HEALTH TECHNOLOGY ANALYSTS

Cost-effectiveness of introducing low-sodium food products in Vietnam

REPORT

MAY 2020

Prepared for

The George Institute for Global Health

Report prepared by

Health Technology Analysts Pty Ltd

TABLES

EXECUTIVE SUMMARY

Background

Cardiovascular disease (CVD) is one of the leading causes of non-communicable disease mortality and morbidity globally. The direct causal relationship between dietary salt (sodium chloride) intake, blood pressure and CVD events such as ischaemic heart disease (IHD) and stroke is now well established. In order to reduce dietary sodium, some countries are considering policies to encourage food industry to substitute some of the sodium chloride by potassium chloride. In Vietnam, previous experiments already demonstrated that low sodium seasonings (salt and Bot Canh) can be produced using potassium chloride. Moreover, these food products were acceptable to consumers and lowered blood pressure.

Objective

This study aims to assess the cost-effectiveness of three alternative sodium reduction strategies in Vietnam. These include (1) the voluntary introduction of low-sodium cooking salt, fish sauce and Bot Canh products in addition to existing sodium-rich products, without any Government involvement, (2) Government support by a campaign and the provision of a subsidy to participating manufacturers for replacing a portion of the sodium in cooking salt, Bot Canh and fish sauce with potassium, and (3) legislation requiring all cooking salt, Bot Canh and fish sauce to have a portion of their sodium content replaced by potassium.

Methods

A Markov cohort model was developed to evaluate the cost-effectiveness of the three alternate salt reduction strategies versus no intervention. A Government perspective was adopted, and the model was designed to capture clinically relevant health states such as IHD and stroke following the reduction of dietary sodium intake and consequent reduction in systolic blood pressure (SBP). The model starts with people aged 30 and average systolic blood pressure (SBP) was calculated according to the Vietnamese population characteristics. The model linked sodium intake to SBP based on a published linear regression model and SBP was linked to the probability of IHD or stroke based on published research. The model followed people over their lifetime to evaluate average costs and quality adjusted life years (QALYs) gained for each strategy. The incremental cost effectiveness ratio (ICER) was calculated as the difference in average costs and QALYs between the three alternate salt reduction strategies and no intervention.

Results

Relative to no intervention, all three of the sodium reduction programmes assessed in this analysis were found to be dominant (less costly and more effective). The voluntary sodium reduction strategy provided the smallest average cost reduction (-3,445₫; US$-0.15) and average effectiveness benefit (0.009 incremental QALYs gained), as it provided the lowest reduction in dietary sodium intake and thus the lowest reduction in IHD or stroke risk. The subsidised strategy provided an average cost saving of -43,189₫ (-US$1.86) and resulted in an average incremental QALY gain of 0.022. The regulatory strategy was the least costly (-43,530 ₫; US$-10.49) and most effective programme scenario (0.074 incremental QALYs gained). This is due to the fact that no cost of salt substitution or media campaign would be sustained by the Vietnamese Government, but the mandatory nature of the legislation would translate a 100% population coverage and hence effectiveness.

Conclusion

This research overall shows that any of the modelled programmes would be a cost-effective strategy for the Vietnam Government in lowering SBP at a population level and consequently lowering the risk of IHD and stroke. The regulatory intervention provides the most cost-effective option; however, it may not fit with the current government policy or could be met with industry and consumer group opposition. The subsidised alternative provides improved stakeholder engagement and still proves to be cost-effective, but it also requires a higher level of Government spending. Considering the high cost of healthcare and the low cost of programme implementation, the Vietnamese Government should strongly consider employing a population-level intervention to reformulate salt with potassium chloride. The regulatory strategy provides insights into the potential health and economic benefits of employing a maximum sodium reduction scenario. However, if this scenario is not feasible the subsidised scenario still provides significant health and economic advantages and should be investigated further and considered.

INTRODUCTION

Cardiovascular disease (CVD) is one of the leading causes of non-communicable disease mortality and morbidity globally [1], with mortality increasing by approximately 15% over the past 10 years [2]. The most common causes of CVD morbidity and mortality are ischaemic heart disease (IHD) and stroke, accounting for 85% of all CVD deaths in 2016 [2, 3]. Further, IHD and stroke are the leading causes of CVD disability-adjusted life-years (DALYs) globally, with the impact on health magnified in lower income countries due to higher exposure to modifiable risk factors and poor access to effective health care interventions [1].

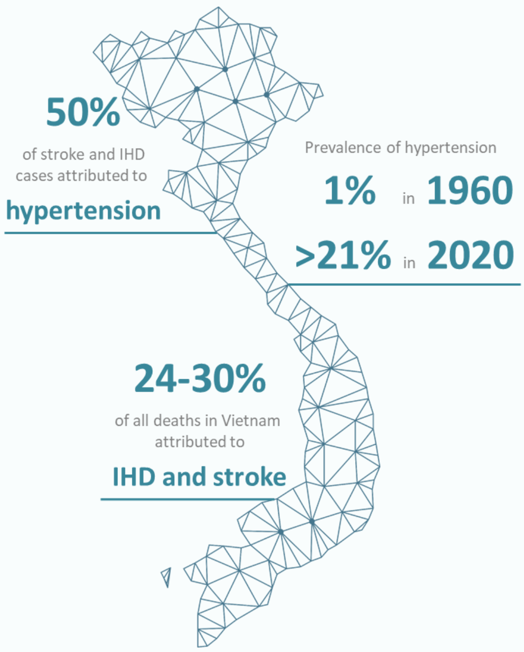
It has long been recognised that hypertension (high blood pressure) is one of the major risk factors for stroke and IHD [4, 5]; approximately 50% of stroke and IHD diagnoses worldwide are attributable to hypertension [6]. Hypertension is an extremely common condition in today's world, and it is estimated that approximately half of the population worldwide will develop hypertension by the age of 65 [6].

The direct causal relationship between dietary salt (sodium chloride) intake and blood pressure has been the subject of intense research and is now well established [7]. Reduction of dietary salt intake is considered an effective measure to reduce blood pressure, with a World Health Organisation (WHO) and Food and Agriculture Organization of the United Nations (FAO) Technical Report recommending the consumption of less than 5 grams (g) of salt per day as a population nutrient intake goal [8]. Given the negative impact of excessive salt consumption on health, the WHO has urged its member states to take action at a population level to reduce dietary salt intake [9].

With economic development and the ageing population, Vietnam has undergone a transition from managing communicable diseases to now confronting a growing population suffering from non-communicable disease[10, 11]. The WHO estimates that non-communicable diseases account for 73% of total deaths in Vietnam, of which approximately 43% are attributed to cardiovascular diseases including IHD and stroke [12]. Hypertension has been one of the primary contributors to the overall burden of disease in Vietnam during this shift. In 1960, the rate of adult hypertension in Northern

Vietnam was 1% [13]. Now, the overall prevalence of hypertension in Vietnam was estimated to be over 21%, raising up to 28% when focussing on a study population with a mean age over 50 [14]. The impact of salt intake on hypertension is amplified due to low literacy rates, poor access to adequate facilities, poor dietary habits and inequitable access to affordable healthcare [11].

A recent survey in Vietnam found that less than half of respondents understood that high salt intake can cause hypertension and only 10% and 5% knew high salt intake could cause stroke and heart attack, respectively [15].



Recent research has estimated the average salt intake in Vietnam to be 9.4 g/day, nearly double the 5 g/day recommended by the WHO [8]. Further, it is estimated that 70% of dietary salt comes from fish sauce, Bot Canh and salt added while cooking [16]. Globally, dietary salt reduction has been accepted as a cost-effective measure for preventing non-communicable diseases[17-26]. In 2013, members of the World Health Assembly agreed on voluntary targets of a 30% relative reduction in the intake of salt through the "Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020"[8].

However, a significant barrier to implementing this recommendation is the lack of resources available to low and middle income countries like Vietnam. It is therefore crucial to thoroughly assess the cost-effectiveness of sodium reduction interventions to justify expenditure and allocation of resources to a population-level prevention initiative. Many countries have already implemented population-wide programmes aimed at reducing population sodium intake through actions including policy and legislation, financial incentives, reformulation, education and media campaigns or labelling [27].

One such method of reducing sodium in food products is the use of a salt substitute such as potassium chloride. In addition to its ability to provide a salty taste, potassium itself is associated with a decreased risk of hypertension which would further contribute to disease risk reduction [28][1]. Therefore, potassium-enriched low sodium food products present an ideal population-level health intervention.

The average daily salt intake in Vietnam is 9.4 grams, whereas the WHO and FAO recommend the consumption of less than 5 grams per day

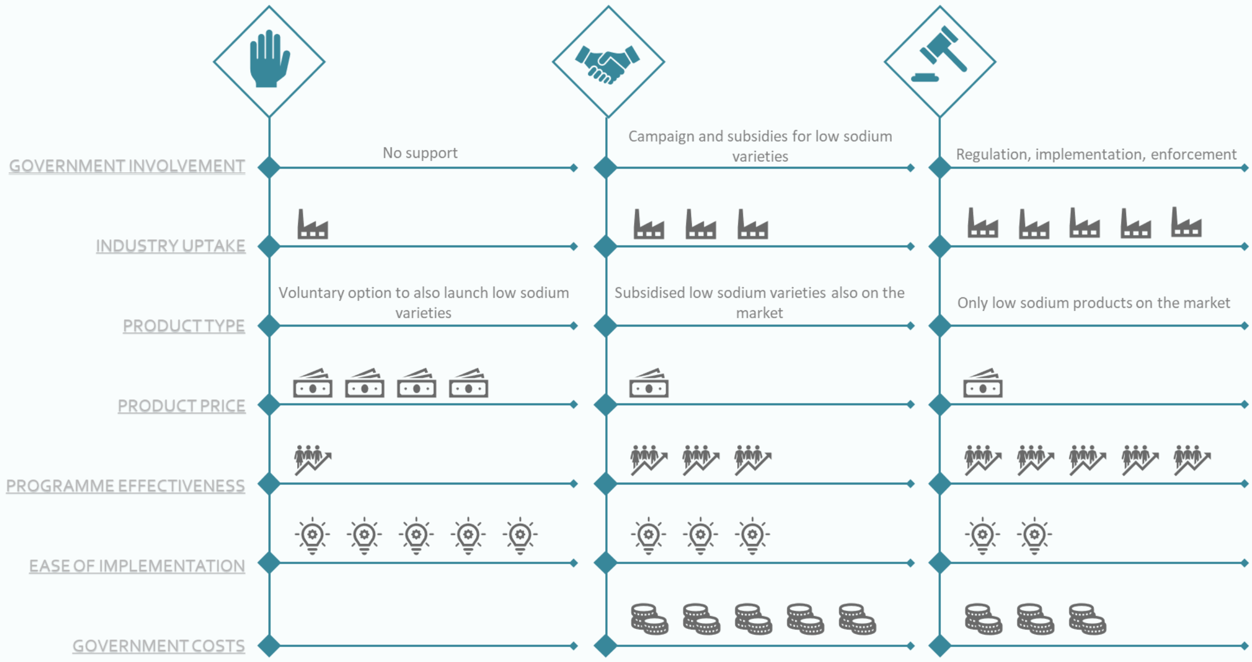
While studies conducted both globally and locally in Vietnam have found salt reduction policies and campaigns to be very cost-effective [21, 25, 29], the outcomes of a salt reduction intervention using potassium-

[1] The beneficial effect of potassium was conservatively not included in this economic evaluation

enriched low sodium food products in this country remains unknown.

This study aims to address this key gap in the literature by assessing the cost-effectiveness of three alternative sodium reduction strategies in Vietnam. These include (1) the voluntary introduction of new low-sodium cooking salt, fish sauce and Bot Canh products on the market without any Government involvement, (2) Government support by a campaign and the provision of a subsidy to participating manufacturers for replacing a portion of the sodium in cooking salt, Bot Canh and fish sauce with potassium, and (3) legislation requiring all cooking salt, Bot Canh and fish sauce to have a portion of their sodium content replaced by potassium. All interventions are compared to the strategy of no intervention, whereby the sodium content of cooking salt, Bot Canh and fish sauce remains unchanged.

Components of each sodium reduction strategy



METHODOLOGY

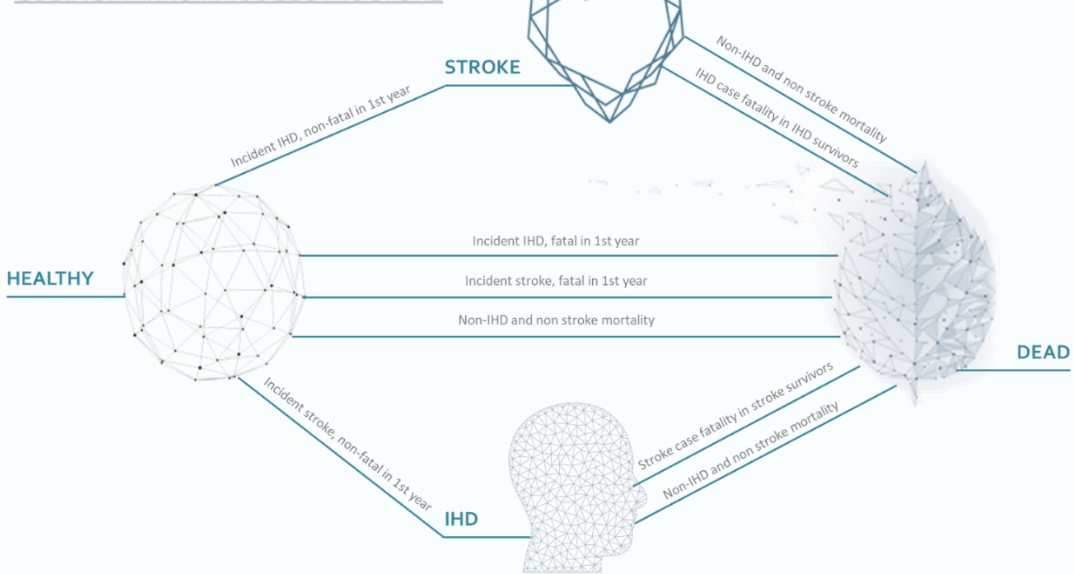
A Markov cohort was developed in TreeAge Pro, a visual tool for creating and analysing decision trees, to choose the optimal strategy as well as measure the effect of uncertainty on each strategy selection. The model was designed to capture clinically relevant health states such as IHD and stroke following the reduction of dietary sodium intake and consequent reduction in systolic blood pressure (SBP). The model attributes quality of life utility scores and costs to individual health states and models a population over time to calculate the incremental cost-effectiveness ratio (ICER).

The model includes four health states, namely healthy, post-stroke, post-IHD and death. Annual transitions capture incidence of stroke and IHD events, mortality due to IHD or stoke events and natural mortality. A simple and transparent model structure was adopted to take into account the most prominent clinical consequences following a reduction in SBP. The model was designed after reviewing previous publications (See Appendix, Table 13).

The model starts with people aged 30 who live normally in the current environment (no intervention) or live with one of three sodium reduction strategies (see the Cobiac Markov model structure below). At the beginning of the model, the average SBP is calculated according to the Vietnamese population characteristics [21, 30]. The model links sodium intake to SBP based on the linear regression model published by Law et al. 1991 [31]. Secondly, SBP is linked to the probability of IHD or stroke based on the percentage relative risk reduction of stroke (6.3% per 1% SBP reduction) and IHD (3.4% per 1% SBP reduction) as published by Cobiac et al. 2012 [25].

Patients that experience a stroke or IHD event either die as a result of the event or progress to a "post-event" health state. In the post-stroke health state, patients have an increased mortality risk compared to the healthy cohort for the lifetime of the model, whereas in the post-IHD cohort there is an increased mortality risk for three years post event, after which mortality reverts back to the natural mortality risk of that age.

COBIAC MARKOV MODEL STRUCTURE



Source: Cobiac 2012 [25]

The time horizon of the economic model spans the lifetime of the Vietnamese population. A lifetime horizon was used to fully capture the benefits and costs associated with the sodium reduction programme. The model uses a discount rate of 3% for both benefits and costs; rates of 0% and 5% were used in sensitivity analysis. This population-wide model evaluates each scenario from a Vietnam Government perspective.

The model was structured based on an existing cost-effectiveness model [25]. This model provides a simple structure with four key health states and transition events that allow the entire cohort to be modelled over time [32]. As the model has a yearly cycle length, the acute phase (initial, short-term event) for IHD and stroke is captured in a state transition, and the chronic phase (post-event, long-term) of the disease is captured in the respective health states. Patients cannot transition from the post-stroke or post-IHD state to the healthy state, and for simplicity it is assumed patients cannot experience more than one stroke or IHD event.

All key model inputs are presented in Table 1 and further described in detail in the report.

Table 1 Key model inputs

Variable name	Input	Source/Description
Clinical events and epidemiology		
Blood pressure	See Table 6	Calculated based on Ha 2010 baseline blood pressure. Reduction in SBP for each intervention was calculated from the reduction of sodium intake with a linear regression using the Law 1991 SBP with no sodium in the diet as reference [21]
Stroke incidence	See Table 7	Ha 2011 [21]
Relative risk of stroke with change in SBP	See Table 8	Cobiac 2012 and intervention specific change in blood pressure from baseline. Each 1% decrease in SBP equals a 6.3% risk reduction for stroke[25]
IHD incidence	See Table 7	Ha 2011 [21]
Relative risk of IHD with change in SBP	See Table 9	Cobiac 2012 and intervention specific change in blood pressure from baseline. Each 1% decrease in SBP equals a 3.4% risk reduction for IHD[25]
Mortality	Vietnam life tables	World Health Organisation and Global Health Observatory; age and gender specific [33]
Mortality following stroke event	37%	Tirschwell 2012 [34]
Long term stroke mortality risk	Year 1: 3.33 Year 2: 2.85 Year 3: 3.44 Year 4: 2.84 Year 5+: 1.56	Kiyohara 2003 [35]. Relative risk of patients with history of stroke compared to healthy controls. Model assumes patients have elevated risk of mortality (1.56x higher) compared to "healthy" population
Mortality of IHD event	Age specific mortality risk	Southeast Asian NCD impact module dataset through the WHO-CHOICE OneHealth tool

Variable name	Input	Source/Description
Long term IHD mortality	Year 1: 18.7% Year 2: 25.0% Year 3: 39.2% Year 4+: Revert back to regular population mortality	Tang 2007 [36]. Model assumes that after Year 3 patients have same mortality risk as rest of "healthy" population
Resource use and programme costs		
Cost of lowering sodium content by potassium-enriched salt substitutes per capita	1,791 ₫ ($0.08)	Calculated as the cost of a sodium reduction Government subsidy included in the subsidised scenario. See Costs section page 15
Personnel Costs for policy implementation and management	Project coordinator, manager, chief accountant, technical specialist etc: 511,526,874 ₫ ($22,039) per year Project administrative assistant/secretary, accountant, interpreter, translator: 295,489,873 ₫ ($12,730.88) per year Clerk, Driver, Auxiliary Staff, Messenger, Cleaner: 155,828,979 ₫ ($6,714) per year Per diem daily subsistence allowance: 4,015,413 ₫ ($173.00)	UN-EU 2015 human resource costs inflated to 2019 US$ and converted to ₫ [37]. Per diem costs from the International Civil Service Commission [38]
Human resource requirements for policy implementation and management	Webb 2017 eTable2	Webb 2017 [29]
Healthcare costs		
Percent of healthcare costs paid by the Government	54%	Local expert opinion; WHO 2018 [39]
Cost of stroke event to Government	13,325,677 ₫ ($574.12)	Khiaocharoen 2012(one off event cost) [40]
Long term cost of stroke to Government	0	Nguyen 2016 identifies stroke patients are cared for at home by family members [41]
Cost of IHD event to Government	17,297,679 ₫ ($745.25)	Nguyen 2016 (one off event cost) [41]
Long term cost of IHD to Government	368,835 ₫ ($15.89)	Nguyen 2016 recurring yearly cost for the lifetime of the patient [41]
Quality of life		
Healthy utility (SBP<130)	Male: 0.734 Female: 0.712	Nguyen 2015 [42]
Stage 1 hypertension utility (SBP >130 and <140)	Male 0.726 Female: 0.705	Nguyen 2015 [42]
Stroke event disutility	-0.312	GBD 2010 [43]
Long term post stroke utility	Year 1: 0.66 Year 2+: 0.68	Luengo-Fernandez 2013 [44]
IHD event disutility	-0.186	GBD 2010 [43]

Variable name	Input	Source/Description
Long term post IHD utility	OR = -0.004	Nguyen 2015 odds ratio of patients who had a history of experiencing a cerebrovascular event compared to those without event. Applied to life of patient [42]

Abbreviations: IHD, ischaemic heart disease; GBD, global burden of disease study; SBP, systolic blood pressure

To ensure that products with a lower sodium content remain appealing to consumers, the food industry always searches for sodium reduction strategies that do not lead to loss in product quality. The reduction of sodium in food products without adjustments for the loss in saltiness can result in consumers switching to other products higher in sodium or compensating the taste difference by adding back sodium during preparation or consumption [45]. Other techniques that can reduce sodium while compensating either fully or partially for the saltiness taste have therefore been explored, and potassium chloride is one of the most commonly used sodium chloride replacements. Potassium chloride is a naturally occurring mineral salt not only associated with a decreased risk in hypertension when incorporated in the diet [28, 46], but also with a good ability to give food products a salty taste [47, 48] [2].

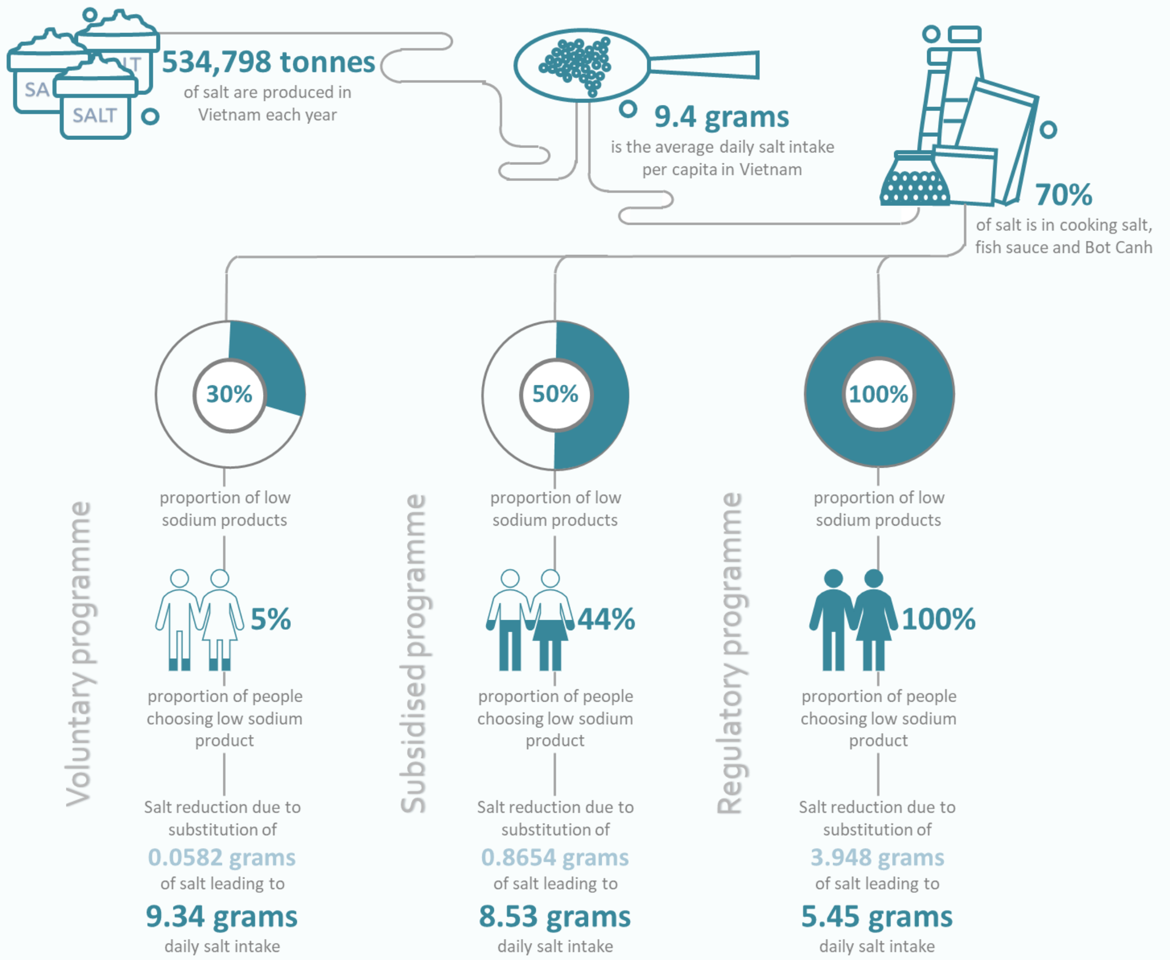
The substitution of sodium chloride in food products with potassium chloride for each modelled scenario is based on the coverage, efficacy and impact formula described by Gillespie et al [49]. The method takes into consideration the proportion of daily sodium intake from the low sodium seasoning products, the proportion of targeted products to be reformulated and the expected uptake of the low sodium products. The proportion of products reformulated reflects the willingness of industry to participate in the development of low sodium products, based on legislation and monetary incentive for reformulation.

For the voluntary intervention, it was assumed that uptake would be low (~5%) as the lack of financial incentive for manufacturers would result in the cost being passed on to the consumer and causing a significant barrier to uptake. The regulatory programme on the other hand would have a high uptake as legislation would guarantee all products are sodium reduced, which would also ensure that population coverage would be 100%.

The population coverage of the subsidised intervention was based on a Vietnamese population survey that found approximately 44% of respondents would limit adding salt or sauces when cooking when given the option [15]. Furthermore, the media and health promotion campaign accompanying the subsidised programme is expected to have an additive effect on the intake of high-sodium products and is reflected in the percent reduction from baseline, as previously described [21].

[2] The beneficial effect of potassium was conservatively not included in this economic evaluation

Steps used to calculate sodium reduction



Notes: an additional 5% reduction from baseline was added to the subsidised intervention to reflect the additional benefit of a communications intervention to reduce salt intake in Vietnam (Do 2015); previous work with The George Institute has demonstrated replacing 60% of sodium with potassium-enriched products reduces blood pressure.
Source: Gillespie, Allen [49]

To reflect the real-world planning and management of a population health intervention, each programme included progressive phases of implementation. The phases of implementation for each programme were modelled on Webb 2017 [29].

The first phase includes two years of project management, training and meetings, advocacy and law enforcement prior to deploying the programme. These years are dedicated to the planning and development of the intervention and therefore no health effects are assumed to take place. Following this stage, the voluntary and subsidised programmes year three to five were dedicated to the partial implementation phase, resulting in 50 percent of the total effect of each respective programme, to account for programme ramp up and deployment. The regulatory programme assumes that from year three the total effect of the programme would be realised, as once legislation is implemented the programme should be 100% effective. From years six onwards, all programmes are assumed to be at full implementation.

Costs

The resources required for the implementation of sodium reduction strategies will vary depending on each assessed intervention; these were applied accordingly in the model, always maintaining a Government perspective.

In addition to the programme costs, the healthcare costs associated with stroke and IHD events will be assessed. All costs were estimated from a Government perspective in 2019 Vietnamese Dong (VND) at an exchange rate of US$1 = 23,210₫. The purchasing power parity (PPP) of 2019 VND from 2015 US$ was calculated to be 7,792 using the CCEMG – EPPI-Centre Cost Converter.[3]

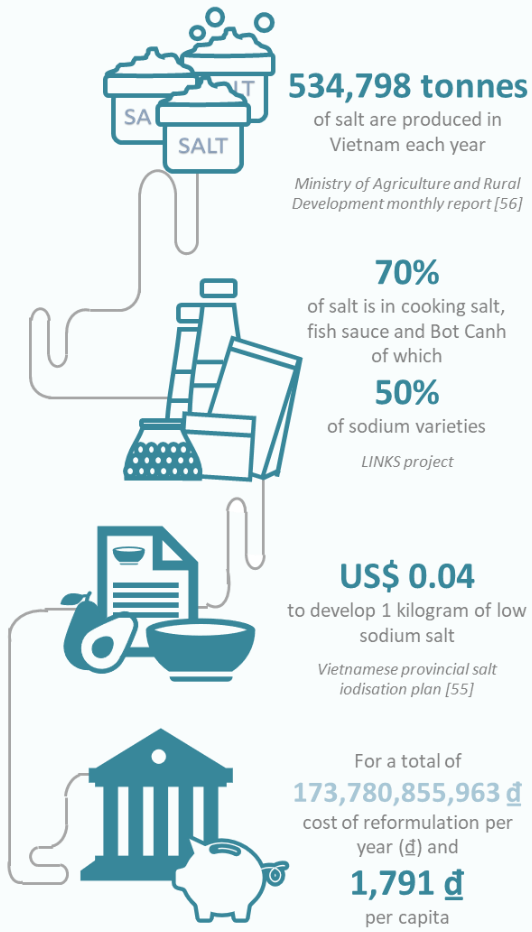
Programme Costs

Given the Government's minimum involvement in the voluntary programme, it was assumed no programme implementation costs would be accrued for the voluntary sodium reduction scenario.

Programme costs for the regulatory and subsidised scenarios comprise of resources required in the planning, development, and implementation of a population-based health intervention as described by the WHO-CHOICE methodology. This includes the estimated unit price of human resources, training, meetings, supplies, equipment and mass media campaigns. The resource needs for the regulatory and subsidised interventions were assessed at both a national and provincial level, to reflect regional nuances in cultural and dietary behaviours between provinces. These needs were based on the exemplar template published by Webb 2017 [29]. Personnel payment norms were based on the average salary used by the United Nations and European Union (UN-EU) agencies in Vietnam [37], inflated to 2019 VND. A per diem daily subsistence allowance of US$173 for attendees of meetings and training was applied, accounting for a travel allowance [38]. The cost of media and communications was incorporated at both a national and provincial level, based on research by Ha 2010 [21].

In addition to programme management costs, the cost of a sodium reduction Government subsidy was included in the subsidised scenario, which was calculated to be 1,791₫ per capita.

Cost of low sodium substitute development



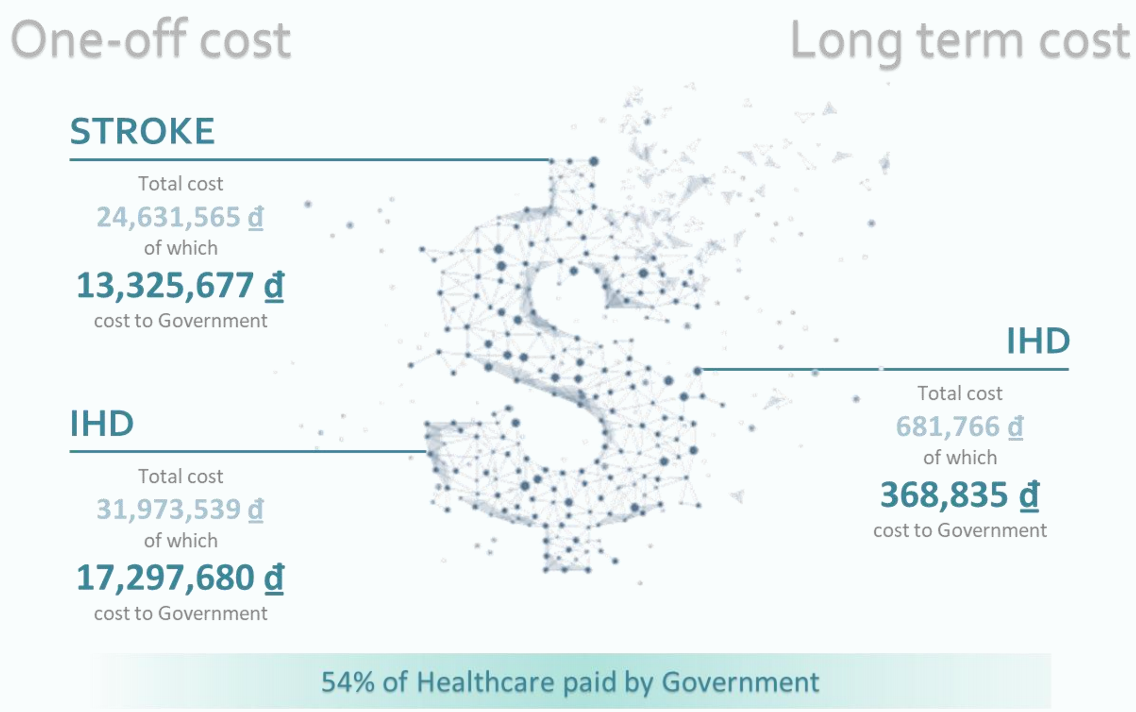
[3] https://eppi.ioe.ac.uk/costconversion/default.aspx

According to the Vietnamese Ministry of Agriculture and Rural Development, Vietnam produces approximately 500 tonnes of salt for human consumption each year. As highlighted above, previous research indicated approximately 70% of salt intake comes from Bot Cahn, fish sauce and salt added when cooking. The literature pertaining to the cost of substituting salt (sodium chloride) with potassium chloride is scarce, and as a result, the cost of salt iodisation was used as a proxy to estimate the cost of salt reformulation per kilogram [50]. As the process of salt substitution with potassium chloride is more complex than salt iodisation this assumption is assessed in a sensitivity analysis.

Healthcare Costs

All healthcare costs included in the analysis are region specific; all costs are derived from Vietnamese specific publications with the exception of the cost of acute stroke event which was obtained from a Thai study [40, 41, 51]. The cost of IHD and stroke was calculated for the acute event, and for the long-term recurring cost of chronic treatment post initial health event. There was no long-term cost of stroke applied in the model as rehabilitation and long-term care is commonly done by family members at home [41].

According to the WHO, the Vietnamese Government pays for approximately 54% of total healthcare expenditure which was verified by a local source [39]. To reflect a Government perspective, all healthcare costs were calculated accordingly.



Source: Khiaocharoen, Pannarunothai [40]; Vo and Le [51]; Nguyen, Wright [41]

RESULTS

Relative to no intervention, all three of the sodium reduction programmes were found to be dominant (less costly and more effective), as presented in Table 2. The average cost of a person over their lifetime to the Vietnamese Government was estimated to be approximately 1 million VND (US$45.39), resulting in an average of approximately 13 QALYs gained.

Whilst all three strategies reduced average Government costs, the voluntary sodium reduction strategy provided the smallest average cost reduction (-3,445₫; US$-0.15) and effectiveness benefit (0.009 incremental QALYs gained), as it provided the lowest reduction in dietary sodium intake and thus the lowest reduction in IHD or stroke risk.

The subsidised strategy provided an average cost saving of -43,189₫ (-US$1.86) and resulted in an average incremental QALY gain of 0.022.

The regulatory strategy was the least costly (-43,530₫; US$-10.49) and most effective programme scenario (0.074 incremental QALYs gained). This is due to the fact that no cost of salt substitution or media campaign would be sustained by the Vietnamese Government, but the mandatory nature of the legislation would translate a 100% population coverage and hence effectiveness.

Table 2 Results of the sodium reduction cost-effectiveness model

Strategy	Cost	Incremental Cost	QALYs	Incremental Effectiveness	ICER
No intervention	1,053,481 ₫ (US$ 45.39)	-	13.33	-	-
Regulatory	809,951 ₫ (US$ 34.90)	-243,530 ₫ (-US$ 10.49)	13.41	0.074	DOMINANT
Subsidised	1,010,292 ₫ (US$ 43.53)	-43,189 ₫ (-US$ 1.86)	13.35	0.022	DOMINANT
Voluntary	1,050,036 ₫ (US$ 45.24)	-3,445 ₫ (-US$ 0.15)	13.34	0.009	DOMINANT

Abbreviations: ICER, incremental cost-effectiveness ratio; QALY, quality adjusted life year

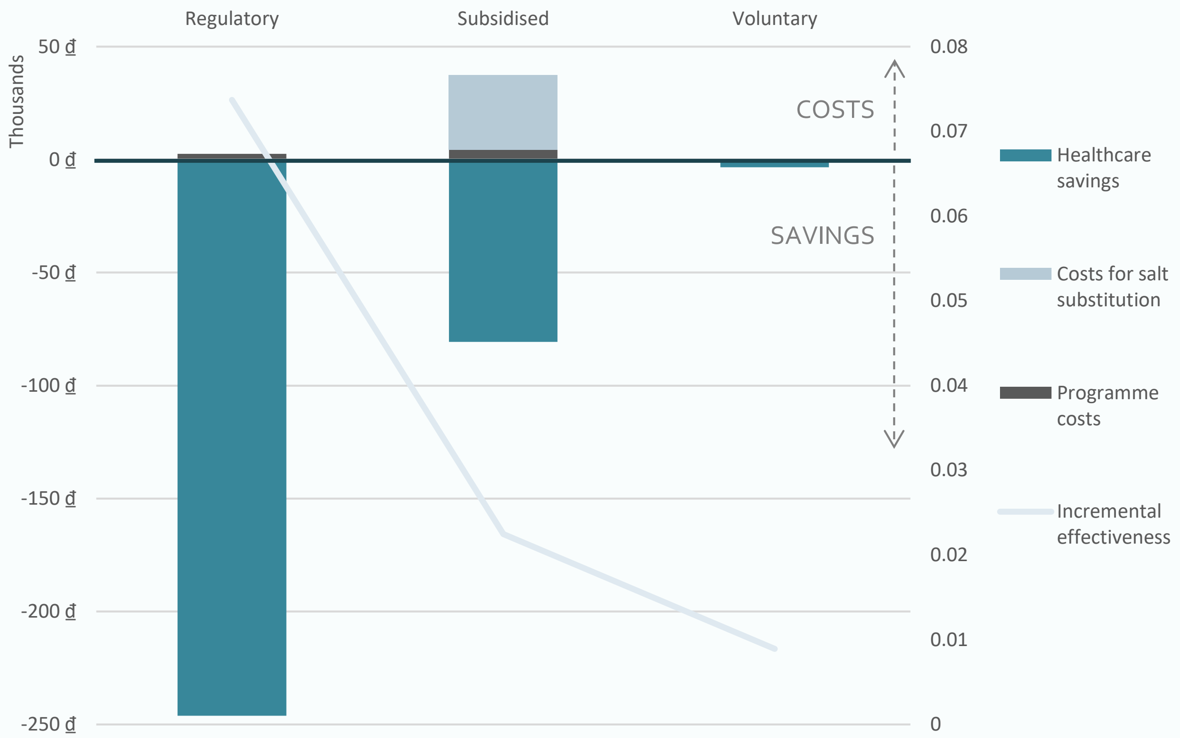
A summary of the costs accrued by the cohort in each programme arm is presented in Table 3.

Table 3 Costs accrued with each sodium reduction programme per capita per year

Parameter	No intervention	Subsidised	Voluntary	Regulatory
Programme cost	0 ₫	63 ₫	0 ₫	37 ₫
Salt reformulation cost	0 ₫	473 ₫	0 ₫	0 ₫
Healthcare cost	15,050 ₫	13,896 ₫	15,001 ₫	11,534 ₫
Total cost	**15,050 ₫**	**14,433 ₫**	**15,001 ₫**	**11,571 ₫**
Total incremental cost	-	***-617 ₫***	***-49 ₫***	***-3,479 ₫***

As shown in Figure 1, it is evident that the high cost of healthcare and low cost of programme implementation per capita per year produces significant cost savings, as a result of the reduced IHD and stroke events associated with the reduction of sodium intake.

Figure 1 Per capita cost and incremental effectiveness of each programme



The total cost of each phase of programme implementation per year is presented in Table 4. The subsidised programme is more costly to develop and implement due to mass media campaigns and associated health promotion and advocacy activities. From a Government perspective, no programme cost is associated with the voluntary programme.

Table 4 Total cost of each programme implementation phase (per year)

Phase	Regulatory	Subsidised
Planning (Year 1)	12,186,495,637 ₫	13,678,227,816 ₫
Development (Year 2)	17,311,069,141 ₫	30,539,726,723 ₫
Partial implementation (Years 3–5)	12,843,983,050 ₫	24,336,782,722 ₫
Full implementation (Years 6+)	12,949,953,247 ₫	21,808,968,902 ₫

A number of one-way sensitivity analyses were run to identify key drivers and assess any uncertainties of the model. The parameters tested and each upper and lower variable are listed in Table 5.

Table 5 Parameters tested in the sensitivity analysis

Parameter	Lower	Base case	Upper
% Products sodium reduced	-10%		10%
Discount rate costs	0%	3%	5%
Discount rate QALYs	0%	3%	5%
Incidence of stroke	-10%		10%
Stroke RR per 1% SBP Δ	4.0%	6.3%	8.0%
Incidence of IHD	-10%		10%
IHD RR per 1% SBP Δ	1.0%	3.4%	5.0%
Event cost Govt: Stroke	0 ₫	12,765,544 ₫	23,596,200 ₫
Event cost Govt: IHD	0 ₫	17,297,680 ₫	31,973,530 ₫
Long term Govt cost: Stroke	0 ₫	0 ₫	25,796,954 ₫
Long term Govt cost: IHD	0 ₫	368,835 ₫	681,766 ₫
Salt substitution cost/kg	$0.02	$0.04	$0.08
Cost of healthcare to Govt	0%	54%	100%
Cost project implementation	-20%		20%
Disutility stroke event	-0.25	-0.31	-0.40
Disutility IHD event	-0.10	-0.19	-0.28
Utility long-term stroke	-10%		10%
Utility long term IHD	-10%		10%
Mortality of stroke	-10%	0.37	10%
Mortality of IHD	-10%		10%

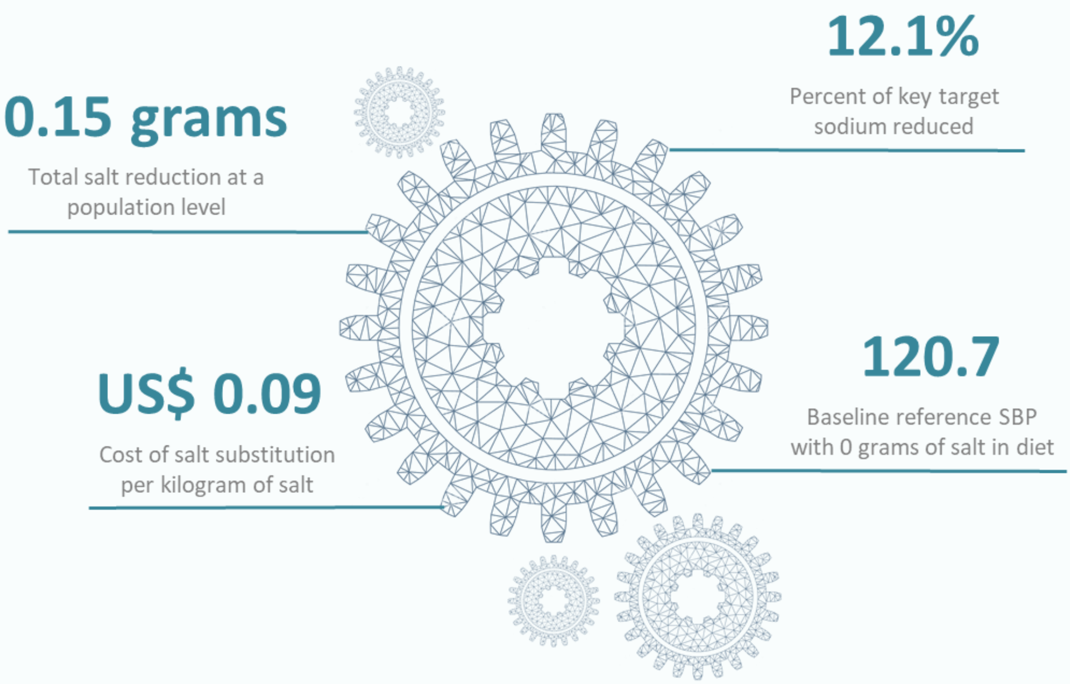
Abbreviations: IHD, ischaemic heart disease; QALYs, quality adjusted life years; SBP, systolic blood pressure

The results of the sensitivity analysis for the regulatory, subsidised and voluntary strategies compared to no intervention are presented in detail in the appendix. Overall, all strategies proved to be robust to all parameter changes, with the ICER remaining dominant for all scenarios except when cost of healthcare to the Government was completely removed.

To further test the model results, threshold analyses were conducted. The threshold analyses identify the point an intervention may no longer be considered exceptional value for money by the Government, as it is no longer less costly and more effective than no intervention (ICER = 0). Four key parameters were changed independently to test the robustness of the subsidised intervention. The cost of salt iodisation was used as a proxy for potassium fortification due to the lack of available data.

For the subsidised programme to no longer be dominant, the cost of salt substitution would have to be more than double the current estimate. The minimum percentage of products that would need to be sodium reduced is approximately 12%, and a salt reduction of 0.15 grams per capita per day would still provide the Government with a less costly and more effective solution compared to no intervention. The uncertainty around the SBP estimate with no salt in the diet was tested. The threshold analysis identified that an ideal SBP of 120.7 mmHg or below would be sufficient to lower the risk of stroke and IHD events, and for the subsidised programme to still be less costly and more effective.

Threshold values where salt reduction is no longer cost-saving



DISCUSSION

The results of this analysis clearly demonstrate how all population level sodium reduction interventions aimed at lowering blood pressure are cost effective and good value for money investment from a Government perspective. Owing to the low cost per capita of programme implementation and the high cost of initial and long-term treatment of stroke and IHD events, all programmes were dominant over no intervention. This is in line with a recent systematic review of cost-effectiveness publications of different interventions to reduce salt consumption, which found 59 of 62 identified scenarios to be cost-saving [52].

The regulatory strategy proved to have the greatest cost saving, as the Government did not incur the cost of salt substitution in the form of subsidisation rebates. The regulatory strategy also provided the greatest quality of life benefit compared to no intervention. This is likely due to it having the greatest coverage and impact on the target population blood pressure. Nonetheless, the regulatory strategy would require a concerted policy-making process to implement the appropriate planning, implementation, and enforcement legislation.

Previous economic evaluations assessing public health interventions have produced similar results. A cost-effectiveness analysis of population level interventions aimed at preventing CVD in Vietnam found all programmes to be very cost-effective according to the classification of Commission on Macroeconomics and Health (CMH) on cost-effectiveness [21]. Due to the scarcity of resources available to low and middle income countries such as Vietnam, Ha et al. determined that a health education programme to reduce salt intake and a combined mass media programme on salt, tobacco and cholesterol were the most cost-effective measures [21]. Webb et al. [29] studied the cost-effectiveness of implementing a national policy comprising of industry agreement, Government monitoring and public education to decrease sodium intake in 183 nations. The research determined cost-effectiveness of the intervention to be greatest in South Asia, however the study did not take into consideration healthcare costs. For Vietnam, the model estimated 246,143 DALYs averted over 10 years with a cost per capita of $0.31. When including healthcare savings from averted stroke and IHD events, our model finds such a programme to be even more cost-effective. For the subsidised programme with a 10-year time horizon excluding healthcare costs and with programme implementation costs only shared by those who potentially receive a health benefit from the intervention (i.e. population aged over 25), the cost per capita is approximately US$0.25. Table 13 (see Appendix) summarises structure, perspective and key assumptions of this analysis, in this broader context of economic evaluation of salt reduction strategies, to compare and assess key similarities and differences.

All modelled scenarios proved to be cost-saving to the Vietnamese Government, owing to the high cost of healthcare and low cost of implementing a population-level sodium reduction strategy

Nonetheless, there are multiple uncertainties in the collected data that may impact the model result. Cultural nuances in disease treatment in Vietnam may result in stroke or IHD mortality to be underreported. One study of case-fatality of initial stroke in Vietnam identified a 28-day mortality 6.7% [53],

considerably lower than mortality used in our model and in other Vietnam-specific models [41, 54]. Pham et al. [53] state the Vietnamese preference is to die at home among family members, therefore stroke related mortality may be underestimated.

Additionally, the long-term recurring cost of IHD and stroke events often varies considerably by case, depending on factors such as severity of disability and family preference for at-home rehabilitation. Nevertheless, all strategies remained dominant when long-term costs of IHD and stroke were not included in the model.

The variability in costs of healthcare in Vietnam and the introduction of the universal healthcare scheme also brings uncertainty to the cost of healthcare to the Government. In 2005, the Government on average covered approximately 32% of treatment costs [55], but this has since increased to approximately half and is expected to increase further in the coming years. Taking this into consideration, a sodium reduction programme that reduces stroke and IHD events would be even more cost-effective as the government pays an increasingly higher share of the healthcare costs. The cost of care in Vietnam also varies greatly on factors such as geographical location [56], and as the costing studies used in this model are generally from hospitals in major urban cities the cost may not be representative of the true cost of stroke and IHD treatment in non-urban areas in Vietnam.

This model does not take into consideration additional health consequences of potassium reformulated salt. Conservatively, the model does not consider the beneficial effect of potassium on blood pressure in the general population [57] nor does it consider the lowered risk of stomach cancer [58]. However, the model does not account for the increased risk of hyperkalaemia in specific population subgroups, including those with kidney disease or diabetes [59].

Lastly, due to the lack of local data for some cost and epidemiology inputs, other countries' sources had to be used as a proxy. To ensure the data was applicable to the Vietnamese scenario, data from neighbouring Asian countries was used where available.

This research overall shows that any of the modelled programmes would be a cost-effective strategy for the Vietnam Government in lowering SBP at a population level and consequently lowering the risk of IHD and stroke. The regulatory intervention provides the most cost-effective option; however, it may not fit within the current government approach or could be met with industry and consumer group opposition. The subsidised alternative provides improved stakeholder engagement and still proves to be cost-effective, but it also requires a higher level of Government spending. Considering the high cost of healthcare and the low cost of programme implementation, the Vietnamese Government should strongly consider employing a population-level intervention to substitute salt with potassium chloride. The regulatory strategy presents a scenario where the potential health and economic benefits of employing a maximum sodium reduction become salient. However, if this is not feasible option in reality, the subsidised scenario provides significant health and economic advantages and remains a highly cost-effective strategy which warrants further investigation and consideration.

APPENDIX

Systolic blood pressure

Sodium serves as an important nutrient in the body and helps nerves and muscles to function correctly. It is also involved in the auto-regulation of the water and fluid balance of the body. Nonetheless, salt can have negative impacts on the body and the cardiovascular system is particularly vulnerable to the adverse effects of excessive sodium consumption.

The hypothesis that a reduced sodium intake (sodium reduction) will reduce blood pressure (BP) and subsequently reduce morbidity and mortality was raised in 1904 on the basis of individual patient cases [60].

A large body of evidence now shows that dietary salt intake plays an important role in regulating blood pressure, and our current high salt intake is responsible for the rise in blood pressure with age [61].

Baseline systolic blood pressure (SBP) was stratified by age and sex, derived from a cost-effectiveness analysis of cardiovascular disease prevention interventions in Vietnam [21]. The age and gender specific SBP for each programme was calculated linearly using the percent sodium reduction from baseline and the estimated mean SBP at zero sodium in economically undeveloped countries [31]. The estimated SBP for each programme is presented in Table 6.

Table 6 Systolic blood pressure according to sodium reduction programme

Age	Baseline	Voluntary	Subsidised	Regulatory
20-29	112.10	112.09	111.79	111.18
30-44	113.77	113.75	113.22	112.15
45-59	124.11	124.02	122.08	118.14
60-69	132.74	132.60	129.48	123.15
70-79	136.15	135.99	132.40	125.13
80+	136.15	135.99	132.40	125.13

Note: sex standardised using Vietnam population statistic of 49% male
Source: Ha 2010, WHO-CHOICE

Stroke and IHD

Raised blood pressure is an important risk factor for cardiovascular disease. In the past, greater emphasis was placed on diastolic blood pressure (DBP), which was though to confer higher risk of for cardiovascular disease than raised SBP [62]. However, recent epidemiological studies have demonstrated that SBP is more strongly associated with cardiovascular disease and raised SBP predicts cardiovascular risk better than raised DBP [63, 64]. About two-thirds of strokes and almost half of cases of ischaemic heart disease can be attributed to systolic blood pressure greater than 115 mm Hg [17].

In order to calculate the reduced risk of stroke and IHD due to a reduction in SBP, the baseline incidence of stroke and IHD events in the Vietnamese population was stratified by age and sex as published by Ha 2010, presented in Table 7. A risk reduction was then applied to each baseline incidence, based on the decrease in SBP.

Table 7 Baseline incidence of stroke and IHD in Vietnam

Age	Stroke		IHD	
	Male	Female	Male	Female
20-29	0.00003	0.00002	0.00013	0.00006
30-44	0.00010	0.00030	0.00003	0.00050
45-59	0.00050	0.00300	0.00100	0.00450
60-69	0.00190	0.01230	0.00210	0.02000
70-79	0.00210	0.03260	0.00230	0.04090
80+	0.00350	0.05320	0.00440	0.05760

Source: Ha 2010

A network meta-analysis used in previous cost-effectiveness studies [25] estimated a 6.3% reduction in the incidence of stroke and 3.4% reduction in the incidence of IHD for every 1% change in SBP [65]. Accordingly, the relative risk reduction for stroke and IHD for each programme according to the reduction in SBP at each age group, is presented in Table 8 and Table 9, respectively.

Table 8 Relative risk reduction of stroke for each sodium reduction programme

Age	Voluntary	Subsidised	Regulatory
20-29	0.99924	0.98235	0.94807
30-44	0.99867	0.96939	0.90995
45-59	0.99554	0.89703	0.69708
60-69	0.99329	0.84524	0.54473
70-79	0.99249	0.82658	0.48983
80+	0.99249	0.82658	0.48983

Source: Calculated from Ha 2010 and Cobiac 2012

The greatest relative risk reduction was observed in the population aged 70 and older under the regulatory programme, whereby the incidence of stroke was reduced by approximately 50 percent. Similarly, for IHD events, incidence was approximately 30 percent lower in the same subgroup.

Table 9 Relative risk reduction of IHD for each sodium reduction programme

Age	Voluntary	Subsidised	Regulatory
20-29	0.99959	0.99047	0.97198
30-44	0.99928	0.98348	0.95140
45-59	0.99759	0.94443	0.83652
60-69	0.99638	0.91648	0.75430
70-79	0.99594	0.90641	0.72467
80+	0.99594	0.90641	0.72467

Source: Calculated from Ha 2010 and Cobiac 2012

Mortality

Experiencing a stroke or an acute IHD event increases mortality risk, both in the short-term during the acute event and in the long-term due to its lingering effects.

Knowledge of the epidemiology of stroke has increased over recent decades and it is well established that stroke is associated with a high risk for death, especially in the first few weeks after the attack [66]. Patients surviving a nonfatal stroke are at higher risk of dying from cardiovascular and cerebrovascular diseases, but the excess mortality was not restricted to those diseases [66].

The same is true for survivors of an acute IHD event. Despite large reductions in IHD mortality rates over the past four decades [67] acute IHD remains a major preventable cause of hospitalisation and death worldwide [68], being the single largest cause of death in the world [69]. Acute or sudden IHD may lead to death of some heart muscle, a myocardial infarction (heart attack).

A Vietnamese hospital study identified 28-day stroke mortality of 37% [34]. Long-term stroke mortality was based on the relative risk of mortality in people with a history of stroke compared to healthy controls [35]. The model assumes that the published stroke mortality risk at 5–10 years is extended to the remaining years of life.

The mortality rate of an acute IHD event is age and gender specific, based on the WHO Southeast Asian NCD impact module dataset through the WHO-CHOICE OneHealth tool.[4] The long-term mortality rate post-acute IHD event is taken from a three year follow-up of patients who experienced acute coronary events [36]. Four years after an IHD event the model assumes patients revert to all-cause mortality risk.

At any point in the model, patients are assumed to be at risk of all-cause mortality. All-cause mortality represents the probability that a person of a specific age will die before their next birthday. All-cause mortality was sourced from the Global Health Observatory data repository Vietnam life tables, stratified by age and sex [33].

[4] https://www.who.int/choice/onehealthtool/en/

Utilities

To enable comparisons when assessing different types of public health interventions and across different areas of healthcare, a common measure is needed. The quality-adjusted life years (QALYs) have been developed in order to encapsulate both the impact of a treatment on a patient's length of life and the impact on their health-related quality of life. This measure is widely used in health economics as a summary measure of health outcome, to inform healthcare resource allocation decisions [70].

In order to generate QALYs, health utilities are required, to weigh life years based on their value or desirability. Utilities are measured on a cardinal scale of 0–1, where 0 indicates death and 1 indicates full health. Using the 'anchors' of 0 and 1, utility measurement is on an interval scale, where the same change means the same irrespective of the part of the scale being considered [70]. By integrating preferences and life years, the QALY provides a common metric to measure the added values from a variety of interventions, making it useful for budget allocation. In principle, deciding to allocate resources toward a specific intervention depends on the value for money question in terms of societal willingness to pay for a QALY gained [71].

Quality of life values for healthy, post-stroke and post-IHD health states were applied in the model, and disutility values for stroke and IHD events were applied at health state transitions.

Disutility values for acute stroke and IHD events were sourced from the Global Burden of Disease study [43]. Disutilities represent the decrement in quality of life due to symptoms or events associated with stroke and IHD events. In the model, disutilities are applied once-off at the time of the event, as well as a recurring disutility that signifies the long-term quality of life lost post-acute event. When someone experiences a stroke, their immediate quality of life markedly lowers compared to someone who is healthy, thus they receive a disutility of -0.312 [43]. Similarly for IHD, a person is assigned a one-off quality of life decrement of -0.186 when experiencing the acute IHD event [43]. Disutilities are applied to the programme effectiveness to take this health impact into account. Those who suffer a stroke or IHD event will often experience long-term impacts on their quality of life, referred to in the model as the post-IHD and post-stroke health states.

The quality of life of patients in the post-IHD health state was calculated using a Vietnamese population specific odds ratio comparing the utility of patients with and without history of previous cerebrovascular event [42], which has previously been used as a proxy for the long-term quality of life in patients with stable cardiovascular disease [41].

Quality of life values for the Vietnamese population were gender specific for the whole cohort according to blood pressure status; patients having "ideal" SBP (<130 mmHg) or Stage 1 SBP (>130 mmHg) [42]. Long-term stroke utility values were sourced from a UK disease-specific population study of the quality of life of patients post-stroke [44].

Sensitivity analyses

The credibility or interpretation of the results of economic evaluations relies on the validity of the methods of analysis or models used and their corresponding assumptions. These can be tested by performing sensitivity analyses or testing the effect of changing such assumptions and observing the effects on the model results. If after performing sensitivity analyses the findings are consistent with those from the primary analysis and would lead to similar conclusions about programme effect, the researcher is reassured that the underlying factors had little or no influence or impact on the primary conclusions. In this situation, the results or the conclusions are said to be "robust". The following tables report the results of the sensitivity analyses performed on each assessed salt reduction programme.

Table 10 Results of the sensitivity analysis: Regulatory strategy

Parameter	Costs		QALYs		ICER	
Base case	-243,530 ₫		0.0737		DOMINANT	
	lower	upper	lower	upper	lower	upper
% Products sodium reduced	-217,840 ₫	-243,530 ₫	0.0666	0.0737	DOMINANT	DOMINANT
Discount rate costs	-621,987 ₫	-137,452 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Discount rate QALYs	-243,530 ₫	-243,530 ₫	0.2042	0.0400	DOMINANT	DOMINANT
Incidence of stroke	-233,774 ₫	-252,856 ₫	0.0688	0.0771	DOMINANT	DOMINANT
Stroke RR per 1% SBP Δ	-198,839 ₫	-277,185 ₫	0.0618	0.0827	DOMINANT	DOMINANT
Incidence of IHD	-234,635 ₫	-252,132 ₫	0.0723	0.0751	DOMINANT	DOMINANT
IHD RR per 1% SBP Δ	-150,014 ₫	-307,442 ₫	0.0470	0.0918	DOMINANT	DOMINANT
Event cost Govt: Stroke	-118,565 ₫	-339,845 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Event cost Govt: IHD	-125,049 ₫	-344,053 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Long term Govt cost: Stroke	-243,530 ₫	-967,996 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Long term Govt cost: IHD	-240,846 ₫	-245,808 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Cost of salt substitution/KG	-243,530 ₫	-243,530 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Cost of healthcare to Govt	2,601 ₫	-452,355 ₫	0.0737	0.0737	35,291 ₫	DOMINANT
Cost project implementation	-244,050 ₫	-243,010 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Disutility stroke event	-243,530 ₫	-243,530 ₫	0.0731	0.0745	DOMINANT	DOMINANT
Disutility IHD event	-243,530 ₫	-243,530 ₫	0.0731	0.0744	DOMINANT	DOMINANT
Utility long-term stroke	-243,530 ₫	-243,530 ₫	0.0756	0.0718	DOMINANT	DOMINANT
Utility long term IHD	-243,530 ₫	-243,530 ₫	0.0737	0.0737	DOMINANT	DOMINANT
Mortality of stroke	-243,529 ₫	-243,531 ₫	0.0726	0.0748	DOMINANT	DOMINANT
Mortality of IHD	-244,044 ₫	-243,016 ₫	0.0717	0.0758	DOMINANT	DOMINANT

Abbreviations: IHD, ischaemic heart disease; QALYs, quality adjusted life years; SBP, systolic blood pressure

Table 11 Results of the sensitivity analysis: Subsidised strategy

Parameter	Costs		QALYs		ICER	
Base case	-43,189 ₫		0.0225		DOMINANT	
	lower	upper	lower	upper	lower	upper
% Products sodium reduced	-39,261 ₫	-47,159 ₫	0.0195	0.0254	DOMINANT	DOMINANT
Discount rate costs	-144,736 ₫	-16,448 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Discount rate QALYs	-43,189 ₫	-43,189 ₫	0.0645	0.0117	DOMINANT	DOMINANT
Incidence of stroke	-40,070 ₫	-46,140 ₫	0.0215	0.0233	DOMINANT	DOMINANT
Stroke RR per 1% SBP Δ	-29,000 ₫	-53,741 ₫	0.0185	0.0254	DOMINANT	DOMINANT
Incidence of IHD	-40,327 ₫	-45,947 ₫	0.0215	0.0234	DOMINANT	DOMINANT
IHD RR per 1% SBP Δ	-12,979 ₫	-63,493 ₫	0.0141	0.0280	DOMINANT	DOMINANT
Event cost Govt: Stroke	-2,251 ₫	-74,742 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Event cost Govt: IHD	-4,262 ₫	-76,216 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Long term Govt cost: Stroke	-43,189 ₫	-468,908 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Long term Govt cost: IHD	-42,307 ₫	-43,937 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Cost of salt substitution/KG	-59,758 ₫	-10,052 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Cost of healthcare to Govt	37,559 ₫	-111,698 ₫	0.0225	0.0225	1,672,529 ₫	DOMINANT
Cost project implementation	-44,073 ₫	-42,305 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Disutility stroke event	-43,189 ₫	-43,189 ₫	0.0223	0.0227	DOMINANT	DOMINANT
Disutility IHD event	-43,189 ₫	-43,189 ₫	0.0223	0.0227	DOMINANT	DOMINANT
Utility long-term stroke	-43,189 ₫	-43,189 ₫	0.0231	0.0218	DOMINANT	DOMINANT
Utility long term IHD	-43,189 ₫	-43,189 ₫	0.0225	0.0225	DOMINANT	DOMINANT
Mortality of stroke	-43,179 ₫	-43,199 ₫	0.0221	0.0228	DOMINANT	DOMINANT
Mortality of IHD	-43,343 ₫	-43,035 ₫	0.0221	0.0228	DOMINANT	DOMINANT

Abbreviations: IHD, ischaemic heart disease; QALYs, quality adjusted life years; SBP, systolic blood pressure

Table 12 Results of the sensitivity analysis: Voluntary strategy

Parameter	Costs		QALYs		ICER	
Base case	-3,445 ₫		0.00891934		DOMINANT	
	lower	upper	lower	upper	lower	upper
% Products sodium reduced	-2,296 ₫	-4,595 ₫	0.0086	0.0092	DOMINANT	DOMINANT
Discount rate costs	-8,646 ₫	-1,966 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Discount rate QALYs	-3,445 ₫	-3,445 ₫	0.0156	0.0066	DOMINANT	DOMINANT
Incidence of stroke	-3,316 ₫	-3,567 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Stroke RR per 1% SBP Δ	-2,849 ₫	-3,886 ₫	0.0088	0.0090	DOMINANT	DOMINANT
Incidence of IHD	-3,327 ₫	-3,559 ₫	0.0089	0.0089	DOMINANT	DOMINANT
IHD RR per 1% SBP Δ	-2,165 ₫	-4,299 ₫	0.0086	0.0092	DOMINANT	DOMINANT
Event cost Govt: Stroke	-1,700 ₫	-4,790 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Event cost Govt: IHD	-1,783 ₫	-4,855 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Long term Govt cost: Stroke	-3,445 ₫	-13,764 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Long term Govt cost: IHD	-3,407 ₫	-3,477 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Cost of salt substitution/KG	-3,445 ₫	-3,445 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Cost of healthcare to Govt	0 ₫	-6,368 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Cost project implementation	-3,445 ₫	-3,445 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Disutility stroke event	-3,445 ₫	-3,445 ₫	0.0089112	0.0089309	DOMINANT	DOMINANT
Disutility IHD event	-3,445 ₫	-3,445 ₫	0.0089111	0.0089284	DOMINANT	DOMINANT
Utility long-term stroke	-3,445 ₫	-3,445 ₫	0.0089464	0.0088923	DOMINANT	DOMINANT
Utility long term IHD	-3,445 ₫	-3,445 ₫	0.0089193	0.0089194	DOMINANT	DOMINANT
Mortality of stroke	-3,445 ₫	-3,445 ₫	0.0089	0.0089	DOMINANT	DOMINANT
Mortality of IHD	-3,452 ₫	-3,438 ₫	0.0089	0.0089	DOMINANT	DOMINANT

Abbreviations: IHD, ischaemic heart disease; QALYs, quality adjusted life years; SBP, systolic blood pressure

Table 13 is provided to enable a comparison of similar salt reduction or regulation publications that are relevant to the presented salt reformulation strategies. Ha 2010, Webb 2017 and Cobiac 2012 are published salt reduction cost-effectiveness studies that provide a gold-standard reference for the economic evaluation presented in this report. The table identifies similarities and differences between the structure, perspective, and key variables applied in Ha 2010, Webb 2017, Cobiac 2012 and The George Institute cost-effectiveness study of salt reformulation programmes detailed in this report.

While this analysis and all published cost-effectiveness studies found a sodium reduction program to be highly cost-effective, the results between analyses differed which may be attributable to a number of factors. This analysis utilised a Markov model with a lifetime (70 years) time horizon to assess the incremental cost per quality adjusted life year, whereas Ha 2011 and Webb 2017 used a 10-year cohort model to assess cost-effectiveness as disability adjusted life years averted per 1,000 people.

A longer time horizon in this model increases the total accrued costs and health effects compared to the Ha 2011 and Webb 2017 analyses. When model parameters were altered to be consistent with Webb 2017, the cost per capita of this model is approximately US$0.25, similar to the cost per capita in Webb of US$0.31. The inclusion of costs also differed between models, which would impact the congruence of results; this analysis included programme and healthcare costs, Ha 2011 included additional societal costs, and Webb did not include healthcare costs. Cobiac 2012 had the most similar structure and perspective as this model, however given the significant differences between the Vietnamese and Australian populations and healthcare systems, this study has lower applicability. Different funding mechanisms, costs of healthcare, and a notable difference between disease incidence and mortality between the two countries likely contributes to differences in results. Notably however, both Cobiac 2012 and this economic evaluation found a sodium reduction programme to be a dominant strategy compared to no intervention.

Table 13 Comparison of cost-effectiveness studies

	Ha 2011	Webb 2017	Cobiac 2012	TGI Salt in Vietnam
Intervention	Health education through mass media to reduce salt intake and a voluntary reduction in salt content of processed foods. Education and individual treatment (b-blocker and diuretic) for high systolic blood pressure (>140mmHg and >160mmHg) Combination treatment with b-blocker, diuretic, statins and aspirin for individuals with absolute risk of cardiovascular event	Soft regulation policy. Government supported industry agreements to reduce sodium in processed foods, Government monitoring of industry compliance, and a public health campaign targeting consumer choices, including sustained pressure on food manufacturers to pursue progressive reformulation, reinforced by food group specific targets, independent monitoring, and a sustained media campaign against excess salt intake.	Population level community heart health program and mandatory reduction of salt in the manufacture of breads, margarines and cereals.	**Voluntary** introduction of new cooking salt, fish sauce and Bot Canh with a potassium-fortified reformulation Provision of **Government subsidy** to manufacturers for replacing high-sodium cooking salt, fish sauce and Bot Canh with potassium-fortified salt products together with media and communication support Regulatory approach: Legislation requiring **compulsory** fortification of salt with potassium, learning from universal iodisation program experience
Time Horizon	10 Year	10 Year closed cohort	Lifetime (35-84)	Lifetime (ages 30-100)
Model structure	Health gains: WHO-CHOICE PopMod Costs: WHO-CHOICE CostIT	Health gains: WHO-CHOICE PopMod Costs: WHO-CHOICE CostIT	Markov model	
Implementation phasing: Effectiveness	Not specified (assumed instant effect)	Effectiveness: "soft regulation" policy: Linear 10% reduction in Na over 10 years. No lag in benefits from SBP reduction and CVD	Not specified (assumed instant effect)	Modified Webb 2017 Years 1-2 All programmes: Planning and development stage, no impact of intervention on SBP Years 3-5 Voluntary and subsidised: Partial implementation stage, 50% impact compared to full implementation Regulatory: Full impact of intervention on SBP Years 6+: All programmes: Full impact of intervention on SBP

	Ha 2011	Webb 2017	Cobiac 2012	TGI Salt in Vietnam
Implementation phasing: Costs	Not specified	Year 1: Planning Year 2: Development Years 3-5: Partial implementation Years 6-10: Full implementation	No phasing for mandatory or voluntary salt reduction	Modified Webb 2017 Years 1-2: Planning and development Years 3-5: Voluntary and subsidised: Partial implementation Regulatory: Full implementation Years 6+: Full implementation
Currency	₫	(I$) International dollars	AU$	₫ and US$
Discounting	3%	3%	3%	3%
Perspective	Individual and national level intervention: includes societal costs	National Government: program costs only	National Government: program and healthcare costs	National Government: programme and healthcare costs (54% of healthcare costs are borne by the Government)
Source of resource use	Not referenced. Likely input from local experts	WHO-CHOICE	WHO-CHOICE	As Webb 2017
Source of resource costs	UN-EU Vietnam and other local sources	WHO-CHOICE	Voluntary salt reduction: Heart Foundation annual fee per product (data not published). Legislative and enforcement: WHO unit costs	UN-EU Vietnam local cost norms 2015 (as Ha 2010 but updated figures) Salt production: 534,798 tonnes (Vietnam The Ministry of Agriculture and Rural Development) Cost of salt reformulation: US$0.04/kg (iodisation used as proxy)
Source of healthcare costs	Drugs: International Drug Price database Diagnostic tests: Not specified Primary and secondary care: Flessa and Dung 2004 (Vietnam specific) Salaries: UN-EU 2007	Healthcare costs not included	MBS, PBS	Initial stroke event: Khiaocharoen 2012 (Thailand) Long-term cost of stroke: No long term cost (Nguyen 2016) Initial IHD event: Nguyen 2016 (Vietnam) Long-term cost of stroke: Nguyen 2016 (Vietnam)

	Ha 2011	Webb 2017	Cobiac 2012	TGI Salt in Vietnam
Event risk reduction	WHO Comparative Risk Assessment Project (Ezzati 2004)	Hypertensive status calculated from the effect of Na reduction on SBP, stratified by age and sex. Effect of SBP reduction on CVD by age	Change in disease incidence with 1% change in SBP: IHD = 3.4%, Stroke 6.3%	As Cobiac 2012. Ha 2010 SBP used as baseline.
Overall mortality	United Nations Population Division Bureau 2007	Global Burden of Disease study 2010 (GBD 2010)	Australian Bureau of Statistics minus IHD and stroke related deaths recorded in the Australian Burden of Disease study	WHO Vietnam life tables 2017
Event specific mortality	Not explicitly specified, likely United Nations Population Division Bureau 2007	WHO-CHOICE	Western Australia Linked Hospital Database. Age and gender specific. 28 day morality and post-28 day mortality	Stroke event: Tirschwell 2012, Vietnam specific Stroke long term: Kiyohara 2003, Japan relative risk compared to healthy controls IHD event: WHO-CHOICE IHD long term: Tang 2007, New Zealand
Source of quality of life values	National burden of disease study Vietnam (data not published)	GBD 2010	Bever dam study (US population). Age and sex specific. IHD first 6 weeks, IHD post 6 weeks and stroke.	Healthy: Nguyen 2015, Vietnam, age and sex specific Stage 1 blood pressure: Nguyen 2015, Vietnam, age and sex specific Stroke event (disutility): GBD 2010 Post stroke: Luengo-Fernandez 2013 IHD event (disutility): GBD 2010 Post IHD: Nguyen 2014 Vietnam specific history of event odds ratio

	Ha 2011	Webb 2017	Cobiac 2012	TGI Salt in Vietnam
Results	Media salt campaign Costs per year: 89 billion ₫ DALYs averted: 45,939 CER: 1,945,002₫ (US$118) per DALY averted (CMH category: very cost-effective)	Soft regulation policy Cost per capita: I$0.31 DALYs averted: 246,143 CER: I$62.00	Mandatory salt reduction Cost per capita: AU$0.81 DALYs averted: 80,000 ICER: Dominant	**No intervention** Cost p.c.: 1,053,481 ₫ (US$45.39) QALY: 13.33 **Regulatory** Cost p.c.: 809,951 ₫ (US$34.49) QALY: 13.41 ICER: Dominant **Subsidised** Cost p.c.: 1,010,292 ₫ (US$43.53) QALY: 13.35 ICER: Dominant **Voluntary** Cost p.c.: 1,050,036 ₫ (US$45.24) QALY: 13.34 ICER: Dominant

Abbreviations: CER, cost-effectiveness ratio; CVD, cardiovascular disease; DALY, disability adjusted life-year; GBD, global burden of disease study; ICER, incremental cost-effectiveness ratio; IHD, ischaemic heart disease; MBS: Medicare Benefits Scheme; PBS, Pharmaceutical Benefits Scheme; p.c., per capita; SBP, systolic blood pressure; WHO, World Health Organisation

Source: Ha and Chisholm [21]; Webb, Fahimi [29]; Cobiac, Magnus [25]

REFERENCES

1. Roth, G.A., et al., *Global, Regional, and National Burden of Cardiovascular Diseases for 10 Causes, 1990 to 2015.* Journal of the American College of Cardiology, 2017. **70**(1): p. 1-25.

2. Naghavi, M., et al., *Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016.* The Lancet, 2017. **390**(10100): p. 1151-1210.

3. World Health Organisation, *Cardiovascular disease fact sheet*. 2017, WHO.

4. Lackland, D.T. and M.A. Weber, *Global burden of cardiovascular disease and stroke: hypertension at the core.* Can J Cardiol, 2015. **31**(5): p. 569-71.

5. Pickering, T.G., *The natural history of hypertension: prehypertension or masked hypertension?* The Journal of Clinical Hypertension, 2007. **9**(10): p. 807-810.

6. Lawes, C.M., S. Vander Hoorn, and A. Rodgers, *Global burden of blood-pressure-related disease, 2001.* Lancet, 2008. **371**(9623): p. 1513-8.

7. He, F.J. and G.A. MacGregor, *A comprehensive review on salt and health and current experience of worldwide salt reduction programmes.* J Hum Hypertens, 2009. **23**(6): p. 363-84.

8. World Health Organisation, *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020*. 2013, WHO: Geneva, Switzerland.

9. World Health Organisation, *Reducing salt intake in populations: Report of WHO Forum and Technical Meeting*. 2006, WHO: Paris.

10. World Health Organisation, *Global status report on noncommunicable diseases 2010*, A. Alwan, Editor. 2011, WHO: Geneva, Switzerland.

11. Ibrahim, M.M. and A. Damasceno, *Hypertension in developing countries.* The Lancet, 2012. **380**(9841): p. 611-619.

12. World Health Organisation, *Noncommunicable diseases country profiles*. 2014, WHO: Geneva, Switzerland.

13. Khan, N.C. and H.H. Khoi, *Double burden of malnutrition: the Vietnamese perspective.* Asia Pacific journal of clinical nutrition, 2008. **17**.

14. Meiqari, L., et al., *Prevalence of Hypertension in Vietnam: A Systematic Review and Meta-Analysis.* Asia-Pacific journal of public health, 2019. **31**(2): p. 101-112.

15. Do, H.T., et al., *Effectiveness of a Communication for Behavioral Impact (COMBI) Intervention to Reduce Salt Intake in a Vietnamese Province Based on Estimations From Spot Urine Samples.* J Clin Hypertens (Greenwich), 2016. **18**(11): p. 1135-1142.

16. Do, H.T., *Hypertension in Vietnam: prevalence, risk groups and eff ects of salt substitution*. 2014, Wageningen University: Wageningen, NL.

17. Murray, C.J., et al., *Effectiveness and costs of interventions to lower systolic blood pressure and cholesterol: a global and regional analysis on reduction of cardiovascular-disease risk.* Lancet, 2003. **361**(9359): p. 717-25.

18. Joffres, M.R., et al., *Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada.* Can J Cardiol, 2007. **23**(6): p. 437-43.

19. Bibbins-Domingo, K., et al., *Projected effect of dietary salt reductions on future cardiovascular disease.* N Engl J Med, 2010. **362**(7): p. 590-9.

20. Smith-Spangler, C.M., et al., *Population strategies to decrease sodium intake and the burden of cardiovascular disease: a cost-effectiveness analysis.* Ann Intern Med, 2010. **152**(8): p. 481-7, w170-3.

21. Ha, D.A. and D. Chisholm, *Cost-effectiveness analysis of interventions to prevent cardiovascular disease in Vietnam.* Health Policy Plan, 2011. **26**(3): p. 210-22.

22. Martikainen, J.A., et al., *Health economic consequences of reducing salt intake and replacing saturated fat with polyunsaturated fat in the adult Finnish population: estimates based on the FINRISK and FINDIET studies.* Eur J Clin Nutr, 2011. **65**(10): p. 1148-55.

23. Wang, G. and B.A. Bowman, *Recent economic evaluations of interventions to prevent cardiovascular disease by reducing sodium intake.* Curr Atheroscler Rep, 2013. **15**(9): p. 349.

24. Mason, H., et al., *A cost effectiveness analysis of salt reduction policies to reduce coronary heart disease in four Eastern Mediterranean countries.* PLoS One, 2014. **9**(1): p. e84445.

25. Cobiac, L.J., et al., *Which Interventions Offer Best Value for Money in Primary Prevention of Cardiovascular Disease?* PLOS ONE, 2012. **7**(7): p. e41842.

26. Cobiac, L.J., T. Vos, and J.L. Veerman, *Cost-effectiveness of interventions to reduce dietary salt intake.* Heart, 2010. **96**(23): p. 1920-5.

27. Hyseni, L., et al., *Systematic review of dietary salt reduction policies: Evidence for an effectiveness hierarchy?* PloS one, 2017. **12**(5): p. e0177535-e0177535.

28. Aburto, N.J., et al., *Effect of increased potassium intake on cardiovascular risk factors and disease: systematic review and meta-analyses.* Bmj, 2013. **346**: p. f1378.

29. Webb, M., et al., *Cost effectiveness of a government supported policy strategy to decrease sodium intake: global analysis across 183 nations.* Bmj, 2017. **356**: p. i6699.

30. Khai, G., L. Viet, and T. Son, *Epidemiological survey of hypertension and its risk factors in Vietnam. Presentation at the World Health Organization's office*. 2008: Hanoi, Vietnam.

31. Law, M.R., C.D. Frost, and N.J. Wald, *Dietary salt and blood pressure.* J Hypertens Suppl, 1991. **9**(6): p. S37-41; discussion S47-9.

32. Briggs, A.D.M., et al., *Choosing an epidemiological model structure for the economic evaluation of non-communicable disease public health interventions.* Population Health Metrics, 2016. **14**(1).

33. Global Health Observatory, *Vietnam Life Tables*, W.H. Organisation;, Editor. 2019.

34. Tirschwell, D.L., et al., *A prospective cohort study of stroke characteristics, care, and mortality in a hospital stroke registry in Vietnam.* BMC neurology, 2012. **12**: p. 150-150.

35. Kiyohara, Y., et al., *Ten-year prognosis of stroke and risk factors for death in a Japanese community: the Hisayama study.* Stroke, 2003. **34**(10): p. 2343-7.

36. Tang, E.W., C.K. Wong, and P. Herbison, *Global Registry of Acute Coronary Events (GRACE) hospital discharge risk score accurately predicts long-term mortality post acute coronary syndrome.* Am Heart J, 2007. **153**(1): p. 29-35.

37. Chi Dzung, N., P. Mehta, and F. Jessen, *UN-EU Guidelines for Financing of Local Costs in Development Co-Operation with Viet Nam*. 2015, Ministry of Planning and Investment of Vietnam, United Nations, European Union: Ha Noi.

38. Bertram, M.Y., et al., *Disease control programme support costs: an update of WHO-CHOICE methodology, price databases and quantity assumptions.* Cost Effectiveness and Resource Allocation, 2017. **15**(1): p. 21.

39. World Health Organisation, *UHC and SDG Country Profile 2018: Viet Nam*. 2018, WHO: Geneva, Switzerland.

40. Khiaocharoen, O., S. Pannarunothai, and C. Zungsontiporn, *Cost of acute and sub-acute care for stroke patients.* J Med Assoc Thai, 2012. **95**(10): p. 1266-77.

41. Nguyen, T.P., et al., *Cost-Effectiveness Analysis of Screening for and Managing Identified Hypertension for Cardiovascular Disease Prevention in Vietnam.* PLoS One, 2016. **11**(5): p. e0155699.

42. Nguyen, T.-P.-L., et al., *Utilities of Patients with Hypertension in Northern Vietnam.* PloS one, 2015. **10**(10): p. e0139560-e0139560.

43. Salomon, J.A., et al., *Common values in assessing health outcomes from disease and injury: disability weights measurement study for the Global Burden of Disease Study 2010.* Lancet, 2012. **380**(9859): p. 2129-43.

44. Luengo-Fernandez, R., et al., *Quality of life after TIA and stroke: ten-year results of the Oxford Vascular Study.* Neurology, 2013. **81**(18): p. 1588-95.

45. Zandstra, E.H., R. Lion, and R.S. Newson, *Salt reduction: Moving from consumer awareness to action.* Food Quality and Preference, 2016. **48**: p. 376-381.

46. Binia, A., et al., *Daily potassium intake and sodium-to-potassium ratio in the reduction of blood pressure: a meta-analysis of randomized controlled trials.* J Hypertens, 2015. **33**(8): p. 1509-20.

47. Murphy, C., A.V. Cardello, and J. Brand, *Tastes of fifteen halide salts following water and NaCl: anion and cation effects.* Physiol Behav, 1981. **26**(6): p. 1083-95.

48. van der Klaauw, N.J. and D.V. Smith, *Taste quality profiles for fifteen organic and inorganic salts.* Physiol Behav, 1995. **58**(2): p. 295-306.

49. Gillespie, D.O., et al., *The Health Equity and Effectiveness of Policy Options to Reduce Dietary Salt Intake in England: Policy Forecast.* PLoS One, 2015. **10**(7): p. e0127927.

50. Thai Nguyen Province People's Committee, *[Approval of the plan, subsidy schemes, supply and pricing strategy for iodised salt to prevent goiter in local ethnic minorities living in mountainous areas in Thai Nguyen province in 2018]*. 2018, Thai Nguyen Province People's Committee: Vietnam.

51. Vo, T.Q. and P.H. Le, *Post-stroke rehabilitation cost with traditional therapy: Evidence from a public hospital.* J Pak Med Assoc, 2019. **69(Suppl 2)**(6): p. S87-s95.

52. Schorling, E., D. Niebuhr, and A. Kroke, *Cost-effectiveness of salt reduction to prevent hypertension and CVD: a systematic review.* Public Health Nutr, 2017. **20**(11): p. 1993-2003.

53. Pham, T.L., et al., *Case-fatality and functional status three months after first-ever stroke in Vietnam.* J Neurol Sci, 2016. **365**: p. 65-71.

54. Nguyen, T.P.L., et al., *Models to Predict the Burden of Cardiovascular Disease Risk in a Rural Mountainous Region of Vietnam.* Value in Health Regional Issues, 2014. **3**: p. 87-93.

55. Lieberman, S.S. and A. Wagstaff, *Health financing and delivery in Vietnam: looking forward*. 2009: World Bank Publications.

56. Nguyen, H.M., *Inequality in healthcare costs between residing and non-residing patients: evidence from Vietnam.* Int J Equity Health, 2017. **16**(1): p. 76.

57. Smith, S.R., P.E. Klotman, and L.P. Svetkey, *Potassium chloride lowers blood pressure and causes natriuresis in older patients with hypertension.* J Am Soc Nephrol, 1992. **2**(8): p. 1302-9.

58. Tsugane, S., *Salt, salted food intake, and risk of gastric cancer: epidemiologic evidence.* Cancer Sci, 2005. **96**(1): p. 1-6.

59. Watanabe, R., *Hyperkalemia in chronic kidney disease.* Rev Assoc Med Bras (1992), 1992. **66Suppl 1**(Suppl 1): p. s31-s36.

60. Ambard, L., *Causes de l'hypertension arterielle.* Arch Gen Med, 1904. **1**: p. 520-533.

61. He, F.J., N.D. Markandu, and G.A. MacGregor, *Modest salt reduction lowers blood pressure in isolated systolic hypertension and combined hypertension.* Hypertension, 2005. **46**(1): p. 66-70.

62. Collins, R., et al., *Blood pressure, stroke, and coronary heart disease. Part 2, Short-term reductions in blood pressure: overview of randomised drug trials in their epidemiological context.* Lancet, 1990. **335**(8693): p. 827-38.

63. Kannel, W.B., *Elevated systolic blood pressure as a cardiovascular risk factor.* Am J Cardiol, 2000. **85**(2): p. 251-5.

64. Lewington, S., et al., *Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies.* Lancet, 2002. **360**(9349): p. 1903-13.

65. Law, M.R., J.K. Morris, and N.J. Wald, *Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies.* BMJ, 2009. **338**: p. b1665.

66. Bronnum-Hansen, H., M. Davidsen, and P. Thorvaldsen, *Long-term survival and causes of death after stroke.* Stroke, 2001. **32**(9): p. 2131-6.

67. Dudas, K., et al., *Trends in out-of-hospital deaths due to coronary heart disease in Sweden (1991 to 2006).* Circulation, 2011. **123**(1): p. 46-52.

68. Iqbal, J. and K.A. Fox, *Epidemiological trends in acute coronary syndromes: understanding the past to predict and improve the future.* Archives of Medical Science Special Issues. **2010**(1): p. 14-14.

69. Finegold, J.A., P. Asaria, and D.P. Francis, *Mortality from ischaemic heart disease by country, region, and age: statistics from World Health Organisation and United Nations.* Int J Cardiol, 2013. **168**(2): p. 934-45.

70. Whitehead, S.J. and S. Ali, *Health outcomes in economic evaluation: the QALY and utilities.* Br Med Bull, 2010. **96**: p. 5-21.

71. Wichmann, A.B., et al., *The use of Quality-Adjusted Life Years in cost-effectiveness analyses in palliative care: Mapping the debate through an integrative review.* Palliat Med, 2017. **31**(4): p. 306-322.