Mathematical Model Brochure

Provisioning Services

Issue 2
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Introduction

This brochure explains in details the standard Mathematical Model that is used to determine recommended spare parts quantities.

The basic principle of the recommendation is to evaluate the risk of failure of a part during its first year of operation. This is called the annual demand. This annual demand (D_{ann}) is compared with the minimum annual demand (MAD) selected by the airline, to decide to recommend the part or not. Further risk of supply chain delays are mitigated by adding further spares to obtain sufficient protection in line with the expected demand (D_{RST}) during the re-supply time.

Understanding the basics of the Airbus recommendation model will help you taking the most out of the RSPL and having the right questions in mind to reduce your Initial Provisioning (IP).

Mathematical Model Step by Step

Step 0 — Airline/Material Parameter

Step 1 — Annual Demand

Step 2 — Demand during re-supply time

Step 3 — Recommended quality

Step 4 — Fine-tuning

Provisioning Parameters – Overview

The parameters needed for the mathematical model are twofold:

1. Material parameters: specific to every part number.
2. Airline parameters: not part number specific, but specific to the airline and reflect their operations, their material strategy and their organization.

Material Parameters

- Mean time between unscheduled removals (MTBUR)
- Essentiality Code (ESS)
- Spare Part Classification (SPC)
- Scrap rate (SCR)
- Lead Time (LTM)
- Mean Shop Processing Time (MST)
- Quantity per A/C (QPA)

Airline Parameters

OPERATIONAL	ADMINISTRATIVE	STRATEGIC
Fleet size (FS)	Administration time (AT)	Protection levels (PL)
Annual flight hours (FH)	Transit time (TT)	Minimum Annual Demand (MAD)
Block time	Turnaround time (TAT)	
APU Consideration factor		

Provisioning Parameters - In Detail

Material Parameters

Meantime between unscheduled removals (MTBUR)

An accepted industry standard for reporting the **reliability of a component**.

Comprises the number of flying hours during a time period divided by the number of unscheduled removals.

For the IP calculation the IP MTBUR is used. It is generally a factor of the Guaranteed MTBUR

Provisioning Parameters - In Detail

Material Parameters | **Essentiality Code (ESS)**

No-Go (1):
The flight **cannot** be dispatched with the part missing or inoperative.

Go-If (2):
The flight **may** be dispatched with the part missing or inoperative dependent upon CDL or MMEL conditions.

Go (3):
The flight **can** always be dispatched with the part missing or inoperative.

Provisioning Parameters - In Detail

Material Parameters

Spare Part Class Code (SPC)

Indicates the classification of the spare part as follows:

0 Reference items	1 Expendable Part	6 Repairable Part	2 Rotable Part
No physical part/fictitious part like drawings	An Expendable Part is **not repairable**.	A Repairable Part is **repairable** but does not have its own Component Maintenance Manual (CMM)	A Rotable Part is a **Repairable** Part that has its own Component Maintenance Manual (**CMM**)

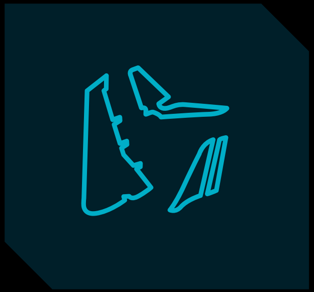
SPC 0

↓

No recommendation

Provisioning Parameters - In Detail

Material Parameters | **Scrap Rate (SCR)**



Identifies the **rate of units** of a given part classified as repairable which, if removed from service, are found to be beyond economic repair and are therefore **scrapped**.

1 —— SCR —— 999

Note: A Scrap Rate of 999 indicates 99.9%.

Provisioning Parameters - In Detail

Material Parameters

Mean Shop Processing Time (MST)	Lead Time (LTM)
It indicates the **total number of calendar days** from receipt of the part at the repair base until dispatch. This includes administration, handling, repair test and other functions at the repair shop. It is applicable to items with the Spare Parts Class Code SPC 2 or SPC 6.	The maximum number of calendar days required by the supplier after receipt of a purchase order to make **shipment** of the quantity ordered.

LTM is the replenishment lead-time, not the IP lead-time

Provisioning Parameters - In Detail

Material Parameters

Quantity Per Aircraft (QPA)

Indicates the **quantity** of the unit installed per aircraft.

Provisioning Parameters - In Detail

Material Parameters	Reason For Selection (RFS)

- 0 Not a potential spare (reference item)
- 1 Wear
- 2 Maintenance Damage
- 3 Loss
- 4 Vibration
- 5 Corrosion
- 6 Deterioration
- 7 Extreme Temperature
- 8 Other
- 9 Not an Initial Provisioning part

RFS 0 → No recommendation

RFS 9 → No recommendation

Provisioning Parameters - In Detail

Airline Parameters

Number of A/C (in the IP period)	Annual flight hours per A/C (FH)
Counts the **number of aircraft** for which the IP exercise shall be run, based on the decision of the customer.	The **total flight hours per year** for all aircraft divided by the number of aircraft.

Provisioning Parameters - In Detail

OPTIONAL PARAMETER

Airline Parameters

Flight Cycle Time	APU Consideration Factor
The average duration in hours of a **representative flight-leg** between take-off and landing.	Percentage of Flight hours which indicates the **average usage of the APU**.

ADMINISTRATIVE

Provisioning Parameters - In Detail

Airline Parameters

Administration Time (AT)

Replenishment Process

Administration Time (Part 1)	Lead Time (LTM)	Administration Time (Part 2)

- Identification of needed Part
- Ordering

- Shipping Time & Customs
- Administration / Follow up
- Good Receipt

AT is the customer's **administration time in handling the replenishment process** of not repairable parts.

It is the total time taken in calendar days from removal of an unrepairable part, placing a purchase order, shipping, customs etc., until the new part is ready for use on the operator's shelf.

This value is added to the Lead Time (LTM) to obtain the re-supply time for expendable material.

Provisioning Parameters - In Detail

Airline Parameters

Transit Time (TT)

Repair Process

$^{1}/_{2}$ of Transit Time (TT)	Mean Shop Processing Time (MST)	$^{1}/_{2}$ of Transit Time (TT)

- Shipping Time
- Administration
- Customs
- Logistics

- Shipping Time
- Administration
- Customs
- Logistics

TT indicates:

The **average time** it takes for a faulty part to be identified and removed from an aircraft until it arrives at the repair station.

+

The time it takes for the repaired part to be dispatched to the airline and restocked.

Provisioning Parameters - In Detail

Airline Parameters

Turn Around Time (TAT)

Repair Process

1/2 of Transit Time (TT)	Mean Shop Processing Time (MST)	1/2 of Transit Time (TT)
• Shipping Time • Administration • Customs • Logistics		• Shipping Time • Administration • Customs • Logistics

TAT is the **sum** of the Transit Time (**TT**) and the Mean Shop Processing Time (**MST**) expressed in calendar days.

TAT = TT + MST

Choosing the TAT as an entry parameter for the recommendations' calculation disregards the TT and the individual part's MST and sets the TAT as a global value for all rotable or repairable spares.

Provisioning Parameters - In Detail

Airline Parameters

Protection Level (PL)

The Protection Level represents the **probability of having the part on stock** if an unscheduled removal happens during the re-supply time. It is usually adapted to Essentiality codes and SPC.

The Protection Level indicates the risk in %.

For example, if PL is 95%:

Out of 100 unscheduled removals during the re-supply time, there will be a spare available in stock 95 times.

Mathematical Model Step by Step

Step 0	Step 1	Step 2	Step 3	Step 4
Airline/Material Parameter	**Annual Demand**	**Demand during re-supply time**	**Recommended quality**	**Fine-tuning**

Step 1: Annual Demand

What is the forecasted annual demand?

The annual demand is the number of unscheduled removals expected for the year for that part.

In the given example,
230 removals are forecasted.

$$D_{ann} = \frac{FH \times FS \times QPA}{MTBUR}$$

Ex: $$230 = \frac{2300 \times 20 \times 10}{2000}$$

D_{ann}	Estimated annual demand	**FS**	Fleet Size	**MTBUR**	Mean Time between Unscheduled Removals
FH	Annual flight hours	**QPA**	Quantity per A/C		

Mathematical Model Step by Step

Step 0	Step 1	Step 2	Step 3	Step 4
Airline/Material Parameter	**Annual Demand**	**Demand during re-supply time**	**Recommended quality**	**Fine-tuning**

Step 2: Demand During Re-supply Time

Are the spare parts always available?

Once the first part has been used (after the first unscheduled removal has happened), the warehouse is not complete anymore because one spare has been put on the aircraft.

1. Could there be further failures until the stock has been re-supplied (replenished) again?
2. How many failures are forecasted?

This is modeled via the demand during re-supply time: how many unscheduled removals will happen, until the first part is back on the shelf.

$$D_{RST} = D_{ann} \times \frac{RST}{365}$$

Daily Demand ($\frac{RST}{365}$)

D_{RST} Demand during Re-Supply Time

RST Re-Supply Time

Step 2: Demand During Re-supply Time

How to determine the Re-supply Time (RST)?

The re-supply time, the time needed for the part to be back on stock, is made up of two terms: the repair time and the re-order time.

These two terms are weighed by the scrap rate.

$$RST = \text{Repair time} + \text{Re-order time}$$

Repair time:

$$\left[(MST + TT) \times \left[1 - \frac{SCR}{1000} \right] \right]$$

Re-order time:

$$\left[\left[\frac{SCR}{1000} \right] \times (LT + AT) \right]$$

MST	Mean Shop Time
TT	Transit Time
SCR	Scrap Rate
LT	Lead-Time
AT	Administrative Time

Mathematical Model Step by Step

Step 0	Step 1	Step 2	Step 3	Step 4
Airline/Material Parameter	**Annual Demand**	**Demand during re-supply time**	**Recommended quality**	**Fine-tuning**

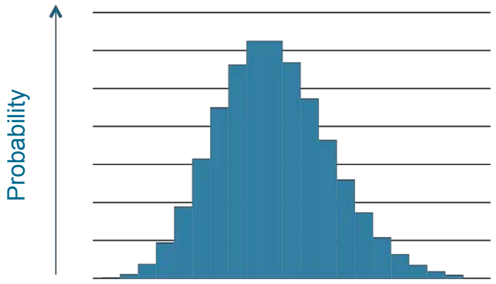
Step 3: Determine Recommended Quantity

How many spare parts are needed to satisfy the DRST?

$$D_{RST} = D_{ann} \times \frac{RST}{365}$$

Ex: *15.75* = *230* x *25 / 365*

The number of unscheduled removals during the Re-Supply Time is assumed to follow a **Poisson distribution**, centered around the D_{RST} .



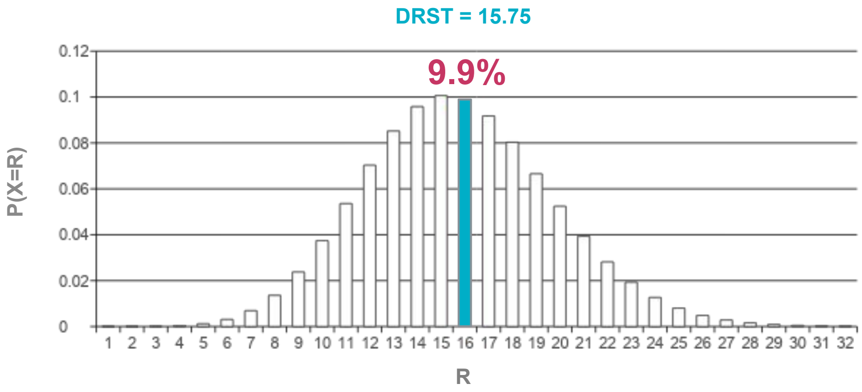
Step 3: Determine Recommended Quantity

What is the probability of exactly 16 parts failing during RST?

Having a D_{RST} of 15.75 in the example given earlier, one might think that the recommended quantity should be 16.
The probability of having exactly 16 parts falling during the re-supply time is given by the Poisson formula:

$$P(X = R) = e^{-D_{RST}} * \frac{(D_{RST})^R}{R!}$$

P	Probability
R	Number of removals during RST
e	Mathematical constant (Euler's Number)
X	Discrete random variable
D_{RST}	Demand during re-supply time



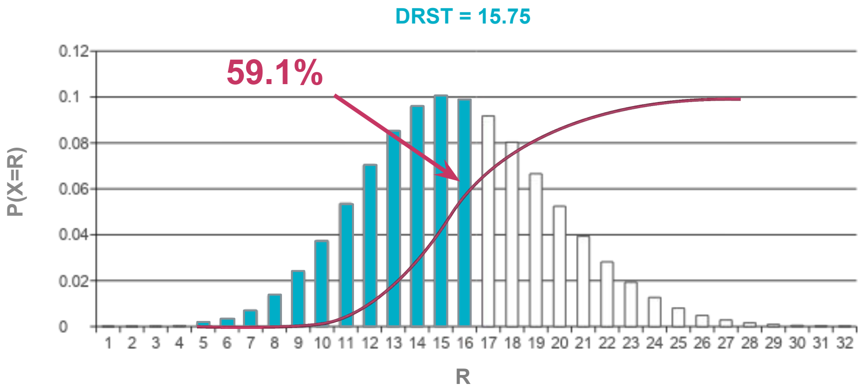
Step 3: Determine Recommended Quantity

Which Protection Level is achieved, when we put 16 spares on stock?

The protection level is the sum of all the probabilities given by the Poisson formula. Indeed, if 16 parts are put on stock, the airline is protected against 0 up to 16 unscheduled removals.

$$P(X \leq R) = e^{-D_{RST}} * \sum_{0}^{R} \frac{(D_{RST})^R}{R!}$$

Achieved Protection Level is 59.1% with 16 parts on stock



P	Probability
R	Number of removals during RST
e	Mathematical constant (Euler's Number)
X	Discrete random variable
D_{RST}	Demand during re-supply time

Step 3: Determine Recommended Quantity

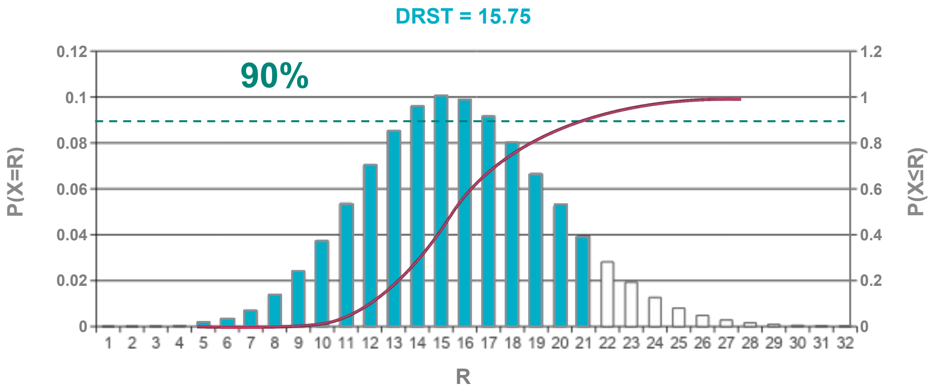
What is the number of parts to be stocked for a Protection Level of 90%?

The recommended quantity is finally calculated following a recursive process, where the achieved protection level is evaluated until it is above the chosen protection level.

Recursive calculation

REC = 0	PL = 0.000014%
⋮	⋮
REC = 19	PL = 82.9%
REC = 20	PL = 88.2%
REC = 21	PL = 92.1%

REC Recommended quantity



Conclusion Basic Mathematical Model

Principle of our Mathematical Model

Material / Airline Parameters	Annual Demand	Demand during re-supply time	Poisson distribution	Recommend quantity
Parameters	D_{ann}	D_{RST}	$P(X \leq R) \geq PL$	REC

Every single part number will go through this process to generate the RSPL

Mathematical Model Step by Step

Step 0	Step 1	Step 2	Step 3	Step 4
Airline/Material Parameter	**Annual Demand**	**Demand during re-supply time**	**Recommended quality**	**Fine-tuning**

Provisioning Parameters - In Detail

OPTIONAL PARAMETER

Airline Parameters

Minimum Annual Demand (MAD)

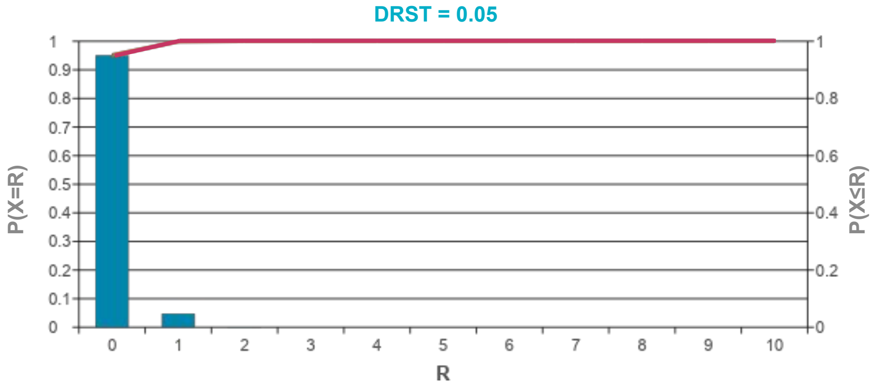
The Minimum Annual Demand is a **decision maker**:
Above the threshold, triggers the first spare to be protected against the risk of first stock.
Below the threshold, discards spares in order to be protected against over-stocking. The probability of failure is considered too low.

IF $D_{ann} <$ MAD ✗	Recommended QTY = 0	Calculation Stopped
IF $D_{ann} \geq$ MAD ✓	Recommended QTY ≥ 1	Calculation Continued

Step 4: Minimum Annual Demand (MAD)

The effect of a low D_{RST}

What is the point of the having the MAD in the recommendation model?
It can happen that the demand during Re-supply time is low, which could lead to zero part being recommended.



Ex: D_{RST} = 0.05; PL = 95 %

P (R ≤ 0) ≈ 95.1% ≥ 95 %

Zero spare parts will be recommended, if the D_{RST} is too low

Step 4: Minimum Annual Demand (MAD)

What drives a low D_{RST}

$$D_{ann} = \frac{FH \times FS \times QPA}{MTBUR}$$

$$RST = \left[\left[(MST + TT) \times \left[1 - \frac{SCR}{1000}\right]\right] + \left[\left[\frac{SCR}{1000}\right] \times (LT + AT)\right]\right]$$

$$D_{RST} = D_{ann} \times \frac{RST}{365}$$

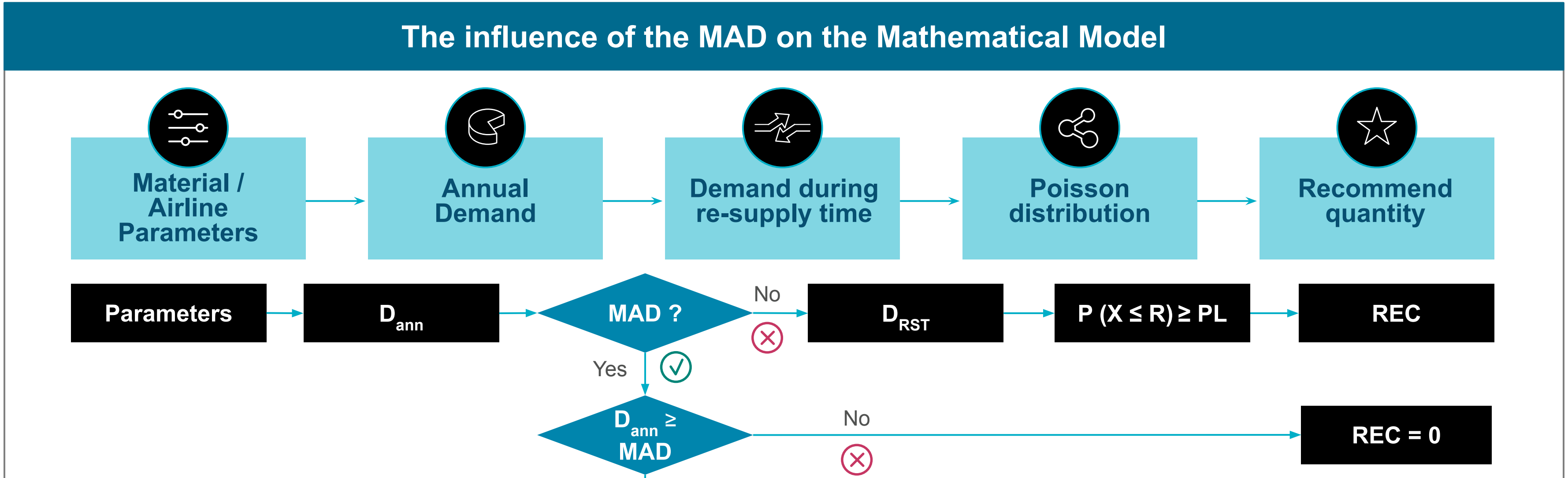
A low number of **flight hours per year** with a **small fleet size** and **high MTBUR** in combination with a **short re-supply time** can lead to a very low D_{RST}

Step 4: Minimum Annual Demand (MAD)

What drives a low D_{RST}

	D_{ann}	No MAD selected	MAD = 0.5
PNR A	0.48	Rec: tbd	Rec: 0
PNR B	0.9	Rec: tbd	Rec: ≥ 1
PNR C	230	Rec: tbd	Rec: ≥ 1

Step 4: Minimum Annual Demand (MAD)



MAD is recommended to operators with small fleets and low flight hours, to ensure more spare parts on stock.

Provisioning Parameters - In Detail

OPTIONAL PARAMETER

Airline Parameters

Protection Level Tolerance (PLT)

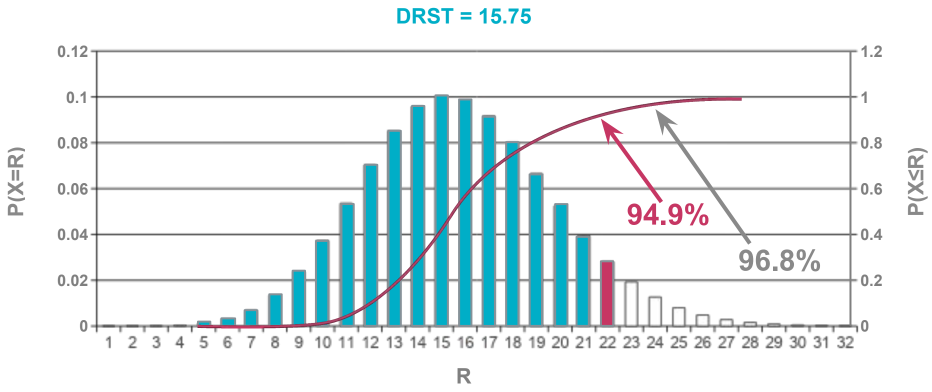
Tolerance level of protection level.

For example for PL 95% and PLT 0.5%, the actual protection level used in the Poisson calculation would be 94.5%.

Step 4: Protection Level Tolerance (PLT)

Gives a flexible margin to the Protection Level

Example: D_{RST} = 15.75; PL = 95%; PLT = 0.5%

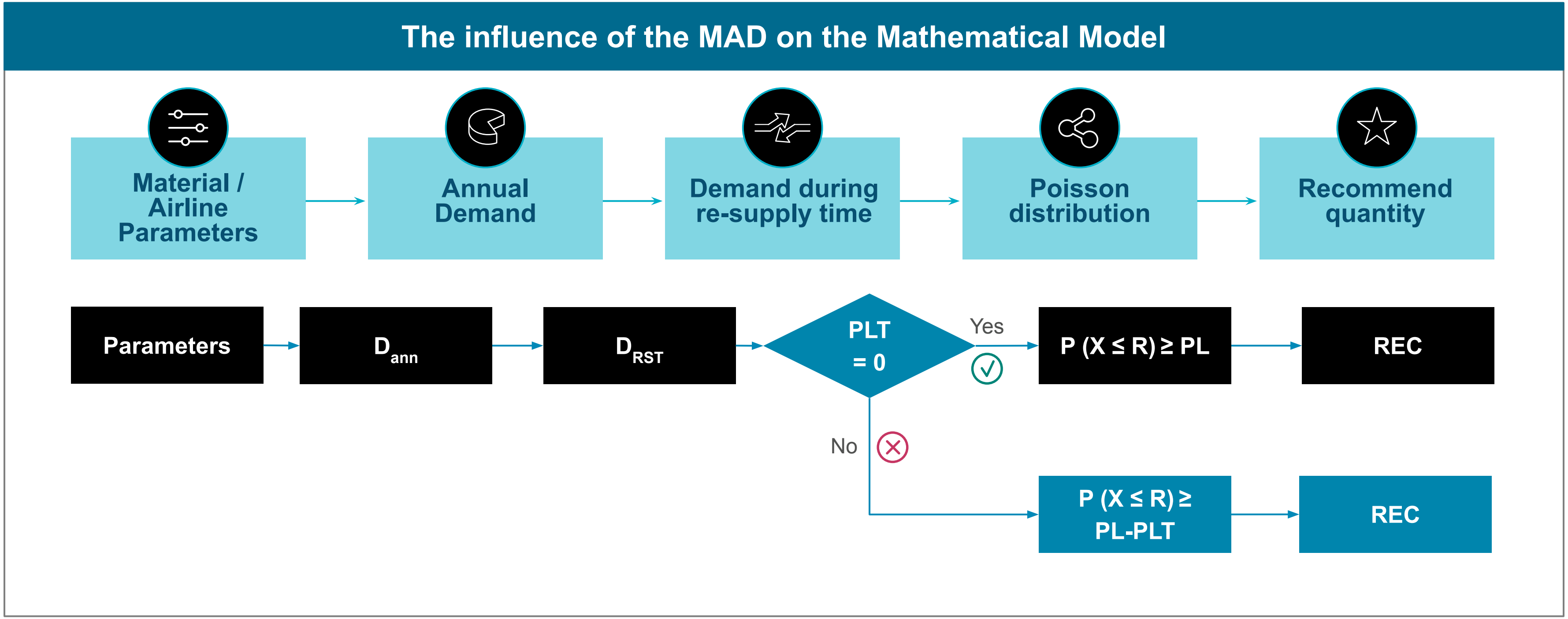


In this example, one spare part less is recommended, to meet the PL within the tolerance.

P (R ≤ 22) ≈ 0.949 = 94.9 % < (95 – 0.5)% = 94.5%

P (R ≤ 23) ≈ 0.968 = 96.8 % ≥ (95 – 0.5)% = 94.5%

Step 4: Protection Level Tolerance (PLT)



List of Acronyms

AT	Administration Time
CDL	Configuration Deviation List
CMM	Component Maintenance Manual
D_{ann}	Annual Demand
D_{RST}	Demand during Re-Supply Time
ESS	Essentiality Code
FH	Flight Hours
FS	Fleet Size
IP	Initial Provisioning
LTM	Lead Time
MAD	Minimum Annual Demand
MMEL	Master Minimum Equipment List

MST	Mean Shop Processing Time
MTBUR	Mean Time Between Unscheduled Removal
PL	Protection Level
PLT	Protection Level Tolerance
QPA	Quantity Per Aircraft
REC	Recommendation
RFS	Reason For Selection
RST	Re-Supply Time
SCR	Scrap Rate
SPC	Spare Part Class
TAT	Turn Around Time
TT	Transit Time

Thank You