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Combating Antimicrobial Resistance through the Control of Healthcare-associated Infections in Bhutan

Evidence Brief for Policy from the RADAAR (IVI)–EVIPNet (WHO) Initiative

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Combating antimicrobial resistance through the control of healthcare-associated infections in Bhutan

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Abbreviations

AI	artificial intelligence
AMR	antimicrobial resistance
ASP	antimicrobial stewardship programme
AWaRe	Access, Watch, Reserve (WHO classification)
BHSQA	Bhutan Healthcare Standard and Quality Assurance
BSI	bloodstream infection
CAUTI	catheter-associated urinary tract infection
CDC	Centers for Disease Prevention and Control
CLABSI	central line-associated bloodstream infection
CRAB	carbapenem-resistant *Acinetobacter baumannii*
CRE	carbapenem-resistant Enterobacterales
CRO	carbapenem-resistant organisms
DALY	disability-adjusted life year
DDD	daily defined dose
EBP	evidence brief for policy
EHHMS	electronic hand hygiene monitoring system
EHR	electronic health record
ePIS	electronic patient information system
ESBL	extended-spectrum beta-lactamase
ESS	electronic surveillance system
EVIPNet	Evidence-informed Policy Network (WHO)
HAI	healthcare-associated infection
HCW	healthcare worker
HCWM	healthcare waste management
HH	hand hygiene
HHC	hand hygiene compliance
HR	human resources
ICU	intensive care unit
IMCOH	Inter-Ministerial Committee for One Health
IPC	infection prevention and control

LMICs	low- and middle-income countries
MDRO	multidrug-resistant organism
MRSA	methicillin-resistant *Staphylococcus aureus*
NI	nosocomial infection
NRH	National Referral Hospital
PMU	project management unit
PPE	personal protective equipment
PPS	point prevalence survey
RADAAR	Regional AMR Data Analysis for Advocacy, Response and Policy
RRH	regional referral hospital
SSI	surgical-site infection
VAP	ventilator-acquired pneumonia
VRE	vancomycin-resistant organism
WASH	water, sanitation and hygiene
WHO	World Health Organization

Key Messages

Antimicrobial resistance (AMR) is a silent pandemic and a global public health threat, directly responsible for 1.27 million deaths in 2019 worldwide. The inappropriate use of antibiotics remains a major driver of AMR, prompting countries and health care institutions worldwide to adopt antimicrobial stewardship (AMS) programmes as a key strategy to address the issue. However, the burden of AMR, particularly of multidrug-resistant organisms (MDROs), continues to grow worldwide. The global prevalence of MDROs has increased by 46% over the past decade, with a growing number of healthcare-associated infections (HAIs) now linked to MDROs. This trend suggests that the AMR has evolved beyond the scope of AMS alone, and we are now in a phase where resistance is spreading globally, regionally, and locally, fueled by HAIs and inadequate infection prevention and control (IPC) practices.

A similar challenge of AMR was observed in Bhutan in recent years. Despite stewardship efforts, the growing use of last-resort antibiotics to treat MDROs highlights the urgent need for coordinated action to strengthen existing AMR containment measures. Systemic gaps, including limited surveillance capacity, inadequate infrastructure and constrained resources are some of the underlying causes of the problem. To combat AMR through the control of HAIs in Bhutan's context, this evidence brief for policy (EBP) proposes four strategic options as outlined below:

Evidence from systematic reviews and other sources on the proposed policy options

Option 1: *Adoption of a real-time electronic surveillance system (ESS) for HAI*

- ✧ ESS significantly improves identification of HAIs (including surgical-site infections [SSIs] and pneumonia) and MDROs compared to manual methods, reducing human error and increasing reliability in infection monitoring.
- ✧ By automating surveillance, ESS reduces staff workload, allows reallocation of resources to direct patient care, and delivers long-term cost savings through prevented infections, offsetting initial implementation investments.
- ✧ Effective ESS adoption depends on technical infrastructure (interoperable health records), adequate funding and staff training, integration with broader IPC/AMS strategies to maximize AMR/HAI reduction.

Option 2: Revamping infrastructure and enhancing isolation to manage infectious diseases

- ✧ Single-room isolation significantly reduces transmission of resistant pathogens (methicillin-resistant *Staphylococcus aureus* [MRSA]/carbapenem-resistant organisms [CROs]), particularly in intensive care units (ICUs). There is sufficient evidence to support this, and meta-analyses confirm lower rates of hospital-acquired bacteraemia and MDRO infections among isolated patients.
- ✧ Universal screening and isolation can be costly and unsuitable in low-prevalence settings. Hence, targeted implementation (in high-risk patients, ICU admissions) optimizes cost–benefit ratios.
- ✧ Isolation carries the risk of psychological harm (depression, anxiety, stigmatization) despite infection control benefits. Therefore, implementation requires balancing infection prevention with mental health support.

Option 3: Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department

- ✧ Combining AMS and IPC measures works better than using them separately to fight drug-resistant infections. Merging AMS with IPC is especially useful where resources are scarce, with hand hygiene being the most effective single measure.
- ✧ Bundled measures (AMS and enhanced cleaning/contact precautions) outperform isolated strategies in combating MDROs, with hand hygiene (HH) compliance emerging as the highest-impact IPC measure within integrated programmes.
- ✧ While direct cost–effectiveness data on combined AMS–IPC are limited, AMS components alone reduce antibiotic expenditures by 12–73% through improved antibiotic use. Integration of AMS–IPC maximizes resource efficiency by linking infection prevention with antimicrobial use optimization.

Option 4: Strengthening hand hygiene (HH) compliance through real-time auditing using an electronic HH monitoring system (EHHMS)

- ✧ Real-time monitoring and an automated feedback system improves HH compliance, with available evidence supporting its role in reducing HAIs and multidrug-resistant (MDR) infection.
- ✧ Despite the initial high cost of establishing EHMMS, a substantial body of evidence shows that it is cost effective in the long term and offers greater return on investment.

Implementation considerations

While each option effectively contributes to reducing HAIs and preventing the spread of MDR infections, implementing all four together would maximize the overall impact by addressing multiple key factors contributing to the transmission of MDROs.

Bhutan's ongoing digital health reforms, along with planned infrastructural expansions, present an opportunity to strengthen HAI surveillance, increase HH compliance through technology, improve infrastructure for infectious disease management and enhance isolation facilities. However, with limited human resources and overlapping roles among key experts, integrating AMS and IPC at the facility level ensures a comprehensive, efficient and strategic approach to tackling AMR.

With appropriate governance and commitment, Bhutan is well positioned to adopt these measures. By engaging stakeholders, investing in digital integration and staff training, the impact can be maximized on reducing HAIs and effectively addressing AMR.

Executive Summary

Antimicrobial resistance (AMR) is an escalating public health crisis in Bhutan, ranking among the top five causes of mortality in 2019. Several commonly encountered pathogens – *Neisseria gonorrhoeae*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* – have shown high levels of resistance to widely used antibiotics. Particularly alarming is the rise of multidrug-resistant organisms (MDROs), such as carbapenem-resistant Enterobacterales (CRE) reported at the National Referral Hospital (NRH). These organisms are a major driver of healthcare-associated infections (HAIs), which significantly increase patient morbidity, mortality, hospital stays and health-care costs.

The NRH saw a sharp increase in carbapenem-resistant organisms (CROs) since 2022, following the relaxation of strict infection prevention and control (IPC) measures implemented during the COVID-19 pandemic. The hospital is facing a surge in highly resistant pathogens, including *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *E. coli,* all classified by the World Health Organization (WHO) as priority pathogens. Concurrently, the growing reliance on last-resort antibiotics such as meropenem and polymyxins indicates a serious threat to treatment options and public health.

Although MDROs emerge due to multiple factors – including antibiotic use and misuse – poor IPC and HAIs play an important role in its spread. Bhutan has demonstrated commendable progress in antimicrobial stewardship (AMS), as reflected by its consistently low antibiotic consumption rates and strong compliance with the WHO's Access, Watch, Reserve (AWaRe) classification. Notably, the proportion of antibiotics from the Access group has exceeded 85% for five consecutive years, surpassing the WHO target of 60%. Additionally, appropriate antibiotic use at sentinel sites has averaged nearly 85%, according to the National Adaptation Plan (NAP) 2025 report. Despite these achievements, the growing threat of AMR, particularly the emergence of MDROs, remains a significant public health concern, a challenge closely associated with HAIs, often driven by suboptimal IPC practices.

The national HAI prevalence rate in the beginning of 2024 was reportedly 12.3%, slightly higher than the set benchmark for the country (12%) and significantly higher than international benchmarks (Singapore: 8.4%, European Union [EU]: 6.5%). These challenges provided the rationale for developing this policy brief focused on strengthening IPC to curb MDROs and combat AMR. Encouragingly, the latest point prevalence survey conducted in July 2025 at the NRH reported a reduced HAI rate of 6.9%, highlighting the results of ongoing efforts by the hospital to address AMR. This improvement is likely driven by the active involvement of the IPC and AMS teams – a multidisciplinary group comprising clinicians, nurses, laboratory staff and pharmacists – and the establishment of the AMR/MDRO alert group, which enables real-time surveillance of MDROs, particularly CROs. Further, the development and implementation of MDRO-CRO guidelines, the creation of isolation rooms and cohorting in the wards, and extensive sensitization of clinicians, nurses and other healthcare workers on MDRO management have collectively contributed to strengthening infection control practices, enhancing patient safety, and ultimately reducing the transmission of resistant pathogens within the hospital.

Despite these gains, challenges remain in the design of healthcare infrastructure, particularly the use of open-floor plans in critical care and emergency units, which was identified as a key structural limitation in effectively managing and preventing the spread of MDROs. Additionally, there is no dedicated IPC and AMS department at NRH staffed with full-time human resources who are experts in these fields. Currently, the existing team is multitasking and managing IPC and AMS responsibilities alongside their primary roles, which may limit the sustainability and effectiveness of interventions.

Similarly, hand hygiene (HH) compliance, a cornerstone of IPC, was reported at 46% in the latest audit conducted in December 2024. While these findings exceed the WHO average of around 40% to as low as 2% in low- and middle-income countries (LMICs) and 20% in high-income countries, the adequacy of the current average remains questionable. Existing benchmarks may still allow significant opportunities for infection transmission. Given the growing threat of AMR, it is timely for WHO to provide guidance and set targets for HAIs and HH compliance, ensuring that they reflect the latest evidence on the spread of AMR through poor transmission-based precautions.

Although progress to date is noteworthy, it may not fully reflect broader systemic risks. Without sustained focus, continued investment, the adoption of innovative technologies and coordinated action, these gains could be quickly reversed, and the threat of AMR will persist.

Globally, AMR is projected to cause up to 10 million deaths annually by 2050 and could result in a 3.8% drop in global gross domestic product (GDP). These projections are based on modelling studies analysing current trends in infection rates, resistance patterns and economic impacts. A similar projection was made for Bhutan, which estimated 124 AMR-related deaths and 464 AMR-associated deaths, surpassing mortality rates for diabetes and TB. Without urgent action, AMR threatens to compromise Bhutan’s healthcare system, burden the economy and endanger future generations.

Four options

This EBP presents four strategic options for addressing AMR by controlling HAIs at the NRH in Bhutan. Based on the WHO and Centers for Disease Prevention and Control (CDC) recommendations and a thorough review of the English-language scientific literature, these interventions were selected for their potential to target key contributing factors at the health system/organizational, health provider and community levels.

The proposed options, grounded in both global evidence and national context, are designed to complement each other as part of an integrated solution rather than stand-alone measures. While each intervention addresses specific aspects of HAI and MDRO prevention, their combined implementation within a broader health system-strengthening framework is expected to yield the greatest impact. The recommendations acknowledge that sustainable AMR reduction requires coordinated action across all healthcare sectors, with these hospital-focused measures forming one critical component of a comprehensive national strategy.

Option 1*: *Adoption of a real-time electronic surveillance system (ESS) for HAI

HAI reporting is well-structured, with IPC link nurses, people in charge and new recruits receiving annual continuing medical education (CME) on IPC and HAI reporting standards. Monthly HAI data from departments and units are compiled by the IPC unit and submitted to the IPC programme for nationwide consolidation. Each department has designated IPC and AMS champions to drive infection prevention bundles, ensure adherence to protocols and strengthen collaboration. The IPC unit also conducts point prevalence surveys (PPS), disseminates findings to relevant wards and discusses targeted interventions. In addition, daily surveillance for CROs-MDROs supports timely interventions and reinforces patient safety through appropriate IPC practices.

Several medium-quality systematic reviews and primary studies confirm that electronic surveillance systems (ESS) significantly reduce HAIs and MDROs compared to manual methods. ESS enhances the identification of surgical-site infections (SSIs), pneumonia and other HAIs with high reliability, minimizing human error and variability.

At the provider level, ESS reduces the workload for infection prevention teams, saves time in data collection, and allows staff to focus on critical interventions rather than manual surveillance, providing greater operational efficiency.

While the initial investment can be high, an ESS provides long-term financial benefits by preventing costly infections and optimizing resource allocation, offering greater return on investment. Additionally, ESS offers better scalability, as it ensures standardized, reproducible surveillance for large-scale adoption across healthcare facilities.

However, successful ESS implementation depends on technical expertise, interoperable health records, adequate funding and staff training.

ESS is a powerful tool for infection control, but its full potential requires strategic investment, system integration and institutional commitment. Combining ESS with targeted interventions can maximize its impact on reducing AMR and HAIs.

Option 2: Revamping infrastructure and enhancing isolation to manage infectious diseases

At NRH, a comprehensive strategy has been implemented to combat infectious diseases, including MDROs-CROs. Real-time surveillance has been developed and is supported by a dedicated MDRO alert group that coordinates timely communication and response. Standardized national guidelines for the clinical management of MDROs-CROs are in place, with cohort isolation practised for affected patients. Despite the current lack of dedicated isolation rooms in the intensive care unit (ICU) and high-dependency unit (HDU), strict contact precautions, including personal protective equipment (PPE) use and HH are enforced within individual patient-care zones in multi-occupancy rooms. During outbreaks, patients are cohorted with clear signage to reinforce compliance. Efforts are ongoing to improve infrastructure, notably transitioning from open ICU layouts to units with single-room isolation to better contain MDROs and reduce the risks of cross-infection.

Evidence from systematic reviews demonstrates that patient isolation strategies are highly effective in reducing the transmission of resistant pathogens such as MRSA and CROs. Single-room isolation significantly decreases the spread of resistant pathogens such as MRSA and CROs, particularly in high-risk areas such as ICUs. Meta-analyses show lower rates of hospital-acquired bacteraemia and MDRO infections among isolated patients compared to those in shared rooms.

The evidence on patient-level impact is mixed. While a meta-analysis found no harmful effect of isolation on patients, a systematic review showed significant psychological consequences of isolation on patients' mental health – linked to depression, anxiety and stigmatization.

Targeted strategies for isolation of patients with MDROs are effective measures in preventing MDRO transmission, but countermeasures to safeguard the patient's mental health must be strongly considered.

Option 3: Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department

Since 2024, the introduction of combined IPC–AMS teams have transformed AMR management in Bhutan. Multidisciplinary teams at the NRH, sentinel sites with microbiology facilities, and military hospitals supported by department-level champions now coordinate ward rounds, real-time surveillance and interhospital collaboration, strengthening the national AMR response. However, the absence of a dedicated IPC–AMS department at NRH with full-time expertise and resources threatens long-term sustainability, underscoring the need for formal establishment and investment**.**

A strong body of evidence, including multiple systematic reviews and primary studies, confirms that integrating AMS with IPC measures – such as standard precautions, enhanced environmental cleaning and contact precautions – delivers superior outcomes in combating MDROs. For instance, evidence shows that these combined interventions demonstrate a synergistic effect in reducing carbapenem-resistant *Acinetobacter baumannii* (CRAB) transmission by 52–72%, proving significantly more effective (relative risk reduction 0.35–0.58) than implementing isolated strategies.

Integrating AMS with IPC measures creates a synergistic approach that optimizes antimicrobial use while reducing the risk of infection transmission. This combined strategy is particularly impactful in LMICs, where diagnostic limitations and high AMR burdens require cost-effective solutions. Evidence shows that such integration can reduce MDRO incidence by up to 70%, with HH compliance emerging as the most influential IPC measure.

Although the authors found no evidence of the cost–effectiveness of combined IPC–AMS measures, systematic reviews found that AMS-driven cost savings on the purchase of antibiotics ranged from 12% to 73%, achieved through reduced antibiotic use and reduced duration of antibiotic therapy.

Option 4: Strengthening hand hygiene (HH) compliance through real-time auditing using electronic HH monitoring systems (EHHMS)

At the NRH, HH is promoted through regular CME for all staff, supported by monthly compliance reports from IPC link nurses and biannual audits by the IPC Unit using the WHO observation tool and knowledge assessments. Findings are shared with departments and accompanied by recommendations to improve practice. While these measures have slightly raised compliance above the WHO global average of 40%, the lack of real-time surveillance continues to limit timely corrective action. Strengthening monitoring systems remains essential to further improve compliance and reduce HAIs.

EHHMS enhance HH compliance by providing real-time feedback to healthcare workers (HCWs), leading to improved adherence and reduction in HAIs. At least three systematic reviews and three primary studies were found demonstrating the benefit of implementing EHHMS in improving HH compliance and reducing HAI and MDRO incidence.

Despite the high initial costs, EHHMS is cost–beneficial, as evidence shows that it prevents 50% of avoidable infections, yielding savings up to 16 times the implementation costs. EHHMS have been found to be 48% more cost efficient compared to manual methods, particularly when implemented in the high-risk areas such as ICUs.

However, evidence of potential harms associated with EHMMS – including ultraviolet (UV) exposure from detection lamps, and pathogen transmission from wearable sensors, audio alerts disturbing patients, visual alarm-induced staff anxiety – must be anticipated and appropriate mitigation strategies implemented.

Opportunities for and barriers to implementation

Bhutan's healthcare system presents a promising landscape for implementing integrated strategies to enhance IPC and AMS. With the recent introduction of the Health Services rules and regulations 2025 and the Bhutan Healthcare Standard and Quality Assurance (BHSQA) standards, there is now a national policy in place providing room to further strengthen IPC and AMS. Additionally, the ongoing roll-out of the National Digital Strategy and electronic patient information system (ePIS) under the Digital Drukyul programme provides a robust platform to support ESS for HAIs, enabling improved real-time detection and response. With strong governance and political will, Bhutan is well positioned to adopt these advancements. Engaging stakeholders and making targeted investments in digital integration and workforce training will be critical for maximizing impact, reducing HAIs and combating AMR.

However, several challenges must be addressed. These include the high costs associated with revamping infrastructure to enhance isolation for infectious diseases, particularly MDROs. Additionally, developing and implementing ESS requires careful attention to data privacy, security and regulatory compliance to ensure the ethical use and reporting of sensitive health information. Furthermore, adopting EHHMS demands significant investment in infrastructure and system-specific costs, including equipment procurement, installation and ongoing maintenance. Although formal IPC and AMS teams exist at the NRH, the absence of a dedicated department staffed by full-time experts limits their growth and effectiveness. As per previous experiences, creating a department and securing formal endorsement from the relevant regulatory body can be challenging.

In summary, while Bhutan has strong foundational elements and opportunities for advancing IPC and AMS through digital, infrastructural and organizational advancements, overcoming financial, ethical and organizational barriers will be essential to realizing these goals sustainably.

1. Introduction

Background

Antimicrobial resistance (AMR) is a rapidly growing public health problem in Bhutan. According to an estimation by the Institute of Health Metrics and Evaluation (IHME), AMR-related deaths ranked among the top five causes of mortality in the country, in 2019 *(1)*. Several commonly found microbes, including *E. coli*, *Neisseria gonorrhoeae*, *P. aeruginosa* and *K. pneumoniae*, show high antibiotic resistance, while newer concerns of the rising multidrug-resistant organisms (MDROs) like carbapenem-resistant Enterobacterales (CRE) are emerging, though the underlying causes are unclear *(2–4)*.

MDROs are primarily bacteria that exhibit resistance to at least one or more categories of antimicrobial drugs. Traditionally known to occur in hospitalized patients, MDROs are increasingly found in healthy people as carriers *(5)*. The global MDRO prevalence has surged with the widespread use of newer-generation antibiotics, narrowing the treatment options against drug-resistant infections *(6)*, prompting the WHO to declare AMR as one of the three most critical public health threats of the 21st century *(7)*. AMR caused an estimated 1.14 million attributable deaths globally in 2021, disproportionately affecting low- and middle-income countries (LMICs), with South Asia reporting one of the highest estimated mortality rates at 76.8 per 100 000 population *(8)*.

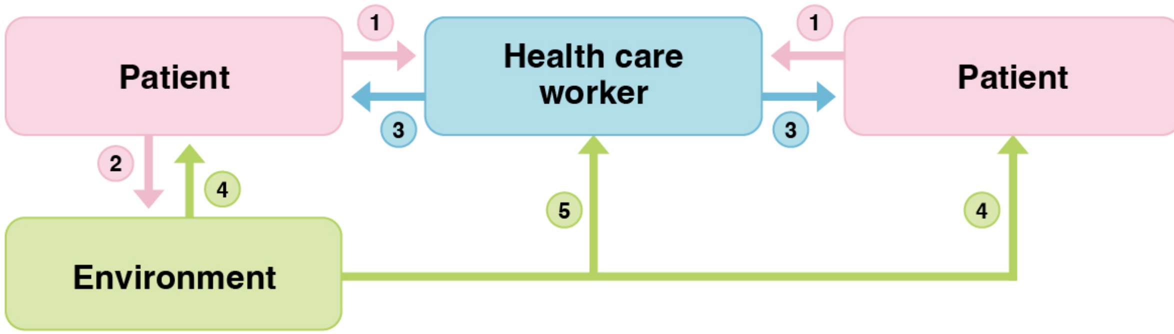
Although MDROs emerge due to multiple factors, including antibiotic use and misuse, poor infection prevention and control (IPC) and healthcare-associated infections (HAIs) *(refer to Box 1*) play an important role in its spread. Evidence suggests that HAI-infected patients are more vulnerable to acquiring life-threatening bloodstream infections (BSIs) caused by MDROs *(9)*.

Increasingly, MDROs are accounting for a greater proportion of HAIs *(9,10)* – with evidence from the European Union (EU) demonstrating that a third of HAIs reported in a point prevalence survey (PPS) in healthcare settings in 2016–2017 were antimicrobial resistant *(11)*. HAIs are those infections that patients acquire while receiving care in healthcare facilities, typically 48 hours after admission or within 30 days of receiving care, which was neither present nor incubating at the time of admission *(12)*. HAIs are a significant global health challenge, resulting in high morbidity, mortality, prolonged hospital stays, disability and increased cost *(13)*.

Box 1: Pathway of MDRO transmission – linkage to HAI

As illustrated in the figure below, the main pathway of MDRO transmission involves a dynamic interaction between patients, HCWs and the environment. Colonized or infected patients are the probable primary source of the MDRO, which then contaminates the HCW through direct contact. Studies have demonstrated transmission of the same bacterial strain from patients to HCWs' hands, gloves and gowns *(14,15)*.

Pathway of MDRO transmission



Adapted from: Blanco N, O'Hara LM, Harris AD. Transmission pathways of multidrug-resistant organisms in the hospital setting: a scoping review. Infect Control Hosp Epidemiol. 2019 Apr 6;40(4):447–56.

Beyond HCW contamination, colonized or infected patients may also shed MDROs into their immediate surroundings, leading to environmental contamination. Yakupogullari et al. demonstrated the presence of *Acinetobacter baumannii* strains from previously infected patients in hospital air that subsequently infected hospitalized patients three months later *(15)*. Similarly, studies report that 2–66% of MRSA acquired by patients can be linked to environmental contamination *(16,17)*.

Evidence consistently supports the HCW-to-patient transmission, particularly of MRSA *(16,18)* and consequently, the decontamination of HCWs for MRSA has been found to result in its reduced transmission *(18)*. A systematic review to analyse the evidence of MRSA on HCW attire has found that HCW attire, particularly long-sleeved white coats, are colonized with MRSA up to 79% *(19)*. These findings underscore the critical role of environmental decontamination and HCW hygiene in interrupting MDRO transmission pathways.

A cross-sectional study that included 9882 patients with MDROs from 2018 to 2022, across 28 hospitals involved in national MDRO surveillance in Malaysia, showed that 78.9% (n=7800) of the MDRO infections were due to HAI. A total of 65.7% (*n*=6489) of patients had no previous encounter with a healthcare facility, and 85.2% (*n*=8423) of patients had no history of surgical intervention within the past month before admission *(9)*.

Likewise, a multicentre prospective observational study conducted in 17 hospitals across Ukraine demonstrated that among 51 659 isolates, MDROs were detected in 29.2% of clinical isolates from patients with HAI, 16.3% of environmental surfaces, and 24.2% of HCWs' hands, gloves and gowns. Notably, 51.9% of isolates showed matching MDRO strains across patients, the hospital environment, and HCWs, suggesting cross-transmission of MDROs *(10)*.

Bhutan's dedication to AMS has resulted in over 85% of antibiotics used in the country over the past five years falling within the WHO "Access" category. This significantly surpasses WHO's recommended target of 60%, demonstrating strong adherence to the WHO Access, Watch, Reserve (AWaRe) classification *(20)*. Concurrently, strict regulation of prescription-only sale of antibiotics at private pharmacies has limited self-medication and misuse of antibiotics in the community. Despite these efforts, the growing problem of AMR, particularly MDROs in hospital settings, highlights that the issue extends beyond antibiotic use. It now involves the transmission and spread of already resistant pathogens not only locally but also regionally and globally, driven by HAIs and inadequate IPC practices.

Currently, there is a lack of a robust evidence-based approach to address AMR through the reduction of HAI. Therefore, the National Medical Services under the Ministry of Health with support from the WHO Evidence-informed Policy Network (EVIPNet) initiated this evidence brief for policy (EBP). This EBP is expected to provide a systemic and sustainable solution to combat AMR that is grounded in current evidence and global best practices.

Development of the evidence brief for policy

The evidence brief focuses on reducing the burden of MDRO infections at the NRH by addressing HAIs. It frames the problem and its underlying causes, proposes four evidence-based options for addressing the problem and highlights key implementation considerations. Designed as a dynamic document, it will subsequently support deliberative dialogue to determine the most feasible solutions for reducing AMR by addressing HAIs at the NRH and hospitals across the country. The brief was developed following a structured process that started with the identification of the problem through a group exercise involving all relevant stakeholders. The "Priority setting tool for prioritizing issues for knowledge translation products" developed in October 2024 by WHO was used to rank and finalize the main issue from a preliminary list of problems.

A core working group was established comprising national experts from human and animal health, Fleming fellows, relevant focal points from the NRH, and the country project management unit (PMU) for the Fleming Fund activities. The Inter-Ministerial Committee for One Health (IMCOH) was established as the steering committee to provide technical oversight to the core group. During the development process, the Regional Antimicrobial resistance Data Analysis for Advocacy, Response and policy (RADAAR) project under the International Vaccine Institute, Republic of Korea, WHO EVIPNet, and international experts in the subject area regularly reviewed the evidence brief. The authors analysed global and local evidence on the problem and options to address it.

The evidence searches prioritized systematic reviews (Box 2 and Annex I) on policy options and their implementation strategies. Additional sources included individual studies, economic analyses, relevant reports from international organizations and the Ministry of Health. The grey literature in the form of unpublished reports, including observation of trends and survey findings, were also consulted.

Box 2: Summary of the methodology

A. Development of the policy brief

This evidence brief aims to facilitate dialogue among key stakeholders involved in policy-making, implementation, and monitoring an analysis of available data on addressing AMR through the control of HAI, particularly in Bhutan. It synthesizes global and local research to propose four context-specific intervention options, supported primarily by systematic reviews and key individual studies. Designed as a dynamic tool for policy dialogue, the brief is expected to help policy-makers evaluate and agree on the most feasible strategies to reduce the burden of MDRO infections and HAIs in hospital settings. The following key steps were taken to prepare the policy brief:

1. Prioritization exercise workshop (virtually, followed by in-person sessions in Thimphu, in October 2024) and identification of the key public health problem.
2. A core working group was established with representatives from the Ministry of Health, NRH, Fleming Fund (FF) PMU, Fleming Fund policy fellows from both human and animal health. The technical working group (TWG) under the IMCOH was designated as the steering committee for the policy brief.
3. The EBP was endorsed at the seventh IMCOH meeting held on 12 December 2024.
4. The terms of reference for the core working group were developed with clear delegation of tasks, and the project timeline was endorsed.
5. Relevant research evidence on the problem, options and implementation considerations was identified, selected, appraised and synthesized.
6. The draft EBP was prepared using the relevant global and national evidence.
7. A stakeholder meeting to conduct a policy dialogue was held on 28 August 2025.
8. The EBP was finalized based on the feedback and review of several external experts.

B. Mobilization of evidence from research

To identify the most current and reliable evidence on interventions addressing MDROs and HAIs, a systematic search was conducted across multiple databases, including Google Scholar, Medline/PubMed, Cochrane, Health Systems Evidence and Health Evidence. The review focused on English-language publications of systematic reviews, meta-analyses, economic evaluations and primary research studies published between January 2020 and June 2025. A few studies published before these dates – identified through reference lists using the snowballing technique – deemed highly relevant to this policy brief were also included. The search strategy employed a combination of keywords related to AMR, infection prevention, and policy interventions, including terms like "multidrug-resistant organisms" "antibiotic stewardship" "healthcare-associated infections" and "infection control guidelines" “Bhutan” “LMIC”.

To complement the database search, additional data were gathered from national and international surveillance reports on infectious diseases, HAIs, and antimicrobial use (AMU) and antimicrobial consumption (AMC). Grey literature from relevant international websites such as WHO and the United States Centers for Disease Control and Prevention (US CDC) was also reviewed to ensure comprehensive coverage of the topic. Tacit knowledge derived from the policy dialogue was also used to develop the policy brief document.

The methodological quality of each systematic review was rigorously assessed using the AMSTAR 2 tool (A Measurement Tool to Assess systematic Reviews), allowing for a critical evaluation of the evidence. Findings were then synthesized based on the strength and reliability of the studies, ensuring that the conclusions drawn were supported by high-quality research. This approach provided a robust foundation for evaluating effective strategies to combat AMR and reduce HAIs in healthcare settings.

Limitations

This is the first EBP produced in Bhutan within the framework of the WHO EVIPNet. However, evidence synthesis involves subjective decisions about the scope, quality and interpretation of the findings. Therefore, this EBP reflects the judgement of the authors and reviewers only.

The main limitation of this brief is the lack of sufficient local data. It relies on global and regional evidence to support policy recommendations for Bhutan. While it references some local data (e.g. HH compliance rates, HAI prevalence), there is a lack of robust local studies on MDRO transmission dynamics, causality or the effectiveness of proposed interventions in Bhutan’s context, which may limit the generalizability of the findings to Bhutan. The gaps in recording critical parameters of AMR and HAIs and reliance on PPS and retrospective studies may have introduced potential biases, hindering a comprehensive understanding of the problem and may have interfered with the design of effective interventions.

The issues surrounding long-term sustainability and implementation challenges may not have been satisfactorily addressed. For instance, a strategy to increase domestic funding for sustaining the policy options are not discussed, although a full road map may not be within the scope of this brief. The lack of a comprehensive cost–benefit analysis for some proposed options may hinder decision-making for policy-makers, especially considering the resource constraints.

Lastly, since the focus is mainly on the NRH, the findings and recommendations may not be fully applicable to the regional referral hospitals (RRHs) and other secondary hospitals with different resources and settings.

2. Description of the problem

The problem – definition and framing

In Bhutan, the increasing burden of AMR in recent years, particularly MDROs, which is largely driven by HAIs and inadequate IPC, poses a significant challenge to public health and healthcare sustainability.

Microbiological culture reports accompanying drug requisition forms from the NRH revealed a concerning increase in the prevalence of carbapenem-resistant organisms (CROs) between 2021 and 2023 (*Table 1*), underscoring the urgent need for an immediate intervention *(21)*.

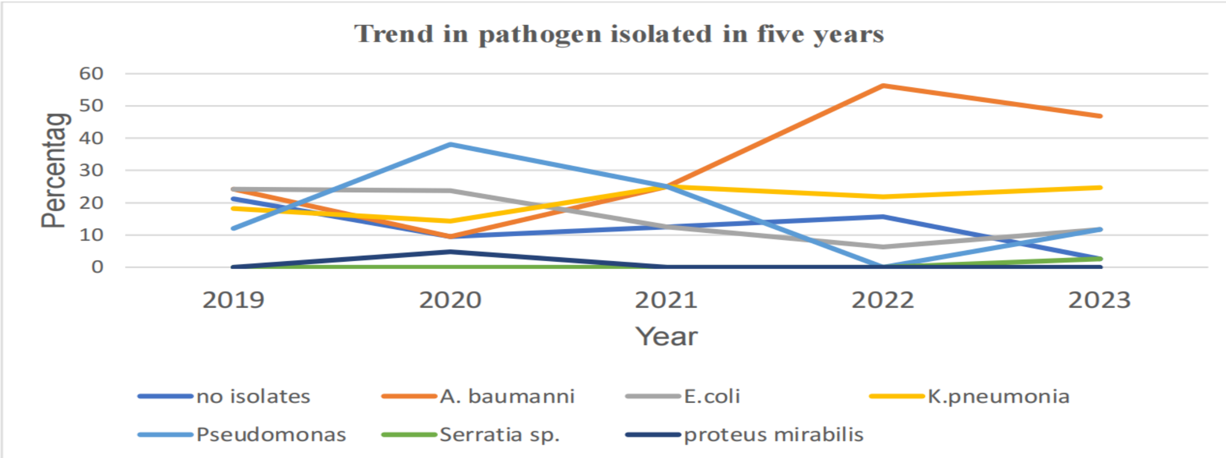
Table 1: Incidence of carbapenem-resistant Enterobacterales (CRE) from 2019 to 2023 at the NRH

Year	Total number of isolates	Number of CRE isolates	% of CRE
2019	2927	33	1.13
2020	5970	21	0.35
2021	6864	8	0.12
2022	6973	32	0.46
2023	6872	77	1.12

Source: Jigme Dorji Wangchuck National Referral Hospital (JDWNRH). Trend in the use of polymyxin B in Bhutan from 2019 to 2023*(21)*

Among the MDROs frequently isolated at the NRH, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Escherichia coli* are prevalent (Fig. 1) *(21)*, which are among the WHO priority list of pathogens against which novel antibiotics are urgently needed *(22)*.

Fig. 1. Trends in positive MDRO isolates at the NRH, 2019–2023

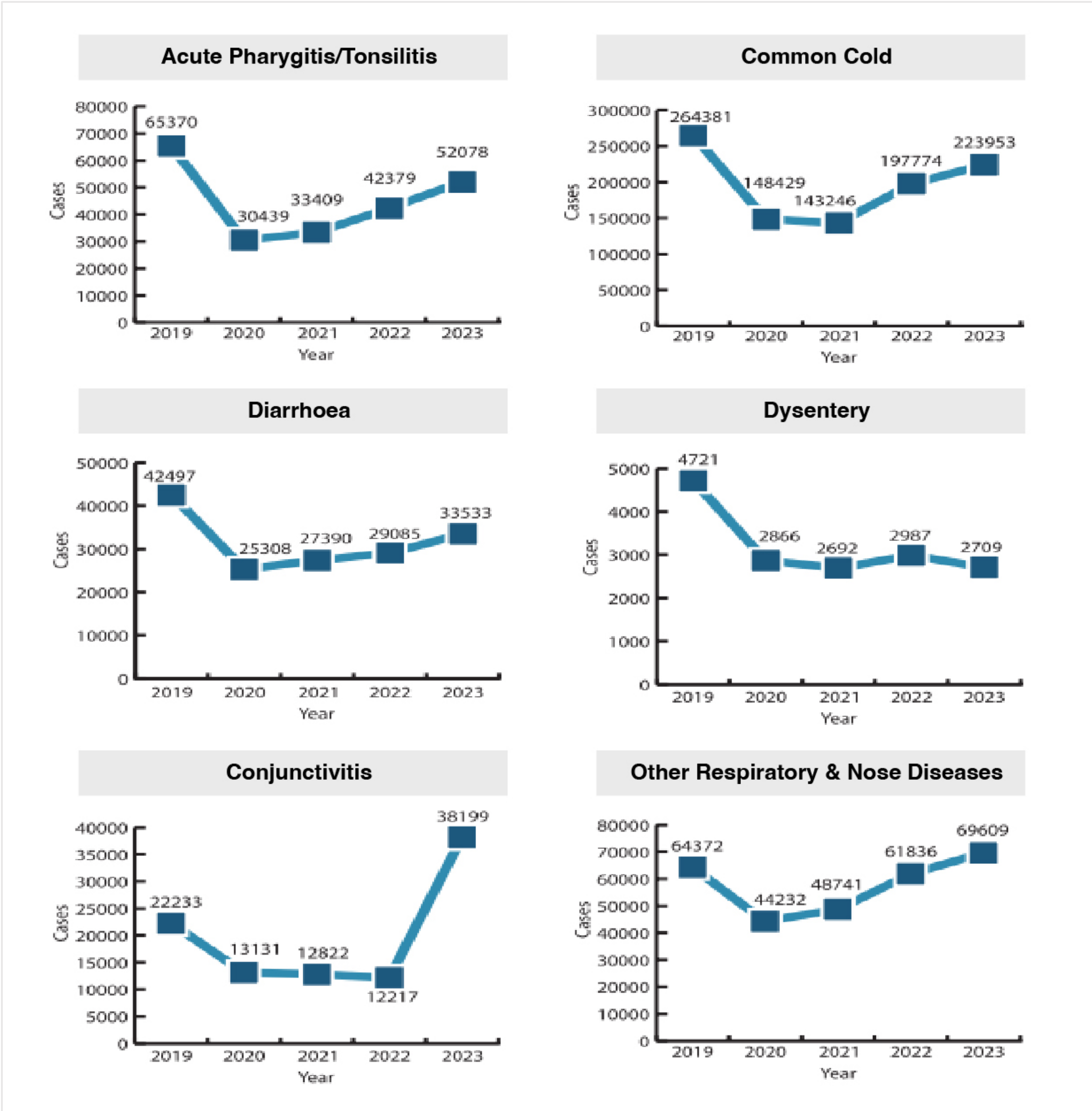


Source: JDWNR Hospital. Trends in the use of polymyxin B in Bhutan from 2019 to 2023 *(21)*

Concurrently, a retrospective analysis of AMC patterns from 2019 to 2022 revealed a concerning escalation in the use of polymyxin, an antibiotic often reserved as a last-resort treatment for multidrug-resistant (MDR) infections. This highlights the growing reliance on last-line antibiotics, which further exacerbates drug resistance, creating a vicious cycle that threatens the efficacy of available therapeutic options.

Furthermore, concerning patterns of AMR are seen from the diarrhoeal disease surveillance. A retrospective study showed that bacterial isolates from diarrhoeal samples exhibited diverse patterns of AMR, notably fluroquinolone-resistance (50%) and extended-spectrum beta-lactamase (ESBL)-producing MDR in 80.7% of isolates *(23).* Diarrhoeal diseases and respiratory illnesses remain the highest reported illnesses related to water, sanitation and hygiene (WASH) among children in Bhutan (Fig. 2), and therefore an important driver of antibiotic use.

Fig. 2. Trends in selected morbidity cases (related to water, sanitation and hygiene)



Source: Annual health bulletin, 2024

The emergence of MDROs is driven by multiple factors ranging from inappropriate use of antibiotics in humans and animals, inadequate diagnostic capacity and insufficient IPC measures *(24)*.

Bhutan has demonstrated commendable progress in AMS, as reflected by its consistently low antibiotic consumption rates and strong compliance with the WHO's AWaRe classification. Notably, the proportion of antibiotics from the Access group has exceeded 85% for five consecutive years, surpassing the WHO target of 60%. Additionally, appropriate antibiotic use at sentinel sites has averaged nearly 85%, according to the national antibiotic prescription survey (NAPS) 2025 report. Despite these achievements, the growing threat of AMR, particularly the emergence of MDROs, remains a significant public health concern, a challenge closely associated with HAIs, often driven by suboptimal IPC practices.

Despite the implementation of IPC programme since 2004, Bhutan has faced persistent challenges with infection control. The national HAI prevalence rate in 2024 was reportedly 12.3% *(25)*, slightly higher than the national benchmark of 12%, but significantly higher than international benchmarks (Singapore: 8.4%, EU: 6.5%) *(26)*. Encouragingly, the latest PPS conducted in July 2025 at the NRH reported a reduced HAI rate of 6.9% *(27)*, highlighting the results of ongoing efforts by the hospital to address AMR and IPC. This improvement is likely driven by the active involvement of the IPC and AMS teams, a multidisciplinary group comprising clinicians, nurses, laboratory staff and pharmacists, and the establishment of the AMR/MDRO alert group, which enables real-time surveillance of MDROs, particularly CROs. However, the monthly surveillance incidence rate from January to June 2025 remained relatively high at 9.31 per 1000 patient-days. Although this is below the national benchmark, it exceeds the prevalence reported in the PPS. This underscores the need for strengthened and real-time surveillance systems to capture a more accurate and comprehensive picture of the HAI burden.

Similarly, HH compliance, a cornerstone of IPC, was reported at 46% in the latest audit conducted in December 2024. While these findings exceed the WHO average of around 40% to as low as 2% in LMICs and 20% in high-income countries, the adequacy of the current average remains questionable. The existing benchmarks may still allow significant opportunities for infection transmission.

There is a lack of definite guidance and set targets by WHO for HAIs and HH. Given the growing threat of AMR, backed by increasing evidence on the spread of AMR through poor transmission-based precautions, it is crucial to establish such goals uniformly.

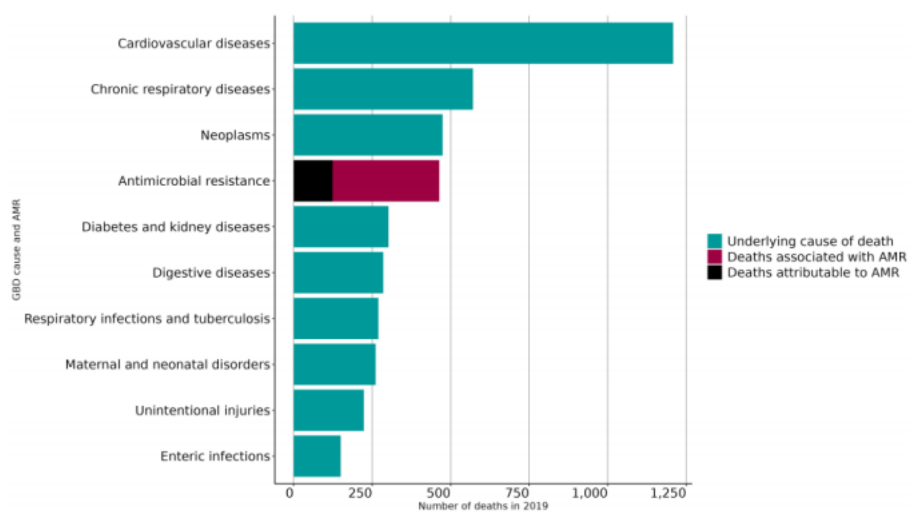
While the progress is noteworthy, it may not sufficiently capture the broader systemic risks and without sustained focus and coordinated action, these gains could quickly reverse, and the threat of AMR will persist.

Size of the problem

According to the estimation by the Institute of Health Metrics and Evaluation (IHME) in 2019, Bhutan had 124 AMR-attributable deaths and 464 AMR-associated deaths *(1)*, higher than the mortality burden due to diabetes, TB, and respiratory infections (Fig. 3)

(1). While Bhutan ranked the second lowest in age-standardized mortality rate (per 100 000 population) among the five South Asian nations, its global ranking – 70th out of 204 countries – indicates a comparatively higher mortality burden on an international scale. The rising MDRO cases present a crucial clinical challenge, particularly MDRO-CROs with 19% of the isolates requiring polymyxin therapy *(21)*.

Fig. 3. Number of deaths by GBD cause highlighting AMR-related deaths in Bhutan, 2019



Source: IHME. Global Research on Antimicrobial Resistance (GRAM) project*(1)*

Despite a lack of local studies on the transmission dynamics and causality of MDROs, reports of important risk factors such as inadequate HH practices among HCWs highlights potential healthcare-associated spread of MDROs *(28)*. For instance, an HH audit at the NRH in December 2024 showed an HH compliance rate of just 46% across selected inpatient units at the NRH *(28).*

HAIs surveillance is routinely implemented across all hospitals in the country. However, the recording and reporting is manual, and a real-time monitoring system is lacking. According to the 2023 National HAI Report, 21 health centres across Bhutan reported a total of 186 HAIs from January to May 2023, translating to an overall HAI rate of 8.289 per 1000 inpatient admissions *(29)*. Nearly half (46.2%) of these cases were reported by NRH, highlighting its disproportionate burden. Among the reported HAIs, surgical-site infections (SSIs) accounted for the highest proportion at 46%, followed by catheter-associated urinary tract infections (CAUTIs) at 17.2%, and ventilator-associated pneumonia (VAP) at 12.1% *(29)*.

Additionally, a 2024 PPS on HAIs revealed an overall prevalence rate of 9.8%, which is slightly higher than the median HAI prevalence in the South-East Asia Region of 9% *(30)*.

Globally, the median prevalence of HAIs varies widely, with the highest reported in Africa at 15%, followed by Australia (9.9%), Europe (6.5%) and the United States (5%). Alarmingly, bacterial isolates associated with these infections were frequently antimicrobial-resistant: according to a systematic review of 92 studies from 20 African countries, the resistance to third-generation cephalosporins was found in 70.3% of Enterobacterales (interquartile range [IQR]: 50–100). Additionally, 70.5% of *Staphylococcus aureus* isolates were methicillin-resistant (IQR: 58.8–80.3), and 55% of *Pseudomonas* species showed resistance to all tested antibiotics (IQR: 27.3–81.3) *(13)*.

In the South-East Asia Region, HAIs contributed to a mortality rate of 7–46% and prolonged hospital stays by 5–21 days, largely driven by MDROs *(31)*. A meta-analysis conducted in Nepal on the prevalence and multidrug resistance of *Klebsiella pneumoniae* highlighted the severity of the issue, reporting a 16% prevalence among positive isolates, with a significant pooled MDR prevalence of 64% *(32)*.

As the *Lancet* report (Box 3) on the global burden of AMR (1990–2019) warns of the catastrophic global impact of unchecked resistance, Bhutan must act decisively.

Box 3: Lancet study on global burden of AMR, 1990–2019

According to the *Lancet* study on global burden of AMR, the sub-Saharan African (SSA) region had the highest AMR mortality rate in 2019 (27.3 per 100 000 attributable to, and 114.8 per 100 000 associated with AMR), despite a decline in AMR deaths among children under 5 years, reflecting challenges such as fragmented health systems, limited ICU capacity, and inadequate access to WASH and antibiotics. The South Asia region followed closely in second place. Both SSA and South Asia had all-age death rates associated with an AMR higher than 75 per 100 000 population. However, looking ahead in time, researchers forecast the highest AMR deaths in South Asia – including India, Pakistan and Bangladesh – with a total of 11.8 million AMR-attributable deaths between 2025 and 2050.

Globally, children under 5 years experienced over 50% reduction in AMR mortality from 1990 to 2021, largely due to vaccination efforts and improved WASH. In contrast, AMR mortality in adults, particularly those over 70 years, increased by >80% from 1990 to 2021, driven by ageing populations, comorbidities and limited vaccine efficacy in older adults.

Carbapenem-resistant Gram-negative bacteria (*Acinetobacter baumannii*, Enterobacterales) saw a substantial increase in attributable burden, with carbapenem resistance now a critical priority due to limited treatment options. Meanwhile, MRSA remains a leading cause of global health loss, despite being classified as highly treatable.

Underlying cause of the problem

The relationship between HAIs and MDROs is cyclical – poor infection control practices lead to more HAIs, which in turn drive the emergence and spread of resistant strains *(33)*. While several key factors – including elderly age, prolonged hospital stay, invasive medical devices, recent surgical procedure or antibiotic use – exacerbate MDRO acquisition in healthcare settings, underlying systemic causes (*see description in Table 2*) play a crucial enabling role for its sustained transmission.

Table 2: Description of the underlying systemic causes of the problem

Governance arrangement	
Gaps in IPC policy and ASP	Although the National Health Policy 2006 and the newly developed healthcare service rules and regulations 2025 mandate health facilities to implement IPC activities *(34)*, there is a lack of clear actionable steps to ensure compliance and accountability, and resource allocation.[1] Similarly, ASP efforts lack the policy mandate or managerial accountability. WHO recognizes the failure to mandate ASP activities as one of the factors hindering its implementation in healthcare facilities in most resource-constrained settings *(35)*. According to the Fifth Global Ministerial Submit on Patient Safety 2023, full implementation of ASP and IPC activities has remained a major gap in all countries due to insufficient political and institutional support, along with limited human and financial resources *(36)*.
Inadequate structural and financial support for IPC and ASP	The mandates of heath facility management and the government as a crucial support system through infrastructural, regulatory and financial support for ASP and IPC are insufficient. Without policy-driven mandates, AMS and IPC remain underprioritized in budgeting and decision-making. At the programmatic level, AMS and IPC are managed separately. Although there is a dedicated IPC programme under the Ministry of Health, it receives very limited financial support.[1] Meanwhile, a national action plan for AMR is in place. AMS activities are coordinated at the programmatic level through the Project Management Unit (PMU), which is solely funded by the Fleming Fund.
Lack of a coordinated approach to IPC–ASP implementation	Although formal IPC and AMS teams are in place at the NRH, the absence of a dedicated department manned by relevant experts limits its advancement. Currently, the existing team is multitasking and managing IPC and AMS responsibilities alongside their primary

[1] Discussed at the policy dialogue held on 28 August 2025 in Thimphu, Bhutan

	roles, which may limit the sustainability and effectiveness of interventions.
Organizational culture on patient safety	HAIs represent one of the most prevalent adverse events in hospital settings and a critical global patient safety challenge. At the core of addressing this issue lies the cultivation of a robust patient safety culture among healthcare professionals, which serves as a fundamental determinant of care quality and infection prevention outcomes *(37)*. A literature review-based study by Van et al. suggests a positive association between HAIs and organization culture centred around key themes, including leadership roles, staff engagement and empowerment, and collaboration *(38)*. A descriptive cross-sectional study in 2021 among different categories of health workers across nine different hospitals in the country demonstrated a low positive score (31%) for the item "*Hospital management seemed interested in-patient safety only after an adverse event happened,"* indicating insufficient leadership engagement and a reactive approach to patient safety *(37)*.
Research and development	Limited data and research on AMR hinder evidence-based policy development, with the absence of key studies on MDROs leading to poor understanding of their disease burden, mortality and economic impact. The *Lancet* reports similar knowledge gaps across low-resource settings with limited laboratory capacity and data collection systems *(39)*, hindering the ability to develop effective solutions.
Delivery arrangements	
Infrastructure gaps at the NRH	By the end of 2023, cohort-based isolation was introduced in the wards for MDRO-CRO. However, the physical layouts of many healthcare facilities in the country, including the NRH, are not ideal for managing infectious diseases, including MDROs. In particular, the continued use of open plan designs in critical care and emergency units was identified as a major architectural limitation, making it difficult to implement effective isolation and containment measures[1]. These findings highlight the urgent need to improve healthcare infrastructure to strengthen transmission-based precautions and enhance IPC measures.
*R**isk of importing MDROs through***	There is sufficient body of evidence that patients involved in medical tourism were twice as likely to be associated with MDROs than

[1] Discussed at the policy dialogue held on 28 August 2025 in Thimphu, Bhutan

patients returning from abroad	general travelers, with the Asia being the commonest geographical origin of travelers with resistant bacteria, accounting for 36% of the total isolates *(40)*. A significant number of Bhutanese travels abroad for medical treatment, either as government-sponsored or self-referred patients, facilitating cross-border transmission of AMR and risking MDRO importation.
Low HH compliance	Low adherence to HH protocols is a critical concern, greatly increasing the risk of HAIs and MDRO spread. A 2016 observational cross-sectional study at NRH revealed a low overall compliance rate of only 33.5% *(41)*.
Lack of a skilled workforce	The shortage of trained/specialized healthcare professionals such as infectious disease physicians and clinical microbiologists poses a significant barrier against advancing IPC efforts. Moreover, IPC efforts are mainly led by focal nurses, but frequent staff changes due to transfers and attrition hinder progress – a challenge commonly shared across LMICs *(42,43).*
Knowledge gaps among the key implementers	A cross-sectional survey on the knowledge of ICU nurses in IPC practices in 13 Asian countries, including Bhutan, found that nurses in higher-income countries and more years of experience had better knowledge. The study recommended periodic training and audits of IPC practices of HCWs working in ICUs, especially in LMICs *(44)*. A 2017 knowledge, attitude and practice (KAP) study at the JDWNRH showed moderate HH knowledge among healthcare workers, but compliance was low at 33.5%, with only 27.8% following the proper technique *(41)*. Despite good access to hand rub, over half had not received recent training. The study highlights the need for regular training, stronger monitoring, and a dedicated IPC unit to improve practices and reduce infection risks.
Financing arrangements	
Heavy reliance on donor funding	The recent Joint External Evaluation highlighted the need for Bhutan to revive its AMR programme and secure sustainable funding in line with national AMR National Action Plan (NAP) priorities. Bhutan's efforts to combat AMR have so far been largely supported by the Fleming Fund, which provided GBP 1.56 million under Phase I and GBP 1.42 million under the ongoing Phase II grant for capacity-building and laboratory strengthening. With the Fleming Fund nearing its end, sustainability remains uncertain. Meanwhile, IPC activities at the NRH and other health facilities rely heavily on donor support from

	the WHO and UN agencies. Dependence on external funding and the absence of dedicated budgets for AMS and IPC continues to constrain infrastructure and long-term sustainability.

Consequences of inaction

According to the *Lancet*, direct AMR-related deaths are forecasted to increase up to 70% by 2050 compared to that in 2022 (Box 4), and AMR-associated deaths are estimated to increase by 75% in the same period, from 4.71 million to 8.22 million per year *(8).*

The overuse of antibiotics has led to the rise of antibiotic-resistant bacteria, or superbugs, which severely undermine treatment effectiveness, while the slow pace of new antimicrobial drug development further worsens the crisis by failing to keep up with the rapid emergence of resistance *(45)*.

MDRO infections often result in treatment failure due to resistance to multiple antibiotic classes. With few options like carbapenems remaining, the rise of CRE – dubbed "nightmare bacteria" – renders even these ineffective, leaving virtually no viable treatment *(46)*.

Patients infected with MDROs often experience prolonged hospital stays, require more intensive care, and face higher healthcare costs, contributing to a growing financial strain on both individuals and institutions. Furthermore, the increased mortality rates associated with these infections urgently calls for comprehensive strategies to combat AMR *(47)*.

The economic impact of AMR is deeply concerning. According to a recent EcoAMR – economic impact of AMR series analysis – AMR could result in GDP losses of up to US$ 960 billion in the livestock sector and an alarming US$ 5.2 trillion in human health *(48)*. Furthermore, the World Bank warns that unchecked AMR could cut global GDP by 3.8% annually by 2050 and push 28 million people into poverty *(49)*.

While these figures highlight the devastating consequences of inaction globally, there is a paucity of information on the health and economic burden of AMR specific to Bhutan. Hence, there is an urgent need for localized analysis to understand the specific burden on Bhutan.

Box 4: Future projection of the global burden of AMR (8)

By 2050, AMR is projected to cause 1.91 million attributable deaths and 8.22 million associated deaths annually worldwide. The 10–20–30 by 2030 target (a 10% reduction in AMR mortality) is unlikely to be met without significant additional interventions. The 2024 *Lancet* series propose a global target of 10% reduction in AMR mortality, 20% reduction in inappropriate use of antibiotics in humans, and 30% reduction of inappropriate antibiotic use in animals by 2030 compared to 2019.

The South Asia region is predicted to bear the highest overall burden in the future, with the forecasted cumulative AMR-attributable death burden from 2025 to 2050 at 11·8 million (95% uncertainty interval [UI] 9·43–14·4). Likewise, the all-age rates of disability-adjusted life years (DALYs) attributable to AMR are forecasted to be highest in South Asia in 2050 (687 DALYs per 100 000 (527–881 DALYs per 100 000).

3. Options for addressing the problem

To address the rising rates of MDROs and HAIs at the NRH this evidence brief outlines four strategic options that have been selected based on global and regional evidence of their potential to reduce HAI and mitigate the growing burden of AMR.

The first strategy focuses on enhancing surveillance systems for HAIs, enabling more accurate tracking, early detection and timely intervention to curb infection outbreaks. The second emphasizes revamping infrastructure to manage infectious diseases and enhance isolation, which is critical in preventing cross-contamination and limiting the spread of resistant strains among vulnerable populations. The third option highlights the integration of IPC and ASP at the facility level for greater coordination and operational efficiency. The final option focuses on adopting an electronic HH monitoring system (EHHMS) to improve HH compliance among HCWs – a fundamental measure for reducing pathogen transmission within healthcare settings.

Option 1: Adoption of a real-time electronic surveillance system (ESS) for HAI

Overview and context

The traditional manual method of surveillance used across hospitals in Bhutan can be resource-intensive, time-consuming, prone to underreporting and bias, limiting its application to the surveillance of only a specific organism or condition *(50)*. Real-time electronic HAI surveillance systems integrate electronic health records (EHRs) with laboratory and clinical data to detect infections early, enabling timely intervention and enhancing IPC practices.

WHO has consistently highlighted the significance of HAI surveillance systems as a vital component of IPC. The recently adopted WHO Global strategy, action plan and monitoring framework for 2024–2030 guides countries on establishing effective HAI surveillance, emphasizing a digital or automated system *(51)*. Digital tools can support HAI surveillance in different ways – by facilitating electronic data entry to eliminate manual processes, improving efficiency and reducing errors, while also enabling automated extraction of patient data from electronic health information systems *(51)*.

Current practice

To ensure that staff are well-informed and competent, IPC link nurses, those in-charge and new recruits undergo annual CME sessions. These focus on reinforcing knowledge of IPC, including the definitions, criteria and systematic reporting of HAIs, ensuring alignment with current standards and protocols.

Monthly reporting of HAIs is carried out by IPC link nurses from each department and unit. These reports are submitted to the IPC unit, which compiles them and submits them to the IPC programme. At the programme level, data from hospitals nationwide are consolidated, providing a comprehensive national overview of HAI trends. This structured system ensures consistency, facilitates benchmarking and guides targeted interventions.

Furthermore, each department has a designated IPC and AMS champion, typically clinicians and nurses, who serve as advocates for implementing infection prevention bundles. Their leadership fosters adherence to protocols, encourages peer learning and strengthens interdisciplinary collaboration, thereby embedding IPC practices into routine care and promoting AMS.

The IPC unit additionally conducts PPS to evaluate the burden of HAIs within the hospital. Results are shared with the relevant wards and units, followed by discussions on specific interventions aimed at reducing HAI rates. This feedback mechanism helps close gaps and reinforces accountability across clinical teams.

Daily surveillance of CROs-MDROs is also a critical component of hospital IPC activities. The IPC team monitors cases closely and recommends or initiates appropriate interventions to ensure that patients receive optimal care under safe IPC practices. This proactive surveillance not only prevents the spread of resistant organisms but also safeguards patient outcomes.

Evidence of impact

At least five systematic reviews of medium quality and four primary studies were found that supported the benefits and effectiveness of ESS in reducing the HAIs and MDROs burden. The evidence of the impact of ESS for HAI, its potential harms, cost–effectiveness and uncertainties are summarized in Table 3.

A medium-quality systematic review show that an ESS for HAI was superior to the conventional manual method of surveillance and outperformed it. ESS exhibit high sensitivity and specificity in identifying SSIs and pneumonia *(50)*, which is further enhanced by the integration of artificial intelligence and machine learning *(52)*. A primary study conducted in a tertiary hospital in China demonstrated that ESS significantly improves HAI detection accuracy and achieves significant reduction in MDRO infection *(53)*. Use of real-time ESS for HAIs to guide targeted interventions is shown to reduce the risk and occurrence of HAIs in ICU settings. A retrospective analysis of ICU patient data in a tertiary hospital in China demonstrated that the use of ESS combined with targeted interventions reduced the prevalence of HAI-MDROs from 5.78% in 2021 to 3.21% in 2022 *(54)*.

In addition to its high efficacy in detecting HAIs, implementation of ESS improved the overall efficiency through workload reduction, time efficiency and standardized surveillance outcomes *(55)*. One systematic review showed that implementing ESS significantly save IPC staff time in data collection and case tracking while maintaining high levels of accuracy, allowing reallocation of resources to other IPC priorities for greater efficiency. It further states that by minimizing the human subjectivity that causes variability in manual surveillance, ESS ensure greater consistency and are thus suitable for large-scale use *(56)*.

Overall, ESS represent a promising tool for HAI control, though its success depends on system design, user training and institutional adoption.

Table 3: Summary of key findings from systematic reviews and primary studies relevant to Option 1

Category	Key findings
Benefits	✧ A medium-quality systematic review found that an ESS exhibits high sensitivity (60–98%) and specificity (61–100%) for identifying SSIs and pneumonia, with some studies reporting a 100% negative predictive value (NPV) *(50)*.

	✧ Likewise, studies from tertiary hospitals, such as one in China, confirm that ESS improve HAI detection accuracy ($P<0.05$) and reduce MDRO rates (0.41% versus 0.52%, $P=0.021$) *(53).* ✧ Furthermore, a systematic review found that the integration of artificial intelligence (AI) and machine learning further augments the effectiveness of ESS, with reports showing a threefold reduction in HAI incidence *(52)*. ✧ A review of automated surveillance of HAI implemented across European institution and hospitals showed workload reduction, accuracy, and time efficiency compared to the manual method *(57,58)*.
Potential harms	✧ Adoption of an ESS may not always guarantee quality surveillance as small differences in implementation, clinical practices, coding procedures can negatively impact the results, leading to harmful consequences *(58)*. ✧ Evidence of alert fatigue from EHR records among health staff members is reported, resulting in a tendency to ignore critical warnings *(59)*, potentially counteracting the positive benefits of ESS.
Resource use, costs and cost–effectiveness	✧ According to one systematic review, ESS require advanced programming skills to create, implement and maintain and reduce the variability in data format *(60)*. In addition, to fully adopt such automated surveillance requires advanced or next-generation EHR, which could mean significant financial resources to build and maintain *(61)*. ✧ Currently, there are insufficient data to determine the cost–effectiveness of infection control surveillance technology, as not all computerized systems are equally effective or efficient. Their performance depends on factors like system design, user training and willingness to adopt the technology *(62).* A study by Wernitz at el. noted that the implementation of computerized admission surveillance for MRSA prevented 48% of predicted nosocomial MRSA infections at a cost saving of €110 237 annually *(63)*. ✧ Although there is a lack of a specific cost–effectiveness or cost–benefit ratio on the use of digital AI in combating HAI, studies estimate that the implementation of AI for diagnosis and treatment in

	hospitals in general could lead to potential savings of US$ 17 881 and US$ 289 634, respectively, per day over a 10-year period *(64)*.
Uncertainty regarding benefits and potential harms	✧ One systematic review found that the ability of electronic methods to detect HAIs is dependent on the availability of clinical data in electronic format. The lack of electronic clinical data has caused failure to detect HAIs in several systems *(50)*. Therefore, its benefit in the surveillance of SSIs may be of concern since their diagnosis is usually symptom-based rather than on microbiology. ✧ Similarly, another systematic review emphasized on making the relevant data available to realize fully automatic HAI surveillance. Whereas, on the other hand, the lack of uniformity in data input adds to its complexity and therefore there is an increased requirement of resources to implement and maintain such a system *(60)*. ✧ Much of the currently available automated surveillance systems are designed by individual hospitals, which are customized to their specific needs. This hinders interoperability between systems and comparison between health facilities, thereby limiting its benefit on a wider scale *(58)*. ✧ A systematic review found that although the sensitivity of electronic systems is generally high, the specificity is inconsistent and frequently requires computer-assisted confirmatory assessment by the infection control staff *(61)*, which may hinder its regular implementation in most healthcare settings.

Option 2: Revamping infrastructure and enhancing isolation to manage infectious diseases

Overview and context

In healthcare settings, the lack of dedicated single-room isolation and the inability to cohort patients based on the pathogens they carry contribute significantly to the spread of MDROs, particularly CROs *(65)*. Studies have shown that patients colonized with MDROs, particularly those harbouring resistant organisms in their gut such as vancomycin-resistant Enterobacteriaceae (VRE) and CRE, can carry these pathogens for extended periods *(66)*. This highlights the importance of implementing isolation and heightened transmission-based precautions.

Current practice [1]

A comprehensive set of strategies has been implemented to address the growing threat of infectious diseases, including MDROs-CROs at the NRH. Real-time surveillance for CROs is currently in place, enabling early detection and prompt intervention. To ensure a coordinated and efficient response, a dedicated MDRO alert group has been established. This group facilitates timely communication and action among relevant stakeholders.

In alignment with national efforts, guidelines have been developed on MDROs-CROs, focusing on both infection prevention and clinical management. These guidelines provide a standardized approach to managing affected patients and preventing further transmission.

Within hospital wards, cohort isolation is actively practised for patients who are either colonized or infected with MDROs. In critical care settings where dedicated isolation rooms are unavailable, patients with MDROs are managed using strict standard and transmission-based precautions. Each bed space in multibed ICU and HDU rooms is treated as an individual care zone. Contact precautions, proper PPE use and rigorous HH are enforced to prevent cross-transmission. During outbreaks, affected patients are cohorted in a designated ICU area, with clear signage displayed to reinforce infection control measures among healthcare staff.

Stakeholders from the JDWNRH have reported continued efforts to enhance the management of infectious diseases. One of the key infrastructure improvements under way is the transition from open-floor ICU layouts to designs that incorporate a limited number of single-room isolation units. This shift aims to create a safer environment by minimizing the risk of cross-infection and allowing more effective containment of MDROs.

Evidence of impact

Sufficient evidence (*see* Table 4) is available to support the effectiveness of implementing isolation for MDROs to reduce their burden. Up to four systematic reviews and six primary studies were found to show the benefits and cost–effectiveness of implementing isolation of MDRO patients. Evidence from systematic reviews demonstrates that patient isolation strategies are highly effective in reducing the transmission of resistant pathogens like MRSA and CROs *(67)*. Coordinated measures, particularly rapid isolation protocols, including universal pre-emptive isolation and targeted isolation of MRSA-positive patients identified via polymerase chain reaction (PCR) testing, yield the most significant reductions in transmission and infection rates, even in endemic settings *(68)*. A systematic

[1] Discussed at the policy dialogue held on 28 August 2025 in Thimphu, Bhutan

review demonstrated that implementing single-room isolation was impactful in reducing HAI rate (odds ratio [OR]: 0.68; 95% confidence interval [CI]: 0.59, 0.79; $P<0.00001$) *(69)*.

There are mixed findings when it comes to the harmful effect on the patient of isolation measures. Whereas a meta-analysis of 19 studies found no adverse effects of isolation on clinical care outcomes *(70)*, on the other hand, a systematic review found significant psychological consequences for patients. Contact isolation is consistently linked to increased depression, anxiety, stigmatization, and reduced healthcare worker interactions, with isolated patients receiving fewer visits from staff *(71)*. These findings indicate that, while isolation measures effectively prevent pathogen transmission, it may inadvertently harm the mental well-being of affected individuals, highlighting critical gaps that must be addressed during implementation.

Table 4: Summary of key findings from systematic reviews and primary studies relevant to Option 2

Category	**Key findings**
Benefits	✧ A systematic review demonstrated that coordinated measures, such as isolating patients, were effective in controlling MRSA even in settings where the infection is endemic (67). ✧ One systematic review and meta-analysis showed that patients in single-room isolation experienced lower nosocomial bacteraemia rates (odds ratio [OR]: 0.73) and lesser odds of MDRO infection (OR: 0.41) than those in multi-patient rooms (69). ✧ A systematic review and meta-analysis found significant benefit of single-patient rooms in reducing HAI colonization compared to multibed wards (65).
Potential harms	✧ A systematic review and meta-analysis that included 19 articles found that there were no adverse events related to clinical care or patient experience of isolation (70). ✧ On the contrary, another systematic review on patient experiences and perception with infections due to MDROs demonstrated a consistent association between contact isolation and increased level of depression and anxiety among patients, in addition to other psychological aspects. These included a feeling of stigmatization and reduced interaction with healthcare provider, as patients in isolation rooms are visited less frequently by health staff (71).

Resource use, costs and cost–effectiveness	✧ An economic evaluation based on a dynamic transmission model showed that although pre-emptive isolation and rapid PCR-based isolation was found to reduce MRSA transmission, it increased cost, and therefore it may be cost effective only in high-prevalence settings, whereas a universal admission and weekly screening using polymerase chain reaction (PCR) for MRSA coupled with isolation was not cost effective (68). ✧ A primary study to evaluate the cost–effectiveness of temporary single-room isolation to reduce HAI risk in a UK National Health Service hospital showed that there is some evidence of cost–effectiveness in adopting single-room isolation (temporary). The study showed that there is a 93% chance that adopting single-room isolation is cost effective at a cost of £20 000 per additional life-year gained (LYG), while even at a lower threshold, at £13 000 per LYG, the probability drops slightly to 87% (72). ✧ Similarly, adopting temporary single-room isolation was found to be cost effective in the Singaporean setting, with an estimated cost-saving of S$ 329 423 and 1754 LYG, for 478 fewer HAIs per 100 000 occupied bed-days (73).
Uncertainty regarding benefits and potential harms	✧ Despite the encouraging findings, the methodological weaknesses of most studies and inadequate reporting in many mean that plausible alternative explanations for reductions in MRSA beyond isolation alone cannot be excluded, as there are no well-designed studies that allowed the role of isolation measures alone to be assessed (67). ✧ In contrast to the positive benefits outlined above, one systematic review looking at the effect of single-room isolation in reducing MDRO infection rates found no significant difference in the transmission of ESBL between single-bed isolation with contact precautions versus standard precautions (incidence rate ratio: 0.99). Likewise, one before-and-after study included in the review found only a 4.8% difference on VRE acquisition in the single-room isolation group compared to the shared-room group, which is below the 10% non-inferiority margin, and therefore not substantial enough to recommend policy changes (74).

Option 3: Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department

Overview and context

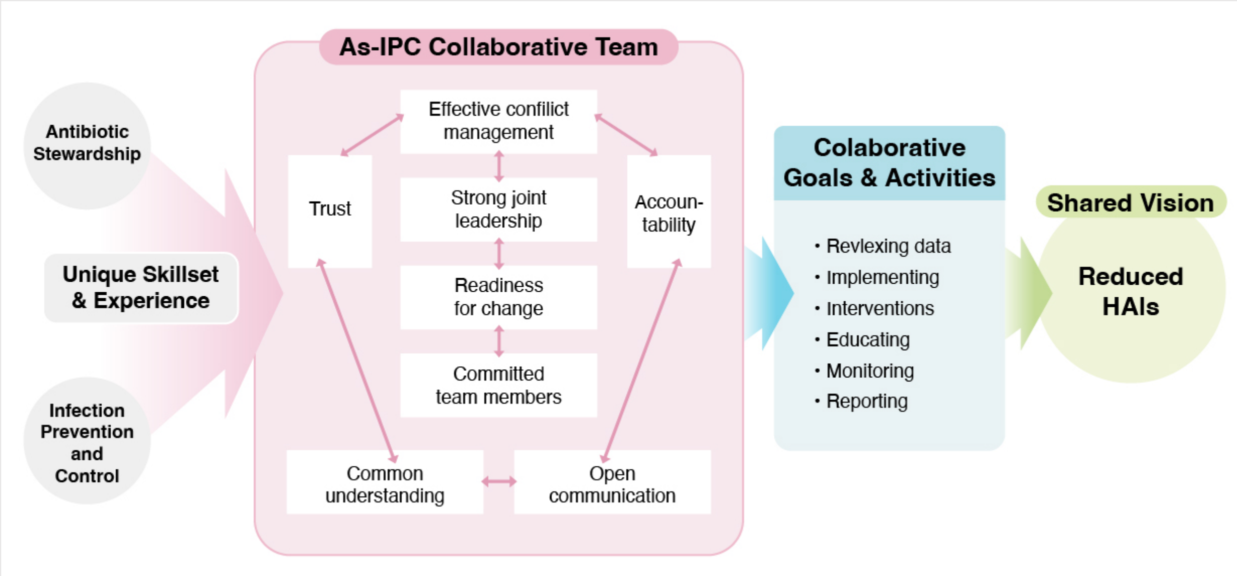
In response to the growing AMR challenges, ASPs have emerged as an essential intervention to optimize antimicrobial use, improve clinical outcomes, and limit the emergence and spread of resistant pathogens *(75,76)*. However, an ASP alone may not be sufficient, and a collaborative approach with the IPC team is essential to comprehensively tackle AMR *(76,77)*.

Strengthening institutional capacity, promoting diagnostic stewardship and embedding ASP within broader IPC frameworks are essential steps toward sustainable AMR mitigation globally. Research shows that while ASP and IPC work well on their own, combining them leads to even better results. This integrated model is particularly relevant for LMICs, which face a high burden of AMR. Addressing this challenge requires strengthening both the IPC and AMS components equally. Given the limited availability of human resources with expertise in this field, there is a need for context-specific and resource-conscious strategies**.** While the synergistic potential between ASP and IPC activities has long been acknowledged, it remains underutilized *(78,79)*. Such synergy can be achieved only through a dedicated department with full-time staff at the hospital level, with further decentralization to regional hospitals.

Manning et al. emphasize that IPC and ASP are inherently interdependent – neither can function effectively in isolation, highlighting that there is a critical need for intentional, strategic collaboration between these disciplines *(79)*. Yet, the lack of resources and limited training and education for HCWs to sustain AMS and IPC strategies, particularly in LMICs, is a significant challenge *(80)*. Hence, the basis for successful implementation of IPC and AMS is the support of political and healthcare leaders through legislation and processes that facilitate the creation of the necessary resources for these programmes *(36)*.

Klobnoch et al. present an ASP and IPC collaborative framework (*see* Fig. 4) to integrate the two disciplines at the facility level. The framework emphasizes the areas of overlap between the two disciplines and includes review of data, implementation of interventions, education, monitoring and reporting *(78)*. Based on the team-of-science approach, the framework leverages the specific skill set and expertise from each area, inculcates a shared leadership role between IPC and ASP professionals, team-building that centres around mutual trust, understanding and open communication to achieve the shared vision of reducing HAIs *(78).*

Fig. 4. AMS and IPC collaborative framework



Adapted from: Knobloch et al., 2021 *(78)*

Additionally, Brink and Richards highlight the key enablers (*see Box* 5) that must be leveraged to achieve an effective synergy between ASP and IPC programme *(81)*.

Box 5: Enablers for achieving synergy between the ASP and IPC programme

Identifying, defining and clarifying the synergistic role of IPC

Developing effective teams and embedding multidisciplinary collaboration

Developing synergistic goals and strategies

Developing robust data-driven institutional action plans

Defining optimal evidence-based strategies for cooperative management of patients

Defining optimal outcome metrics of these combined efforts

Tailoring educational strategies to suit all disciplines simultaneously

Utilizing advanced information technology (IT) tools to support ASP and IPC monitoring and implementation, e.g. multidimensional dashboards

Providing systemwide performance and outcome feedback utilizing IT tools

Translating generated outcomes via enhanced communication strategies to sustain awareness and engagement

Studying the benefits and costs of different combined interventional strategies to provide scientific data that support allocation of increased resources

Establishing universal quantitative end-points for IPC and ASP control efforts for AMR organisms

Current practice [1]

Prior to 2024, AMS at the national hospital was managed solely by one pharmacist, while IPC activities were overseen by a single IPC nurse (at times two) at the hospital level. There was no dedicated department, proper HR planning, or allocation of resources to support these critical functions. Recognizing this gap, the country's only infectious disease physician introduced a unique and transformative concept: the establishment of a combined IPC and AMS team. This approach was based on the understanding that IPC and AMS are intrinsically linked, sharing the common goal of reducing the spread of AMR, particularly HAIs and improving patient outcomes.

While AMS focuses on optimizing antibiotic use to prevent the emergence of resistance, IPC emphasizes the prevention of infections within healthcare settings, including those caused by resistant organisms. Given their complementary objectives, a multidisciplinary IPC and AMS team was formally established at the NRH. This team includes a clinical lead, IPC nurses, an AMR laboratory focal person, an AMS pharmacist, and a representative from the hospital's quality control division.

Similar multidisciplinary teams have now been formed in three other sentinel hospitals equipped with microbiology culture facilities. Additionally, the military hospital, which operates under a different antibiotic supply chain, has also developed its own IPC and AMS team. The NRH team plays a central role in guiding and mentoring these teams across sentinel sites, thereby facilitating the cascading of IPC and AMS efforts to smaller hospitals within their catchment areas.

To further decentralize and strengthen these initiatives, each clinical department has identified IPC and AMS "champions", typically a clinician and a nurse, who are responsible for implementing and promoting best practices within their respective units. Supported by the Fleming Fund, team members have also had the opportunity to gain exposure and training at the National Centre for Infectious Diseases (NCID) in Singapore and in San Lorenzo, the Philippines.

Today, these teams work in a well-coordinated manner, conducting IPC–AMS joint ward rounds, carrying out real-time surveillance for CROs, and providing timely feedback to clinical teams. Collaboration between hospitals has also strengthened, ensuring a unified and effective response to AMR across the healthcare system.

Currently, at the NRH, there is no dedicated IPC and AMS department staffed with full-time human resources (HR) who are experts in these fields. The existing team is multitasking and managing IPC and AMS responsibilities alongside their primary roles,

[1] Discussed at the policy dialogue held on 28 August 2025 in Thimphu, Bhutan

which may limit the sustainability and effectiveness of interventions. Efforts to create an IPC and AMS unit have been ongoing, but for better HR support and resource allocation, it was proposed to establish a dedicated department with infrastructure, HR and other resources in place.

Evidence of impact

Up to six systematic reviews, one scoping review and one primary study collectively demonstrate the advantages of combining ASP and the IPC programme.

A systematic review demonstrated that when ASP was combined with intensified infection control measures, the incidence rates of MDROs decreased by up to 70%, with HH compliance having the biggest effect of all the infection control measures *(82)*.

Robust evidence demonstrates that integrated IPC strategies – combining standard precautions, environmental cleaning, contact precautions and ASP – are most effective against MDROs. These bundled approaches show clear synergy, reducing CRAB acquisition by 52–72% and demonstrating greater effectiveness compared to single interventions *(83)*. The impact of ASP is further amplified when combined with IPC measures like HH (which reduces HAIs by 48%) *(84)*. Notably, these strategies prove feasible even in LMIC settings, with ICU-focused bundles showing success in reducing resistance rates.

A systematic review and network meta-analysis showed that combining contact precautions with antiseptic baths cuts transmission by 62%, while adding antibiotic stewardship to standard precautions reduces infections by 42%. The most effective triple approach (standard precaution + contact precautions + stewardship) slashes MRSA rates by 65% and curbs hospital wide spread *(85)*.

The synergistic effect of IPC and ASPs on controlling MDROs was demonstrated in a retrospective, observational study conducted in a tertiary hospital in Argentina in 2023. The study showed that the joint implementation of IPC measures and ASP was associated with a significant reduction in the CRE infection rate, in addition to decreased VAP and CLABSI during the study period *(86)*. Similarly, Lee et al. found that implementing an IPC focused on HH and hospital cleanliness, backed by a robust ASP, could reduce the MDRO burden by 85% (Table 5) *(87)*.

Table 5: Summary of key findings from systematic reviews and primary studies relevant to Option 3

Category	Key findings
Benefits	✧ A primary study on the impact of combining ASP and IPC measures on resistance rates and colonization pressure of carbapenem-resistant *Acinetobacter baumannii* (CRAB) in the ICU of a tertiary care centre in Lebanon demonstrated overall reduction in *A. baumannii* resistance and a sustained reduction in CRAB, showcasing the feasibility of implementing such integrated ASP–IPC programmes effectively in LMIC settings *(88)*. ✧ One systematic review and network meta-analysis that included 42 studies showed that a combined multipronged approach of standard care (STD – HH, contact precaution), source control (SCT), environmental cleaning (ENV) and ASP were most effective in preventing MDR Gram-negative bacterial infection. Critically, combining interventions demonstrated a clear synergy: adding ENV to STD and ASP reduced CRAB acquisition by 72%, while adding SCT to STD and ENV lowered it by 52% *(83)*. ✧ One systematic review and meta-analysis showed that implementation of HH enhances the impact of ASP in reducing infection and colonization by antimicrobial-resistant bacteria. ASP and HH implemented together showed a 66% reduction in the incidence ratio of infection and colonization of MDRO-Gram negative bacteria compared to just 51% reduction when ASP was implemented alone *(82)*. ✧ A systematic review and network meta-analysis of 97 studies revealed that combined infection control strategies, particularly contact precautions (SP) + chlorhexidine gluconate baths (CHG) (RR, 0.38 [0.18, 0.79]) and standard precaution (SP) + CP + ASP (RR, 0.58 [0.37, 0.92]), were significantly more effective at reducing MDRO acquisition than SP alone. Notably, subgroup analyses demonstrated that the triple intervention (SP + CP + ASP) was the most impactful strategy, with a significant reduction in MRSA acquisition (RR, 0.35 [0.14, 0.92]) and hospital wide MDRO transmission *(85)*. ✧ Similarly, one systematic review showed that ASP interventions were associated with reductions in antimicrobial utilization (11–38% defined daily doses/1000 patient-days), lower total antimicrobial costs (US$ 5–10/patient-day), shorter average duration of antibiotic

	therapy, less inappropriate use and fewer antibiotic adverse events. Stewardship interventions beyond 6 months were associated with reductions in AMR rates *(89)*. ✧ A systematic review of 32 studies showed that ASP reduced the incidence of infections and colonization with MDR Gram-negative bacteria (51% reduction), ESBL-producing Gram-negative bacteria (48% reduction), and MRSA (37% reduction), as well as the incidence of *C. difficile* infections (32% reduction) *(53)*. ASP were more effective when implemented with infection control measures (incidence ratio (IR) of target infections and colonization: 0·69), especially HH interventions (IR 0·34), than when implemented alone *(82)*.
Potential harms	✧ There were no documented patient harms that resulted from ASP implementation.
Resource use, costs and cost–effectiveness	✧ Implementing ASP in a hospital-based setting was found to be cost effective. Two systematic reviews found that ASP-driven (through reduced antibiotic use and reduced duration of antibiotic therapy) cost savings on the purchase of antibiotics ranged from 12% to 73% *(84,90)*. ✧ Similarly, a systematic review of five articles on the economic evaluation of ASP found it cost effective in hospital settings, although it cautions on the usefulness of the data on cost and benefit in current evidence-based practice due to inconsistencies in the study design and the depth of ASP intervention employed *(91)*.
Uncertainty regarding benefits and potential harms	✧ Notwithstanding the wide range of benefits brought by the implementation of ASP, there is a low certainty of its effect on reducing antibiotic resistance. According to a systematic review in which 20 out of 221 studies focused on the impact of ASP intervention on AMR, none were randomized controlled trials (RCT) while only eight were quasi-experimental *(92)*. ✧ ASP alone may not be sufficient in achieving reduction in infection and colonization by antibiotic-resistant bacteria but is more effective when combined with infection control measures *(82)*.

Option 4: Strengthening hand hygiene compliance (HHC) through real-time auditing using an electronic HH monitoring system (EHHMS)

Overview and context

HH is universally recognized as the cornerstone of IPC in healthcare settings and HHC is widely considered as the foundation for preventing MDRO spread, particularly in intensive care units (ICU) *(93)*. However, according to the WHO, the HHC by HCWs remains generally poor worldwide, with an average compliance rate of only 59.6% in ICUs – with notable disparities between high-income (64.5%) versus low-income (9.1%) countries *(94)*.

To address the poor HHC, the WHO HH Research Agenda (2023–2030) highlights critical priorities for the next two decades, emphasizing the expansion of HH research and the enhanced use of information technology to improve the accuracy and impact of HHC monitoring *(94)*.

In Bhutan, HHC remains a challenge due to behavioural factors despite regular trainings and resources provided to HCWs. HHC rates reported by hospitals are inconsistent and widely differ from year to year, between hospitals and within hospitals. Therefore, it is essential to strengthen monitoring of HHC by adopting innovative solutions using appropriate digital tools.

EHHMS work by using instant alerts – visual, auditory, vibratory – to notify HCWs of missed or poor-quality HH and even detect skipped steps or improper technique through sensors. UV devices highlight unclean hand areas *(95)*.

Current practice [1]

To strengthen HH compliance, a number of coordinated strategies have been implemented across the facility. The IPC Unit conducts structured audits twice a year using the WHO Hand Hygiene Observation Tool and complements these with questionnaires to assess staff knowledge. In addition to the audits, IPC link nurses from each department submit monthly reports on HH practices. These reports are shared with all heads of departments, ensuring ongoing monitoring and fostering a culture of accountability. These sessions also serve as a platform for reviewing performance, identifying challenges, proposing tailored interventions and setting specific, measurable goals for improvement.

[1] Discussed at the policy dialogue held on 28 August 2025 in Thimphu, Bhutan

To support continuous learning, regular education initiatives, including CME sessions, are organized, keeping staff updated on current best practices in infection prevention.

Furthermore, each department has a designated champion for IPC and AMS, including both clinicians and nurses. These champions play a critical role in promoting driving and sustaining HH practices within their respective teams, ensuring that efforts are maintained consistently across all areas.

Despite these systematic efforts, overall HHC remains low, though it is slightly higher than the WHO reported global average of 40%. The key challenge is the absence of real-time surveillance, which limits timely feedback and corrective action.

Introducing real-time monitoring mechanisms is therefore essential to improving compliance and, ultimately, reducing HAIs.

Evidence of impact

At least three systematic reviews and three primary studies were found demonstrating the benefit of implementing EHHMS in improving HHC and reducing HAI and MDRO incidence. An experimental study to assess HHC and the impact of real-time reminders showed improved HCW compliance to HH, particularly in rooms that had activated reminders (visual and audio) compared to rooms without reminders *(96)*. Likewise, a controlled experimental study also found that real-time feedback by wireless technology connected to a patient's invasive device (enhanced feedback loop) resulted in a significant increase in HHC by HCWs (69.5% in the enhanced group vs 59.1% in the basic group) *(97)*.

Regarding the cost implication, while EHHMS requires significant initial investment, its long-term value or return on investment is clearly evident. A cost–effectiveness analysis of EHHMS in a tertiary hospital in Mexico demonstrated a potential cost savings of US$ 308 927 to US$ 546 795 by implementing an automated HH monitoring system compared to non-implementation of the system (US$ 464 102 vs US$ 773 029–1 010 898), over a six-month assessment period *(98)*. For policy-makers, the key challenge is balancing initial investment with long-term benefits. EHHMS offer enhanced tracking of compliance and greater reduction in infections; however, focusing implementation in high-traffic areas may yield the most favourable cost–benefit outcomes.

The evidence of the impact of EHHMS in improving HHC and reducing HAIs, its cost–effectiveness and associated harms are summarized in Table 6.

Table 6: Summary of key findings from systematic reviews and primary studies relevant to Option 4

Category	Key findings
Benefits	✧ A systematic review on intelligent technology interventions for HH found that real-time feedback, automated monitoring and wearable badges significantly improved compliance among HCWs. These tools enabled continuous tracking and instant reminders, reinforcing behaviour change. Compared to usual care, the interventions increased HH compliance (RR: 1.56) and significantly reduced HAI rates (RR: 0.25), though they had no significant effect on MDRO detection (RR: 0.53) *(99)*. ✧ Similarly, another systematic review and meta-analysis on IT interventions found that tools like electronic counters, remote monitoring and real-time reminders significantly improved HHC among HCWs. These technologies offered efficient, scalable solutions for promoting adherence to HH (OR: 3.06). The interventions showed a clear positive impact on compliance rates, supporting their role in reducing HAI risks *(100)*. ✧ A primary study conducted in a tertiary hospital in Sweden to assess the improvement in HHC by adopting electronic HH monitoring with a digital feedback system showed that HH adherence increased significantly compared to the baseline (37.9% vs 52.5%), with a mean increase of 14.5% *(101)*.
Potential harms	✧ EHHMS can cause device-related injury or harm to users. For instance, the use of UV lamps used for detecting the quality of HH can cause UV-related skin and eye damage. Similarly, wearable sensor devices (to indicate HH quality) such as wrist watches, bracelets and rings themselves can harbour pathogens and cause contamination of the user's hands *(98)*. ✧ Additionally, devices using audio alerts were found to disturb patients while resting, while colour-coded alarms have been found to cause anxiety among staff members *(99)*.
Resource use, costs and cost–effectiveness	✧ HH improvement strategies can prevent up to 50% of avoidable infections in health-care settings while generating cost savings approximately 16 times greater than the investment required for implementation. The review recommends the use of automated HH monitoring systems for better results *(102)*.

	✧ Establishment of EHHMS can be costly, which could offset some of the benefits. One systematic review found that the cost of installing an electronic dispenser-assisted system in an ICU cost up to US$ 40 000 in 2012, and around US$ 50 000 for installing video cameras in a 17-bed ICU *(95)*. ✧ A primary study conducted in a tertiary hospital in China found that the EHHMS showed more cost–effectiveness, cost–efficiency (48.11% vs 14.2%), and cost–benefit compared to the manual system, particularly across high-risk departments, which require the most HH practices and greater monitoring *(103)*.
Uncertainty regarding benefits and potential harms	✧ A systematic review highlighted that, despite their potential, EHHMS challenges included accuracy, data integration, privacy and confidentiality, usability, associated costs, and the need for infrastructure improvements. Additionally, the review highlighted the absence of standardized measurement tools to evaluate system performance (95). ✧ A meta-analysis of 36 studies found that intelligent technology, such as real-time monitoring systems, improved HH compliance and helped reduce HAIs. However, the studies showed significant variability and were often of low quality, making the results less conclusive. There is uncertainty about the long-term sustainability of these improvements. Further high-quality research is needed to validate these findings (99). ✧ A before-and-after study to compare EHHMS versus manual-based systems conducted across 40 clinical departments in a tertiary hospital in China found no significant difference between the two system in HAI reduction. However, the cost–effectiveness of the electronic system over the manual system outweighs this uncertainty, especially considering the burden of disease caused by HAIs (103). ✧ In contrast, two systematic reviews conducted in 2014 and 2024 concluded that there are insufficient high-quality real-world studies to recommend the widespread use of EHHMS. It identifies the need for better designed studies and cost transparency to justify its implementation (104,105).

4. Considerations in implementing the four options

This section discusses the potential barriers in implementing each of the options at the organizational or health systems level, health provider level, and the community level, including sociocultural barriers where relevant to Bhutan's context. The authors also discuss counterstrategies (Table 7) based on global experience and local context to best overcome the barriers.

Potential barriers and counterstrategies

Option 1: Adoption of a real-time ESS for HAI

Several aspects have to be considered when developing an ESS for HAI, including privacy, data-sharing, data security, ethical considerations, laws and regulations on data reporting, as well as data protection *(57)*. Not addressing these factors properly could hinder the adoption of ESS and become a barrier to its implementation. Potential barriers to the implementation of ESS can be categorized under health systems, at the health provider level and financial and political factors, as discussed below.

Health system level

Health systems factors that can potentially hinder the implementation of a robust ESS for HAI include limited diagnostic capacity, inadequate IT infrastructure and integration challenges. Diagnostic limitations, including support from an insufficient and an overwhelmed microbiology laboratory, could compromise data quality and comparability due to inconsistent diagnostic methods. IT infrastructure constraints hinder electronic data extraction, reporting and integration across systems (e.g. EHRs, laboratory databases). Data-sharing gaps between facilities and infection control programmes further impede surveillance efforts, while integration challenges with laboratory results and patient demographics reduce data reliability. Additionally, a lack of surveillance culture marked by limited awareness and institutional commitment undermine system implementation and success *(106,107)*. Addressing these interconnected issues is critical for strengthening electronic/automated HAI surveillance.

Health provider level

To operate and maintain a complex digitized HAI surveillance system requires well-trained and motivated human resources for health. Currently, there is a significant shortage of necessary expertise and capacity in several key areas – planning and protocol development, infectious diseases, microbiology laboratory and data analysis *(106)*.

The limited capacity in strategic planning and protocol development for HAI surveillance often results in inconsistent and unreliable data quality due to variations in data collection methods, case definitions and reporting procedures. In addition, there is a lack of staff who can regularly analyse HAI surveillance data, and IPC practitioners who can interpret HAI surveillance data *(42,106,107)*.

According to a systematic review, ESS may not be readily accepted among healthcare providers as evidence suggests that technological innovations in healthcare are often rejected or abandoned by staff due to a perceived misunderstanding of its long-term benefits *(108)*. Such an inherent HCW resistance to change is not uncommon, especially when newer technology gets introduced. Therefore, a cautious approach with a proper end-user engagement strategy from the beginning is crucial.

Financial and political factors

In resource-constrained settings, financial limitations are a major obstacle, as surveillance activities are often perceived as non-essential, resulting in inadequate funding and unsustainable programmes. Compounding this issue is the difficulty in securing long-term financial support for ongoing surveillance efforts. Political factors further impede progress, where a lack of government commitment undermines implementation *(42)*.

Option 2*:* Revamping infrastructure and enhancing isolation to manage infectious diseases

Isolation for MDROs imposes major costs on hospitals, including extensive PPE use, infrastructure investments for revamping open-floor plan units into single-room isolation/cubicles to manage infectious diseases. Additionally, the cost of recruiting extra human resources, training and retaining them can be expensive and difficult to afford for many countries *(109)*. Such financial demands are especially difficult for hospitals in resource-limited settings, where sustainability is a major challenge.

Organizational level

Establishing dedicated single-room isolation facilities ideally requires an exclusive set of properly trained and motivated HCWs, particularly nurses *(110)*. However, as Bhutan grapples with the ongoing crisis of nursing shortages (short by 824 nurses as of 2024), any new initiative that further strains the already thinly spread nursing staff is expected to be a major barrier *(111)*. For instance, implementing cohorting of staff along with patients to manage MDRO isolation units, as practised in some regions, can add a burden on the staff and the health system *(112)*.

Health provider level

HCWs assigned to work in isolation wards require a number of favourable attributes, including psychological preparedness, occupational readiness, a sense of professional obligation, in addition to capacity-building, resources and managerial support *(113)*. Experiences from the COVID-19 pandemic have shown that HCW burnout syndrome –

characterized by emotional exhaustion, depersonalization and diminished personal accomplishment – was more prevalent among those who worked in isolation wards, which was further aggravated by the fear of acquiring infection or transmitting it to their families *(112)*.

Sociocultural context

Bhutan is known for its closely knit social fabric; visiting the sick during their hospital stay is one representation of this sociocultural network. However, such practices lead to overcrowding of wards, single-room cabins and even ICUs, disrupting patient care and routine hospital procedures, including cleaning and disinfection protocols. Without a proper strategy to address unregulated patient visitors in isolation rooms, infection control protocols cannot be fully enforced, threatening to disrupt implementation of the policy.

Option 3: ***Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department***

Health system arrangement

In most health systems, AMS and IPC are known to operate as parallel but disconnected strategies to address AMR. Although both are critical, their siloed implementation limits their collective impact on AMR(78). AMS focuses on the rational use of antibiotics, while IPC emphasizes infection prevention in health facilities through HH, cleaning and disinfection, and safe healthcare waste management (HCWM). This difference in primary objectives has led to the perception of AMS as a pharmacy-led activity, whereas IPC is traditionally seen as a nurse-led initiative. Additionally, these programmes are often funded separately, with the UK Fleming Fund primarily supporting AMS, while IPC relies on a combination of government and donor funding.

Health provider level

Inadequate knowledge of healthcare providers on AMS and IPC, mainly driven by insufficient staff engagement, can pose a significant challenge to their implementation. Above all, a “readiness to change” is essential among staff members, grounded in mutual trust and respect of each other’s roles, will enable the fostering of a joint leadership approach *(78)*. It is crucial to invest in continuous education and engagement of staff members through peer-to-peer mentoring.

Community level

Non-compliance of patients with IPC measures in hospitals is found to hinder successful IPC intervention, as shown by a qualitative study to explore the barriers to implementing

IPC measures in selected hospitals in Nigeria. Non-compliance is mainly driven by multiple factors, including inadequate knowledge of IPC, poor socioeconomic status and negative attitude towards IPC *(114)*. Continuous public engagement through awareness campaigns is necessary to ensure compliance to IPC measures.

Option 4: ***Strengthening hand hygiene compliance (HHC) through real-time auditing using EHHMS***

Organizational level

The adoption of an EHHMS in healthcare settings requires substantial investment in both infrastructure improvement and system-specific costs, such as purchasing equipment and covering installation and maintenance expenses *(95)*. An assessment of the adoption of an EHMMS in acute care hospitals in New York found that only two hospitals had adopted it out of the 56 hospitals that responded to the survey, with cost (79.6%) being the primary reason for non-adoption *(115)*. However, while the upfront investment required for EHHMS may seem discouraging, the financial burden of HAIs presents a compelling counterargument.

Provider level

The adoption of EHHMS is often hindered by HCWs' privacy-related apprehensions as HCWs tend to view such systems as intrusive, believing they facilitate excessive surveillance of their routine practices. Such perceptions foster distrust toward the technology and resistance against adopting it *(95)*.

Sensor devices are found to be less user-friendly, particularly wearable devices, which can be bulky, heavy and inconvenient to wear. Systems that use sensor devices with a limited range cause HCWs to frequently adjust their movement and location at the workplace *(95)*. One of the main concerns among HCWs regarding the EHHMS was its accuracy in monitoring handwashing opportunities, especially when using proxy indicators such as entry/exit from the isolation room, which is prone to either over- or underestimation of HH compliance *(116)*. Likewise, the use of radiofrequency techniques was found to be prone to miscalculation of HH numbers such as double counting with more than one person within a certain range *(117)*.

Concerns regarding acceptance of digital devices by HCWs and declining level of adherence to wearing such devices over time were shared by participants.[1] There is a risk of poor uptake of new technologies by HCWs, especially when introduced solely from the patient benefit perspective (Table 7).

Table 7: Summary of implementation considerations for the four options

Level	Barriers	Counterstrategies
Option 1: *Establishment of a real-time electronic surveillance system (ESS) for HAI*		
Health system (governance, legal and regulatory issues related to ESS)	✧ High cost of initial installation – available ESS tools require integration into the local EHR system and validation, which is time-consuming and costly *(118)* ✧ Further, to maintain the system, continuous IT support is essential, the cost of IT services may offset future IT time saved *(118)* ✧ Driven by data privacy issues, ESS faces important ethical, legal and operational challenges *(106)*	✧ The key stakeholders, including the Ministry of Health (MoH) and government technology (Govtech) agency should essentially work from the inception phase to integrate ESS into the existing electronic patient information system (ePIS) ✧ Essential to involve clinicians, nurses, IT personnel, legal experts and patients from the inception phase to address the complex operational challenges from the beginning
Health provider level	✧ Resistance from HCWs due to misunderstanding of the long-term benefit and a perceived work burden that an ESS may introduce *(106)* ✧ Clinicians' distrust of algorithm-driven results without validation *(106)* ✧ Critical shortage of trained professionals in infectious diseases, microbiology and data analysis, leading to inconsistent data quality and	✧ Early engagement of end-users, leadership commitment, embedding HAI reduction in hospital key performance indicators (KPIs), and adequate training of staff

	limited capacity to interpret HAI surveillance results *(106)*	
Financial and political constraints	✧ Resource constraints, lack of political commitment and weak policy support hinder sustainable funding and implementation of HAI surveillance in resource-limited settings *(42,106,107)*	✧ Advocate HAI surveillance as a cost-saving investment, engage policy-makers with evidence on the economic impact of HAI
Option 2: *Revamping infrastructure and enhancing isolation for managing infectious diseases*		
Organizational level	✧ Limited incorporation of IPC standards in the planning and renovation of hospital facilities ✧ Limited resources to revamp existing hospital structures for optimal infectious disease management and IPC practices ✧ Managing dedicated isolation facilities requires adequate, well-trained and motivated HCWs, particularly nurses *(110)*. The ongoing trend of rising attrition of nurses is expected to pose a significant challenge to establishing dedicated isolation facilities	✧ Ensuring IPC standards are incorporated during the planning and design of new hospital facilities, as well as in the renovation of existing ones ✧ Funding should be secured and detailed proposals developed to upgrade facilities, ensuring adequate isolation capacity and adherence to IPC standards ✧ Developing strategies to optimize the workforce such as task-shifting, incentivizing nurses through both monetary and non-financial incentives such as career opportunities ✧ Adopting technological solutions to reduce the work burden
Provider level	✧ Isolation ward staff can experience severe burnout (emotional exhaustion,	✧ A multifaceted strategy is necessary aimed at managing workload.

	detachment, low morale), exacerbated by infection risks and fear of transmission to their families *(112,113)*	Limited duty hours, flexible work schedules and setting realistic workplace expectations with adequate resources and training *(119)* ✧ Mental health support such as mindfulness and stress management programmes, and peer support are found useful *(119)*
Sociocultural context	✧ Bhutan's strong sociocultural practice of visiting hospitalized loved ones leads to ward overcrowding, disrupting care, cleaning protocols and infection control, especially in isolation units ✧ Strong association of stigma with isolation can have a significant impact on the patient's psychological well-being such as feeling of uncertainty, labelling, exclusion, etc., adversely impacting patient compliance to isolation protocols *(120)*	✧ Implement a strict structured visiting policy, invest in strategies to reduce direct contact, such as virtual calls ✧ Conduct constant rigorous public awareness to educate the community on infection risks ✧ Develop strategies to provide patients with social and emotional support, including counselling services, and ensure the provision of an optimal quality of care for those in isolation *(120)*
Option 3: Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department		
Organizational level	✧ Lack of a dedicated IPC and AMS department staffed with full-time HR who are experts in these fields could hinder the	✧ Establish dedicated IPC and AMS departments staffed with full-time, trained personnel to

	long-term sustainability of the integrated IPC–AMS approach)[1] ✧ Absence of an organizational mandate hinders the formal integration of IPC and AMS activities. Additional challenges include a shortage of trained personnel, limited IT infrastructure and the lack of a centralized reporting platform, restricting effective synergy between the two disciplines ✧ Inadequate leadership support, absence of consensus guidelines, and lack of regulatory mandates or accountability mechanisms hinder the integration of ASP and IPC efforts. Additionally, a shortage of trained personnel, limited IT infrastructure, and the absence of a centralized reporting platform are major barriers to achieving synergy between the two disciplines (35,121)	ensure effective implementation and long-term sustainability of the integrated IPC AMS approach ✧ Empower the integrated IPC AMS team by establishing a dedicated department with sufficient full-time staff, resources and IT support to serve as an oversight body that enables seamless coordination and data-driven decision-making *(78)*
Provider level	✧ Inadequate health-care provider knowledge of ASP and IPC largely due to poor staff engagement significantly hinders effective implementation *(78)*	✧ Targeted education and staff engagement strategies, including peer-to-peer mentoring through clinical champions *(122)*, and involvement of frontline workers in decision-making *(78)* ✧ Introduce mandatory preservice IPC–AMS certification

		✧ Introduce IPC–AMS modules in the medical education curriculum
Community level	✧ Non-compliance of patients with IPC measures and limited community awareness on antibiotics, hygiene and regulations hinder successful IPC–AMS interventions. Factors include inadequate IPC knowledge, poor socioeconomic status, negative attitudes toward IPC and easy access to antibiotics outside regulated settings *(123–125)*	✧ Implement continuous public engagement and awareness campaigns to improve adherence to IPC measures, promote responsible antibiotic use, and strengthen community understanding of hygiene practices, thereby supporting the effectiveness of integrated IPC AMS initiatives
Option 4: *Strengthening hand hygiene compliance (HHC) through real-time auditing using an electronic HH monitoring system (EHHMS)*		
Organizational level	✧ Adopting an EHHMS in healthcare requires significant investment in infrastructure, equipment, installation and maintenance. Cost was found to be one of the main barriers to successful adoption of EHHMS. However, while it requires upfront investment, the greater cost of HAIs makes it a financially justified solution *(95,115)*	✧ Integration into a broader digital health initiative – Bhutan's newly established ePIS – offers the advantage of having a single platform across all health facilities in the country, which allows uniform reporting and monitoring of data ✧ Policy-level advocacy on the return on investment vs the greater cost of HAIs
Provider level	✧ Sensor-based monitoring devices, especially bulky wearables or those with limited range, disrupt HCWs' routines by requiring frequent movement adjustments,	✧ Organizations must create clear policies on data collection and use and be transparent about privacy concerns and system limitations.

	hindering effective implementation *(95)* ✧ Perception of EHHMS as intrusive by HCWs, raising privacy concerns that lead to distrust and resistance to adoption *(95,116)* ✧ Concerns on the accuracy of EHHMS	Test the systems in real clinical settings before implementation, involve end-users during both the testing and decision-making process *(116)* ✧ Strong leadership is essential to guide the process. Institute measures to share feedback with HCWs in a meaningful way *(116)* ✧ In addition, targeted direct observations may be needed to supplement electronic data *(116)*

Potential opportunities to implement the options

Option 1: Establishment of real-time electronic surveillance system (ESS) for HAI

Bhutan's National Digital Strategy, a BTN 10 billion investment under the 13th Five Year Plan (FYP), presents a great opportunity to leverage support for the establishment of an ESS for HAI. Digital advancement in healthcare is one of the key focus areas of the National Digital Strategy. Additionally, this policy option aligns with Bhutan's e-Government master plan and the national e-Health strategy that aims to improve health outcomes by empowering healthcare providers and citizens through technology *(126)*.

The electronic patient information system (ePIS), launched in 2023 under Bhutan's Digital Flagship Programme, has been rolled out across all health facilities in the country *(127)*. Although the system has integrated civil registration, the immigration database and the laboratory information system, it remains in early development and has yet to realize its full potential, such as HAI alert and tracking capabilities to enhance patient safety.

Systematic reviews highlight the feasibility of ESS for HAI, demonstrating their seamless integration into existing health information systems, and advocate the development of ESS to harness the vast potential of hospital-based electronic data, optimizing surveillance accuracy and efficiency *(50)*. Bhutan is well positioned to build on the progress of the ePIS to develop an ESS, which could greatly strengthen the country's ability to manage the growing burden of HAIs and help curb the escalating threat of MDROs.

Option 2: Revamping infrastructure and enhancing isolation for infectious disease management in hospital settings

Health infrastructure remains a critical enabler of effective IPC. Embedding IPC principles into hospital design, adopting pragmatic phased implementation, and ensuring coordinated financial and human resource planning are essential for sustainable, high-quality IPC.

A detailed costed proposal for converting open-floor ICU layouts into designs with a limited number of single-room isolation units is currently pending approval and allocation of funds to enable implementation. This presents an opportunity to integrate enhanced isolation capacity for future hospitals and healthcare infrastructure, strengthening preparedness and response for infectious diseases.

The planned BTN 8.9 billion multidisciplinary super specialty hospital in Thimphu, set to begin in March 2026, offers a timely scope to incorporate infrastructure suited for isolation of infectious diseases during the design phase. Infrastructure investments must be complemented by capacity-building, as dedicated nursing and ancillary staff are essential for effective MDRO isolation *(128)*.

Option 3: Empowerment of the integrated IPC–AMS team through the establishment of a dedicated department

The BHSQA implemented across health centres in Bhutan outlines the minimum requirements for providing quality healthcare services and mandates every health centre to ensure the quality and safety of health services. The BHSQA captures elements of both IPC and AMS – mandating health facilities to report on HAIs (CAUTI and CLABSI), and the appropriateness of surgical antibiotic prophylaxis *(129)*. However, there is significant potential for the BHSQA to expand its scope by incorporating a broader set of indicators related to antibiotic use and IPC. Doing so would promote better integration of these two areas under its overarching goals of patient safety and healthcare quality.

Additionally, the new Health Service Rules and Regulations for Bhutan 2025, which mandate health facilities to implement IPC, offer an ideal opportunity to strengthen IPC and AMS governance and structure for effective implementation.

The ongoing health sector transformation with the establishment of NRH as an autonomous agency offers the opportunity to establish a dedicated department staffed with full-time relevant experts.

Option 4: Strengthening hand hygiene compliance (HHC) through real-time auditing using an electronic HH monitoring system (EHHMS)

Bhutan's strong health system governance, relatively small network of hospitals and strong political commitment to improving public health present a unique advantage. These strengths should be strategically leveraged to support the introduction and successful implementation of EHHMS. Early engagement of key stakeholders – including HCWs and decision-makers – is essential. Advocacy efforts should highlight the potential benefits of improved compliance with HH, particularly its role in reducing HAIs and strengthening overall health system performance.

Bhutan has a functional IPC programme across all hospitals. EHHMS can directly support and strengthen IPC practices in hospitals by improving compliance with HH and potentially reduce HAIs (Table 8).

Table 8: Summary of opportunities to implement the four options

Policy options	**Opportunity considerations**
Option 1: *Establishment of real-time electronic surveillance system (ESS) for HAI*	✧ Bhutan's e-Government master plan and e-Health strategy aim to improve health outcomes by empowering health providers and citizens through technology *(126).* These create a favourable political environment for adopting innovative digital health solutions to important health challenges such as HAI and AMR.
Option 2*: Revamping infrastructure and enhancing isolation to manage infectious diseases*	✧ IPC principles can be embedded into hospital infrastructure standards, adopting a pragmatic and phased implementation plan, and ensuring that both the financial and human resource aspects are planned holistically to ensure sustainability.[1]
Option 3: *Empowerment of the integrated IPC–AMS team through the*	✧ Bhutan has a functional healthcare standard and quality assurance framework – BHSQA, which

establishment of a dedicated department	mandates health facilities to ensure the quality and safety of health services *(129)*. However, there is a potential opportunity to widen its scope by incorporating a broader set of indicators related to AMR and IPC. ✧ In line with the ongoing efforts at the NRH to establish an integrated unit, it is important to aim for a dedicated department for IPC and AMS. This department should be staffed with full-time experts to ensure efficient implementation and better resource allocation.
Option 4: *Strengthening hand hygiene compliance (HHC) through real-time auditing using an electronic HH monitoring system (EHHMS)*	✧ Bhutan's national IPC programme, established since 2004, is implemented across all health centres in the country. It lays the foundation for adopting innovative digital tools to enhance real-time monitoring and feedback on HH practices and ensure desirable compliance.

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6. Annexes

Annex 1: Summary of evidence relevant to the four options

Table A1: Summary of evidence relevant to Option 1

Systematic review	Focus	Key findings	AMSTAR 2 checklist rating	Proportion of studies conducted in Bhutan
Freeman R, Moore LSP, Alvarez LG, Charlett A, Holmes A. Advances in electronic surveillance for healthcare-associated infections in the 21st century: a systematic review. J Hosp Infect. 2013;84(2):106–19.	To evaluate the utility, performance and feasibility of electronic surveillance systems (ESS) for detecting and monitoring healthcare-associated infections (HAIs) in the 21st century	The study suggests that ESS can be integrated into hospital systems for real-time, continuous surveillance, reducing workload. ESS was found to demonstrate a high sensitivity (72–100%) in detecting bloodstream infections (BSIs) and urinary tract infections (UTIs) whereas it had variable specificity (37–100%), with lower accuracy for device-associated infections (e.g. CLABSI, CAUTI). Algorithms combining multiple data sources (e.g. microbiology + ICD codes) outperformed single-source methods. However, the limited accuracy for infections without microbiological confirmation (e.g. surgical-site infections) was a key utility challenge. Meanwhile, due to the use of hospital-specific data systems designed to suit the need of individual centres there are transferability and interoperability issues.	Moderate	0/44
Li Y, Gong Z, Lu Y, Hu G, Cai R, Chen Z. Impact of nosocomial infections surveillance on nosocomial infection rates: a systematic review. Int J Surg. 2017;42: 164–9.	To evaluate the impact of nosocomial infection (NI) surveillance programmes on reducing NI rates in healthcare settings	The results show that surveillance programmes were associated with a lower incidence of NIs, particularly for device-associated infections (e.g. central line-associated BSIs, ventilator-associated pneumonia). Electronic surveillance showed promise for efficiency but required validation against clinical outcomes, whereas manual surveillance was robust but resource intensive. However, there was significant variability in	Moderate	0/25

		definitions, compliance and data quality across the studies included. To sustain the impact of reduction in NIs, a concurrent infection control measure (e.g. hand hygiene) was necessary, underscoring that surveillance alone is insufficient and must be paired with additional IPC interventions to drive meaningful reductions in HAIs.		
Irgang L, Barth H, Holmén M. Data-driven technologies as enablers for value creation in the prevention of surgical site infections: a systematic review. J Healthc Inform Res. 2023;7(1):1–41.	How data-driven technology (DDT) enables value creation in the prevention of surgical-site infections (SSIs) classifying benefits into four dimensions – cost reduction, functional, experiential (patient experience), and symbolic values (patient empowerment), rather than only focusing on clinical or technical outcomes.	The findings show that most of the DDTs were applied in clean and clean-contaminated surgeries with no studies in dirty, contaminated surgeries. The majority of studies focused on DDT application in the postoperative stage to monitor wound healing and patient recovery, followed by its use in surveillance (real-time infection monitoring and outbreak detection), and few studies focused on the use of DDT at the preoperative stage to predict the risk of SSI. Machine learning was the most widely used technology followed by smart phone apps (used to share pictures of the wound with physicians, which enables remote monitoring and reduces hospital visits), and sensors (installed in the operating room [OR] to track the frequency of staff movement in and out of the OR). Use of machine learning offers a better advantage as it allows identification of risks and trends, which is usually difficult to perform manually. A combination of both types of data could improve accuracy and speed in identifying SSI risks. Most studies focus on the instrumental value, emphasizing technical functionality, data accuracy, and reliability, primarily benefiting physicians and nurses. However, there is limited research on cost–effectiveness, with most cost–benefit analyses focusing on the hospital perspective without much attention to its cost–benefit to other stakeholders, including patients, families and administrators.	low	0/59

Streefkerk HRA, Verkooijen RP, Bramer WM, Verbrugh HA. Electronically assisted surveillance systems of healthcare-associated infections: a systematic review. Eurosurveillance. 2020;25(2):1900321.	Evaluating the performance and quality of electronically assisted surveillance systems (EASS) for detecting HAIs	Most of the studies included describe the use of EASS in the ICU setting targeting only specific HAIs such as VAP and CLABSI, whereas only 9 out of 78 studies describe a hospitalwide application of the EASS enabling the detection of all major HAIs. This suggests that the hospitalwide EHRs or data warehouses are still not ready to be used to support decision-making and surveillance. EASS showed better sensitivity in detecting HAIs but varied in specificity, leading to false positives requiring manual confirmation, which can be an added burden. Although efforts to digitize HAI surveillance were expected to improve efficiency, only 20% of the studies showed an actual time reduction by introducing EASS. In addition, many studies (77%) lacked other quality indicators, mainly the use of different population data in developing and validating the tool. The EASS that use multisource data – microbiology culture, clinical chemistry and antibiotic prescription – in combination offered the best performance. In conclusion, the study indicates that the implementation of a fully digitized HAI surveillance globally may take longer and is unlikely within this decade.	Moderate	0/78
Cato KD, Cohen B, Larson E. Data elements and validation methods used for electronic surveillance of health care-associated infections: a systematic review. Am J Infect Control. 2015;43(6):600–5.	The study describes the primary data sources, data elements, and validation methods currently used in electronic surveillance of HAI and compares these data elements and validation methods.	The results show that most of the studies included (83%) used recommended data sources (microbiology culture, antibiotic prescription, ICD code) for detection of HAI, whereas 17% of studies did not use recommended data, highlighting gaps in the availability of relevant data to achieve a fully automated HAI surveillance system. Meanwhile, the variability in or lack of standardization of data format increases its complexity, hinders interoperability, and limits its uniform implementation. While the numerator validation of confirming HAI was common, the denominator	Moderate	0/30

		validation (population at risk) was rare (only 10% study), while none of the studies performed external validation. ESS were found to be resource-intensive, technically complex, and with limited transferability or scalability. Although it was found that the systems using multisource data performed better, the lack of validation led to uncertain reliability. In conclusion, the study notes that ESS offers a time-efficient and more accurate HAI surveillance, but inconsistent data format, inadequate validation and technical difficulty limits its effectiveness.		

Table A2: Summary of evidence relevant to Option 2

Systematic review	**Focus**	**Key findings**	**AMSTAR 2 checklist rating**	**Proportion of studies conducted in Bhutan**
Stiller A, Salm F, Bischoff P, Gastmeier P. Relationship between hospital ward design and healthcare-associated infection rates: a systematic review and meta-analysis. Antimicrob Resist Infect Control. 2016 Dec 29;5(1):51.	The main focus of the article is to systematically review and analyse the relationship between hospital ward design elements, mainly single-patient rooms, hand rub dispenser accessibility, and room size, and the rates of HAI and colonization.	Hospital ward design plays significant role in reducing the HAI burden. Implementation of single-patient room isolation was associated with a 45% lower risk of HAI and colonization with MDRO compared to open wards. Additionally, the accessibility of alcohol-based hand rub dispensers near the patient bed significantly improves hand hygiene compliance among healthcare workers, which is a critical factor in infection prevention. The authors conclude that architectural considerations such as single-room occupancy and strategically placed dispensers should be integral components of multifaceted infection control strategies in healthcare settings.	Low	0/15

Cooper BS, Stone SP, Kibbler CC, Cookson BD, Roberts JA, Medley GF et al. Isolation measures in the hospital management of methicillin resistant *Staphylococcus aureus* (MRSA): systematic review of the literature. BMJ. 2004 Sep 4;329(7465):533.	To evaluate the evidence for the effectiveness of isolation measures (such as isolation wards, nurse cohorting, single rooms, and barrier precautions) in reducing the incidence of MRSA colonization and infection among hospital inpatients.	While many studies report success in reducing MRSA transmission through interventions that include isolation (such as dedicated wards, nurse cohorting or single rooms), the vast majority of these studies employed multiple simultaneous control measures like improved hand hygiene and antibiotic restriction, making it impossible to assess the impact of individual interventions. The authors conclude that while there is evidence that concerted efforts, including isolation, can reduce MRSA, there is no robust evidence to evaluate isolation measures on their own. However, it is recommended that the current isolation protocols are continued until more rigorous research provides better evidence.	Medium	0/46
Zhang Zhang Z, Tan X, Shi H, Zhao J, Zhang H, Li J et al. Effect of single-patient room design on the incidence of nosocomial infection in the intensive care unit: a systematic review and meta-analysis. Front Med (Lausanne). 2024 Jun 10;11: 1421055.	To examine the impact of single-patient room isolation on reducing HAI in the ICU setting	Implementing a single-patient room design in ICU is a highly effective strategy for reducing the incidence of HAIs. Single-room isolation was found to significantly lower the overall HAI rate, the incidence density of infections (per patient-days) and the acquisition of MDROs. This protective effect was achieved through several mechanisms, including the reduction in overcrowding and contact between patients and healthcare workers, minimizing the shared use of contaminated equipment, and improved HH compliance by providing clear signages for isolation precautions. Despite their higher initial cost, the study strongly recommends the implementation of single-room isolation for its proven benefit in infection control.	High	0/12
AlRawashdeh MM, Ishak A, Al-Bunnia A, Agouridis AP, Lytras T, Spernovasilis N et al. Patient experiences and	To review and synthesize the psychological and emotional impact of	Hospitalized patients with MDRO infections experience significant negative psychological effects, often exacerbated by the contact isolation measures required to prevent transmission. These patients	Moderate	0/17

perceptions with infections due to multidrug-resistant organisms: a systematic review. Pathogens. 2024 Sep 22;13(9):817	MDRO infections on hospitalized adult patients, with a specific emphasis on the effects of contact isolation	consistently report higher levels of depression and anxiety compared to non-isolated patients. Furthermore, they frequently experience feelings of stigma, loneliness, guilt and anger, and often report feeling poorly informed about their condition. In addition, communication gaps between healthcare providers and patients resulting from fewer interactions with healthcare staff aggravate the patient's psychological distress. The study emphasizes the urgent need for a more holistic and patient-centred approach to care, including better communication strategy and integrating mental health support.		

Table A3: Summary of evidence relevant to Option 3

Systematic review	Focus	Key findings	AMSTAR 2 checklist rating	Proportion of studies conducted in Bhutan
Stiller Baur D, Gladstone BP, Burkert F, Carrara E, Foschi F, Döbele S et al. Effect of antibiotic stewardship on the incidence of infection and colonisation with antibiotic-resistant bacteria and Clostridium difficile infection: a systematic review and meta-analysis. Lancet Infect Dis. 2017 Sep;17(9):990–1001.	To evaluate the effect of antibiotic stewardship on reducing the incidence of infections and colonization caused by antibiotic-resistant bacteria and *Clostridium difficile* in hospital inpatients	The implementation of AMS in hospitals led to a significant reduction in the incidence of infections and colonization with MDRO. AMS were associated with a 51% reduction in MDR Gram-negative bacteria, a 48% reduction in extended-spectrum β-lactamase (ESBL)-producing Gram-negative bacteria, a 37% reduction in MRSA, and a 32% reduction in *Clostridium difficile* infections. A critical finding was that the effectiveness of AMS was substantially enhanced when they were co-implemented with infection control measures, particularly hand hygiene interventions, which	High	0/32

		led to a 66% reduction in resistance rates compared to a 17% reduction from stewardship alone.		
Teerawattanapong N, Kengkla K, Dilokthornsakul P, Saokaew S, Apisarnthanarak A, Chaiyakunapruk N. Prevention and control of multidrug-resistant Gram-negative bacteria in adult intensive care units: a systematic review and network meta-analysis. Clin Infect Dis. 2017 May 15;64(Suppl_2):S51–S60. Available from: https://doi.org/10.1093/cid/cix112	To determine the most effective infection IPC strategies for preventing the acquisition, colonization of and infection with MDR Gram-negative bacteria in adult ICUs	A comprehensive, multifaceted approach is the most effective strategy for preventing MDR Gram-negative bacteria in adult ICUs) The key finding is that a four-component strategy, combining standard care (HH and contact precautions), antimicrobial stewardship, enhanced environmental cleaning, and source control such as chlorhexidine bathing, was the most effective intervention, reducing the acquisition of MDR Gram-negative bacteria by 95% compared to standard care alone.	Moderate	0/42
Geng Geng Y, Liu Z, Ma X, Pan T, Chen M, Dang J et al. Infection prevention and control measures for multidrug-resistant organisms: a systematic review and network meta-analysis. Infection. 2025; Available from: https://doi.org/10.1007/s15010-025-02498-9 (online ahead of print)	To determine the most effective combinations of IPC measures for preventing the acquisition, infection and colonization of MDROs in hospitalized patients, and how these vary based on the clinical setting (ICU vs hospitalwide) and the type of resistant bacteria	The optimal intervention depends on the goal (preventing acquisition, infection or colonization), the location (ICU or entire hospital), and the specific MDRO targeted. The study found that contact precaution + chlorhexidine gluconate bath was best for preventing MDRO acquisition in the ICU, while standard precaution + contact precaution + ASP was most effective hospitalwide.	Low	0/97

Table A4: Summary of evidence relevant to Option 4

Systematic review	Focus	Key findings	AMSTAR 2 checklist rating	Proportion of studies conducted in Bhutan
Zhang Y, Chen X, Lao Y, Qiu X, Liu K, Zhuang Y et al. Effects of the implementation of intelligent technology for hand hygiene in hospitals: systematic review and meta-analysis. J Med Internet Res. 2023;25:e37249.	To evaluate the effects of implementing intelligent technology on HH compliance among HCWs	The implementation of intelligent technology for HH in hospitals is associated with significant improvements in HH compliance among HCWs and a reduction in HAIs, but it does not show a statistically significant effect on MDRO detection rates. The use of intelligent technologies such as electronic reminders, real-time monitoring, feedback systems, and educational components increased HH compliance by 56% and reduced HAIs by 75%.	Moderate	0/36
Lin T, Lin C, Chen K, Hsu H. Information technology on hand hygiene compliance among health care professionals: a systematic review and meta-analysis. J Nurs Manag. 2021 Sep 9;29(6):1857–68.	To evaluate the effectiveness of information technology (IT) interventions on improving hand hygiene compliance among healthcare professionals	IT interventions significantly improved HH compliance among HCWs, resulting in an overall OR of 3.06. The most effective technologies identified were real-time reminder and feedback systems, electronic counting devices with remote monitoring, and automated HH monitoring systems. These interventions were found to reduce reliance on direct observation, which is susceptible to the Hawthorne effect and labour-intensive.	Low	0/13
Wang C, Jiang W, Yang K, Yu D, Newn J, Sarsenbayeva Z et al. Electronic monitoring systems for hand hygiene: systematic review of technology. J Med Internet Res. 2021 Nov 24;23(11):e27880	To discuss the capabilities and limitations of various technologies adopted in EHHMS	EHHMS face significant challenges in accuracy, data integration, privacy, usability, cost and infrastructure. In addition, there is a lack of standardized metrics to evaluate and compare the performance of these systems.	Low	0/73

		The review highlights that while various technologies (such as sensors, cameras and real-time locating systems) are being used to monitor both HH compliance and quality, their effectiveness is limited by technical and practical issues.		

Annex 2: List of attendees at the policy dialogue

Sl.no	Name	Designation	Organization
1	Mr Pemba Wangchuk	Secretary	Ministry of Health
2	Dr Pem Namgyel	President	JDWNR Hospital & Khesar Gyalpo University of Medical Science of Bhutan
3	Dr Mimi Lhamu Mynak	President	National Medical Service
4	Mr Kinga Jamphel	Director	Department of Health Service, Ministry of Health
5	Dr Kuenzang Wangdi	Director	Department of Clinical Services, National Medical Service
6	Dr Tashi Yangzom Dorji	Director	Department of Livestock, Ministry of Agriculture & Livestock
7	Mr Karma Jamtsho	Director	Department of Public Health, Ministry of Health
8	Mrs Gyem Bidha	Director	Bhutan Food and Drug Authority
9	Dr Yonten Jamtsho	Anaesthesiologist	Intensive care unit, JDWNR Hospital
10	Dr Narapati Dahal	Animal health specialist	Department of Livestock, Ministry of Agriculture & Livestock
11	Dr Rinzin Pem	Chief Programme Officer	Department of Livestock, Ministry of Agriculture & Livestock
12	Ms Dechen Tshomo	Asst Planning Officer	Policy & Planning Division, MoH
13	Mr Nidup Dorji	Asst Environment Officer	Department of Environment and Climate Change, Ministry of Environment & Natural Resources
14	Ms Chhimi Lhamu	Nursing Superintendent	JDWNR Hospital
15	Dr Nima Gyeltshen	Veterinary Officer	National Center for Animal Health
16	Dr Nima Wangdi	Veterinary Officer	National Veterinary Hospital
17	Mr Uguen Norbu	Sr Communication Officer	Health Promotion & Risk Communication Division, MoH
18	Mr Jigme Kelzang	Chief Programme Officer	Healthcare Standard and Quality Assurance Division, MoH
19	Mr Jigme Tenzin	Chief Regulatory Officer	Medical Products Division, Bhutan Food & Drug Authority
20	Mr Nima Nima	Sr Communication Technician	Health Promotion Division, MoH
21	Mr Khando Wangchuk	Asst Pharmacist	JDWNR Hospital
22	Dr Jamphel Tshering	Officiating Medical Superintendent	JDWNR Hospital

23	Ms Sonam Peldon	Officiating Chief Programme Officer	Department of Clinical Services, National Medical Service
24	Ms Ugyen Dema Dorji	Programme Officer	Department of Clinical Services, National Medical Service
25	Mrs Thinley	Programme Officer	Department of Clinical Services, National Medical Service
26	Ms Tshering Cheki	Chief Programme Officer	Quality Assurance unit, JDWNR Hospital
27	Mr Sonam Wangdi	Chief Forestry Officer	Department of Forest & Park Services
28	Ms Phuentsho Seldon Wangmo	Assistant Programme Officer (APO)	Ministry of Finance
29	Mr Amin Ngawang Tashi	Chief Pharmacist	Royal Center for Disease Control