



CEBRA Report Cover Page

Title, ID, & Output #	1501F Performance Indicators for Border Compliance Phase 2 Output 4.			
Project Type	Standard			
Project Sponsor	Raelene Vivian	DAWR Project Leader/s	Andrew Trainer	
CEBRA Project Leader	Andrew Robinson	NZ MPI Project Leader/s	N/A	
Project Objectives	<p>Robust performance and effectiveness measurement of each pathway regulated by the department under the Quarantine Act 1908 (now the Biosecurity Act 2015), namely:</p> <ol style="list-style-type: none"> 1) Cargo, comprising <ol style="list-style-type: none"> a. Break-bulk cargo, b. Bulk cargo c. Commercial air cargo, d. Non-commercial air cargo, e. Containerised sea cargo, f. Military equipment, g. Temporary Imports 2) Mail, comprising <ol style="list-style-type: none"> a. Letters b. Non Letters 3) Travellers (Declarant), comprising <ol style="list-style-type: none"> a. Air travellers b. Cruise travellers, 4) Travellers (Non-Declarant), comprising <ol style="list-style-type: none"> a. Air travellers b. Cruise travellers c. Cruise day-trippers 5) Commercial vessels 6) Sea containers (External) 7) Aircraft arrivals, and 8) Non-commercial vessels 			
Outputs	<p>Phase 1 reported on the review of existing performance indicators and recommended best practice performance indicators.</p> <p>Phase 2 (this report) report of how those performance indicators can be applied to the novel import pathways.</p>			
CEBRA Workplan Budget	Year 2015-16			
	\$110 000			
Project Changes	Nil			
Research Outcomes	<p>Identified that the existing performance indicators used in the Mail and Travellers pathways are still best practice. The performance indicators are:</p> <ul style="list-style-type: none"> • Approaching compliance (formerly Before Intervention Compliance or BIC) • Residual compliance (formerly Port Intervention Compliance or PIC) • Non Compliance Effectiveness (NCE) • Hit Rate. <p>Mapped the import pathways with flow diagrams and identified the end point and leakage surveys required to calculate the performance indicators.</p>			
Recommendations	The department has commenced the planning to implement the recommended performance indicators to all import pathways.			
Related Documents	KPIcalculators.zip (compressed zip archive file of spreadsheets that demonstrate KPI calculation)			
Report Complete				

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CEBRA Project 1501F – Performance Indicators for Border Compliance

Phase Two – Gold Standard

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Background/Context

Over the past decade, the Department of Agriculture and Water Resources (the department) has adopted a risk-based approach to managing the biosecurity risk of various pathways. This adoption has placed new demands upon the department's data capture and reporting systems. Following the Australian National Audit Office's 2001 report, *inspection effectiveness* was used as the primary indicator of inspectorate performance. However, concomitant with the implementation of a risk-based approach to management, a richer suite of indicators was required.

In 2011, ACERA Project 1001I, 'DAFF Biosecurity Quarantine Operations Risk Return Performance Indicators Report 1', recommended 'post-intervention compliance' of the pathway as a performance indicator. An extension to this work in 2013 (ACERA Project 1101D) broadened the scope of the indicators, implementing them for the international passengers pathway, and assessing the effect on prioritisation of passenger cohorts for further interaction¹. That project advocated four key performance indicators (KPIs), and provided examples of computing and reporting these indicators. The indicators included:

1. Before-intervention Compliance (BIC),
2. Post-intervention Compliance (PIC),
3. Non-compliance Effectiveness (NCE), and
4. Hit Rate (HR)

which will now be referred to as

1. Approaching Compliance (AC),
2. Residual Compliance (RC),
3. Non-compliance Effectiveness (NCE), and
4. Hit Rate (HR).

These indicators are simple and useful measures of performance that account for compliance and inspectorate performance before and after departmental interaction. They describe important aspects of the Department's effectiveness at reducing non-compliance, providing a holistic view of performance in each pathway.

The department implemented these indicators for the traveller and mail pathways. Equivalent performance indicators have not been developed for the regulation of imported cargo or arriving international vessels and aircraft.

This document aims to provide a pictorial description of the underlying process of the eight pathways as defined in the phase one report. It builds on the work from

¹ By interaction or process, we mean any and all contact of the department with a pathway. Formerly, the word intervention was more commonly used.

past CEBRA and ACERA projects, particularly 1101D and 1301B, describing how the methods discussed in those reports might be applied across the pathways to calculate associated KPIs, with confidence intervals.

Flowcharts & unit experience

Flowcharts

The starting point for KPI calculation is to accurately map the processes of each import pathway using a flowchart. Flowcharts can be found in the 'Pathway groups: KPI calculation manual' chapter. An example of an import pathway is the letters pathway, which mapped out in a flowchart with nodes representing the different stages of the interaction process such as the initial pool, screening, inspection and whether units were released or not.

These mappings were performed by CEBRA in collaboration with the department, with reference to the pathway descriptions and Sankey diagrams² provided by the department as part of the phase one output. Some pathways follow analogous processes and hence have been clustered into groups. A group is simply defined as a set of pathways that follow the same flowchart. Separate KPIs will still be calculated for each pathway, but the method (and spreadsheet) used to calculate KPIs for each member of a group will be the same.

The flowcharts are intended to represent the different events along a pathway. To do this it is first necessary to define three things, namely: (i) what is meant by 'pre-' and 'post-interaction', (ii) the statistical *unit* that will be used for KPI calculation, and (iii) the 'KPI criterion', that is, what constitutes non-compliance for the purposes of calculating the KPIs.

Pre- and post-interaction

The calculation of KPIs compares two states: the pre- and post-interaction states. It is important to define what these two states mean. The definition of post-interaction is generally the state following all departmental interaction, but the pre-interaction state takes a little more thought. It may be the state without any interaction at all, or it could be the state that exists when the department first becomes aware of a unit, which is generally more measurable and is the definition that will be used for this report. Other definitions are also possible. Seizures from leakage surveys are not considered part of departmental interaction, as these units would otherwise have been leaked.

Units

The statistical unit is the unit upon which a determination of compliance is made by the inspector. For instance, for cargo, the unit is the consignment, and for travellers, it is the traveller (Table 1).

² See Schmidt, 2006

85 **Table 1:** Groups and units

<i>Group</i>	<i>Pathway(s)</i>	<i>Unit</i>
A: Cargo	<ul style="list-style-type: none"> • Break bulk cargo • Bulk cargo • Commercial Air cargo • Non-commercial air cargo • Containerised sea cargo • Military equipment • Temporary imports 	Consignment (a single lodgement with one entry number)
B: Mail	<ul style="list-style-type: none"> • Mail (letters) • Mail (non-letters) 	Mail item (letter/Other Article/parcel/Express Mail Service)
C_i: Travellers (declarants)	<ul style="list-style-type: none"> • Air travellers (declarants) • Cruise travellers (declarants) 	Traveller (with baggage, if relevant)
C_{ii}: Travellers (non-declarants)	<ul style="list-style-type: none"> • Air travellers (non-declarants) • Cruise travellers (non-declarants) • Cruise travellers (day trippers) 	Traveller (with baggage, if relevant)
D: Commercial Vessels	<ul style="list-style-type: none"> • Commercial vessels 	Vessel
E: External containers	<ul style="list-style-type: none"> • External containers 	Container
F: Aircraft arrivals	<ul style="list-style-type: none"> • Aircraft arrivals 	Aircraft
G: Non-commercial Vessels	<ul style="list-style-type: none"> • Non-commercial vessels 	Vessel

90 Note that the identification of the unit is both a limiting and necessary step. The goal of implementing KPIs is to measure our performance in interacting with incoming units. This is done by estimating the biosecurity risk and by calculating the level of compliance with the KPI criterion (to be defined below), and also to determine the effectiveness and efficiency of the tools that the department uses for mitigating non-compliance.

95 It is necessary to identify a unit in order to have something upon which to measure non-compliance. It is also necessary to identify the unit for the purpose of meaningful reporting. However, the usefulness of this concept can be undermined by the fact that units and the KPI criterion may not be homogenous in relation to biosecurity risk, that is, two non-compliant units may have quite different levels of biosecurity risk associated with them.

100 Nevertheless, defining the unit is necessary for the calculation of the recommended KPIs. So long as the definition of the unit is fixed, it enables comparison of KPIs over time for a pathway. When comparing KPIs across pathways, this should always be

done with reference to the units and to the actual biosecurity risk associated with the KPI criterion in each of the pathways.

KPI criterion

The final requirement is the definition of the 'KPI criterion'. This is a list of all conditions against which the KPIs measure compliance. If a unit has one or more of these conditions, then it is defined to be non-compliant, for the purposes of the calculation of the KPIs. Note that this definition is pathway specific and doesn't necessarily have to match up exactly with either a unit containing biosecurity risk material, or regulatory non-compliance. The pathway holders decide which conditions are appropriate to include in this list. Throughout this document, non-compliance will be defined relative to the KPI criterion, unless specified otherwise.

Whether a unit is released or not affects the KPIs: particularly, it relates to the outgoing volume for the RC calculation. A unit that is found to be non-compliant with respect to the KPI criterion at the very end of the process will not be released. However, there could be conditions in which a unit is not released but under which we **do not** want to record a non-compliance in the measurement of the KPIs. These conditions are labelled as the *non-KPI criterion*. Non-KPI criterion is defined as a list of conditions that are relevant to the department's operations, but are not included in the KPI criterion.

An example to illustrate the difference between a KPI criterion and a non-KPI criterion is to look at two arriving vessels that both have a swarm of bees on board. The master of the first vessel reports the swarm, and so is compliant with the department's requirements. The master of the second vessel doesn't report the swarm, and so is not compliant with the department's requirements.

If the KPIs should focus on the vessel masters' compliance, then we include only 'vessel with undeclared bees' to be in the KPI criterion. However, the biosecurity risk material present on both vessels is of interest to the department, and would result in a ship being refused entry if the risk is not removed. In this case, 'vessel with declared bees' would be included in the non-KPI criterion.

Flowchart volumes

Ideally, unit volumes are collected at each node (signified by a letter/s) in a flowchart. For instance, we might like to know the volume of units that make up the initial pool, the volume that are sent for screening then inspection, and the volume that are released following inspection, the volume treated and then released following inspection and the volume not released.

Each group will have somewhat different requirements, and each KPI requires only some of the volumes. Furthermore, the values of some nodes can be computed from other nodes. For instance, imagine that we know the number of units sent to a screening node, and following screening, all units are either released or sent for

150 inspection. If we know the number inspected and the number screened, these figures can be used to determine the number released following screening.

155 An important note to make here is that the flowcharts depict the **gold standard**. The intermediate nodes and endpoints classify the units for the purpose of optimal KPI calculation. In reality, collecting the information at these levels might be operationally difficult or infeasible, and in that case, compromise will be necessary. The discussion around how these compromises might look will make up part of the phase three deliverables, however, some discussion of this is given in this report (see Pathway groups: KPI calculation manual chapter).

160 Endpoint characterisation

For any group of pathways, a unit follows the process as mapped out in the flowchart, and eventually ends up in one of the mutually exclusive 'endpoints' (coloured boxes at the bottom of each flowchart).

165 The following discussion relates to a classification of endpoints into different types based on *unit experience*, that is, the journey of the unit through the system, including any profiling, inspections and actions, and whether the unit was released or not. Further, 'seizures' and 'leakage' are defined. The purpose both of defining seizures and leakages and of classifying endpoints into different types is to facilitate
170 the explanation of KPI calculation.

Seizures and leakage

The terms 'seizures' and 'leakage' are used throughout this document. Here, *seizures* are defined as units that were identified as being KPI criterion non-compliant during
175 the department's operations (excluding those identified during endpoint leakage surveys). *Leaked* units are non-compliant with respect to the KPI criterion at the end of interactions, that is, undetected non-compliance. The rate of leakage is generally unknown and must be estimated by using endpoint surveys.

180 Endpoint types

The path of units through the system defines how the KPIs should be calculated but to simplify the explanation of KPI calculation we focus as much as possible on the endpoints of the pathways. Each unit passing through the process as depicted in a flowchart concludes its journey in one of a set of mutually exclusive endpoints. The
185 endpoints effectively classify units that have the same path.

Largely, endpoints can be classified as one of three types, designated by differing colours in the flowcharts:

- 190 • *Released (green)*: Units in these endpoints were found to be compliant with respect to the criterion, to the best ability of the tools available for identifying non-compliance. It is possible to have leakage in such endpoints, that is, some units in this category can be incorrectly identified as compliant.
- 195 • *Released following action for KPI criterion non-compliance (blue)*: Endpoints containing units that were identified as being KPI criterion non-compliant at some stage of the process. Effort was expended to rectify the non-compliance, after which the unit was determined to be compliant with respect to the KPI criterion. The units in these endpoints can be classified as
200 seizures. Given imperfect detection and treatment methods, units in this type of endpoint may still be non-compliant following release (i.e., they may contain leakage).

- *Not released (red)*: These are endpoints with units that are identified as being non-compliant, and are then either destroyed or exported. The units in these endpoints count only toward seizures. No leakage is possible as the units in these endpoints, by definition, are removed from the import chain.

The methodology will focus on the red, blue and green categories, which are the majority of unit experiences. The appendix describes some examples of other unit experiences, together with suggestions for how the KPIs might be adjusted in such situations.

As mentioned earlier, each endpoint is a cohort of units that have been through the same path. One reason for identifying these cohorts is to allow KPI calculation specific to, for instance, screening type; a second reason involves identifying cohorts with different leakage rates.

A blue category endpoint is likely to have a different leakage rate than its associated green category endpoint. By ‘associated endpoint’, we mean two endpoints sharing a parent node. Consider two units that have the same interaction (say, two air cargo consignments that hit the same profile are inspected, then sent for inspection following screening). If one is identified as being KPI criterion non-compliant and is then treated for that non-compliance and released (blue category), this unit will have a lower chance of containing leakage than a unit that was determined compliant and has received no treatment at all (green category), if the treatment is effective at eliminating all KPI criterion non-compliance. However, if the treatment is not effective at removing all KPI criterion non-compliance, or some of the non-compliance was not detected by the inspection, then the opposite could very well be true. Therefore, it is important to distinguish between these two endpoint types.

Endpoint surveys

Knowledge about leakage is essential for KPI calculation. Endpoint surveys should be conducted (with both survey volumes and non-compliance counts being recorded) at all released endpoints, in order to estimate what percentage of these units are not compliant with respect to the KPI criterion. The leakage rates are also likely to differ between different endpoints, hence, surveys taken for one endpoint are not necessarily useful for estimating leakage in another endpoint. For example, endpoint surveys are undertaken behind a range of screening tools in the international passengers pathway, including assess and release, x-ray, and manual inspection. Please refer to CEBRA report 1301B for more detail about how to implement and apply endpoint surveys.

A note on endpoint choice

Ideally, cohorts of units with the same levels of leakage should be identified. In the flowcharts, these cohorts are represented by the endpoints. While we recommend at least the level of detail described in the flowcharts for KPI calculation, it is possible to further divide the endpoints in cases where there are identifiable collections of units within an endpoint that are known to have differing leakage rates. This level of

250 granularity for KPI calculations can lead to problems such as small survey volumes in
some collections (see CEBRA report 1301B). However, it is possible that, for
reporting, in some cases groups will be calculated first at a lower level, for example
by airport for travellers, before aggregation to a national level. There is a cost in
255 amalgamating groups that likely have different leakage rates, as variances will be
underestimated.

A note on confidence intervals and timing

The purpose of a confidence interval is to communicate the statistical quality of an
estimate. A wide interval suggests that the quality is low; perhaps because the
260 sample size is too small relative to the underlying variability of the process. In any
case, the estimate accompanied by a wide interval should be interpreted with
caution. A narrow interval suggests that the quality is high, and the estimate can be
interpreted with a degree of certainty.

265 The benefit of confidence intervals for the regulator is to prevent over-reaction to
random swings of the KPIs. In a sense, confidence intervals provide information
about the size of the swings that may be reasonably well ignored. For example, if
inspection effectiveness in January is reported as 60% and in February as 50%, then
it is tempting to believe that some kind of attention is needed. However, if the
270 reporting in January is 60% (45, 75), meaning that the value that is best supported by
the data is 60%, but it is hard to distinguish statistically between the values within
the range (45, 75), and in February is 50% (40, 60), then the month to month change
is well within the range of uncertainty, and more data should be collected before
implementing severe management measures. The value may well swing back up next
275 month with no further attention.

Commonly, confidence intervals accompany the estimates themselves, as above.
However, in an integrated measurement and management system, other options are
possible.

280 First, the confidence interval can be interpreted and informally communicated by
the analyst, providing an assessment of the quality of the estimates – e.g. “don’t
take these estimates very seriously, wait until we have two more months’ data” or
“the evidence for these estimates is strong.” This contextual information will help
285 the manager avoid over-reacting to the signals.

Second, the confidence interval can be used by the analyst to guide the hierarchical
and temporal granularity at which the estimates are computed and reported. The
KPIs are measuring a process that changes over time, so it is necessary to choose a
290 unit of time as a basis for calculations, e.g., monthly, or annual, and also a reporting
cycle, which may differ. That is, the KPI report may be issued monthly, for example,
based on information from the previous quarter. If the analyst finds that the monthly
confidence intervals of a KPI are too wide, then perhaps the monthly reporting of the
most recent quarter’s figures will be better. Alternatively, reporting for some KPIs

295 might occur at a higher geographical level, for example, statistics may be pooled for smaller regions.

KPI formulation

The following set of indicators is the same as was recommended by CEBRA project 1101D. The current project began with an extensive review of both peer-reviewed scientific literature and annual reports, and interviews of analysts in comparable regulatory authorities. The finding of that review was that the set of indicators recommended by 1101D were still state of the art. The calculation of estimates is given below with confidence intervals being left to the appendix.

Seizures, leakage and the overlap

For any process, whether a unit is counted as a leakage, seizure, both or neither, depends on the KPI being calculated.

The red endpoints contain only seizures, green endpoints only contain leakage, while blue endpoints have both seizures and leakage. As mentioned earlier, a blue category endpoint is likely to have a different leakage rate than its associated green category endpoint. The consequence of allowing for distinction between these types of endpoints is a slight tweak to the KPI calculations.

If we want to calculate total seizures for the process, it should be calculated as the sum of all units in blue and red endpoints combined. This can be formulated as:

$$S = \text{total seized} = \sum_{br} V_i$$

where

V_i = the number of units in endpoint i , and

br symbolises that the sum should be calculated across all blue and red endpoints.

Total leakage, L , on the other hand, is a random variable calculated from surveys on the endpoints. A point estimate can be calculated as:

$$\hat{L} = \sum_{gb} \hat{L}_i = \sum_{gb} V_i \hat{l}_i$$

where

\hat{L}_i = the estimated leaked units in endpoint i

\hat{l}_i = the sample leakage rate in endpoint i , and

gb symbolises that the sum should be calculated across all green and blue endpoints.

Because interaction isn't perfect, some units passing through blue endpoints will still have non-compliance. Such units will be counted as both seizures and leakage. This needs to be taken into account in the calculation of the KPIs.

The number of double-counted units, o (for overlap), is the estimated leakage through the blue endpoints and is estimated as:

$$\hat{o} = \sum_b \hat{L}_i = \sum_b V_i \hat{l}_i$$

Approaching Compliance

The AC is the ‘approaching compliance’, that is, the proportion of units that are compliant before any interaction with the department. We can think of it as being a measure that assists in understanding the inherent risk of the pathway. The formula for AC for any pathway is:

$$\begin{aligned}
 AC &= \frac{\text{number of compliant units in pathway before interaction}}{\text{pathway incoming volume (in units)}} \\
 &= 1 - \frac{\text{number of noncompliant units in pathway before interaction}}{\text{pathway incoming volume (in units)}} \\
 &= 1 - \frac{\text{total seized} + \text{total leaked} - \text{overlap}}{\text{pathway incoming volume (in units)}} \\
 &= 1 - \frac{S + L - o}{V}
 \end{aligned}$$

where

V: is the number of units in the pathway of interest.

The point estimate for AC is:

$$\widehat{AC} = 1 - \frac{S + \hat{L} - \hat{o}}{V} = 1 - \frac{\sum_{br} V_i + \sum_g V_i \hat{l}_i}{V}$$

This is one minus the proportion of units that were non-compliant pre-interaction, that is, the units in the red and blue categories as well as the estimated leakage in the green category.

Residual Compliance

The RC is the proportion of outgoing units that are compliant following interaction with the department:

$$\begin{aligned}
 RC &= \frac{\text{number of compliant units in pathway post interaction}}{\text{pathway outgoing volume (in units)}} \\
 &= 1 - \frac{\text{number of noncompliant units in pathway post interaction}}{\text{pathway outgoing volume (in units)}} \\
 &= 1 - \frac{\text{total leaked}}{\text{pathway outgoing volume (in units)}} \\
 &= 1 - \frac{L}{V - \sum_r V_i}
 \end{aligned}$$

Note that the volumes in the red endpoints are subtracted from the initial volume in the denominator, as these units are not released.

The point estimate for RC is:

$$\widehat{RC} = 1 - \frac{\hat{L}}{V - \sum_r V_i} = 1 - \frac{\sum_{gb} V_i \hat{l}_i}{V - \sum_r V_i}$$

Non-Compliance Effectiveness

The non-compliance effectiveness (NCE) of a tool tells us the sensitivity of that tool at identifying non-compliant units. The formula for calculating the NCE differs

between a screening or an inspection tool. To calculate the NCE of screening and inspection, we define, for any node, θ :

- 365 $c_{>\theta}$: indicates that a sum should be taken across all c endpoints that are at least one node away from θ
 $c_{\theta+}$: indicates that a sum should be taken across all c endpoints after θ
 c_{θ} : indicates the c endpoints that branch directly off node θ .
In these cases, c might be g for green endpoints, br for blue and red endpoints, and
370 so on.

NCE screening

- The NCE of screening (as defined for a particular tool) is the proportion of noncompliant units that were sent for further interaction, for instance, inspection, or alternatively, seizing these units for treatment or exportation/destruction. For any
375 node θ :

$$\begin{aligned} NCE_{screen}(\theta) &= \frac{\text{noncompliant units referred or seized after passing through } \theta}{\text{noncompliant units screened through } \theta} \\ &= \frac{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i l_i}{\sum_{br>\theta} V_i + \sum_{g_{\theta+}} V_i l_i} \end{aligned}$$

where

l_i is the true proportion leaked in endpoint i .

- 380 This can generally be estimated by:

$$\widehat{NCE}_{screen}(\theta) = \frac{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i \hat{l}_i}{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i \hat{l}_i + \sum_{g_{\theta}} V_i \hat{l}_i}$$

- A KPI criterion non-compliant unit that was sent for inspection after screening (i.e. those units with the $> \theta$ subscript) had the correct decision made at the screening stage, whether or not inspection then picked up the non-compliance. Note that the
385 formula given above, of the estimate in terms of green, blue and red endpoints, will occasionally need slight modification, because of the nuances of some pathways, as noted in Pathway groups: KPI calculation manual.

NCE inspection

- The NCE of inspection is applicable for inspection nodes only. These nodes generally lead to endpoints only, with some exceptions. Group E: External containers is a little different as there are multiple inspections on one unit. This will be discussed in more detail later.

395

$$NCE_{inspection} = \frac{\text{Noncompliant units seized after passing through } \theta}{\text{noncompliant units inspected through } \theta}$$

A question arises in the calculation of the numerator, namely, whether or not to include those units that were seized, but subsequently still have leakage, that is, the

‘overlap’. For these units, the inspection tool has picked up some of the criterion non-compliance, but despite this, we recommend not including these units, as they still have some remaining non-compliance. Hence, for any node θ , the NCE inspection is:

$$NCE_{inspect}(\theta) = \frac{\sum_{r_\theta} V_i + \sum_{b_\theta} V_i (1 - l_i)}{\sum_{br_\theta} V_i + \sum_{g_\theta} V_i l_i}$$

This can be estimated by:

$$\widehat{NCE}_{inspect}(\theta) = \frac{\sum_{r_\theta} V_i + \sum_{b_\theta} V_i (1 - \hat{l}_i)}{\sum_{br_\theta} V_i + \sum_{g_\theta} V_i \hat{l}_i}$$

As noted earlier, for the blue category in the numerator, the leakage has been subtracted from that treated, because these units are still non-compliant following treatment.

Hit rate

The hit rate can be calculated for any node, to determine the proportion of KPI criterion non-compliant units entering that node. This is useful in looking at the load on different tools with respect to the underlying contamination they are being sent.

$$\text{Hit rate} = \frac{\text{noncompliant units entering node}}{\text{volume entering node (in units)}}$$

So, the point estimate of the hit rate for node θ can be estimated by:

$$\widehat{hr}_\theta = \frac{\sum_{br_{\theta+}} V_i + \sum_{g_{\theta+}} V_i \hat{l}_i}{V_\theta}$$

Pathway groups: KPI calculation manual

This manual gives some further description for how KPIs are to be calculated for the different pathways. Generally:

V_i is the volume (or seizures for red endpoints) at node i

n_i are the surveys at node i

x_i are the endpoint survey seizures at node i

z_α is the value that creates $(1 - \alpha)\%$ CIs for the standard normal distribution

$\hat{l}_i = \frac{x_i}{n_i}$ and

$\widehat{Var}(\hat{l}_i) = \left(1 + \frac{z_\alpha^2}{n_i}\right)^{-2} \left(\frac{1}{n_i} \hat{l}_i (1 - \hat{l}_i) + \frac{z_\alpha^2}{4n_i^2}\right)$ are the Wilson variances (see CEBRA report 1301B for more detail).

Table 2: KPI formulae

KPI	Point estimate	Interval ³
AC	$1 - \frac{S + \hat{L} - \hat{\theta}}{V}$	$\widehat{AC} \pm z_\alpha \hat{\sigma}_{\widehat{AC}}$ where $\hat{\sigma}_{\widehat{AC}}^2 = \frac{1}{V^2} \sum_g V_i^2 \widehat{Var}(\hat{l}_i)$
RC	$1 - \frac{\hat{L}}{V - \sum_r V_i}$	$\widehat{RC} \pm z_\alpha \hat{\sigma}_{\widehat{RC}}$ where $\hat{\sigma}_{\widehat{RC}}^2 = \frac{1}{(V - \sum_r V_i)^2} \sum_{gb} V_i^2 \widehat{Var}(\hat{l}_i)$
NCE screening (node θ)	$\frac{\bar{x}}{\bar{x} + \bar{y}} = \frac{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i \hat{l}_i}{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i \hat{l}_i + \sum_{g\theta} V_i \hat{l}_i}$	$\frac{1}{1 + \frac{\bar{x}\bar{y} \mp z_\alpha \sqrt{\bar{y}^2 \hat{\sigma}_x^2 + \bar{x}^2 \hat{\sigma}_y^2 - z_\alpha^2 \hat{\sigma}_x^2 \hat{\sigma}_y^2}}{\bar{x}^2 - z_\alpha^2 \hat{\sigma}_x^2}}$ where $\hat{\sigma}_x^2 = \sum_{g>\theta} V_i^2 \widehat{Var}(\hat{l}_i)$ $\hat{\sigma}_y^2 = \sum_{g\theta} V_i^2 \widehat{Var}(\hat{l}_i)$
NCE inspection (node θ)	$\frac{\bar{x}}{\bar{y}} = \frac{\sum_{r\theta} V_i + \sum_{b\theta} V_i (1 - \hat{l}_i)}{\sum_{br\theta} V_i + \sum_{g\theta} V_i \hat{l}_i}$	$\widehat{NCE}_{inspect}(\theta) \pm z_\alpha \hat{\sigma}_{\widehat{NCE}_{inspect}(\theta)}$ where $\hat{\sigma}_{\widehat{NCE}_{inspect}(\theta)}^2 = \left(\frac{\bar{x}}{\bar{y}^2}\right)^2 \sum_{g\theta} V_i^2 \widehat{Var}(\hat{l}_i)$ $= \left(\frac{\bar{x}}{\bar{y}^2}\right)^2 \hat{\sigma}_y^2$
Hit rate (node θ)	$\widehat{hr}_\theta = \frac{\sum_{br\theta+} V_i + \sum_{g\theta+} V_i \hat{l}_i}{V_\theta}$	$\widehat{hr}_\theta \pm z_\alpha \hat{\sigma}_{\widehat{hr}_\theta}$ where $\hat{\sigma}_{\widehat{hr}_\theta}^2 = \frac{1}{V_\theta^2} \sum_{g\theta+} V_i^2 \widehat{Var}(\hat{l}_i)$

³ See Appendix B: Confidence Intervals for more detail

This guide assumes that $n_i \neq 0$ unless $V_i = 0$ for each i in the set of endpoints where endpoint surveys are to be collected. To adjust AC and RC in cases of no surveys in some blue and green endpoints, see the methodology in the relevant section. In the case of missing survey data for NCE or hit rate calculations, we do not recommend an alternative survey set.

Spreadsheets

The following pages describe more specifically how the KPIs are calculated for each group. The formulae presented are applied in the spreadsheets accompanying this report. The information that needs to be collected for KPI calculation is highlighted in the spreadsheets. Note that not all node volumes are required, some volumes can be determined from the volumes in other nodes. The high-lighted nodes represent one set of data that would be required to do this, but there may be other options that are, practically, more feasible. Alternative information collection strategies can be determined with reference to the flowcharts and the 'notes on calculation' in the tables under 'Nodes' for each group.

The spreadsheets have a flexible confidence for interval reporting. The default is 95%.

Undetected units

Several pathways have undetected units. These are units that are not identified in normal department operations but are still potentially non-compliant. An example of such a vessel is an illegally arriving boat. In the case where the volume in this category is determined to be irrelevant or negligible, a 0 should be entered in the relevant position in the spreadsheet.

Given that the units in this category are undetected, it is difficult both to get a handle on the volume as well as the level of leakage through these channels. However, information may be available through other sources. For instance, Department of Immigration and Border Protection keep a record of the number of illegally arriving vessels and travellers that were intercepted⁴. These unannounced vessels could be surveyed, and likely have the same rate of leakage as those vessels that were never detected.

The strength of this tool is in testing the effect on the KPIs of different assumptions about volumes and leakage rates.

⁴ <https://www.border.gov.au/about/reports-publications/research-statistics/statistics/live-in-australia/immigration-detention>

475 Group A: Cargo

Unit

Consignment

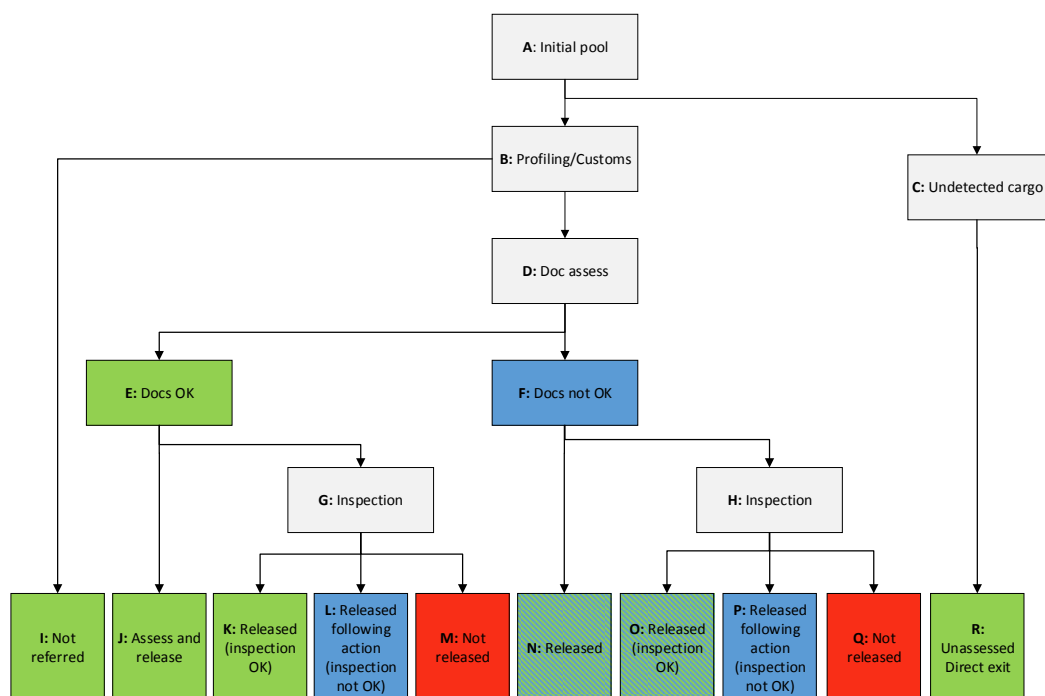


Figure A: Cargo flowchart

480 Description

The cargo group covers all cargo pathways, including:

- Break bulk cargo
- Bulk cargo
- Commercial Air cargo
- Non-commercial air cargo
- Containerised sea cargo
- Military equipment
- Temporary imports

490 The KPI criterion for this pathway includes a result of 'not OK' for the document assessment and/or 'not OK' for the inspection.

Node C (which is irrelevant for military equipment and temporary imports) relates to illegally smuggled cargo that is not recorded in the system and passes through the border undetected. Note that this does not include undeclared items that are part of a consignment that is declared.

In this case, we have a slightly unusual case, in that nodes N and O are blue-green nodes. In this case that means that they are counted as blue endpoints for the purposes of AC and RC calculations, given that they are below the 'docs not OK' breakdown. However, for the purpose of inspection NCE and hit rate, they are

treated as green endpoints. This is the most logical way to calculate the NCE and hit rate, because the inspection is not necessarily targeting the type of non-compliance identified by the document assessment. Nodes E and F have been coloured green and blue not because they're endpoints, but to show the result of doc assessment. The result of the document assessment is either that 'docs are ok', and the unit moves to the next stage (green), or that 'docs are not ok' and the unit has some action to fix this NC with the criterion (blue).

Nodes

Level	Type	Node	Notes on calculation
Initial pool	Volume	A	$A=B+C$
Profiling/Customs	Volume	B	
Undetected cargo	Volume	C	
Doc assess	Volume	D	
Docs OK	Volume	E	
Docs not OK	Volume	F	$F=D-E$
Inspection, docs OK	Volume	G	
Inspection, docs not OK	Volume	H	
Released, not referred	Volume, green endpoint	I	$I=B-D$
Assessed and released, docs OK	Volume, green endpoint	J	$J=E-G$
Released following inspection OK, docs OK	Volume, green endpoint	K	$K=G-L-M$
Released following action, inspection not OK, docs OK	Volume, blue endpoint	L	
Not released following inspection, docs OK	Seizure, red endpoint	M	
Released, assess and release, docs not OK	Volume, blue-green endpoint	N	$N=F-H$
Released following inspection OK, docs not OK	Volume, blue-green endpoint	O	$O=H-P-Q$
Released following action, inspection not OK, docs not OK	Volume, blue endpoint	P	
Not released following inspection, docs not OK	Seizure, red endpoint	Q	
Released, unassessed direct	Volume, green endpoint	R	$R=C$

exit, undetected			
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Surveys

Surveys should be taken at I, J, K, L, N, O, and P. Leakage information at R, if available, is also useful. When implementing the endpoint surveys, these are constructed in the following streams:

- Not referred (I)
- Assess and release (J, N), noting whether or not a 'docs not OK' result was previously recorded against the unit
- Inspection (K, L, O, P), noting whether or not a 'docs not OK' result was previously recorded against the unit, and whether or not a unit has undergone any action for KPI criterion non-compliance, such as treatment

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_L + V_M + V_F$$

$$\hat{L} = V_I \frac{x_I}{n_I} + V_J \frac{x_J}{n_J} + V_K \frac{x_K}{n_K} + V_L \frac{x_L}{n_L} + V_N \frac{x_N}{n_N} + V_O \frac{x_O}{n_O} + V_P \frac{x_P}{n_P} + V_R \frac{x_R}{n_R}$$

$$\hat{o} = V_L \frac{x_L}{n_L} + V_N \frac{x_N}{n_N} + V_O \frac{x_O}{n_O} + V_P \frac{x_P}{n_P}$$

$$\hat{\sigma}_{AC} = \sqrt{\sum_{i=\{I,J,K,R\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

$$\hat{\sigma}_{RC} = \sqrt{\sum_{i=\{I,J,K,L,N,O,P,R\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
Profiling/Customs referral	$S + \hat{L} - \hat{o} - y - V_R \hat{l}_R$	$V_I \hat{l}_I$	$\sum_{i=\{J,K\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_I^2 \widehat{Var}(\hat{l}_I)$
Screening: doc assessment to inspection	$\sum_{i=\{L,M,P,Q\}} V_i + \sum_{i=\{K,O\}} V_i \hat{l}_i$	$V_J \hat{l}_J + V_N \hat{l}_N$	$\sum_{i=\{K,O\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$\sum_{i=\{J,N\}} V_i^2 \widehat{Var}(\hat{l}_i)$
Inspection	$\sum_{i=\{M,Q\}} V_i + \sum_{i=\{L,P\}} V_i (1 - \hat{l}_i)$	$\sum_{i=\{L,M,P,Q\}} V_i + \sum_{i=\{K,O\}} V_i \hat{l}_i$	-	$\sum_{i=\{K,O\}} V_i^2 \widehat{Var}(\hat{l}_i)$

Hit rate

Node	Point estimate	$\hat{\sigma}_{hr_\theta}$
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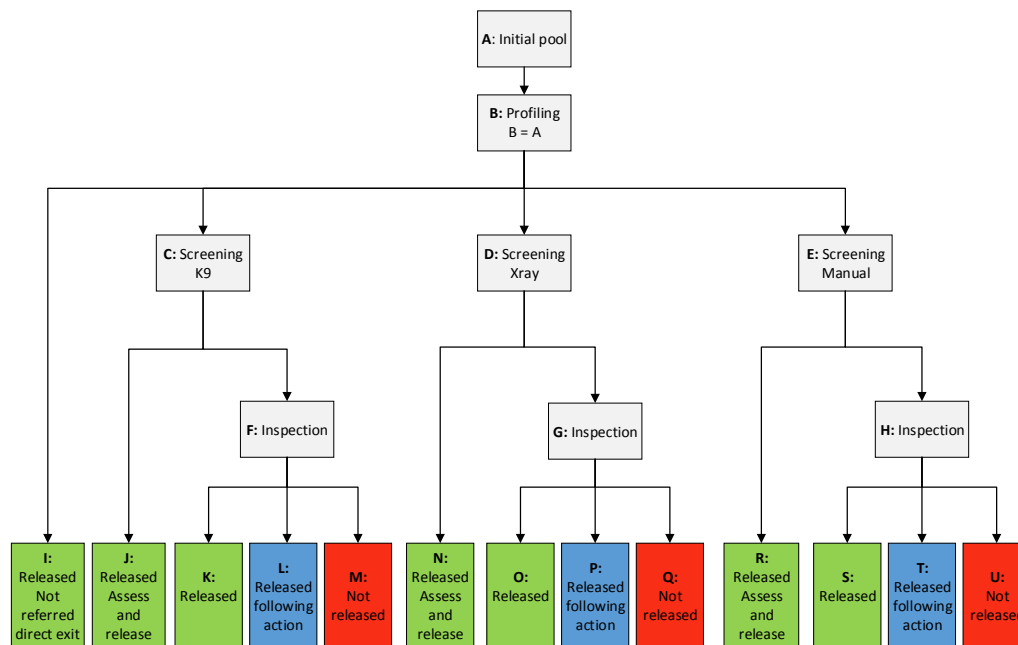
Screening: doc assessment	$\frac{V_F + V_M + V_L + V_K \hat{l}_K + V_J \hat{l}_J}{V_D}$	$\frac{\sqrt{(V_K)^2 \widehat{Var}(\hat{l}_K) + (V_J)^2 \widehat{Var}(\hat{l}_J)}}{V_D}$
Docs OK	$\frac{V_M + V_L + V_K \hat{l}_K + V_J \hat{l}_J}{V_E}$	$\frac{\sqrt{(V_K)^2 \widehat{Var}(\hat{l}_K) + (V_J)^2 \widehat{Var}(\hat{l}_J)}}{V_E}$
Docs not OK	$\frac{V_Q + V_P + V_O \hat{l}_O + V_N \hat{l}_N}{V_F}$	$\frac{\sqrt{(V_O)^2 \widehat{Var}(\hat{l}_O) + (V_N)^2 \widehat{Var}(\hat{l}_N)}}{V_F}$
Inspection	$\frac{\sum_{i=\{L,M,P,Q\}} V_i + \sum_{i=\{K,O\}} V_i \hat{l}_i}{V_G + V_H}$	$\frac{\sqrt{(V_O)^2 \widehat{Var}(\hat{l}_O) + (V_K)^2 \widehat{Var}(\hat{l}_K)}}{V_G + \mathbb{I}_H}$

530

Group B: Mail

Unit

Mail item



535 **Figure B:** Mail flowchart

Description

This group refers to both letter and non-letter class. The flowchart and spreadsheet can be applied to either of these pathways. The criterion for the KPIs for both letter and non-letter class refer to compliance with biosecurity regulation.

540

Nodes

Level	Type	Node	Notes on calculation
Initial pool	Volume	A	
Profiling	Volume	B	B=A
Screening: K9	Volume	C	
Screening: Xray	Volume	D	
Screening: Manual	Volume	E	
Inspection following K9 screening	Volume	F	
Inspection following Xray screening	Volume	G	
Inspection following Manual screening	Volume	H	
Released, not referred, direct exit	Volume, green endpoint	I	$I = B - C - D - E$
Released following K9	Volume, green	J	$J = C - F$

screened	endpoint		
Released following inspection and K9 screening	Volume, green endpoint	K	K=F-L-M
Released following action after inspection and K9 screening	Seizure, blue endpoint	L	
Not released, following inspection and K9 screening	Seizure, red endpoint	M	
Released following Xray screened	Volume, green endpoint	N	N=D-G
Released following inspection and Xray screening	Volume, green endpoint	O	O=G-P-Q
Released following action after inspection and Xray screening	Seizure, blue endpoint	P	
Not released, following inspection and Xray screening	Seizure, red endpoint	Q	
Released following manual screened	Volume, green endpoint	R	R=E-H
Released following inspection and manual screening	Volume, green endpoint	S	S=H-T-U
Released following action after inspection and manual screening	Seizure, blue endpoint	T	
Not released, following inspection and manual screening	Seizure, red endpoint	U	

Surveys

545 Surveys should be taken at I, J, K, L, N, O, P, R, S and T. When implementing the endpoint surveys, these are constructed in the following streams:

- Not referred (I)
- Assess and release (J, N, R), noting which screening tool a unit had applied to it
- Inspection (K, L, O, P, S, T), noting which screening tool a unit had applied to it, and whether or not a unit has undergone any action for KPI criterion non-compliance, such as treatment

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_L + V_M + V_P + V_Q + V_T + \mathbb{Q}_U$$

$$\hat{L} = V_I \hat{l}_I + V_J \hat{l}_J + V_K \hat{l}_K + V_L \hat{l}_L + V_N \hat{l}_N + V_O \hat{l}_O + V_P \hat{l}_P + V_R \hat{l}_R + V_S \hat{l}_S + V_T \hat{l}_T$$

$$\hat{o} = V_L \hat{l}_L + V_P \hat{l}_P + V_T \hat{l}_T$$

$$\hat{\sigma}_{\widehat{AC}} = \sqrt{\sum_{i=\{I,J,K,N,O,R,S\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

$$\hat{\sigma}_{\widehat{RC}} = \sqrt{\sum_{i=\{I,J,K,L,N,O,P,R,S,T\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

555

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
Profiling	$S + \hat{L} - \hat{o}$ $- \bar{y}$	$V_I \hat{l}_I$	$\sum_{i=\{J,K,N,O,R,S\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_I^2 \widehat{Var}(\hat{l}_I)$
Screening: K9	$V_L + V_M$ $+ V_K \hat{l}_K$	$V_J \hat{l}_J$	$V_K^2 \widehat{Var}(\hat{l}_K)$	$V_J^2 \widehat{Var}(\hat{l}_J)$
Screening: Xray	$V_P + V_Q$ $+ V_O \hat{l}_O$	$V_N \hat{l}_N$	$V_O^2 \widehat{Var}(\hat{l}_O)$	$V_N^2 \widehat{Var}(\hat{l}_N)$
Screening: Manual	$V_T + V_U$ $+ V_S \hat{l}_S$	$V_R \hat{l}_R$	$V_S^2 \widehat{Var}(\hat{l}_S)$	$V_R^2 \widehat{Var}(\hat{l}_R)$
Inspection	$\sum_{i=\{M,Q,U\}} V_i$ $+ \sum_{i=\{L,P,T\}} V_i (1$ $- \hat{l}_i)$	$\sum_{i=\{K,O,S\}} V_i \hat{l}_i$ $+ \sum_{i=\{L,P,T,M,Q,U\}} V_i$	-	$\sum_{i=\{K,O,S\}} V_i^2 \widehat{Var}(\hat{l}_i)$

Hit rate

Node	Point estimate	$\hat{\sigma}_{hr_\theta}$
Direct exit	\hat{l}_I	$\sqrt{\widehat{Var}(\hat{l}_I)}$
Screening	$\frac{\sum_{i=\{K,J,O,N,S,R\}} V_i \hat{l}_i + \sum_{i=\{L,M,P,Q,T,U\}} V_i}{V_C + V_D + V_E}$	$\frac{\sqrt{\sum_{i=\{K,J,O,N,S,R\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_C + V_D + V_E}$
Screening: K9	$\frac{V_L + V_M + V_K \hat{l}_K + V_J \hat{l}_J}{V_C}$	$\frac{\sqrt{(V_K)^2 \widehat{Var}(\hat{l}_K) + (V_J)^2 \widehat{Var}(\hat{l}_J)}}{V_C}$
Screening: Xray	$\frac{V_P + V_Q + V_O \hat{l}_O + V_N \hat{l}_N}{V_D}$	$\frac{\sqrt{(V_O)^2 \widehat{Var}(\hat{l}_O) + (V_N)^2 \widehat{Var}(\hat{l}_N)}}{V_D}$
Screening: Manual	$\frac{V_T + V_U + V_S \hat{l}_S + V_R \hat{l}_R}{V_E}$	$\frac{\sqrt{(V_S)^2 \widehat{Var}(\hat{l}_S) + (V_R)^2 \widehat{Var}(\hat{l}_R)}}{V_E}$
Inspection	$\frac{\sum_{i=\{L,M,P,Q,T,U\}} V_i + \sum_{i=\{K,O,S\}} V_i \hat{l}_i}{V_F + V_G + V_H}$	$\frac{\sqrt{\sum_{i=\{K,O,S\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_F + V_G + V_H}$

560 **Group C: Travellers**

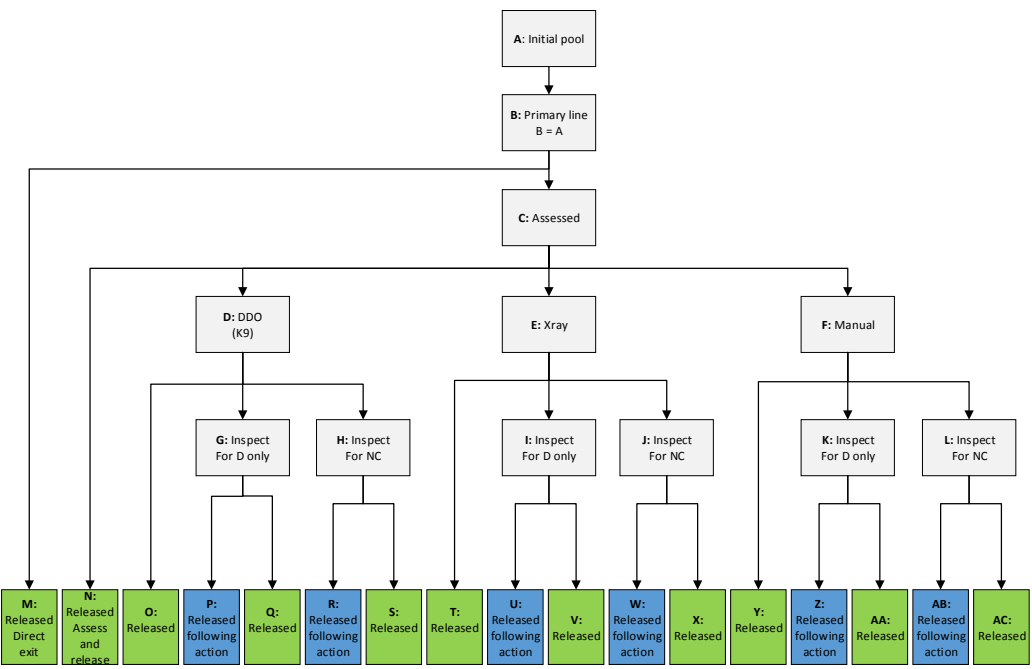
Unit
Traveller

Description

565 This group depicts the process of traveller pathways. It could be used to get KPIs for air travellers, sea travellers (including undetected arrivals) and day-trippers. Undetected passengers are included in node C in the Non-declarants sub-group. The KPI criterion for this group is a non-compliance, not just the identification of biosecurity risk material. Note that the blue endpoints refer only to seizures of undeclared non-compliance. Hence, KPIs are calculated separately for declarants and non-declarants, with an added spreadsheet that combines the figures into overall KPIs for the pathway.

570

Subgroup C_i: Travellers (declarants)



575 **Figure C_i: Declarant travellers flowchart**

Nodes

Level	Type	Node	Notes on calculation
Initial Pool	Volume	A	
Primary line	Volume	B	B=A
Assessed	Volume	C	
Screened: DDO/K9	Volume	D	

Screened: Xray	Volume	E	
Screened: Manual	Volume	F	
Inspect for declared goods only, following K9 screening	Volume	G	
Inspect for non-compliance, following K9 screening	Volume	H	
Inspect for declared goods only, following Xray screening	Volume	I	
Inspect for non-compliance, following Xray screening	Volume	J	
Inspect for declared goods only, following Manual screening	Volume	K	
Inspect for non-compliance, following Manual screening	Volume	L	
Released, direct exit, unassessed	Volume, green endpoint	M	$M=B-C$
Released, assess and release	Volume, green endpoint	N	$N=C-D-E-F$
Released following K9 screening	Volume, green endpoint	O	$O=D-G-H$
Released following action and inspection for declared goods after K9 screening	Seizure, blue endpoint	P	
Released following inspection for declared goods after K9 screening	Volume, green endpoint	Q	$Q=G-P$
Released following action after inspection and K9 screening	Seizure, blue endpoint	R	
Released following inspection after K9 screening	Volume, green endpoint	S	$S=H-R$
Released following Xray screening	Volume, green endpoint	T	$T=E-I-J$
Released following action and inspection for declared goods after Xray screening	Seizure, blue endpoint	U	
Released following inspection for declared	Volume, green endpoint	V	$V=I-U$

goods after Xray screening			
Released following action after inspection and Xray screening	Seizure, blue endpoint	W	
Released following inspection after Xray screening	Volume, green endpoint	X	X=J-W
Released following Manual screening	Volume, green endpoint	Y	Y=F-K-L
Released following action and inspection for declared goods after Manual screening	Seizure, blue endpoint	Z	
Released following inspection for declared goods after Manual screening	Volume, green endpoint	AA	AA=K-Z
Released following action after inspection and Manual screening	Seizure, blue endpoint	AB	
Released following inspection after Manual screening	Volume, green endpoint	AC	AC=L-AB

580 Surveys

Surveys should be taken at M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, AA, AB and AC. When implementing the endpoint surveys, these will be constructed in the following streams:

- Direct exit (M)
- Assess and release (N)
- Screened and release (O, T, Y), noting which screening tool a unit had applied to it
- Inspection for declared goods only (P, Q, U, V, Z, AA), noting which screening tool a unit had applied to it and whether or not the traveller had an action taken against them, such as a good treated or taken off them
- Inspection (R, S, W, X, AB, AC), noting which screening tool a unit had applied to it and whether or not the traveller had an action taken against them, such as a good treated or taken off them

595 Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_P + V_R + V_U + V_W + V_Z + V_{AB}$$

$$\hat{L} = \sum_{i=\{M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z,AA,AB,AC\}} V_i \hat{l}_i$$

$$\hat{\delta} = V_P \hat{l}_P + V_R \hat{l}_R + V_U \hat{l}_U + V_W \hat{l}_W + V_Z \hat{l}_Z + V_{AB} \hat{l}_{AB}$$

$$\hat{\sigma}_{\widehat{AC}} = \sqrt{\sum_{i=\{M,N,O,Q,S,T,V,X,Y,AA,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

$$\hat{\sigma}_{\widehat{RC}} = \sqrt{\sum_{i=\{M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z,AA,AB,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

NCE

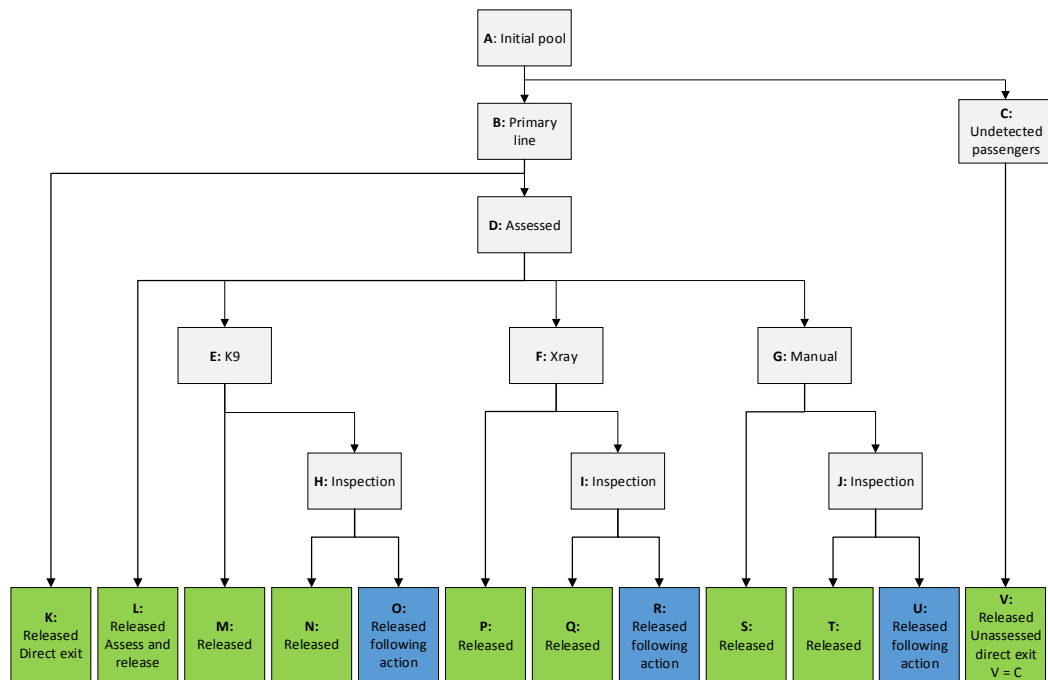
Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
Screening: Profiling	$S + \hat{L} - \hat{\delta} - \bar{y}$	$V_M \hat{l}_M$	$\sum_{i=\{N,O,Q,S,T,V,X,Y,AA,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_M^2 \widehat{Var}(\hat{l}_M)$
Screening: Assessment	$S + \hat{L} - \hat{\delta} - V_M \hat{l}_M - \bar{y}$	$V_N \hat{l}_N$	$\sum_{i=\{O,Q,S,T,V,X,Y,AA,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_N^2 \widehat{Var}(\hat{l}_N)$
Screening: K9	$V_Q \hat{l}_Q + V_S \hat{l}_S + V_P + V_R$	$V_O \hat{l}_O$	$V_Q^2 \widehat{Var}(\hat{l}_Q) + V_S^2 \widehat{Var}(\hat{l}_S)$	$V_O^2 \widehat{Var}(\hat{l}_O)$
Screening: Xray	$V_V \hat{l}_V + V_X \hat{l}_X + V_U + V_W$	$V_T \hat{l}_T$	$V_V^2 \widehat{Var}(\hat{l}_V) + V_X^2 \widehat{Var}(\hat{l}_X)$	$V_T^2 \widehat{Var}(\hat{l}_T)$
Screening: Manual	$V_{AA} \hat{l}_{AA} + V_{AC} \hat{l}_{AC} + V_Z + V_{AB}$	$V_Y \hat{l}_Y$	$V_{AA}^2 \widehat{Var}(\hat{l}_{AA}) + V_{AC}^2 \widehat{Var}(\hat{l}_{AC})$	$V_Y^2 \widehat{Var}(\hat{l}_Y)$
Inspection for declared only	$\sum_{i=\{P,U,Z\}} V_i (1 - \hat{l}_i)$	$\sum_{i=\{P,U,Z\}} V_i + \sum_{i=\{Q,V,AA\}} V_i \hat{l}_i$	-	$\sum_{i=\{Q,V,AA\}} V_i^2 \widehat{Var}(\hat{l}_i)$
Inspection	$\sum_{i=\{R,W,AB\}} V_i (1 - \hat{l}_i)$	$\sum_{i=\{R,W,AB\}} V_i + \sum_{i=\{S,X,AC\}} V_i \hat{l}_i$	-	$\sum_{i=\{S,X,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)$

600 Hit rate

Node	Point estimate	$\hat{\sigma}_{\widehat{hr}_\theta}$
Screening	$\frac{\sum_{i=\{P,R,U,W,Z,AB\}} V_i + \sum_{i=\{Q,S,O,V,X,T,AA,AC,Y\}} V_i \hat{l}_i}{V_D + V_E + V_F}$	$\frac{\sqrt{\sum_{i=\{Q,S,O,V,X,T,AA,AC,Y\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_D + V_E + V_F}$
No screening	\hat{l}_N	$\widehat{Var}(\hat{l}_N)$
Screening: K9	$\frac{V_Q \hat{l}_Q + V_S \hat{l}_S + V_P + V_R + V_O \hat{l}_O}{V_D}$	$\frac{\sqrt{\sum_{i=\{Q,S,O\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_D}$
Screening: Xray	$\frac{V_V \hat{l}_V + V_X \hat{l}_X + V_U + V_W + V_T \hat{l}_T}{V_E}$	$\frac{\sqrt{\sum_{i=\{V,W,T\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_E}$
Screening: Manual	$\frac{V_{AA} \hat{l}_{AA} + V_{AC} \hat{l}_{AC} + V_Z + V_{AB} + V_Y \hat{l}_Y}{V_F}$	$\frac{\sqrt{\sum_{i=\{AA,AC,Y\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_F}$

Inspection for declared only	$\frac{V_P + V_U + V_Z + V_Q \hat{l}_Q + V_V \hat{l}_V + V_{AA} \hat{l}_{AA}}{V_G + V_I + V_K}$	$\frac{\sqrt{\sum_{i=\{Q,V,AA\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_G + V_I + V_K}$
Inspection	$\frac{V_R + V_W + V_{AB} + V_S \hat{l}_S + V_X \hat{l}_X + V_{AC} \hat{l}_{AC}}{V_H + V_J + V_L}$	$\frac{\sqrt{\sum_{i=\{S,X,AC\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_H + V_J + V_L}$

Subgroup C_{ii}: Travellers (non-declarants)



605 **Figure C_{ii}:** Non-declarant travellers flowchart

Nodes

Level	Type	Node	Notes on calculation
Initial Pool	Volume	A	$A=B+C$
Primary line	Volume	B	
Undetected travellers	Volume	C	
Assessed	Volume	D	
Screened: DDO/K9	Volume	E	
Screened: Xray	Volume	F	
Screened: Manual	Volume	G	
Inspection following K9 screening	Volume	H	
Inspection following Xray screening	Volume	I	
Inspection following Manual screening	Volume	J	
Released, direct exit, unassessed	Volume, green endpoint	K	$K=B-D$
Released, assess and release	Volume, green endpoint	L	$L=D-E-F-G$
Released following K9 screening	Volume, green endpoint	M	$M=E-H$
Released following	Volume, green	N	$N=H-O$

inspection after K9 screening	endpoint		
Released following action and inspection after K9 screening	Seizure, blue endpoint	O	
Released following Xray screening	Volume, green endpoint	P	P=F-I
Released following inspection after Xray screening	Volume, green endpoint	Q	Q=I-R
Released following action and inspection after Xray screening	Seizure, blue endpoint	R	
Released following Manual screening	Volume, green endpoint	S	S=G-J
Released following inspection after Manual screening	Volume, green endpoint	T	T=J-U
Released following action and inspection after Manual screening	Seizure, blue endpoint	U	
Released, undetected, unassessed, direct exit	Volume, green endpoint	V	V=C

Surveys

- 610 Surveys should be taken at K, L, M, N, O, P, Q, R, S, T and U. Leakage information at V, if available, is also useful. When implementing the endpoint surveys, these will be constructed in the following streams:
- Direct exit (K)
 - Assess and release (L)
 - 615 • Screened and release (M, P, S), noting which screening tool a unit had applied to it
 - Inspection (N, O, Q, R, T, U), noting which screening tool a unit had applied to it and whether or not the traveller had an action taken against them, such as a good treated or taken off them

620

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_O + V_R + V_U$$

$$\hat{L} = \sum_{i=\{K,L,M,N,O,P,Q,R,S,T,U,V\}} V_i \hat{l}_i$$

$$\hat{o} = V_O \hat{l}_O + V_R \hat{l}_R + V_U \hat{l}_U$$

$$\hat{\sigma}_{AC} = \sqrt{\sum_{i=\{K,L,M,N,P,Q,S,T,V\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

$$\hat{\sigma}_{RC} = \sqrt{\sum_{i=\{K,L,M,N,O,P,Q,R,S,T,U,V\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
Screening: Profiling	$S + \hat{L} - \hat{\delta}$ $- V_K \hat{l}_K$ $- V_V \hat{l}_V$	$V_K \hat{l}_K$	$\sum_{i=\{L,M,N,P,Q,S,T\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_K^2 \widehat{Var}(\hat{l}_K)$
Screening: Assessment	$S + \hat{L} - \hat{\delta}$ $- V_K \hat{l}_K - y$ $- V_V \hat{l}_V$	$V_L \hat{l}_L$	$\sum_{i=\{M,N,P,Q,S,T\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$V_L^2 \widehat{Var}(\hat{l}_L)$
Screening: K9	$V_N \hat{l}_N + V_O$	$V_M \hat{l}_M$	$V_N^2 \widehat{Var}(\hat{l}_N)$	$V_M^2 \widehat{Var}(\hat{l}_M)$
Screening: Xray	$V_Q \hat{l}_Q + V_R$	$V_P \hat{l}_P$	$V_Q^2 \widehat{Var}(\hat{l}_Q)$	$V_P^2 \widehat{Var}(\hat{l}_P)$
Screening: Manual	$V_T \hat{l}_T + V_U$	$V_S \hat{l}_S$	$V_T^2 \widehat{Var}(\hat{l}_T)$	$V_S^2 \widehat{Var}(\hat{l}_S)$
Inspection	$\sum_{i=\{O,R,U\}} V_i (1$ $- \hat{l}_i)$	$\sum_{i=\{O,R,U\}} V_i$ $+ \sum_{i=\{N,Q,T\}} V_i \hat{l}_i$	-	$\sum_{i=\{N,Q,T\}} V_i^2 \widehat{Var}(\hat{l}_i)$

625

Hit rate

Node	Point estimate	$\hat{\sigma}_{hr_\theta}$
Screening	$\frac{\sum_{i=\{O,R,U\}} V_i + \sum_{i=\{N,Q,T,M,P,S\}} V_i \hat{l}_i}{V_E + V_F + V_G}$	$\frac{\sqrt{\sum_{i=\{N,Q,T,M,P,S\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_E + V_F + V_G}$
No screening	\hat{l}_L	$\widehat{Var}(\hat{l}_L)$
Screening: K9	$\frac{V_N \hat{l}_N + V_O + V_M \hat{l}_M}{V_E}$	$\frac{\sqrt{\sum_{i=\{N,M\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_E}$
Screening: Xray	$\frac{V_Q \hat{l}_Q + V_R + V_P \hat{l}_P}{V_F}$	$\frac{\sqrt{\sum_{i=\{Q,P\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_F}$
Screening: Manual	$\frac{V_T \hat{l}_T + V_U + V_S \hat{l}_S}{V_G}$	$\frac{\sqrt{\sum_{i=\{S,T\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_G}$
Inspection	$\frac{V_O + V_R + V_U + V_N \hat{l}_N + V_Q \hat{l}_Q + V_T \hat{l}_T}{V_H + V_I + V_J}$	$\frac{\sqrt{\sum_{i=\{N,Q,T\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_H + V_I + V_J}$

Combining subgroups C_i and C_{ii}

Description

- 630 It may be of interest to get the combined AC and RC across declarants and non-declarants for air travellers, and the combined AC and RC across declarants and non-declarants for sea travellers.

Calculating KPIs

- 635 Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_{A,C_i} + V_{A,C_{ii}}$$

$$S = S_{C_i} + S_{C_{ii}}$$

$$\hat{L} = \hat{L}_{C_i} + \hat{L}_{C_{ii}}$$

$$\hat{o} = \hat{o}_{C_i} + \hat{o}_{C_{ii}}$$

$$\hat{\sigma}_{\widehat{AC}} = \frac{1}{V} \sqrt{(V_{A,C_i} \hat{\sigma}_{\widehat{AC},C_i})^2 + (V_{A,C_{ii}} \hat{\sigma}_{\widehat{AC},C_{ii}})^2}$$

$$\hat{\sigma}_{\widehat{RC}} = \frac{1}{V} \sqrt{(V_{A,D_i} \hat{\sigma}_{\widehat{RC},C_i})^2 + (V_{A,D_{ii}} \hat{\sigma}_{\widehat{RC},C_{ii}})^2}$$

where the subscripts C_i and C_{ii} refer to the output from those subgroups.

Group D: Commercial vessels

Unit

640 Vessel

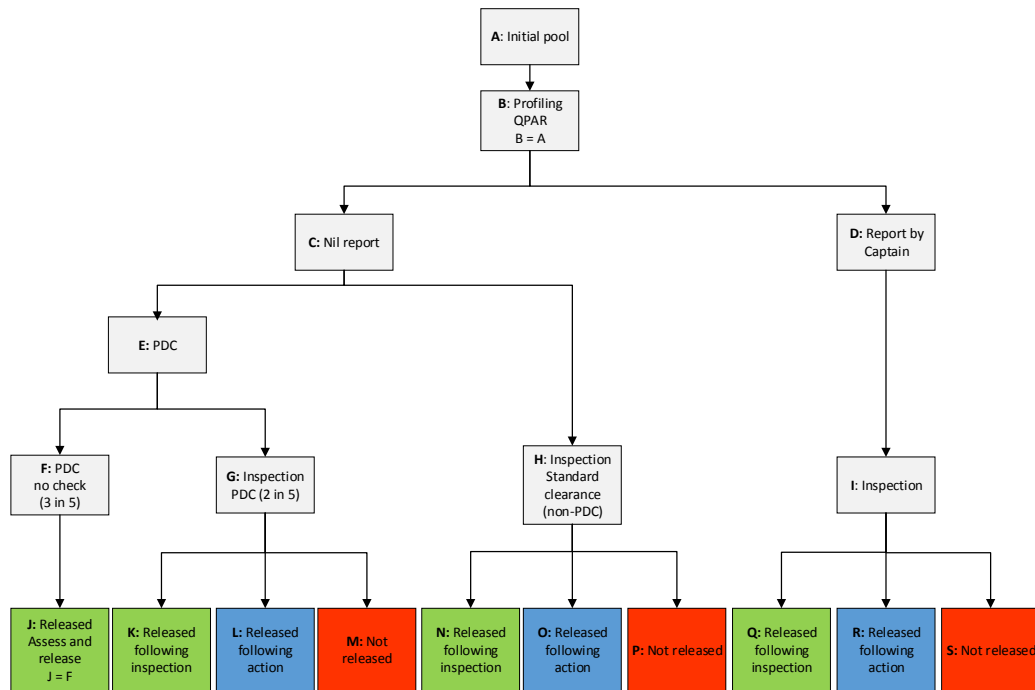


Figure D: Commercial vessels flowchart

Description

645 Non-compliance for this pathway is determined through document assessment (PDC and report by captain, if relevant) and inspection.

Nodes

Level	Type	Node	Notes on calculation
Initial Pool	Volume	A	
QPAR	Volume	B	B=A
Nil report	Volume	C	
Report	Volume	D	D=B-C
PDC (nil report)	Volume	E	
No inspection, PDC (nil report)	Volume	F	F=E-G
Inspection, PDC (nil report)	Volume	G	
Inspection, non-PDC (nil report)	Volume	H	H=C-E
Inspection, report	Volume	I	I=D
Released, assess and release	Volume, green endpoint	J	J=F

Released following inspection (nil report, PDC)	Volume, green endpoint	K	K=G-L-M
Released following treatment and inspection (nil report, PDC)	Seizure, blue endpoint	L	
Not released following inspection (nil report, PDC)	Seizure, red endpoint	M	
Released following inspection (nil report, non-PDC)	Volume, green endpoint	N	N=H-O-P
Released following treatment and inspection (nil report, non-PDC)	Seizure, blue endpoint	O	
Not released following inspection (nil report, non-PDC)	Seizure, red endpoint	P	
Released following inspection (report)	Volume, green endpoint	Q	Q=I-R-S
Released following treatment and inspection (report)	Seizure, blue endpoint	R	
Not released following inspection (report)	Seizure, red endpoint	S	

Surveys

650 Surveys should be taken at J, K, L, N, O, Q and R. When implementing the endpoint surveys, these can be constructed in the following streams:

- Assess and release (J)
- Inspection (K, L, N, O, Q, R), noting whether the vessel had a report by the captain, and if not, whether it was subject to PDC or not

655

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = \sum_{i=\{L,M,O,P,R,S\}} V_i$$

$$\hat{L} = \sum_{i=\{J,K,L,N,O,Q,R\}} V_i \hat{l}_i$$

$$\hat{o} = \sum_{i=\{L,O,R\}} V_i \hat{l}_i$$

$$\hat{\sigma}_{\widehat{AC}} = \sqrt{\sum_{i=\{J,K,N,Q\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

$$\hat{\sigma}_{\widehat{RC}} = \sqrt{\sum_{i=\{J,K,L,N,O,Q,R\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
Inspection	$\sum_{i=\{M,P,S\}} V_i$ + $\sum_{i=\{L,O,R\}} V_i(1 - \hat{l}_i)$	$\sum_{i=\{M,P,S,L,O,R\}} V_i$ + $\sum_{i=\{K,N,Q\}} V_i \hat{l}_i$	-	$\sum_{i=\{K,N,Q\}} V_i^2 \widehat{Var}(\hat{l}_i)$

660

Hit rate

Node	Point estimate	$\hat{\sigma}_{\widehat{hr}_\theta}$
Inspection: PDC	$\frac{V_K \hat{l}_K + V_L + V_M}{V_G}$	$\frac{V_K \sqrt{\widehat{Var}(\hat{l}_K)}}{V_G}$
Inspection: non-PDC	$\frac{V_N \hat{l}_N + V_O + V_P}{V_H}$	$\frac{V_N \sqrt{\widehat{Var}(\hat{l}_N)}}{V_H}$
Inspection: report	$\frac{V_Q \hat{l}_Q + V_R + V_S}{V_I}$	$\frac{V_Q \sqrt{\widehat{Var}(\hat{l}_Q)}}{V_I}$

Group E: External containers

Unit

665 Container

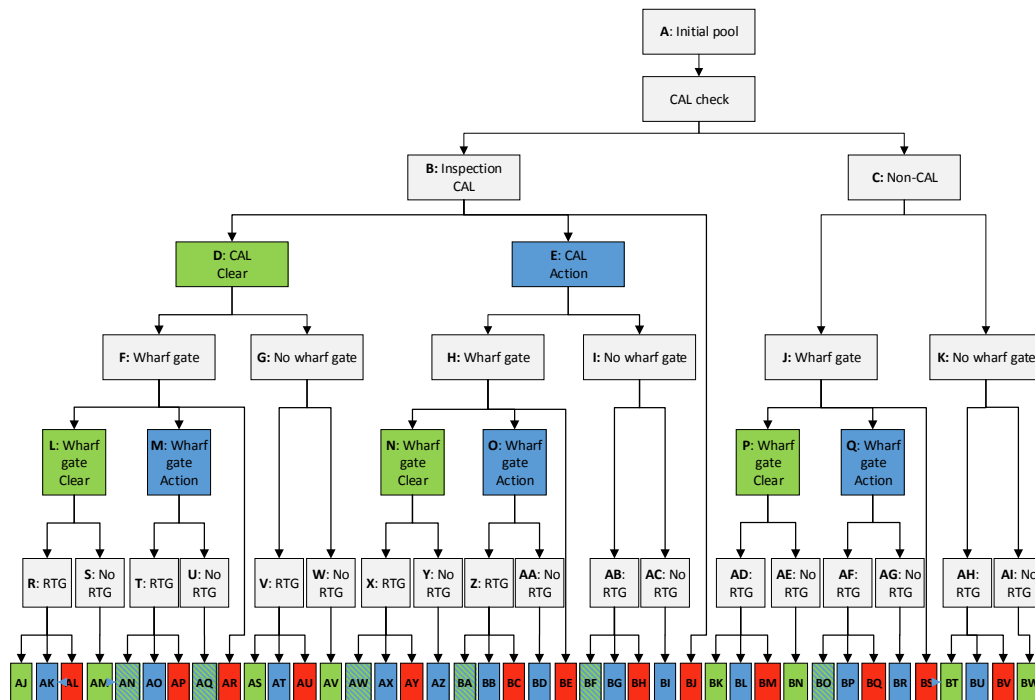


Figure E: External containers flowchart

Description

670 In this group, it is possible that a container could have up to three inspections, a country action list (CAL) inspection, a wharf gate, and a rural tailgate (RTG), hence there are many endpoints. This group is similar to cargo in that some endpoints (in this case, AN, AQ, AW, BA, BF and BO) are blue-green. That is, they are treated as either blue or green endpoints, depending on the KPI being calculated.

675 In particular, the NCE calculations for the CAL and wharf gate inspections are different to the standard inspection NCE calculations. Due to the fact that, for some units, there are multiple inspections, it is possible, in some cases, to determine that an earlier inspection has failed. For example, note that the units going into node E were all actioned for non-compliance with the KPI criterion following the CAL inspection, yet, following wharf gate inspection, some units were again actioned for KPI criterion non-compliance (i.e. node O), indicating that the earlier inspection and treatment had failed to pick up and/or get rid of all KPI criterion non-compliance. These nuances are captured in the KPIs by recalling that:

$$NCE_{inspection} = \frac{\text{Noncompliant units seized after passing through } \theta}{\text{noncompliant units inspected through } \theta}$$

685

where 'seized' in this sense means that the units were found to be non-compliant but were no longer non-compliant following action that was administered as a result of passing through the inspection for which the KPI is being calculated.

690 **Nodes**

Level	Type	Node	Notes on calculation
Initial pool	Volume	A	
CAL	Volume	B	
non-CAL	Volume	C	$C=A-B$
CAL clear	Volume	D	$D=B-E-BJ$
CAL action	Seizure	E	
wharf gate (CAL clear)	Volume	F	
no wharf gate (CAL clear)	Volume	G	$G=D-F$
wharf gate (CAL actioned)	Volume	H	
no wharf gate (CAL actioned)	Volume	I	$I=E-H$
wharf gate (non-CAL)	Volume	J	
no wharf gate (non-CAL)	Volume	K	$K=C-J$
wharf gate clear (CAL clear)	Volume	L	$L=F-M-AR$
wharf gate action (CAL clear)	Seizure	M	
wharf gate clear (CAL action)	Volume	N	$N=H-O-BE$
wharf gate action (CAL actioned)	Seizure	O	
wharf gate clear (non-CAL)	Volume	P	$P=J-Q-BS$
wharf gate action (non-CAL)	Seizure	Q	
RTG (CAL clear, wharf gate clear)	Volume	R	
no RTG (CAL clear, wharf gate)	Volume	S	$S=L-R$
RTG (CAL clear, wharf gate actioned)	Volume	T	
no RTG (CAL clear, wharf gate actioned)	Volume	U	$U=M-T$
RTG (CAL clear, no wharf)	Volume	V	
no RTG (CAL clear, no	Volume	W	$W=G-V$

wharf)			
RTG (CAL actioned, wharf gate clear)	Volume	X	
no RTG (CAL actioned, wharf gate)	Volume	Y	$Y=N-X$
RTG (CAL actioned, wharf gate actioned)	Volume	Z	
no RTG (CAL actioned, wharf gate actioned)	Volume	AA	$AA=O-Z$
RTG (CAL actioned, no wharf gate)	Volume	AB	
no RTG (CAL actioned, no wharf gate)	Volume	AC	$AC=I-AB$
RTG (non-CAL, wharf gate clear)	Volume	AD	
no RTG (non-CAL, wharf gate clear)	Volume	AE	$AE=P-AD$
RTG (non-CAL, wharf gate actioned)	Volume	AF	
no RTG (non-CAL, wharf gate actioned)	Volume	AG	$AG=Q-AF$
RTG (non-CAL, no wharf gate)	Volume	AH	
no RTG (non-CAL, no wharf gate)	Volume	AI	$AI=K-AH$
released (RTG, CAL clear, wharf gate clear)	Volume, green endpoint	AJ	$AJ=R-AK-AL$
released following action (RTG, CAL clear, wharf gate clear)	Seizure, blue endpoint	AK	
not released (RTG, CAL clear, wharf gate clear)	Seizure, red endpoint	AL	
released (no RTG, CAL clear, wharf gate clear)	Volume, green endpoint	AM	$AM=S$
released (RTG, CAL clear, wharf gate actioned)	Seizure, blue-green endpoint	AN	$AN=T-AO-AP$
released following action (RTG, CAL clear, wharf gate actioned)	Seizure, blue endpoint	AO	
not released (RTG, CAL clear, wharf gate actioned)	Seizure, red endpoint	AP	
released following action (no RTG, CAL clear, wharf gate)	Seizure, blue-green endpoint	AQ	$AQ=U$

not released (CAL clear, wharf gate)	Seizure, red endpoint	AR	
released (RTG, CAL clear, no wharf gate)	Volume, green endpoint	AS	AS=V-AT-AU
released following action (RTG, CAL clear, no wharf gate)	Seizure, blue endpoint	AT	
not released (RTG, CAL clear, no wharf gate)	Seizure, red endpoint	AU	
released (no RTG, CAL clear, no wharf gate)	Volume, green endpoint	AV	AV=W
released (RTG, CAL actioned, wharf gate clear)	Volume, blue-green endpoint	AW	AW=X-AX-AY
released following action (RTG, CAL actioned, wharf gate clear)	Seizure, blue endpoint	AX	
not released (RTG, CAL actioned, wharf gate clear)	Seizure, red endpoint	AY	
released (no RTG, CAL actioned, wharf gate clear)	Seizure, blue endpoint	AZ	AZ=Y
released (RTG, CAL actioned, wharf gate actioned)	Volume, blue-green endpoint	BA	BA=Z-BB-BC
released following action (RTG, CAL actioned, wharf gate actioned)	Seizure, blue endpoint	BB	
not released (RTG, CAL actioned, wharf gate actioned)	Seizure, red endpoint	BC	
released (no RTG, CAL actioned, wharf gate actioned)	Seizure, blue endpoint	BD	BD=AA
not released (CAL actioned, wharf gate)	Seizure, red endpoint	BE	
released (RTG, CAL actioned, no wharf gate)	Volume, blue-green endpoint	BF	BF=AB-BG-BH
released following action (RTG, CAL actioned, no wharf gate)	Seizure, blue endpoint	BG	
not released (RTG, CAL	Seizure, red	BH	

actioned, no wharf gate)	endpoint		
released following action (no RTG, CAL, no wharf gate)	Seizure, blue endpoint	BI	BI=AC
not released (CAL)	Seizure, red endpoint	BJ	
released (RTG, non-CAL, wharf gate clear)	Volume, green endpoint	BK	BK=AD–BL–BM
released following action (RTG, non-CAL, wharf gate clear)	Seizure, blue endpoint	BL	
not released (RTG, non-CAL, wharf gate clear)	Seizure, red endpoint	BM	
released (no RTG, non-CAL, wharf gate inspection)	Volume, green endpoint	BN	BN=AE
released (RTG, non-CAL, wharf gate actioned)	Volume, blue-green endpoint	BO	BO=AF–BP–BQ
released following action (RTG, non-CAL, wharf gate actioned)	Seizure, blue endpoint	BP	
not released (RTG, non-CAL, wharf gate actioned)	Seizure, red endpoint	BQ	
released following action (no RTG, non-CAL, wharf gate inspection)	Seizure, blue endpoint	BR	BR=AG
not released (non-CAL, wharf gate inspection)	Seizure, red endpoint	BS	
released (RTG, non-CAL, no wharf gate)	Volume, green endpoint	BT	BT=AH–BU–BV
released following action (RTG, non-CAL, no wharf gate)	Seizure, blue endpoint	BU	
not released (RTG, non-CAL, no wharf gate)	Seizure, red endpoint	BV	
released (no RTG, non-CAL, no wharf gate)	Volume, green endpoint	BW	BW=AI

Surveys

695 Surveys should be taken at AJ, AK, AM, AN, AO, AQ, AS, AT, AV, AW, AX, AZ, BA, BB, BD, BF, BG, BI, BK, BL, BN, BO, BP, BR, BT, BU, and BW. For this group, the

adjustment for cases where there are no surveys is a little more complicated. Because multiple inspections and multiple treatments are allowed, green endpoints likely have highly differing leakage rates, as do blue endpoints. It is not unreasonable to assume that units with the same number of inspections and actions have similar leakage rates, so long as effectiveness rates of inspection are similar. As long as this holds, to calculate AC and RC, it is enough to require that some surveys must be taken in each of these ten cohorts:

		Inspections			
		0	1	2	3
Treatments	0	BW	AV, BN, BT	AM, AS, BK	AJ
	1	-	BI, BR, BU	AQ, AT, AZ, BF, BL, BO	AK, AN, AW
	2	-	-	BD, BG, BP	AO, AX, BA
	3	-	-	-	BB

Calculating KPIs

It is worth noting that, in this case, later inspections act as proxy leakage surveys for earlier inspections. For instance, look at nodes O and E. Node O comes after node E, indicating that the action exerted at node E did not identify and/or remove all criterion non-compliance, hence, by our definitions, the CAL inspection failed on these units.

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = \sum_{i=\{E,M,O,Q,AK,AL,AR,AT,AU,BJ,BL,BM,BS,AU,BV\}} V_i$$

$$\hat{L} = \sum_{i=\{AJ,AK,AM,AN,AO,AQ,AS,AT,AV,AW,AX,AZ,BA,BB,BD,BF,BG,BI,BK,BL,BN,BO,BP,BR,BU,BW\}} V_i \hat{l}_i$$

$$\hat{o} = \sum_{i=\{AK,AN,AO,AQ,AT,AW,AX,AZ,BA,BB,BD,BF,BG,BI,BL,BP,BR,AU\}} V_i \hat{l}_i$$

$$\hat{\sigma}_{AC} = \sqrt{\sum_{i=\{AJ,AM,AS,AV,BK,BN,BT,BW\}} V_i^2 \widehat{var}(\hat{l}_i)}$$

$$\hat{\sigma}_{RC} = \sqrt{\sum_{i=\{AJ,AM,AS,AV,BK,BN,BT,BW,AK,AN,AO,AQ,AT,AW,AX,AZ,BA,BB,BD,BF,BG,BI,BL,BP,BR,AU\}} V_i^2 \widehat{var}(\hat{l}_i)}$$

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_x^2$	$\hat{\sigma}_y^2$
------	-----------	-----------	--------------------	--------------------

Profiling: CAL	$\sum_{i=\{E,BJ,AT,AU,AR,M,AK,AL\}} V_i + \sum_{i=\{AS,AV,AM,AJ\}} V_i \hat{l}_i$	$\sum_{i=\{Q,BL,BM,BS,BU,BV\}} V_i + \sum_{i=\{BK,BN,BT,BW\}} V_i \hat{l}_i$	$\sum_{i=\{AS,AV,AM,AJ\}} V_i^2 \widehat{Var}(\hat{l}_i)$	$\sum_{i=\{BK,BN,BT,BW\}} V_i^2 \widehat{Var}(\hat{l}_i)$
Inspection: CAL	$\sum_{i=\{AW,AZ,BF,BI\}} V_i (1 - \hat{l}_i) + V_{BJ}$	$\sum_{i=\{E,BJ,AT,AU,AR,M,AK,AL\}} V_i + \sum_{i=\{AS,AV,AM,AJ\}} V_i \hat{l}_i$	-	$\sum_{i=\{AS,AV,AM,AJ\}} V_i^2 \widehat{Var}(\hat{l}_i)$
Inspection: wharf gate	$\sum_{i=\{AN,AQ,BA,BD,BO,BR\}} V_i (1 - \hat{l}_i) + \sum_{i=\{AR,BE,BS\}} V_i$	$\sum_{i=\{AJ,AM,AW,AZ,BK,BN\}} V_i \hat{l}_i + \sum_{i=\{M,AR,O,BE,Q,BS,AK,AL,AX,AY,BL,BM\}} V_i$	-	$\sum_{i=\{AJ,AM,AW,AZ,BK,BN\}} V_i^2 \widehat{Var}(\hat{l}_i)$
Inspection: rural tailgate	$\sum_{i=\{AK,AO,AT,AX,BB,BG,BL,BP,BU\}} V_i (1 - \hat{l}_i) + \sum_{i=\{AL,AP,AU,AY,BC,BH,BM,BQ,BV\}} V_i$	$\sum_{i=\{AT,AN,AS,AW,BA,BF,BK,BO,AT\}} V_i \hat{l}_i + \sum_{i=\{AK,AO,AT,AX,BB,BG,BL,BP,BU,AL,AP,AU,AY,BC,BH,BQ,BQ,BV\}} V_i$	-	$\sum_{i=\{AT,AN,AS,AW,BA,BF,BK,BO,AT\}} V_i^2 \widehat{Var}(\hat{l}_i)$

715 Hit rate

Node	Point estimate	$\hat{\sigma}_{\widehat{hr}_\theta}$
CAL	$\frac{\sum_{i=\{E,BJ,AT,AU,AR,M,AK,AL\}} V_i + \sum_{i=\{AS,AV,AM,AJ\}} V_i \hat{l}_i}{V_B}$	$\frac{\sqrt{\sum_{i=\{AS,AV,AM,AJ\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_B}$
Non-CAL	$\frac{\sum_{i=\{Q,BL,BM,BS,BU,BV\}} V_i + \sum_{i=\{BK,BN,BT,BW\}} V_i \hat{l}_i}{V_C}$	$\frac{\sqrt{\sum_{i=\{BK,BN,BT,BW\}} V_i^2 \widehat{Var}(\hat{l}_i)}}{V_C}$

Group F: Aircraft arrivals

Unit

720 Aircraft

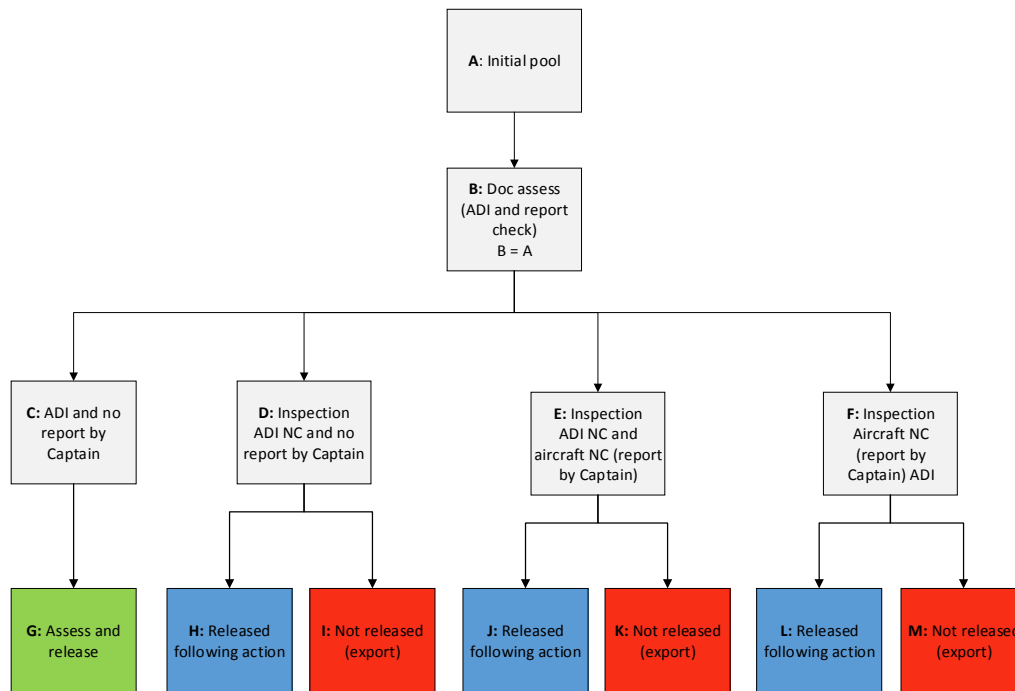


Figure F: Aircraft arrivals flowchart

Description

725 For this pathway, either a report by the captain (aircraft non-compliance) or an ADI (aircraft disinfection insecticide) non-compliance is in the KPI criterion.

Nodes

Level	Type	Node	Notes on calculation
Initial Pool	Volume	A	
Doc assess (ADI & report checks)	Volume	B	B=A
ADI & no report by captain	Volume	C	C=B-D-E-F
Inspection: ADI NC & no report by captain	Volume	D	
Inspection: ADI NC & aircraft NC (report by captain)	Volume	E	
Inspection: ADI & aircraft NC (report by captain)	Volume	F	

Released, assess and release	Volume, green endpoint	G	G=C
Released following action	Seizure, blue endpoint	H	
Not released	Seizure, red endpoint	I	I=D-H
Released following action	Seizure, blue endpoint	J	
Not released	Seizure, red endpoint	K	K=E-J
Released following action	Seizure, blue endpoint	L	
Not released	Seizure, red endpoint	M	M=F-L

730 Surveys

Surveys should be taken at G, H, J and L.

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_H + V_I + V_J + V_K + V_L + V_M$$

$$\hat{L} = V_G \hat{l}_G + V_H \hat{l}_H + V_J \hat{l}_J + V_L \hat{l}_L$$

$$\hat{o} = V_H \hat{l}_H + V_J \hat{l}_J + V_L \hat{l}_L$$

$$\hat{\sigma}_{AC} = V_G \sqrt{\widehat{Var}(\hat{l}_G)}$$

$$\hat{\sigma}_{RC} = \sqrt{\sum_{i=\{G,H,J,L\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

735

NCE

In this case, an NCE of screening can be calculated as the proportion of non-compliant aircraft that are sent for inspection. It's a measure of the effectiveness of ADI and captains' reports as tools to identify noncompliance. Because all units against which reports are made are inspected, all the variability for the NCE of screening in this case is in the denominator, which differs to the usual formula. In this case, it's similar to the usual inspection NCE, and indeed, in this case, we use the interval:

740

$$\widehat{NCE}_{screen}(\theta) \pm z_\alpha \hat{\sigma}_{\widehat{NCE}_{screen}(\theta)}$$

where

$$\hat{\sigma}_{\widehat{NCE}_{screen}(\theta)}^2 = \left(\frac{\bar{x}}{\bar{y}^2}\right)^2 \sum_{g_\theta} V_i^2 \widehat{Var}(\hat{l}_i) = \left(\frac{\bar{x}}{\bar{y}^2}\right)^2 \hat{\sigma}_y^2$$

745

The inspection NCE, on the other hand, has no variability in the denominator as all units sent for inspection are non-compliant. To calculate the inspection NCE, again, a tweak is used on the usual formula. In this case, we use the fact that

$$\begin{aligned} \text{Var}\left(\frac{\sum_r V_i + \sum_b V_i(1 - \hat{l}_i)}{\sum_{rb} V_i}\right) &= \frac{1}{(\sum_{rb} V_i)^2} \text{Var}\left(\sum_r V_i + \sum_b V_i(1 - \hat{l}_i)\right) \\ &= \frac{1}{(\sum_{rb} V_i)^2} \text{Var}\left(\sum_b V_i(1 - \hat{l}_i)\right) \end{aligned}$$

750 which can be estimated by

$$\hat{\eta}^2 \approx \frac{1}{\bar{y}^2} \sum_b V_i^2 \widehat{\text{Var}}(\hat{l}_i)$$

in place of the usual variance $\hat{\sigma}_{NCE_{inspect}(\theta)}^2$.

Node	\bar{x}	\bar{y}	$\hat{\eta}^2$	$\hat{\sigma}_y^2$
Screening	S	$S + V_G \hat{l}_G$	-	$V_G^2 \widehat{\text{Var}}(\hat{l}_G)$
Inspection: ADI NC & no report by captain	$V_I + V_H(1 - \hat{l}_H)$	$V_I + V_H$	$\frac{V_H^2 \widehat{\text{Var}}(\hat{l}_H)}{(V_I + V_H)^2}$	-
Inspection: ADI NC & aircraft NC (report by captain)	$V_K + V_J(1 - \hat{l}_J)$	$V_K + V_J$	$\frac{V_J^2 \widehat{\text{Var}}(\hat{l}_J)}{(V_K + V_J)^2}$	-
Inspection: ADI & aircraft NC (report by captain)	$V_M + V_L(1 - \hat{l}_L)$	$V_M + V_L$	$\frac{V_L^2 \widehat{\text{Var}}(\hat{l}_L)}{(V_M + V_L)^2}$	-

Hit rate

755 By the definition of noncompliance, the units that have an ADI or captain's report non-compliance are KPI criterion non-compliant, so the hit rate for these categories is simply 1.

Group G: Non-commercial vessels

760 **Unit**
Vessel

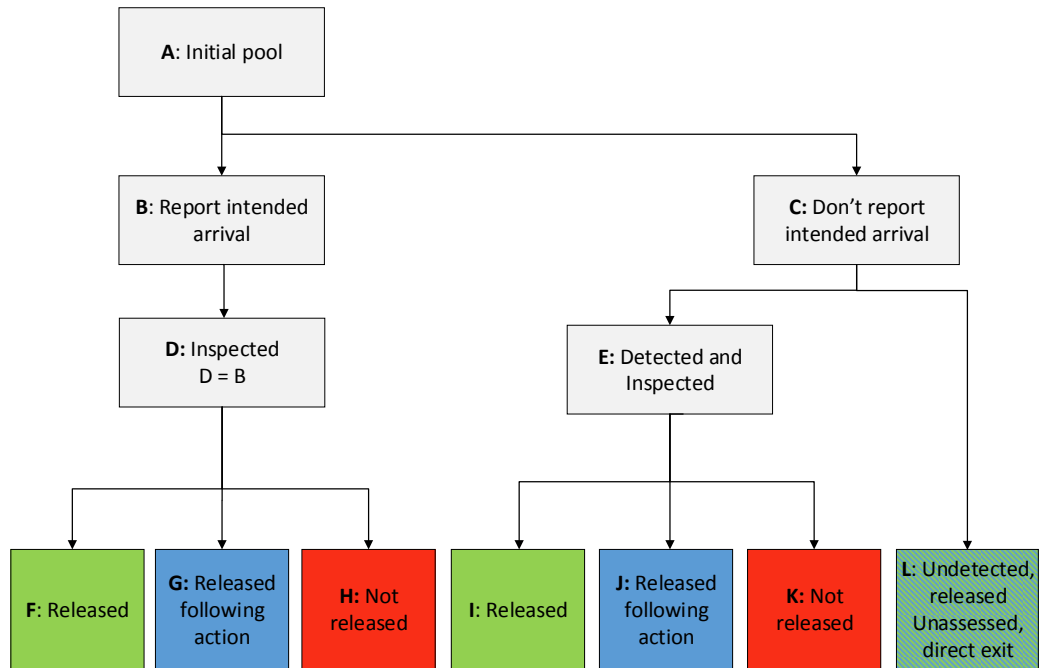


Figure G: Non-commercial vessels flowchart

765 **Description**

For this pathway group, 100% of incoming vessels that are reported are inspected. The KPI criterion constitutes vessels with inspection results of 'FAIL' or 'NON-CONFORMITY'.

770 All vessels arriving in Australia must report intended arrival. However, while unlikely, it is not impossible that a vessel in this pathway could avoid detection by not reporting intended arrival (consider, for example, asylum seeker boats).

Nodes

Level	Type	Node	Notes on calculation
Initial pool	Volume	A	$A=B+C$
Report intended arrival	Volume	B	
Don't report intended arrival	Volume	C	$C=E+L$
Inspected	Volume	D	$D=B$
Detected and inspected	Volume	E	
Released following inspection	Volume, green endpoint	F	$F=D-G-H$

Released following inspection and action	Seizure, blue endpoint	G	
Not released following inspection	Seizure, red endpoint	H	
Released following inspection	Volume, green endpoint	I	I=E-J-K
Released following inspection and action	Seizure, blue endpoint	J	
Not released following inspection	Seizure, red endpoint	K	
Released, unassessed direct exit	Volume, green endpoint	L	

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Surveys

Surveys should be taken at F, G, I and J. For surveys in L, namely of those boats that don't declare arrival and weren't identified, information could potentially be gleaned from boats that were intercepted as part of customs operations, that is the detected

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at node E. A leakage rate estimate for L would be: $\frac{V_I \hat{l}_I + V_J + V_K}{V_E}$.

Calculating KPIs

Total volume, seizures, leakage, overlap and standard deviation (for AC and RC)

$$V = V_A$$

$$S = V_G + V_H + V_J + V_K$$

$$\hat{L} = V_F \frac{x_F}{n_F} + V_G \frac{x_G}{n_G} + V_I \frac{x_I}{n_I} + V_J \frac{x_J}{n_J} + V_L \frac{x_L}{n_L}$$

$$\hat{o} = V_G \frac{x_G}{n_G} + V_J \frac{x_J}{n_J}$$

$$\hat{\sigma}_{AC} = \sqrt{V_F^2 \widehat{Var}(\hat{l}_F) + V_I^2 \widehat{Var}(\hat{l}_I) + V_L^2 \widehat{Var}(\hat{l}_L)}$$

$$\hat{\sigma}_{RC} = \sqrt{\sum_{i=\{F,G,I,J,L\}} V_i^2 \widehat{Var}(\hat{l}_i)}$$

785

NCE

Node	\bar{x}	\bar{y}	$\hat{\sigma}_y^2$
Inspection (D)	$\sum_{i=\{G,J\}} V_i (1 - \hat{l}_i) + V_H + V_K$	$\sum_{i=\{G,H,J,K\}} V_i + \sum_{i=\{F,I\}} V_i \hat{l}_i$	$V_F^2 \widehat{Var}(\hat{l}_F) + V_I^2 \widehat{Var}(\hat{l}_I)$

Hit rate

Node	Point estimate	$\hat{\sigma}_{\widehat{hr}_\theta}$
Inspection (D)	$\frac{V_G + V_H + V_F \hat{l}_F}{V_D}$	$\frac{\sqrt{(V_F)^2 \widehat{Var}(\hat{l}_F)}}{V_D}$
Inspection on unreported (E)	$\frac{V_J + V_K + V_I \hat{l}_I}{V_E}$	$\frac{\sqrt{(V_I)^2 \widehat{Var}(\hat{l}_I)}}{V_E}$

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Appendix A

Endpoint types: Extended discussion

The green, blue and red endpoints are focused on, as these reflect the majority of unit experiences. However, other experiences are possible. Two such experiences are listed below, together with how their inclusion would change the KPI calculations.

(i) Not released for non-KPI criterion reasons

These are endpoints with units that were not released (i.e. either destroyed or forbidden entry) due to a non-KPI criterion non-compliance, rather than a KPI criterion non-compliance. The units in this category are assumed compliant (at the end of the department process) for KPI criterion reasons, but in truth they may not be.

Because the unit is not released, it is not included as containing leakage for post-interaction stream, but it is included as an incoming non-compliance for pre-interaction KPI calculation. To adjust the KPIs, the volume of this category should be subtracted from the volume on the denominator of the RC. For the AC, the units in this category can be thought of as two types:

- Those that were found to be non-compliant with respect to the criterion at some point in the process (and some action was taken so that they are now assumed compliant)
- Those that were never found to be non-compliant

The first category should be treated as a blue endpoint for the purposes of AC calculations, and the second category as a green endpoint. Given that the calculation of AC requires estimates of leakage for the green endpoints, the units in the second category should be surveyed to glean a good estimate for the AC. For NCE and hit rate calculations, endpoints in the first category should be treated as blue endpoints, while the second category should be treated as green endpoints.

(ii) Released following action for non-KPI criterion non-compliance only, where treatment could have an effect on the criterion compliance

It is unlikely that this scenario will be relevant to the KPI pathway calculations. For our iteration of the process, it was considered together with the department and found to be non-applicable. For completeness, we describe it below.

These are endpoints containing units that were identified as being non-KPI criterion non-compliant at some stage of interaction. Effort was expended to rectify the non-compliance, but the action required could potentially change the compliance of the unit with respect to the criterion. As an example, say that 'insect A' is in the KPI criterion and 'insect B' is in the non-KPI criterion. A unit is identified as containing insect B, and sent for a fumigation, which also happens to kill insect A. The unit is released without the fact that it contained insect A upon entry ever being discovered (i.e. release assuming compliant with both criterion and non-KPI criterion).

In this case, the compliance status has been changed as a result of an action against the non-KPI criterion. Note that this only includes units that were never found to be

non-compliant with respect to the criterion, and hence, under the green/blue/red paradigm, fall into green endpoints.

840 This is an issue for KPI calculation because the outgoing compliance rate for these
units is higher than the incoming compliance rate. In this case, surveys should be
done on the endpoint, but also at the point just before the action that might affect
compliance is conducted. For the AC, the endpoint should be treated as a green
845 endpoint as usual, while, for the RC, the endpoint should be counted as a green
endpoint but using the surveys conducted prior to treatment. For NCE and hit rate
calculations, the treatment will depend on whether the node for which the KPIs are
being calculated is before or after treatment. If it is before, the pre-treatment survey
should be used, while for those occurring afterward, the endpoint survey
information should be used.

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Appendix B: Confidence Intervals

Approaching Compliance

855 Treating seizures and volumes as known constants, and leakage as an unknown random variable, the variance of AC can be formulated as follows

$$Var(\widehat{AC}) = Var\left(1 - \frac{S + \hat{L} - \hat{\delta}}{V}\right)$$

$$= \frac{1}{V^2} Var(\hat{L} - \hat{\delta})$$

$$= \frac{1}{V^2} Var\left(\sum_g V_i \hat{l}_i\right)$$

860 An estimate for this variance is

$$\hat{\sigma}_{AC}^2 = \frac{1}{V^2} \sum_g V_i^2 \widehat{Var}(\hat{l}_i)$$

where the $\widehat{Var}(\hat{l}_i)$ are estimates calculated using the Wilson variance approximation as described in CEBRA report 1301B:

$$\widehat{Var}(\hat{l}_i) = \left(1 + \frac{z_\alpha^2}{n_i}\right)^{-2} \left(\frac{1}{n_i} \hat{l}_i(1 - \hat{l}_i) + \frac{z_\alpha^2}{4n_i^2}\right)$$

865 where

$$\hat{l}_i = \frac{\text{survey seized endpoint } i}{\text{survey leaked endpoint } i} = \frac{x_i}{n_i} \text{ and}$$

z_α is the $1 - \frac{\alpha}{2}$ percentile for the standard normal distribution.

The Wilson variance for $Var(\hat{l}_i)$ will be used throughout for variance calculations.

870 The confidence interval for AC is then calculated as:

$$\widehat{AC} \pm z_\alpha \hat{\sigma}_{AC}$$

It is possible that, occasionally, the confidence interval values calculated using this method fall outside the limit [0,1]. In this case, the confidence intervals should be truncated to these values.

875

No surveys in some endpoints

In the event that one or more green endpoints have no surveys, there are several options. One method could be to extend the period of time under consideration until surveys in all green endpoints are included in the data.

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Another method is to extrapolate the leakage rate from historical data or using expert opinion. If not much confidence is attached to the extrapolation, use a small

885 survey volume to reflect this. Alternatively, if the user has confidence in the extrapolated leakage rate, larger survey volumes may be attached.

For the AC leakage, we advocate using an adjusted estimate for the number leaked that is based on a weighted average leakage rate that is calculated across the other green endpoints. So, the estimate for the number leaked (excluding the overlap)
890 becomes:

$$\begin{aligned}\hat{L} - \hat{o} &= \sum_g V_i \hat{l}_i \\ &\approx \sum_{g_l} V_i \hat{l}_i + \left(\sum_{g_{nl}} V_i \right) \times \left(\frac{\sum_{g_l} V_i \hat{l}_i}{\sum_{g_l} V_i} \right) \\ &= \sum_{g_l} V_i \hat{l}_i + \left(\sum_{g_l} V_i \hat{l}_i \right) \times \left(\frac{\sum_{g_{nl}} V_i}{\sum_{g_l} V_i} \right) \\ &= \sum_{g_l} V_i \hat{l}_i \left(1 + \frac{\sum_{g_{nl}} V_i}{\sum_{g_l} V_i} \right)\end{aligned}$$

where

g_l denotes the subset of green endpoints where at least one endpoint survey has been conducted, and

895 g_{nl} denotes the subset of green endpoints where no endpoint surveys have been conducted.

The formula for the point estimate for the AC then stays the same. While we allow the assumption that green endpoints have similar leakage rates, in order to present
900 suitably conservative interval estimates, we add complete uncertainty to these assumptions. That is, we let the leakage contribution of the endpoints that have unknown leakage range from 0 to all units leaked ($\sum_{g_{nl}} V_i$).

Incorporating this assumption, the confidence interval for the AC becomes:

905

$$\left(1 - \frac{S + \sum_{g_l} V_i \hat{l}_i + \sum_{g_{nl}} V_i}{V} - z_\alpha \hat{\tau}_{AC}, 1 - \frac{S + \sum_{g_l} V_i \hat{l}_i}{V} + z_\alpha \hat{\tau}_{AC} \right)$$

where

$$\hat{\tau}_{AC}^2 = \frac{1}{V^2} \sum_{g_l} V_i^2 \widehat{Var}(\hat{l}_i).$$

910 If a pathway has no surveys in any green endpoints, there's no clear way to get an estimate for the leakage and hence to calculate a point estimate for AC. As long as seizure information is available, we can still have an upper bound for the AC, equal to $1 - \frac{S}{V}$, but leakage information is required to get a more accurate bound.

915 **Residual Compliance**

The variance of RC can be formulated as follows:

$$\begin{aligned} Var(\widehat{RC}) &= Var\left(1 - \frac{\hat{L}}{V - \sum_r V_i}\right) \\ &= \frac{1}{(V - \sum_r V_i)^2} Var\left(\sum_{gb} V_i \hat{l}_i\right) \end{aligned}$$

920 This can be estimated by:

$$\hat{\sigma}_{\widehat{RC}}^2 = \frac{1}{(V - \sum_r V_i)^2} \sum_{gb} V_i^2 Var(\hat{l}_i)$$

The confidence interval for RC is then calculated as:

$$\widehat{RC} \pm z_\alpha \hat{\sigma}_{\widehat{RC}}$$

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Occasionally, the confidence interval values calculated using this method fall outside the limit [0,1]. In this case, the confidence intervals should be truncated to these values.

930 **No surveys in some endpoints**

In the event that one or more green or blue endpoints have no surveys, again, the time frame over which the KPIs are being calculated should be extended. If this does not solve the issue, we advocate using an adjusted estimate for the number leaked that is based on a weighted average leakage rate calculated across the other green endpoints (to estimate the leakage in the unsurveyed green endpoint/s) and blue endpoints (to estimate the leakage in the unsurveyed blue endpoint/s). So, the estimate for the number leaked becomes:

935

$$\begin{aligned} \hat{L} &= \sum_{gb} V_i \hat{l}_i \\ &\approx \sum_{g_l} V_i \hat{l}_i + \sum_{g_{nl}} V_i \left(\frac{\sum_{g_l} V_i \hat{l}_i}{\sum_{g_l} V_i} \right) + \sum_{b_l} V_i \hat{l}_i + \sum_{b_{nl}} V_i \left(\frac{\sum_{b_l} V_i \hat{l}_i}{\sum_{b_l} V_i} \right) \\ &= \sum_{g_l} V_i \hat{l}_i \left(1 + \frac{\sum_{g_{nl}} V_i}{\sum_{g_l} V_i} \right) + \sum_{b_l} V_i \hat{l}_i \left(1 + \frac{\sum_{b_{nl}} V_i}{\sum_{b_l} V_i} \right) \end{aligned}$$

940 where

b_l denotes the subset of blue endpoints where at least one endpoint survey has been conducted, and

b_{nl} denotes the subset of blue endpoints where no endpoint surveys have been conducted.

945

The formula for the point estimate for the RC then stays the same (but uses the new definition for \hat{L}). While we allow the assumption that all green and all blue endpoints have similar leakage rates, in order to present suitably conservative interval estimates, we add complete uncertainty to these assumptions. That is, we let the leakage contribution of the endpoints that have unknown leakage range from 0 to all units leaked ($\sum_{g_{nl}b_{nl}} V_i$).

950

Incorporating this assumption into the lower and upper endpoints, we adjust the variance to:

$$\hat{t}_{RC}^2 = \frac{1}{V^2} \sum_{gbl} V_i^2 \widehat{Var}(\hat{l}_i)$$

955

and the endpoints become:

$$\left(1 - \frac{\sum_{g_l b_l} V_i \hat{l}_i + \sum_{g_{nl} b_{nl}} V_i}{V} - z_\alpha \hat{t}_{RC}, 1 - \frac{\sum_{g_l b_l} V_i \hat{l}_i}{V} + z_\alpha \hat{t}_{RC} \right)$$

If a pathway has no surveys in any green and/or blue endpoints, it is impossible to get an estimate for the leakage and hence to calculate a point estimate for RC.

960

NCE screening

The confidence interval for this proportion is more complicated than those for the other KPIs, as both the numerator and denominator have random terms in them. To get around this, we use an approximation.

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Note that $\{g_{\theta+}\} = \{g_\theta\} \cup \{g_{\theta>}\}$. That is, the set of all green endpoints that come off some node θ is the same as the set of green endpoints that lead directly from θ combined with all the green endpoints that come from passing through at least one other node before reaching an endpoint. The same relationship holds if we replace g with any other combination of g, r and b. From this, we get:

970

$$\sum_{g_{\theta+}} V_i l_i = \sum_{g_{\theta>}} V_i l_i + \sum_{g_\theta} V_i l_i$$

so

$$\begin{aligned} NCE_{screen}(\theta) &= \frac{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i l_i}{\sum_{br>\theta} V_i + \sum_{g>\theta} V_i l_i + \sum_{g_\theta} V_i l_i} \\ &= \frac{x}{x + y} \end{aligned}$$

where

975

$$x = \sum_{br>\theta} V_i + \sum_{g>\theta} V_i l_i$$

$$y = \sum_{g_{\theta}} V_i l_i$$

There are a number of methods for variance calculation, including the direct, delta and Fieller methods (Fieller, 1940).

980 **Direct method**

The direct variance method is described in ACERA paper 1101D. As shown earlier, the NCE of screening can be reformulated as follows:

$$NCE_{screen} = \frac{x}{x + y}$$

where

$$x = \sum_{br > \theta} V_i + \sum_{g > \theta} V_i l_i$$

$$y = \sum_{g_{\theta}} V_i l_i$$

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In the methodology of 1101D, $\sum_{br > \theta} V_i = b_i$, $\sum_{g > \theta} V_i l_i = l_i$ and $\sum_{g_{\theta}} V_i l_i = l_r$.

We assume that x and y are independent. Also, under the central limit theorem, x and y are normally distributed (these are weighted sums of leakage point estimates for different end points).

990

Letting $e = \frac{x}{x+y}$, we get:

$$x(1 - e) - ye = 0$$

We consider the random variable $x(1 - e) - ye$. Conditioned on e (i.e. treating e as a constant),

995

$$x(1 - e) - ye \sim N(\mu_x(1 - e) - \mu_y e, \sigma_x^2(1 - e)^2 + \sigma_y^2 e^2)$$

Constructing a $(1 - \alpha)\%$ confidence interval gives the formula:

$$\frac{\bar{x}(1 - e) - \bar{y}e}{\sqrt{\hat{\sigma}_x^2(1 - e)^2 + \hat{\sigma}_y^2 e^2}} \approx \pm z_{\alpha}$$

1000

where

$$\hat{\sigma}_x^2 = Var\left(\sum_{g > \theta} V_i \hat{l}_i\right) = \sum_{g > \theta} V_i^2 \widehat{Var}(\hat{l}_i)$$

$$\hat{\sigma}_y^2 = Var\left(\sum_{g_{\theta}} V_i \hat{l}_i\right) = \sum_{g_{\theta}} V_i^2 \widehat{Var}(\hat{l}_i)$$

$$\bar{x} = \sum_{br > \theta} V_i + \sum_{g > \theta} V_i \hat{l}_i$$

$$\bar{y} = \sum_{g > \theta} V_i \hat{l}_i$$

Squaring both sides and rearranging leads to a quadratic equation in $r = \frac{1-e}{e}$. The

solutions for r are $\frac{\bar{x}\bar{y} \pm z_\alpha \sqrt{\bar{y}^2 \hat{\sigma}_x^2 + \bar{x}^2 \hat{\sigma}_y^2 - z_\alpha^2 \hat{\sigma}_x^2 \hat{\sigma}_y^2}}{\bar{x}^2 - z_\alpha^2 \hat{\sigma}_x^2}$.

1005 These can be back transformed to get an interval for e , using the fact that $e = \frac{1}{1+r}$.

Delta method

The delta method, also described in ACERA paper 1101D, expresses the NCE of screening as a function of a ratio of two independent random variables, to which we
 1010 can apply a Taylor series approximation. Note that $NCE_{screen}(\theta) = \frac{x}{x+y}$ can be formulated as $NCE_{screen}(\theta) = \frac{1}{1+\frac{y}{x}} = \frac{1}{1+r}$, where $r = \frac{y}{x}$ is the ratio of two independent random variables.

The idea behind the delta method is to estimate a standard error for r , and,
 1015 assuming the sampling distribution for this statistic is approximately normal, build a confidence interval for r . This interval is then back-transformed to get an interval for the $NCE_{screen}(\theta)$ by using the relationship $NCE_{screen}(\theta) = \frac{1}{1+r}$.

A Taylor's series expansion is applied to the ratio $\frac{y}{x}$ to get the standard error for r .
 1020 After simplifying, we get to the following formula:

$$\hat{\sigma}_{\hat{r}} = \hat{r} \sqrt{\frac{\hat{\sigma}_y}{y^2} + \frac{\hat{\sigma}_x}{x^2}}$$

So, the interval for NCE_{screen} under this method is:

$$\left(\frac{1}{1 + \hat{r} + z_\alpha \hat{\sigma}_{\hat{r}}}, \frac{1}{1 + \hat{r} - z_\alpha \hat{\sigma}_{\hat{r}}} \right)$$

Fieller's method

Fieller's theorem allows for the calculation of a confidence interval for the ratio of
 1025 two means. In this case, we let $NCE_{screen} = -\frac{\hat{\psi}}{\hat{\beta}} = \gamma$.

If $\hat{\psi}$ and $\hat{\beta}$ have a bivariate normal distribution with variance-covariance matrix given by:

$$\begin{bmatrix} v_{11} & v_{12} \\ v_{12} & v_{22} \end{bmatrix},$$

1030

then $\hat{\psi} + \gamma \hat{\beta} \sim N(0, \sigma^2)$ where

$$\sigma^2 = v_{11} + 2\gamma v_{12} + \gamma^2 v_{22}$$

Given that $Z = \frac{\hat{\psi} + \gamma \hat{\beta}}{\sigma}$ is a standard normal random variable, its square is a chi-squared random variable with 1 degree of freedom. Using the quadratic formula to solve the inequality

$$\frac{(\hat{\psi} + \gamma \hat{\beta})^2}{v_{11} + 2\gamma v_{12} + \gamma^2 v_{22}} < z_{\alpha}^2$$

for γ , gives the Fieller interval:

$$\hat{\gamma} + \left(\frac{k}{1 - k} \right) \left(\hat{\gamma} + \frac{v_{12}}{v_{22}} \right) \pm \frac{z_{\alpha}}{\hat{\beta}(1 - \frac{v_{12}}{v_{22}})} \sqrt{\left(v_{11} + 2\hat{\gamma}v_{12} + \hat{\gamma}^2 v_{22} - k \left(v_{11} - \frac{v_{12}^2}{v_{22}} \right) \right)}$$

where

$$k = \frac{z_{\alpha}^2 v_{22}}{\hat{\beta}^2}.$$

Comparison

Following the recommendation in ACERA report 1101D, the method we recommend is the direct method.

The difference between the Fieller and the direct methods is that the expansion used in the direct method makes more efficient use of the data. Fieller's method implements variances and covariances of x and $x + y$, so, in effect, it double counts the variation in x .

The normal approximation to the binomial is used for the variance estimate for the calculation by the delta and Fieller's methods. Hence it is not surprising that these methods do not perform well for small sample sizes and extreme proportions.

Nonetheless, all three methods were considered and tested on simulated data for the air cargo pathway. They were found to produce very similar intervals.

Applying the direct method for the calculation of the intervals for screening NCEs, the resulting interval is:

$$\frac{1}{1 + \frac{\bar{x}\bar{y} \mp z_{\alpha}\sqrt{\bar{y}^2\hat{\sigma}_x^2 + \bar{x}^2\hat{\sigma}_y^2 - z_{\alpha}^2\hat{\sigma}_x^2\hat{\sigma}_y^2}}{\bar{x}^2 - z_{\alpha}^2\hat{\sigma}_x^2}}$$

where

$$\hat{\sigma}_x^2 = Var\left(\sum_{g>\theta} V_i \hat{l}_i\right) = \sum_{g>\theta} V_i^2 \widehat{Var}(\hat{l}_i)$$

$$\hat{\sigma}_y^2 = Var\left(\sum_{g\theta} V_i \hat{l}_i\right) = \sum_{g\theta} V_i^2 \widehat{Var}(\hat{l}_i)$$

$$\bar{x} = \sum_{br_{\theta}} V_i + \sum_{g_{\theta}} V_i \hat{l}_i$$

$$\bar{y} = \sum_{g_{\theta}} V_i \hat{l}_i$$

NCE inspection

For the NCE for inspection

1065

$$NCE_{inspect}(\theta) = \frac{\sum_{r_{\theta}} V_i + \sum_{b_{\theta}} V_i (1 - l_i)}{\sum_{br_{\theta}} V_i + \sum_{g_{\theta}} V_i l_i}$$

$$= \frac{x}{y}$$

where

$$x = \sum_{r_{\theta}} V_i + \sum_{b_{\theta}} V_i (1 - l_i)$$

$$y = \sum_{br_{\theta}} V_i + \sum_{g_{\theta}} V_i l_i$$

1070

Let us assume that the treatment methods are fairly good at rectifying KPI criterion non-compliance once it is identified, that is, that l_i is likely to be low in the blue endpoints, so x is close to constant. Using this assumption (without which, the interval becomes very complicated), we can get a variance estimate to calculate confidence intervals.

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First, let $f(y) = \frac{1}{y}$ (so $f'(y) = -\frac{1}{y^2}$) and apply a Taylor's series expansion. Note that on the second line we use the assumption that the variability of x is negligible.

$$\begin{aligned} Var(NCE_{inspect}(\theta)) &= Var\left(\frac{x}{y}\right) \\ &\approx x^2 Var\left(\frac{1}{y}\right) \\ &= x^2 Var(f(y)) \\ &\approx x^2 (f'(y))^2 Var(y) \\ &\approx x^2 \left(-\frac{1}{y^2}\right)^2 Var\left(\sum_{g_{\theta}} V_i \hat{l}_i\right) \\ &\approx \left(\frac{x}{\bar{y}^2}\right)^2 \sum_{g_{\theta}} V_i^2 \widehat{Var}(\hat{l}_i) \end{aligned}$$

So:

$$Var(NCE_{inspect}(\theta)) \approx \left(\frac{\bar{x}}{\bar{y}^2}\right)^2 \sum_{g_{\theta}} V_i^2 \widehat{Var}(\hat{l}_i) = \hat{\sigma}_{NCE_{inspect}(\theta)}^2$$

where

1080 $\bar{x} = \sum_{r_\theta} V_i + \sum_{b_\theta} V_i (1 - \hat{l}_i)$
 $\bar{y} = \sum_{br_\theta} V_i + \sum_{g_\theta} V_i \hat{l}_i$ and
 $\widehat{Var}(\hat{l}_i)$ are the Wilson variances as described in the AC interval calculation.

The confidence interval for the inspection NCE for θ is then calculated as:

1085

$$\widehat{NCE}_{inspect}(\theta) \pm z_\alpha \hat{\sigma}_{\widehat{NCE}_{inspect}(\theta)}$$

Occasionally, the confidence interval values calculated using this method fall outside the limit [0,1]. In this case, the confidence intervals are truncated to these values.

1090 **Hit rate**

In this case, the variability comes from the leakage terms in the numerator. To get CIs for hit rates, we use the following estimate for the variance of hit rate:

$$\begin{aligned} Var(\widehat{hr}_\theta) &= Var\left(\frac{\sum_{br_{\theta+}} V_i + \sum_{g_{\theta+}} V_i \hat{l}_i}{V_\theta}\right) \\ &= \frac{1}{V_\theta^2} Var\left(\sum_{g_{\theta+}} V_i \hat{l}_i\right) \\ &= \frac{1}{V_\theta^2} \sum_{g_{\theta+}} V_i^2 Var(\hat{l}_i) \\ &\approx \frac{1}{V_\theta^2} \sum_{g_{\theta+}} V_i^2 \widehat{Var}(\hat{l}_i) = \hat{\sigma}_{\widehat{hr}_\theta}^2 \end{aligned}$$

1095 where $\widehat{Var}(\hat{l}_i)$ are the Wilson variances as described in the AC interval calculation.
The confidence interval for the hit rate for the node θ is then calculated as:

$$\widehat{hr}_\theta \pm z_\alpha \hat{\sigma}_{\widehat{hr}_\theta}$$

1100 Occasionally, the confidence interval values calculated using this method fall outside the limit [0,1]. In this case, the confidence intervals are truncated to these values.

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1120 **Glossary**

Approaching Compliance (AC): the proportion of units that are compliant with respect to the KPI criterion pre-interaction

Flowchart: A schematic diagram depicting the process of a group (of pathways)

1125

Hit Rate (HR): the proportion of KPI criterion non-compliant units entering a specified node

Interaction: Any and all contact of the department with a pathway. Formerly, the word intervention was more commonly used

1130

KPI criterion: A list of conditions against which the KPIs measure non-compliance

Non-compliance Effectiveness (NCE): the sensitivity of a tool at identifying KPI criterion non-compliant units

1135

Non-KPI criterion: A list of conditions not included in the KPI criterion but that a unit must be compliant with before being released

Process: See 'interaction'

1140

Residual Compliance (RC): the proportion of released units that are compliant post-interaction

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