Requirements specification for a quality dashboard for exploring National Clinical Audit data

Version 1.1 Prepared by the QualDash Team

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Revision History

Name	Date	Reason For Changes	Version
Requirements specification for a quality dashboard for exploring National Clinical Audit data	Jan 2019	Amendments based on Lay Advisory Group feedback	1.1

1. Introduction

QualDash is a project that aims to develop and evaluate a web-based quality dashboard that supports users' exploration of National Clinical Audit (NCA) data, by offering individualisation, visualisation and interaction techniques, with the overall aim of improving quality of care and clinical outcomes.

The aim of this document is to specify the functional requirements for a quality dashboard for exploring NCA data i.e. what such a dashboard should do and enable others to do with NCA data. These requirements were identified from interviews with a range of stakeholders including clinical teams, quality and safety (Q&S) committees, NHS Trust boards, and Clinical Commissioning Groups (CCGs) and from a workshop held with audit suppliers, see **Appendix B** for further details about study methods. In publishing this requirements specification, our intention is to provide a resource that is useful for NCAs that are looking to develop their own quality dashboard.

A glossary of the terms used in this document can be accessed in **Appendix A**.

1.1 How functional requirements are presented and illustrated in this document

Based on the data analysis from the interviews and the supplier workshop, we identified that a quality dashboard will need to offer functionality to support 7 main user goals i.e. what users want/need to accomplish using the quality dashboard. These goals are as follows:

G1: Manage user account e.g. functions that let users log in and out of the system;

G2: Manage user profile e.g. functions that let users customise the main screen of the dashboard to their needs;

G3: Visualise data e.g. functions that enable users to display information in the form of charts or graphs;

G4: Interaction and root cause analysis e.g. functions that enable users to change and/or explore the visualisations e.g. by adding or removing variables;

G5: Reporting e.g. functions that allow users to generate and export reports;

G6: Notification e.g. functions that alert users to certain information;

G7: Data quality monitoring e.g. functions that allow users to see the accuracy and completeness of the data;

G8: System navigation and control e.g. functions that facilitate navigation through the dashboard.

Section 2 of this document describes some user goals, with the help of use cases. Use cases describe (1) what the user wishes to achieve (intention in context), (2) example actions that could be taken by a user to achieve the intended task, and (3) variables that the user can specify to achieve the intended task. For example, if a user wants to access the software, they will need to be able to do the following tasks - log in, log out and they may also want to change their password. Suggested techniques are also briefly listed for each use case to inform design decisions and the final list of functional requirements for a quality dashboard.

Section 3 provides details of the potential users of a quality dashboard known as ‘user classes’, for example the clinical leads of a service, usually a consultant. Section 3.2 provides examples of how these individuals and groups might use a quality dashboard in practice in the form of ‘scenarios’. Each scenario weaves together a set of use cases (actions) to tell a story of what the user could do. For example, a consultant may monitor the number of falls on their ward quarterly using NCA data. Using the dashboard for this purpose, they would complete the following tasks (1) log into the system, (2) generate a bar chart depicting the number of falls per month. If they observe an increase in incidents of falls in one month, they may want to perform further tasks such as generate a visualisition to show the case mix or age of the patients in that month to understand why the number of incidents increased in that month. The scenarios highlight the tasks used to

accomplish the activity and reference the functional requirements that support the scenario.

Section 4 provides a list of the functional requirements (referenced in section 3) that a quality dashboard should support, based around user goals G3 (visualise data), G4 (interaction and root cause analysis), and G8 (system navigation and control). These requirements are cross referenced with the scenarios in section 3 to clarify which actions a requirement can support.

Section 5 describes all other nonfunctional requirements i.e. requirements that are important but not part of the quality dashboard technology, such as the quality (accuracy and completeness) of the NCA data.

2. Product Goals and Use Cases

2.1.1 G1: Manage User Account

- **Intention in context**: user intends to provide credentials to access the software
- **Scope**: affects what audit data is loaded in the main screen
- **Main actions**:
    - Login
    - Logout
    - Change password

2.1.2 G2: Manage User Profile

- **Intention in context**: user intends to set/ retrieve default preferences to:
    - View two main key performance metrics (KPMs) agreed upon between the analysis team and the end users of a particular audit
    - Specify up to three additional KPMs that users can access with quick links from their home screen
- **Scope**: affects the number of visualisations and the types of metrics loaded into the main screen
- **Main actions**:
    - Select audit
    - Add metric
    - Remove metric

2.1.3 G3: Visualise Data

- **Intention in context**: user intends to view visualisations to monitor metrics of care quality
- **Scope**: main purpose of the dashboard

- **Main actions**:

  From the supplier workshop and interviews, several user task categories were found; for detailed task analysis, **see BELIV manuscript**

  Broadly speaking, user tasks are questions that users wish to answer via observing visualisations. Given the diversity of the tasks of interest to different users in different audits, we took a taxonomical approach to classify and group tasks that would lead to similar visualisation requirements.

  This grouping is three-dimensional so it considers:

  1. The number of variables involved in a task and data type of each (the type cardinality dimension)
  2. Whether a task requires aggregate level or patient-level data (the granularity dimension)
  3. The type of information users are seeking when observing a visualisation to answer the question (the information target dimension).

  The following table summarises different task categories as populated in data collected from the suppliers' workshop and from interviews with users of the Paediatric Intensive Care Audit Network (PICANet), see **Appendix B** for further details about the interviews and workshop. To reduce the number of categories, task categories involving more than two variables are typically mapped to their two-variable basis (see Figure 7 in **BELIV manuscript**). We include here three-variable categories that did not match any two-variable basis.

  Notation:

  - A number and a letter are used to denote a variable count and type combination. For example (1q, 1n) means a task category includes one quantitative and one nominal variable.
  - **q:** quantitative, **n:** nominal, **o:** ordinal, **t:** temporal
  - The bullets under each category in the table list the different targets.
  - Numbers in the table show how many tasks fall within each category.

- X's display the existence of a specific target in the tasks within a category.

Table 1 Two Variable Tasks

Task category	Workshop	PICANet
(1q, 1t) aggregate	**13**	**30**
• Specific value	X	X
• Proportion	X	X
• Trend	X	X
• Frequency		X
• Outlier		
• Cluster		
• Data object		
• Distribution		
• Association		
(1q, 1t) individual	**4**	**0**
• Specific value		
• Proportion		
• Trend		
• Frequency		
• Outlier		
• Cluster	X	
• Data object		
• Distribution		
• Association		
(1q, 1n) aggregate	**9**	**12**
• Specific value	X	X
• Proportion	X	X
• Trend		
• Frequency		
• Outlier	X	
• Cluster		
• Data object		

• Distribution • Association		X X
(1q, 1n) individual • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**4** X	**0**
(2q) individual • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**0**	**1** X
(1q, 1o) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution	**3** X X X	**0**

• Association		
(1q, 2n) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**7** X X X X X	**10** X X X X
(1q, 2n) individual • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**0**	**3** X
(1q, 1n, 1t) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution	**2** X X X	**2** X X

• Association		
(1q, 1n, 1o) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**0**	**1** X
(1q, 1n, 1o) individual • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**3** X X X X	**0**
(2q, 1n) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object	**0**	**1** X

• Distribution • Association		X
(2q, 1t) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**0**	**1** X X
(2n, 1t) aggregate • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**0**	**1** X
(2Q, 1N, 1O) • Specific value • Proportion • Trend • Frequency • Outlier • Cluster	**2** X	**0**

• Data object • Distribution • Association	X	
(2Q, 2N, 1O) • Specific value • Proportion • Trend • Frequency • Outlier • Cluster • Data object • Distribution • Association	**1** X	**0**
Comparison Tasks	Regional	Units with similar resources

2.1.3.1 Two-variable Use Cases

PICANet*:* 42 of the 69 tasks collected for PICANet involved only two variables. Of these, 30 involved observing a quantitative variable over time, 11 were to observe a quantitative variable grouped by a nominal, and one was to observe two quantitative variables together. All 42 tasks dealt with aggregate-level data (no patient-level data was required).

WORKSHOP: The workshop tasks fell within the same three categories, in addition to one more category that involved a quantitative variable and an ordinal variable. Furthermore, the workshop tasks exhibited slightly more diversity in granularity. More individual-level tasks came up.

We develop here use cases for the three main task categories that appeared in both PICANet interviews and the workshop activity.

2.1.3.1.1 Use case 1: Monitor a quantity over time

- Intention in context: user wishes to monitor the progression of a certain quantity over time.
- Example tasks:
    - What is the complication / success rate on a monthly basis?
    - What is the seasonal variation in the number of deaths?
- Metrics (quantities):
    - Death / Standard Mortality Ratio
    - Refusals
    - Demand (Admission count)
    - Re-admission within 48 hours
    - Accidental extubations
    - Discharges
    - Intubation
    - Infection
    - Bed occupancy
    - Ventilation days
    - Activity
- Information targets: trends and frequencies, proportions, specific values
- Suggested visualisations: bar chart, line chart, area chart.
- Suggested interactions:
    - Change quantity
    - Modify time scale
    - Add categorical grouping
    - Select value range
    - Export selection to a new visualization

2.1.3.1.2 Use case 2: Monitor a quantity grouped by a nominal

- Intention in context: user wishes to monitor a value distribution over several categories
- Example Tasks:
    - Is a patient group with specific gender and ethnicity more likely to die?
    - Who was responsible for discharging patients with re-admission? *(a higher-dimensionality task with three variables (1q, 2n) at patient granularity)*
- (Metric, category) pairs:
    - Length of stay, diagnosis
    - Demand, premature
    - Staffing level, unit
    - Medical infrastructure, unit
    - Ventilated cases, unit
    - Complication count, complication type
    - Days intubated, unit
    - Length of stay, unit
    - Re-admitted patient count, physician name
- Information targets: specific values, proportion, distribution, association
- Suggested visualisations: pie chart, bar chart, heatmap
- Suggested interactions:
    - Change quantity (measure)
    - Change categorical
    - Add categorical
    - Select category
    - Export selection to a new visualisation

2.1.3.1.3 Use case 3: Monitor two quantitative variables

Example tasks:

- How does the trend in number of admissions (e.g. reduction) affect the nurse staffing?
- Compare the number of bed days for patients with their midnight returns *(patient level)*

Measures pairs:

- (number of admissions, nurse staffing)
- (number of bed days, midnight returns)

Information target: association

Suggested visualisations: scatter plot

Suggested interactions:

- Change measure
- Add categorical
- Select value range
- Export selection to a new visualisation

2.1.3.2 Three-variable Use Cases:

PICANet: 21 PICANet tasks involved three variables. Of these,

- 13 tasks included one quantitative and 2 nominals (1q, 2n).
- Two tasks included 1 quantitative, 1 nominal and 1 temporal (1q, 1n, 1t).
- One task included 1 quantitative, 1 nominal and 1 ordinal (1q, 1n, 1o).
- One task included 2 quantitative and 1 nominal (2q, 1n).
- Two tasks included either 2 quantitative over time (2q, 1t) or 2 nominals over time (2n, 1t).

WORKSHOP: The majority of three-variable tasks collected in the workshop activity required monitoring a quantitative variable grouped by two nominals (1q, 2n). One new category appeared in the workshop which is the individual-level tasks involving (1q, 1n, 1o). Three such tasks exist in the workshop data.

Some of the collected three-variable cases can be traced back to their base cases (2-variable cases) as follows (for details of this mapping see figure 7 in **BELIV paper**):

- ✓ (1q, 2n) --> (1q, 1n) [***Use case 2: Monitor a quantity grouped by a nominal***]
- ✓ (1q, 1n, 1t) --> (1q, 1t) [***Use case 1: Monitor a quantity over time***]
- ✓ (2q, 1n) --> (2q) [***Use case 3: Monitor two quantitative variables***]
- ✓ (2q, 1t) --> (2q) [***Use case 3: Monitor two quantitative variables***]
- ✓ (1q, 1n, 1o) --> (1q, 1n) [***Use case 2: Monitor a quantity grouped by a nominal***]
- ✓ **(2n, 1t)**

We develop a use case for the last one since we could not trace it to an existing use case.

2.1.3.2.1 Use Case 4: Monitor 2 categories over time

- Intention in context: users wish to track data categories and sub-categories over time.
- Example tasks:
  - What time of night or day were patients with re-admissions discharged? (patient-level)
- Category, sub-category, time> tuples:
  - Patients, re-admitted patients, discharge time
- Information targets: distribution
- Suggested visualisations: grouped bar chart, area chart
- Suggested interactions:
  - Change categorical
  - Add categorical
  - Select time range
  - Export selection to a new visualisation

2.1.3.3 Higher level tasks:

We list below some PICANet tasks that could potentially involve higher level inference. More information is needed about these tasks in order to classify them using our three-dimensional task space.

Understanding risk-adjusted SMR for children with varying degrees of risk
Compare units that have similar resources
Identify genuine inadvertent extubations
Identify risk factors and avoidable factors for inadvertent extubations
What is the pattern in cardiac activity of patients?
What is the pattern of success rate for patients?
What is the pattern of established feeding for patients?
In a given geographical area, what variables exhibit interesting patterns?

2.1.4 G4: Interaction and Root Cause Analysis

- Intention in context: user wishes to create more screen space to allow further exploration and root cause analysis
- Scope: affects the way visualisations are laid out for reporting purposes.
- Main actions:
    - Overlay comparators and benchmarks
    - Add/Remove visualisation
    - Edit existing visualisation
        - Change variables
        - Add more variables
        - Change visual encoding of a variable

Interaction Use Cases:

To match the actions above, we develop the following use cases:

2.1.4.1 Use Case 5: Comparators and benchmarks

- Intention in context: users wish to compare their unit's performance with that of other units or with national averages and benchmarks.
- Background:

  92% of responses in the visualisation activity of the suppliers' workshop were positive toward requiring the quality dashboard to enable users to compare their units' performance against national averages or benchmarks. Interviews with PICANet experts further revealed the need to be selective in the comparison. This selectiveness is motivated by their need to compare against specific units that have similar resources and are expected to receive a similar case mix.
- Example tasks:
  - Does the rate of mortality/ morbidity vary with trends at the regional or national level?
  - Do organisational factors like size or configuration play a part in rates of morbidity or mortality?

- Suggested interactions:
  - Edit comparison settings: to enable users to select what to compare against
  - Show/ hide comparators: to enable users to toggle between single unit view and comparators view.

2.1.4.2 Use Case 6: Add/ remove chart(s)

- Intention in context: users wish to be selective on the visualisations that are displayed in the quality dashboard to make the best use of their screen space.
- Background:

  One of the top 3 interaction requirements, as prioritised by the workshop participants, is to enable users of the quality dashboard to control what is being displayed on the screen.

- Suggested interactions:
    - Create a new chart
    - Delete existing chart
    - Show/ hide chart

2.1.4.3 Use Case 7: Axis controls

- Intention in context: users wish to control what variables are being displayed on each axis within a chart and to control the scale of each axis, which in turn defines how data values are binned and mapped to the different ticks along each axis.
- Background:

  One of the interaction requirements that were found essential by the majority of the workshop participants is to enable users to select time periods and select patients whose data is being displayed.
- Suggested interactions:
    - Modify scale / binning
    - Modify variable mapping

2.1.4.4 Use Case 8: Add/ remove variable(s)

- Intention in context: users wish to add/ remove variables to/from an existing chart.
- Background:

  As described in sections 2.2.1 and 2.2.2, the vast majority of tasks users wish to perform include only two or three variables. In order to support users' transition between two- and three-variable tasks, a quality dashboard should offer functionality to add and remove variables to existing charts. In cases where users wish to include more than three variables, a quality dashboard should create a trellis to accommodate more variables. This is based on the feedback from workshop participants who stressed that no more than three variables should be displayed in the same chart, in order to cater for users with varying levels of graph literacy.

- Suggested interactions:
    - Add new variable
    - Select variable encoding
    - Remove variable

2.1.4.5 Use Case 9: Modify visual encoding

- Intention in context: user wish to modify the mapping between data components and visual components in an existing visualisation.
- Background:

    In order to support a flexible workflow while making efficient use of screen space, a design consideration here is to avoid requiring users to create a new chart every time they wish to modify their query. Therefore, a quality dashboard should enable users to edit the visual encodings that already exist in displayed visualisations.
- Suggested interactions:
    - Select visual encoding (e.g. color, shape, size).

2.1.5 G5: Reporting

- Intention in context: Users wish to export visualisations for reporting and presentation purposes
- Scope: affects the quality of product outcomes.
- Main actions:

Table 2 Reporting Actions

Functionality	Supporting Claims
F6.1: Layout different charts for comparison	• Participants want NCA data to be presented in ways they can relate clearly to their own roles and to their units/Trusts, as when suppliers provide individualised reports for users: '*You want it specific to you so that you can then use that for whatever it is that you need or even just in your appraisal or department… and say: this is what we're achieving*' (Site 2, Patient Service Manager) • British Cardiovascular Intervention Society, for example, provides slides individualised to each Trust, while other audits make it easy for users to access their own data or request custom reports (Site 2, Cardiologist)
F6.2: Add / hide charts	• Several participants in corporate roles, whose jobs involve extracting information from different NCA reports, pointed out that the diverse presentational formats of reports made it difficult to find relevant information quickly
F6.3: Export visualisations	[Prioritised in workshop]
F6.4: Save / edit report	[Prioritised in workshop]

2.1.6 G6: Notification

- Intention in context: Users wish to receive notifications from the quality dashboard, which are triggered by user-defined events.
- Scope: affects the quality of product outcomes
- Main actions:
    - Define an event
    - Receive notification upon event trigger

2.1.7 G7: Data Quality Monitoring

- Intention in context: Users wish to stay informed on data completeness and validation status
- Scope: affects users' understanding of visualised data.
- Main actions:
    - Summarise missing data
    - Summarise validation status

2.1.8 G*: System Navigation and Control

Links to above functionalities to facilitate navigation through the system.

3. User Classes and Scenarios

3.1 User Classes

The user classes in the table below were identified in analysis of interview data, see **Appendix B** for further details about the interviews.

Table 3: User Classes

Class	*Professional Role*	*Potential use of Quality Dashboard*	*Frequency*
Clinical Lead	*Consultant /Nurse*	*Clinical governance meetings / morbidity and mortality meetings / routine monitoring of certain metrics/ summary of annual report*	*Monthly (depending on site)*

Class	***Professional Role***	***Potential use of Quality Dashboard***	***Frequency***
Registrars	*Junior Doctors*	*Data exploration/analysis for projects for professional development*	*At least once in a rotation*
Data Collection and Management	*Audit Coordinator, Data Base Managers, Data Collection Clerks – mixture of nurses, registrars, and non-clinical staff*	*Answer queries re. patients by clinical staff, check quality of data*	*Collate data to answer queries as needed (weekly/monthly), data collection occurs daily*
Divisional level management	*Divisional Quality and Safety Lead / Child Health Directorate - Non-medical background /Nurses*	*Monitor performance of division*	*Interaction with NCA data limited by specialty (quality markers of interest) / need for NCA data in role*
Trust Information Managers	*Manage data for multiple audits – typically non-medical background*	*Check quality of data and produce data reports for meetings and committees. Receive notifications when annual report is published*	*Interaction with NCA data limited to specific time points e.g. when annual report published*
Quality and Safety Committee	*Quality Governance Manager, Clinical Effectiveness Lead*	*Monitor and manage service performance / provide assurance of quality and safety*	*Interaction with NCA data limited. Depends on meeting agenda, Trust priorities, and*

Class	*Professional Role*	*Potential use of Quality Dashboard*	*Frequency*
			specific instances where 'red flag' problems have been escalated, may also engage with NCA data where examples of good practice are highlighted

3.2 User Scenarios

3.2.1 User Scenario 1: Accidental Extubation

Primary actor: PICANet clinical lead

- Looking at accidental extubation per month [**Use case 1: Monitor a quantity over time**]
- The expert sees on a bar chart that there is a spike in March [**FR 1 Display bar chart**]
- She observes the details of every month (in this case the numbers underlying each bar) and sees that there were 2 extubations in January, 2 in February and 8 in March [**FR 20 Details**]
- She modifies the time axis to zoom in on the details of March [Use Case 7: Axis controls] [**FR 12 Modify scale**].
- She begins to stratify the patients' case mix that were admitted during this month [**Use Case 8: Add/ remove variable(s)**] [**FR 15 Add**].
- She performs a root cause analysis of what happened [**FR 18 Screen space for analysis**]. She looks at:

- Where these patients were coming from [**FR 8 Add new chart, FR 1 Display bar chart**]
- The case mix [**FR 1 Display bar chart**], in which she may observe:
  - Scenario 1: they had admitted four general patients and four cardiac patients in March **[FR 20 Details**], which had not appeared in earlier months.
    - She may want to look into risk factors for the cardiac patient cohort [**FR 19 New brush, FR 20 Details**]
    - She may observe staffing data and note if they'd had any recent changes in the cardiac service staffing [**FR 1 Display bar chart**] (***Note****: staffing data may not be available in PICANET*).
    - She may notice that a new transport team or a new cohort of nurses had just joined in March, this may for instance be visible on a bar chart that displays number of nurses appointed on a monthly basis [**FR 1 Display bar chart**].
    - She may then decide that a new educational package needs to go out (intervention).
  - Scenario 2: a larger than usual number of cases with pneumonia were admitted in March which resulted in respiratory deterioration
    - She may want to view national data on pneumonia to see where they stand **[FR 7 Show/hide comparators/benchmark**]
    - She may want to ring one of the comparable sites and ask what they are doing about it to come up with a plan for quality improvement (intervention).

3.2.2 User Scenario 2: High Mortality and Poor Data Quality

Primary actor: PICANet clinical lead

- Looking at SMR on a time continuum (as a line chart with time on the x-axis), she sees a spike and notices that her unit's curve is approaching the "dodgy area" (the upper limit of the normal range of SMR). [**Use case 1: Monitor a quantity over time**] [**FR 2 Display line chart**].
- She decides to drill down on the details around the time when the spike happened [**FR 19 New brush**] [**FR 18 Screen space for analysis**].
- Looking at diagnosis (part of case mix) and blood gas reading (part of severity index) to see if there are any unusual patterns [**FR 8 Add new chart, FR 1 Display bar chart**].
    - She checks to see that diagnosis has to be entered as a medical not a surgical one. [**FR 20 Details**]
    - She checks to see that comorbidity boxes follow a code (e.g. down syndrome has certain financial burdens on the PICU and is coded accordingly) [**FR 20 Details**].
    - She finds that blood gas reading levels were different from normal in that month [**FR 20 Details**].
    - Now she wants to find out why this is the case.
        - She views staffing data and realises that a new transport team was just appointed and that this new team has been recording the wrong blood gas reading values [**FR 1 Display bar chart**] [**FR 8 Add new chart**] [**FR 17 Change encoding**].
        - Once the readings are fixed, the severity index becomes higher and the risk-adjusted SMR falls back within normal range [**FR 1 Display bar chart**].
        - She makes some decisions for future data entry to prevent this from happening again: reinforces matching discharge summary with PICANet forms (on a per form basis) to detect early on these types of mistakes (intervention).

3.2.3 User Scenario 3: Benchmarking

Primary actor: PICANet clinical lead

- User manages settings to set the following comparison criteria [**FR 6 Change comparison settings**]:
    - She is not interested in seeing data from all units because it would be like comparing apples and oranges.
    - She is also not interested in geographic location (*N.B. this is in contrast to data that was collected in the suppliers workshop, as the suppliers repeatedly mentioned regional comparison*)
    - She wants to see the units that are most similar to her unit in terms of case mix and resources [**FR 5 Display scatter plot**] [**FR 15 Add**].
    - She wants to prioritse those units that are performing well to compare her unit to the best [**FR 7 Show/hide comparators/benchmark**].

- She looks at a monthly view of her unit's SMR / risk-adjusted SMR / accidental extubations / re-admissions; and looks at other units and sees that her unit is about to hit the upper limit of the normal range [**FR 2 Display line chart**] [**FR 1 Display bar chart**] [**FR 7 Show/hide comparators/benchmark**].
- Maybe she received a popup message to alert her that that specific metric is about to get out of normal range) or that some of the other units are consistently lower than her unit.

- The units that she selects:
    - Don't have cardiac because her unit doesn't have cardiac (service type)
    - Have a lot of spinal, new surgery, and neurology cases (case mix)
    - Have had admissions with similar severity of illness as her unit's patients (case mix)
    - Have a similar demand / bed occupancy (size) – mentioned 10 units in the UK that have cardiac and have a very high demand. Explained that looking

at the number of admissions alone is not enough to determine demand. The case mix is very important to go along with it.
    - Have a similar financial situation (resources)
    - Have staff with similar academic level (human resources)
- Comparing to those units, she overviews:
    - Length of stay --> looks for trends and outliers (outliers can happen if her unit admitted any long term patients that have extended their overall length of stay) [**FR 2 Display line chart**]
    - SMR over time --> looks for details on units consistently having lower SMR than hers [**FR 19 New brush**, **FR 20 Details on demand**]
- Comparing to those units, she drills down to [**FR 18 Screen space for analysis**] [**FR 8 Add new chart**]:
    - Individual parameters and observes variables underneath them [**FR 1 Display bar chart**]
    - Can take a look at **average** central line infection rate for example [**FR 1 Display bar chart**].
    - She looks at this data over time for her unit versus another unit (the one with the lower SMR) [**FR 2 Display line chart**]
    - She needs to decide on an appropriate time frame and time scale for this comparison to make sense [**FR 12 Modify scale**]
    - Maybe she found a spike in central line infection rate in her unit. She goes and investigates that and finds that lines were not being put in properly.
        - She takes a look at resources and finds that they had just changed to a new type of line from a new supplier. The new type is made with cheaper material, which makes it more loose and more prone to infection
        - She decides that they need to switch back to their original supplier (intervention)
    - Maybe she notices that the index of severity (for risk-adjusted mortality) was very low in a specific period of time [**FR 2 Display line chart**][**FR 13 Select x-axis**].

- She looks at staffing and finds that they had just changed to a new transport team that has junior paramedics.
- That resulted in an incorrect recording of blood gas reading levels
- Once the correct blood gas reading levels were entered, the index of severity went up and the risk-adjusted SMR of her unit went low.

3.2.4 User Scenario 4: Benchmarking for quality improvement for STEMI

Primary actor: MINAP clinical lead

- The expert looks at the total number of primaries (i.e. ST-Elevation Myocardial Infarction (STEMI) patients) per month on a bar chart [**FR 1 Display bar chart**]
- He wishes to see the percentage of these patients who have not met the target benchmark of call to balloon time, which should be less than an hour [**FR 15 Add variable**].
- The expert then wishes to see a breakdown of these cases that did not meet the target:
  - He observes where they came from (source) [**FR 15 Add variable**]
  - He wishes to see the distribution/ median/ average of the Call to Balloon (CTB) time for the hospital / district [**FR 8 Add new chart**].

3.3 User Documentation

1. The quality dashboard should be intuitive to use, so that staff can use it straight away with minimal or perhaps no training
2. Training should be provided online e.g. via a webinar
3. Tooltips to help novice users locate different functionalities.

4. Functional requirements

This section lists features that should be available in a quality dashboard and their corresponding functional requirements (FRs) for user goals G3 (visualise data), G4

(interaction and root cause analysis), and G8 (system navigation and control). A priority value out of 10 is given to each requirement.

4.1 Visualise Data

4.3.1 Description and Priority

High priority. Main screen shows charts for the two main KPMs in addition to up to three more specified in the user profile.

4.3.2 Stimulus/Response Sequences

User login.

4.3.3 Functional Requirements

FR 1 Display bar chart

Description	Visualise an aggregate data overview in a bar chart view
Input	Data query includes information on data fields: x and y * if x is quantitative, then a default binning is calculated (user will later be able to change the default) *if x is temporal, the default time scale is monthly aggregates. (user will later be able to change the default)
Output	Scalable Vector Graphics (SVG) rendered
Dependencies	User profile contains a default query, or a user selection specifies a new query
Source	Use case 1: Monitor a quantity over time Use case 2: Monitor a quantity grouped by a nominal
Priority	10/10

FR 2 Display line chart

Description	Visualise temporal data as a line chart
Input	Data query includes information on: * data fields * aggregation/binning variable (if any) * time scale * filters on population (if any)
Output	SVG rendered
Dependencies	User profile contains a default query with a continuous time scale or user selection creates a new query
Source	Use case 1: Monitor a quantity over time
Priority	10/10

FR 3 Display area chart

Description	Visualise temporal data as an area chart
Input	Data query includes information on: * data fields * aggregation/binning variable (if any) * time scale * filters on population (if any)
Output	SVG rendered
Dependencies	User profile contains a default query with a continuous time scale or user selection creates a new query
Source	Use case 1: Monitor a quantity over time
Priority	3/10

FR 4 Display pie chart

Description	Visualise categorical data as a pie chart
Input	Data query includes information on: * data fields * filters on population (if any)
Output	SVG rendered
Dependencies	User profile contains a default metric
Source	Use case 2: Monitor a quantity grouped by a nominal

Priority	3/10

FR 5 Display scatter plot

Description	Visualise two quantitative variables in a scatter view
Input	Data query includes a selection of two quantitative variables
Output	SVG rendered
Dependencies	Two quantitative variables are available in the dataset
Source	Use case 3: Monitor two quantitative variables
Priority	10/10

4.2 Interaction and Root Cause Analysis

4.4.1 Description and Priority

High priority. Users are allowed to modify the contents of existing visualisations and add new ones.

4.4.2 Stimulus/Response Sequences

User is logged in and is viewing either the main screen or a canvas for analysis.

4.4.3 Functional Requirements

Functionality to modify chart contents in different ways (Use cases 5 - 9):

1. *Comparators and benchmarks*
2. *Add/ remove chart(s)*
3. *Axis controls*
4. *Add/ remove variable(s)*
5. *Modify visual encoding*

4.2.1.1 Comparators and Benchmarks

FR 6 Change comparison settings

Description	Allow users to select benchmarks or data specific to similar units for comparison.

	Design alternatives: • Comparators shown in drop-down menu • Comparators shown as draggable elements (to be dragged into a chart) • Comparators shown as check boxes (to be included or excluded)
Input	User selection and external data source
Output	SVG updated
Dependencies	External Database is accessible
Source	Use Case 5: Comparators and benchmarks
Priority	8/10

FR 7 Show/hide comparators/benchmark

Description	Overlay a curve or other visual component that shows a target or benchmark or comparator(s) to support comparison. Design alternatives: • Check box to show/ hide GUI elements representing comparators
Input	Data aggregates from other units or on a national scale
Output	SVG updated
Dependencies	Data is visualised in a chart
Source	Use Case 5: Comparators and benchmarks
Priority	10/10

4.2.1.2 Add/ Remove Chart

- **FR 8 Add new chart**

Description	Create space for a new visualisation. Includes prompt for user to select data components and chart type. Design alternatives: • User creates a new brush in an existing chart [FR 19 New Brush] and then right-clicks on the chart. User then selects a menu item called ‘Export Selection’ from the context menu. This exports the data records selected by the brush into the new chart

	• User clicks on a '+' button on the current chart, in which case the same data of the current chart is displayed in the new chart.
Input	User action and data selection
Output	SVG rendered
Dependencies	Database is accessible
Source	Use Case 6: Add/ remove chart(s)
Priority	9/10

FR 9 Delete chart

Description	Remove a chart from display and from memory. Design alternatives: • Drag the chart into a bin • Select a chart then click a delete button • Select a chart then press shift + delete
Input	Mouse action
Output	SVG deleted
Dependencies	Chart is displayed
Source	Use Case 6: Add/ remove chart(s)
Priority	9/10

FR 10 Hide chart

Description	Remove a chart from the main display but keep it in memory to be restored upon request. Design alternatives: • Click a minimize icon on the top right corner of the div containing the chart • Drag the chart to a hidden area • Right-click a chart then select 'Hide' • Click a chart then press Ctrl + H • Select a chart from a drop-down menu to toggle its visibility
Input	A QualCard containing a chart
Output	SVG hidden
Dependencies	Chart is displayed
Source	Use Case 6: Add/ remove chart(s)

Priority	9/10

FR 11 Show chart

Description	Remove a chart from the main display Design alternatives: • Select a chart from a drop-down menu to toggle its visibility • Inspect thumbnails of hidden charts and double click a thumbnail to open a hidden chart
Input	A QualCard containing a chart
Output	SVG destroyed
Dependencies	Chart is displayed
Source	Use Case 6: Add/ remove chart(s)
Priority	9/10

4.2.1.3 Axis Controls

- *Modify scale / binning*
- *Modify variable mapping*

FR 12 Modify scale

Description	Modify the scale mapping a variable to an axis Design alternatives: • Use a zoom-in technique like mouse scroll • Use sliders to control the end points of an axis • Use custom options like months, days, years (in case of time axis)
Input	Variable to be rescaled
Output	Rescaled axis and SVG updated
Dependencies	A chart is rendered
Source	Use Case 7: Axis controls
Priority	10/10

FR 13 Select x-axis

Description	A default field is set for visualisation. Users are presented with a drop-down menu to select other fields. Design alternatives: • User selects a data field from a drop-down menu to be assigned to the x-axis
Input	Options from database (possibly prioritsed by user tasks in our data collection).
Output	SVG rendered
Dependencies	A chart is rendered
Source	Use Case 7: Axis controls
Priority	10/10

FR 14 Select y-axis

Description	A default field is set for chart visualisation. Users are presented with a drop-down menu to select other fields. Design alternatives: • User selects a data field from a drop-down menu to be assigned to the y-axis.
Input	Options from database (possibly prioritsed by user tasks in our data collection).
Output	SVG rendered
Dependencies	A chart is rendered
Source	Use Case 7: Axis controls
Priority	10/10

4.2.1.4 Add/ remove Variable(s)

FR 15 Add variable

Description	Add a variable to an existing chart. Design alternatives: • User clicks a '+' button under the list of variables

	currently displayed on a chart. User then selects the field from a drop-down menu containing all fields in the database. • User right-clicks on a chart and selects ‘add variable’ to open a menu containing all fields in the database.
Input	Options from database (possibly prioritised by user tasks in our data collection).
Output	SVG updated
Dependencies	A chart is rendered
Source	Use Case 8: Add/ remove variable(s)
Priority	10/10

FR 16 Remove variable

Description	Remove a variable from an existing chart Design alternatives: • User clicks a ‘x’ button after selecting one of the variables in the list of currently displayed variables.
Input	List of variables already encoded in the chart
Output	SVG updated
Dependencies	A chart is rendered
Source	Use Case 8: Add/ remove variable(s)
Priority	10/10

4.2.1.5 Modify Visual Encoding

FR 17 Change encoding

Description	Change the visual encoding that is assigned to a variable Design alternatives: • Select variables from a drop-down menu for a specific encoding • Drag elements around between visual encodings
Input	List of variables already included in the chart and their corresponding visual encodings.
Output	SVG updated
Dependencies	A chart is rendered

Source	Use Case 9: Modify visual encoding
Priority	8/10

4.2.1.6 Miscellaneous interactions

In addition to use cases, the following functional requirements are intended to support users' workflow and are based on design considerations from the visualisation literature.

FR 18 Screen space for analysis

Description	Creates a new canvas page for root cause analysis Design alternatives: • User clicks a button on the home screen to create a new browser tab containing a new canvas page. • User clicks a button on the home screen to overlay a new canvas on top of the existing browser window
Input	User selects one of the charts in the home screen then right-clicks and clicks 'root cause analysis'
Output	New tab window with the analysis canvas
Dependencies	Data is visualised in a chart and a brush is created
Source	
Priority	8/10

FR 19 New brush

Description	Selection of visual components in a chart Design alternatives: • Drag mouse over selection • Click a button to enter brushing mode then drag mouse over selection.
Input	User clicks and drags mouse over a range of visual components
Output	Visual components highlighted in display and brush added to the data model
Dependencies	Data is visualised in a chart
Source	

Priority	8/10

FR 20 Details on demand

Description	Values underlying a visual component are displayed when the user hovers the mouse over it Design alternatives: • User hovers the mouse over visual elements to view their underlying details. • User right-clicks a selection and clicks on ‘show table’ to create a separate view in which the data is displayed in a table to reveal details.
Input	Mouse cursor position on the screen
Output	Tooltip overlaid on SVG to display value(s)
Dependencies	Data is visualised in a chart
Source	
Priority	8/10

4.3 System Navigation and Control

FR 21 Account management

Description	Navigate to the account management page
Input	User click
Output	Account management HTML page
Dependencies	User logged in
Source	
Priority	10/10

FR 22 Show alerts

Description	Navigate to the alerts page
Input	User click
Output	History of alerts sorted from most to least recent
Dependencies	User logged in
Source	
Priority	10/10

FR 23 Save session

Description	Creates a JSON file that includes a description of the session and its contents
Input	Session file name
Output	Save username_filename.json to disk
Dependencies	User logged in
Source	
Priority	8/10

FR 24 Load session

Description	Load an existing session from a saved JSON file
Input	User-selected JSON session file
Output	SVG rendered
Dependencies	Database is accessible and user logged in
Source	
Priority	8/10

FR 25 Load report

Description	Load a previously saved report
Input	User-selected report file
Output	Report editor launched
Dependencies	Report file exists and is accessible
Source	
Priority	8/10

FR 26 Show database status

Description	Navigate to a page that only includes the data quality dashboard
Input	User click
Output	HTML page containing data quality information
Dependencies	
Source	
Priority	10/10

5. Other Nonfunctional Requirements

5.1 Security Requirements

Although several participants expressed interest in accessing the dashboard online from any location (i.e. access would not be limited to within Trusts' intranet sites), data security is paramount, and might require restricted, password-protected access.

5.2 Software Quality Attributes

Structural changes to audit data that may happen in the future can affect the data model for the quality dashboard. To account for this possibility, we use the MVC (Model View Controller) programming paradigm in developing the quality dashboard, which separates code that handles data requests and data model management (the model) from the front-end code (the view) and uses a controller to mediate between them

5.3 Data Quality Requirements

Data needs to be accurate, timely and as complete as possible. Participants want access to their own full NCA datasets, and, if possible, access to comparative data from other Trusts, and/or national averages.

5.4 Look and Feel Requirements

Participants would like a quality dashboard to be appealing visually, featuring graphical representations rather than pages of figures and statistics, colourful and with a simple design, especially at the front-end:

> *Colours and icons, something that will grab their eyes, instead of it all looking like tickboxes*. (Site 3, MINAP Coordinator).

They do not want to see tightly packed pages of text or numbers, but a 'clean', honed-down front screen, displaying a limited number of significant metrics or incorporating a menu of options/icons so that users can select the variables important to them with the capacity to access more detailed information if desired. For each metric or indicator, there might be a page showing the Trust's position against the national average, illustrated by a graph, a Trust Data Manager gave the National Emergency Laparotomy Audit as an example of good practice, whilst other participants commended the Healthcare Quality Improvement Partnership national benchmarking information format, which has already been subject to consultation.

Participants emphasised the need for brevity and simplicity at the Trust Board and sub-committee level in particular, given the limited time members of such committees have to review data. the 'traffic light' or '*RAG-rating'* system (where cells are highlighted red, amber or green to indicate performance that falls below, almost falls below, or meets required standards) was favoured by several participants, because it is used frequently within Trusts and enables users to identify potential problems at a glance (although

several participants also pointed out that it does not capture nuances within data, as when a target has not been met for sound clinical reasons).

5.5 Environmental Requirements

Participants feel it would be easier and clearer for users to look at data on a screen (some thought they were most likely to use a quality dashboard on their work PCs, others on handheld devices, and still others on large screens in meeting rooms) rather than in hard-copy documents or notes.

6. Appendix A: Glossary

Accidental Extubation	Removal of the endotracheal (breathing) tube either occurring during procedures performed by healthcare workers, or in "self extubation", if the patient removes it.
Association	A relationship or correlation between two, or more, variables.
Audit Supplier	Suppliers collate and store data from UK hospitals in secure registries, from which reports are produced.
British Association of Urological Surgeons (BAUS) Audit	The British Association of Urological Surgeons publish surgeon level outcomes data about the surgeries performed.
Care Quality Commission (CQC)	The Care Quality Commission monitor, inspect and regulate services to make sure they meet fundamental standards of quality and safety. They publish their findings, including performance ratings, to help people choose where they receive care.
Cardinality	The number of elements in a set
Case Mix	Used as a synonym for cohort; it essentially groups statistically related patients e.g. male patients under the age of 50, who present with a myocardial infarction and also undergo emergency coronary artery bypass surgery.
Categorical (nominal) variable	A categorical variable (sometimes called a nominal variable) is one that has two or more categories, but there is no intrinsic ordering to the categories. For example, gender is a categorical variable having two categories (male and female) and there is no intrinsic ordering to the categories.

Clinical Audit	Clinical audit is a quality improvement process that seeks to improve patient care and outcomes through systematic review of care against explicit criteria e.g. national clinical guidelines.
Clinical Commissioning Groups (CCGs)	Clinical Commissioning Groups (CCGs) were created following the Health and Social Care Act in 2012, and replaced Primary Care Trusts on 1 April 2013. They are clinically-led statutory NHS bodies responsible for the planning and commissioning of health care services for their local area.
Cluster	When data in the metric visualised seem to be 'gathered' around a particular area.
Clinical Dashboard	Clinical dashboards are used to display information about the performance of individual clinicians compared to expected quality standards, to inform clinicians' decisions about patient care.
Dashboard	A dashboard is a visual display of information, consolidated and arranged on a single page or screen so the information can be monitored at a glance.
Data Quality	The extent to which the data used is accurate and complete.
Distribution	A general pattern or description of how attributes are distributed over a record set: how varied they are, what values occur most frequently, whether there are outliers (a few values greatly differing from the rest), etc.
Elective Surgery National Patient Reported Outcome Measures (PROMS) Programme	Patient Reported Outcome Measures (PROMs) measure health-related quality of life as reported by patients themselves. The national PROMs programme began in 2009 and four surgical procedures were chosen to be included: total hip replacement; total knee replacement; varicose veins and groin hernia surgery
Frequency	Frequency is the number of occurrences of a repeating event per unit of time. It is also referred to as temporal frequency,
Functional Requirements	A functional requirement defines a function of a system or its component – it describes what the system does or should do.

Granularity	The level of detail considered in a metric e.g. individual patient data, service level data
Healthcare Quality Improvement Partnership (HQIP)	The Healthcare Quality Improvement Partnership (HQIP) was established to promote quality in healthcare, and in particular to increase the impact that clinical audit has on healthcare quality improvement. The Healthcare Quality Improvement Partnership centrally manages over 100 National Clinical Audits in the United Kingdom (UK) on behalf of NHS England.
Independent Audits	Independent audits are National Clinical Audits that are not managed by the Healthcare Quality Improvement Partnership; they have three main funding arrangements; 1) subscription by NHS Trusts; 2) by a charity or professional body; and 3) by NHS England.
Intubation	The placement of a flexible plastic tube into the trachea (windpipe) to maintain an open airway or to serve as a conduit through which to administer certain drugs.
Key Performance Metric (KPM)	A measurable value that demonstrates how effectively a company is achieving **key** objectives.
Metric	A system or standard of measurement
Myocardial Infarction	Myocardial infarction (MI), commonly known as a heart attack, occurs when blood flow decreases or stops to a part of the heart, causing damage to the heart muscle
Myocardial Ischaemia National Audit Project (MINAP)	The Myocardial Ischaemia National Audit Project (MINAP) is a national clinical audit of the management of heart attack. It supplies participating hospitals and ambulance services in England, Wales and Northern Ireland with a record of their management and compares this with nationally and internationally agreed standards.

National Cardiac Arrest Audit (NCAA)	The National Cardiac Arrest Audit (NCAA) monitors and reports on the incidence of, and outcome from, in-hospital cardiac arrest in order to inform practice and policy. It is a joint initiative between the Resuscitation Council (UK) and ICNARC (Intensive Care National Audit & Research Centre).
National Clinical Audits (NCAs)	National Clinical Audits (NCAs) collect data nationwide to systematically measure the quality of care delivered by clinical teams and provider organisations, and to stimulate quality improvement initiatives.
National Clinical Audit and Patient Outcomes Programme (NCAPOP)	National Clinical Audit and Patient Outcomes Programme (NCAPOP) audits are commissioned and managed on behalf of NHS England by HQIP. The programme comprises more than 30 national audits related to some of the most commonly-occurring conditions. These collect and analyse data supplied by local clinicians to provide a national picture of care standards for that specific condition. The Myocardial Ischaemia National Audit Project and The Paediatric Intensive Care Audit Network are included in the National Clinical Audit and Patient Outcomes Programme.
National Institute for Health Research (NIHR)	The National Institute for Health Research funds health and care research that translates discoveries into practical products, treatments, devices and procedures. The QualDash project is funded by the National Institute for Health Research.
National Audit of Cardiovascular Rehabilitation (NACR)	The National Audit of Cardiovascular Rehabilitation aims to monitor and support cardiovascular rehabilitation teams and commissioners in delivering high-quality and effective services, to evidence-based standards, for the benefit of all eligible patients.
NHS England	NHS England leads the National Health Service (NHS) in England. They set the priorities and direction of the NHS. They commission services, primary care, some public health services, offender healthcare, and some services for the armed forces.

Ordinal variable	An ordinal variable is similar to a categorical variable, but has a clear ordering of the variables. For example, economic status, can be classified as low, medium and high. However, the spacing between the values may not be the same across the levels of the variables.
Outlier	An observation point in the metric visualised that is distant from other observations.
Paediatric Intensive Care Audit Network (PICANet)	The Paediatric Intensive Care Audit Network (PICANet) records details of the treatment of all critically ill children in paediatric intensive care units (PICUs). It was established to develop and maintain a high quality clinical database of paediatric intensive care activity in order to identify best clinical practice, monitor supply and demand, monitor and review outcomes of treatment episodes, facilitate healthcare planning and quantify resource requirements, study the epidemiology of critical illness in children
Proportion	A proportion refers to the fraction of the total that possesses a certain attribute. For example out of a bird, a fish, a dog, and a cat. The proportion of pets with four legs is 2/4 or 0.50.
Quality Dashboard	Quality dashboards are used to display information that can be used to monitor the performance of clinical teams and organisations e.g. information about wards or hospitals to inform operational decision making and quality improvement initiatives.

Quality Improvement	There is no single definition of quality improvement. However, a number of definitions describe it as a systematic approach that uses specific techniques to improve quality. **Quality:** The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge. **Improvement**: Better patient experience and outcomes achieved through changing provider 48rganiza and Organisation through using a systematic change method and strategies.
Quality and Safety Committee	Usually constituted as a standing **Committee** of the Trust Board. It is authorised to seek the information it requires from members of staff regarding quality and/or safety.
QualDash	The QualDash project aims to design a computer based, interactive quality dashboard that uses novel visualisation techniques so that healthcare professionals and managers can easily and quickly explore audit data.
Quantitative variable	Variables that are measured on a numeric or quantitative scale
RAG rating	Red Amber Green (RAG) or 'traffic light' system used to rate service performance
Standard Mortality Ratio (SMR)	Standardised Mortality Ratio (SMR) is a ratio between the observed number of deaths in a study population and the number of deaths that would be expected, based on the age- and sex-specific rates in a standard population and the population size of the study population by the same age/sex groups.
Task taxonomy	A classification of tasks that users aim to perform in order to make sense of data and gain insight.
Temporal variable	Variables that are measured over time.

Trend	A pattern of gradual change or a general tendency of a series of data points to move in a certain direction over time, represented in a visualsiation.
Trellis	Trellis layout split the visualisation of a dataset into different panels. Each panel displays a subset of the original data table where the subsets are defined by the categories available in a column or hierarchy.
Trust Board	NHS Trusts are governed by a Board of Directors consisting of both Executive Directors, appointed to specific roles within the organisation, and Non-Executive Directors, who do not work for the Trust but bring a range of external expertise with them.
Type Cardinality	The number of elements in each set of a specific data type e.g 1n 1q is a type cardinality for a set containing 1 quantitative and 1 nominal variable
Variable	A feature, or factor that is liable to vary or change. We use the term here to refer to data columns.
Visualisation	Visualisation is any technique for creating images, diagrams, or animations to communicate a message.

7. Appendix B: Methods for identifying Functional Requirements

Background

Phase 1 of the QualDash project aimed to develop a program theory that explained how and in what contexts use of QualDash would lead to improvements in care quality and to identify requirements for the design and adoption of QualDash. These objectives were met primarily through (1) interviews with members of clinical teams, quality sub-committees, Trust Boards and clinical commissioning groups, and (2) a workshop with audit suppliers representing a range of audit suppliers, held at the Kings Fund

Identifying functional requirements: Interviews

Interviews participants were recruited across five sites, including three Teaching Hospital Trusts and two District General Hospitals. To identify requirements that were applicable beyond a single audit, the sampling strategy was designed to target users of the Myocardial Ischaemia National Audit Project (MINAP) and the Paediatric Intensive Care Audit Network (PICANet). Both audits are managed by the Healthcare Quality Improvement Partnership (HQIP) as part of the National Clinical Audit and Patient Outcomes Programme (NCAPOP), but were selected based on variation in clinical speciality, patient groups, performance measures and suppliers. Representatives of NCAs managed independently of HQIP, e.g. the National Audit of Cardiac Rehabilitation (NACR), and NCAs that provide feedback about individual rather than service-level performance, e.g. the British Association of Urological Surgeons (BAUS) audits were also invited to participate. In total 54 participants were recruited across the five study sites; see **Table 1** for overview.

Table 1: Participants by role and audit

	Role	PICANet	MINAP	BAUS	NACR		Total
Clinical Team (Roles related to specific NCAs)	Doctors	5	7	1	0		13
	Nurses	3	6	0	2		11
	Audit Clerks	3	1	0	0		4
	Other	1	1	0	0		2
	Total	12	15	1	2		30
Other Groups (Roles not related to specific NCAs)	Trust Board	Quality &Safety Committee	Information Manager	CCG	Nurses	Other	
Total	2	6	5	4	4	3	24
Grand Total							54

An interview schedule was used to prompt discussion of the functions participants believed should be offered by a quality dashboard to support use of audit data. Data analyses resulted in a draft specification in which requirements were grouped into the following five categories:

(1) Interaction: These requirements are concerned with how users will interact with QualDash.

- **FR.i.01** QualDash should allow the user to choose what data are displayed
- **FR.i.02** QualDash should allow the user to select the time period over which the data is displayed
- **FR.i.03** QualDash should allow the user to quickly access (‘at the touch of a button’) frequently reviewed data
- **FR.i.04** QualDash should allow the user to select certain groups of patients to look at (e.g. based on age, condition)
- **FR.i.05** QualDash should allow the user to ‘drill down’ for further detail, to understand the reasons behind the data
- **FR.i.06** QualDash should support simultaneous use by multiple users (e.g. in the context of a meeting)

(2) Visualisation: These requirements are concerned with what data are displayed on QualDash and how they are displayed.

- **FR.v.01** QualDash should display static visualisations depicting key performance metrics
- **FR.v.02** QualDash should initially display data for all patients included in the service’s/organisation’s audit data
- **FR.v.03** QualDash should provide comparative data from other services/organisations
- **FR.v.04** QualDash should enable users to monitor their performance against particular targets/benchmark
- **FR.v.05** QualDash should enable users to monitor their performance against the national average

- **FR.v.06** QualDash should enable users to monitor care pathways, i.e. to see data for metrics presented chronologically, reflect the different points at which they occur along the care pathway

(3) Data quality: These requirements are concerned with the timeliness, completeness, and correctness of the data that QualDash will display.

- **FR.dq.01** QualDash should display 'real time' data
- **FR.dq.02** QualDash should display data that is less than three months old
- **FR.dq.03** QualDash should make the user aware when incomplete data are displayed

(4) Reporting: These requirements are concerned with the reports that QualDash produces.

- **FR.r.01** QualDash should allow the user to produce and save customised reports
- **FR.r.02** QualDash should allow the user to edit saved reports (i.e. it is not just a static PDF that is created and the user doesn't have to start again if they want to change something on the report)
- **FR.r.03** QualDash should allow the user to cut and paste information from QualDash produced reports into Word and Excel
- **FR.r.04** QualDash should produce reports that summarise the annual report and compares the service's/organisation's performance against those results

(5) Notifications: These requirements are concerned with functionality within QualDash to make users aware of certain information.

- **FR.n.01** QualDash should make the user aware of areas of improvement or concern, e.g. using 'traffic light' colours
- **FR.n.02** QualDash should issue alerts, e.g. triggering an email when performance drifts out of the normal range

The Supplier Workshop

To assess the generalisability of the requirements outside the five interview sites and audits, the supplier workshop included a purposive sample of participants, that represented a range of NCAs (covering NCAPOP and independent NCAs, as well as audits where participation is at the individual clinician level), and representatives of HQIP. Currently, NCAPOP and independent NCAs are delivered by a total of 37 suppliers, with some responsible for up to five separate audits. Where a supplier delivered more than one NCA in this way, we approached the national clinical lead for each NCA. Twenty one participants attended the workshop, with 22 audits represented.

In preparation for the workshop, participants were sent the draft requirements specification developed as a result of the interviews. During the workshop participants took part in activities where they prioritised what they considered to be the top three requirements, and to indicate which requirements they considered essential from the perspective of their audit. An activity to explore visualisation requirements also took place, where participants completed worksheets to explain how they prefer to explore, confirm (test a hypothesis) or present data visually. The lists created by the groups for sessions 1 and 3 were analysed quantitatively to identify which functional requirements were considered essential by all groups. These are summarised below in **Table 2.**

Table 2: Requirements for QualDash that all workshop participants considered essential

Visualisation
Targets and Benchmarks: QualDash should enable users to monitor their performance against particular targets/benchmark
Interaction
Choose Time Period: QualDash should allow the user to select the time period over which the data is displayed
Patient Selection: QualDash should allow the user to select certain groups of patients to look at (e.g. based on age, condition)
Reporting
Cut and Paste: QualDash should allow the user to cut and paste information from QualDash produced reports into Word and Excel
Notification
Alert via QualDash: QualDash should make the user aware of areas of improvement or concern, e.g. using ‘traffic light’ colours
Data quality
Notify of incomplete Data: QualDash should make the user aware when incomplete data are displayed

Next, the final ranking of priorities was combined to produce a list of functional requirements ordered by priority, see **Table 3**.

Table 3: Prioritised QualDash requirements

Interaction Top 3
1. Choose Data Displayed: QualDash should allow the user to choose what data are displayed
2. Choose Time Period: QualDash should allow the user to select the time period over which the data is displayed
3. Patient Selection: QualDash should allow the user to select certain groups of patients to look at (e.g. based on age, condition)
Visualisation Top 4 (3 and 4 very close)
1. Targets and Benchmarks: QualDash should enable users to monitor their performance against particular targets/benchmark
2. Data of all Patients: QualDash should initially display data for all patients
3. Key Performance Metrics: QualDash should display static visualisations depicting key performance metrics
4. National Average: QualDash should enable users to monitor their performance against the national average
Reporting and notifications Top 3
1. Customised Reports: QualDash should allow the user to produce and save customised reports
2. Annual Report Summary: QualDash should produce reports that summarise the annual report and compares the service's/organisation's performance against those results

3. Cut and Paste: QualDash should allow the user to cut and paste information from QualDash produced reports into Word and Excel

Data quality Top 3
1. Notify of incomplete Data: QualDash should make the user aware when incomplete data are displayed
2. Real Time Data: QualDash should display ‘real time’ data
3. Only show validated data
Strong support for both onsite and offsite access, with data appropriately secure

8. Appendix C: Analysis Models

When applying the three-dimensional task space to user tasks for PICANet and MINAP users, we apply certain rules:

- Whenever participants spoke of some characteristics of patients (patients are the referrers) a decision was made based on the granularity of the task:
    - If the task requires patient-level detail then patients were considered as referrers and were not counted as a variable. This means that individual patients need to be visualised as individual visual elements (e.g. points on a scatterplot) to answer this type of question, as opposed to being aggregated as a count (quantitative value) that translates to a visual attribute like size or height (e.g. bar height in a bar chart). An example task for this is:
        - Of STEMI patients that did not meet the VTB target, who were the patients that were direct/ indirect admission?

      In this example, the user does not just want counts of patients but wishes to drill down to the level of detail of the individual patient(s)' names and be able to look at them individually.

      Designing a visualisation for this would require us to display patient records along an axis (or in a table) to enable users to visually distinguish each patient.
    - If the task required unit-level aggregates, then patient_count was added as a quantitative variable.

9. Contact Details

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