

## **Business Intelligence and its Applications in the Public Healthcare System**

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### **Abstract**

Business intelligence (BI) has been known as a popular tool in business management and decision support systems. BI helps to transform raw data into smart information. There are many BI tools such as extract transform and load (ETL), data warehouse, online analytical processing (OLAP), and dashboard. BI tools are usually used in public health fields for financial and administrative purposes. Now BI is also helping public health organisations with diagnosing and treating patients with long term conditions and evaluating alternative treatments based on outcomes analyses. BI is composed of four steps: integration, storage, analysis, and presentation. BI usually uses a dashboard in the presentation step to deliver the information to end users. The development an effective dashboard is still a challenge.

**Keywords:** Business intelligence, dashboard, decision support system, public health, OLAP, data warehouse

### **Introduction**

Information access is of critical importance in the practice of the public health service. Having timely, accurate and readily available information is essential in monitoring the health of communities and populations. Having access to public health data is essential for determining the association of environmental exposures to diseases, as well as measuring the progress and the efficacy of interventions. Effective public health practice relies on the availability of public health data sources and assessment tools to convey information to investigators, practitioners, policy makers, and the general public [1]. Increasing the availability of neighbourhood socioeconomic, health, and environmental characteristics will allow individuals to obtain the knowledge needed to make informed decisions concerning their own health risks and may prompt collective action to equalise the burden of environmental health risks. Many systems have been developed using business

intelligence (BI). How to develop an effective BI tool and determine in which areas of the public health service it can be applied is still a challenge.

### **What is business intelligence?**

In the economy of today, organisations have a lot of information to gather and process in order to be able to make the best decision as fast as possible. One of the solutions that can improve the decision making process is BI [2]. BI tools help transforming raw data into smart information and knowledge [3,4]. Knowledge is typically obtained about customer needs, customer decision-making processes, the competition, conditions in the industry, and general economic, technological, and cultural trends [3]. The term BI was first introduced by Luhn (1958) as “a set of concepts and methods to improve business decision-making by using fact-based support systems” [5]. Currently, BI refers to methodologies and

technologies for the collection, integration, and analysis of all relevant information in a business for the purpose of better business decision-making [3,6-9]. Objectives of BI include understanding of a firm's internal and external strengths and weaknesses, understanding of the relationship between different data for better decision-making, detecting opportunities for innovation, and finding cost reduction and optimal deployment of resources [6,10].

BI tools are types of application software designed to report, analyse and present data. The key general categories of BI tools are: spreadsheets, reporting and querying software (tools that extract, sort, summarise, and present selected data), online analytical processing (OLAP) tools, digital dashboards, data mining, process mining, and business performance management [11]. We can classify BI tools into two classes [12-15]:

**1. Database management system intelligence tools.** These tools are used to manipulate massive operational data and to extract

essential business information from them. Examples include decision support systems (DSS), executive information systems (EIS), online-analytical processing (OLAP), data warehouses, data mining systems, knowledge management (KM), geographic information systems (GIS), digital dashboards etc. They are built on database management systems and are used to reveal trends and patterns that would otherwise be buried in their huge operational databases.

**2. Competitive intelligence tools.** These tools aim at systematically collecting and analysing information from the competitive environment to assist organisational decision making. The information is mainly gathered from public sources such as those available on the Internet.

In the market today, there are many major BI tool vendors such as SAP/Business Objects [16], IBM-Cognos [17], Oracle-Hyperion [18], SAS [19], and MicroStrategy [20]. Many acquisitions of BI tool vendors have occurred since 2002 [21].

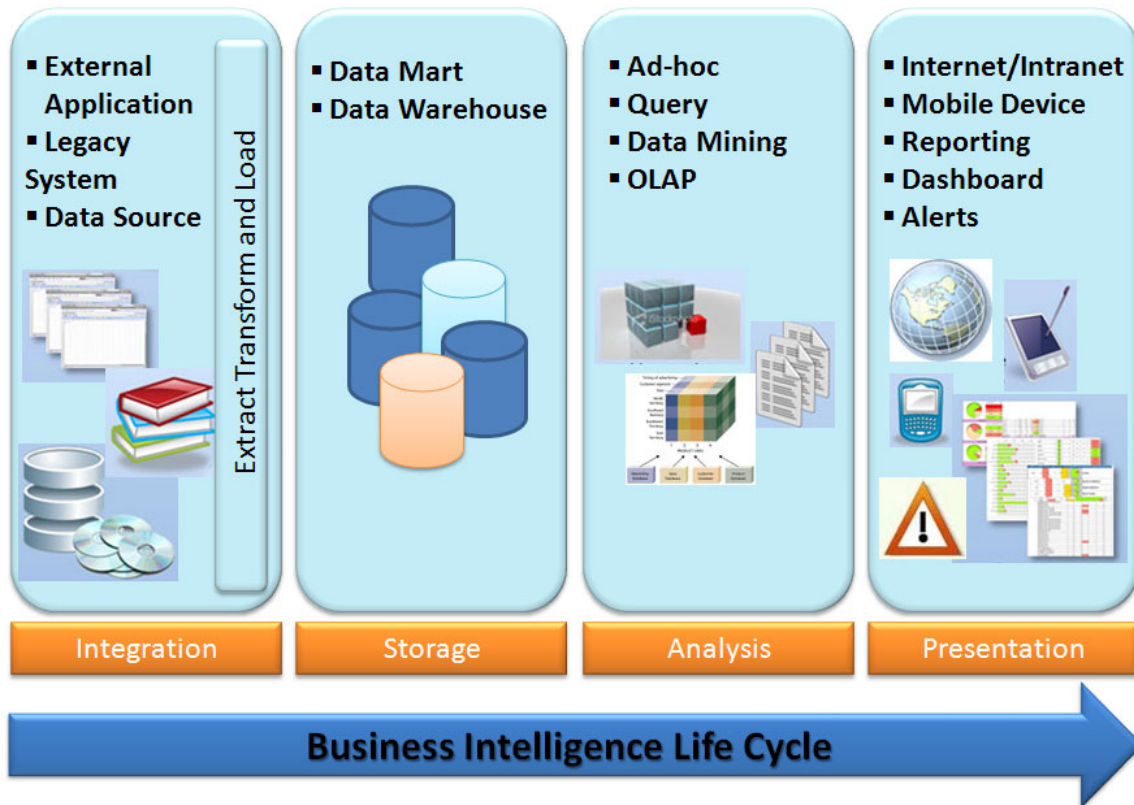


Figure 1 Four steps involved in BI and their related processes.

### Conceptual architecture for BI

Generally, BI is comprised of four steps: integration, storage, analysis and presentation (**Figure 1**) [6,9,22-26]:

**1. Integration.** This is a key step in BI as this is where data from different sources is checked for consistency and subsequently converted into a unified format. The process of integration is known as Extract Transform and Load (ETL) in BI terminology.

**2. Storage.** This step organises information in a data warehouse, often using a relational database management system. Relational databases are the most popular model currently in use in commercial and open-source databases. Working with large databases can be time-consuming from an analytic standpoint.

**3. Analysis.** This step is a way of organising data, which is much more suitable for analysis and report. This step uses an OLAP. Data are represented by data cubes instead of tables and organised in a multidimensional aggregated format. This format allows fast analysis by turning raw data into a format that is more easily understood by the user. Relational databases can be connected to OLAP in a variety of ways using both open-source and proprietary tools. Objective metrics or key performance indicators (KPIs) must be defined.

**4. Presentation.** This step delivers the BI solution to the end users. Executive management, business analysts, power users and casual users are empowered to make more informed business decisions. The knowledge acquired through this process can then be used to adjust or change current behaviour, and to help the organisation move towards optimal processes or goals. Tools designed to present KPIs such as Balanced Scorecards or Quality Dashboards have been used in public health [24]. These tools allow various activities to be monitored within the hospital environment.

### Critical success factors in BI implementation

Although there are many factors that could affect the implementation process of a BI system, the following are the critical success factors in BI implementation [27]:

1. Business-driven methodology and project management.
2. Vision and planning.
3. Management support & sponsorship.
4. Data management and quality.
5. Mapping solutions to user requirements.
6. Performance considerations of the BI system.
7. Robust and expandable framework.

### BI in public health

Public health organisations collect significant volumes of data. Quality information helps to identify and prioritise problems, develop and evaluate policies and actions, and organise clinical health services delivery. It also guides research and development to contribute to standards and guidelines development as well as to monitor progress and inform the public [28].

BI has been used for years in public health for financial, administrative purposes, and for gainful action-oriented information that enhances patient care, organisational efficiency, and situational awareness [24]. Now BI is also helping public health organisations with diagnosing and treating patients with long term conditions and evaluating alternative treatments based on outcomes analyses. For example, data from operation-level clinical systems can be used to prioritise heart bypass surgery versus angioplasty by looking at how quickly patients are discharged and whether they are readmitted. Additional capabilities include the ability to distinguish previously unrecognised disease patterns, identify at-risk patients, and review the performance of individual physicians [4]. Many systems in public health developed using BI are shown in the

**Table 1.**

**Table 1** BI tools and objectives in public health.

Public Health Fields	BI Tools	Objectives	References
<ul style="list-style-type: none"> <li>▪ <b>Radiology</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ ETL</li> <li>▪ Data Warehouse</li> <li>▪ OLAP</li> <li>▪ Dashboard</li> <li>▪ Data mining</li> </ul>	<ul style="list-style-type: none"> <li>▪ Improve in healthcare quality, safety, efficiency, financial performance</li> </ul>	[24]
<ul style="list-style-type: none"> <li>▪ <b>Environmental Health</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ Data Warehouse</li> <li>▪ OLAP</li> <li>▪ Data mining</li> <li>▪ SOLAP</li> <li>▪ Data visualisation</li> </ul>	<ul style="list-style-type: none"> <li>▪ Reduce health risks caused by an environmental source</li> <li>▪ Access to statistics and other information</li> <li>▪ Discover new knowledge</li> </ul>	[28]
<ul style="list-style-type: none"> <li>▪ <b>Traditional Chinese medicine</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ ETL</li> <li>▪ Data Warehouse</li> <li>▪ OLAP</li> <li>▪ Data mining</li> </ul>	<ul style="list-style-type: none"> <li>▪ Make medical knowledge discovery to diagnosis or prognosis prediction</li> <li>▪ Design clinical decision support system to assist physicians and other health professionals with decision making tasks</li> </ul>	[29]
<ul style="list-style-type: none"> <li>▪ <b>Healthcare</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ ETL</li> <li>▪ Data Warehouse</li> <li>▪ OLAP</li> <li>▪ Dashboard</li> <li>▪ Data mining</li> <li>▪ HTML-based information tool combine: Text information with diagrams and Short video sequences</li> <li>▪ Web application</li> <li>▪ Computerised Patient Record (CPR)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Support communication between care givers</li> <li>▪ Perform hospital population surveillance</li> <li>▪ Enable clinical quality initiatives</li> <li>▪ Share decision-making (SDM)</li> <li>▪ Support Health-care planning</li> <li>▪ Support in decision making by local and regional health-care authorities</li> <li>▪ Remote diagnosis and treatment</li> <li>▪ Monitor patient’s body conditions</li> <li>▪ Quality improvement for patient receiving care</li> </ul>	[24,30-42]
<ul style="list-style-type: none"> <li>▪ <b>Public health management and disease control</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ ETL</li> <li>▪ Data warehouse</li> <li>▪ Data mining</li> <li>▪ Decision Support System</li> <li>▪ Operation supporting system</li> <li>▪ GIS</li> <li>▪ Knowledge Discovery in Database</li> <li>▪ Statistical tools</li> <li>▪ Rule inference tools</li> </ul>	<ul style="list-style-type: none"> <li>▪ Support the physician or practitioner/patient relationship and plan of care</li> <li>▪ Ensure quality of the care and patient security</li> <li>▪ Reduce costs</li> </ul>	[43-54]
<ul style="list-style-type: none"> <li>▪ <b>Health promotion</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ Web technology</li> <li>▪ Decision Support System</li> <li>▪ Relational database</li> </ul>	<ul style="list-style-type: none"> <li>▪ Patient monitoring and treatment</li> <li>▪ Make decisions about medication persistency</li> <li>▪ Motivate patients to continue taking their medications</li> </ul>	[28,55-57]

There are several factors needed to be considered when we apply BI in public health. First, the metrics chosen for monitoring should meet the objective of the project. Second, the way we collect a set of data and how we are going to do data cleaning. Third, the system architecture should be suitable for the public health system that we are working on. Fourth, how often we should collect the data and have data updated. Fifth, we should design an effective report and who is using the report that is generated. Sixth, we need to design the right to gain access to the web-database, and how many user groups. Finally, it is a public health system, so security is very important. Therefore, the system's security should be carefully and properly done.

#### **Why should we use a dashboard decision system?**

The effective use of visual models for sharing qualitative information has been explored both as a general tool and through applications such as in education, public health, and business management [58]. The dashboard is one of the solutions used in a variety of areas to summarise key metrics for managing complex enterprises to help with management and decision-making so that one can see the most salient information at a glance [59-61]. In management information systems, a dashboard is defined as a graphical user interface that organises and presents information in a format that is easy to read and interpret [58]. Essentially, a dashboard is a preset OLAP display and one tool in BI [62]. The idea of dashboards follows the study of decision support systems in the 1970s. Dashboards as we know them today

began appearing in the late 1990s with the surge of the Internet [63]. The dashboard idea has been used in public health for many solutions such as blood management, health care, medical procurement, bioterrorism preparedness, disease management and control, and environmental health [28,45,48,50,52,54,60-61,64-65].

Dashboards allow managers to monitor the contribution of the various departments in their organisation. By gauging exactly how well an organisation is performing overall, they allow you to capture and report specific data points from each department within the organisation, thus providing a "snapshot" of performance. Dashboards display critical information in a form that will allow rapid decisions, reduced costs, and better confidence [48]. Benefits of using dashboards include:

1. Visual presentation of performance measures.
2. Ability to identify and correct negative trends, generate detailed reports showing new trends and make more informed decisions based on collected business intelligence.
3. Measurement of efficiencies and inefficiencies.
4. Alignment of strategies and organisational goals.
5. Time saving over running multiple reports.
6. Achievement of total visibility of all systems instantly.

Users generally have different dashboard requirements. There are three main types of users using the dashboard decision system (**Table 2**) [66]:

**Table 2** Three main dashboard types, application, user types, scope, update interval, advantage and disadvantages of each dash board type.

Dashboard Type	Application	User types	Scope	Update Interval	Advantage	Disadvantage
<b>Operational</b>	monitor systems or line-level KPIs	Line workers	Individual	Real time for active monitoring	Alert in real-time or near time	More information requires more time to read or understand Unanalysed information
<b>Tactical</b>	Review Progress	Supervisors	Team/department	Daily/Weekly	Spend only a small amount of time because it is a specific individual or role information Provide a distinct set of information that is easy to read	Unable to support comparison information in long time period analysis
<b>Strategic</b>	Measure performance	Executives and managers	Enterprise	Monthly/Quarterly	Information shown in a glance Only use a small time to read and understand	Summary information cannot viewed in detail or must use drill down to show detail

1. Operational dashboards. These tools are used by line workers to monitor systems or line-level KPIs. For example, a line worker monitoring how much product has been shipped from a warehouse in the past hour, may only want to be alerted visually when the deliveries fall below a threshold or when enough products are available to deliver a shipment. It may require real-time or event-driven data. The data may be streamed to the dashboard in real time for active monitoring or data is delivered only when an event or threshold is passed.

2. Tactical dashboards. These tools are usually authored and maintained by IT staff, and may have direct involvement or collaboration of business/power users. Any user, such as a sales or insurance agent or a bond portfolio manager, requires a distinct set of information to do his or her job. Sales agents at an electronics store need to know how many TVs they need to sell this week in order to hit their target for the month. Users will likely spend only a small amount of time with this tool, so information must be highly personalised to the specific individual or role.

3. Strategic dashboards. These tools are usually authored and maintained by the BI team.

They are built for executives and managers who want insight into how their business is performing. For example, regional sales managers want to know at a glance how their team are tracking toward their targets for the quarter. KPIs quickly show who is on track and who is likely to miss the target. It may require integration with performance management and balanced Scorecard methodology to provide top-down and bottom-up understanding of the business. Executives are busy and often on the go, and may want to take dashboards offline to review on the airplane or when otherwise not connected.

#### How to develop a good dashboard?

Like a car's dashboard (or control panel), a software dashboard provides decision makers with the input necessary to "drive" the business. Thus, a graphical user interface may be designed to display summaries, graphics (e.g., bar charts, pie charts, bullet graphs, "sparklines," etc.), and gauges (with colours similar to traffic lights) in a portal-like framework to highlight important information [65]. Dashboards may be laid out to track the flows inherent in the business processes that they monitor. Graphically, users may see the high-level

processes and then drill down into low level data [67]. Specialised dashboards may track all corporate functions. Examples include human resources, recruiting, sales, operations, security, information technology, project management, customer relationship management and many more departmental dashboards. Dashboard projects involve business units as the driver and the information technology department as the enabler.

Dashboards provide distinct and powerful means to communicate information with specific benefits, but they also pose a specific set of design challenges [68]. The information shown in dashboard is presented visually as a combination of text and graphics. As such, the design challenges are largely challenges of visual design. The process of actually implementing a dashboard may involve any number of technical challenges associated with software, data, and computing environment, but the fundamental design challenges are visual in nature. To design dashboards effectively, you must understand visual perception such as what works, what does not, and why. Dashboards include the most important information one must know to achieve specific objectives. To achieve even a single objective often requires a collection of information that is not otherwise related, information that comes from diverse sources and is related to different business functions. The information is of whatever type needed to do a job. Dashboard displays are not just

for executives and managers but they are for anyone who has objectives to meet.

The success of dashboard projects often depends on the metrics that are chosen for monitoring [24]. Key performance indicators, balanced scorecards, and sales performance figures are some of the content appropriate on dashboards [69]. To design dashboards effectively, we need to consider the following requirements [70]:

- Support different metric sets for different goals and context-specific help.
- Enable organisation and project level displays, hyperlinks that display tabular formats of the underlying data and hyperlinks to view or “drill down” hierarchically to more detailed data.
- Define points-of-contact that identify persons responsible for feedback and follow-up, data trends and the date through which the data are current and lower and upper control limits and hyperlinks for displaying outliers.
- Utilise different types of displays or gauges for different types of data.
- Highlight overall metric status using red, yellow, green or similar indicators.

Three main types of dashboard dominate the market today (**Table 3**):

1. Stand-alone software applications.
2. Web-Browser based applications.
3. Desktop applications also known as desktop widgets which are driven by a widget engine.

**Table 3** Three main types of dashboard decision system dominating the market today.

Dashboard Type	Advantage	Disadvantage
<b>Stand-alone software application</b>	Spend less time to access and read the information	Cannot connect via network or Internet
<b>Web-browser based application</b>	Easy to access and manage via the Internet	Have a technical limitation depending on the web-technology
<b>Desktop widgets</b>	Can share and exchange information via network	Cannot connect via the Internet The access time depends on a network size

Most dashboards are displayed in a web-browser because it is easy to use and can be provided via the Internet. The information in the dashboard can be updated in real time or

periodically (depending on the objective it serves). For example, for monitoring air traffic using a dashboard, you must be informed immediately when something is wrong and you should be able

to refresh information in real time. On the other hand, if you are making strategic decisions about how to boost sales, a snapshot of information as of last night or perhaps even as of the end of last month would work fine.

In almost all cases, dashboards primarily display quantitative measures of what is going on (in the business, in the market, in the project, on the shop floor, and so on). These measures are displayed either by themselves or in combination with related measures. Measures of what is happening come in different forms depending on what they measure (sales, productivity, customer satisfaction) and how they measure it (sales in dollars, sales in units, average delivery time). Measures of what is happening are often compared to related measures to enhance their meaning with evaluative context. Here are the most common comparative measures and an example of each in brackets [68]:

1. The same measure at the same point in time in the past (the same day last year).
2. The same measure at some other point in time in the past (the end of last year).
3. The current target for the measure (a budget for the current period).
4. Relationship to a future target (we are at 75 % of this year's budget).
5. A prior prediction of the measure (a forecast of where we expected to be today).
6. Relationship to a future prediction of the measure (we are already at 90 % of this quarter's forecast).
7. A measure of the norm for this measure (monthly average or normal range).
8. An extrapolation of the current measure in the form of a probable future, either at a specific point in the future or as a time series (forecast as of the coming year end).
9. Competitors' versions of the same measure (either individual or multiple measures in a time series; our top competitors' year-to-date revenues)
10. A separate but related measure (revenue compared to profit).

Measures of what's currently going on may be displayed either as a single measure combined with one or more comparative measures, as in the examples above, or as:

- Multiple instances of a measure, each representing a subdivision of the measure into separate categories (for example, sales subdivided

into regions or a count of sales subdivided into numeric ranges in the form of a frequency distribution).

- Temporal instances of a measure (that is, a time series, such as monthly versions of the measure).

Time series in particular provides context for a richer understanding of what is going on and how well it is going. Because a dashboard of data must be evaluated quickly, it is often useful to directly declare whether something is good or bad. Evaluative information likes this may be encoded in a dashboard as special visual objects (e.g. traffic lights) or visual attributes (e.g. displaying the measure in red to indicate a serious condition). When designed properly, simple visual indicators can clearly alert users to the state of particular measures without altering the overall design of the dashboard. Evaluative indicators need not be limited to binary distinctions between good and bad, but if they exceed the limit of five distinct states (e.g. very bad, bad, acceptable, good, and very good), they run the risk of too much complexity for efficient perception.

The process of developing the dashboard begins with the identification of characteristics which are important for state policy makers to measure. These include cost, access, infrastructure, quality and public health. Examples of the following characteristics draw attention to the critical questions facing the delivery of public healthcare [71]:

1. Cost: What does it cost to provide healthcare to the organisation and how is it changing?
2. Access: Does the current healthcare system provide 'appropriate' access to services?
3. Infrastructure: Is the healthcare system 'right-sized?' Does the supply of healthcare support an efficient healthcare system?
4. Quality: Does the healthcare system provide high quality/efficient care?
5. Public Health: How is the health and well-being of the organisation?

The dashboard indicators answer specific questions on the status of the healthcare system. There are four indicators for each of the five major characteristics chosen because they provide important information about each of the major characteristics. For example, private insurance premiums are an important indicator of healthcare costs. Because these indicators also come from



nationally recognised sources, are updated frequently, and are fully vetted, the indicators are appropriate for the dashboard model.

To create an aggregate score across all measures, relative scores for each indicator are averaged across major content areas, and the mean of the content area average scores produces a total score. These results should be a source of concern for policy makers, as they suggest that the state's relatively high cost of healthcare and high quality care is not necessarily translating into a healthy population, or one with high access to care.

### **Dashboard in public health**

Dashboards have been used to deliver BI solutions to end users. The knowledge acquired through this process can be used to adjust or change current behaviour, empower them to make more informed business decisions, and to help the organisation move towards optimal processes or goals. In the field of healthcare, dashboards can be used to diagnose problem areas and drive management or volunteer interventions related to just about any hospital activity [61]. A tool set, known as a Clinical Dashboard, is being developed to help clinicians capture and present the information they need to inform daily decisions that improve quality of patient care. Good quality information is essential to help clinicians with real-time problem solving and ensure that the right services and best possible care are provided to patients. The clinical dashboard will contain locally defined clinical indicators, which can help improve a clinical team's ability to focus on improving the quality of care with immediate effect [40]. Many systems in public health that are developed using dashboard are shown in the **Table 1**. There is keen interest in performance management systems that include high level performance indicators across national and international health systems. This interest derives from a wide range of motivations including [72]:

- stronger governance.
- better accountability.
- improved community understanding of health systems.
- enhanced consumer influence within health systems.

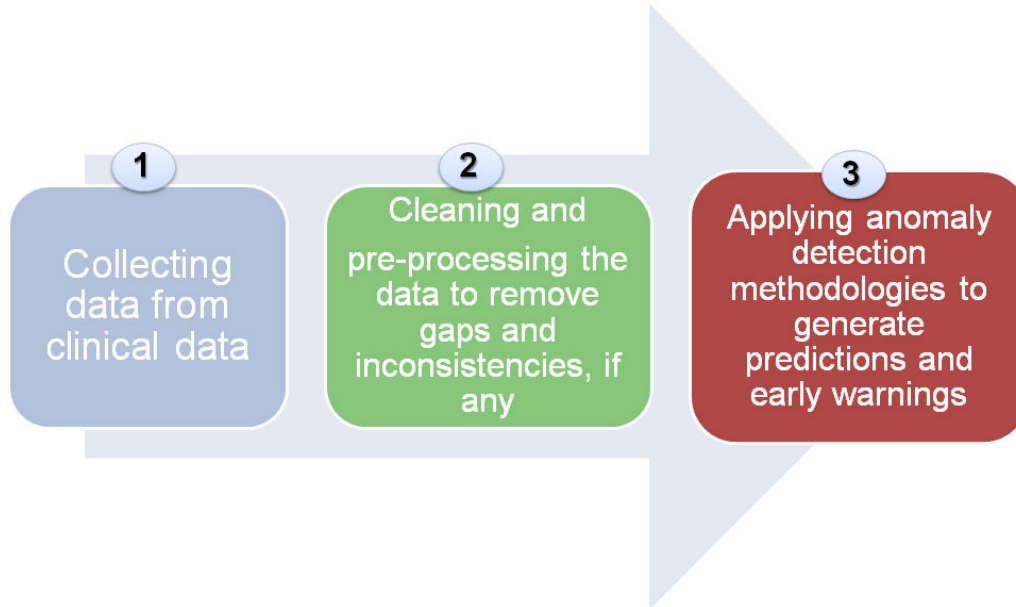
- promotion of competition between providers and services.

- service quality improvement.

The key criterion within the information environment when applying computers to support public health preparedness is not so much infrastructure, commercial products, third party tools, or even existing public health practice as an understanding of component integration, or rather the components that can be built within a standard based environment for vocabularies and communications. This will increase interoperability between information systems thereby reducing time to process and analyse data for decision support [50].

Key performance indicators may include dashboards giving information on public health status, benchmarking home healthcare, or comparing hospitals, hospital and department-level progress and activity, patient status and more [61]. The current measuring and reporting mechanisms across the health system are diverse, with a range of indicators used at departmental, area health service and facility/service levels [72]. Key performance indicators should reflect the priorities and strategic direction of the system effectively creating a management dashboard for health. Using the term dashboard to describe a high-level set of indicators is supported as a dashboard provides an overview of performance and acts as an early warning sign on areas where performance needs to be improved or policy requires review or development.

Public health usually uses dashboards for surveillance and activity monitoring in environmental and public health domain that often involves (**Figure 2**) firstly collecting data from clinical data (patient records, billing information, lab results, etc.) as well as both hardware and/or software sensors which generate multi-model multi-scale spatio-temporal data. Secondly, cleaning and pre-processing the data to remove gaps and inconsistencies, if any, and finally applying anomaly detection methodologies to generate predictions and early warnings. Predictions are often based on the environmental and public health threat models [51].



**Figure 2** Three steps involved in using dashboard for public health.

### Conclusion

Business intelligence (BI) refers to methodologies and technologies for the collection, integration, and analysis of all relevant information in a business for the purpose of better business decision-making. Four steps involved in BI include integration, storage, analysis and presentation. Many tools are used in each BI step such as DSS, EIS, ETL, Data warehouse, and dashboard. Dashboard is a tool used in the presentation step involved in BI. Dashboards are used in a variety of situations to help with management and decision-making. They may help manage people or processes to steer the user in the right direction. One dashboard that all drivers are familiar with is a car dashboard. The success of dashboard projects often depends on the metrics that are chosen for monitoring so key performance indicators, balanced scorecards, and sales performance figures are some of the content appropriate on dashboards.

Public healthcare service usually collects great volumes of data. Quality information helps to identify and prioritise problems, to develop and evaluate policies and actions, and to organise clinical health service delivery. To achieve these objectives, BI is used as a tool to develop a system for efficient and effective decision-making in

public health. Many fields in public health, such as blood management, medical procurement, bioterrorism preparedness, disease management and control, and environmental health, use BI tools to develop the system and dashboards to deliver information to end users. There are three main types of dashboard on the market today. The web-browser based is the most popular because it as an effective tool, easy to access and can be managed anytime and anywhere. BI has made significant contributions to the cost-effective development of the public health system.

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