
Safety Performance Measurement - SPI & ALoSP Development

(APRAST-6 Workshop)

6 April 2015

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Safety Performance Measurement (SPM): SPIs & ALoSP Development

Agenda

1. Definition
2. Why measure safety performance
3. Safety Performance Indicators
4. Alert level
5. Target setting
6. SPI data template & trending chart
7. Acceptable Level of Safety Performance
Quiz, Discussion, Q&A

1. SPM Definition

“Safety Performance Measurement” in the context of this presentation refers to the process of measuring and monitoring *safety related outcomes* associated with a given operational system or organisation.

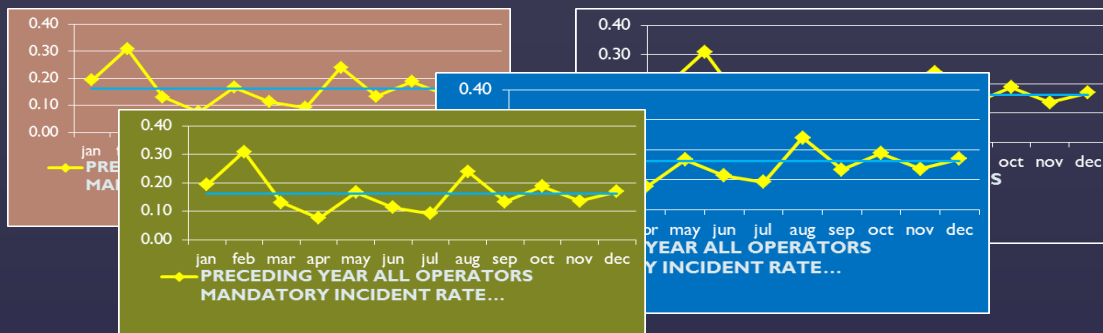
2. Why measure safety performance

- *A19, 3.1.1- Each State shall establish an SSP for the management of safety in the State, in order to achieve an acceptable level of safety performance in civil aviation*
- *A19, 3.1.2 - The acceptable level of safety performance to be achieved shall be established by the State”*
- *SSP Element 3.2 - Safety data collection, analysis and exchange*
- *SMS Element 3.1 - Safety performance monitoring and measurement*

- ❖ *Quote -“You cannot manage what you cannot measure”*

3. Safety Performance Indicators [Doc 9859, 4.3.5; C4-App4]

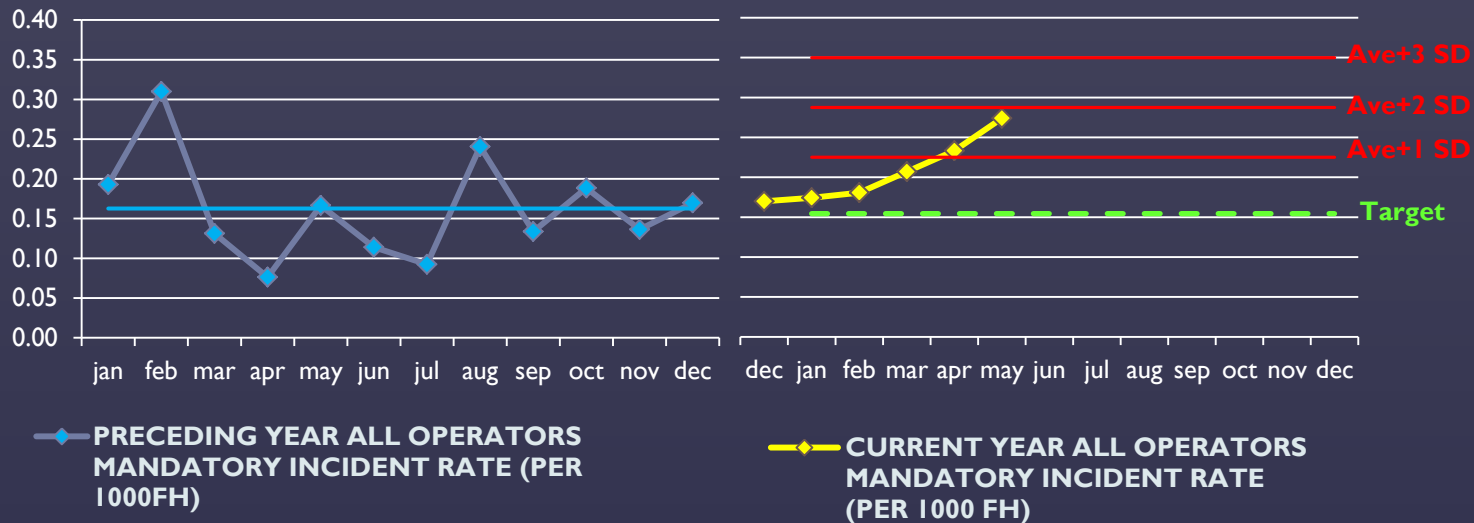
- ▶ Develop a package of SPIs to manifest and measure the State's safety performance
- ▶ SPIs pertaining to safety related outcomes
- ▶ Accidents, serious incidents, incidents, non-conformances, etc
- ▶ High Consequence & Lower Consequence SPIs
- Aggregate SPIs for each aviation service provider sector



3. Two SPI Performance Markers

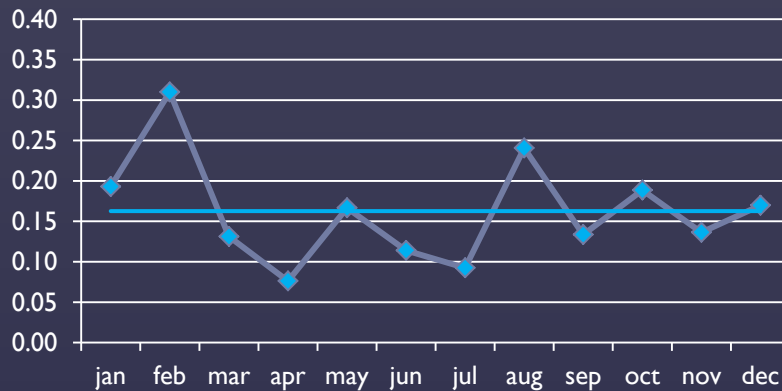
[Doc 9859, 4.3.5.6]

- ▶ Establish high occurrence rate **Alert trigger** within each SPI
- ▶ Establish planned improvement **Target level** within each SPI

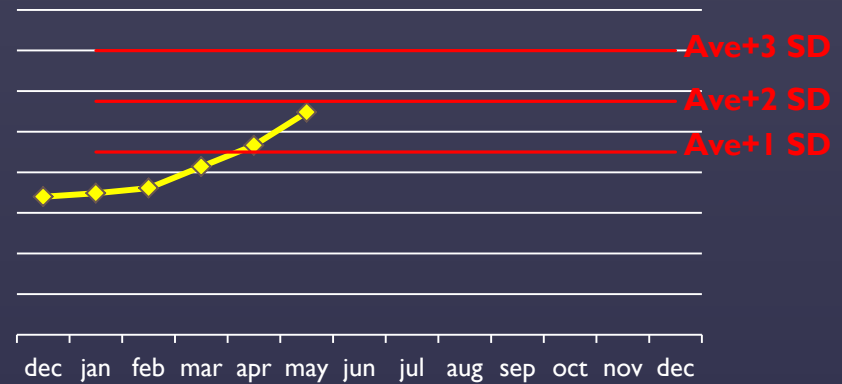


4. Alert Trigger setting

- ▶ Statistical Alarm bell (out of control criteria)
- ▶ Based on SPI's preceding period's data performance i.e Average & Standard Deviation values
- ▶ Ave+1SD; Ave+2SD; Ave+3SD
- Continuous monitoring for abnormal trends

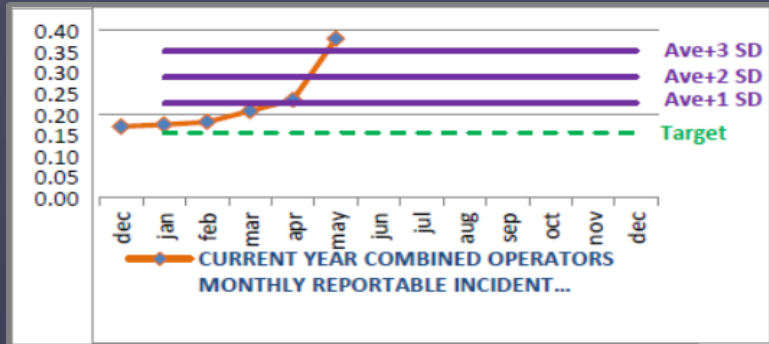


◆ PRECEDING YEAR ALL OPERATORS MANDATORY INCIDENT RATE (PER 1000FH)

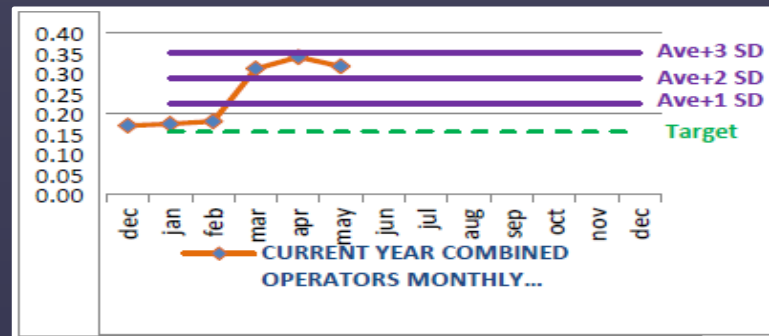


◆ CURRENT YEAR ALL OPERATORS MANDATORY INCIDENT RATE (PER 1000 FH)

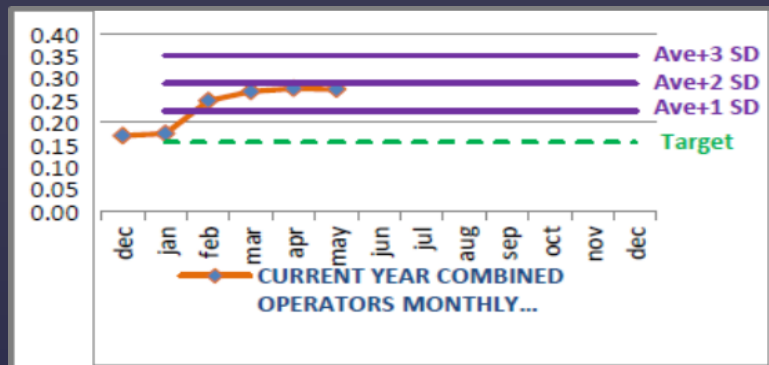
4. Alert Trigger setting – 3 criteria



- One single point above 3-SD line



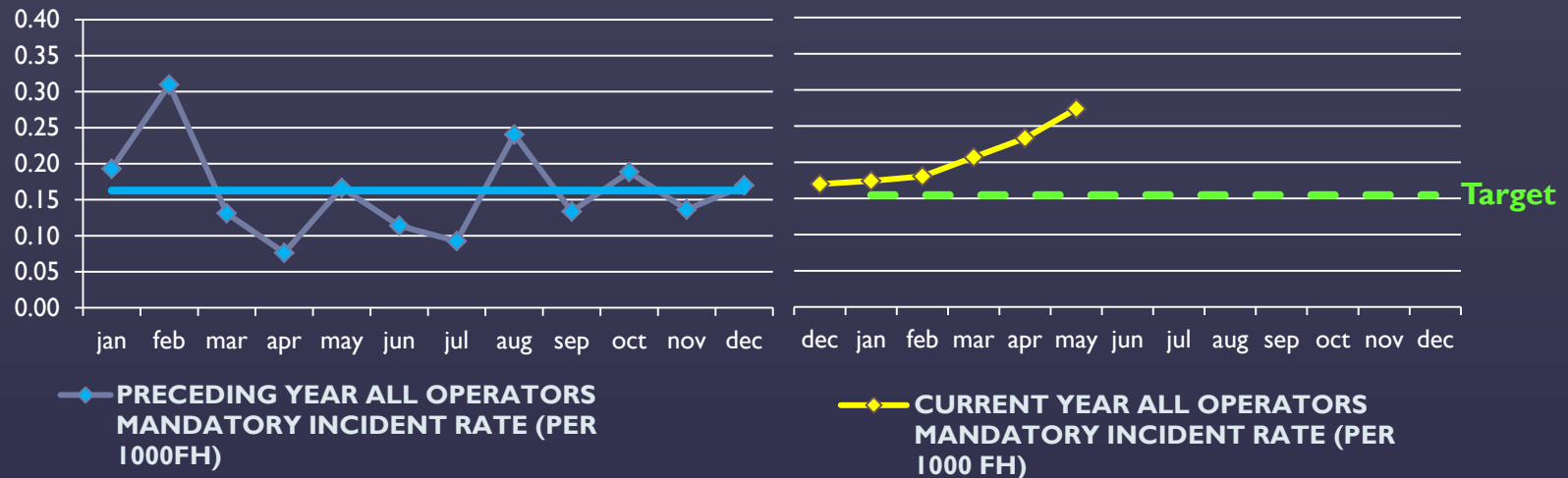
- Two or more consecutive points above 2-SD line



- Three or more consecutive points above 1-SD line

5. Target Level setting

- ▶ A planned (desired) occurrence rate improvement for a new monitoring period
- ▶ Reduction (eg 5%) of **current period's Average** over **preceding period's Average rate**
- Target achievement assessed at end of each monitoring period



6. SPI Data Template & Trending Chart

Here >>

- ▶ Use standardized SPI data template
- ▶ Annotate **number of occurrences & movements** at relevant intervals
- ❑ Verify **Alert** settings & planned improvement **Target** (eg 5%)

SSP High Consequence Safety Indicator Example (with Alert and Target Setting Criteria)

Preceding Year				
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Ave (line)
jan	51,837	10.00	0.19	0.16
feb	48,406	15.00	0.31	0.16
mar	53,354	7.00	0.13	0.16
apr	52,513	4.00	0.08	0.16
may	54,037	9.00	0.17	0.16
jun	52,673	6.00	0.11	0.16
jul	54,086	5.00	0.09	0.16
aug	54,043	13.00	0.24	0.16
sep	52,383	7.00	0.13	0.16
oct	53,042	10.00	0.19	0.16
nov	51,353	7.00	0.14	0.16
dec	53,006	9.00	0.17	0.16

Ave	0.16
SD	0.06

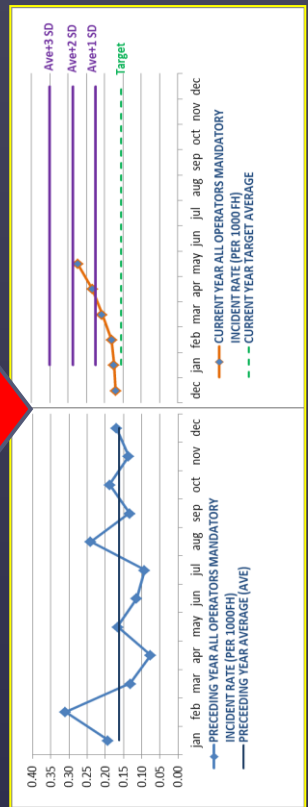
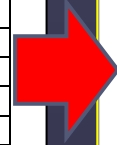
Ave+1SD	Ave+2SD	Ave+3SD
0.23	0.29	0.35

Current Year Alert Level setting criteria is:
Preceding Year Ave + 1/2/3 SD

Current year				Current Year Alert Levels			Current Year Target (line)
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Preceding Year Ave +1SD (line)	Preceding Year Ave +2SD (line)	Preceding Year Ave +3SD (line)	
dec	53006	9.00	0.17				
jan	51635	9.00	0.17	0.23	0.29	0.35	0.15
feb	44295	8	0.18	0.23	0.29	0.35	0.15
mar	48323	10	0.21	0.23	0.29	0.35	0.15
apr	47176	11	0.23	0.23	0.29	0.35	0.15
may	47469	13	0.27	0.23	0.29	0.35	0.15
jun				0.23	0.29	0.35	0.15
jul				0.23	0.29	0.35	0.15
aug				0.23	0.29	0.35	0.15
sep				0.23	0.29	0.35	0.15
oct				0.23	0.29	0.35	0.15
nov				0.23	0.29	0.35	0.15
dec				0.23	0.29	0.35	0.15

* Rate Calculation: (per 1000 FH)

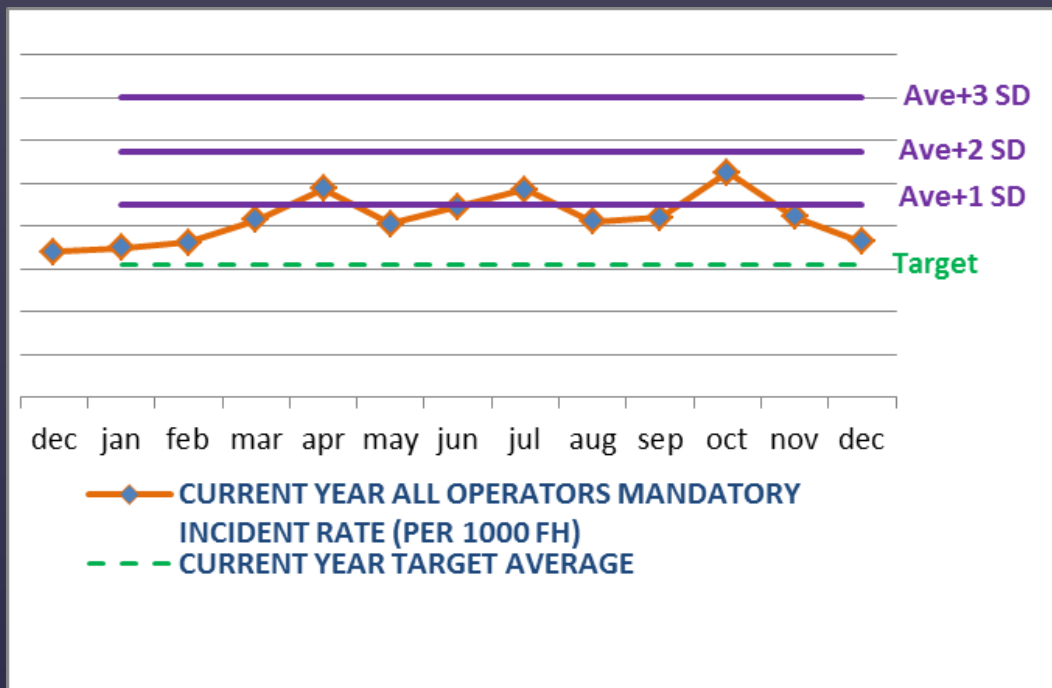
Current Year Target is say 5% Ave rate improvement over the Ave rate for the preceding year, which is: **0.15**



7. Acceptable Level of Safety Performance

At end of a monitoring period –

- ▶ Each *SPI's performance* is manifested by its own Alert & Target achievement outcome as follows:



- ▶ Alert avoidance – Yes / No
- ▶ Target achieved – Yes/ No

7. Acceptable Level of Safety Performance

Consequently –

► A package of SPLs' performance is manifested by its consolidated Alert & Target achievement outcome



High Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (4), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (3), No (0)]
1 CAA aggregate Air Operators monthly accident/ serious incident rate [per 1000 FH]	2009 Average Rate + 1/2/3 SD. (annual reset)	4	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
2 CAA aggregate Aerodromes monthly ground accident/ serious incidents rate - involving any aircraft [per 10,000 ground movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	4	3 % improvement of the 2010 Average Rate over the 2009 Average Rate.	3
3 CAA aggregate ATS monthly FIR serious incidents rate - involving any aircraft [per 100,000 air movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	0	4 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	8	Sub-total	3
	Max	12	Max	9
Lower Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (2), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (1), No (0)]
CAA aggregate Air Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	0
CAA annual Air Operator Line Station surveillance inspection Ave LEI% (for each Operator).	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI	1
CAA annual Foreign Air Operators Ramp sampling inspection program.	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit; OR <25% of Foreign Operators inspected	2	Not less than 50% of Foreign Operators to be inspected	0
CAA aggregate Aerodrome Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	0	<10% Average LEI; AND <1 level 2 finding per audit	0
CAA aggregate ATS Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate ATS quarterly FIR TCAS RA incidents rate - involving any aircraft [per 10,000 flight movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	2	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
CAA aggregate D&M/ MRO Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate AMO (MRO) quarterly rate of component warranty claims due to (Major) technical defects.	2009 Average Rate + 1/2/3 SD. (annual reset)	0	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	12	Sub-total	3
	Max	16	Max	8
	No Alert %	71.4%	Target Achieved %	35.3%
	Overall ALOS Performance		57.8%	

7. Acceptable Level of Safety Performance

At the beginning of a new monitoring period -

- ▶ Organization establish its desired minimum *consolidated* Alert & Target achievement outcome (i.e ALoSP), after taking into consideration the previous period's performance (**57.8%** in below illustration)
- ▶ Could **60%** be a possible ALoSP to be established for the next monitoring period?

CAA aggregate D&M/ MRO Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate AMO (MRO) quarterly rate of component warranty claims due to (Major) technical defects.	2009 Average Rate + 1/2/3 SD. (annual reset)	0	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	12	Sub-total	3
	Max	16	Max	8
	No Alert %	71.4%	Target Achieved %	35.3%
	Overall ALoS Performance	57.8%		

7. Acceptable Level of Safety Performance

▶ This *established ALoSP* (eg **60%**) is then measured against the *actual consolidated Alert & Target* achievement outcome at the end of the monitoring period, to verify its achievement

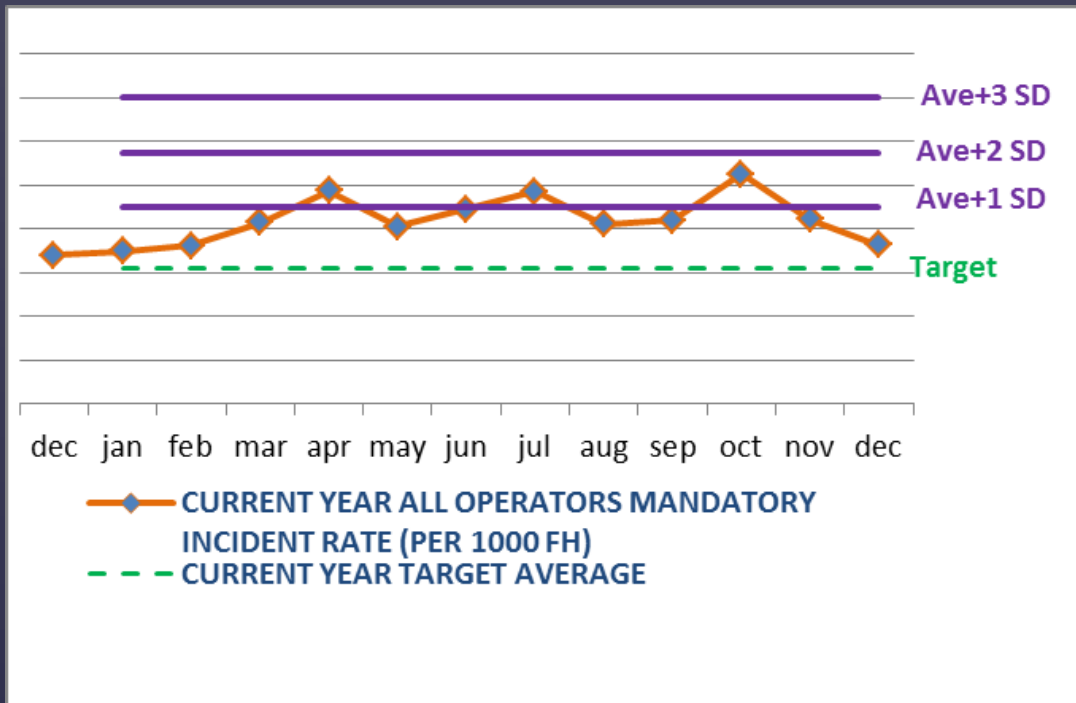
□ Q: What would a **100%** ALoSP mean?

Ans: All Targets achieved + zero Alerts

CAA aggregate D&M/ MRO Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate AMO (MRO) quarterly rate of component warranty claims due to (Major) technical defects.	2009 Average Rate + 1/2/3 SD. (annual reset)	0	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	12	Sub-total	3
	Max	16	Max	8
	No Alert %	71.4%	Target Achieved %	35.3%
	Overall ALoS Performance	57.8%		

Quiz:

- ▶ At the end of a current 12 month monitoring period, there were 3 data points (Apr, Jul, Oct) that went above the “Ave+1SD” Alert line as shown here:



Q: Has this SPL chart breached an Alert condition?

Answer: NO!

(non consecutive points!)

Quiz

- ▶ A Target setting is the planned Alert level to be achieved.

TRUE / FALSE?

➤ Answer: FALSE

- Target level is meant to *be achieved*
- Alert level is meant to *be avoided*

Quiz

- ▶ An Acceptable Level of Safety Performance can be established and monitored for achievement by the consolidated Alert & Target outcome of a package of SPIs.

- ▶ TRUE / FALSE

- ▶ Ans:TRUE

In summary

- ▶ Manage safety performance by measuring it
- ▶ Develop a package of SPIs to measure safety performance
- ▶ Set individual SPI Alert & Target performance markers based on safety metrics principles
- ▶ Consolidate SPIs package Alert & Target outcomes to manifest the system's overall safety performance
- Establish and achieve the organization's acceptable level of safety performance through the consolidated outcome of the SPIs package

Discussion / Questions

SPM: SPIs-ALoSP

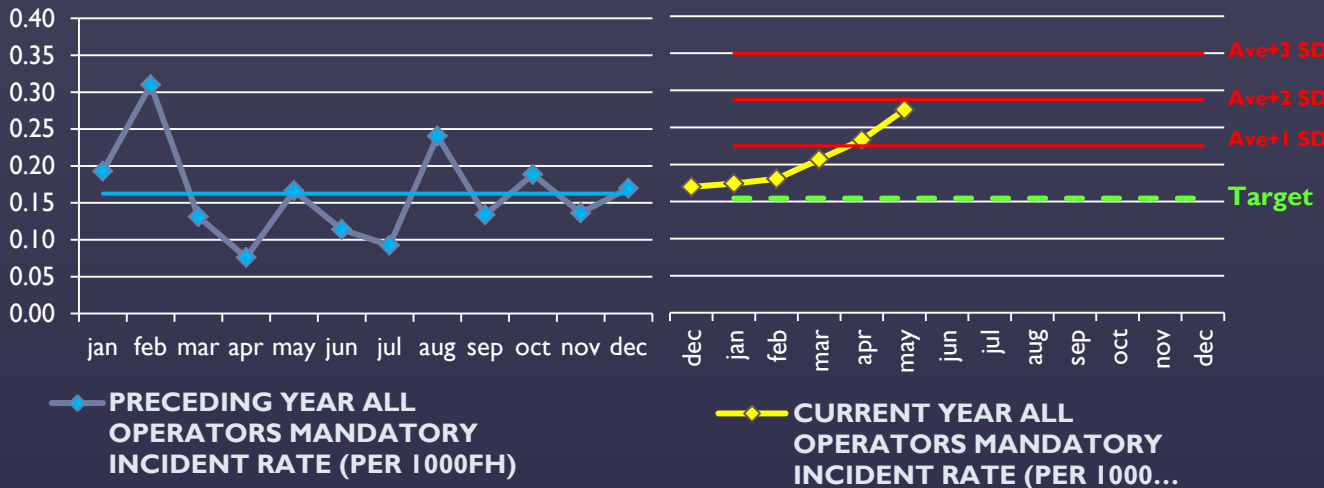
SSP High Consequence Safety Indicator Example (with Alert and Target Setting Criteria)

Preceding Year					Current year				Current Year Alert Levels			Current Year Target (line)
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Ave (line)	Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Preceding Year Ave +1SD (line)	Preceding Year Ave +2SD (line)	Preceding Year Ave +3SD (line)	
jan	51,837	10.00	0.19	0.16	dec	53,006	9.00	0.17				0.15
feb	48,406	15.00	0.31	0.16	jan	51,635	9.00	0.17	0.23	0.29	0.35	0.15
mar	53,354	7.00	0.13	0.16	feb	44,295	8	0.18	0.23	0.29	0.35	0.15
apr	52,513	4.00	0.08	0.16	mar	48,323	10	0.21	0.23	0.29	0.35	0.15
may	54,037	9.00	0.17	0.16	apr	47,176	11	0.23	0.23	0.29	0.35	0.15
jun	52,673	6.00	0.11	0.16	may	47,469	13	0.27	0.23	0.29	0.35	0.15
jul	54,086	5.00	0.09	0.16	jun				0.23	0.29	0.35	0.15
aug	54,043	13.00	0.24	0.16	jul				0.23	0.29	0.35	0.15
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nov	51,353	7.00	0.14	0.16	oct				0.23	0.29	0.35	0.15
dec	53,006	9.00	0.17	0.16	nov				0.23	0.29	0.35	0.15
		Ave	0.16		dec				0.23	0.29	0.35	0.15
		SD	0.06									
	Ave+1SD	Ave+2SD	Ave+3SD									
	0.23	0.29	0.35									

* Rate Calculation: (per 1000 FH)

Current Year Alert Level setting criteria is: Preceding Year Ave + 1/2/3 SD

Current Year Target is say 5% Ave rate improvement over the Ave rate for the preceding year, which is: 0.15



High Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (4), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (3), No (0)]
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2 CAA aggregate Aerodromes monthly ground accident/serious incidents rate - involving any aircraft (per 10,000 ground movements)	2009 Average Rate + 1/2/3 SD. (annual reset)	4	2% improvement of the 2010 Average Rate over the 2009 Average Rate.	3
3 CAA aggregate ATS monthly FIR serious incidents rate - involving any aircraft (per 100,000 air movements)	2009 Average Rate + 1/2/3 SD. (annual reset)	0	4% improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	8		3
	Max	12		9
Lower Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (2), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (1), No (0)]
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CAA aggregate ATS Operators Organization annual surveillance/audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate ATS quarterly FIR TCAS RA incidents rate - involving any aircraft (per 10,000 flight movements)	2009 Average Rate + 1/2/3 SD. (annual reset)	2	5% improvement of the 2010 Average Rate over the 2009 Average Rate.	0
CAA aggregate D&M MRO Organization annual surveillance/audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
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	Sub-total	12		3
	Max	16		8
	No Alert %	71.4%	Target Achieved %	35.3%
	Overall ALoSP Performance			57.8%

SSP Safety Performance Indicators and ALoSP

3-Apr-15

Contents:

Sheet 1 Instructions for WGs

Sheet 2 SSP-SMS Safety Performance Indicators correlation [>>](#)

Sheet 3 Safety Indicator Chart [>>](#)

Sheet 4 SPI Data Sheet [>>](#)

Sheet 5A SPIs Summary Package Performance (ALoSP) [>>](#)

Purpose –

Template for the selection and development of individual SPIs with harmonized Alert & Target setting procedure.

Include procedure for consolidation of the SPIs' individual Alert and Target performance outcomes to derive the ALoSP (applicable for SSP & SMS).

Safety Indicators Development and ALoS Performance Monitoring

Instructions for Working Groups:

Apr-15

- 1 Browse SMM 4.3.5 and C4-App4 for detailed GM on this subject.
- 2 This exercise is to develop one example of a high consequence SSP/ SMS Safety Performance Indicator chart, as in Sheet 3.
- 3 Elect a group discussion coordinator and also have some one (with laptop) to make entries in the SPI data sheet (Sheet 4).
- 4 Browse examples of SPIs for the various sectors, as listed in Sheet 2 attached (or other sources).
- 5 Decide on one high consequence (accidents/ serious incidents data trend) SPI chart to be developed.
- 6 Fill out the SPI data sheet (Sheet 4) with required details for your intended SPI chart i.e occurrence numbers and FH/ FC/ Air or Grd Movements. Actual data preferred, otherwise provide approximate viable figures based on experience. Customize column descriptions to suit your SPI description.
- 7 If time permit, develop another lower consequence SPI chart (routine incidents, etc) using the same procedure. (Browse lower consequence SPI examples column in Sheet 2)
- 8 Be prepared to share your completed SPI charts and comments with others.

Examples of Safety Indicators (SSP) & Safety Performance Indicators (SMS)

6Mar14

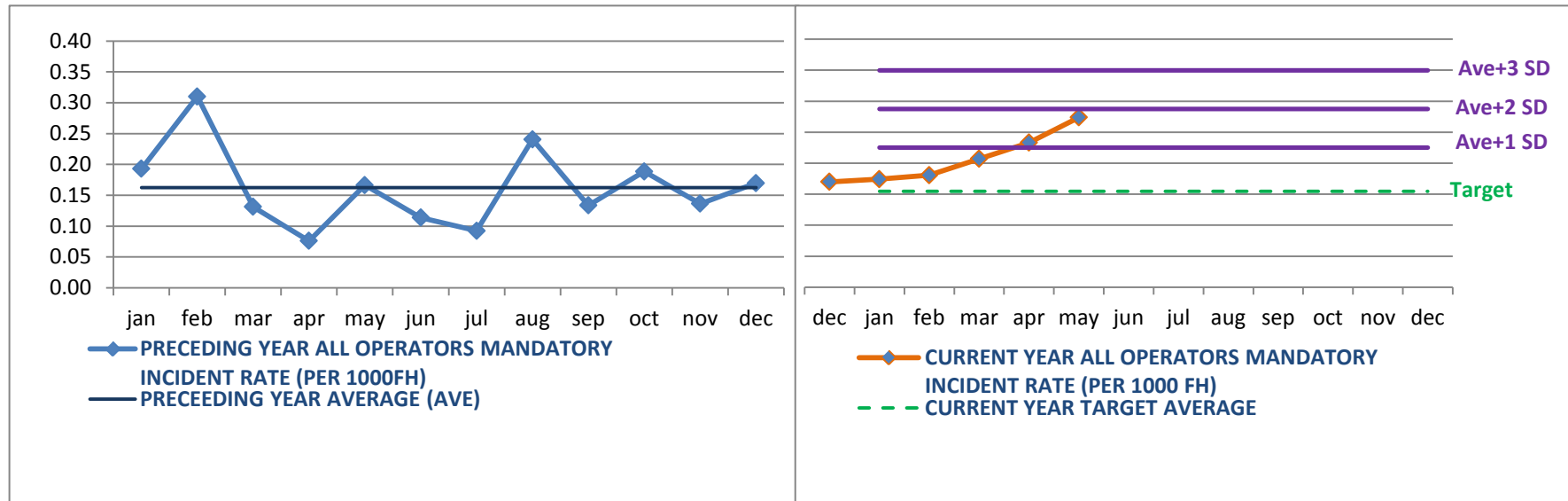
SSP Safety Indicators (Aggregate State)						SMS Safety Performance Indicators (Individual Service Provider)					
High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)			High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)		
Safety Indicator	Alert level criteria	Target level criteria	Safety Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria
Air Operators (Air Operators of the State only)											
CAA aggregate Air Operators monthly serious incident rate (eg per 1000FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA aggregate Air Operator annual surveillance Audit LEI% or findings rate (findings per audit)	Consideration	Consideration	Air Operator Individual Fleet monthly serious incident rate (eg per 1000FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Operator Combined Fleet monthly Incident rate (eg per 1000FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.
CAA aggregate Air Operators quarterly Engine IFSD incident rate (eg per 1000 FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA aggregate Air Operator annual Line Station Inspection LEI% or findings rate (findings per inspection)	Consideration	Consideration	Air Operator Combined Fleet monthly serious incident rate (eg per 1000FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Operator Internal QMS annual audit LEI% or findings rate (findings per audit)	Consideration	Consideration
CAA aggregate Air Operators quarterly IFTB incident rate (eg per 1000 FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA annual Foreign Air Operators Ramp surveillance inspection Ave LEI% (for each Foreign Operator).	Consideration	Consideration	Air Operator Engine IFSD incident rate (eg per 1000 FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Operator Voluntary Hazard reports rate [eg per 1000 FH]	Consideration	Consideration
			CAA aggregate Operators' DGR incident reports rate [eg per 1000 FH]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Air Operator Air Turn Back (ATB, technical) incident rate (eg per 1000 FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Operator DGR incident reports rate [eg per 1000 FH]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.
ETC						Air Operator RTO (high speed) incident rate (eg per 1000 FH)	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean			
Aerodrome Operators											

SSP Safety Indicators (Aggregate State)						SMS Safety Performance Indicators (Individual Service Provider)					
High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)			High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)		
Safety Indicator	Alert level criteria	Target level criteria	Safety Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria
CAA aggregate aerodromes quarterly ground accident/ serious incidents rate - involving any aircraft [eg per 10,000 ground movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA aggregate Aerodrome Operators annual surveillance Audit LEI% or findings rate (findings per audit)	Consideration	Consideration	Aerodrome Operator quarterly ground accident/ serious incident rate - involving any aircraft [eg per 10,000 ground movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Aerodrome Operator Internal QMS annual audit LEI% or findings rate (findings per audit)	Consideration	Consideration
CAA aggregate aerodromes monthly/ quarterly Runway Excursion incidents rate - involving any aircraft [eg per 10,000 departures]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.				Aerodromes Operator quarterly Runway Excursion incidents rate - involving any aircraft [eg per 10,000 departures]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Aerodrome Operator quarterly Runway Foreign Object Report (FOR) rate [eg per 10,000 ground movements]	Consideration	Consideration
CAA aggregate aerodromes monthly/ quarterly Runway Incursion incidents rate - involving any aircraft [eg per 10,000 departures]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.				Aerodromes Operator quarterly Runway Incursion incidents rate - involving any aircraft [eg per 10,000 departures]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	Operator Voluntary Hazard reports rate [per operational personnel per quarter]	Consideration	Consideration

SSP Safety Indicators (Aggregate State)						SMS Safety Performance Indicators (Individual Service Provider)					
High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)			High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)		
Safety Indicator	Alert level criteria	Target level criteria	Safety Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria	Safety Performance Indicator	Alert level criteria	Target level criteria
									Aerodrome Operator quarterly aircraft ground Foreign Object Damage (FOD) incident report rate - involving damage to aircraft [eg per 10,000 ground movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.
ETC											
ATS Operators											
CAA aggregate ATS quarterly FIR (airspace) serious incidents rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA aggregate ATS quarterly FIR TCAS RA incidents rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	ATS provider quarterly FIR serious incidents rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	ATS Operator quarterly FIR TCAS RA incidents rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.
CAA aggregate quarterly near miss incident rate [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	CAA aggregate ATS quarterly FIR Level Bust (LOS) incident rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	ATS provider quarterly/ annual near miss incident rate [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	ATS Operator quarterly FIR Level Bust (LOS) incident rate - involving any aircraft [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.
			CAA aggregate ATS Operators annual surveillance Audit LE1% or findings rate (findings per audit)	Consideration	Consideration	ATS provider quarterly/ annual GPWS/ EGPWS incident rate [eg per 100,000 flight movements]	Ave + 1/2/3 SD. (annual or 2 yearly reset)	___% (eg 5%) improvement between each annual Mean Rate.	ATS Operator Internal QMS annual audit LE1% or findings rate (findings per audit)	Consideration	Consideration

SSP High Consequence Safety Indicator Example (with Alert and Target Setting Criteria)

/ SafetyIndicators_N_ALoS_Performance_v9



A) Alert Level Setting:

Alert level for a new monitoring period (current year) is based on the preceding period's performance (preceding year), namely its data points Average & Std Deviation. The 3 alert lines are Ave+1SD, Ave+2SD and Ave+3SD

C) Target Level Setting(Planned Improvement) :

Target setting may be less structured than Alert level setting - eg target the new (current year) monitoring period's Ave rate to be say 5% lower (better) than the preceding period's Ave value.

B) Alert Level Trigger:

An Alert (abnormal/ unacceptable trend) is indicated if **ANY** of the conditions below are met for the current monitoring period (current year):

- Any single point is above 3 SD line
- 2 consecutive points are above 2 SD line
- 3 consecutive points are above 1 SD line

When an Alert is triggered (potential high risk or out of control situation), appropriate follow-up action is expected, such as further analysis to determine source and root cause of the abnormal incident rate and any necessary action to address the unacceptable trend .

D) Target Achievement:

At end of the current year, if the Ave rate for the current year is at least 5% or more lower than the preceding year's Ave rate, then the set Target of 5% improvement is deemed to have been achieved.

E) Alert & Target Levels - Validity Period:

Alert & Target levels should be reviewed/reset for each new monitoring period, based on the equivalent preceding period's Ave rate & SD, as applicable.

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SSP High Consequence Safety Indicator Example (with Alert and Target Setting Criteria)

Preceding Year				
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Ave (line)
jan	51,837	10.00	0.19	0.16
feb	48,406	15.00	0.31	0.16
mar	53,354	7.00	0.13	0.16
apr	52,513	4.00	0.08	0.16
may	54,037	9.00	0.17	0.16
jun	52,673	6.00	0.11	0.16
jul	54,086	5.00	0.09	0.16
aug	54,043	13.00	0.24	0.16
sep	52,383	7.00	0.13	0.16
oct	53,042	10.00	0.19	0.16
nov	51,353	7.00	0.14	0.16
dec	53,006	9.00	0.17	0.16

Ave			0.16
SD			0.06
Ave+1SD	Ave+2SD	Ave+3SD	
0.23	0.29	0.35	

Current Year Alert Level setting criteria is:
Preceding Year Ave + 1/2/3 SD

Current year				Current Year Alert Levels			Current Year Target (line)
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Preceding Year Ave +1SD (line)	Preceding Year Ave +2SD (line)	Preceding Year Ave +3SD (line)	
dec	53006	9.00	0.17				
jan	51635	9.00	0.17	0.23	0.29	0.35	0.15
feb	44295	8	0.18	0.23	0.29	0.35	0.15
mar	48323	10	0.21	0.23	0.29	0.35	0.15
apr	47176	11	0.23	0.23	0.29	0.35	0.15
may	47469	13	0.27	0.23	0.29	0.35	0.15
jun				0.23	0.29	0.35	0.15
jul				0.23	0.29	0.35	0.15
aug				0.23	0.29	0.35	0.15
sep				0.23	0.29	0.35	0.15
oct				0.23	0.29	0.35	0.15
nov				0.23	0.29	0.35	0.15
dec				0.23	0.29	0.35	0.15

* Rate Calculation:(per 1000 FH)

Current Year Target is say 5% Ave rate improvement over the Ave rate for the preceding year, which is: **0.15**

- SPI Chart >>>
- Contents >>>
- ALoSP >>>

Example: State "X" SSP ALoS Performance Summary (say for Year 2010)

High Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes/ No]	SI Target level/ criteria (for 2010)	Target Achieved [Yes/ No]
1 CAA aggregate Air Operators monthly accident/ serious incident rate [per 1000 FH]	2009 Average Rate + 1/2/3 SD. (annual reset)	Y	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	N
2 CAA aggregate Aerodromes monthly ground accident/ serious incidents rate - involving any aircraft [per 10,000 ground movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	Y	3 % improvement of the 2010 Average Rate over the 2009 Average Rate.	Y
3 CAA aggregate ATS monthly FIR serious incidents rate - involving any aircraft [per 100,000 air movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	N	4 % improvement of the 2010 Average Rate over the 2009 Average Rate.	N

Lower Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes/ No]	SI Target level/ criteria (for 2010)	Target Achieved [Yes/ No]
CAA aggregate Air Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	Y	<10% Average LEI; AND <1 level 2 finding per audit	N
CAA annual Air Operator Line Station surveillance inspection Ave LEI% (for each Operator).	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	Y	<10% Average LEI	Y
CAA annual Foreign Air Operators Ramp sampling inspection program.	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit; OR <25% of Foreign Operators inspected	Y	Not less than 50% of Foreign Operators to be inspected	N
CAA aggregate Aerodrome Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	N	<10% Average LEI; AND <1 level 2 finding per audit	N

Lower Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes/ No]	SI Target level/ criteria (for 2010)	Target Achieved [Yes/ No]
CAA aggregate ATS Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	Y	<10% Average LEI; AND <1 level 2 finding per audit	Y
CAA aggregate ATS quarterly FIR TCAS RA incidents rate - involving any aircraft [per 10,000 flight movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	Y	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	N
CAA aggregate D&M/ MRO Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	Y	<10% Average LEI; AND <1 level 2 finding per audit	Y
CAA aggregate AMO (MRO) quarterly rate of component warranty claims due to (Major) technical defects.	2009 Average Rate + 1/2/3 SD. (annual reset)	N	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	N

Note 1: Other Process Indicators - Apart from above SSP level Safety Indicators, there may be other systems level indicators within each operational areas. Examples would include process or system-specific monitoring indicators in AIR, OPS, AGA etc or indicators associated with performance-based programs such as fatigue risk management or fuel management. Such process or system-specific indicators should rightly be administered as part of the system or process concerned. They may be viewed as specific system or process level indicators which undergird the higher level SSP monitoring safety indicators. They should be addressed within the respective system or process manuals/ SOPs as appropriate. Nevertheless, the criteria for setting alert or target levels for such indicators could preferably be aligned with that of the SSP level safety indicators where applicable.

Note 2: Selection of Indicators & Settings - The combination (or package) of High and Lower Consequence Safety Indicators is to be selected by a State according to the scope of their aviation system. For those Indicators where the suggested Alert or Target levels setting criteria is not applicable, the State may consider any alternate criteria as appropriate. General guidance is to set Alerts and Targets that take into consideration recent historical or current performance.

Example: State "X" SSP ALoS Performance Measurement (say for Year 2010)

High Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (4), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (3), No (0)]
1 CAA aggregate Air Operators monthly accident/ serious incident rate [per 1000 FH]	2009 Average Rate + 1/2/3 SD. (annual reset)	4	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
2 CAA aggregate Aerodromes monthly ground accident/ serious incidents rate - involving any aircraft [per 10,000 ground movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	4	3 % improvement of the 2010 Average Rate over the 2009 Average Rate.	3
3 CAA aggregate ATS monthly FIR serious incidents rate - involving any aircraft [per 100,000 air movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	0	4 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	8	Sub-total	3
	Max	12	Max	9

Lower Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (2), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (1), No (0)]
CAA aggregate Air Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	0
CAA annual Air Operator Line Station surveillance inspection Ave LEI% (for each Operator).	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI	1
CAA annual Foreign Air Operators Ramp sampling inspection program.	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit; OR <25% of Foreign Operators inspected	2	Not less than 50% of Foreign Operators to be inspected	0
CAA aggregate Aerodrome Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	0	<10% Average LEI; AND <1 level 2 finding per audit	0

CAA aggregate ATS Operators Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate ATS quarterly FIR TCAS RA incidents rate - involving any aircraft [per 10,000 flight movements]	2009 Average Rate + 1/2/3 SD. (annual reset)	2	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
CAA aggregate D&M/ MRO Organization annual surveillance/ audit outcomes	>25% Average LEI; OR any level 1 finding; OR >5 level 2 findings per audit	2	<10% Average LEI; AND <1 level 2 finding per audit	1
CAA aggregate AMO (MRO) quarterly rate of component warranty claims due to (Major) technical defects.	2009 Average Rate + 1/2/3 SD. (annual reset)	0	5 % improvement of the 2010 Average Rate over the 2009 Average Rate.	0
	Sub-total	12	Sub-total	3
	Max	16	Max	8
	No Alert %	71.4%	Target Achieved %	35.3%
	Overall ALoS Performance	57.8%		

Note 1: Other Process Indicators - Apart from above SSP level Safety Indicators, there may be other systems level indicators within each operational areas. Examples would include process or system-specific monitoring indicators in AIR, OPS, AGA etc or indicators associated with performance-based programs such as fatigue risk management or fuel management. Such process or system-specific indicators should rightly be administered as part of the system or process concerned. They may be viewed as specific system or process level indicators which undergird the higher level SSP monitoring safety indicators. They should be addressed within the respective system or process manuals/ SOPs as appropriate. Nevertheless, the criteria for setting alert or target levels for such indicators should preferably be aligned with that of the SSP level safety indicators where applicable.

Note 2: Indicators & Settings - The combination (or package) of High and Lower Consequence Safety Indicators is to be selected by a State according to the scope of their aviation system. For those Indicators where the suggested Alert or Target levels setting criteria is not applicable, the State may consider any alternate criteria as appropriate. General guidance is to set Alerts and Targets that take into consideration recent historical or current performance.

Note 3: Weightage - Alert and Target scores between High and Lower Consequence indicators are weighted (4, 3, 2, 1) as indicated in the respective header columns. High consequence indicator "Alert Not Breached" has highest (4 pt) score whilst Lower consequence indicator "Target Achieved" has lowest (1 pt) score.

Note 4: Overall Score Interpretation - A SSP with **100%** overall performance score implies that the SSP has **achieved ALL** Target Levels of its Safety Indicators as well as **not breached ANY** Alert levels of its Safety Indicators. Conversely, a SSP with **0%** overall performance score implies that the SSP has **not achieved ANY** Target Levels of its Safety Indicators as well as **having breached ALL** Alert levels of its Safety Indicators.

SAFETY PERFORMANCE MEASUREMENT

- **QUANTIFYING PERFORMANCE INDICATORS AND AN ACCEPTABLE LEVEL OF SAFETY**

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SAFETY PERFORMANCE MEASUREMENT – QUANTIFYING PERFORMANCE INDICATORS AND AN ACCEPTABLE LEVEL OF SAFETY

1 INTRODUCTION

“Safety Performance Measurement” in the context of this paper essentially refers to the process of measuring safety related outcomes associated with a given operational system or organisation. Specifically, it is written in the context of today’s State Safety Programme (SSP) and Safety Management System (SMS) environment.

2 WHY MEASURE SAFETY PERFORMANCE

Safety management Standards and Recommended Practices (SARPs) had been progressively introduced by ICAO since 2001. The main framework of these safety management SARPs are the SSP and SMS. Amongst other requirements, these safety management provisions had introduced the expectation for States to achieve an acceptable level of safety performance:

“Each State shall establish an SSP for the management of safety in the State, in order to achieve an acceptable level of safety performance in civil aviation” – A19, 3.1.1

The active verb here is “to achieve”. It is a good thing that the next immediate clause says:

“The acceptable level of safety performance to be achieved shall be established by the State” – A19, 3.1.2

So, that “level” which States are supposed to achieve is based on that which States are going to establish themselves.

Objectively speaking, the expected bottom line (most onerous outcome) from these two clauses can possibly result in a theoretical scenario like this:

“Show me (a safety management Auditor quoting A19, 3.1.1/ 2) whether you have achieved (or not achieved) your acceptable level of safety performance. We will just take it that your own quantum of acceptable level of safety performance (which has been determined by your State) is reasonable. Now, just show me whether you have achieved it, or not...”

Even if such a bottom-line question is not coming from your SSP or SMS auditor, any discerning Accountable Executive or Safety Committee Chairman would probably ask anyway, sooner or later.

It has been said *“You cannot manage what you cannot measure” (Drucker)*. So, obviously we must be able to manage *and measure* safety performance, before anyone can expect us to achieve it (to whatever level)!

3 HOW TO MEASURE SAFETY PERFORMANCE

To achieve an acceptable level (or any level) of safety performance, an organization will firstly need to establish a mechanism to measure its safety performance. After that, it will then

decide on what is that acceptable level of safety to be achieved, within a given monitoring period.

Taking into consideration A19, 3.1.1 and 3.1.2 expectations, we will need to ensure a few characteristics of the safety performance measurement mechanism and indicators which are to be developed:

- a) They should be quantitative and measurable.
- b) They should be an expression of the safety performance status of the aviation system or operational areas.
- c) They should have provision for monitoring performance in relation to certain data-based performance markers.
- d) They should collectively be able to give a bottom line measurable performance status.
- e) This bottom line performance status should be able to tell whether the planned acceptable level of safety performance has been achieved or not, at the end of a monitoring period.

Now, do we need to start from scratch to search for such safety performance measurement mechanisms or indicators? Apparently not. Some aviation quality management systems or reliability control systems (especially large commercial air operators) have been traditionally known to utilise technical or reliability related indicators to track the performance of specific system processes. Examples include engine in-flight shut down rate, component failure rate, technical delay rate, etc. Hence, the existence of such technical indicators is a good place to start our appreciation of safety indicator models for SSP and SMS. Thus, within the large commercial air operators and their AMO/ DMO¹ sectors, development of SSP-SMS safety indicators is a matter of starting with the adaptation of certain existing technical or reliability related indicators to meet the higher level SSP-SMS expectations.

As for the other sectors of service provider (AGA, ANS, ATO, IGA²) where they may have no prior experience with Reliability or Quality Control systems indicators; such may then need to familiarise themselves with fundamental data trending charts for the purpose of developing SSP-SMS safety performance indicators. Figures 1 and 2 provide an illustration of a common basic data chart and a continuous data trending chart respectively.

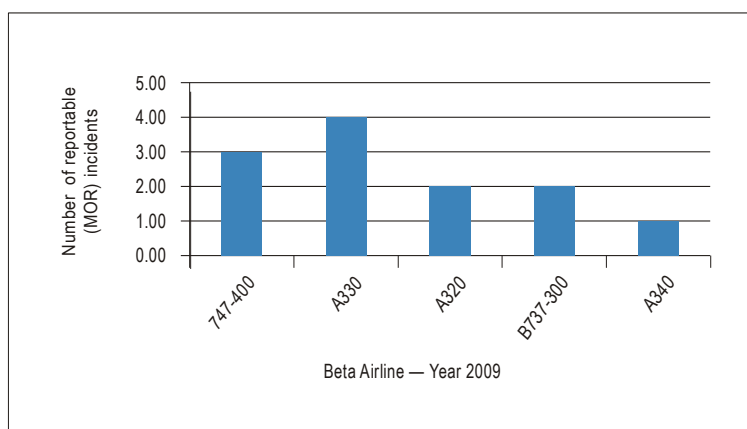


Figure 1: A basic data analysis chart

¹ AMO/ DMO – Approved Maintenance Organisation/ Design & Manufacturing Organisation

² Aerodrome, Air Navigation Services, Approved Training Organisations, International General Aviation

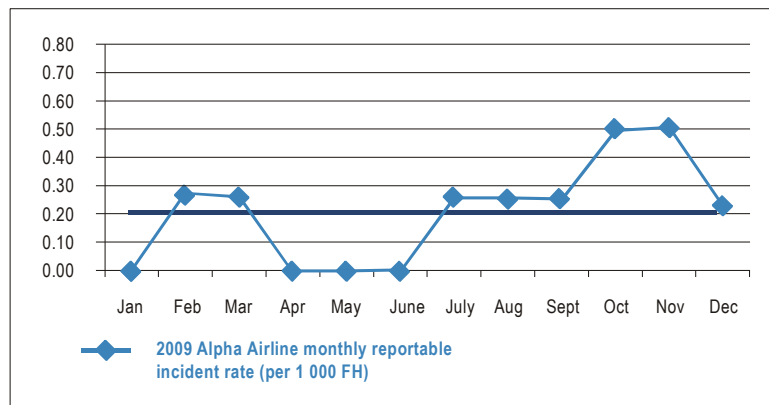


Figure 2: A continuous trending chart

The two figures show a one-time status of reportable incidents for each aircraft type (Figure 1) and a continuing incidents trending of the airline’s entire fleet (Figure 2). However, these two charts cannot serve as SSP-SMS safety performance indicator candidates yet, because they have no built-in performance measures – such as Alert and Target settings. Without such safety metrics performance measuring pointers or markers, there is no provision for interpretation and collation of the performance of each indicator (and ultimately the package of indicators) at the end of a given monitoring period.

We need to convert the (otherwise) qualitative performance of a data trending chart into a quantitative outcome, by means of measuring (counting) two key safety metrics markers – Alert avoidance and Target achievement status. It is like interpreting the health of a patient by just two key parameters – heart rate (low rate *achievement*) and blood pressure (high pressure *avoidance*).

Thus, a safety performance indicator has to be more than just a basic data chart, more than just a continuous data trending chart. It must have the capability for building in planned Targets to be achieved as well as Alert levels to be avoided. These two complementary and parallel markers will then serve to transform a common data trending chart into a safety performance indicator. By means of these two observable and countable markers, the performance of a safety indicator is made quantifiable. This quantification process (at end of monitoring period) is achieved by asking two basic questions:

- 1) Has the indicator breached its Alert level? [Yes/ No] and
- 2) Has the indicator achieved its planned Target performance level? [Yes/ No]

These two safety metrics performance markers are somewhat like those little built-in green pips and red warning flags within the various indicators in an aircraft cockpit. They will serve to tell the pilot whether he has not achieved his Target EPR³ (required power) or whether he has an EGT⁴ Alert (potential engine fire) during his takeoff run; either of which event can mean aborting the takeoff altogether. These aircraft systems safety indicators are the origin of this

³ EPR – Engine Pressure Ratio

⁴ EGT – Exhaust Gas Temperature

terminology that we use for our SSP-SMS safety performance measurement mechanism today.

4 ALERT LEVELS

Besides serving as one of the two data trending performance quantifiers, an alert level is fundamentally the caution light or alarm bell of a Safety Performance Indicator (SPI). Its common safety metrics terminology is called “Out of Control Criteria (OCC)⁵”. Breaching an Alert level implies that a data set has trended into an abnormal/undesirable region (in relation to its historical performance). In the case of a safety (occurrences) indicator it would mean an abnormal escalation of the occurrence type being tracked, implying a high risk situation of subsequent “out of control” occurrence rates. The determination of such an Alert boundary or level is associated with the recent historical data trending behaviour of the same indicator. The rationale for this is to ensure that a safety indicator’s current Alert setting has taken into consideration its own recent historical performance or behaviour. The historical data performance is specifically measured by means of two characteristics of the historical data set:

- a) Average value, and
- b) Standard Deviation (SD) value

From these two values (Average and SD), the Alert level for the current (or next) monitoring period of the safety indicator chart is derived and plotted as follows:

- 1) Average + 1 SD,
- 2) Average + 2 SD, and
- 3) Average + 3 SD

Figure 3 depicts the typical three Alert level lines as derived from the above three [Average + 1/ 2/ 3 SD] values. The “Preceding Year” is the historical data set whilst the “Current Year” is where the three Alert lines have been plotted, based on the preceding data set.

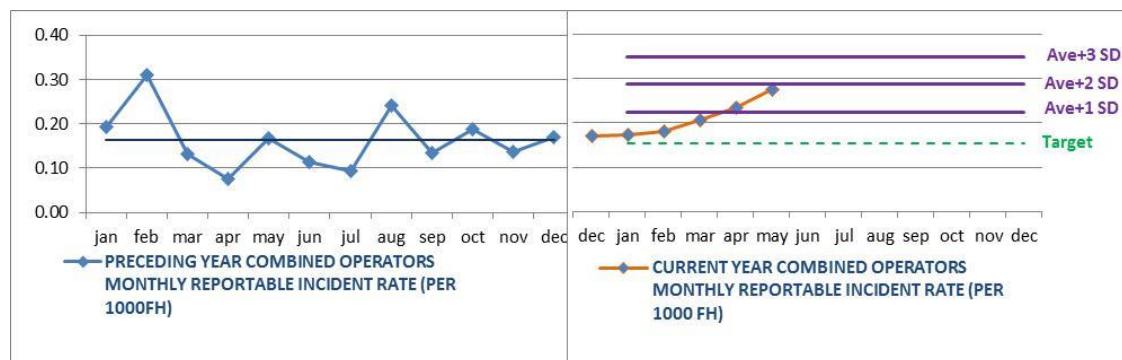


Figure 3: Alert levels based on historical Average and SD values⁶

The formula for calculating SD value (part of most spread sheet software, eg Excel) is “=STDEV”.

For manual calculation purpose, the SD (Population) formula is:

⁵ Safety Metrics by Christopher A. Janicak, OCC - pg 47

⁶ Figure 3 is an extract from ICAO SMM Doc 9859 (3rd Ed, 2013), pg 4-App 4-7

$$STDEVP = \sqrt{\frac{\sum(x - \mu)^2}{N}}$$

where “x” is the value of each data point, “N” is the number of data points and “μ” is the average value of all the data points.

A SD is the average deviation of the data set’s collective individual deviations from their Mean. Hence, if a data set is highly volatile (large deviations), its SD value will be greater than if the data set was less volatile (smaller deviations). This SD value is the key to our Alert setting criteria, as it is a volatility measure of the preceding data set. This SD value will automatically adjust the value and spacing of the 3 Alert lines based on the preceding data’s behaviour.

A manual calculation illustration is as follows:

Consider a data set consisting of the following eight values:

2, 4, 4, 4, 5, 5, 7, 9.

These eight data points have the average (mean) of 5:

$$\frac{2 + 4 + 4 + 4 + 5 + 5 + 7 + 9}{8} = 5$$

To calculate the SD (Population), first calculate the difference of each data point from the average, and square the result of each:

$$\begin{array}{ll} (2 - 5)^2 = (-3)^2 = 9 & (5 - 5)^2 = 0^2 = 0 \\ (4 - 5)^2 = (-1)^2 = 1 & (5 - 5)^2 = 0^2 = 0 \\ (4 - 5)^2 = (-1)^2 = 1 & (7 - 5)^2 = 2^2 = 4 \\ (4 - 5)^2 = (-1)^2 = 1 & (9 - 5)^2 = 4^2 = 16 \end{array}$$

Next, calculate the average of these values, and take the square root:

$$\sqrt{\frac{(9 + 1 + 1 + 1 + 0 + 0 + 4 + 16)}{8}} = 2$$

Hence, the SD (Population) for the above illustrative eight values is 2

5 ALERT TRIGGER

An Alert (abnormal/ unacceptable trend) is indicated if **ANY** of the conditions below are met for the current monitoring period:

- Any single point is above [Average + 3 SD] line
- 2 (or more) consecutive points are above [Average + 2 SD] line
- 3 (or more) consecutive points are above Average + 1 SD] line

These three separate Alert lines establish an equitable criteria to ensure that only a valid Alert situation is captured as such.

Criteria (a) captures a situation where a single data point has exceeded the previous Average deviation (from the Mean value) by *more than three times*. In other words, the occurrence rate during the data point update period (one month, in the case of Figure 3) is *more than three times* the historical Average deviation (from the Average value). This is obviously unacceptable and hence warrants an Alert to be triggered, *even though only one data point is involved*.

Criteria (b) and (c) are complementary graduated Alert levels to capture a relatively lower quantum of data point deviation beyond the 2 standard deviation and 1 standard deviation Alert levels respectively. In conjunction with their respective lower deviation quantum, the (b) and (c) Alert conditions of “2 (or more) consecutive points” and “3 (or more) consecutive points” are hence provided for. Refer Fig 4 below for an illustration of these 3 Alert conditions.

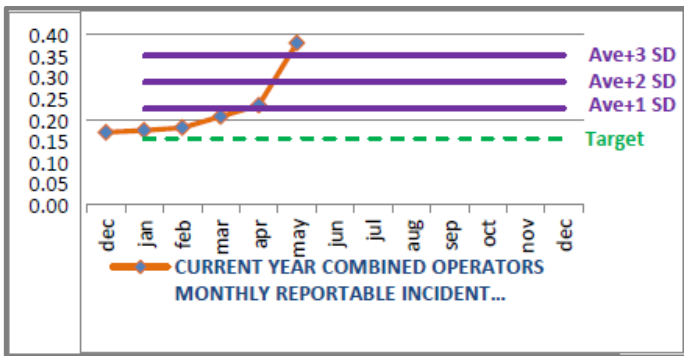


Figure 4-1, Alert (a):Single point above 3 SD

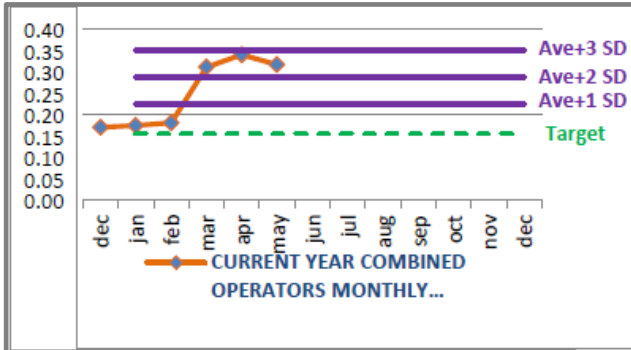


Figure 4-2, Alert (b):Two (or more) consecutive points above 2 SD

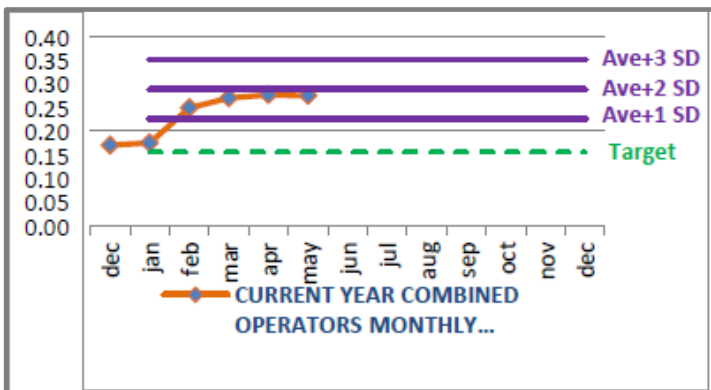


Figure 4-3, Alert (c):Three (or more) consecutive points above 1 SD

Armed with such a package of three complementary alert levels, a safety indicator is poised to trigger a genuine Alert condition based on valid statistical criteria. It will effectively capture any sudden (single data point) high risk spike as well as any sustained high occurrence rate deviations, which are equally unacceptable.

6 FOLLOW UP ACTIONS TO AN ALERT

Safety performance indicators are normally reviewed by a scheduled Safety Review Committee or appropriate platform. Where an Alert has been triggered for any given indicator, an enquiry or investigation should be conducted to explain or determine the reason for the Alert condition. The Safety Office concerned would preferably have anticipated the Committee's enquiry and should be prepared to account for the Alert level breach. This may involve prior liaison with service providers or operational areas concerned.

There is a logical connection between a safety indicator Alert mechanism and an organisation's occurrence investigation as well as Hazard Identification and Risk Mitigation (HIRM) processes. Where a SPI pertaining to certain type or category of incident has triggered an Alert, it implies that there is an abnormally high occurrence of that type or category of incidents. In order to arrest such an abnormal incident rate, necessary analysis of all the relevant incidents' records (such as incident notification or incident investigation reports) would be necessary. This is to identify potential issues such as significant recurrence of a particular incident type (whether due to one particular equipment or the same series of equipment), or that there was a series of multiple (connected or unconnected) incidents for that period concerned. The evaluation of such occurrence investigation reports can also determine if adequate and effective corrective actions have indeed been taken or recommended by the relevant investigators to address the causes of those incidents, and hence ensure their non-recurrence. If investigations performed are not sufficiently thorough to address root cause or latent conditions, then recurrence of the same incident type can be expected. Thus, there is a connection between inadequate incident investigation processes and subsequent sustained high incident rates, because actions taken or recommended from previous investigations were off the mark or did not address underlying issues or hazards.

Where there should be any hazards identified in the course of incident investigation records review, and found to have been inadequately addressed, this can then bring in the organisation's HIRM process. Thus in an SSP-SMS environment, there should be a constant connection between its safety performance monitoring, occurrence investigation and HIRM processes.

In the case of a lower consequence SPI, say Runway-Apron Foreign Objects Debris reports, a triggered Alert would imply that there is a high likelihood of seeing a subsequent Alert in its related higher consequence SPIs, e.g. Aircraft Foreign Objects Damage incidents, or Engine Foreign Object Damage incidents. This would invariably be so, if no timely and effective corrective actions were taken in relation to the lower consequence SPI's Alert.

7 TARGET SETTING

Target setting is a less structured process than Alert setting. It is essentially a desired or planned percentage improvement over the preceding period's Average occurrence rate. The Target level is represented by the dotted line in Figure 3. In this case it is five percentage points below (better) than the preceding data period. This Target level is meant to be compared with the current monitoring period's Average value (which is to be calculated at the end of the current monitoring period). If the current period's Average value should be below (better) than this Target line (preceding year's Average) then the Target performance *has been achieved*. If the current period's Average is above (worse) than the Target line, then the Target *has not been achieved*.

There should be an objective rationale for determining the Target quantum of a given SPI, whether it should be 1%, 5% or 10%. Primarily, it should be correlated to the nature, scope and aggressiveness of actions taken or planned with regard to the purpose of improving the safety and reliability performance of the operational process underlying that SPI.

8 SPI DATA TABLE AND CHART GENERATION

In order to generate a SPI trending chart shown in Figure 3, it will be necessary to collate and annotate the preceding and current data sets on an Excel spreadsheet shown in Figure 5 below:

SSP High Consequence Safety Indicator Example (with Alert and Target Setting Criteria)												
Preceding Year					Current year				Current Year Alert Levels			Current
Mth	All Operators Total FH	All Operators Incidents	Incident Rate*	Ave (line)	Mth	All Operators Total FH	All Operators Incidents	Incident Rate*	Preceding Year Ave +1SD (line)	Preceding Year Ave +2SD (line)	Preceding Year Ave +3SD (line)	Year Target (line)
jan	51,837	10.00	0.19	0.16	dec	53006	9.00	0.17				
feb	48,406	15.00	0.31	0.16	jan	51635	9.00	0.17	0.23	0.29	0.35	0.15
mar	53,354	7.00	0.13	0.16	feb	44295	11	0.25	0.23	0.29	0.35	0.15
apr	52,513	4.00	0.08	0.16	mar	48323	13	0.27	0.23	0.29	0.35	0.15
may	54,037	9.00	0.17	0.16	apr	47176	13	0.28	0.23	0.29	0.35	0.15
jun	52,673	6.00	0.11	0.16	may	47469	13	0.27	0.23	0.29	0.35	0.15
jul	54,086	5.00	0.09	0.16	jun				0.23	0.29	0.35	0.15
aug	54,043	13.00	0.24	0.16	jul				0.23	0.29	0.35	0.15
sep	52,383	7.00	0.13	0.16	aug				0.23	0.29	0.35	0.15
oct	53,042	10.00	0.19	0.16	sep				0.23	0.29	0.35	0.15
nov	51,353	7.00	0.14	0.16	oct				0.23	0.29	0.35	0.15
dec	53,006	9.00	0.17	0.16	nov				0.23	0.29	0.35	0.15
		Ave	0.16		dec				0.23	0.29	0.35	0.15
		SD	0.06									

* Rate Calculation: (per 1000 FH)			
Ave+1SD	Ave+2SD	Ave+3SD	
0.23	0.29	0.35	

* Rate Calculation: (per 1000 FH)	
Current Year Alert Level setting criteria is: Preceding Year Ave + 1/2/3 SD	

* Rate Calculation: (per 1000 FH)	
Current Year Target is say 5% Ave rate improvement over the Ave rate for the preceding year, which is:	0.15

Figure: 5 – SPI Data Table⁷

Such an Excel data sheet is to be annotated with all the necessary data pertaining to the SPI concerned, namely its preceding and current period's occurrence numbers, flight hours/ cycles/ movements as applicable. The required formulae for Average, standard deviation (STDEV), Alert and Target settings are built-in as indicated. The completed table can then generate the required SPI chart (Figure 3) automatically, with the Excel charting function.

9 ALERT AND TARGET VALIDITY PERIOD

Alert and Target settings are based on a SPI's recent historical behaviour. With this rationale in mind, it is apparent that Alert level and Target settings should be updated between appropriate monitoring periods. This would be especially important where there has been significant change in the volatility of past data sets (Higher SD value will result in bigger margins in-between Alert lines and vice versa). Theoretically, Alert level and Target settings can be recalculated at the end of each monitoring period, say yearly. However, this may not be the case, depending on factors as the number of data points per monitoring period and the volatility of those data points. Any major operational environment changes such as new equipment or additional service providers may deserve a review of Alert levels, Targets or

⁷ Figure 4 is an extract from ICAO SMM Doc 9859 (3rd Ed, 2013), pg 4-App 4-8

even SPI validity. In any case, the validity of Alert levels and Target settings should preferably not exceed the period of its related historical data points.

10 WHAT SPIs PACKAGE DO WE NEED

For the purpose of SSP-SMS safety performance measurement, an organisation will need to distinguish a special package of strategic and pertinent *safety* performance indicators from other normal business indicators. The normal *business* indicators or key performance indicators (KPIs) will continue to be maintained by the organisation for its specific business purposes and should not be mixed with their SSP-SMS SPIs. The fundamental reason is that SSP-SMS interaction expects the service provider’s SMS SPIs to be congruent to the SSP SPIs and hence be subject to the civil aviation authority’s agreement and oversight. Thus, a service provider’s SMS documentation should address its specific SMS SPIs only.

Selection of a package of SSP-SMS SPIs should be preceded by collating a list of all the organisation’s *existing* indicators (including any technical or reliability indicators and KPIs). Such a document will afford the SPIs selection team a good overview of what are the currently available indicators and their respective data sources. An illustrative format for maintaining a bank (tabulation) of potential SSP indicators is shown in Figure 5.

Examples of Safety Indicators (SSP) & Safety Performance Indicators (SMS)											
SSP Safety Indicators (Aggregate State)						SMS Safety Performance Indicators (Individual Service Provider)					
High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)			High Consequence Indicators (Occurrence/ Outcome-based)			Lower Consequence Indicators (Event/ Activity-based)		
Safety Indicator	Alert level criteria	Target level criteria	Safety Indicator	Alert level criteria	Target level criteria	SPI	Alert level criteria	Target level criteria	SPI	Alert level criteria	Target level criteria
Air Operators											
SSP Air Operators High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	SSP Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	Air Operator SMS High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	Air Operator SMS Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.
Etc.											
Aerodrome Operators											
SSP Aerodromes High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	SSP Aerodromes Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	Aerodrome SMS High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	Aerodrome SMS Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.
Etc.											
ATS Operators											
SSP ATS High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	SSP ATS Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	ATS SMS High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	ATS SMS Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.
Etc.											
POA/ DOA/ MRO Organizations											
SSP AMOs High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	SSP AMOs Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	AMO SMS High Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.	AMO SMS Lower Consequence SPI No 1	Ave + 1/2/3 SD. (annual or 2 yearly reset)	...% (eg 5%) improvement between each annual Mean Rate.
Etc.											
Other Aviation Sectors, etc.											

Figure 5: SPIs tabulation (collation) format⁸

A package of selected SPIs will need to include *High consequence* safety related outcome indicators (accidents, serious/ mandatory incidents). This should then subsequently (later phase) be supported by *Lower consequence* indicators (e.g. routine incidents, specific process/ system/ area indicators, etc). Such *High* and *Lower consequence* SPIs are sometimes termed as *lagging* and *leading* indicators. Thereafter, the organisation may also consider *supplementary* indicators to monitor safety related organisational behaviour and activity where appropriate.

⁸ Figure 5 is an adaptation from ICAO SMM (Doc 9859, 3rd Ed, 2013), pg 4-App 4-3

When considering the selection of supplementary behaviour and activity related indicators, an organisation should well be aware of their constraints. These would include measurement or quantification viability as well as the possibility of encouraging unwarranted activities or bias, for the sake of attaining certain targets. Notwithstanding this, there is no doubt that adopting a mechanism to measure, and hence encourage positive organisational behaviour or safety culture is something which can be considered as a frontier behavioural SPI in a fully matured SSP-SMS environment. Further discussion on such a possible organisational safety culture (risk profile) measurement concept can be found in ICAO Safety Management Manual (SMM) 3rd edition (2013)⁹. If such an organisational risk profile (ORP) is adopted by a State, it can be a comprehensive measurement of its service providers' organisational risk profile. The aggregate outcome from such an ORP measurement mechanism can then be a comprehensive behaviour/ activity indicator, to supplement the primary SPIs.

11 MEASURING PERFORMANCE OF A SSP- SMS SPIs PACKAGE

Once a package of selected SPIs is in place, their individual as well as summary performance can be measured. The outcomes of each SPI's Alert and Target markers can be in the form of "YES/ NO" answers, or to be more quantitative, allocation of positive points for achievement of a Target and avoidance of an Alert. The points system can facilitate weighting between High consequence, Lower consequence and possibly supplementary indicators. An illustration of a quantitative performance measure for a package of SSP SPIs is in Figure 6.

⁹ SMM Doc 9859 (3rd Ed, 2013), App 1 to Chapter 2

Illustration of SSP ALoS Performance Measurement				
High Consequence Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (4), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (3), No (0)]
1 High Consequence SPI No 1	Preceding Period Ave Rate + 1/2/3 SD	4	5 % improvement of Current Period Ave rate over Preceding Period Ave	0
2 High Consequence SPI No 2	Preceding Period Ave Rate + 1/2/3 SD	0	6 % improvement of Current Period Ave rate over Preceding Period Ave rate.	0
3 High Consequence SPI No 3	Preceding Yr Ave Rate + 1/2/3 SD	4	3 % improvement of Current Period Ave rate over Preceding Period Ave rate.	3
4 Etc				
	Sub-total	8	Sub-total	3
	Max	12	Max	9
Lower Consequence & Supplementary Safety Indicators				
Safety Indicator (SI) Description	SI Alert Level/ Criteria (for 2010)	Alert level Not Breached [Yes (2), No (0)]	SI Target level/ criteria (for 2010)	Target Achieved [Yes (1), No (0)]
1 Lower Consequence No 1	Preceding Period Ave Rate + 1/2/3 SD	2	3 % improvement of Current Period Ave rate over Preceding Period Ave rate.	1
2 Lower Consequence No 2	Preceding Period Ave Rate + 1/2/3 SD	2	4 % improvement of Current Period Ave rate over Preceding Period Ave rate.	0
3 Lower Consequence No 3	Preceding Period Ave Rate + 1/2/3 SD	0	2 % improvement of Current Period Ave rate over Preceding Period Ave rate.	0
4 Lower Consequence No 4	Preceding Period Ave Rate + 1/2/3 SD	2	6 % improvement of Current Period Ave rate over Preceding Period Ave rate.	0
5 Lower Consequence No 5	Preceding Period Ave Rate + 1/2/3 SD	2	3 % improvement of Current Period Ave rate over Preceding Period Ave rate.	1
6 Etc				
	Sub-total	8	Sub-total	2
	Max	10	Max	5
	No Alert %	72.7%	Target Achieved %	35.7%
Overall SSP ALoS Performance			58.3%	

Figure 6: SSP SPIs Package Performance Measure¹⁰

Hence, a SMS or SSP overall safety performance can be manifested by the summary Alert avoidance and Target achievement outcomes of its package of selected SPIs by tracking and counting their Target achievement and Alert avoidance outcomes respectively.

12 ACCEPTABLE LEVEL OF SAFETY PERFORMANCE

With reference to Figure 6, the quantitative summary performance of the package of SPIs is self-evident at the bottom-line titled “Overall SSP Acceptable Level of Safety Performance (ALoSP)”. In this illustration it is “58.3%”. Does this 58.3% percentage meet the minimum overall performance expectation of the State (SSP)? As per A19 (3.1.2), “*The acceptable level of safety performance to be achieved shall be established by the State*”. If the State (in this Figure 6 illustration) had established its ALoSP at say, 50%, then it would have achieved its ALoSP.

13 CHARACTERISTICS OF AN EFFECTIVE AND VIABLE PACKAGE OF SPIs

¹⁰ Figure 6 is an adaptation from ICAO SMM (Doc 9859, 3rd Ed, 2013), pg 4-App 4-9

Some questions which an effective package of SPIs should be able to answer *positively* are as follows:

- a) Do we have a balanced package of safety indicators, measuring High and Lower consequence safety/quality outcomes primarily?
- b) Does each safety indicator have an objective high risk or undesirable trend Alert trigger criteria?
- c) Does each safety indicator have an objective (desired/ planned) Target setting criteria?
- d) Would any of these indicators, by virtue of its target or alert settings, inadvertently result in the creation of unexpected or unwarranted organisational activities or behaviour?
- e) Does each safety indicator provide us with a continuous perspective of its current trending in relation to its recent historical performance?
- f) Do we have supplementary indicators measuring organisational safety-related behaviour or activities which are pertinent to the organisation's safety culture or risk profile measurement?
- g) Can our package of safety indicators provide us with a bottom line quantitative measure of our overall organisation safety performance?
- h) Will we be able to compare or benchmark the performance of our individual or package of indicators internally or externally?
- i) Are we able to account for the performance of an aggregate safety indicator to its various individual contributing sources or service providers, when necessary?

14 BENEFITS OF HARMONISED SAFETY PERFORMANCE MEASUREMENT.

Some apparent benefits of adopting objective safety performance measurement mechanisms as illustrated in this paper (which mechanism is also addressed in ICAO SMM 3rd Edition) are as follows:

- a) Much less subjectivity to the issue of "what is my acceptable level of safety performance"
- b) Harmonised SPIs Alert and Target setting criteria based on objective safety metrics principles.
- c) No more plucking of an SPI Alert level out of thin air, or using a "grandfather" alert level.
- d) Allow inter-organisation sharing/ benchmarking of SPI performance.
- e) Facilitate the overall consolidated (bottom line) safety performance measure of a package of SMS or SSP SPIs.

15 CONCLUSION

Employing basic safety metrics principles to monitor and measure safety performance is an objective and reasonable way to go. Without an underlying SPIs quantification mechanism, an organisation's safety performance report may just consist of subjective accounts, interpretations and promises.