Quantification of FRAM models using Coloured Petri Nets

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Structure of presentation:

0. Problem
1. Why Coloured Petri nets?
2. FRAM model
3. FRAM model example
4. CPN of this model
5. Summary

0. Problem

How often a variability level of an event can be reached?

1. Why Coloured Petri nets?

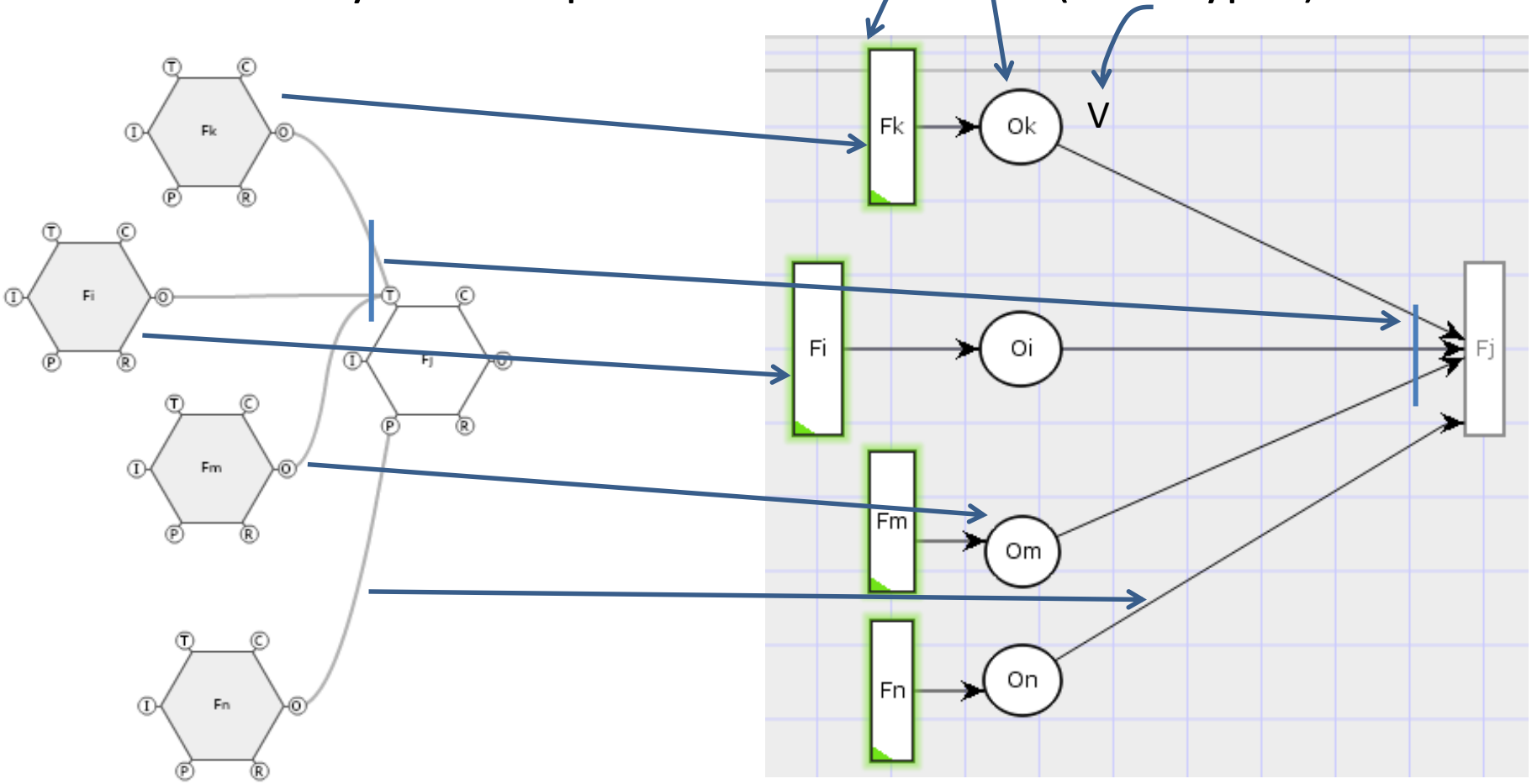
Expressive power of Coloured Petri Nets (CPNs):

- System dynamics modelling,
- Interaction between structure components and functions modelling,
- Complicated semantics can be expressed owing to different data types represented by „coloures”,
- Resource competition modelling,
- Time features,
- Stochastic processes expressing.

1. Why Coloured Petri nets?

Visual analogies:

- FRAM aspects as CPN places,
- FRAM functions as CPN transitions,
- Variability set of aspects as CPN coloures (data-types).



1. Why Coloured Petri nets?

Software tool:

CPN Tools, http://cpntools.org/

2. FRAM model

Time variability set:

$$V_T = \{On\ time(OT), Too\ early(TE), Too\ late(TL), Not\ at\ all(NA)\}$$

Time variability probability distribution set

$$VD_T = \{On\ time\ PD(OTPD), Too\ early\ PD(TEPD), Too\ late\ PD(TLPD), Not\ at\ all\ PD(NAPD\}$$

$Too\ early\ PD(TEPD)$ denotes probability distribution:

Value	Probability
On time	0.15
Too early	0.7
Too late	0.1
Not at all	0.05

[R. Partiarca, G. Di Gravio, F. Costantino, Monte Carlo simulation to assess performance variability in the FRAM, FRAMily 2016]

2. FRAM model

Precision variability set

$$V_P = \{Precise(P), Acceptable(A), Imprecise(I), Wrong(W)\}$$

Precision variability probability distribution set

$$VD_P = \{Precise\ PD(PPD), Acceptable\ PD(APD), Imprecise\ PD(IPD), Wrong\ PD(WPD)\}$$

$Imprecise\ PD$ denotes probability distribution:

Value	Probability
Precise	0.05
Acceptable	0.2
Imprecise	0.7
Wrong	0.05

[R. Partiarca, G. Di Gravio, F. Costantino, Monte Carlo simulation to assess performance variability in the FRAM, FRAMily 2016]

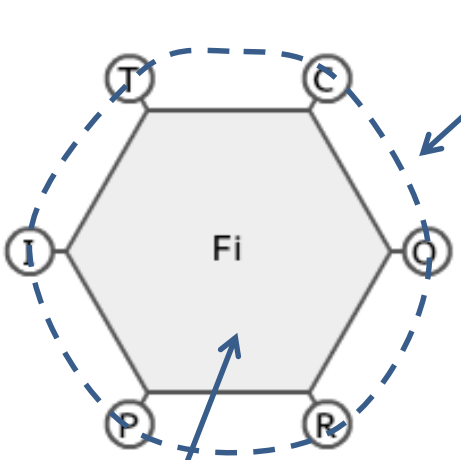
2. FRAM model

Variability set:

$$V \subset V_T \times V_P$$

Ii, Ci, Ti, Pi, Ri, Oi – input, control, time, precondition, resource, output aspects of function F_i with variability from the set V,

$$(On\ time(OT), Precise(P)), \ldots, (Not\ at\ all(NA), Wrong(W)) \in V$$



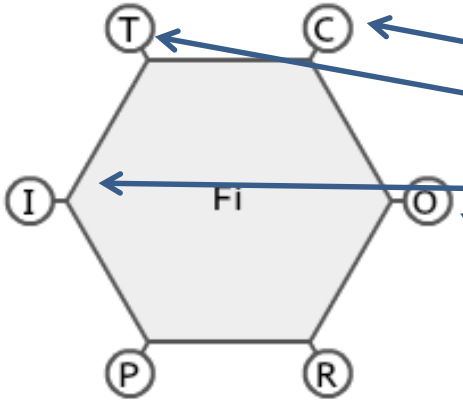
Variability probability distribution set for output variability generation:

$$(ONPD, APD), \ldots, (TEPD, APD) \in VD \subset VD_T \times VD_P$$

2. FRAM model

Example

The aspects Pi, Ri do not influence the variability of function Fi output

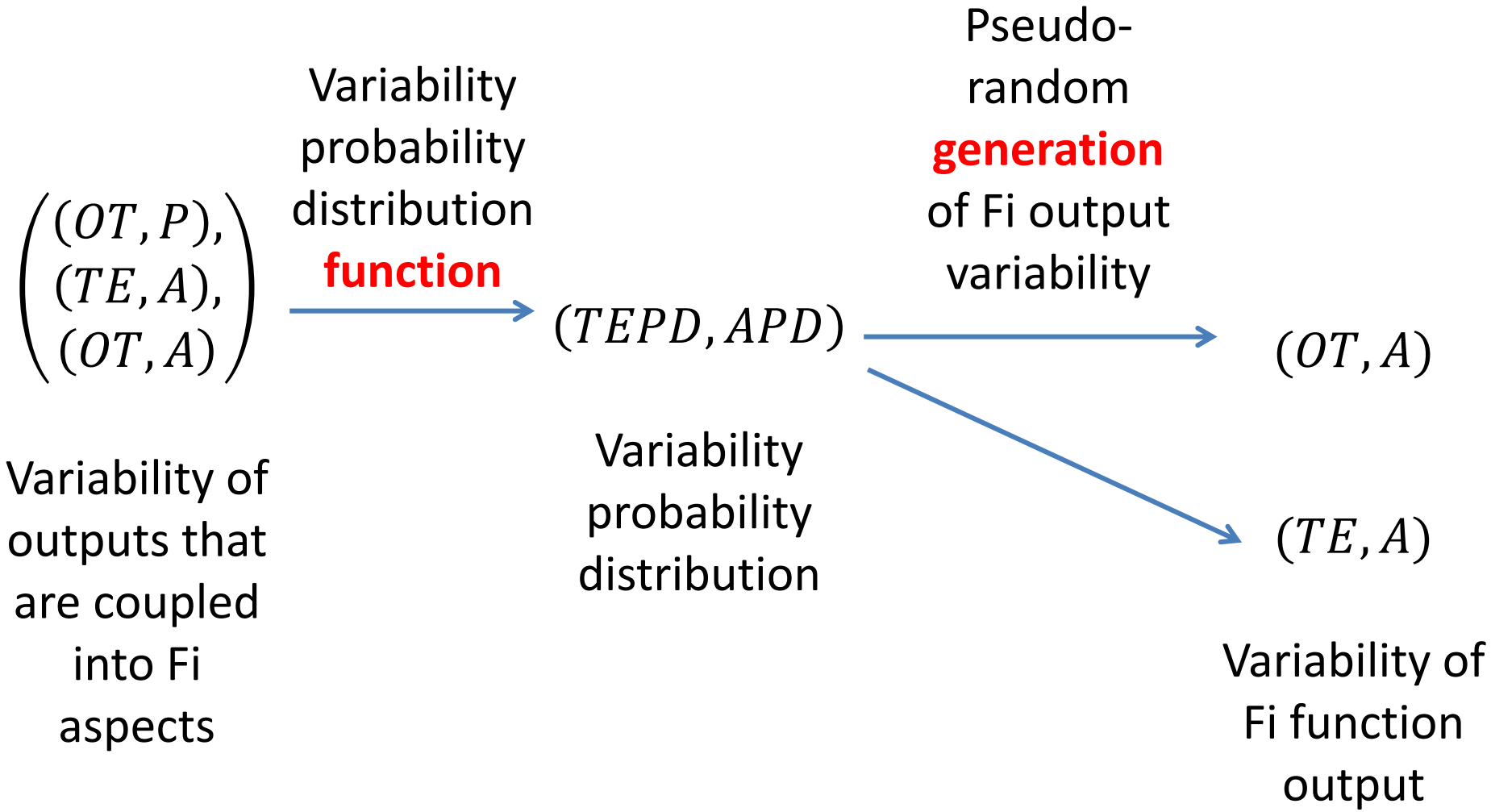


$$\big((OT, P), (TE, A), (OT, A)\big) \rightarrow (OT, A)$$

relation !!!

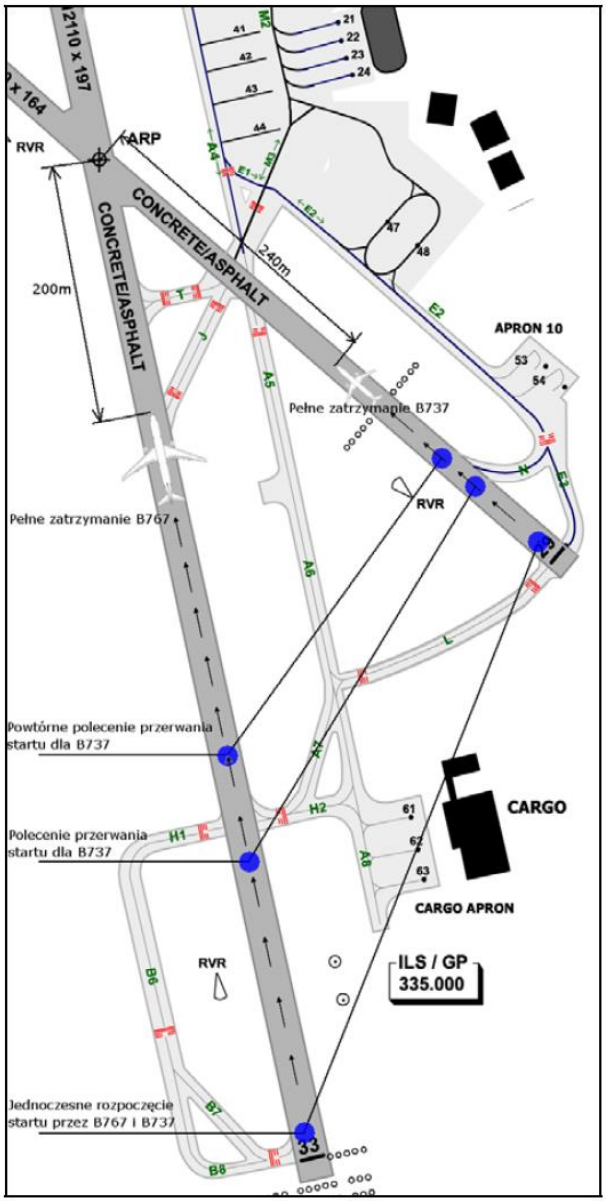
$$\big((OT, P), (TE, A), (OT, A)\big) \rightarrow (TE, A)$$

3. FRAM model



Model of FRAM function Fi behaviour

3. FRAM model example



Phases of aircraft movement during departure:

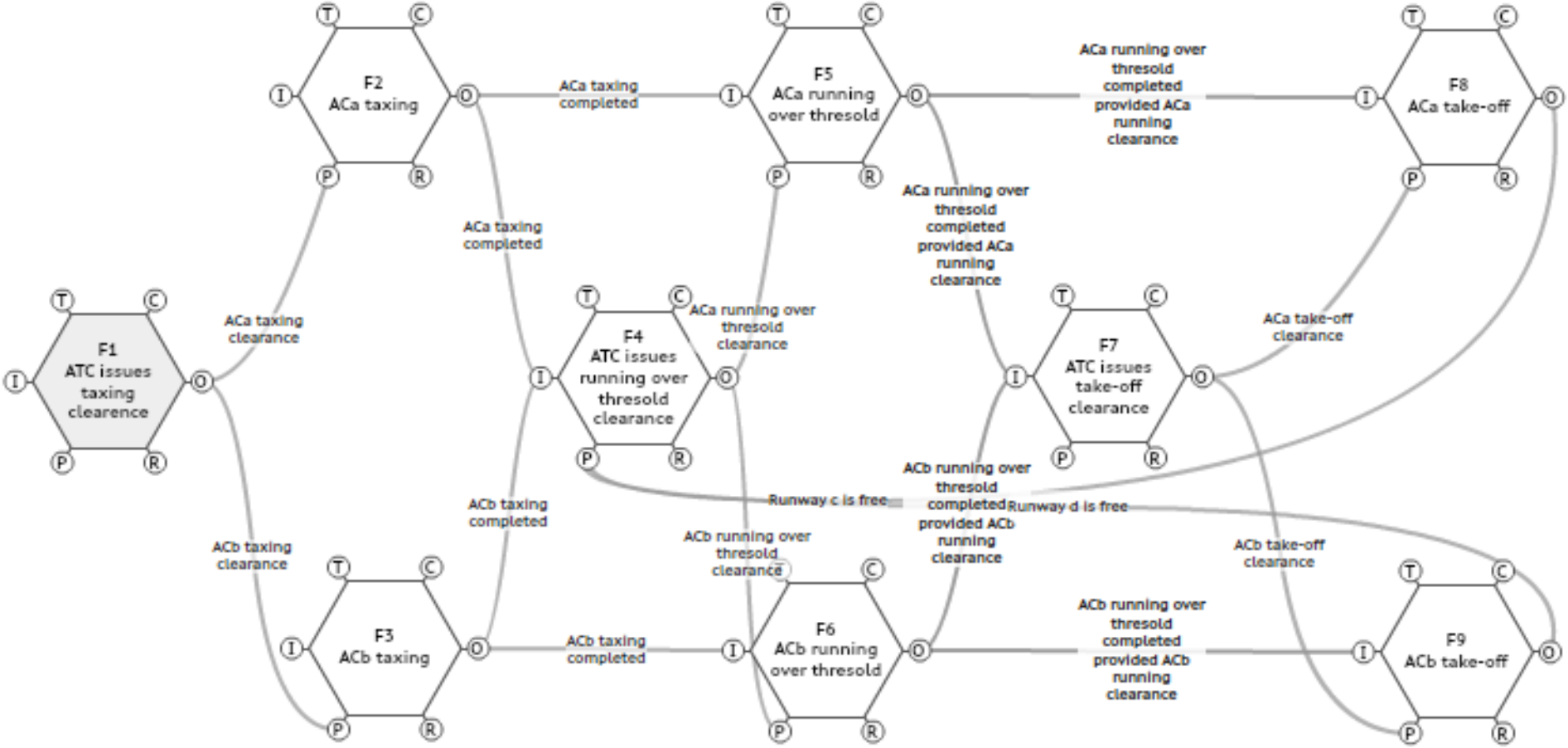
1. Taxing,
2. Running over runway thresold,
3. Take-off.

Goal

Comparison of variabilities in the cases without and with the recommendation:

„When there are runway crossings, no more than one aircraft can be waiting for permission to take-off on the runway and, as a general principle, waiting should be on the taxiway before the runway threshold.”

3. FRAM model example



ACa taxing completed (O2)	ACb taxing completed (O3)	Runway c is free (O8)	Runway d is free (O9)	Internal condition: runway c is free	Internal condition: runway d is free	ACa running over threshold clearance (O4)	ACb running over threshold clearance (O4)
P, A	NA	NA	NA	$T \rightarrow F$ 4)	T	APD	NAPD
P,A 1)	P,A						
NA	P,A	NA	NA	T	$T \rightarrow F$	NAPD	APD
All possible combinations 3)				T	F	NAPD	NAPD
				F	T		
				F	F		
I, W	I, W 2)	All possible combinations				NAPD	NAPD
		P,A		$F \rightarrow T$			
			P,A		$F \rightarrow T$		
		I,W					
			I,W				

Oi – output of function Fi
P,A,I,W – Precise, Acceptable, Imprecise, Wrong
NA – Not at all
APD – Acceptable Probability Distribution
NAPD – Not at all Probability Distribution
T, F – logical values of the internal conditions

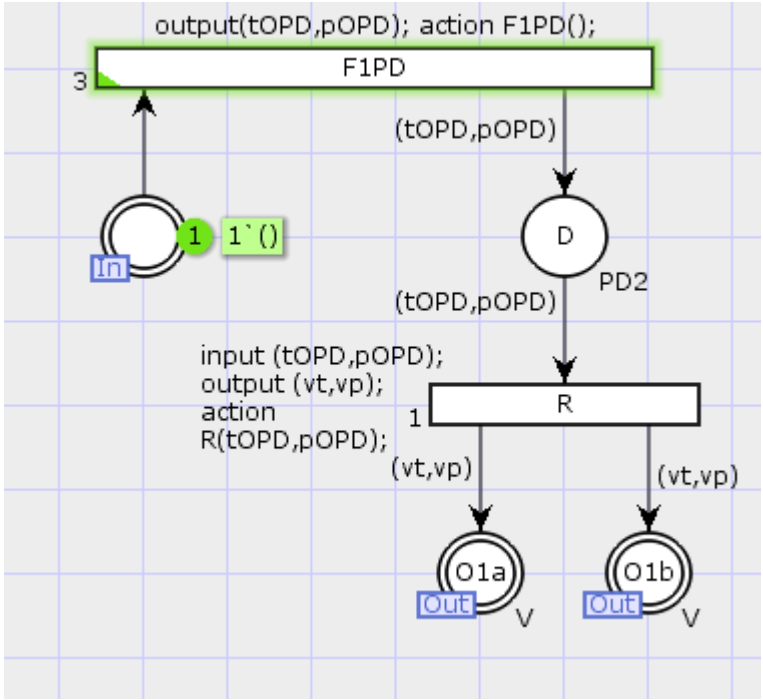
Function F4 output variability probability distribution function table

4. CPN of the FRAM model

Model is hierarchic:

1. Overall structure,
2. Nine subnets for each function Fi

F1



Summary

- Model of FRAM function behaviour has been proposed **Is it correct?**
- Variability probability distribution function (table) is complicated
- Generalizations:
  - The other time and precision variability sets,
  - The other time and precision variability probability distribution sets (even one-value distributions),
  - Different variability sets and variability probability distribution sets for different events,