# AUTOMATED RISK DETECTION

## *What are the Key Elements Needed to Create a Multi-source, Pattern-based Risk Detection System?*

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Keywords: Information, Analysis, Risk, Regulation.

Abstract: The Healthcare Commission, the national regulator for health care in England, uses an innovative risk detection system to target its inspections of National Health Service organisations. At the core of the system is a tool that enables: gathering of information from a huge variety of sources, and of varying types; mapping this information to the regulatory framework; and analysing this information in a comparable way to detect patterns that could indicate risk. The tool has demonstrated itself to be flexible and reliable, and its risk estimates have been consistently proven to be effective at discovering failure compared with non-targeted inspections.

## 1 INTRODUCTION

From its creation in 2004, the Healthcare Commission has always set out to be targeted and proportionate in its work (Kennedy, 2003), relying on intelligent use of information to guide its inspections and reducing the regulatory burden on well performing providers. This is in line with modern regulatory thinking in the UK, which advocates a risk-based approach to regulation (Office for Public Sector Reform, 2003). Clearly, this puts a focus on obtaining high quality information, and managing and using it appropriately.

A further change in England's regulatory landscape in 2004 was a move away from performance assessment solely through key performance indicators known as "star ratings" (Healthcare Commission, 2005) and towards an assessment against standards. By their nature, standards tend to be broader and less well defined than performance indicators. In this case, the Standards for Better Health (Department of Health, 2004) are set at a very high level, meaning that there is no single set of indicators that can measure them accurately.

Our solution was to gather as many imperfect measures as possible to try to describe performance against the standard, while acknowledging their imperfection by following up with inspection on areas where our system detects risk of non-compliance. In this way, the system produces compliance risk estimates, not judgements. Given that we are assessing 44 part-standards in nearly 400 organisations, a huge amount of information is required and needs a highly sophisticated system to manage and analyse it. This paper explores the lessons learnt from developing that system, and the emergent key elements that are required for any system like this to function.

## 2 KEY ELEMENTS OF THE SYSTEM

The system's primary task is to support the Commission's main inspection programme, the Core Standards Assessment, but also supports risk targeting for many other assessments.

Through our programme of development, three key functions of the system became clear;

1. Being able to align information (by analysis unit)
2. Being able to map information (by analysis topic)
3. Being able to compare multiple sources to produce an overall result

Blunt I., Chitnis X. and Roberts A. (2009).
AUTOMATED RISK DETECTION - What are the Key Elements Needed to Create a Multi-source, Pattern-based Risk Detection System? .
In *Proceedings of the International Conference on Health Informatics*, pages 393-397
DOI: 10.5220/0001781803930397

## 2.1 Structuring Information

### 2.1.1 Sourcing Data

One of the core principles of our risk targeting is that we will not require any bespoke data collection, but rely solely on existing information. Another is that the system is opportunitistic, and does not rely on good national coverage for inclusion. We aim to use "everything the Commission knows" to risk assess organisations.

Any member of staff can add data to the system, a decision taken because we find that data are more reliably stored if they are imported by staff using it for their own ends, rather than hire administrative staff solely to load data. Incoming data can come from any source, any location, and any format, although the majority of these arrive as spreadsheets containing a handful of measures.

### 2.1.2 Formatting Data

Once data are received and assessed as fit for purpose, they are transferred to a data template for entry to main database.

The key unique identifier is the organisation code (NACS code for NHS), although this could be any consistent label to identify a specific unit of analysis. If multiple measures have been supplied, this is where they are divided into value/numerator/denominator format, or category name and rank if they are categorical. New measures can also be created by combining separate numerators and denominators from different sources at this stage. The data template also stores metadata to feed to the main database, as discussed in the next section.

### 2.1.3 Storing Data & Structure

Each one of the measures described above is referred to as an "item", and each dataset is a "time period" of that item which that consists of individual "observations", which are either a value, numerator and denominator or a list of categories, depending on their type. Items can have many "time periods", which allows us to align measures over time and reduces the amount of metadata that have to be re-entered.

Key meta data are information about: description of the measure (including type, numerator and denominator units); source details; dates that the data relate to; audit trail data (file paths, URLs etc); an assessment of reliability of the information; and the "sentinel distribution" – which notes whether high, low or extreme values should increase our estimation of risk.

### 2.1.4 Handling Free Text Intelligence

As well as traditional numerical measures, the system also makes extensive use of comments derived from free text sources. This is an important way of capturing input from patient groups and including isolated, opportunitistic intelligence such as investigation reports and information discovered by our local staff.

This information is structured by a team of analysts who code each comment against a taxonomy (currently the Standards for Better Health). As well as topic, they also assess whether the information tells us something positive or negative about an organisation and issues around the reliability of the comment and the strength of relationship between the comment and the taxonomy element.

## 2.2 Mapping Information

The system is designed to analyse a range of intelligence related to a user-created assessment framework. The frameworks will be determined by the goals of the assessment programme, rather than the information available.

A very simple structure allows us to create item groups (with descriptive metadata) and map items against them to mimic these frameworks. We can also create a multilayer framework by mapping item groups to other item groups (a conceptual example is shown in figure 1). The item groups can represent any construct of the assessment framework, be it a standard, a part standard, criteria, topic, question etc. The system will analyse the most recent time period available when the group result is requested.

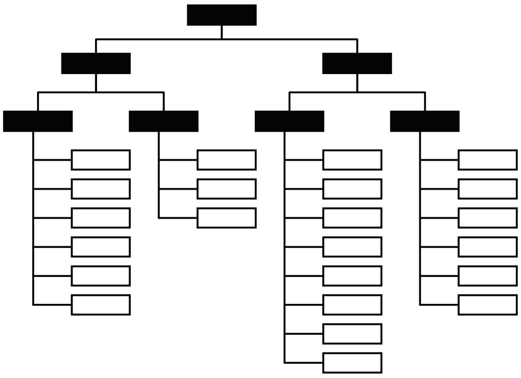


Figure 1: Conceptual representation of a simple framework containing items (white) and item groups (black).

Clearly, some items will be more important in the framework than others. Importance might be due to how accurately it measures the framework construct, the authority of the intelligence (e.g. a formal judgement carries more weight than a data analysis) and its "real world" value (e.g. mortality measures should outweigh bureaucratic process measures). Items are weighted accordingly as part of the mapping process, and can even be given a "super-weighting" that allows them to "trump" everything else in group.

## 2.3 Analysing Information

### 2.3.1 Item Level

The analysis process brings together many different types of data. For each item of information, we assess the difference between the observed result for a particular organisation and an expected level of performance on a common scale using the most appropriate analysis for that item. The outcome of this analysis is an "oddness" score which is a statistical measure of how far each organisation's performance is from the expected level for that measure. None of our methods penalise (or reward) organisations simply for being at the bottom (or top) of a list - they are designed to look for genuine differences from our expectation. It is entirely possible that all organisations will be performing similarly to expectation on a data item.

We make a number of "stock" analysis methods available to the user, who will be heavily guided by information type towards an appropriate choice. The system will also suggest analysis settings based on characteristics of the data.

Our analysis methods are tailored to data type (proportions, ratios etc) and take account of the possibility that an organisation's results may be affected by chance variation. To do this we use a modified Z score (Spiegelhalter, 2005).

The expected level of performance against which a organisation is compared can be calculated in several ways. For some items, organisations are compared against the national average of all organisations. In other cases - such as waiting times for example - an expected level of performance has been set down for organisations in government policies. For some data items we recognise that organisations' performance may be significantly influenced by factors beyond their control. There are two main ways we adjust for this. Either the 'raw' data are standardised (for example by age and sex) before import or we may set our expectation for that organisation as the average performance of a group of other organisations with similar local circumstances (referred to as the 'benchmark group'). We use various benchmarking groups in our analysis, including deprivation, population turnover and disease prevalence.

Where data are categorical, we achieve analysis results on the common risk scale by assuming an underlying normal distribution in the frequency data and assessing distance between each observation and the expectation (either an imposed target or set as the ordinal category that contains the median observation).

Our free text comments are scored by analysts as discussed in section 2.1.4. These factors are then translated into a score that is nominally equivalent to the scores on the common risk scale.

### 2.3.2 Pattern Detection at Group Level

For organisations whose performance over a range of items appears to be "oddly" poor, we infer that there may be a risk of failure against the given framework. However, there are many reasons why an organisation that raises concerns in our analysis might be found legitimately to be compliant by inspection. The organisation will have access to much better local sources of evidence than are available to the Commission at a national level for risk assessment. They will also have the benefit of the most up-to-date information. It might also be that, while the organisation is not performing well compared with other organisations, they are still meeting the minimum needed for acceptable performance against the framework.

For each item of information, we assess whether the organisation's result was in line with what we would expect, as outlined in section 2.3.1 above. The results for all items mapped to an item group (including qualitative information) are then aggregated together. This produces an overall group "oddness" score that is directly comparable to the item oddness.

Our main method of combining the results from each item of information is not to calculate a simple average, but instead enables us to highlight patterns of poor performance. For example, an item group may be assessed as being at high risk where several items of information are worse or tending towards worse than expected, but none exceed the threshold to be notable in their own right.

When combining this volume of information, rules-based or directly weighted aggregation models that finely balance every item against each other become unsustainably complex. Our model uses broad weights discussed in section 2.2 and then automatically avoids double counting by adjusting for the degree of auto-correlation within the item group. This allows us to include any relevant measure without needing to consider whether it measures the same underlying factors as other measures.

Lastly, as the system takes item groups with massively different amounts of information and produces directly comparable risk estimates, we need to consider the confidence we should have in that risk estimate. In general, it would be unreasonable and disproportionate to trigger an inspection based on just one or two observations.

Other aggregation methods are also available, which can include taking a conventional mean of item results or counting the number of outlying observations in each group.

## 2.4 Outputs

### 2.4.1 Selection Models

The core business output is to inform our selection models that are run separately from the main system to allow for swift customisation and adjustment. However, they are all based in some way on the risk estimates produced by Compass.

Typically selection models are either absolute, in which any organisation with more than a certain number of high risk item groups are inspected, or prioritised, in which the X% most risky organisations are selected dependent on resource available. We have that facility to apply almost any model that is desired by the assessment programme.

### 2.4.2 Presenting Results

In addition to triggering inspections, it is important that the system can also display its results both to help inspection staff engage with the risk assessment and to provide an audit trail to the inspected organisation to show that the selection was objective and robust. We also make the results available to the public on our website.

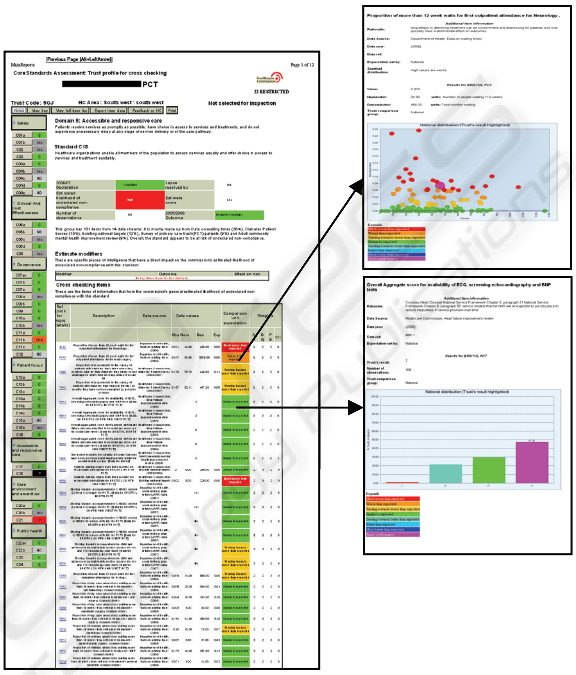
This is achieved with a customised reporting tool, that takes a direct transfer from the "live" system when a new set of results are released. A screenshot example is shown in figure 2.

# 3 RESULTS AND USAGE

## 3.1 Core Purpose Results

Demonstrating the success of a risk targeting system can often be problematic, as the resulting inspection programmes tend to be entirely risk-based. Indeed, most of our smaller reviews operate in this way.

However, our main inspection programme, the Core Standards Assessment, contains a parallel element of random selection, which allows us to judge the effectiveness of our risk detection. Our success criterion is simply that the system should detect more non-compliance than selecting organisations by chance alone.



Core Standards Assessment: Trust profile for cross checking

[redacted] PCT

Trust Code: 5QJ HC Area: South west \ south west

Not selected for inspection

Domain 5: Accessible and responsive care

Patients receive services as promptly as possible, have choice in access to services and treatments, and do not experience unnecessary delay at any stage of service delivery or of the care pathway.

Standard C18

Healthcare organisations enable all members of the population to access services equally and offer choice in access to services and treatment equitably.

| | | | |
|---|---|---|---|
| 2006/07 Declaration | Compliant | Lapse resolved by | n/a |
| Estimated likelihood of undeclared non-compliance | High | Estimate score | 1.5x |
| Number of observations | 151 | 2005/2006 Outcome | Declared Compliant |

This group has 151 items from 14 data streams. It is mostly made up from Data on waiting times (36%), Diabetes Patient Survey (15%), Existing national targets (12%), Survey of primary care trust (PCT) patients (9%) and Adult community mental health improvement review (9%). Overall, the standard appears to be at risk of undeclared non-compliance.

Estimate modifiers

These are specific pieces of intelligence that have a direct impact on the commission's estimated likelihood of undeclared non-compliance with this standard

| Modifier | Outcome | Effect on risk |
|---|---|---|
| No key items found for this standard. | | |

Cross checking items

These are the items of information that form the commission's general estimated likelihood of undeclared non-compliance with this standard

| Ref (click for more details) | Description | Data source | Data values | | | | Comparison with expectation | Weights | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Obs | Num | Den | Exp | | C | DQ | PE | Crl |

Proportion of more than 12 week waits for first outpatient attendance for Neurology .

Additional item information

| | |
|---|---|
| Rationale: | long delays in delivering treatment can be inconvenient and distressing for patients and may possibly have a detrimental effect on outcomes |
| Data Source: | Department of Health, Data on waiting times |
| Data year: | (2006) |
| Data ref: | |
| Expectation set by: | National |
| Sentinel distribution: | High values are worse |

Results for BRISTOL PCT

| | | | |
|---|---|---|---|
| Value: | 0.074 | | |
| Numerator: | 34.00 | units: | Number of people waiting >12 weeks |
| Denominator: | 458.00 | units: | Total number waiting |
| Trust comparison group: | National | | |

Overall Aggregate score for availability of ECG, screening echocardiography and BNP tests

Additional item information

| | |
|---|---|
| Rationale: | Coronary Heart Disease National Service Framework Chapter 6, paragraph 31 National Service Framework Chapter 6, paragraph 58. service models that the NHS will be expected to put into place to reduce inequalities in service provision over time |
| Data Source: | Healthcare Commission, Heart failure improvement review |
| Data year: | (2006) |
| Data ref: | item 1 |
| Expectation set by: | National |

Results for BRISTOL PCT

| | |
|---|---|
| Trust's result: | 2 |
| Number of observations: | 306 |
| Trust comparison group: | National |

Figure 2: Screenshot from our interactive reporting tool. Users can drill down for more information on any item.

In the two years for which results are currently available risk targeted inspections discovered twice (2005/2006) and then three times more (2006/2007) non-compliance than inspections selected at random (Bardsley et al, 2008 1&2). Therefore the system has achieved its core objective.

However, there is still scope to improve. For example, we know that we can target some standards more accurately than others, and this is often a consequence of the information available.

We also know that our inspectors are increasingly engaging with the system, as the number of local intelligence reports submitted has increased nearly five-fold since the first application (1160 comments for 2005/2006 compared with 5508 for 2007/2008).

## 3.2 Additional Uses

Success of a system can also be measured by its adoption in other business areas. In addition to supporting most of the Commission's NHS risk-targeted work, the system also provides a regular rolling update of risk status to our local staff (independent of inspections) to prompt extra gathering of local intelligence. The system can also be exploited as an intelligence-base, and has informed many other assessment programmes by providing information but not targeting.

## 4 CONCLUSIONS / DISCUSSION

The system's risk estimates have been proven to be an effective method of targeting the Commission's inspections, and our approach to estimating performance against frameworks using multiple information sources has been validated. The success of the system has led to wide scale adoption by the Healthcare Commission, and it has also been used in a number of other ways that build on the benefits of having created such a large structured intelligence-base.

Additionally, we believe that the range and scope of the information that we have collected and focused for a common purpose is unprecedented in the field of healthcare information handling, although several others have advocated the use of investigating organisational performance by using multiple measures (Yates & Davidge 1984, Harley et al 2005).

One important innovation is the integration of quantitative and qualitative intelligence, firstly to maximise the use we make of our intelligence and also because it has allowed our inspectors to engage with a targeting system that some might consider centralist. Being able to submit extra evidence to influence the next round of risk assessment – and seeing their input reflected – has increased their feelings of ownership for the risk estimates that the system produces. Another important effect has been to help embed the approach of using data to prompt further questions, as proposed by Lilford et al (Lilford et al, 2004), rather than to pass judgement directly.

This approach is extensible to any regulator (even sectors other than health), and to any organisation with good data on a large number of sub-units, by applying the key elements identified in this paper.

One of the current challenges for this approach is to extend it to areas that are less rich with information such as independent sector health care and social care.

## ACKNOWLEDGEMENTS

We would like to acknowledge the contributions from many teams within the Healthcare Commission but in particular members, past and present, of the Screening Development Team and most notably Martin Bardsley, David Spiegelhalter and Theo Georghiou.

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