Health Data Collaborative / World Health Organisation

Making the case for investing in Routine Health Information Systems (RHIS) to achieve the health-related SDGs: a scoping review.

RFP-2022-DDI-DNA-CNG-0001 | HQ/DDI/DNA/CNG and HQ/DDI/DNA/HIS

DRAFT REPORT OF FINDINGS

Xavier Bosch-Capblanch, Edward Nicol, Marguerite Batta, Christian Auer, Natalie Leon, Fabrizio Tediosi

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Swiss TPH
Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse
Associated Institute of the University of Basel

saMRC advancinglife

CONTACTS

Swiss TPH
Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

Associated Institute of the University of Basel

Swiss Tropical and Public Health Institute
Kreuzstrasse 2
4123 Allschwil
Switzerland
www.swisstph.ch

Xavier Bosch-Capblanch
Project Leader
Swiss Centre for International Health
Systems Strengthening and Health Promotion Unit
Tel.: +41 61 284 83 19
E-mail: x.bosch@swisstph.ch

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Disclaimer

The views and ideas expressed herein are those of the author(s) and do not necessarily imply or reflect the opinion of Swiss TPH or SAMRC.

ABBREVIATIONS

CRVS	Civil Registration and Vital Statistics
DALY	Disability-adjusted life years
GDP	Gross Domestic Product
HIS	Health Information System
ICER	Incremental Cost-Effectiveness Ratio
IS	Information Systems
LMIS	Logistics Management Information System
QALY	Quality-adjusted life years
QC	Quality of Care
QIP	Quality Improvement Project
RHIS	Routine Health Information System
ROI	Return of Investment
SAMRC	South African Medical Research Council
Swiss TPH	Swiss Tropical and Public Health Institute
WHO	World Health Organisation
WP	Work package

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Executive summary

The Routine Health Information System (RHIS) of a country serves as the basis for the delivery of health care. While the reporting aspects of the RHIS have been highlighted for years, the use of the RHIS data for decision-making and quality improvement has been less prominent in the literature. Making the case for investment in RHIS is a potentially useful approach to advocate for investments in RHIS by Ministries of Health, donors and the international health community. We understand the call from the Health Data Collaborative / World Health Organisation (WHO) on "Making the case for investing in Routine Health Information Systems (RHIS) to achieve the health-related SDGs" as a contribution "to develop and adopt a common framework and good data governance practices underpinned by a globally unifying set of principles that build on or adapt WHO's data principles". The objective of this scoping review is to identify frameworks and research approaches that can inform the development of economic analyses on RHIS interventions.

We carried out a scoping review with the aim to synthesise RHIS frameworks, drawing as well from the experience of the team leading this work and ad hoc literature resources provided by partners.

We searched electronic databases and carried out manual searches using a specific search strategy. We consider as relevant, those references that focus on economic studies of health systems interventions reporting on investments and outcomes. We used standard systematic review methods. We carried out a narrative synthesis of findings.

We identified the range of RHIS conceptual frameworks available that were used to support the scoping review. We screened for relevance 1,026 studies and the full text screening of the relevant studies ended up with 17 included studies. Studies were published between 2001 and 2022. Most of studies reported on relatively small interventions and reported outcomes directly related to the intervention. We also examined the "Dalberg" report and noted the methodological limitations that should be under consideration when interpreting its findings.

We did not assess the risk of bias. However, none of the studies seem to have used a standard, widely accepted methodology, studies were observational with only a few of them taking into account confounding in their analyses and we cannot ascertain to which extent the benefits reported are due to selective reporting of outcomes or to bias.

We confirmed that return of investments for RHIS are difficult to establish, mainly because some kind and size of attributions needs to be established or assumed. We discuss the limitations of the economic approach and provide some considerations on the way forward.

1 Background and objectives

The Routine Health Information System (RHIS) of a country serves as the basis for the delivery of health care. While the reporting aspects of the RHIS have been highlighted for years [1] and with this the importance of the quality of data [2], the use of the RHIS data for decision-making and quality improvement, while also often mentioned, has been less prominent [2, 3]. A good RHIS is rooted in data collected at service delivery points and, hence, should support and enhance the clinical work of the front-line health workers, thus potentially having a large return on investment. Making the case for investment in RHIS is a useful approach to advocate for investments in RHIS by Ministries of Finances, donors and the international health community. We understand the call from the World Health Organisation (WHO) on "Making the case for investing in Routine Health Information Systems (RHIS) to achieve the health-related SDGs" as a contribution "to develop and adopt a common framework and good data governance practices underpinned by a globally unifying set of principles that build on or adapt WHO's data principles" [4].

There is scant evidence on the links between availability of data and decision-making [1], and there are studies that did not find a clear link between data availability and decision-making [5]. Others point at the overload of indicators to governmental health information systems [6]. How the RHIS, especially the registers in the health facilities, can support health workers in their clinical work, public health work and managerial work is often overlooked but it is a paramount aspect of the RHIS - an aspect that has great potential to improve the quality of services, and, thus, reduce morbidity and mortality [7].

Ideally, any research on health systems and health information systems should be guided by a validated conceptual framework. However, to our knowledge, there is no health systems analytical framework widely accepted. This may be partially due to the complexity of health systems and also to the challenges in carrying out applied research in these areas. Facing the task to inform the *Health Data Collaborative* and WHO on return of investments of RHIS, we have proposed carrying out a scoping review to describe examples of methods and implementation of return of investment analyses.

The objective of this scoping review is to identify types of health information systems components, health information systems investments and health information systems outcomes, used in economic analyses that look at both investments and returns.

2 Methods

We carried out a scoping review with the aim to synthesise RHIS frameworks based on the experience of the team leading this work and ad hoc literature resources provided by WHO, partners and groups of experts, participating in meetings and collating their feed-back.

2.1 Literature searches

Using the same methodology applied by Hotchkiss et al [8], a search of four electronic databases (PubMed, Web of Science, Scopus, and Cochrane Library) was performed in addition to searching Google Scholar, the International Journal of Medical Informatics, and MEASURE Evaluation websites. Appropriate keywords and Medical Subject Heading (MeSH) terms, with corresponding synonyms and associated terms (Annex 1) were used to identify relevant studies that report on frameworks for RHIS, published between 1 January 2007 and 31 October 2022. We also hand-searched for potential studies, and reference lists of identified papers were searched for relevant studies.

All selected citations were imported into Thomson Reuter EndNote X7 software, and duplicates were removed manually. The full text of eligible articles were screened and key relevant features of identified RHIS conceptual frameworks were then systematically extracted, summarised and classified under the terms 'inputs', 'processes', 'outputs' and 'outcomes'.

We consider as relevant, those references that focus on economic studies of health systems interventions (e.g. health information, human resources, management, equipment) or programmes that provide some quantitative data on (1) investments (e.g. funding, training, any investment to improve the system) and/or (2) returns or outputs (e.g. changes in health status of people, efficiency in managing services, skills of health workers, quality of care).

The following are considered as not relevant: opinions, editorials, frameworks and alike, without any quantitative data; as well as clinical interventions (i.e. medicines, vaccines, surgery).

2.2 Criteria for considering studies for this review

We considered studies that have been carried out in any context, including high-, middle- and low-income countries, as well as fragile states. The review also considered any health system setting provided that it offers routine health care or routine public health interventions (e.g. promotion of health, disease prevention, community mobilisation). Studies where the research settings or settings where health care is delivered under experimental situations were excluded. Language was restricted to English.

2.2.1 Types of studies

We considered any study design that:

- uses research methods, which are explicitly described
- focuses on both 'inputs' and 'outputs' to the health system or sub-system, considering 'inputs' as investments and outputs as any result that is produced by the system
- has a quantitative component
- explicitly targets a health system domain (as opposed to clinical or disease domains)

2.2.2 Types of systems components

We considered any health system or sub-system component, including:

- health information systems or sub-systems, as a matter of priority; prioritising routine health information systems, including health services records, human resources, logistics, finances and others
- other knowledge management systems, such as policy formulation, knowledge translation and communication systems
- Procurement & supplies systems
- Management sub-systems (e.g. maintenance, supplies, health administration)

2.2.3 Types of investments

We included studies that reported any type of investment including:

- direct financial support
- investments in human resources
- investments in infrastructures, equipment or supplies
- investments at community level linked to health system use

2.2.4 Types of outcome measures

Studies that reported on any type of output or outcome related to investment were considered, such as:

- health status, disease prevalence or incidence
- quality of care, including access and coverage of interventions
- data use
- data availability and quality
- use of resources and efficiency

2.3 Search methods for identification of studies

2.3.1 Electronic literature databases

Using a comprehensive search strategy and keywords, an electronic search of three online databases (PubMed, Scopus and Web of Science) was performed to identify suitable studies on RHIS return on investment. Search strategies were developed by devising relevant search terms. The main concepts and keywords such as health information systems, investment(s), impact

evaluation, economic evaluation, and synonyms for each keyword were identified. These were used in conjunction with wildcards (*), phrase searching (“ “), and Boolean operators (AND, OR) to broaden/narrow the search. These terms were combined, modified according to the databases, and used to identify relevant studies in selected databases.

The initial search strategy, which included identified keywords and terms categorised by priority, based on the research team’s perception of relevance in relation to the inclusion criteria (Annex 2, Options 2 and 4), was developed for one of the databases (PubMed) using subject headings and free-text words that described “Return on investment”. Search strategies for the other databases were adapted from the initial strategy according to each database’s specific requirements. The full search strategy for all databases is included in Annex 2.

2.3.2 Searching other sources

We collected references obtained by other means, such as those that are already available to the team, those obtained in ad hoc searches (Google Scholar, MEASURE Evaluation and, grey literature in OpenGrey) and the references provided by panels of experts and stakeholders related to this work.

Full text documents are stored in a common server and can be entered into a database created using XLM forms created for this.

2.4 Data analysis and collection

2.4.1 Selection of studies

All references were stored in the institutional server using a reference manager. Duplicates where automatically detected by the reference manager and labelled as such. All references were exported into BibTex format and uploaded into the KoboToolbox server to be integrated into the relevance XML form.

A single reviewer scrutinised references for relevance based on titles and abstracts, in order to identify references that are clearly out of the scope of this review. In case of doubt, references were marked as ‘unclear’ and a second reviewer scrutinised for relevance. The assessment was done in the mentioned XML form.

Abstracts or full text of relevant studies were scrutinised against the inclusion and exclusion criteria by a single reviewer. In case of doubt, the study was marked as ‘unclear’ and assessed by another reviewer. Included studies were further processed for data extraction.

2.4.2 Data extraction and management

The following types of item were extracted from the included studies:

- Identification of the study (e.g. reference identification number, author, year)
- Study information (e.g. study design, location(s), time frame)
- Health system domain (e.g. human resources, supplies, quality)
- Health information systems sub-domain (e.g. routine, digital, surveillance)
- Intervention or event of interest (e.g. financing, training)
- Comparators (i.e. alternative intervention or event)

- Input estimates (e.g. human resources, costs included - financial/economic)
- Data availability outputs (e.g. quality of data, amount of data)
- Data use outputs (e.g. data feeding into management decision-making)
- Services use outcomes (e.g. coverage)
- Health status outcomes (e.g. incidence of disease)
- (Other) Impact estimates (financial or economic benefits)
- Risk of bias assessments, specific to the study designs.

2.5 Analytical approach

We carried out a narrative synthesis of findings. We included quantitative data where available, but did not attempt to carry out any meta-analyses due to the heterogeneity of settings, systems and outcomes.

3 Findings

3.1 Health Information Systems frameworks

As a first step, to identify components of RHIS, we identified the range of RHIS conceptual frameworks available. Table 1 summarises the main features of the RHIS frameworks, classified under the terms 'inputs', 'processes', 'outputs' and 'outcomes'.

Table 1. Mapping conceptual frameworks for RHIS evaluation (1995 -2022)*

Authors/ Conceptual Framework	Inputs[a]	Processes	Outputs[b]	Outcomes[c]
Goodhue and Thompson (1995) [9] - Technology-to-Performance Chain (TPC)	• Task characteristics • Technology characteristics • Individual characteristics • Precursors of utilization: expected consequences of use, affect toward using, social norms, habits, facilitating conditions.	• Task-technology fit • Utilization	• Individual performance: effectiveness, efficiency, quality	N/A
Gremy et al. (1999) [10] - Health information systems evaluation	• General concept (model, aims, meaning, ethics)	• Preparation of machine (Software, data definition and entry) • Execution of the program	• Interpretation	• Decisions taken (social representation)
Shaw (2002) [11] - CHEATS[d]	• Technical	• Appropriateness of technologies • Video and sound quality • Ease of use • Technology specific training • Reliability of technology		• Clinical • Human and organisational • Educational • Administrative • Social

[a] Determinants.

[b] RHIS data quality and information use.

[c] Health systems functioning, health systems performance.

[d] CHEATS: six aspects for evaluating ICTs in health care have been identified:

- Clinical
- Human and organisational
- Educational
- Administrative
- Technical
- Social

Authors/ Conceptual Framework	Inputs[a]	Processes	Outputs[b]	Outcomes[c]
Grant et al. (2002) [12] - Total Evaluation and Acceptance Methodology (TEAM)	Tactical • Planning • Resources ❖ ersonnel ❖ quipment ❖ ime • Communication • Costs Operational • Software • Human Computer Interface • Electronic communication.	Strategic • Integration into current practice • Security/confidentiality/sharing • Management/analysis tools • Architecture		
Kushniruk (2002) [13] - Systems development life cycle		• Usability of systems		
Kazanjian et al. (2002) [14] - Health Technology Assessment Framework	Economic concerns (cost-effectiveness analysis), social context (ethical, legal, and political concerns)	• Technology assessment activity (scientific evidence)		• Population at risk of problem (death rate) • Population impact (quality of well-being)
DeLone and McLean (2003) [15] - IS Success Model Applied to RHIS by Lau et al. (2007) [16] - Benefits Evaluation Framework		• Information quality - completeness, accuracy, availability, timeliness, reliability • System quality - functionality, performance (access, reliability, response time), security • Service quality - responsiveness of IS support	• Intention to use/use - actual system use, self-reported system use • User satisfaction - user competency, user perceptions, ease of use	<u>Net Benefits</u> • Quality of care (patient safety, appropriateness and effectiveness, health outcomes) • Productivity (efficiency, coordination of care, net costs) • Service access
De Savigny and Binka (2004) [17] - A Pathway for Evidence-Based Planning	• Data	• Data cleaning • Controlling • Organizing • Analysing • Integrating	• Information • Evidence • Knowledge	• Actions/decisions regarding implementation of plans and systems • Impact of actions/ decisions • Monitoring change • Forecasting

Authors/ Conceptual Framework	Inputs[a]	Processes	Outputs[b]	Outcomes[c]
MEASURE Evaluation (2005) [18] - Data Demand and Information Use Framework	• Technical • Organisational • Behavioural • Health system and individual level factors	• Data collection and analysis	• Information availability • Information demand • Information use for decision-making	• Service coverage • Service quality • Efficiency
Hanmer et al. (2007) [19]	• Technical- software fit with user requirements, information system supplier knowledge of health system environment; appropriateness of information system design • Resource availability at the provincial and health facility levels • Organisational and contractual mechanisms, management commitment to success • Behavioural - knowledge and understanding of information system	• Perceived usefulness of information system	• Effective use of information system and/ or outputs	
Labkoff et al. (2007) [20] - Health information infrastructure progress evaluation framework			• Completeness of information • Degree of usage • Type of usage • Financial sustainability	
Health Metrics Network (2008) [21] - Framework and standards for country health information systems	• HIS planning frameworks • Personnel • Financing • Logistics support • ICT • Coordinating mechanisms	• Indicators • Data sources • Data management (data storage, processes to ensure data quality, data processing and compilation)	• Information products • Dissemination and use	
Yusof et al. (2008) [22] – HOT-Fit		• System quality • Information quality • Services quality	• System use • User satisfaction • Organisation structure and environment	• Net Benefits - clinical practice, efficiency, effectiveness, decision-making quality, error reduction, communication, clinical outcomes

Authors/ Conceptual Framework	Inputs[a]	Processes	Outputs[b]	Outcomes[c]
Aqil et al. (2009) [23] - PRISM Framework	• Technical - complexity of reporting form, RHIS design, software, IT complexity • Organisational - governance, planning, training, supervision, finances, information distribution, promotion of a culture of information • Behavioural - data quality checking skills, levels of knowledge of RHIS rationale, problem solving skills, RHIS tasks competence, RHIS task confidence, motivation	• Data collection • Data transmission • Data processing • Data analysis • Data display • Data quality checks • Feedback	• Data quality - relevance, completeness, timeliness, accuracy • Information use - for identifying problems, for considering and making decisions, and for advocacy	• Service Coverage
Yen (2010) [24] - Health Information Technology Usability Evaluation		• Perceived usefulness (learnability, competency, perform speed, flexibility/ customizability) • Perceived ease of use (error prevention, other outcomes, information needs, memorability)	• Efficiency • Effectiveness	
Sockolow et al. (2012) [25] - The Health Information Technology Reference-based Evaluation Framework (HITREF)	• Structural quality (organizational support/capacity, hardware, software, functionality)	• Effects on quality processes (efficiency, appropriateness of patient care, organizational or social quality, technology selection/development, implementation, training)	• Quality of information logistics (completeness or correctness of data, cost of information processing, user satisfaction, patient privacy, patient satisfaction, diffusion)	• Effects on outcome quality of care (outcome quality of care, costs of patient, patient satisfaction with care, patient related knowledge), unintended consequences/benefits, barriers, or facilitators to adoption
Garcia-Smith et al. (2013) [26] - Clinical Information Systems Success Model (CISSM)	• Systems performance (ease of use, access, reliability) social influence (social/service support) • Facilitating conditions (behavioural control, work processes)		• Information quality (usefulness, completeness, format, accuracy) • Use dependency clinician satisfaction	• Net benefit (standards compliance)

Authors/ Conceptual Framework	Inputs[a]	Processes	Outputs[b]	Outcomes[c]
Stylianides et al. (2018) [27] An Evaluation Framework for Health Information Systems	• Technology - System quality, Safety • Human Factor – Collaboration, Satisfaction • Organization -Procedures			
Zuske et al. (2022) [1] – HIS functions	• Paper-based tools using clinical decision support approach	• 12 functions	• Decision-making	• Clinical care

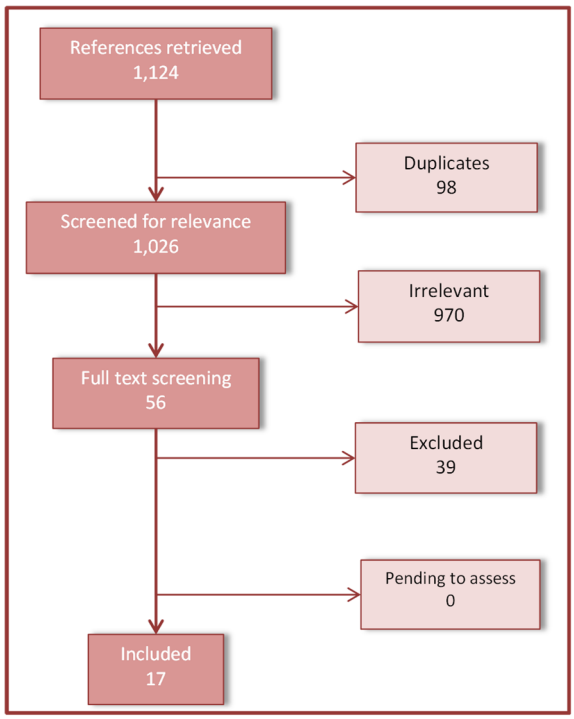
*Adapted and updated from Nicol, E. 2015 [28].

3.2 Scoping review of the literature

3.2.1 Description of studies

Figure 1 depicts the number of studies identified and considered at each stage. With our search strategy, we retrieved 1,124 references and screened for relevance 1,026 after removing duplicates. The full text screening of the relevant studies ended up with 17 included studies. Other studies coming from manual searches or known to the review team were also considered in this review.

Figure 1. Flow of studies through each stage of the review.



3.2.2 Characteristics of included studies

The following table summarises the main parameters of the included studies. The full citations can be found in Annex 2. For abbreviations and table footnotes (e.g. [1], [09]), see bottom of the table.

Table 2. Description of studies included in the review.

Author and year	Countries	Type of system	Study design	Study details	Sampling	Participants	Domain
Cunningham-Myrie 2008 [1]	Seven countries [9]	RHIS NCD	Cross-sectional or survey, Key Informant Interviews	Observational; Cross-sectional, multiple measures; Only one group or arm; Retrospective	Countries - multiple countries, data collected from regional health bodies/PAHO/ministries of health. [12]	Diabetes and Hypertension (N: NA)	NA Regular services
Driessen 2015	Uganda	HRIS	Key Informant Interviews, Case study	Observational; Cross-sectional, single measure; Only one group or arm; Retrospective	Institutions - case study sites [13]	End Users (N: 6) | HRHIS Implementation Team - Purposively identified (N: NA)	HRHIS in Ugandan healthcare.
Garrido 2004 [2]	United States		Modelling and projections	Observational; Retrospective	Countries (clusters: Region) [14]	Subject Matter Experts (N: NA)	HIS Kaiser Permanente Invest Electronic Medical Records
Khowaja 2022 [3]	Canada		Interrupted Time Series, ROI	Observational; Cross-sectional, multiple measures; Comparative; Retrospective	Sub-national areas in a country - several provinces, several hospitals. [16]	Canada (exc. BC) Sepsis (N: NA) | BC Sepsis (N: NA)	BCSN vs. Standard Care
Kurihara 2001 [4]	Japan		Cross-sectional or survey, Cost analysis	Observational; Cross-sectional, multiple measures; Comparative	Institutions [17]	Physician Opinion - Purposively identified (N: 50)	Filmless System H-CRT vs. Filmless System CRT vs. Film-based System

Author and year	Countries	Type of system	Study design	Study details	Sampling	Participants	Domain
Makhija 2017	Colombia		Longitudinal or cohort, Case-control	Observational; Longitudinal; Comparative; Retrospective	Institutions - colombian rts; 42 dialysis centers, 8 pd clinics, and 2 predialysis clinics.	PD peritonitis patients - Random (N: 201) (M: 57.7%) | PD non-peritonitis patients - Random (N: 852) (M: 56.6%)	The PD CQI program
Mukherjee 2014	India		Cross-sectional or survey, Key Informant Interviews	Observational; Cross-sectional, multiple measures; Comparative; Retrospective	Institutions - several hospitals, staff in several categories (clusters: Districts; Hospitals; Professional categories) [15]	HMIS Hospital Staff (N: 216) | TPBS Hospital Staff (N: 91)	Hospital Management Info Systems vs. Traditional paper-based
Ochalek 2020 [7]	33 countries [10]		Model	Observational; Cross-sectional, multiple measures; Only one group or arm; Retrospective	Countries - several countries from larger data set [22]	High-income (N: NA) | OECD (N: NA) | BRIICS - Purposively identified (N: 6)	NA
Parente 2001	United States		Cross-sectional or survey, Cost analyses	Observational; Cross-sectional, multiple measures; Comparative	Institutions - several hospitals [18]	US Hospital CIS (N: NA) | US Hospital No CIS (N: NA)	Clinical Information System vs. Standard Information System
Popovich 2012 [5]	United States		Case study, Economic model	Observational; Cross-sectional, multiple measures; Only one group or arm; Retrospective	Sub-national areas in a country [19]	Healthcare Providers - Unknown (N: NA)	EHR Health Registry vs. Non-EHR, Non-sharing
Rejeb 2017	France	Model/ Simulation	Observational; Cross-sectional, multiple measures	Institutions - 3 hospitals for data, simulated hospital [20]	Cancer Consultations (N: 180)		HCS vs. JPC vs. LBC
Stroetmann 2007 [8]	10 countries [11]		Case study, Cost benefit analysis	Observational; Cross-sectional, multiple measures; Only one group or arm; Retrospective	Case studies that span several countries.	Healthcare service (N: NA)	E-Health Application
Wang 2018 [6]	United States		"Research model."	Observational; Cross-sectional, single measure; Comparative; Retrospective	Services - one healthcare data provider [21]	Hospitals - Sequential selection from a list of entities (N: 3,266)	Hospitals

N: sample size; NA: not available; BC: British Columbia

Table footnotes

1. This study didn't use any patients. Used national-level data derived from health ministries. Different data may have also come from different years.
2. It provides an abridged version of a study completed regarding the result of the investment, and simulations.
3. Cost of follow-up care per case was the only variable (included in average sepsis costs measured more than twice, and at different time intervals than the ones given).
4. Physicians are the participants. However, they do not seem to actually be using either of the FLSs. Rather, their opinions were obtained to understand their hesitation on the interventions and controls. They use a PC-based IVW, but not either FLS.
5. This is a case study, and does not have participants. Though the study details its objective to determine the RoI of the use of EHRs for a specific MU objective, it also gives the ROI of EHRs in general.
6. Study factors in variables for outcomes in practical and model sense. A sensitivity analysis also reported.
7. A modelling study with economic data from other texts and datasets.
8. The text is a truncated version of a longer text. Quality, access, and efficiency don't have more details.
9. Antigua and Barbuda, Bahamas, Barbados, Guyana, Jamaica, Saint Lucia and Trinidad and Tobago.
10. Australia, Austria, Brazil, Canada, Chile, China, Croatia, Estonia, Finland, France, Germany, Hungary, India, Indonesia, Italy, Japan, Korea, Lithuania, Mexico, Netherlands, New Zealand, Portugal, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey, United Kingdom, United States and Uruguay.
11. Belgium, Czech Republic, Denmark, France, Germany, Netherlands, Romania, Spain, Sweden and United Kingdom.
12. Caribbean countries chosen based on diversity of population size, geography, economic wealth and ethno-cultural differences. Epidemiological data form, and morbidity and mortality were disseminated to countries by Chief Medical Officer or PAHO. Interviews were conducted with people involved with clinical management/health information systems of diabetes, hypertension, and related complications.
13. Institutions reflecting different healthcare system services.
14. West, Northwest, and Pacific states of United States.
15. Sampling was dependent on objective: (1) Comparison of cost-effectiveness of HMIS with paper-based systems in terms of data reliability (several hospitals); (2) Compare satisfaction levels of end-users between HMIS and TPBS (hospital staff); (3) Comparison of perspectives of end-user between HMIS and TPBS (hospital staff).
16. Data came from in-hospital sepsis cases and mortality across 9 provinces; Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, and Saskatchewan. Cannot tell if data is from one hospital per province, or multiple.
17. Unclear.
18. Sample of hospitals came from the ProPAC hospital survey.
19. Unclear.
20. Simulations are from literature or participating hospitals, unclear.
21. Definitive Healthcare, the subscribed healthcare data provider, was used for the data set for reasons as given by the authors: 1) Wide range spanning 8000 hospitals across the US, 2) data set is frequently updated, 3) dataset provides information concerning hospital financial performance
22. From a previously existing DALY and economic data set (127 countries), the authors chose high income countries, 2 countries from the Organization for Economic Cooperation and Development, and BRIICS (Brazil, Russia, India, Indonesia, China, South Africa) to amount to 33 countries.

In total there were 17 studies included. Studies were published between 2001[a] and 2022 in a variety of countries including: Canada, Colombia, France, India, Japan, Uganda and the United

[a] Our search strategy included 2007 to 2022. However, three articles before 2007 were included in our scoping review through hand-searches and searching in reference lists.

States. Some studies included several countries in Europe, the Caribbean and elsewhere. The majority of studies focused on HICs, for example, only 3 out of 10 single country studies being from LMICs (among the remaining 7, 4 were from the USA, one each from Canada, Japan and France). All study designs were observational, some of them retrospective. Comparisons were made, but still using observational study designs. Two studies used mathematical modelling and most of the studies used basic statistical approaches. There was no study using a random sampling approach for the selection of individuals or entities. The health information domains varied: several were hospital based and one was related to human resources information systems. We also included studies that estimated some type of financial returns of quality of care interventions, not explicitly containing information systems investments.

Due to the heterogeneity of studies, we are not able to do a quantitative synthesis and provide a narrative description of studies.

3.2.3 Details of included studies

Cunningham-Myrie 2008

This study is based on data collected from the HIS and visits to the seven CARICOM country members. They describe epidemiological data, particularly on mortality and non-communicable diseases (NCD) as well as health care costs related to hypertension, diabetes, haemodialysis and peritoneal dialysis. Comparing the data from different countries authors highlight limitations of the HIS, depending on the countries; namely:

- no standardise surveillance system; data supplied through surveys;
- computerised systems exists at national level, but the capacity of staff to retrieve data is limited;
- computer in some hospital records offices are inexistent or insufficient;
- large inconsistencies in mortality data between PAHO and CARED data
- incomplete filling of forms by doctors;
- insufficient personnel for data management functions;
- routine collection in the private sector was absent;
- inconsistent ICD-10 coding.

Interestingly, the authors conclude that control of NCD will require good HIS that can deliver the information required for decision-making. “The CARICOM governments must therefore commit themselves to mobilizing and sustaining the resources (human, material and financial) that are necessary” (page 391).

Driessen 2015

This study assesses some effects of the Uganda’s Human Resources for Health Information System (HRHIS), implemented with support from the US Agency for International Development. The impact is evaluated with respect to time and costs reduction of selected activities that required information on human resources. To this end the study used existing administrative data and conducted in depth interviews of key informants involved in implementing the new system?. The study targeted six different cases or institutions, such as Ministry of Health entities and professional bodies.

Authors describe large savings in several activities that require access to HR information (e.g. preparing reports) and conclude that "HRISs […] can dramatically improve the capture and use of data for health workforce decision-making".

Table 3. Efficiency gains, before and after the implementation of a human resources information system [Driessen 2015].

	Before	After	Efficiency gain (USD)	
Allied Health Professionals Council renewals				
Time for 1 renewal (min)	300	10		
Costs (0.91 USD/h)	4.55	0.15	4.40	93.33%
Ministry of Health's Human Resources Management report generation				
Report preparation (days)	79.99	0.02		
Cost (8.73 USD/d)	698.31	0.17	698.14	99.95%
Ministry of Health's Human Resources Development annual report generation				
Report preparation (days)	39.51	0.01		
Cost (8.73 USD/d)	344.90	0.06	344.84	99.96%

Garrido 2004

This study was carried out by a Health Maintenance Organization promoting electronic information systems. It presents an "IT business case" of an inpatient medial record system, including 36 categories[a] of benefits contributing to a positive cash flow within an 8.5 years period. They used a mix of approaches, including collection of routine data as well as interviews and created three scenarios, projecting cash flow to 2012. The limited methodological explanations make it impossible to fully understand the analytical outputs. Authors estimate that net cash flow is negative and decreases over three years, and then increases to become even in 2012 and positive afterwards and attribute 35% of net benefits of changes in average length of stay. The study hypothesises about the mechanisms that link changes in the HIS with performance improvements.

[a] In the following domains: staff efficiency, length of stay, legacy systems, litigation and malpractice, materials management, medical records, staff efficiency and pharmacy.

Table 4. Parameters and costs-savings related to an inpatient medical record systems [Garrido 2004].

Cumulative cash flow (in years)	
Basic scenario	8.5
Conservative scenario	10.1
Aggressive scenario	6.1
Investment in HIS	1 billion USD
Cash flow	2 billion USD
Reduction of long term hospital cost structure	2.30%
Increase of revenue projections	0.60%
Reduction in medical records supplies (e.g. paper system)	30% to 50%

Khowaja 2022

This study reports on an investment case of a quality improvement initiative to reduce sepsis in a Canadian provincial hospital. This is a retrospective study comparing British Columbia and part of the rest of Canada. Costs were modelled as incremental costs estimated as the difference between costs due to sepsis and costs of 'standard' hospital stays. Costs were multiplied by the number of cases averted. The study offers time trends, suggesting the ROI increased from 12.9 CAD to 112.5 CAD in five years.

Table 5. Benefit-cost ratio of a quality improvement initiative [Khowaja 2022].

Variables	2014	2015	2016	2017	2018
Types of costs avoided					
Health system: in-hospital cases	958,578	2,231,049	5,439,221	11,502,445	16,983,992
Health system: follow-up care	2,216,841	4,927,836	11,100,510	21,553,472	31,003,624
Health system: deaths	128,607	294,808	685,307	1,307,856	1,854,941
Out-of-pocket for families: deaths	85,738	196,539	456,871	871,904	1,236,627
Societal (all inclusive)	**3,389,764**	**7,650,232**	**17,681,909**	**35,235,677**	**51,079,184**
Cumulative investment **BCSN program costs**	**243,144**	**308,507**	**376,880**	**412,826**	**449,962**
Return on investment					
Societal savings, minus BCSN investment	**3,146,620**	**7,341,725**	**17,305,029**	**34,822,851**	**50,629,222**
Benefit-cost ratio (societal savings/BCSN investment)	**12.9**	**23.8**	**45.9**	**84.4**	**112.5**

BCSN: British Columbia Sepsis Network

Kurihara 2001

This study compared different technological approaches in radiology, across a series of 'model hospitals', with parameters estimated from real hospitals data, in Japan. In essence, the study compares the costs of two technological approaches. In a five-year period, film-less radiology compared to film-based radiology saves 18% and 14% of costs in 100- and 500-bed hospitals, respectively. Interestingly, authors state the profitability ultimately depends on the insurance system.

Makhija 2017

Makhija 2017 determines the net savings of a Continuous Quality Improvement (CQI) program related to peritonitis cases in Colombia. The study refers to the term ROI, although it is estimated as the proportion of costs savings due to the number of peritonitis cases averted: 169% and 82%, depending on different scenarios based on the number of cases averted.

Table 6. Cost analyses in the prevention of peritonitis cases [Makhija 2017].

		cost per patient (4,000 patients)
Cost of episode of peritonitis (USD)	250.13	
Cost of implementing the CQI program	147,000	36.75
CQI maintaining cost per year	119,000	29.75
CQI maintaining cost for the 7 years	833,000	208.25
CQI cost for the 8 years	980,000	245
	Standard scenario	**Conservative scenario**
Number of episodes of peritonitis prevented by CQI	10,409	7,052
Cost per prevented episode	94.15	138.97
Discounted net economic value of the PD CQI program over 8 years	1,346,431	679,143
Average (undiscounted) annual savings	207,027	100,734
ROI	**169%**	**82%**

PD: Peritoneal Dialysis

Mukherjee 2014

This study addresses several issues related to a hospital management information system, including incremental cost-effectiveness ratio (ICER), in Tamil Nadu (India). It compares an electronic information system (HMIS) with a traditional paper based systems (TPBS). The study involved hospitals with paper systems and others with electronic systems. ICER was calculated as the ratio between the difference of the electronic and paper-based costs and the difference of data reliability scores in electronic and paper-based systems. ICER was estimated using a provider perspective. Data sources were not fully described but they seemed to be mainly routine information collected in hospitals. Authors assumed that data reliability was directly proportional to the effectiveness of the system and that effectiveness of the system was directly proportional to the amount of time saved for carrying out a given task and they mention this assumption in the limitations of the study.

Table 7. Incremental cost-effectiveness ratios of hospital information system [Mukherjee 2014].

	HMIS	TPBS
Day-wise cost for operating the data system per hospital (in Indian Rupees)	2,511.80	78.97
Effectiveness score	0.98	0.25
ICER	3,301.33	
Average time taken to perform (in seconds)		
a) Outpatient registration for new patients	21.64	22.50
b) Outpatient registration for old patients	0.00	13.66
c) Doctors consultation in the general OPD	27.99	26.74
d) Dispensing drugs at the pharmacy	23.46	18.28

HMIS: electronic system; TPBS: traditional paper-based system.

Ochalek 2020

This is a mix of ecological study and review of studies, across several countries, reporting on costs per DALY averted or QALY gained and the proportion of GDP per capita. Most of the costs per DALY averted are around 70% of GDP, although they can range between 17% and 375%. The study is of limited value for this scoping review. However, it provides useful parameters that can be actually used in other econometric studies.

Parente 2001

Parente and Dunbar look at the financial performance of having integrated clinical and financial information systems in 1,308 hospital settings. They used 1993 hospital survey databases. In essence, they carried out a multi-variate analysis concluding that hospitals with information systems have higher financial performance, even across several years, from 1993 to 1996.

Table 8. Financial margin in hospitals with and without integrated information system [Parente 2001].

	Hospitals with information system	Hospitals without information systems
1993	4.80%	3.40%
1994	4.54%	3.81%
1995	5.80%	4.95%
1996	5.59%	5.07%

Popovich 2012

The study summarises an example case study that modelled the exchange of immunisation records between provider-based electronic health records and state immunisation registries, demonstrating the potential for increased provider revenue. A model was developed to estimate revenue value for exchanging immunisation records and increasing the EHR public health ROI. Returns are estimated as revenue increases (e.g. more patients), cost reductions due to efficiency

gains and improved services because of better data. The model focuses on the aftermath of the Hurricane Katrina, suggesting that the availability of electronic immunisation records saved a substantial number of unnecessary re-vaccinations. The estimation of net revenue ranged from 24,000 to 60,000 USD.

Rejeb 2017

This is a methodologically complex study proposing an approach to estimate the impact of "high-level HIS" into patient pathways; i.e. using a combination of (ii) Architecture of Integrated Information Systems (ARIS), (ii) micro-costing approach for cost evaluation and (iii) Discrete-Event Simulation (DES) approach.

The study highlights the limitation of current HIS assessments: (i) the short-term of the assessments (which could be overcome by flow modelling and simulation) and (ii) their limited capacity to capture the 'dynamic' of the system (which could be overcome by probability distributions to better fit the randomness related to the system). It is applied to in three cancer services in hospital settings.

HIS costs per unit of activity, attributed to oncological activities, are estimated based on known overall HIS costs, which are attributed to those activities according to the estimated use rate, and then divided by the total amount of activities over a time period.

Costs data (see Table 9) suggest that HIS components (e.g. report dictation with vocal recognition and integration of HIS software) can reduce consultation costs by around 10% and 2% respectively, while imaging software increases costs by 7%.

Different scenarios are created based on the availability of HIS tools in the three hospitals. Based on the reduction of consultation costs in scenarios with more or better HIS components, and the ARIS model, they conclude that HIS implementation led to (i) decrease of staff occupation rate; (ii) quality and consultation time increase; (iii) decrease of patient waiting times; and (iv) that costs of HIS components are negligible when considering human resources costs.

Table 9. Cost reduction per consultation in several HIS investment scenarios [Rejeb 2017].

	A	B1		B2	
(costs in EUR)	Scenario 2 with HIS improvements	Scenarios without the HIS improvements			
		Scenario 41		Scenario 42	
HIS improvements	Cost per consultation	Cost per consultation	Cost reduction	Cost per consultation	Cost reduction
Report dictation with vocal recognition	43.18	48.02	11.22%	47.64	10.33%
Integration of HIS software	43.18	43.45	0.63%	43.96	1.80%
Imaging software	43.18	42.64	-1.26%	40.72	-5.69%

Stroetmann 2007

Stroetmann reports on a cost-benefit analysis of 10 e-Health applications in Europe. The details of the methodology are fully developed in another article [29]. Costs were estimated taking into account both investment and running costs. Benefits were categorised as (i) quality, (ii) access and (iii) efficiency. In order to estimate the monetary value of benefits, authors used several strategies: cost changes, willingness to pay and cost avoidance.

The study shows as well time trends across the 10 applications, from 1994 to 2008, showing a moderate increase of costs and a rather more substantial increase of benefits, having a negative balance up to 1996, and a remarkable positive balance in 2008.

Table 10. Benefits related to information systems interventions across 10 case studies [Stroetmann 2007].

	Case studies	Year start	Year end	Cumulative investment costs	Cumulative benefit by 2008	Productivity gain	Benefits for citizens	Benefits for providers
1	Electronic insurance card	2000	2008	1,500,000	3,500,000	65%	96%	4%
2	E-prescribing	2000	2008	155,000,000	330,000,000	58%	20%	80%
3	Electronic ambulance dispatch	1995	2008	15,000,000	35,000,000	38%	90%	10%
4	Electronic patient record system	1995	2008	7,600,000	30,000,000	17%	8%	92%
5	Web-based, electronic health records	1998	2008	90,000,000	180,000,000	74%	10%	90%
6	Vaccination support system	1996	2008	25,500,000	43,000,000	41%	96%	4%
7	Danish health data network	1994	2008	725,000,000	1,400,000,000	97%	2%	98%
8	Supply chain optimization hospital	2004	2008	390,000	470,000	9%	3%	97%
9	NHS Direct Online Web-information service	1998	2008	100,000,000	550,000,000	85%	13%	87%
10	Teleradiology	2001	2008	800,000	5,000,000	34%	86%	14%

Wang 2018

Wang explored a dataset of hospitals in US to look at the impact of health information systems on financial performance and productivity. Financial performance was measured in terms of “return on assets” (ROA) and productivity in terms of net revenue per bed. For information investments, authors considered operating and capital IT budget available in the databases. The authors considered as well controlling for certain variables and implemented a regression model.

Table 11. Impact of investments in RHIS on return on assets, net income and revenue [Wang 2018].

	Increase in ROA	Increase in net income		Increase in revenue	
per 1 million in operating IT investments (USD)	0.0011	130,339	0.74%	6,050,000	0.71%
per 1 million in capital IT investments (USD)	0.0021	248,829	1.41%	11,430,000	1.35%

3.2.4 Additional study – "Dalberg" report

Dalberg [30] reports that "Data creates real value through new economic and impact opportunities, and cost savings through everything from process efficiencies to reduced corruption; analysis of past investments has shown an average return of USD 32 for every dollar invested" (pages 3 and 12). And: "This means that fully funding data ecosystems over the next eight years could create approximately USD 1.4 trillion in additional value over the same period – equivalent to the total funding need of SDG 3 (Good Health and Well-Being) for four to six years" (page 12).

Their approach consists of:

(a) analyses of individual cases;
(b) segmentation by thematic groups;
(c) aggregation of thematic groups into global weighed average.

The overall ROI was estimated based on 12 ROI estimates resulting from partial ROI of three types of countries by income level (i.e. LIC, MIC and HIC) and four sectors (i.e. education, health, agriculture and government), 3 x 4 = 12. There were no data in four of the 12 categories: health in HIC, agriculture in MIC and HIC and form of government administration in LIC. The weights applied were the proportion of countries in each category. The weights within types of countries were estimated as the sum of the ratios of governmental health expenditure, governmental expenditure in education, agriculture, forestry and fishing value added and government expense. Within each of the 12 categories, ROI from different studies was simply averaged.

A full comment on the methodology can be found in Annex 4.

4 Discussion and conclusion

We completed a scoping review of studies that can bring some methodological insights on how to approach a ROI case in the context of health systems interventions, particularly, health information systems. We identified a range of frameworks of RHIS, and categorised the components of each framework in terms of inputs, processes, outputs and outcomes.

Studies were, in general, very limited in offering a theory of change or suggested mechanisms by which investing in HIS would bring certain benefits beyond the health system. In other cases, the links between investments and outcomes were very direct; for example, electronic systems reduce the transmission time of information and the time required to trigger services (e.g. treatments). Two studies looked at financial performance outcomes (i.e. very closely related to the investments) and, interestingly, used similar data sources, i.e. datasets with hospital data from the US (Parente 2001 and Wang 2018).

The methodological questions of ROI cases encompass (i) what is included in the investment component; (ii) what is considered a return; and (iii) how those items are brought together into a quantitative expression. None of the studies seem to have used a standard, widely accepted methodology, despite that most of them used similar terminology, such as cost-benefit or ROI. The methodologic descriptions (e.g. data sources, analytical approaches) tend to be very limited as well as the availability of data [Garrido 2004]. Some studies used real settings and others used a mix of modelling approaches, even modelling the services hosting the system changes described in the study [Kurihara 2001]. However, some attempts to standardise analytical approaches, including modelling, are available [31, 32]. Studies had other gaps in the completeness of reporting. We could not find in the methods section of any of the studies a reference to a standard methodology, either. The only study which had a more methodological focus providing a way forward to estimate DALYs and QALYs, was Ochalek 2020.

An important implication of the lack of a standard methodology is that findings from different studies cannot be compared, because they refer to different items and calculations. And, maybe more importantly, that it is difficult to exert a value judgment on the reported findings. Several questions are raised: For example, what does it really imply for health services a productivity gain that ranges from 9% to 97%; or for a society, benefits for citizens that range from 2% to 96% [Stroetmann 2007]? What are the acceptable thresholds that make an investment worthwhile? And how do studies consider who pays for HIS investments and who benefits from them? For instance, while investments are typically assigned to providers, benefits may affect mainly payers and users of services [Garrido 2004].

This is even more striking if we consider the quality of the underlying studies. Despite that we have not assessed the Risk of Bias, as we would have done in a systematic review, several methodological limitations were apparent. For example, studies were observational with only a few of them taking into account confounding in their analyses; confidence intervals, a measure of uncertainty, were not reported; subjects or entities (e.g. hospitals) were not randomly selected, compromising the representativeness of the sample and, therefore, the external validity of findings.

The implications of the methodological caveats in the interpretation of findings are crucial. It is appealing that all studies invariably suggested a positive effect of investments in HIS or quality improvement interventions [33]. We cannot ascertain to which extent the net benefits reported across all studies are due to the real impact of interventions, to the selective reporting of outcomes or to bias. The wide scope of different methods may support the consistency of findings despite the methodological reservations, but we cannot speculate on this.

There are other issues that need to be taken into account in the interpretation of findings. One of them is the setting; for example, several studies were carried out in hospitals and their interventions may not be applicable to other health care levels and settings or the findings may be different. Another issue is the timing of events. This is well described in several studies that suggest that net benefits or ROI change over time and benefits actually tend to increase over time as capital investment is spread along several years (e.g. return of investments, cash flow, or other measures) [Garrido 2004, Khowaja 2022, Makhija 2017]. Also, the fact that most of the studies focus on very specific information sub-systems or tools makes it very difficult to extrapolate the findings to investments that could affect the HIS as a whole.

Interestingly, several studies looked at quality improvement interventions [e.g. Khowaja 2022, Makhija 2017] or had a quality of care perspective. Although the idea that information systems are quality of care instruments is not new [34], it may deserve more attention. Actually, those studies that have a quality of care perspective use quality of care dimensions as part of the potential benefits linked to investments. Consistently, other systematics reviews have identified improvements in quality and utilization of needed healthcare services and coverage as one of the main categories of benefits of HIS [33, 35].

Indeed, the effects of interventions, i.e. the benefit of investments, depend not only on the implementation of a certain technology but also on how it is used within the wider systems. A very illustrative example is the one provided by Popovich 2012 suggesting that it was the capacity of the systems to exchange information across several health care actors that could bring savings and reimbursement gains. The issue of integration was addressed in Parante 2001. Several studies also pointed at factors that may facilitate or jeopardise the impact of information system interventions on costs or other outcomes. Although we did not extract these data, most of the issues related to capacity budding, sound systems design, acceptability by users and technological appropriateness, integration and interoperability, to mention a few.

Return of investments for RHIS are difficult to establish, mainly because some kind and size of attributions needs to be established or assumed. Most of the studies looked at relatively direct benefits, such as (i) information system performance [e.g. Mukherjee 2014], or (ii) savings in costs of services not used as a result of the investment (e.g. less cases, less hospital stays, less burial expenses, Khowaja 2022, Makhija 2017). We could not find studies looking at health service coverage or health outcomes.

This scoping review has several limitations. We have not attempted to establish robust links between investments and returns, since for this we would have needed other methodological approaches and other types of evidence that, we believe, may not be available. We have been

unable to draw a clear line between RHIS and other interventions, since this would have left out studies from related areas that could provide useful evidence. Although we aimed to exclude clinical-based studies, it was sometimes unclear where to draw the line between information system-focussed and health service/programme-focussed interventions (such as those focussed on quality of care improvement). We potentially missed identifying eligible studies from grey literature and relevant studies prior to 2007. This was a date arbitrarily set to limit studies involving more recently developed information technology and also for feasibility reasons. Nevertheless, we have decided to keep older studies that were picked up by the search strategy. In addition, due to a lag in adding and indexing articles in various online databases, our review could fail to locate the most recent publications and research. Another limitation was that most of the included studies were from medium- and high-income countries hence the generalisability of the results might be limited.

In conclusion, we note the following:

- Economic studies estimating the return of investments on HIS:
  - tend to be framed in the context of clinical care;
  - understand HIS as quality of care instruments, which inform the 'benefits' of investments.
- Studies do not apply a standard methodology that could make results comparable and that could inform the clinical, public health or policy relevance of findings.
- Critical issues to interpret the findings of ROI include:
  - health systems specific setting
  - items included in the calculations
  - analytical approach
  - time trends of the estimates
- The main challenges to produce a meaningful ROI case on RHIS include:
  - building consensus on the scope, assumptions and hypothesis supporting ROIs on RHIS;
  - finding the balance between imperfect existing data and the data requirements for robust analytical approaches;
  - identifying appropriately robust methodological approaches for studying ROI for RHIS;
  - standardising methods to allow comparisons across settings, geographical areas and time;
  - linking the interpretation of analytical outputs with funding decisions.

ANNEXES

Annex 1. Search strategy for the scoping review

PubMed search output: 35 document reports

Search number	Query	Results
3	#1 AND #2	35
2	"Routine health information system"[tiab] OR "health information system"[tiab] OR RHIS [tiab] OR HIS	15,181
1	"evaluation framework"[tiab] OR "Evaluation Framework"[tiab] OR "framework, evaluation" [tiab]	361

Web of Science database: 25 document reports

"evaluation framework" OR "Evaluation Framework" OR "framework, evaluation" (Topic) and "Routine health information system" OR "health information system" OR RHIS OR HIS (Topic) and **Article** or **Proceeding Paper** (Document Types) and **Health Care Sciences Services** (Web of Science Categories)

Scopus database: 33 document reports

TITLE-ABS-KEY ("evaluation framework" OR "Evaluation Framework") AND TITLE-ABS-KEY ("Routine health information system" OR "health information system")) AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NURS"))

MEASURE Evaluation Website: 2 document reports

(Evaluation framework) AND (Routine health information system)

International Journal of medical informatics: 100 document reports

(Evaluation framework) AND (health information system)

Google scholar search: 26 document reports.

We initially established terms by priority, based on our own perception of relevance in relation to the inclusion criteria of the scoping review, as follows:

- Priority 1: Return on investment; Investment case; Business case; Economic impact; Economic evaluation;
- Priority 2: Impact evaluation; Net benefit; Cost-benefit; Health financing;
- Priority 3: Budget impact; Costs and cost analysis; Cost effectiveness analysis; Cost allocation; Cost-benefit analysis; Cost-minimization analysis; Cost-utility analysis; Cost control; Cost savings; Savings; Direct service costs; Health expenditures; Financing; Resource allocation; Health care financing; Health system financing; Out of pocket payments; Health care access; Equity.

Based on several iterations, we implemented the following search strategies:

OPTION 2: PubMed search

Search number	Query	Results
8	#4 AND #6	136
6	#1 AND #5	892
5	"health expenditures" OR "health expenditure"*[tiab] OR "public health expenditure"[tiab] OR "public health financing"[tiab] OR " health financing" OR "health budgeting"[tiab]	27,047
4	#2 OR #3	4,198,680
3	Investments[mh] OR invest*[tiab]	4,197,090
2	"Value for money"[tiab]	1,973
1	Economics, medical[tiab] OR medical economics[tiab] OR economic analysis[tiab] OR economic analyses[tiab] OR economic evaluation*[tiab] OR economic impact[tiab] OR impact evaluation[tiab]	36,684

OPTION 4 Updated

WHO_RHIS_PubMed search: 9 document report

Search number	Query	Results
10	#8 AND #9	9
9	Health information systems[mh] OR health information system*[tiab] OR routine health information system*[tiab] OR routine health information system*[tiab]	5,683
8	#4 AND #7	136
7	#1 AND #6	892
6	"health expenditures" OR "health expenditure"*[tiab] OR "public health expenditure"[tiab] OR "public health financing"[tiab] OR " health financing" OR "health budgeting"[tiab]	27,047
4	#2 OR #3	4,198,680
3	Investments[mh] OR invest*[tiab]	4,197,090
2	"Value for money"[tiab]	1,973
1	Economics, medical[tiab] OR medical economics[tiab] OR economic analysis[tiab] OR economic analyses[tiab] OR economic evaluation*[tiab] OR economic impact[tiab] OR impact evaluation[tiab]	36,684

Web of science database: 8 reports

"Economics, medical" OR "medical economics" OR "economic analysis" OR "economic analyses" OR "economic evaluation*" OR "economic impact" OR "impact evaluation" (Topic) and "Value for money" OR Investments OR invest* OR "health expenditures" OR "health expenditure"* OR

"public health expenditure" OR "public health financing" OR " health financing" OR "health budgeting" (Topic) and "Health information systems" OR "health information system*" OR "routine health information system*" OR "routine health information system" (Topic

Scopus database: 687 reports

(TITLE-ABS-KEY ("medical economics" OR "economic impact") AND TITLE-ABS-KEY ("Value for money" OR investments OR "public health expenditure" OR "public health financing" OR "health financing") OR TITLE-ABS-KEY ("Health information systems" OR "routine health information system" OR rhis OR his)) AND (LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "MEDI")) AND (EXCLUDE (SUBJAREA , "SOCI") OR EXCLUDE (SUBJAREA , "ENVI") OR EXCLUDE (SUBJAREA , "ENGI") OR EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "PSYC") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "PHAR") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "MULT") OR EXCLUDE (SUBJAREA , "DENT")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007)) AND (EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "NURS"))

Others (Google search and hand-picked): 14 document reports

Annex 2. Citations of included studies

1. **Augusto NA** - Augusto, Vincent and Rejeb, Olfa and Xie, Xiaolan and Aloui, Saber and Perrier, Lionel and Biron, Pierre and Durand, Thierry. Performance evaluation of health information systems using aris modeling and discrete-event simulation. 2015 Winter Simulation Conference (WSC). 2015:1503-1514.
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6. **Kurihara 2001** - Kurihara, Y. and Yoshida, S. and Geshi, H. and Kubo, Y. and Kitazoe, Y. Economic analysis of a filmless system based on the hospital information system. Stud Health Technol Inform. 2001;84(Pt 2):1166-70.
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Annex 4. Comments on "Dalberg" methodology

The following issues were in the Dalberg study were not fully elucidated: search strategy to find cases; any additional selection criteria of cases, apart from data completeness; estimates of social and institutional benefits and their economic equivalents across all sectors (only health and education explained); rationale for the selection of weights. Additionally, we noted the following:

- **Overall interpretation of the quantitative estimate.** While there is a value in having a single figure in a return of investment case (i.e. 32 USD), we believe that it may be challenging to use this as an argument to advocate for supporting RHIS investments. Even in an ideal scenario, where such a figure would be accurate, coming from a representative sample of situations and having low uncertainty, decision-makers may not be willing to engage with evidence that rests on sophisticated methods and varied explicit (or implicit) assumptions. The complexity of using economic evaluation for decision making [36] and the limited credibility of modelling studies does not ease the situation [37]. The following issues further illustrate these challenges.
- **Publication bias.** Any process which does not use a systematic literature search will suffer from publication bias. Even using systematic and comprehensive literature searches, publication bias cannot be completely ruled out, although it can be illustrated using graphical methods. In this situation, it is not possible to ascertain how close or far away the current estimate is from an hypothetical 'true' value, should all relevant evidence had been examined.
- **Quality of data of the underlying studies.** It seems the authors did not assess the quality of the data in the underlying studies (e.g. in terms of accuracy or completeness). For example, authors imputed data assuming linearity in time trends.
- **Methodological quality of underlying studies.** The quality of underlying evidence has to be assessed in modelling and, particularly, when used for decision-making [38]. It has been widely reported that the quality of evidence influences the credibility of findings [39]. All studies are subject to different types of bias and, regardless whether bias is described or not, findings should be examined under the light of potential biases. This is also important when communicating evidence as it has been shown that there are implications on how evidence is interpreted depending on the knowledge of the underlying quality of the evidence provided [40].
- **Uncertainty.** Any estimate has some level of accuracy and precision. Accuracy is related to the difference between a quantitative estimate and its 'true' value; precision is related to the capacity of the measurement instrument to provide the same estimate in repeated measures. Confidence intervals measure the precision of an estimate providing a range of the 'most frequent' values that could be expected. There are several factors that 'penalise' precision; namely, the size of the sample of subjects or events used to measure the estimate. Dalberg provides, though, a range: "the range of returns across the analyzed investments was USD 7 to USD 73 per dollar spent; see Chapter 2 and Annex 1 for more detail on this economic ROI analysis (page 3). It cannot be ruled out that with other case studies the estimates could have been substantially different and even be below 1. This aspect may influence the credibility of the estimate itself; but more importantly, could mislead decision-makers.
- **Diverse sectors.** The approach by Dalberg purposively used data coming from different sectors: agriculture, education, health and government across three income groups, based on World Bank classifications (page 31). While this is possible, it introduces a lot of heterogeneity that, in usual circumstances, would prevent pooling data together. Furthermore, pooling data together has other methodological requirements that may have not been totally fulfilled in the current analysis [41]. This also relies on the assumption that the relative contribution of so many different sectors (i.e. agriculture, education, health and government) can be estimated or that they are equivalent.

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