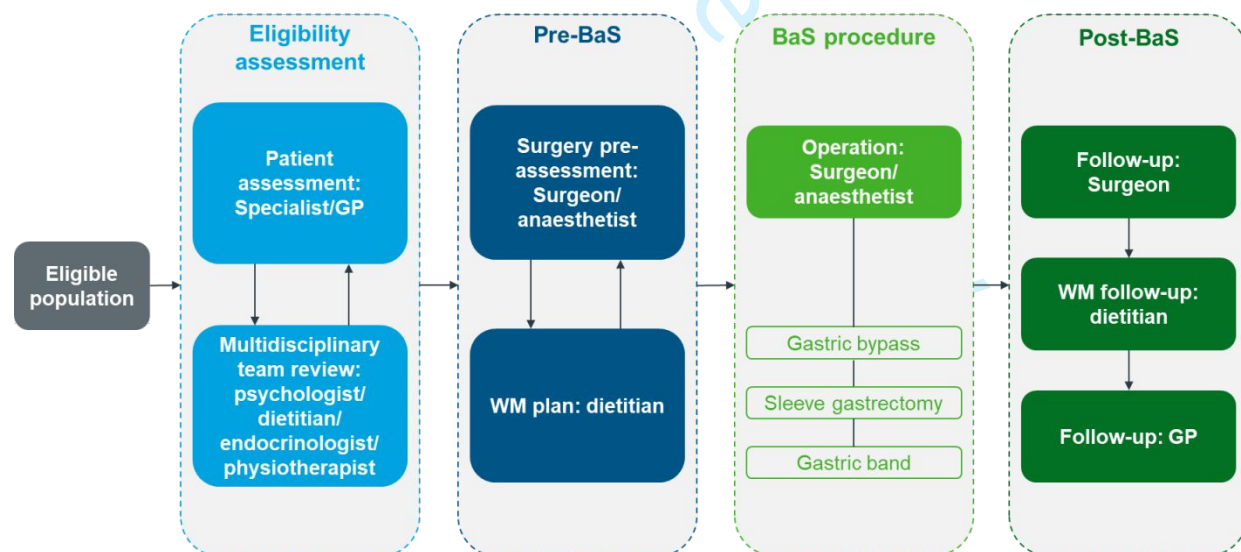
We used a landscape assessment and a pragmatic literature review to develop a stepwise patient pathway and construct the BaS scale-up model for NHS England. Three experienced bariatric surgeons working in the NHS validated the conceptual framework.

Model structure

We used a decision-tree approach including four distinct steps of the patient pathway (eligibility assessment, pre-BaS assessment, BaS procedure, and post-BaS follow-up) to capture associated resource use (Figure 1). These four distinct steps constitute the standard UK patient pathway and have been previously described in the surgical intervention arm in the simulation model by Tako et al (30). We estimated the total costs at current capacity and also over a 20-year time horizon under each of the following BaS scale-up strategies: Strategy 1: maximising NHS capacity: this

strategy involved pushing the current capacity to its maximum potential given the current resources and personnel with no additional infrastructure or personnel included during scale-up. The additional resource use in terms of personnel time was assumed to be proportional to the increase in capacity with the cost of each additional operation being the same; Strategy 2: maximising current NHS and private sector capacity: in addition to maximising NHS capacity, this strategy involved utilising a proportion of private sector capacity without additional infrastructure or personnel. The cost of surgery in the NHS and private sector was assumed to be equivalent (this is the total cost to society wherein patients are not charged or compensated); Strategy 3: adding infrastructure to increase the current NHS capacity: in addition to maximising NHS capacity given current resources, this strategy involved building more facilities and adding personnel to increase the current capacity, both of which were assumed to be exclusively dedicated to BaS.

Figure 1: Patient pathway for BaS scale-up model



BaS, bariatric surgery; GP, general practitioner; WM, weight management.

Key assumptions: Based on literature findings (31) we assumed only a sub-cohort of the whole eligible patient population required the multidisciplinary team review in the eligibility assessment stage (since not all patients required all services/resources) and this was validated by bariatric surgeons. We considered no cost discounting or inflation. A fixed number of incident cases were added each year to the fixed prevalent patient population. Additionally, we assumed the cost of short-term complications (30 days) were included in the procedure costs, and no additional costs were considered, while long-term complications (occurring at years 1 and 2) were captured in the same year to account for the total costs incurred per patient, as they were expected to be continuous from the previous years. We assumed that 100% of new staff capacity would be focused on BaS in the scale-up strategy and gastric band surgery would be phased out at a constant rate over the next 10 years, as per input from the bariatric surgeons (32).

Model inputs

We obtained all model inputs from published evidence and/or expert opinions from five NHS Key Decision Makers (KDMs). To gather data regarding infrastructure costs and resource utilisation, we held online interviews with the KDMs working in BaS with experience in the setup, management, and expansion of new or current BaS clinics within NHS England. Three NHS bariatric surgeons validated the key model inputs (patient preferences, costs, capacity, and resource use). Population inputs are described in Table 1a. Source for cost and capacity inputs are described in Table 1b–c and Supplementary Table 1, respectively. Complication rates and healthcare resource utilisation are described in Supplementary Table 2 and Supplementary Table 3, respectively. To estimate costs, resource use data were captured during each step of the patient pathway and combined with unit cost information, including all medical personnel

involved and the time spent; revision surgery; hospitalisation; outpatient / inpatient visits [frequency and costs]; and monitoring tests [frequency and costs]).

Table 1: Population, cost, and capacity inputs for BaS scale-up model

a) Population inputs

	Model input	Source
Total population (≥ 18 years age)	44,715,345	(33)
Proportion of population eligible for BaS (NICE guidelines)	7.78%	(23)
Obesity incidence rate (annual)	2.97%	(6)
Prevalent population (NICE guidelines eligibility criteria)	3,478,854	(6)
Incident population (annual) (NICE guidelines eligibility criteria)	103,261	(6)
Proportion of eligible population that are estimated to receive BaS*	10.00%	Assumption
Estimated current eligible population size**	347,885	Calculated
Estimated newly eligible population size (annual)***	10,326	

*There are several reasons why a patient may not receive BaS despite being eligible; these include (but are not limited to) patient preference, physician preference/attitude towards BaS, along with costs and waiting lists.

**Calculated using prevalent population keeping proportion of eligible population who receive BaS as 10%.

***Calculated using incident population keeping proportion of eligible population who receive BaS as 10%.

BMI, body mass index; NICE, National Institute for Health and Care Excellence

b) Cost inputs

Inputs	Source
Cost per procedure for gastric band, sleeve gastrectomy, and gastric bypass*	NHS reference costs (34)
Complication treatment costs (cost per episode for cholecystectomy, abdominal wall hernia operations, banding operations, leakage and abscess, obstruction, stricture, gastric ulcer)	
Cosmetic surgery cost	Excluded from cost inputs

Cost per episode for gastric ulcer (included 8-week antibiotics treatment, one GP visit, and one diagnostic test)	NHS reference costs (34)
Infrastructure costs for BaS scale-up (small- and large scale facilities): <ul style="list-style-type: none">• Number of BaS procedures per year (facility capacity)• Cost of setting up facility• Time required to set up the facility (in years)• Time required for facility to be fully functional (in years)	PMR KDMs' interviews**

*All the resource costs incurred at every stage of the patient pathway were assumed to be included in the procedure for all eligible costs patients.

**Data from the PMR report are described in Supplementary Table 1.

BaS, bariatric surgery; NHS, National Health Service; KDMs, key decision makers

c) Capacity inputs

Inputs	Source
Current annual capacity (number of BaS) for NHS and private sector*	(35), PMR KDMs' interviews**
Maximum potential annual capacity	PMR KDMs' interviews**
Current BaS distribution by procedure type (gastric band, sleeve gastrectomy and gastric bypass) for 2013–2018	(36)
BaS distribution by procedure type (for scale-up strategy)***	Inputs from bariatric surgeons**

*2018–2019 data are included; 2020–2022 data are excluded, since numbers were underrepresented due to COVID-19 pandemic.

**Data from PMR report are described in Supplementary Table 1.

***Based on bariatric surgeons' opinion that the gastric band procedure is the least effective BaS and is assumed to be gradually phased out in next 10 years.

BaS, bariatric surgery; NHS, National Health Service; KDMs, key decision makers

Analyses

Base-case analysis

We selected the eligible population (incident and prevalent) as per the NICE guidelines' eligibility criteria. We estimated the proportion of the eligible population receiving BaS to be

10% (based on expert opinion and an Office of Health Economics study (37)) and we used this in the base-case for all three scale-up strategies. We considered a 20-year time horizon appropriate for achieving the target BaS capacity and eligible population.

Scenario and sensitivity analysis

We only conducted scenario and sensitivity analyses for strategy 3 as it is more flexible to cover a greater proportion of the eligible patient population.

Scenario analysis

We performed scenario analyses and one-way sensitivity analysis (OWSA) to test the model robustness and identify model drivers. Scenario 1 included different proportions (5%, 25%, and 100%) of the eligible population over a 20-year time horizon. Scenario 2 assessed the distribution of gastric bypass procedure. Scenario 3 evaluated the impact of change in the eligible population (population with BMI ≥ 40 kg/m²).

One-way sensitivity analysis

We adjusted input model parameters by 20% of their default value to evaluate the robustness of the results and the influence of individual parameters. The uncertainty in assumptions/inputs was captured as lower and upper bounds and displayed in a tornado diagram.

RESULTS

Base-case analysis

The prevalent and annual incident targeted eligible population sizes were estimated at 347,885 and 10,326, respectively. The total targeted eligible population size over 20 years was estimated at 554,405. With the current capacity in NHS England, the total number of BaS procedures

(including revision surgery) were estimated to be 140,220 (revision surgeries: 2,474) over 20 years, which is significantly smaller than the estimated total population size. The associated annual and overall costs were £70.6 million and £1.4 billion, respectively. We calculated the BaS backlog as the combination of ‘current eligible population’ and ‘newly eligible population’ added each year and it was estimated to be 424,143 over 20 years. The outcomes of the base-case analysis for all three strategies are described (Table 2). Detailed results on the cost breakdown associated with the procedure and the complications are described in Supplementary materials, as well as the cost versus capacity over 20 years for the current and projected scenarios.

Strategy 1: Maximising current NHS capacity

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 157,760 (revision surgeries: 2,867; incremental: 17,540 BaS). This was calculated as the maximum potential NHS capacity (i.e., number of BaS completed annually) multiplied by the time horizon i.e., 20 years. The maximum potential capacity was taken as 12.5% more than the current capacity, based on KDMs’ inputs. The projections estimated the largest increment for gastric bypass (22,362), followed by sleeve gastrectomy (5,758). The number of gastric band operations was projected to decrease from 15,889 to 4,915 (incremental: -10,974). The total annual cost was projected to increase to £83.7 million, and the overall total cost was estimated to increase to £1.7 billion (Supplementary Table 4). Scaling up with strategy 1 would reduce the backlog to 407,023 over 20 years (Table 2 and Supplementary Figure 1).

Strategy 2: Maximising current private sector and NHS capacity

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 232,760 (revision surgeries: 4,229; incremental: 92,540 BaS). This was calculated as the maximum potential NHS capacity and the potential increase in private sector

capacity utilised by the NHS multiplied by the time horizon. The maximum potential capacity was taken as 12.5% more than the current based on expert inputs, and the potential additional capacity from the private sector utilised by the public was assumed to be 25%. The projections estimated the largest increment for gastric bypass (56,245), followed by sleeve gastrectomy (43,176). The number of gastric band operations was projected to decrease from 15,889 to 7,251 (incremental: -8,637). The total annual cost was projected to increase to £123.5 million, and the overall total cost was estimated to increase to £2.5 billion over 20 years (Supplementary Table 5). Scaling up would reduce the backlog to 332,023 (Table 2).

Strategy 3: Adding infrastructure to increase current NHS capacity.

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 564,784 (revision operations: 10,295; incremental: 424,563 BaS). In this strategy, this number was estimated after adding the infrastructure to cover the entire prevalent and incident population over 20 years. The projections estimated the largest increment for gastric bypass surgery (212,499), followed by sleeve gastrectomy (207,528). The number of gastric band operations was projected to decrease from 15,889 to 12,603 (incremental: -3,286). Additionally, the number of revision operations was projected to increase from 2,474 to 10,295 over the next 20 years, and the highest incremental component was represented by gastric bypass (5,859). The total annual cost was projected to increase to £319.4 million. The overall total cost was projected to increase to £6.4 billion over 20 years. The incremental cost related to BaS procedure costs represented the largest component, amounting to 85.6% of the total cost (incremental value of £4.3 billion). This was followed by the infrastructure cost of the BaS scale-up, with an incremental value of £362.5 million. Incremental costs related to complications, personnel (post-BaS follow-up), and revision surgery represented only a small fraction of total

costs, amounting to incremental values of £246.6 million, £81.6 million, and £24.8 million, respectively (Supplementary Table 6). Scaling up would reduce the backlog to zero over 20 years, considering the proportion of the eligible patient population estimated to receive BaS was 10% (Table 2).

BaS scale-up over 20 years would require an additional 49 facilities and 4,081 personnel, the majority of whom would be nurses, healthcare assistants/healthcare service workers, anaesthetists, and surgeons.

Table 2: Base-case analysis: Incremental values over 20 years*

	Strategy 1: Maximising current NHS capacity	Strategy 2: Maximising current NHS and private sector capacity	Strategy 3: Adding infrastructure to increase current NHS capacity
Number of BaS procedures (n)	17,147	90,784	416,742
Gastric band	-10,974	-8,637	-3,286
Sleeve gastrectomy	5,758	43,176	207,528
Gastric bypass	22,362	56,245	212,499
BaS backlog (n)			
Current	424,143	424,143	424,143
Projected	407,023	332,023	0
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£0	£362,500,000
Number of additional facilities needed - Small scale facility	N/A	N/A	1
Number of additional facilities needed - Large scale facility	N/A	N/A	48
Procedure costs	£238,217,988	£974,230,140	£4,261,177,612

Gastric band	-£57,616,922	-£45,349,121	-£17,250,674
Sleeve gastrectomy	£55,291,672	£414,570,055	£1,992,636,562
Gastric bypass	£240,543,238	£605,009,206	£2,285,791,723
Revision surgery–Gastric band	-£204,198	-£160,720	-£61,137
Revision surgery–Sleeve gastrectomy	£237,606	£1,781,543	£8,563,008
Revision surgery–Gastric bypass	£1,710,880	£4,303,170	£16,257,852
Personnel costs–Post-BaS follow-up	£3,385,898	£17,924,406	£81,597,599
Complication costs	£19,539,294	£60,590,462	£246,629,873
Gastric band	-£2,991,137	-£2,354,264	-£895,555
Sleeve gastrectomy	£1,259,693	£9,445,023	£45,397,631
Gastric bypass	£21,270,737	£53,499,703	£202,127,798
Total–20 years	£262,887,469	£1,058,669,001	£4,976,664,806
Total–Annual*	£13,144,373	£52,933,450	£248,833,240

BaS, bariatric surgery; N/A, not applicable; *all the incremental values are represented for 20-year time horizon, except the total annual cost

Scenario analysis

Scenario 1: Proportion of eligible population who would receive BaS

In this scenario analysis (Table 3), we modified only the proportion of the eligible population in the base-case settings (assumed as 10%) for strategy 3.

5% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 173,943, and the annual incident target population size was estimated at 5,163. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 282,371 (revision surgeries: 5,140; incremental: 14,172 BaS). The total annual and 20-year costs were projected to

increase to £156.0 million and £3.1 billion, respectively. Scaling up would require an additional full-time 1,251 personnel and 16 new facilities (1 small scale, 15 large scale) dedicated to BaS.

25% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 869,714, and the annual incident target population size was estimated at 25,815. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 1,411,958 (revision surgeries: 25,756; incremental: 1,271,738 BaS). The total annual and 20-year costs were projected to increase to £809.7 million and £16.2 billion, respectively. Scaling up would require an additional full-time 12,576 personnel and 149 new facilities (1 small scale, 148 large scale) dedicated to BaS.

100% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 3,478,854, and the annual incident target population size was estimated at 103,261. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 5,647,832 (revision surgeries: 103,065; incremental: 5,507,613 BaS). The total annual and 20-year costs were projected to increase to £3.3 billion and £65.2 billion, respectively. Scaling up would require 55,042 full-time additional personnel and 647 new facilities (1 small scale, 646 large scale) dedicated to BaS.

Scenario 2: Distribution of BaS by type of procedure over 20-year time horizon

In this scenario, the capacity inputs for the type of procedure were kept at 100%, while other base-case settings were the same. Time to achieve BaS distribution with either of the surgery type being 100% was 10 years.

Gastric bypass at 100%

Over a 20-year time horizon, the number of BaS (including revision surgery) procedures was projected to increase from 140,220 to 569,693 (incremental: 429,473 BaS). The number of gastric bypass, sleeve gastrectomy and gastric band operations was projected to be 484,346, 58,378 and 12,715, respectively. The total annual and 20-years costs were projected to increase to £341.7 million and £6.8 billion, respectively. Scaling up using this scenario would require only 4,518 additional full-time personnel dedicated to BaS over 20 years.

Scenario 3: Eligible population with BMI ≥ 40 kg/m²

Over a 20-year time horizon, with 10% of the eligible population receiving BaS, the prevalent and annual incident target population sizes were estimated at 149,500 and 4,033, respectively and the number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 234,474 (revision surgeries: 4,266; incremental: 94,254). The total annual cost was projected to increase from £70.6 million to £119.6 million. The overall total cost was projected to increase from £1.4 billion to £2.4 billion over 20 years. BaS scale-up would require an additional full-time 681 personnel dedicated to BaS.

Table 3: Scenario analysis

Base-Case/Scenarios	Number of BaS (including revision surgery)	Total 20-year costs for current scenario (in billions)	Total 20-year costs for projected scenario (in billions)	Incremental (in billions)
Base-case: Strategy 3	564,784	£1.4	£6.4	£5.0
Proportion of eligible population who would receive BaS: 5%	282,371	£1.4	£3.1	£1.7

Proportion of eligible population who would receive BaS: 25%	1,411,958	£1.4	£16.2	£14.8
Proportion of eligible population who would receive BaS: 100%	5,647,832	£1.4	£65.2	£63.8
Distribution of BaS by type of procedure: Gastric bypass surgery: 100%	569,693	£1.4	£6.8	£5.4
Eligible population with BMI ≥ 40 kg/m ²	234,474	£1.4	£2.4	£1.0

*10-year cost.
BaS, bariatric surgery; UK, United Kingdom

One-way sensitivity analysis

The OWSA results indicate that the model was most sensitive to patient preference for BaS, the proportion of the population eligible for BaS (NICE guidelines), and the cost per procedure for gastric bypass and sleeve gastrectomy (Supplementary Figure 3). The OWSA demonstrated the robustness of the model even with ±20% variation in the majority of input parameter values.

DISCUSSION

To our knowledge, this is the first study to evaluate the required investment of scaling up BaS to address the unmet needs in the NHS. This study demonstrated that scaling up BaS to treat obesity will be challenging due to the need for further investment; even within the context of only 5% to 10% of the eligible population modelled to receive BaS. Based on the model estimates, the economic investment required to scale-up BaS capacity by 12.5% to maximise the current NHS England capacity, without scaling up the infrastructure and personnel was estimated to require an incremental cost of £13.7 million/year, with a capacity to conduct an additional

17K operations over 20 years, reducing the backlog to approximately 407K over a 20-year time horizon. Another strategy to maximise BaS use in NHS and private sectors, increased the capacity by an additional 91K operations over 20 years and increased the total annual cost by £52.9 million, which reduced the backlog to 332K operations. The third strategy, maximising NHS capacity, along with the addition of infrastructure and personnel, aimed to provide BaS to the whole target population and resolve the backlog. This scaling supported an additional 417K surgeries over 20 years with an additional budget of £248.8 million/year. The total 20-year incremental costs to NHS England were estimated at £5 billion, including £4.3 billion for procedures, £363 million for infrastructure, and £247 million for 4,081 additional personnel.

All these strategies require significant investment, especially if bariatric surgery were to be used as the sole treatment strategy to address the needs for the eligible population. However, there is no single treatment strategy that will address all the demands of the high prevalence of obesity and its impact on health and economics.

To reduce obesity prevalence and its health consequences will require expansion of all treatment strategies combined with a system-wide, holistic and multifaceted approach to obesity, combining prevention with treatment strategies (9).

Although scaling up the capacity of BaS to cover 10% of those eligible may be unrealistic from an investment perspective, base-case Strategy 1 appears more achievable in terms of economic investment, despite the reduction in the backlog being relatively minimal. The data suggest that Strategy 3 is most beneficial in covering the eligible population that opts for BaS, considering an estimated 10% of the population will receive BaS out of a total eligible population of 5.5 million. However, the feasibility of such a substantial economic investment cannot be predicted (estimation of £5 billion) over a 20-year time horizon, despite the well-established cost-

effectiveness of BaS (37). The required investment for Strategy 3 is likely to be significantly offset by the economic benefits achieved by the reduction in incidence/severity of ORCs in these patients. The economic benefits associated with BaS have been estimated at £1.25 billion over a three-year period for 25% of the eligible population opting for BaS (37). These economic benefits were mainly related to additional paid work generated after BaS and potential reduction in disability benefits (37). In addition, Strategy 3, which involves the addition of personnel, may also considerably reduce waiting times, as indicated by a simulation study, where the addition of three surgeons and two physicians to a UK healthcare centre reduced waiting times by five weeks (30).

In the scenario analysis, varying the proportion of the eligible population receiving BaS from 10% to 5%, 25%, and 100% proportionally increased the budget from £1.4 billion to £3.1 billion, £16.2 billion, and £65.2 billion, respectively. This is in line with a prior study which suggested that the economic impact increased in tandem with the proportion of the eligible population that would undergo surgery (37). Our study also assessed the impact on model results with increasing incidence rate of obesity. This further corroborates the need for the NHS to evaluate the significance of BaS in the management of severe and complex obesity. Additionally, the economic estimate of this study is based on 10% of the eligible population receiving BaS, therefore at least 90% of the eligible population will require alternative intervention.

Our model suggests that a preference for performing only gastric bypass will require a larger investment than performing sleeve gastrectomy over the course of 20 years (£6.8 billion versus £6.0 billion, respectively). This could be partially explained by its association with higher complication rates (36) and no increase in patients' return to work (38). However, our study only takes a limited economic and resource perspective on the selection of the most appropriate

operation type; any NHS prioritisation should also account for surgery efficacy, complication rates, and cost-effectiveness. This study will also assist other healthcare systems around the world facing similar challenges.

Our study has some limitations. Firstly, several assumptions were made in the cost estimates for scale-up scenarios, and certain elements such as training costs and inflation were not included. However, this was mitigated through opinions from five KDMs and three bariatric surgeons. Secondly, the clinical benefit and cost offsets associated with BaS were not considered while populating the model, which will reduce the net budget impact. Thirdly, a conservative approach was used in calculating cost inputs (e.g., a cost-minimisation approach was used to calculate the number of new facilities required); of note, full efficiency was assumed for personnel in the projected scenario, while no delays in setting up new facilities and becoming fully functional were included in the model. This conservative estimate suggests that the required investment could be much higher than the current estimate. This could be further corroborated by additional eligibility criteria for BaS as per the new NICE guidelines 2023 (9), including patients agreeing to long-term follow-up after surgery and the inclusion of other ethnicities (South Asian, Chinese, etc) with a lower BMI threshold (9). It is also important to consider that over a 20-year time horizon, there could be further changes in the current NICE guidelines to lower the BMI eligibility criteria to include populations with a BMI >35 kg/m² without comorbidities, according to the recent updates in IFSO and American Society for Metabolic and Bariatric Surgery guidelines (39). This would further increase the size of the eligible population, thereby impacting economic investment and the backlog. Additionally, this modelling-based study should also be supported by the real time measurement of investment by NHS and resource use in future.

Our study has several strengths including being one of the first in the UK to estimate the economic investment and resources required to scale-up the capacity of BaS in England. We used inputs from bariatric surgeons and KDMs regarding scaling up BaS in England to provide a realistic perspective. Additionally, inputs and patient pathway design/assumptions were validated to reflect the real-world scenario. We also conducted sensitivity and scenario analysis to test the uncertainties in model inputs and assumptions.

CONCLUSION

We have presented several approaches to expand BaS capacity in NHS England based on available investment funding. Realistically, expansion beyond a small proportion of the eligible cohort will be challenging given the significant upfront economic investment and additional requirements of infrastructure and personnel. Therefore, in order to meet the demands of increasing prevalence of obesity and its complications, multiple treatment approaches will be needed in addition to bariatric surgery, and scalable treatment options will be required.

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SUPPLEMENTARY INFORMATION

Supplementary Table 1: Results from PMR report

Input parameter			Input value
Cost inputs	Infrastructure costs for BaS scale-up (small scale facilities)	Facility capacity (number of BaS per year)	150.00
		Cost of setting up a facility	£2,500,000.00
		Time required for setting up a facility (in years)	1.00
		Time required for the facility to be fully functional (in years)	0.00
	Infrastructure costs for BaS scale-up (large scale facilities)	Facility capacity (number of BaS per year)	500.00
		Cost of setting up a facility	£7,500,000.00
		Time required for setting up a facility (in years)	3.00
		Time required for the facility to be fully functional (in years)	0.00
		Number of BaS per year (facility capacity)	500.00
	Capacity inputs	Current annual capacity (number of BaS)	NHS
Private sector			15,000
Maximum potential annual capacity		NHS	7,888
		Private sector	18,750
BaS distribution by procedure type (for scale-up strategy)		Gastric band	0.00%
		Sleeve gastrectomy	50.00%
		Gastric bypass	50.00%
Eligibility assessment stage	Number of personnel visits	GP	1.00
		Psychologist	1.50
		Dietitian	1.00
		Endocrinologist	1.00
		Physiotherapist	1.00
	Personnel time per visit (in mins)	GP	30.00
		Psychologist	60.00
		Dietitian	30.00
		Endocrinologist	30.00
		Physiotherapist	45.00

	Proportion of population requiring personnel visits/monitoring	GP	100.00%
		Psychologist	100.00%
		Dietitian	100.00%
		Endocrinologist	80.00%
		Physiotherapist	100.00%
		Blood test	100.00%
		ECG	100.00%
Pre-BaS stage	Personnel time per visit (in mins)	Surgeon	30.00
		Dietitian	45.00
		Anaesthetist	30.00
Post-BaS follow-up	Follow-up visits (up to 24 months post-BaS)	Nurse	4.00
		Surgeon	1.00
		Dietitian	3.00
		GP	0.00
	Follow-up visits (24 to 48 months post-BaS)	Nurse	0.00
		Surgeon	0.00
		Dietitian	0.00
		GP	4.00
	Personnel time per visit (in mins)	Nurse	10.00
		Surgeon	10.00
		Dietitian	10.00
		GP	10.00
Resource utilisation	Number of working hours per personnel (annual)	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	2160 each*
	Proportion of time spent on BaS (Current scenario)	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	50% each
	Proportion of time spent on BaS for new personnel added in scale-up scenario	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	100% each

*based on 48-hour work week for 45 weeks per year.
BaS, bariatric surgery; ECG, electrocardiogram; GP, general physician

Supplementary Table 2: Complication rates

Short-term complications (30 days)				Source
Complication rate (proportion of patient population)	Gastric band	Sleeve gastrectomy	Gastric bypass	(36)
Bleed	0.00%	13.00%	18.90%	
Obstruction	0.00%	0.00%	8.70%	
Leak	7.40%	0.00%	6.60%	
Revision surgery	2.20%	0.20%	1.30%	
Long-term complications				(31)
Complication rate (proportion of patient population)	Gastric band	Sleeve gastrectomy	Gastric bypass	
Cholecystectomy, 1-year	1.00%	0.00%	1.55%	
Cholecystectomy, 2-year	0.00%	0.00%	1.93%	
Abdominal wall hernia operations, 1-year	0.50%	1.90%	0.88%	
Abdominal wall hernia operations, 2-year	3.10%	0.00%	1.22%	
Banding operations, 1-year	0.00%	0.00%	3.60%	
Banding operations, 2-year	0.00%	0.00%	7.10%	
Plastic operations, 1-year	0.00%	0.00%	0.41%	
Plastic operations, 2-year	0.80%	6.30%	5.04%	
Leakage and abscess, 1-year	0.00%	0.19%	0.19%	
Leakage and abscess, 2-year	0.00%	0.14%	0.14%	
Obstruction, 1-year	0.00%	1.74%	1.74%	
Obstruction, 2-year	0.00%	3.31%	3.31%	
Stricture, 1-year	0.00%	0.22%	0.22%	
Stricture, 2-year	0.00%	0.11%	0.11%	
Gastric ulcer, 1-year	1.05%	1.05%	1.05%	
Gastric ulcer, 2-year	0.95%	0.95%	0.95%	
Cholecystectomy 1-year, revision surgery	1.40%	1.40%	1.40%	
Cholecystectomy 2-year, revision surgery	0.70%	0.70%	0.70%	
Hernia operations 1-year, revision surgery	4.55%	4.55%	4.55%	
Hernia operations 2-year, revision surgery	5.18%	5.18%	5.18%	
Plastic operations 1-year, revision surgery	1.30%	1.30%	1.30%	
Plastic operations 2-year, revision surgery	3.40%	3.40%	3.40%	
Other complications 1-year, revision surgery	7.40%	7.40%	7.40%	
Other complications 2-year, revision surgery	5.50%	5.50%	5.50%	

Supplementary Table 3: Healthcare resource utilisation

Input	Source
Eligibility assessment stage*	
Number of personnel visits	Expert inputs**, (31)
Personnel time per visit (in mins)	Expert inputs**
Monitoring frequency (blood test, ECG)	(31)
Proportion of population requiring personnel visits/monitoring	Expert inputs**, (31)
Pre-BaS stage*	
Number of personnel visits	(31)
Personnel time per visit (in mins)	Expert inputs**
Proportion of population requiring personnel	(31)
BaS procedure	
Time spent (in mins)—gastric band/sleeve gastrectomy/ gastric bypass (surgeon, registrar surgery, anaesthetist, registrar / trainee anaesthesiology, nurses, operating department practitioner, healthcare assistant/healthcare service worker, operation theatre)	(40)
Hospital stays (number of days) (gastric band, sleeve gastrectomy, gastric bypass)	(31)
Post-BaS follow-up*	
Follow-up visits (up to 24 months post-BaS, 24 to 48 months post-BaS)	Expert inputs**, (31)
Personnel time per visit (in mins)	Assumption, validated through PMR QoL interviews Mar 2023**
Resource utilisation	
Number of working hours per personnel (annual) (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption (based on 48-hour work week for 45 weeks per year)**
Proportion of time spent on BaS (current scenario) (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption**
Proportion of time spent on BaS for new personnel added in scale-up scenario (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption**

*Refer to Figure 1 for information on the personnel involved.

**Data from PMR report are described in Supplementary Table 1.

BaS, bariatric surgery; ECG, electrocardiogram; GP, general physician

Supplementary Table 4: Base-case results for scenario of maximising current NHS capacity

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	4,915	-10,974
Sleeve gastrectomy	72,949	78,707	5,758
Gastric bypass	48,909	71,271	22,362
Total	137,746	154,893	17,147
Revision surgery–Gastric band	406	126	-280
Revision surgery–Sleeve gastrectomy	719	776	57
Revision surgery–Gastric bypass	1,349	1,965	617
Total	2,474	2,867	393
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£0	£0
Procedure costs	£1,309,959,040	£1,548,177,028	£238,217,988
Gastric band	£83,421,834	£25,804,911	-£57,616,922
Sleeve gastrectomy	£700,438,431	£755,730,103	£55,291,672
Gastric bypass	£526,098,776	£766,642,014	£240,543,238
Revision surgery–Gastric band	£295,652	£91,454	-£204,198
Revision surgery–Sleeve gastrectomy	£3,010,012	£3,247,618	£237,606
Revision surgery–Gastric bypass	£3,741,914	£5,452,794	£1,710,880
Revision surgery costs	£7,047,578	£8,791,867	£1,744,289
Personnel costs–Post-BaS follow-up	£27,195,369	£30,581,267	£3,385,898
Complication costs	£66,810,472	£86,349,765	£19,539,294
Gastric band	£4,330,778	£1,339,642	-£2,991,137
Sleeve gastrectomy	£15,957,875	£17,217,568	£1,259,693
Gastric bypass	£46,521,818	£67,792,555	£21,270,737
Total–20 years	£1,411,012,459	£1,673,899,928	£262,887,469
Total–Annual	£70,550,623	£83,694,996	£13,144,373

BaS, bariatric surgery

Supplementary Table 5: Base-case results for scenario of maximising current NHS and private sector capacity

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	7,251	-8,637
Sleeve gastrectomy	72,949	116,125	43,176
Gastric bypass	48,909	105,154	56,245
Total	137,746	228,531	90,784
Revision surgery - Gastric band	406	185	-221
Revision surgery - Sleeve gastrectomy	719	1,145	426
Revision surgery - Gastric bypass	1,349	2,899	1,551
Total	2,474	4,229	1,756
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£0	£0
Procedure costs	£1,309,959,040	£2,284,189,181	£974,230,140
Gastric band	£83,421,834	£38,072,713	-£45,349,121
Sleeve gastrectomy	£700,438,431	£1,115,008,486	£414,570,055
Gastric bypass	£526,098,776	£1,131,107,982	£605,009,206
Revision surgery–Gastric band	£295,652	£134,932	-£160,720
Revision surgery–Sleeve gastrectomy	£3,010,012	£4,791,554	£1,781,543
Revision surgery–Gastric bypass	£3,741,914	£8,045,084	£4,303,170
Revision surgery costs	£7,047,578	£12,971,570	£5,923,992
Personnel costs–Post-BaS follow-up	£27,195,369	£45,119,775	£17,924,406
Complication costs	£66,810,472	£127,400,934	£60,590,462
Gastric band	£4,330,778	£1,976,515	-£2,354,264
Sleeve gastrectomy	£15,957,875	£25,402,898	£9,445,023
Gastric bypass	£46,521,818	£100,021,521	£53,499,703
Total–20 years	£1,411,012,459	£2,469,681,460	£1,058,669,001
Total–Annual	£70,550,623	£123,484,073	£52,933,450

BaS, bariatric surgery

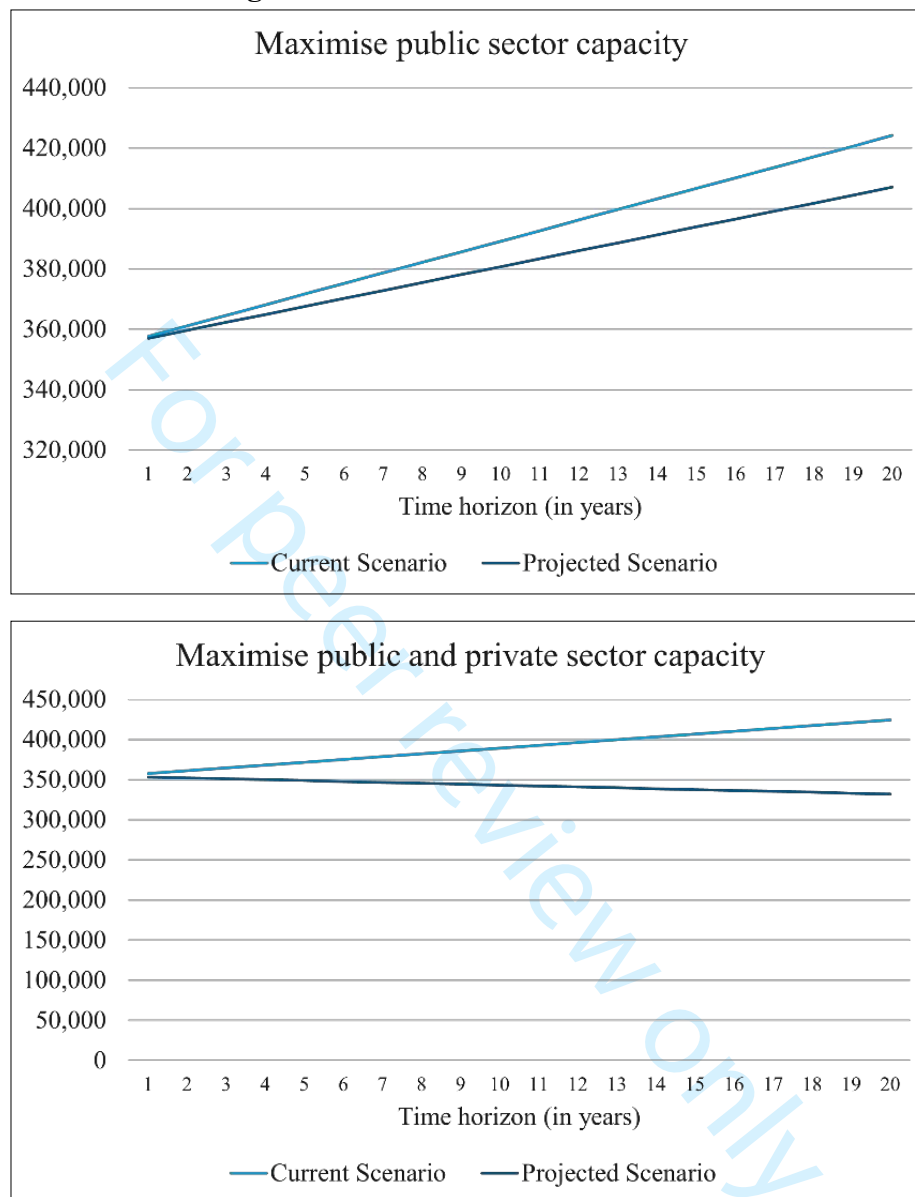
Supplementary Table 6: Base-case results for scenario of maximising current NHS capacity and adding the infrastructure

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	12,603	-3,286
Sleeve gastrectomy	72,949	280,477	207,528
Gastric bypass	48,909	261,408	212,499

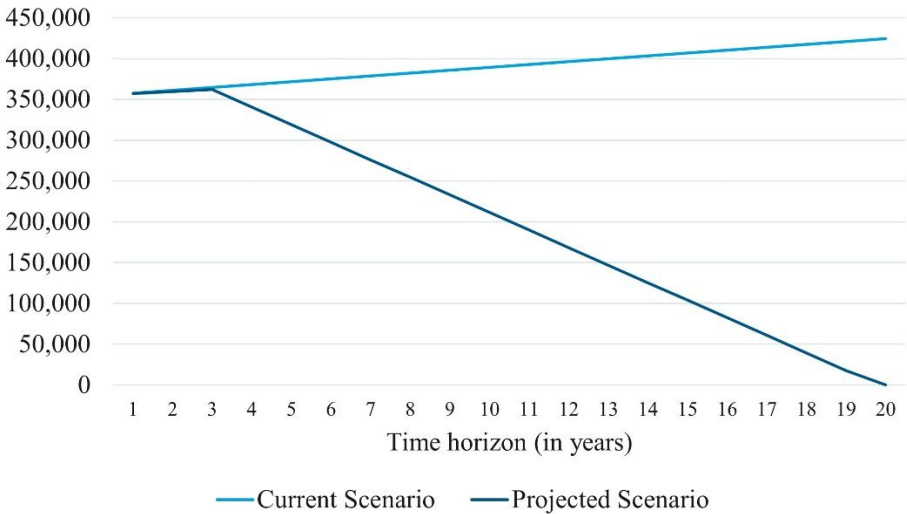
Total	137,746	554,489	416,742
Revision surgery–Gastric band	406	322	-84
Revision surgery–Sleeve gastrectomy	719	2,765	2,046
Revision surgery–Gastric bypass	1,349	7,207	5,859
Total	2,474	10,295	7,821
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£362,500,000	£362,500,000
Procedure costs	£1,309,959,040	£5,571,136,652	£4,261,177,612
Gastric band	£83,421,834	£66,171,160	-£17,250,674
Sleeve gastrectomy	£700,438,431	£2,693,074,993	£1,992,636,562
Gastric bypass	£526,098,776	£2,811,890,500	£2,285,791,723
Revision surgery–Gastric band	£295,652	£234,514	-£61,137
Revision surgery–Sleeve gastrectomy	£3,010,012	£11,573,020	£8,563,008
Revision surgery–Gastric bypass	£3,741,914	£19,999,766	£16,257,852
Revision surgery costs	£7,047,578	£31,807,300	£24,759,722
Personnel costs–Post-BaS follow-up	£27,195,369	£108,792,968	£81,597,599
Complication costs	£66,810,472	£313,440,345	£246,629,873
Gastric band	£4,330,778	£3,435,223	-£895,555
Sleeve gastrectomy	£15,957,875	£61,355,506	£45,397,631
Gastric bypass	£46,521,818	£248,649,616	£202,127,798
Total–20 years	£1,411,012,459	£6,387,677,265	£4,976,664,806
Total–Annual	£70,550,623	£319,383,863	£248,833,240
Number of personnel required			
GP	139	337	198
Mental health professional	192	469	277
Dietitian	222	544	322
Endocrinologist	52	126	74
Physiotherapist	96	235	139
Surgeon	265	668	403
Anaesthetist	275	693	418
Registrar surgery	192	494	302
Registrar/Trainee anaesthesiology	197	523	326
Operating department practitioner	218	552	334
Healthcare assistant/Healthcare service worker	371	953	582
Nurse	464	1170	706
Total	2683	6764	4081

BaS, bariatric surgery, GP, general physician

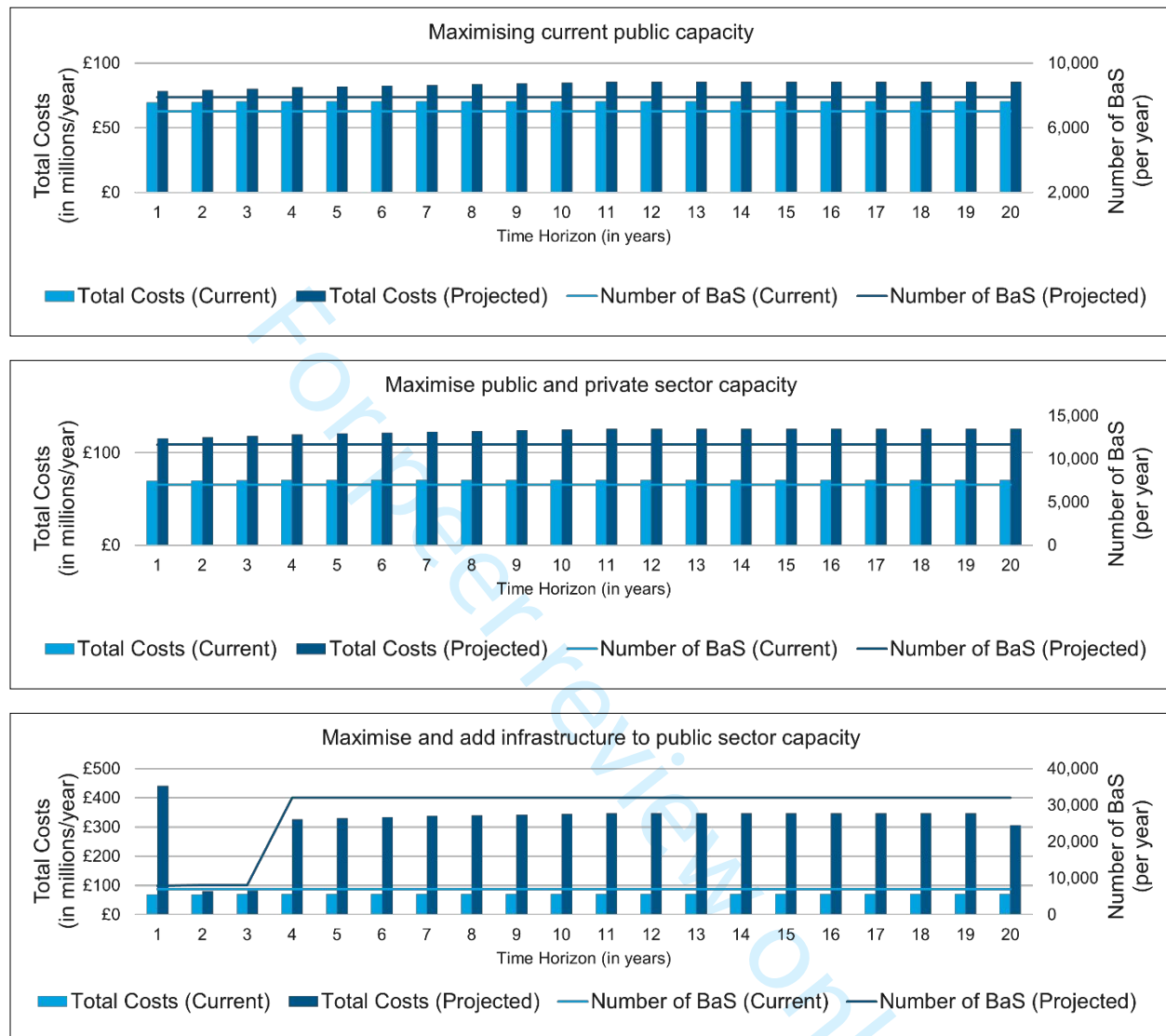
Supplementary Figure 1: BaS Backlog ((number of BaS needed including revision surgeries) for the three strategies



Maximise and add infrastructure to NHS capacity

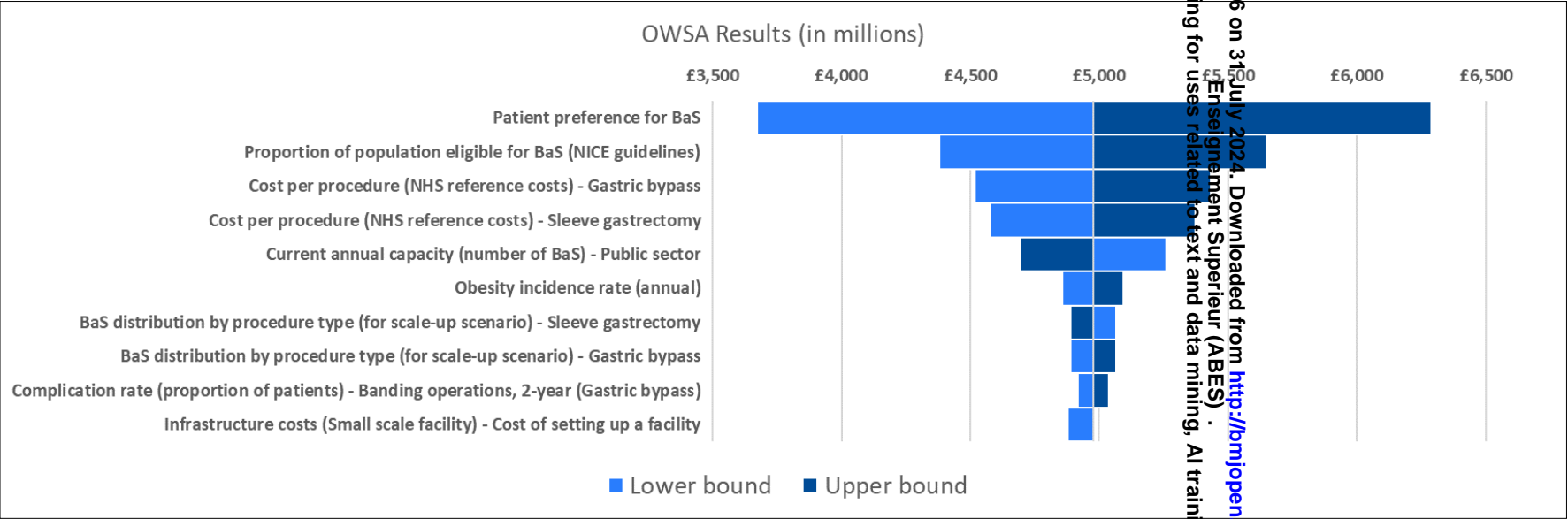


Supplementary Figure 2: Cost versus capacity over time for the three strategies



BaS, bariatric surgery

Supplementary Figure 3: One-way sensitivity analysis



BaS, bariatric surgery; NHS, National Health Service; NICE, National Institute for Health and Care Excellence; OWSA, one-way sensitivity analysis

Supplementary Text 1: Scenario Analysis

Scenarios were also assessed for below mentioned assumptions, maintaining all the other base-case settings.

Scenario 1: Time horizon

Time horizon of 10 years

This scenario considered the current eligible population but only added new eligible population for 10 years. Over a 10-year time horizon, with 10% eligible population receiving BaS, prevalent and annual incident target population sizes were the same as in the base-case. The number of BaS procedures (including revision surgery) was projected to increase from 70,110 to 459,590 (incremental: 389,480 BaS). The total annual cost and total ten-year cost were projected to increase to £563.0 million and £5.6 billion, respectively. Scaling up using this scenario would require only 3,730 additional full-time personnel dedicated to BaS.

Scenario 2: Distribution of BaS by type of procedure over 20-year time horizon

Sleeve gastrectomy at 100%

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 559,873 (incremental: 419,653 BaS) over a 20-year time horizon. The number of gastric bypass, sleeve gastrectomy and gastric band surgeries was projected to be 38,938, 501,941 and 12,649, respectively. The total annual cost and total 20-year cost were projected to increase to £297.5 million and £6.0 billion, respectively. Scaling up using this scenario would require only 3,653 additional full-time personnel dedicated to BaS over 20 years.

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Scenario 3: Increased incident rate of obesity (sourced from Cancer Research UK, 2022 (41), estimated based on projected change between 2019 and 2040 for England, i.e. mean of obesity and severe obesity)

Over a 20-year time horizon, with 10% of the eligible population receiving BaS, after increasing the annual incident rate to 3.33%, the prevalent target population size was estimated at 3,478,854, and the annual incident target population size was estimated at 115,846. The number of BaS (including revision surgery) was projected to increase from 140,220 to 590,424 (revision surgeries: 10,763; incremental: 450,204 BaS). The total annual cost and total 20-year cost were projected to increase to £334.2 million and £6.7 billion, respectively.

CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Title, Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Abstract, Page 3-4
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Introduction, Page 5-6
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Note reported
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Methods: Table 1
Setting and location	6	Provide relevant contextual information that may influence findings.	Methods: First Paragraph
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Methods: Model structure
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Methods: First Paragraph
Time horizon	9	State the time horizon for the study and why appropriate.	Methods: Model structure
Discount rate	10	Report the discount rate(s) and reason chosen.	Methods: Key assumptions
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Methods: Model structure
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Methods: Model structure
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Methods: Model inputs
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Methods: Table 1

Topic	No.	Item	Location where item is reported
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Note fully reported, Methods: Table 1
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Methods: Model structure
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Methods: Key assumptions
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	Not applicable
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	Not applicable
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Not applicable
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	Not applicable
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Supplementary Table 1-3
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Results, page 11 - 15
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Results: Scenario analysis, One-way sensitivity analysis, and Supplementary Text 1
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	Results: Scenario analysis
Discussion			
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Discussion
Other relevant information			

Topic	No.	Item	Location where item is reported
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Page 2
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 2

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Assessing economic investment required to scale-up bariatric surgery capacity in England: a health economic modelling analysis

James Baker-Knight¹, Dimitri J Pournaras², Kamal Mahawar^{3,4}, Richard Welbourn^{5,6}, Yuxin Li⁷,
Yuvraj Sharma⁷, Ines Guerra⁷, Abd Tahrani¹

Affiliations:

1. Novo Nordisk A/S, Denmark; 2. North Bristol NHS Trust, Southmead Hospital, UK; 3. South Tyneside and Sunderland NHS Foundation Trust, UK; 4. University of Sunderland, UK; 5. Musgrove Park Hospital, Somerset NHS Foundation Trust, UK; 6. Bristol Medical School, Population Health Sciences, University of Bristol, UK; 7. IQVIA Ltd., UK

Correspondence to:

James Baker-Knight

JMKG@novonordisk.com

KEYWORDS

Bariatric surgery; COVID-19; Cost-effectiveness analysis; Metabolic surgery; Obesity.

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3 **ABSTRACT**

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6 **Objectives**

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8 To quantify the economic investment required to increase bariatric surgery (BaS) capacity in

9 National Health Service (NHS) England considering the growing obesity prevalence, and low

10 provision of BaS in England despite its high clinical effectiveness.

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15 **Design**

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17 Data were included for the patients with obesity who were eligible for BaS. We used a decision-

18 tree approach including four distinct steps of the patient pathway to capture all associated

19 resource use. We estimated total costs according to the current capacity (current scenario) and

20 three BaS scaling up strategies over a time horizon of 20 years (projected scenario): maximising

21 NHS capacity (strategy 1), maximising NHS and private sector capacity (strategy 2), and adding

22 infrastructure to NHS capacity to cover the entire prevalent and incident obesity populations

23 (strategy 3).

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35 **Setting**

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37 BaS centres based in NHS and private sector hospitals in England.

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41 **Main outcome measures**

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43 Number of BaS procedures (including revision surgery), cost (GBP) and resource utilisation over

44 20 years.

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48 **Results**

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50 At current capacity, the number of BaS procedures and total cost over 20 years were estimated to

51 be 140,220 and £1.4 billion, respectively. For strategy 1, these values were projected to increase

52 to 157,760 and £1.7 billion, respectively. For strategy 2, the values were projected to increase to

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232,760 and £2.5 billion. Strategy 3 showed the highest increase to 564,784 and £6.4 billion, respectively, with an additional 4,081 personnel and 49 facilities required over 20 years.

Conclusions

The expansion of BaS capacity in England beyond a small proportion of the eligible population will likely be challenging given the significant upfront economic investment and additional requirement of personnel and infrastructure.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study estimates the economic investment and resources required to scale-up the capacity of bariatric surgery (BaS) in England.
- The study used the inputs from bariatric surgeons and Key Decision Makers to provide a realistic perspective regarding scaling up BaS in England.
- Sensitivity and scenario analysis were conducted to test the uncertainties around model inputs and assumptions.
- A conservative approach was used in calculating cost inputs and several assumptions were made in cost estimates for scale-up scenarios, such as exclusion of costs related to supplementation, medication, outpatient follow-up, cosmetic surgery.
- The study did not consider the potential change in National Institute for Health and Care Excellence guidelines and change in the landscape of anti-obesity medications over a 20-year time horizon.

INTRODUCTION

Effective obesity treatment can not only improve the health of treated patients but also reduce the economic impact across health systems globally, including in the United Kingdom (UK) (1-4).

Obesity is associated with reduced life expectancy and multiple long-term complications (5). The Health Survey of England 2019 indicated that 28% of adults had obesity (body mass index [BMI] ≥ 30 kg/m²) and 3.3% had severe obesity (BMI ≥ 40 kg/m²) (6). By 2060, the projected prevalence of UK adults who are overweight or have obesity will be 84.8% (7). The current cost of obesity and associated complications for the National Health Service (NHS) is £6.1 billion (around 4% of the total NHS spending on health services in 2022/23 (8)), and for society, £27 billion, which is projected to increase 4-5-fold by 2050 (1). The NHS has established policies that address the growing challenges to obesity treatment provision and access in England (5).

The UK National Institute for Health and Care Excellence (NICE) recommend bariatric surgery (BaS) as the most effective treatment option for the management of severe obesity (9). That includes people with BMI above 40 kg/m², or BMI above 35 kg/m² with obesity-related complications [ORCs], or BMI above 30 kg/m² with recent onset T2DM in specific situations (9). BaS results in significant sustained long-term weight loss beyond 7 years (10-12), improved health (11), and decreased cardiovascular disease, cancer (13-16) and mortality (9, 15, 17). It is the most clinically effective and cost-effective intervention for weight management when compared with no intervention or lifestyle interventions (18-21).

The UK pathway to BaS starts with a general practitioner (GP) assessment, followed by a referral to the primary care specialist weight management clinic (22). Prior to the referral patients must engage with a Tier 3 clinic for weight management for at least 12 months (22). The bariatric dietician at the primary care specialist weight management clinic would support the

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3 patient for lifestyle change over the next 6 months, before they refer the patient to bariatric
4 surgeon (22). The patient then attends a pre-assessment clinic with a bariatric nurse to follow a
5 pre-operative diet, leading to BaS (22).
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10 The immediate cost of BaS in the UK was estimated to be £9.16 million per 1,000 operated
11 population in 2008-2013, with an additional discounted lifetime healthcare cost of £15.26 million
12 (19). However, only an estimated 0.2% of the annual eligible population in England receive BaS,
13 and the number also includes revision operations for complications, poor weight loss, and weight
14 regain (23). Reasons for the low penetration of BaS in the NHS include factors related to the
15 funding and physician preference or attitude towards BaS, or patient preference (24-26). In those
16 accepted for surgery, there remain prolonged waiting times (19, 27, 28) due to limited NHS
17 capacity and prioritisation of other surgical procedures (29).
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29 There is a need to understand the feasibility of scaling up BaS, particularly with the increasing
30 prevalence of obesity (6) and its complications. While there is awareness of the limited capacity
31 of the NHS to address the need for BaS, data on the economic investment required to scale-up
32 BaS are sparse. In line with NHS expansion plans (5), this study aims to estimate the investment
33 and resources required to scale-up NHS capacity for BaS capacity in England. These results will
34 guide healthcare systems and health technology assessment bodies in making informed decisions
35 on scaling up BaS and efficient management of resources to treat obesity.
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46 **METHODS**

47 We used a landscape assessment and a pragmatic literature review to develop a stepwise patient
48 pathway and construct the BaS scale-up model for NHS England. Three experienced bariatric
49 surgeons working in the NHS validated the conceptual framework.
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Model structure

We used a decision-tree approach including four distinct steps of the patient pathway (eligibility assessment, pre-BaS assessment, BaS procedure, and post-BaS follow-up) to capture associated resource use (Figure 1). These steps constitute the standard UK patient pathway and have been previously described by Tako et al (30). We estimated the total costs at current capacity and also over a 20-year time horizon under each of the following BaS scale-up strategies: Strategy 1: maximising NHS capacity: which involved pushing the current capacity to its maximum potential given the current resources and personnel without additional infrastructure or personnel included during scale-up. The additional resource use in terms of personnel time was assumed to be proportional to the increase in capacity with the cost of each additional operation being the same; Strategy 2: maximising current NHS and private sector capacity: in addition to maximising NHS capacity, this strategy involved utilising a proportion of private sector capacity without additional infrastructure/personnel. The cost of surgery in the NHS and private sector was assumed to be equivalent (this is the total cost to society wherein patients are not charged or compensated) and the cost equivalence between NHS and private sector for BaS was assumed i.e., NHS purchases private care at NHS prices; Strategy 3: adding infrastructure to increase the current NHS capacity: in addition to maximising NHS capacity given current resources, this strategy involved building more facilities and adding personnel to increase the current capacity, both of which were assumed to be exclusively dedicated to BaS.

Key assumptions

Based on literature (31) we assumed that all eligible patients required the multidisciplinary team review in the eligibility assessment stage and this was validated by bariatric surgeons. However, not all patients were required to visit all the personnel included in the multidisciplinary team

review (e.g., 100% patients needed the consultation with GP and bariatric surgeons, but only 80% visited an endocrinologist). We considered no cost discounting or inflation. A fixed number of incident cases were added each year to the fixed prevalent patient population. Additionally, we assumed the cost of short-term complications (30 days) were included in the procedure costs, and no additional costs were considered, while long-term complications (occurring at years 1 and 2) were captured in the same year to account for the total costs incurred per patient, as they were expected to be continuous from the previous years. We assumed that 100% of new staff capacity would be focused on BaS in the scale-up strategy and gastric band surgery would be phased out at a constant rate over the next 10 years, as per input from the bariatric surgeons (32).

Model inputs

We obtained all model inputs from published evidence and/or expert opinions from five NHS Key Decision Makers (KDMs). To gather data regarding infrastructure costs and resource utilisation, we held online interviews with the KDMs working in BaS with experience in the setup, management, and expansion of new or current BaS clinics within NHS England. Three NHS bariatric surgeons validated the key model inputs (patient preferences, costs, capacity, and resource use). Population, cost and capacity inputs are described in Table 1a, Table 1b–c and Supplementary Table 1, respectively. Complication rates and healthcare resource utilisation are described in Supplementary Table 2 and 3, respectively. To estimate costs, resource use data were captured during each step of the patient pathway and combined with unit cost information, including all medical personnel involved and the time spent; revision surgery; hospitalisation; outpatient / inpatient visits [frequency and costs]; and monitoring tests [frequency and costs]).

Table 1. Population, cost, and capacity inputs for BaS scale-up model

a) Population inputs

	Model input	Source
Total population (≥ 18 years age)	44,715,345	(33)
Proportion of population eligible for BaS (NICE guidelines)	7.78%	(34)
Obesity incidence rate (annual)	2.97%	(6)
Prevalent population (NICE guidelines eligibility criteria)	3,478,854	(6)
Incident population (annual) (NICE guidelines eligibility criteria)	103,261	(6)
Proportion of eligible population that are estimated to receive BaS*	10.00%	Assumption
Estimated current eligible population size**	347,885	Calculated
Estimated newly eligible population size (annual)***	10,326	

*There are several reasons why a patient may not receive BaS despite being eligible; these include (but are not limited to) patient preference, physician preference/attitude towards BaS, along with costs and waiting lists.

**Calculated using prevalent population keeping proportion of eligible population who receive BaS as 10%.

***Calculated using incident population keeping proportion of eligible population who receive BaS as 10%.

BMI, body mass index; NICE, National Institute for Health and Care Excellence.

b) Cost inputs

Inputs	Source
Cost per procedure for gastric band, sleeve gastrectomy, and gastric bypass*	NHS reference costs (35)
Complication treatment costs (cost per episode for cholecystectomy, abdominal wall hernia operations, banding operations, leakage and abscess, obstruction, stricture, gastric ulcer)	
Cosmetic surgery cost	Excluded from cost inputs
Cost per episode for gastric ulcer (included 8-week antibiotics treatment, one GP visit, and one diagnostic test)	NHS reference costs (35)
Infrastructure costs for BaS scale-up (small- and large scale facilities): <ul style="list-style-type: none"> Number of BaS procedures per year (facility capacity) Cost of setting up facility Time required to set up the facility (in years) Time required for facility to be fully functional (in years) 	PMR KDMs' interviews**

*All the resource costs incurred at every stage of the patient pathway were assumed to be included in the procedure for all eligible costs patients.
**Data from the PMR report are described in Supplementary Table 1.
Among five KDMs, three were head of the departments (gastroenterologist, two were the lead for BaS), one was C-level executives/board member of a hospital and one was the director of procurement.
BaS, bariatric surgery; NHS, National Health Service; KDMs, key decision makers, PMR, primary market research.

c) Capacity inputs

Inputs	Source
Current annual capacity (number of BaS) for NHS and private sector*	(36), PMR KDMs' interviews**
Maximum potential annual capacity	PMR KDMs' interviews**
Current BaS distribution by procedure type (gastric band, sleeve gastrectomy and gastric bypass) for 2013–2018	(37)
BaS distribution by procedure type (for scale-up strategy)***	Inputs from bariatric surgeons**

*2018–2019 data are included; 2020–2022 data are excluded, since numbers were underrepresented due to COVID-19 pandemic.
**Data from PMR report are described in Supplementary Table 1.
***Based on bariatric surgeons' opinion that the gastric band procedure is the least effective BaS and is assumed to be gradually phased out in next 10 years.
Among five KDMs, three were head of the departments (gastroenterologist, two were the lead for BaS), one was C-level executives/board member of a hospital and one was the director of procurement.
BaS, bariatric surgery; NHS, National Health Service; KDMs, key decision makers; PMR, primary market research.

Analyses

Base-case analysis

We selected the eligible population (incident and prevalent) as per the NICE guidelines' eligibility criteria. We estimated the proportion of the eligible population receiving BaS to be 10% (based on expert opinion and an Office of Health Economics study (38)) and we used this in the base-case for all three scale-up strategies. We considered a 20-year time horizon appropriate for achieving the target BaS capacity and eligible population.

Scenario and sensitivity analysis

We only conducted scenario and sensitivity analyses for strategy 3 as it is more flexible to cover a greater proportion of the eligible patient population.

Scenario analysis

We performed scenario analyses and one-way sensitivity analysis (OWSA) to test the model robustness and identify model drivers. Scenario 1 included different proportions (5%, 25%, and 100%) of the eligible population over a 20-year time horizon. Scenario 2 assessed the distribution of gastric bypass procedure. Scenario 3 evaluated the impact of change in the eligible population (population with BMI ≥ 40 kg/m²).

One-way sensitivity analysis

We adjusted input model parameters by 20% of their default value to evaluate the robustness of the results and the influence of individual parameters. The uncertainty in assumptions/inputs was captured as lower and upper bounds and displayed in a tornado diagram.

Ethics approval

Ethics approval was not needed for this study since this was a modelling-based study.

Patient and public involvement

None.

RESULTS

Base-case analysis

The prevalent and annual incident targeted eligible population sizes were estimated at 347,885 and 10,326, respectively. The total targeted eligible population size over 20 years was estimated at 554,405. With the current capacity in NHS England, the total number of BaS procedures (including revision surgery) were estimated to be 140,220 (revision surgeries: 2,474) over 20 years, which is significantly smaller than the estimated total population size. The associated annual and overall costs were £70.6 million and £1.4 billion, respectively. We calculated the BaS backlog as the combination of ‘current eligible population’ and ‘newly eligible population’ added each year and it was estimated to be 424,143 over 20 years. The outcomes of the base-case analysis for all three strategies are described (Table 2). Detailed results on the cost breakdown associated with the procedure and the complications are described in Supplementary materials, as well as the cost versus capacity over 20 years for the current and projected scenarios.

Strategy 1: Maximising current NHS capacity

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 157,760 (revision surgeries: 2,867; incremental: 17,540 BaS). This was calculated as the maximum potential NHS capacity (i.e., number of BaS completed annually) multiplied by the time horizon i.e., 20 years. The maximum potential capacity was taken as 12.5% more than the current capacity (KDMs’ inputs). The projections estimated the largest increment for gastric bypass (22,362), followed by sleeve gastrectomy (5,758). The number of gastric band operations was projected to decrease from 15,889 to 4,915 (incremental: -10,974). The total annual cost was projected to increase to £83.7 million, and the overall total cost was estimated to increase to £1.7 billion (Supplementary Table 4). Supplementary Figure 1 illustrates the total costs compared to capacity in both current and projected scenarios. Scaling up with

strategy 1 would reduce the backlog to 407,023 over 20 years (Table 2 and Supplementary Figure 2).

Strategy 2: Maximising current private sector and NHS capacity

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 232,760 (revision surgeries: 4,229; incremental: 92,540 BaS). This was calculated as the maximum potential NHS capacity and the potential increase in private sector capacity utilised by the NHS multiplied by the time horizon. The maximum potential capacity was taken as 12.5% more than the current based on expert inputs, and the potential additional capacity from the private sector utilised by the public was assumed to be 25%. The projections estimated the largest increment for gastric bypass (56,245), followed by sleeve gastrectomy (43,176). The number of gastric band operations was projected to decrease from 15,889 to 7,251 (incremental: -8,637). The total annual cost was projected to increase to £123.5 million, and the overall total cost was estimated to increase to £2.5 billion over 20 years (Supplementary Table 5). Scaling up would reduce the backlog to 332,023 (Table 2).

Strategy 3: Adding infrastructure to increase current NHS capacity

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase to 564,784 (revision operations: 10,295; incremental: 424,563 BaS). In this strategy, this number was estimated after adding the infrastructure to cover the entire prevalent and incident population over 20 years. The projections estimated the largest increment for gastric bypass surgery (212,499), followed by sleeve gastrectomy (207,528). The number of gastric band operations was projected to decrease from 15,889 to 12,603 (incremental: -3,286).

Additionally, the number of revision operations was projected to increase from 2,474 to 10,295 over the next 20 years, and the highest incremental component was represented by gastric bypass

(5,859). The total annual cost was projected to increase to £319.4 million. The overall total cost was projected to increase to £6.4 billion over 20 years. The incremental cost related to BaS procedure costs represented the largest component, amounting to 85.6% of the total cost (incremental value of £4.3 billion). This was followed by the infrastructure cost of the BaS scale-up, with an incremental value of £362.5 million. Incremental costs related to complications, personnel (post-BaS follow-up), and revision surgery represented only a small fraction of total costs, amounting to incremental values of £246.6 million, £81.6 million, and £24.8 million, respectively (Supplementary Table 6). Scaling up would reduce the backlog to zero over 20 years, considering the proportion of the eligible patient population estimated to receive BaS was 10% (Table 2).

BaS scale-up over 20 years would require an additional 49 facilities and 4,081 personnel, the majority of whom would be nurses, healthcare assistants/healthcare service workers, anaesthetists, and surgeons.

Table 2. Base-case analysis: Incremental values over 20 years*

	Strategy 1: Maximising current NHS capacity	Strategy 2: Maximising current NHS and private sector capacity	Strategy 3: Adding infrastructure to increase current NHS capacity
Number of BaS procedures (n)	17,147	90,784	416,742
Gastric band	-10,974	-8,637	-3,286
Sleeve gastrectomy	5,758	43,176	207,528
Gastric bypass	22,362	56,245	212,499
BaS backlog (n)			
Current	424,143	424,143	424,143
Projected	407,023	332,023	0
Cost breakdown			

Infrastructure costs of BaS scale-up	£0	£0	£362,500,000
Number of additional facilities needed - Small scale facility	N/A	N/A	1
Number of additional facilities needed - Large scale facility	N/A	N/A	48
Procedure costs	£238,217,988	£974,230,140	£4,261,177,612
Gastric band	-£57,616,922	-£45,349,121	-£17,250,674
Sleeve gastrectomy	£55,291,672	£414,570,055	£1,992,636,562
Gastric bypass	£240,543,238	£605,009,206	£2,285,791,723
Revision surgery–Gastric band	-£204,198	-£160,720	-£61,137
Revision surgery–Sleeve gastrectomy	£237,606	£1,781,543	£8,563,008
Revision surgery–Gastric bypass	£1,710,880	£4,303,170	£16,257,852
Personnel costs–Post-BaS follow-up	£3,385,898	£17,924,406	£81,597,599
Complication costs	£19,539,294	£60,590,462	£246,629,873
Gastric band	-£2,991,137	-£2,354,264	-£895,555
Sleeve gastrectomy	£1,259,693	£9,445,023	£45,397,631
Gastric bypass	£21,270,737	£53,499,703	£202,127,798
Total–20 years	£262,887,469	£1,058,669,001	£4,976,664,806
Total–Annual*	£13,144,373	£52,933,450	£248,833,240

BaS, bariatric surgery; N/A, not applicable; *all the incremental values are represented for 20-year time horizon, except the total annual cost.

Scenario analysis

In scenario 1, as the proportion of eligible population receiving BaS were varied from 5% to 100%, the target population size, the number of BaS procedures, and the total costs also varied significantly. For instance, at 100% coverage, the total number of BaS was estimated at

5,647,832, and the total 20-year costs were projected to increase to £65.2 billion. In Scenario 2, achieving 100% distribution of gastric bypass over 10 years resulted in an increase in the number of BaS procedures to 569,693 and total 20-year costs to £6.8 billion. In scenario 3, with 10% of the eligible population with BMI \geq 40 kg/m² receiving BaS, the overall total cost was projected to increase from £1.4 billion to £2.4 billion over 20 years, which is considerably lower than the base case value.

Table 3 presents summary results of the scenarios, and detailed results for these scenarios are described in Supplementary text 1.

Table 3. Scenario analysis

Base-case/Scenarios	Number of BaS (including revision surgery)	Total 20-year costs for current scenario (in billions)	Total 20-year costs for projected scenario (in billions)	Incremental (in billions)
Base-case: Strategy 3	564,784	£1.4	£6.4	£5.0
Proportion of eligible population who would receive BaS: 5%	282,371	£1.4	£3.1	£1.7
Proportion of eligible population who would receive BaS: 25%	1,411,958	£1.4	£16.2	£14.8
Proportion of eligible population who would receive BaS: 100%	5,647,832	£1.4	£65.2	£63.8
Distribution of BaS by type of procedure: Gastric bypass surgery: 100%	569,693	£1.4	£6.8	£5.4
Eligible population with BMI \geq 40 kg/m ²	234,474	£1.4	£2.4	£1.0

*10-year cost.
BaS, bariatric surgery; UK, United Kingdom.

One-way sensitivity analysis

The OWSA results indicate that the model was most sensitive to patient preference for BaS, the proportion of the population eligible for BaS (NICE guidelines), and the cost per procedure for gastric bypass and sleeve gastrectomy (Supplementary Figure 3). The OWSA demonstrated the robustness of the model even with $\pm 20\%$ variation in the majority of input parameter values.

DISCUSSION

To our knowledge, this is the first study to evaluate the required investment of scaling up BaS to address the unmet needs in the NHS. This study demonstrated that scaling up BaS to treat obesity will be challenging due to the need for further investment; even within the context of only 5% to 10% of the eligible population modelled to receive BaS. Based on the model estimates, the economic investment required to scale-up BaS capacity by 12.5% to maximise the current NHS England capacity, without scaling up the infrastructure and personnel was estimated to require an incremental cost of £13.7 million/year, with a capacity to conduct an additional 17K operations over 20 years, reducing the backlog to approximately 407K over a 20-year time horizon. Another strategy to maximise BaS use in NHS and private sectors, increased the capacity by an additional 91K operations over 20 years and increased the total annual cost by £52.9 million, which reduced the backlog to 332K operations. The third strategy, maximising NHS capacity, along with the addition of infrastructure and personnel, aimed to provide BaS to the whole target population and resolve the backlog, which supported an additional 417K surgeries over 20 years with an additional budget of £248.8 million/year. The total 20-year incremental costs to NHS England were estimated at £5 billion, including £4.3 billion for procedures, £363 million for infrastructure, and £247 million for 4,081 additional personnel.

All these strategies require significant investment, especially if BaS were to be used as the sole treatment strategy to address the needs for the eligible population. However, there is no single treatment strategy that will address all the demands of the high prevalence of obesity and its impact on health and economics.

To reduce obesity prevalence and its health consequences will require expansion of all treatment strategies combined with a system-wide, holistic and multifaceted approach to obesity, combining prevention with treatment strategies (9).

Although scaling up the capacity of BaS to cover 10% of those eligible may be unrealistic from an investment perspective, base-case Strategy 1 appears more achievable in terms of economic investment, despite the reduction in backlog being relatively minimal. The data suggest that Strategy 3 is most beneficial in covering the eligible population that opts for BaS, considering an estimated 10% of the population will receive BaS out of a total eligible population of 5.5 million. However, the feasibility of such substantial economic investment cannot be predicted (estimation of £5 billion) over a 20-year time horizon, despite the well-established cost-effectiveness of BaS (38). The required investment for Strategy 3 is likely to be significantly offset by the economic benefits achieved by the reduction in incidence/severity of ORCs in these patients. The economic benefits associated with BaS have been estimated at £1.25 billion over a three-year period for 25% of the eligible population opting for BaS (38). These benefits were primarily related to additional paid work generated after BaS and potential reduction in disability benefits (38). In addition, Strategy 3, which involves the addition of personnel, may considerably reduce waiting times, as indicated by a simulation study, where the addition of three surgeons and two physicians to a UK healthcare centre reduced waiting times by five weeks (30).

In the scenario analysis, varying the proportion of the eligible population receiving BaS from 10% to 5%, 25%, and 100% proportionally increased the budget from £1.4 billion to £3.1 billion, £16.2 billion, and £65.2 billion, respectively. This is in line with a prior study which suggested that the economic impact increased in tandem with the proportion of the eligible population that would undergo surgery (38). Our study also assessed the impact on model results with increasing incidence rate of obesity. This further corroborates the need for the NHS to evaluate the significance of BaS in the management of severe and complex obesity. Additionally, the economic estimate of this study is based on 10% of the eligible population receiving BaS, therefore at least 90% of the eligible population will require alternative intervention.

Our model suggests that a preference for performing only gastric bypass will require a larger investment than performing sleeve gastrectomy over the course of 20 years (£6.8 billion versus £6.0 billion, respectively). This could be partially explained by its association with higher complication rates (37) and no increase in patients' return to work (39). However, our study only takes a limited economic and resource perspective on the selection of the most appropriate operation type; any NHS prioritisation should also account for surgery efficacy, complication rates, and cost-effectiveness. This study will also assist other healthcare systems around the world facing similar challenges.

It is important to acknowledge the limitations of our study. Firstly, several assumptions were made in the cost estimates for scale-up scenarios, and the model took a conservative approach with respect to costs; certain elements such as training costs, nutritional supplements and medication costs, outpatient hospitalisation during follow-up, and additional follow-up costs in special population such as pregnant women, diabetes, etc were not included. Secondly, the model didn't include cost offsets associated with long-term benefits of BaS to the overall NHS budget

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e.g. reduction in diabetes and other obesity related co-morbidities, maternal BaS related reduction in obesity in offspring (40), etc.. Thirdly, the model assumed long-term complications only up to 2 years due to limited data availability (41). Although wide range of prevalence data related to long-term complications is available, data related to their associated costs to the health care system is limited. This is in line with similar assumptions made by previous studies evaluating cost-effectiveness of BaS (31, 42-44). In addition, the model did not include the cost of cosmetic/plastic surgery. Although, cosmetic surgery can have a significant impact on the patients' well-being with respect to psycho-social recovery and improved maintenance of weight loss, funding for this in the NHS is extremely rare (45, 46). Furthermore, a conservative approach was used in calculating cost inputs (e.g., a cost-minimisation approach was used to calculate the number of new facilities required); of note, full efficiency was assumed for personnel in the projected scenario, while no delays in setting up new facilities and becoming fully functional were included in the model. This conservative estimate suggests that the required investment could be much higher than the current estimate. This could be further corroborated by additional eligibility criteria for BaS as per the new NICE guidelines 2023 (9), including patients agreeing to long-term follow-up after surgery and the inclusion of other ethnicities (South Asian, Chinese, etc) with a lower BMI threshold (9). It is also important to consider that over a 20-year time horizon, there could be further changes in the current NICE guidelines to lower the BMI eligibility criteria to include populations with a BMI >35 kg/m² without comorbidities, according to the recent updates in IFSO and American Society for Metabolic and Bariatric Surgery guidelines (47). This would further increase the size of the eligible population, thereby impacting economic investment and the backlog. In addition, there is uncertainty regarding the future landscape of anti-obesity medications (AOMs) over next 20 years, which could offer an effective

way of managing obesity. Although the AOM prices could fall beyond a certain period, they could still be more expensive than BaS over long-term. Hence it is too complex to capture AOMs costs in this study and considering the model base case assumes only 10% of eligible patients receive BaS, the remaining patients would still require other interventions to manage obesity. Additionally, this modelling-based study should also be supported by the real time measurement of investment by NHS and resource use in future.

Our study has several strengths including being one of the first in the UK to estimate the economic investment and resources required to scale-up the capacity of BaS in England. We used inputs from bariatric surgeons and KDMs regarding scaling up BaS in England to provide a realistic perspective. Additionally, inputs and patient pathway design/assumptions were validated to reflect the real-world scenario. We also conducted sensitivity and scenario analysis to test the uncertainties in model inputs and assumptions.

CONCLUSION

We have presented several approaches to expand BaS capacity in NHS England based on available investment funding. Realistically, expansion beyond a small proportion of the eligible cohort will be challenging given the significant upfront economic investment and additional requirements of infrastructure and personnel. Therefore, in order to meet the demands of increasing prevalence of obesity and its complications, multiple treatment approaches will be needed in addition to BaS, and scalable treatment options will be required.

COMPETING INTERESTS

James Baker-Knight and Abd Tahrani are current employees of Novo Nordisk and hold shares in the company. Dimitri J Pournaras has been funded by the Royal College of Surgeons of England. He receives consulting fees from Johnson & Johnson, GSK, Pfizer and Novo Nordisk and payments for lectures, presentations, and educational events from Johnson & Johnson, Medtronic, and Novo Nordisk. Kamal Mahawar has been paid honoraria for educational activities related to bariatric surgery by various corporate organisations and NHS Trusts. Richard Welbourn has no competing interests to declare. Yuxin Li, Yuvraj Sharma and Ines Guerra are employees of IQVIA and have received consulting fees from Novo Nordisk.

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Novo Nordisk A/S (grant no: NA).

CONTRIBUTORS

Conception/design: James Baker-Knight, Yuxin Li, Yuvraj Sharma, Abd Tahrani. Analysis and interpretation of data: Yuxin Li, Yuvraj Sharma, Ines Guerra. First draft of the manuscript: Yuxin Li, Yuvraj Sharma. Manuscript revision and approval: James Baker-Knight, Yuxin Li, Yuvraj Sharma, Ines Guerra, Dimitri J Pournaras, Kamal Mahawar, Richard Welbourn, Abd Tahrani.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article or uploaded as supplemental information.

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FIGURE TITLE/LEGEND

Figure 1. Patient pathway for BaS scale-up model

The figure represents the patient pathway applied in the analysis, comprising four distinct steps (shown in separate blocks): eligibility assessment, pre-BaS assessment, BaS procedure, and post-BaS follow-up. BaS, bariatric surgery; GP, general practitioner; WM, weight management.

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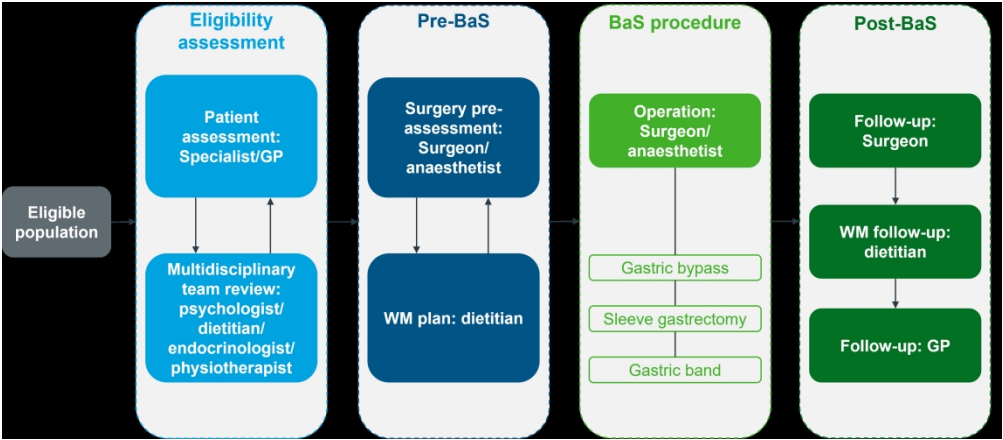


Figure 1: Patient pathway for BaS scale-up model

Figure 1 represents the patient pathway applied in the analysis, comprising four distinct steps (shown in separate blocks): eligibility assessment, pre-BaS assessment, BaS procedure, and post-BaS follow-up.

301x131mm (300 x 300 DPI)

SUPPLEMENTARY INFORMATION

Supplementary Table 1: Results from PMR report

Input parameter			Input value
Cost inputs	Infrastructure costs for BaS scale-up (small scale facilities)	Facility capacity (number of BaS per year)	150.00
		Cost of setting up a facility	£2,500,000.00
		Time required for setting up a facility (in years)	1.00
		Time required for the facility to be fully functional (in years)	0.00
	Infrastructure costs for BaS scale-up (large scale facilities)	Facility capacity (number of BaS per year)	500.00
		Cost of setting up a facility	£7,500,000.00
		Time required for setting up a facility (in years)	3.00
		Time required for the facility to be fully functional (in years)	0.00
		Number of BaS per year (facility capacity)	500.00
	Capacity inputs	Current annual capacity (number of BaS)	NHS
Private sector			15,000
Maximum potential annual capacity		NHS	7,888
		Private sector	18,750
BaS distribution by procedure type (for scale-up strategy)		Gastric band	0.00%
		Sleeve gastrectomy	50.00%
		Gastric bypass	50.00%
Eligibility assessment stage	Number of personnel visits	GP	1.00
		Psychologist	1.50
		Dietitian	1.00
		Endocrinologist	1.00
		Physiotherapist	1.00
	Personnel time per visit (in mins)	GP	30.00
		Psychologist	60.00
		Dietitian	30.00
		Endocrinologist	30.00
		Physiotherapist	45.00

	Proportion of population requiring personnel visits/monitoring	GP	100.00%
		Psychologist	100.00%
		Dietitian	100.00%
		Endocrinologist	80.00%
		Physiotherapist	100.00%
		Blood test	100.00%
		ECG	100.00%
Pre-BaS stage	Personnel time per visit (in mins)	Surgeon	30.00
		Dietitian	45.00
		Anaesthetist	30.00
Post-BaS follow-up	Follow-up visits (up to 24 months post-BaS)	Nurse	4.00
		Surgeon	1.00
		Dietitian	3.00
		GP	0.00
	Follow-up visits (24 to 48 months post-BaS)	Nurse	0.00
		Surgeon	0.00
		Dietitian	0.00
		GP	4.00
	Personnel time per visit (in mins)	Nurse	10.00
		Surgeon	10.00
		Dietitian	10.00
		GP	10.00
Resource utilisation	Number of working hours per personnel (annual)	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	2160 each*
	Proportion of time spent on BaS (Current scenario)	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	50% each
	Proportion of time spent on BaS for new personnel added in scale-up scenario	(GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	100% each

*based on 48-hour work week for 45 weeks per year.

BaS, bariatric surgery; ECG, electrocardiogram; GP, general physician; PMR, primary market research

Supplementary Table 2: Complication rates

Short-term complications (30 days)				Source
Complication rate (proportion of patient population)	Gastric band	Sleeve gastrectomy	Gastric bypass	(36)
Bleed	0.00%	13.00%	18.90%	
Obstruction	0.00%	0.00%	8.70%	
Leak	7.40%	0.00%	6.60%	
Revision surgery	2.20%	0.20%	1.30%	
Long-term complications				(31)
Complication rate (proportion of patient population)	Gastric band	Sleeve gastrectomy	Gastric bypass	
Cholecystectomy, 1-year	1.00%	0.00%	1.55%	
Cholecystectomy, 2-year	0.00%	0.00%	1.93%	
Abdominal wall hernia operations, 1-year	0.50%	1.90%	0.88%	
Abdominal wall hernia operations, 2-year	3.10%	0.00%	1.22%	
Banding operations, 1-year	0.00%	0.00%	3.60%	
Banding operations, 2-year	0.00%	0.00%	7.10%	
Plastic operations, 1-year	0.00%	0.00%	0.41%	
Plastic operations, 2-year	0.80%	6.30%	5.04%	
Leakage and abscess, 1-year	0.00%	0.19%	0.19%	
Leakage and abscess, 2-year	0.00%	0.14%	0.14%	
Obstruction, 1-year	0.00%	1.74%	1.74%	
Obstruction, 2-year	0.00%	3.31%	3.31%	
Stricture, 1-year	0.00%	0.22%	0.22%	
Stricture, 2-year	0.00%	0.11%	0.11%	
Gastric ulcer, 1-year	1.05%	1.05%	1.05%	
Gastric ulcer, 2-year	0.95%	0.95%	0.95%	
Cholecystectomy 1-year, revision surgery	1.40%	1.40%	1.40%	
Cholecystectomy 2-year, revision surgery	0.70%	0.70%	0.70%	
Hernia operations 1-year, revision surgery	4.55%	4.55%	4.55%	
Hernia operations 2-year, revision surgery	5.18%	5.18%	5.18%	
Plastic operations 1-year, revision surgery	1.30%	1.30%	1.30%	
Plastic operations 2-year, revision surgery	3.40%	3.40%	3.40%	
Other complications 1-year, revision surgery	7.40%	7.40%	7.40%	
Other complications 2-year, revision surgery	5.50%	5.50%	5.50%	

Supplementary Table 3: Healthcare resource utilisation

Input	Source
Eligibility assessment stage*	
Number of personnel visits	Expert inputs**, (31)
Personnel time per visit (in mins)	Expert inputs**
Monitoring frequency (blood test, ECG)	(31)
Proportion of population requiring personnel visits/monitoring	Expert inputs**, (31)
Pre-BaS stage*	
Number of personnel visits	(31)
Personnel time per visit (in mins)	Expert inputs**
Proportion of population requiring personnel	(31)
BaS procedure	
Time spent (in mins)—gastric band/sleeve gastrectomy/ gastric bypass (surgeon, registrar surgery, anaesthetist, registrar / trainee anaesthesiology, nurses, operating department practitioner, healthcare assistant/healthcare service worker, operation theatre)	(40)
Hospital stays (number of days) (gastric band, sleeve gastrectomy, gastric bypass)	(31)
Post-BaS follow-up*	
Follow-up visits (up to 24 months post-BaS, 24 to 48 months post-BaS)	Expert inputs**, (31)
Personnel time per visit (in mins)	Assumption, validated through PMR QoL interviews Mar 2023**
Resource utilisation	
Number of working hours per personnel (annual) (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption (based on 48-hour work week for 45 weeks per year)**
Proportion of time spent on BaS (current scenario) (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption**
Proportion of time spent on BaS for new personnel added in scale-up scenario (GP, psychologist, dietitian, endocrinologist, physiotherapist, surgeon, anaesthetist, registrar surgery, registrar/trainee anaesthesiology, operating department practitioner, healthcare assistant/healthcare service worker, nurse)	Assumption**

*Refer to Figure 1 for information on the personnel involved.

**Data from PMR report are described in Supplementary Table 1.

BaS, bariatric surgery; ECG, electrocardiogram; GP, general physician; PMR, primary market research

Supplementary Table 4: Base-case results for scenario of maximising current NHS capacity

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	4,915	-10,974
Sleeve gastrectomy	72,949	78,707	5,758
Gastric bypass	48,909	71,271	22,362
Total	137,746	154,893	17,147
Revision surgery–Gastric band	406	126	-280
Revision surgery–Sleeve gastrectomy	719	776	57
Revision surgery–Gastric bypass	1,349	1,965	617
Total	2,474	2,867	393
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£0	£0
Procedure costs	£1,309,959,040	£1,548,177,028	£238,217,988
Gastric band	£83,421,834	£25,804,911	-£57,616,922
Sleeve gastrectomy	£700,438,431	£755,730,103	£55,291,672
Gastric bypass	£526,098,776	£766,642,014	£240,543,238
Revision surgery–Gastric band	£295,652	£91,454	-£204,198
Revision surgery–Sleeve gastrectomy	£3,010,012	£3,247,618	£237,606
Revision surgery–Gastric bypass	£3,741,914	£5,452,794	£1,710,880
Revision surgery costs	£7,047,578	£8,791,867	£1,744,289
Personnel costs–Post-BaS follow-up	£27,195,369	£30,581,267	£3,385,898
Complication costs	£66,810,472	£86,349,765	£19,539,294
Gastric band	£4,330,778	£1,339,642	-£2,991,137
Sleeve gastrectomy	£15,957,875	£17,217,568	£1,259,693
Gastric bypass	£46,521,818	£67,792,555	£21,270,737
Total–20 years	£1,411,012,459	£1,673,899,928	£262,887,469
Total–Annual	£70,550,623	£83,694,996	£13,144,373

BaS, bariatric surgery

Supplementary Table 5: Base-case results for scenario of maximising current NHS and private sector capacity

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	7,251	-8,637
Sleeve gastrectomy	72,949	116,125	43,176
Gastric bypass	48,909	105,154	56,245
Total	137,746	228,531	90,784
Revision surgery - Gastric band	406	185	-221
Revision surgery - Sleeve gastrectomy	719	1,145	426
Revision surgery - Gastric bypass	1,349	2,899	1,551
Total	2,474	4,229	1,756
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£0	£0
Procedure costs	£1,309,959,040	£2,284,189,181	£974,230,140
Gastric band	£83,421,834	£38,072,713	-£45,349,121
Sleeve gastrectomy	£700,438,431	£1,115,008,486	£414,570,055
Gastric bypass	£526,098,776	£1,131,107,982	£605,009,206
Revision surgery–Gastric band	£295,652	£134,932	-£160,720
Revision surgery–Sleeve gastrectomy	£3,010,012	£4,791,554	£1,781,543
Revision surgery–Gastric bypass	£3,741,914	£8,045,084	£4,303,170
Revision surgery costs	£7,047,578	£12,971,570	£5,923,992
Personnel costs–Post-BaS follow-up	£27,195,369	£45,119,775	£17,924,406
Complication costs	£66,810,472	£127,400,934	£60,590,462
Gastric band	£4,330,778	£1,976,515	-£2,354,264
Sleeve gastrectomy	£15,957,875	£25,402,898	£9,445,023
Gastric bypass	£46,521,818	£100,021,521	£53,499,703
Total–20 years	£1,411,012,459	£2,469,681,460	£1,058,669,001
Total–Annual	£70,550,623	£123,484,073	£52,933,450

BaS, bariatric surgery

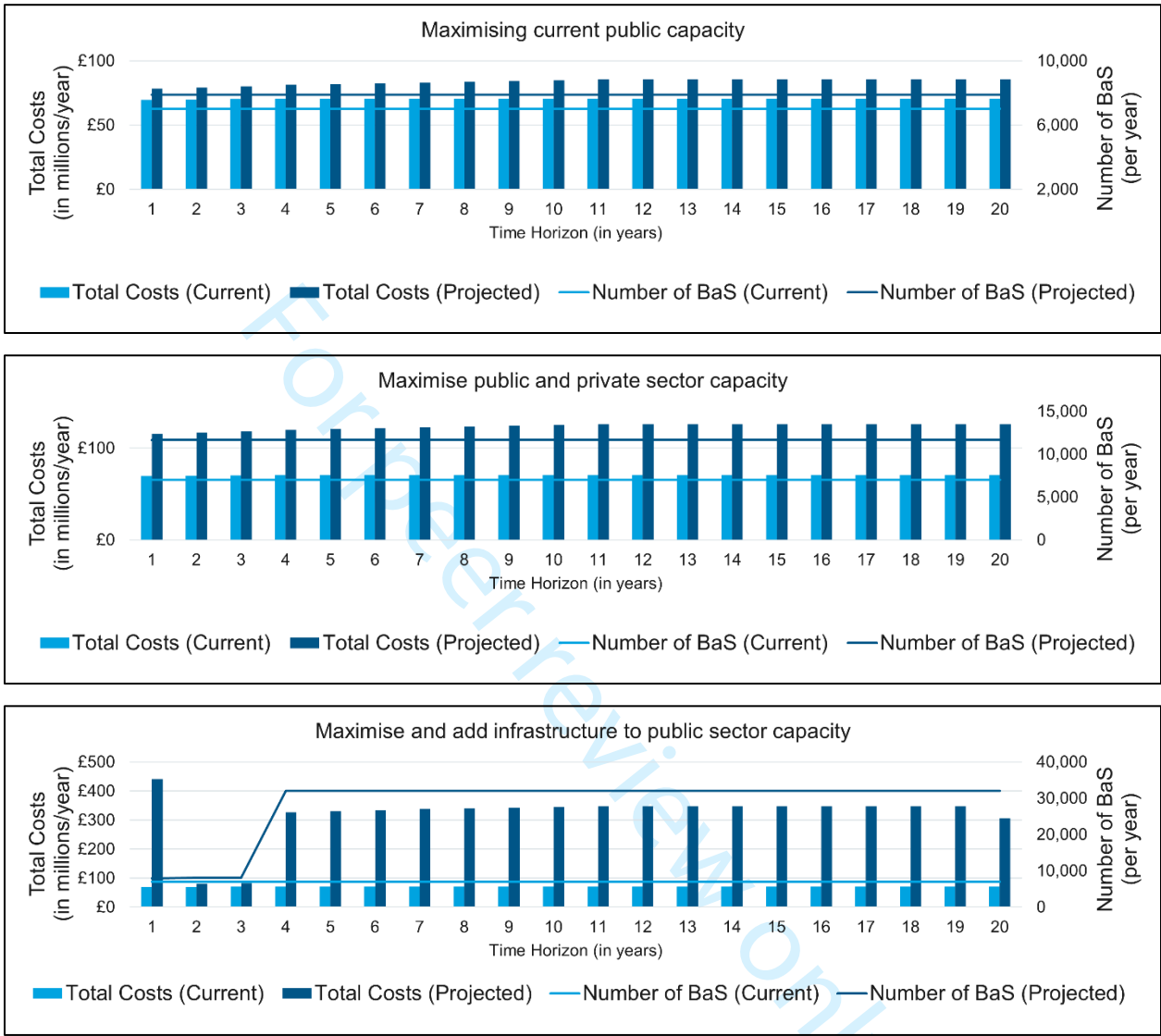
Supplementary Table 6: Base-case results for scenario of maximising current NHS capacity and adding the infrastructure

	Current scenario	Projected scenario	Incremental
Number of BaS procedures (n)			
Gastric band	15,889	12,603	-3,286
Sleeve gastrectomy	72,949	280,477	207,528
Gastric bypass	48,909	261,408	212,499

Total	137,746	554,489	416,742
Revision surgery–Gastric band	406	322	-84
Revision surgery–Sleeve gastrectomy	719	2,765	2,046
Revision surgery–Gastric bypass	1,349	7,207	5,859
Total	2,474	10,295	7,821
Cost breakdown			
Infrastructure costs of BaS scale-up	£0	£362,500,000	£362,500,000
Procedure costs	£1,309,959,040	£5,571,136,652	£4,261,177,612
Gastric band	£83,421,834	£66,171,160	-£17,250,674
Sleeve gastrectomy	£700,438,431	£2,693,074,993	£1,992,636,562
Gastric bypass	£526,098,776	£2,811,890,500	£2,285,791,723
Revision surgery–Gastric band	£295,652	£234,514	-£61,137
Revision surgery–Sleeve gastrectomy	£3,010,012	£11,573,020	£8,563,008
Revision surgery–Gastric bypass	£3,741,914	£19,999,766	£16,257,852
Revision surgery costs	£7,047,578	£31,807,300	£24,759,722
Personnel costs–Post-BaS follow-up	£27,195,369	£108,792,968	£81,597,599
Complication costs	£66,810,472	£313,440,345	£246,629,873
Gastric band	£4,330,778	£3,435,223	-£895,555
Sleeve gastrectomy	£15,957,875	£61,355,506	£45,397,631
Gastric bypass	£46,521,818	£248,649,616	£202,127,798
Total–20 years	£1,411,012,459	£6,387,677,265	£4,976,664,806
Total–Annual	£70,550,623	£319,383,863	£248,833,240
Number of personnel required			
GP	139	337	198
Mental health professional	192	469	277
Dietitian	222	544	322
Endocrinologist	52	126	74
Physiotherapist	96	235	139
Surgeon	265	668	403
Anaesthetist	275	693	418
Registrar surgery	192	494	302
Registrar/Trainee anaesthesiology	197	523	326
Operating department practitioner	218	552	334
Healthcare assistant/Healthcare service worker	371	953	582
Nurse	464	1170	706
Total	2683	6764	4081

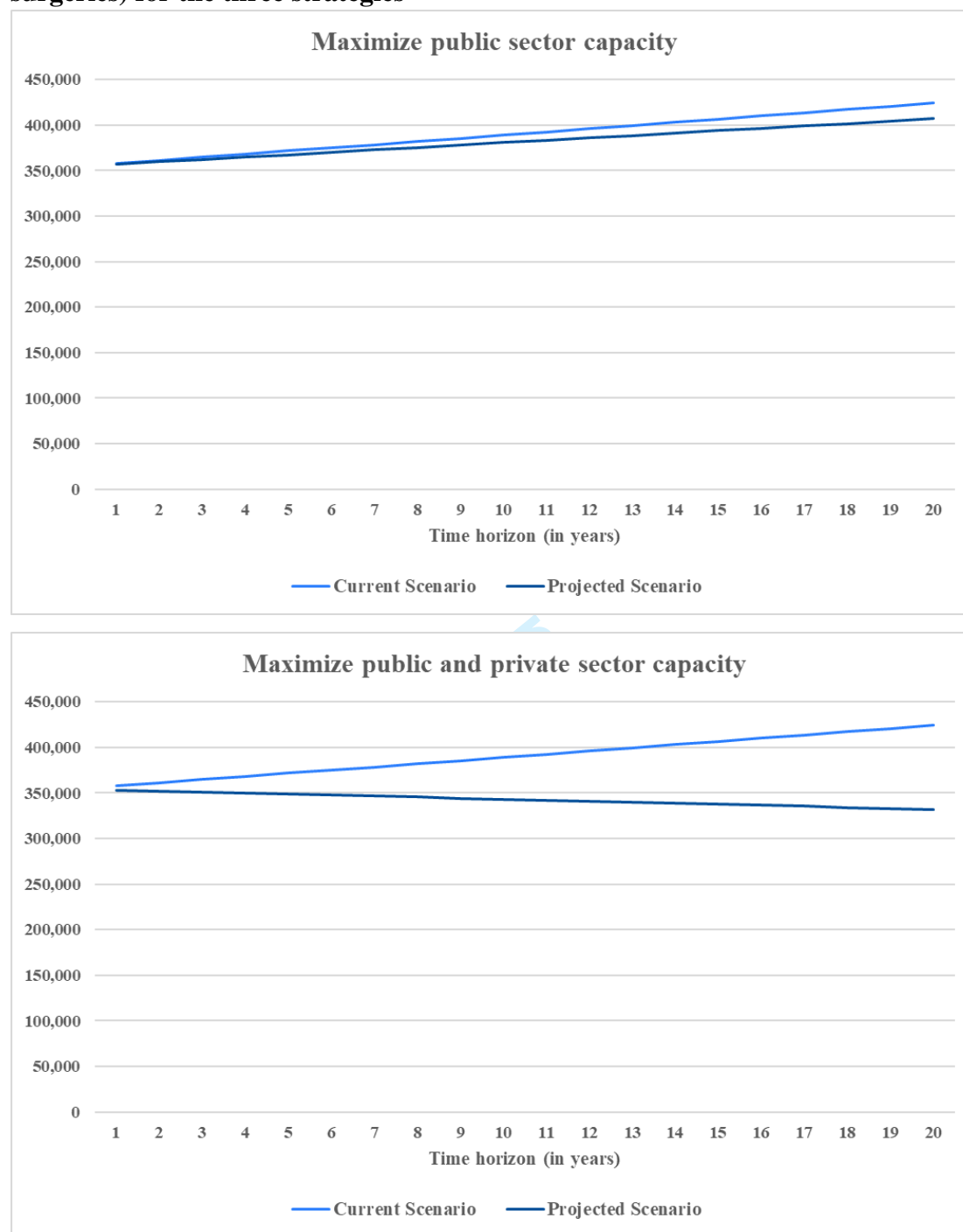
BaS, bariatric surgery, GP, general physician

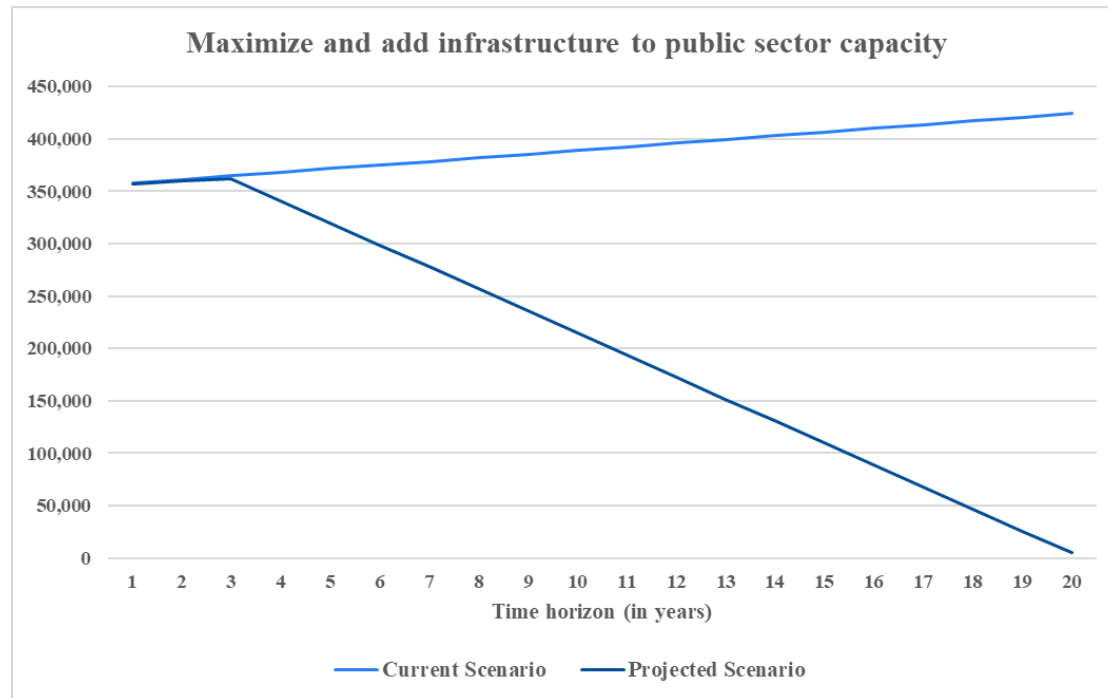
Supplementary Figure 1: Cost versus capacity over time for the three strategies



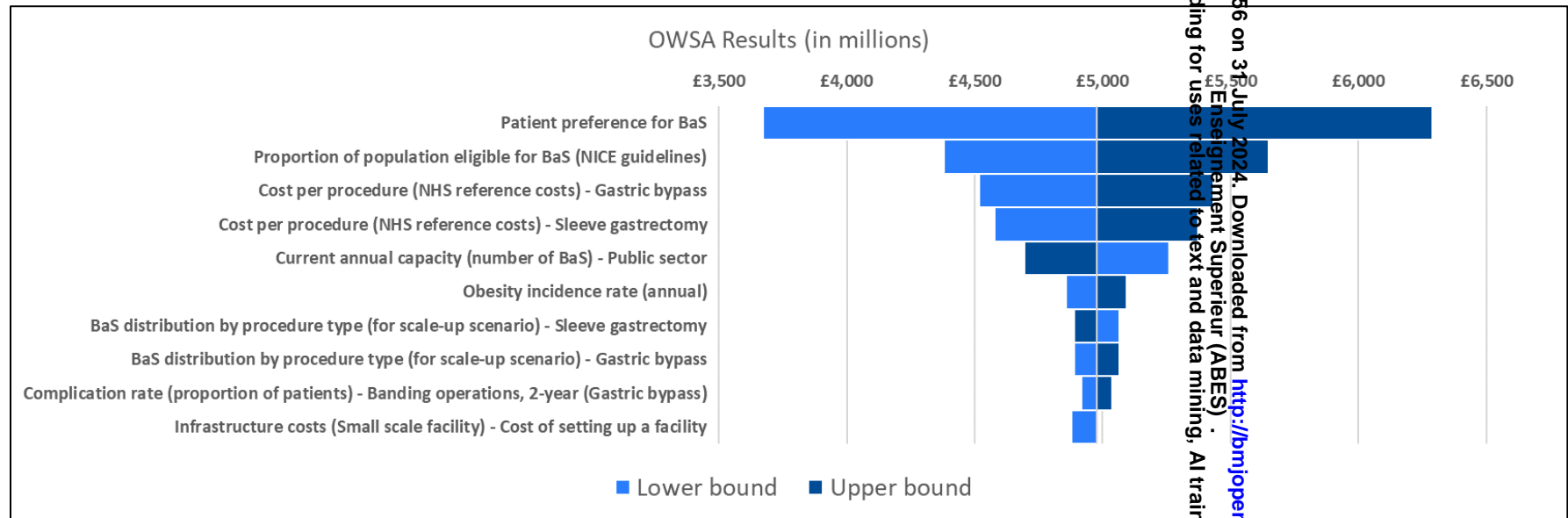
BaS, bariatric surgery

Supplementary Figure 2: BaS Backlog (number of BaS needed including revision surgeries) for the three strategies





Supplementary Figure 3: One-way sensitivity analysis



BaS, bariatric surgery; NHS, National Health Service; NICE, National Institute for Health and Care Excellence; OWSA, one-way sensitivity analysis

Supplementary Text 1: Scenario Analysis

Scenarios were also assessed for below mentioned assumptions, maintaining all the other base-case settings.

Scenario 1: Proportion of eligible population who would receive BaS

In this scenario analysis, we modified only the proportion of the eligible population in the base-case settings (assumed as 10%) for strategy 3.

5% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 173,943, and the annual incident target population size was estimated at 5,163. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 282,371 (revision surgeries: 5,140; incremental: 14,172 BaS). The total annual and 20-year costs were projected to increase to £156.0 million and £3.1 billion, respectively. Scaling up would require an additional full-time 1,251 personnel and 16 new facilities (1 small scale, 15 large scale) dedicated to BaS.

25% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 869,714, and the annual incident target population size was estimated at 25,815. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 1,411,958 (revision surgeries: 25,756; incremental: 1,271,738 BaS). The total annual and 20-year costs were projected to increase to £809.7 million and £16.2 billion, respectively. Scaling up would require an additional full-time 12,576 personnel and 149 new facilities (1 small scale, 148 large scale) dedicated to BaS.

Since the reported prevalence of Type 2 diabetes among BaS eligible patients in the UK ranges from 27% to 31%, this scenario can be interpreted as representing targeting patients with diabetes (39, 40). However, it is important to note that this scenario doesn't capture any additional costs for BaS management that may be specific to patients with diabetes.

100% of eligible population who receive BaS over a 20-year time horizon

Over a 20-year time horizon, the prevalent target population size was estimated at 3,478,854, and the annual incident target population size was estimated at 103,261. The number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 5,647,832 (revision surgeries: 103,065; incremental: 5,507,613 BaS). The total annual and 20-year costs were projected to increase to £3.3 billion and £65.2 billion, respectively. Scaling up would require 55,042 full-time additional personnel and 647 new facilities (1 small scale, 646 large scale) dedicated to BaS.

Scenario 2: Distribution of BaS by type of procedure over 20-year time horizon

In this scenario, the time to achieve 100% distribution of gastric bypass was 10 years, while other base-case settings remain the same.

Gastric bypass at 100%

Over a 20-year time horizon, the number of BaS (including revision surgery) procedures was projected to increase from 140,220 to 569,693 (incremental: 429,473 BaS). The number of gastric bypass, sleeve gastrectomy and gastric band operations was projected to be 484,346, 58,378 and 12,715, respectively. The total annual and 20-years costs were projected to increase to £341.7 million and £6.8 billion, respectively. Scaling up using this scenario would require only 4,518 additional full-time personnel dedicated to BaS over 20 years.

50% of new staff capacity is focused on BaS and it takes 1 year for a facility to be fully functional from the time it's built

Over a 20-year time horizon, the number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 564,783 (incremental: 424,563 BaS). The total annual cost and total 20-year cost were projected to increase to £249.8 million and £5.0 billion, respectively. Scaling up using this scenario would require only 8,177 additional full-time personnel dedicated to BaS.

Scenario 3: Eligible population with BMI ≥ 40 kg/m²

Over a 20-year time horizon, with 10% of the eligible population receiving BaS, the prevalent and annual incident target population sizes were estimated at 149,500 and 4,033, respectively and the number of BaS procedures (including revision surgery) was projected to increase from 140,220 to 234,474 (revision surgeries: 4,266; incremental: 94,254). The total annual cost was projected to increase from £70.6 million to £119.6 million. The overall total cost was projected to increase from £1.4 billion to £2.4 billion over 20 years. BaS scale-up would require an additional full-time 681 personnel dedicated to BaS.

Scenario 4: Time horizon

Time horizon of 10 years

This scenario considered the current eligible population but only added new eligible population for 10 years. Over a 10-year time horizon, with 10% eligible population receiving BaS, prevalent and annual incident target population sizes were the same as in the base-case. The number of BaS procedures (including revision surgery) was projected to increase from 70,110 to 459,590 (incremental: 389,480 BaS). The total annual cost and total ten-year cost were projected to

increase to £563.0 million and £5.6 billion, respectively. Scaling up using this scenario would require only 3,730 additional full-time personnel dedicated to BaS.

Scenario 5: Increased incident rate of obesity (sourced from Cancer Research UK, 2022 (41), estimated based on projected change between 2019 and 2040 for England, i.e. mean of obesity and severe obesity)

Over a 20-year time horizon, with 10% of the eligible population receiving BaS, after increasing the annual incident rate to 3.33%, the prevalent target population size was estimated at 3,478,854, and the annual incident target population size was estimated at 115,846. The number of BaS (including revision surgery) was projected to increase from 140,220 to 590,424 (revision surgeries: 10,763; incremental: 450,204 BaS). The total annual cost and total 20-year cost were projected to increase to £334.2 million and £6.7 billion, respectively.

CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Title, Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Abstract, Page 3-4
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Introduction section, Page 6-7
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Note reported
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Methods section: Table 1
Setting and location	6	Provide relevant contextual information that may influence findings.	Methods section: First Paragraph
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Methods section: Model structure
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Methods section: First Paragraph
Time horizon	9	State the time horizon for the study and why appropriate.	Methods section: Model structure
Discount rate	10	Report the discount rate(s) and reason chosen.	Methods section: Key assumptions
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Methods section: Model structure

Topic	No.	Item	Location where item is reported
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Methods section: Model structure
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Methods section: Model inputs
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Methods section: Table 1
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Note fully reported, Methods: Table 1
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Methods section: Model structure
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Methods section: Key assumptions
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	Not applicable
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	Not applicable
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Not applicable
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	Not applicable
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Supplementary Table 1-3

Topic	No.	Item	Location where item is reported
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Results section, page 13 - 17
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Results section: Scenario analysis, One-way sensitivity analysis, and Supplementary Text 1
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	Results section: Scenario analysis
Discussion			
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Discussion section
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Page 24
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 23

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008