Opened Vial Wastage

from Indicative to Expected

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World Health Organization

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Warm-up quiz

Warm-up quiz

1. Measles vaccine is presented in a 10 dose vial.
   In one immunization session 5 children are immunized.
   What is the opened vial wastage rate for the session?

50%

2. In another session 15 children are immunized.
   What is the wastage rate?

25%

⇒ If you know the session size,
you know the session wastage rate!

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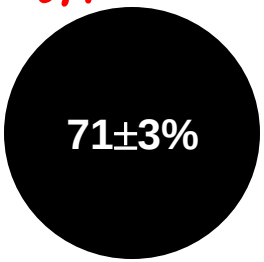
Warm-up quiz

3. Measles is presented in a 20 dose vial.
   Ardbeg Health Facility holds 5 immunization sessions per week.
   The facility administered 100 doses of Measles last year.
   What was its opened vial wastage rate?

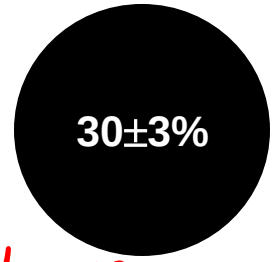
MEAN SESSION SIZE = # DOSES / # SESSIONS = 100 / (5 × 52) = 0.4

4. Measles is presented in a 20 dose vial.
   Lagavulin Health Facility holds 1 immunization session per week.
   The facility administered 300 doses of Measles last year.
   What was its opened vial wastage rate?



MEAN SESSION SIZE = # DOSES / # SESSIONS = 300 / (1 × 52) = 5.8

5. Measles is presented in a 20 dose vial.
   Cardhu Health Facility holds 2 immunization sessions per week.
   The facility administered 2000 doses of Measles last year.
   What was its opened vial wastage rate?



MEAN SESSION SIZE = # DOSES / # SESSIONS = 2000 / (2 × 52) = 19.2

⇒ If you know the ***mean*** session size,
you know the ***expected*** wastage rate!

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Session size model

$$\mathrm{P}\left(n; N, \frac{1}{S}\right) = \binom{N}{n}\left(\frac{1}{S}\right)^{N}\left(1-\frac{1}{S}\right)^{N-n}$$

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Binomial distribution: Example 1 Diana plays darts

Diana has 3 darts, and the probability that she hits the board with each throw is 10%.

Q. What is the probability that Diana hits the board with all three throws?

A. $\mathrm{P}(3) = 0.1 \times 0.1 \times 0.1 = 0.001 = \mathrm{P}(\text{successes} = 3; \text{tries} = 3, \text{probability} = 0.1)$

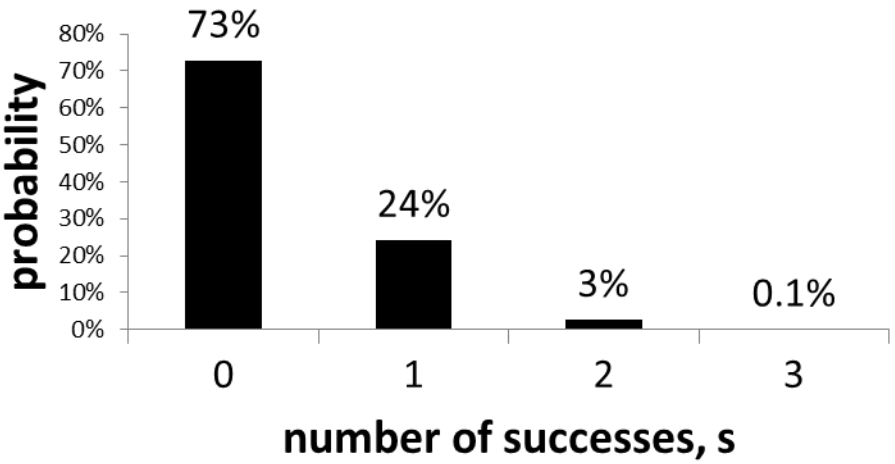
Q. What is the probability that Diana misses the board with all three throws?

A. $\mathrm{P}(0) = 0.9 \times 0.9 \times 0.9 = 0.729 = \mathrm{P}(s = 0;\ t = 3,\ p = 0.1)$

Q. What is the probability that Diana hits the board once in three throws?

A. $\mathrm{P}(1) = 0.1 \times 0.9 \times 0.9$

$$\mathrm{P}(s; t = 3, p = 0.1) = \binom{3}{s} (0.1)^s (1 - 0.1)^{3-s}$$



Binomial distribution: Example 2A Queen of Hearts

A deck of playing cards is shuffled and one card is drawn.

Q. What is the probability of drawing the Queen of Hearts?

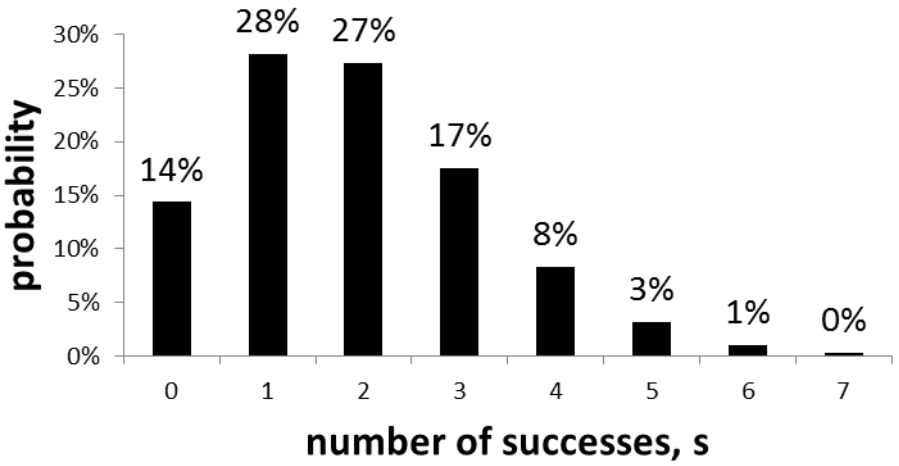
A. P(Q of H) = 1/52 ≅ 0.02 = 2%

Repeat the ***shuffle and draw*** 100 times (with replacement).

Q. What is the probability of drawing the Queen of Hearts 3 times in 100 draws?

A. $\mathrm{P}(3) = \frac{1}{52} \times \frac{1}{52} \times \frac{1}{52} \times \frac{51}{52} \times \cdots \times \frac{51}{52} \times \frac{100\times99\times98}{3\times2} = \mathrm{P}(s = 3;\ t = 100,\ p = 1/52) = 0.17 = 17\%$

$$\mathrm{P}\left(s; t = 100, p = \frac{1}{52}\right) = \binom{100}{s}\left(\frac{1}{52}\right)^{s}\left(1 - \frac{1}{52}\right)^{100-s}$$



Binomial distribution: Example 2B Immunization session

Definition:

session size = # doses administered during an immunization session

Assumptions:

A1 Births are uniformly randomly distributed throughout the year.

A2 Children are immunized according to the national immunization schedule (or as close as possible).

A1 + **A2** $\Rightarrow$ administered doses are randomly distributed amongst the sessions.

Note: If there are 2 or more sessions per week, **A2** $\Rightarrow$ each session is equally popular!

Binomial distribution: Example 2B Immunization session

A health facility holds one Measles immunization session per week (52 per year), and 100 doses are administered in one year.

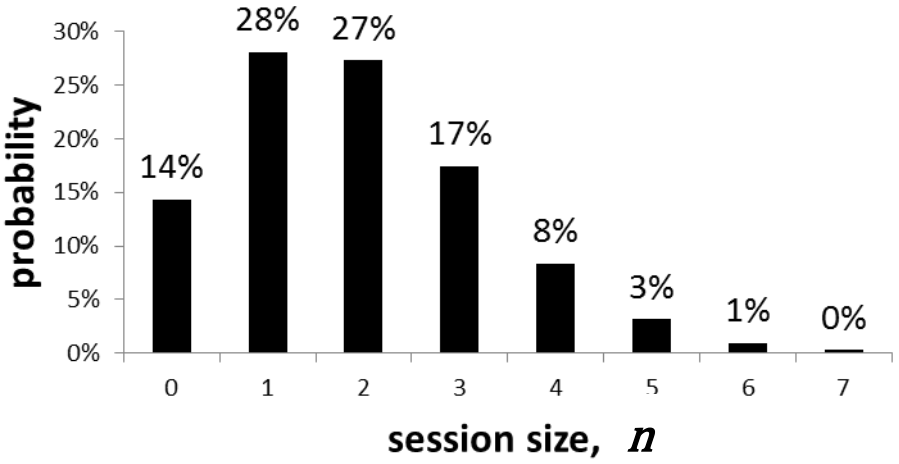
Q. What is the probability that any given dose is administered in the 12th session?

A. P(12th session) = 1/52 ≅ 2%

Q. What is the probability that 3 of the 100 doses are administered in the 12th session?

A. P(3 doses in 12th session) = P(n = 3; N = 100, p = 1/52) = 17%

$$\mathrm{P}\left(n; N = 100, p = \frac{1}{52}\right) = \binom{100}{n}\left(\frac{1}{52}\right)^{n}\left(1 - \frac{1}{52}\right)^{100-n}$$



*Number of doses administered in one year = annual birth rate × number of doses per infant × coverage.

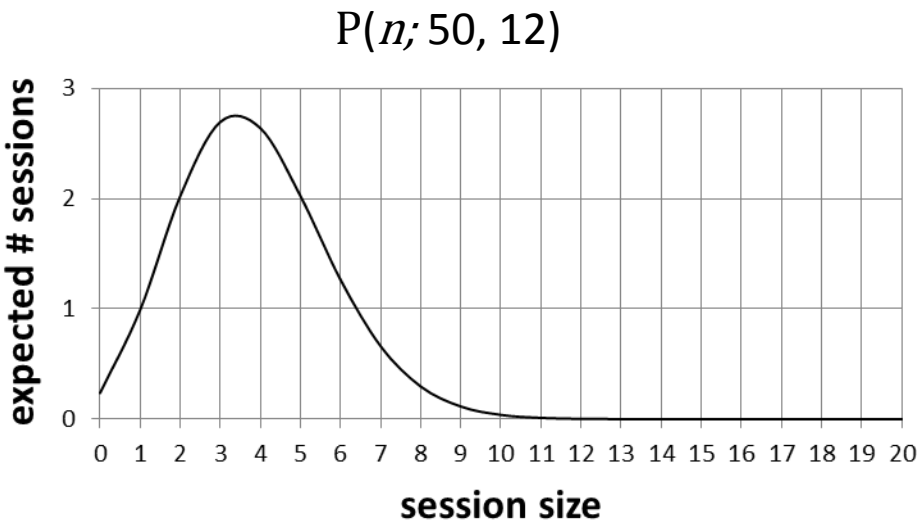
Session size model

If assumptions **A1** and **A2** hold, the session size probability distribution is Binomial:

$$\mathrm{P}\left(n; N, \frac{1}{S}\right) = \binom{N}{n}\left(\frac{1}{S}\right)^{n}\left(1-\frac{1}{S}\right)^{N-n}$$

where

- n is the session size,
- N is the number of doses administered per year, and,
- S is the number of sessions per year.



Note: $\mathrm{P}(n\,;\,1000{,}260) \cong \mathrm{P}(n\,;\,200{,}52) \cong \mathrm{P}(n\,;\,50{,}12)$

The distribution is actually determined by the mean session size (N/S) only !

Opened vial wastage model

$$w(N,S,m) = \frac{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [m - (n \bmod m)]}{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [n + m - (n \bmod m)]}$$

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Opened vial wastage: Definition and assumptions

Definition: open vial wastage rate

$$\text{wastage rate} = \frac{\text{number of doses wasted (discarded after 6 hours or 28 days)}}{\text{number of doses used (administered or wasted)}}$$

Assumptions:

A3 Vaccine is always available

A4 Children are never refused vaccination

Note:

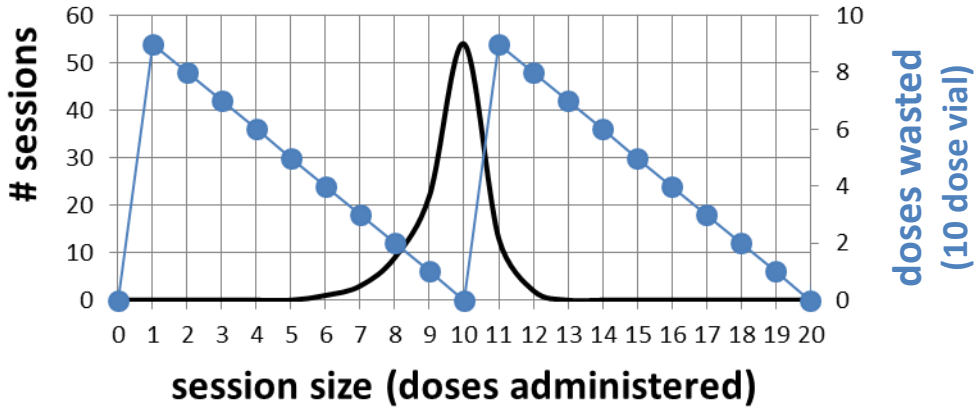
- A3 is an aspiration and is assumed when planning, forecasting, and monitoring wastage. Stock-outs are not accommodated in plans or forecasts, and expected wastage rate values are evaluated assuming no stock-outs.
- A4 is a policy statement AND an aspiration. A ***policy*** of never refusing vaccination, and an aspiration that the policy is properly implemented by managers and health workers.
- In what follows, the policy of never refusing vaccination could in principle be replaced with any other policy – it's just Algebra!
- Multi-dose vial session size data from more than 250 immunization locations in 3 countries where a policy of never refusing is in place, demonstrate clearly that the policy is properly implemented.
- Multi-dose vial session size data from outreach locations in Burkina-Faso, where some multi-dose vial "*vaccines are offered only when the number of children justifies the opening of vials*", demonstrate clearly that the policy is implemented.
- So available session size data strongly suggest that where children are refused vaccine, it is because it is policy to do so, rather than because of failure to properly implement a policy of never refusing.
- Given that it is policy never to refuse, that the policy is implemented is assumed when planning, forecasting, and monitoring wastage. A certain level of refusal is not accommodated in plans or forecasts, and expected wastage rate values are evaluated assuming no refusal.

Opened vial wastage: and the session size distribution

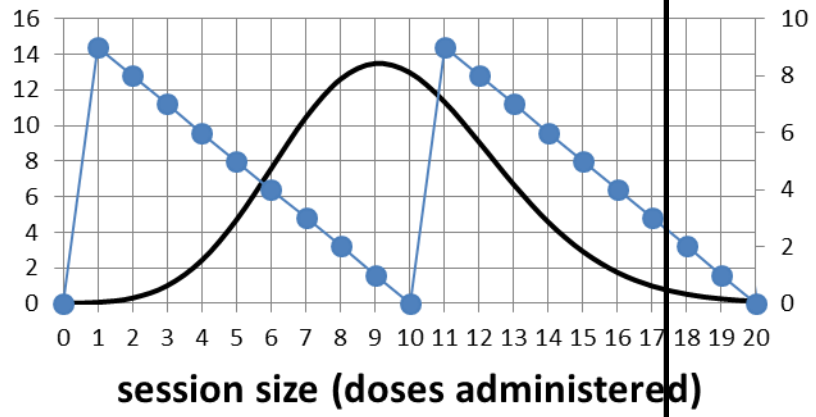
Two session size distributions, each with 1000 doses administered in 104 sessions…

…but with quite different opened vial wastage rates (10 dose vial)!

wastage rate = 16%



wastage rate = 30%



So, mean session size ⇏ expected wastage rate

But, mean session size + A1 + A2 ⇒ session size distribution

+ A3 + A4 ⇒ expected wastage rate

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Opened vial wastage model

If assumptions A1, A2, A3 and A4 hold, the expected wastage rate (w) of a facility is:

$$w(N,S,m) = \frac{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [m - (n \bmod m)]}{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [n + m - (n \bmod m)]}$$

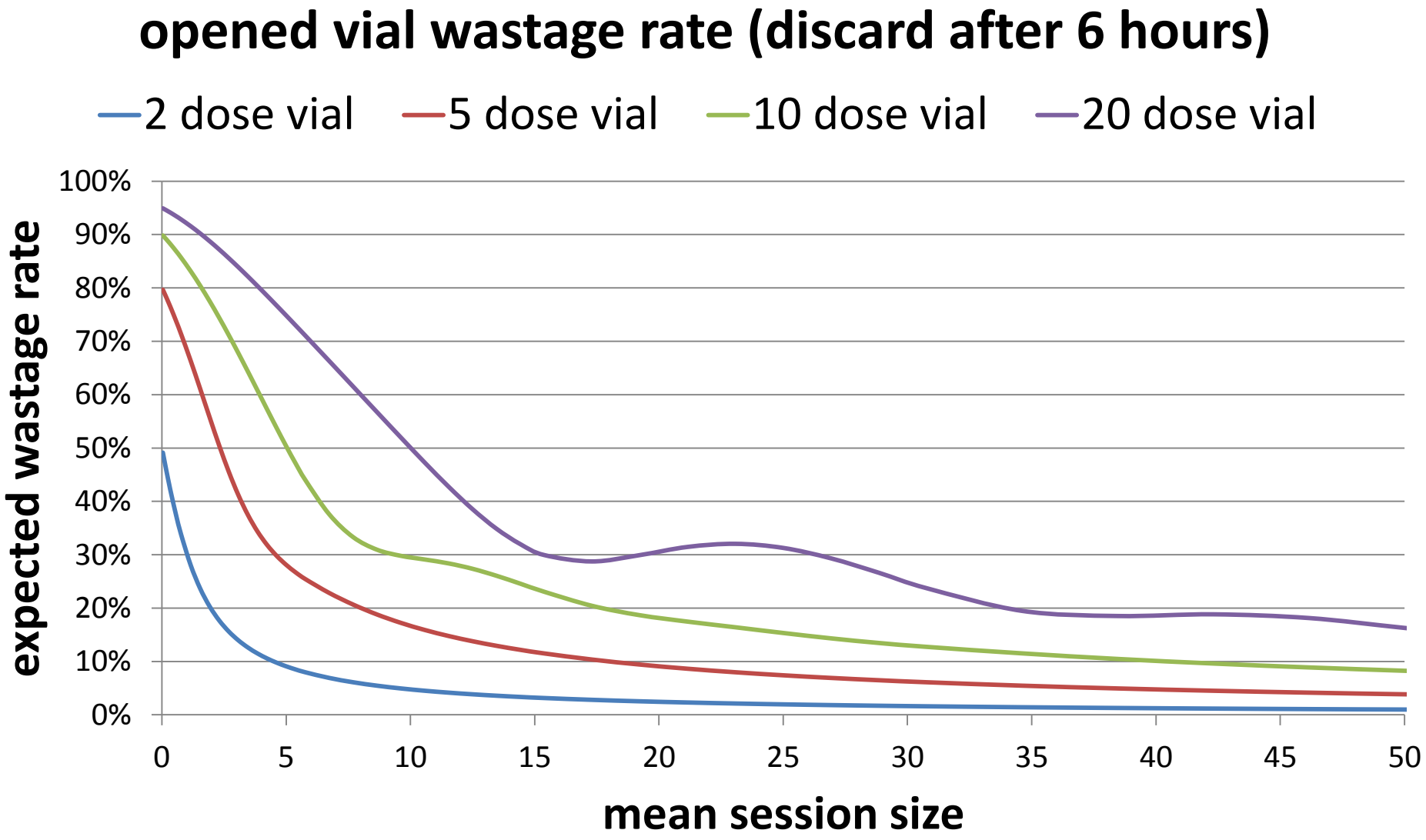
where

- N is the number of doses administered in one year,
- S is the number of sessions in one year, and,
- m is the number of doses per vial*.

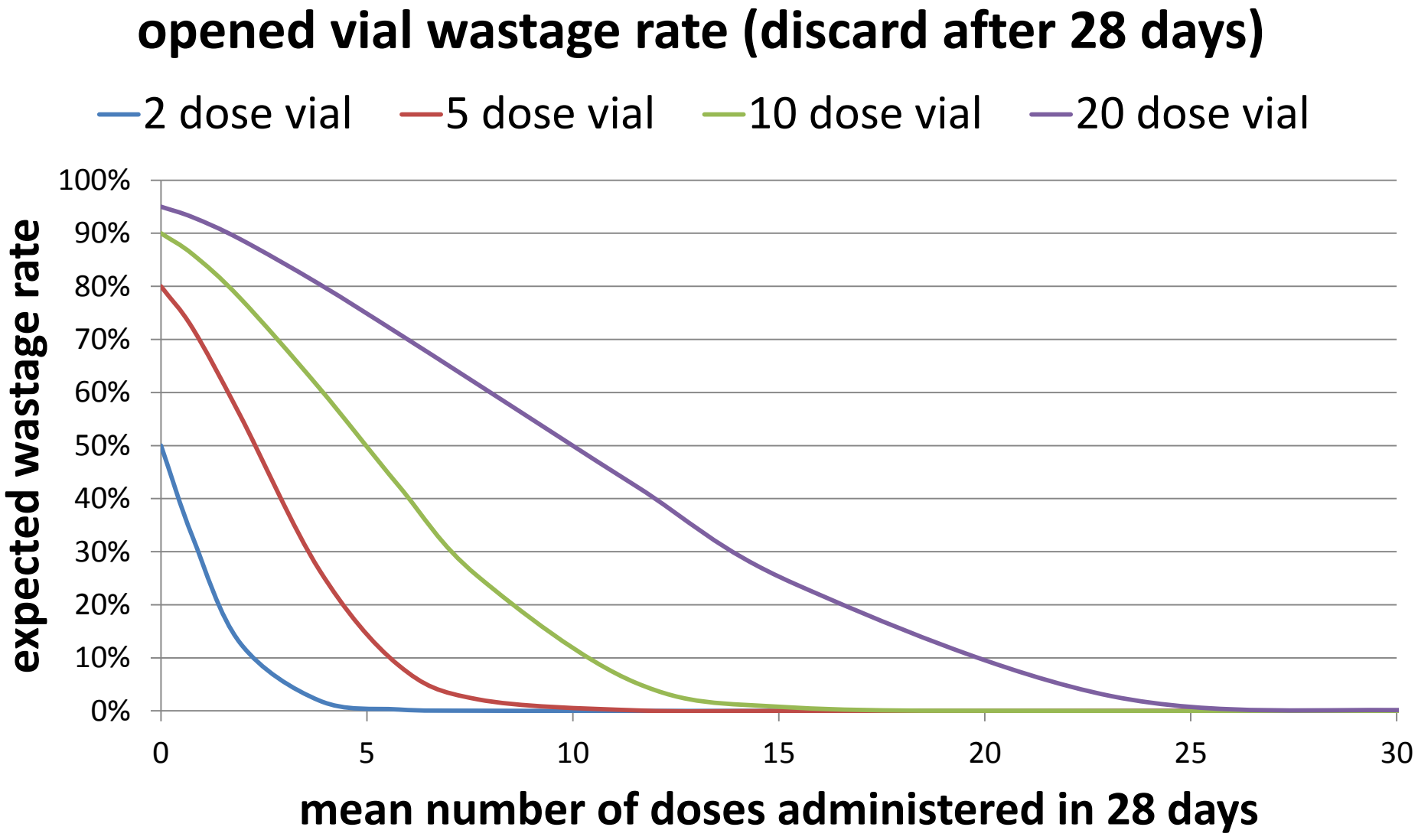
Note: The expected wastage rate actually depends only on the mean session size (N/S) and the vial size (m): $w(N,S,m) = w(N/S,m)$.

*The expected wastage rate also depends on the MDVP, 6 hours or 28 days.

Open vial wastage: expected values



Open vial wastage: expected values



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Tools: Look-up table

Expected opened vial wastage rates

discard after 6 hours				
mean session size	vial size			
	2 dose	5 dose	10 dose	20 dose
~0.00	50%	80%	90%	95%
0.10	48%	79%	90%	95%
0.19	45%	78%	89%	95%
0.29	43%	77%	89%	94%
0.38	41%	76%	88%	94%
0.58	37%	74%	87%	93%
0.77	34%	71%	86%	93%
1.15	28%	66%	83%	92%
1.54	24%	61%	80%	90%
1.92	20%	56%	77%	89%
2.31	18%	50%	74%	87%
2.69	16%	46%	71%	86%
3.08	14%	41%	68%	84%
3.46	13%	37%	64%	82%
3.85	11%	34%	61%	80%
4.23	11%	32%	57%	79%
4.62	10%	30%	54%	77%
5.00	9%	28%	50%	75%
5.38	8%	27%	47%	73%
		25%	44%	71%
		23%	38%	66%

discard after 28 days				
mean doses / month	vial size			
	2 dose	5 dose	10 dose	20 dose
~0.00	50%	80%	90%	95%
0.77	33%	72%	86%	93%
1.92	13%	56%	78%	89%
3.85	2%	27%	61%	80%
5.77	0%	9%	42%	71%
7.69	0%	2%	25%	62%
11.54	0%	0%	5%	42%
15.38	0%	0%	1%	24%
23.08	0%	0%	0%	3%
30.77	0%	0%	0%	0%

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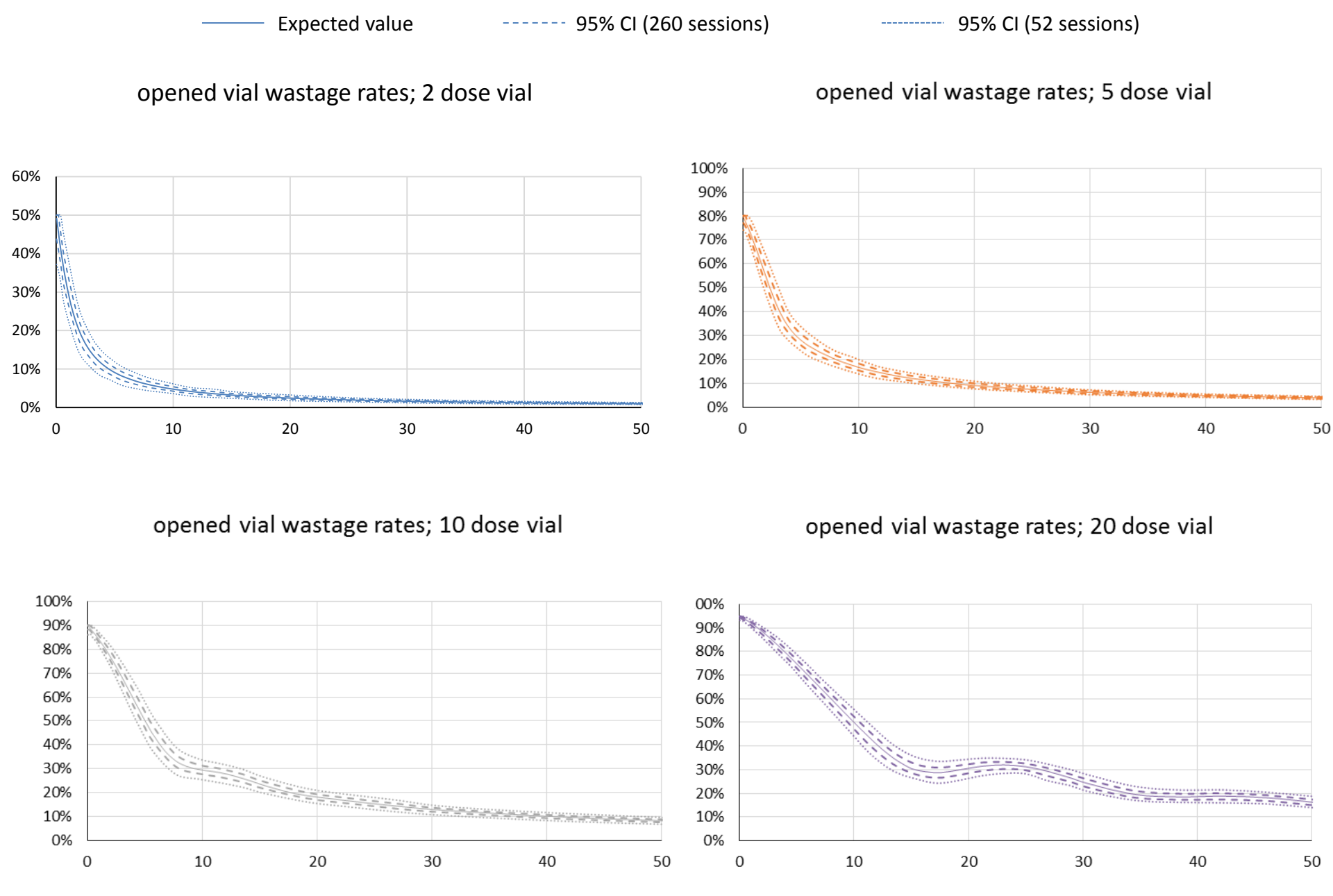
Open vial wastage: confidence intervals

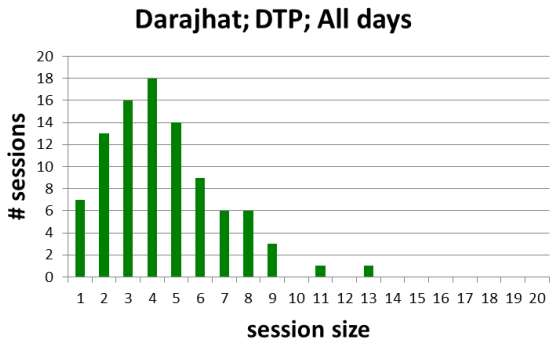


Session size data

Session size distributions: Data

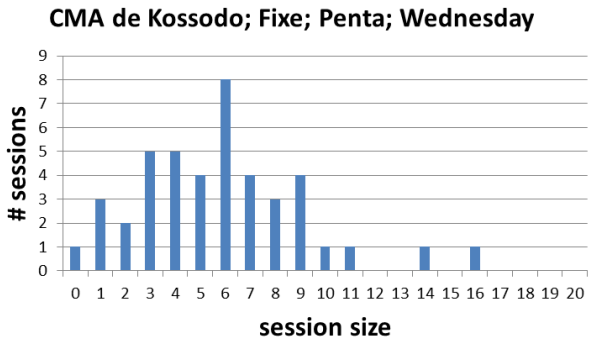
Bangladesh

DTP (10 dose vial)
148 locations (fixed, outreach)
01/2004 to 12/2004.



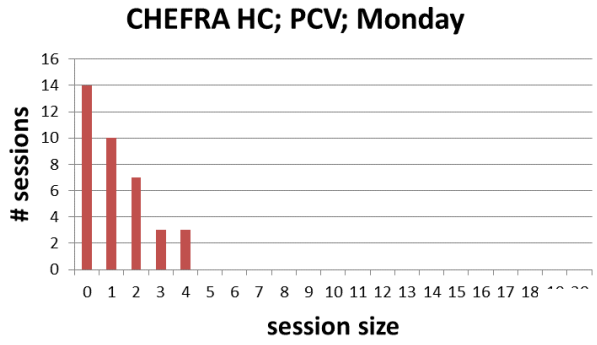
Burkina Faso

Penta (1 dose vial)
4 locations (fixed, outreach)
12/2007 to 12/2008



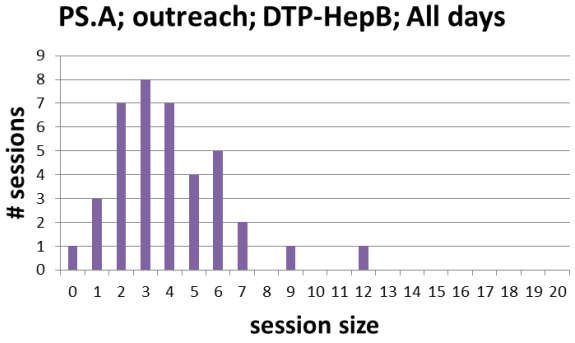
Ethiopia

PCV (2 dose vial)
102 locations
10/2011 to 06/2012.



Cambodia

DTP-HepB (10 dose vial)
8 locations (outreach)
11-12/2003



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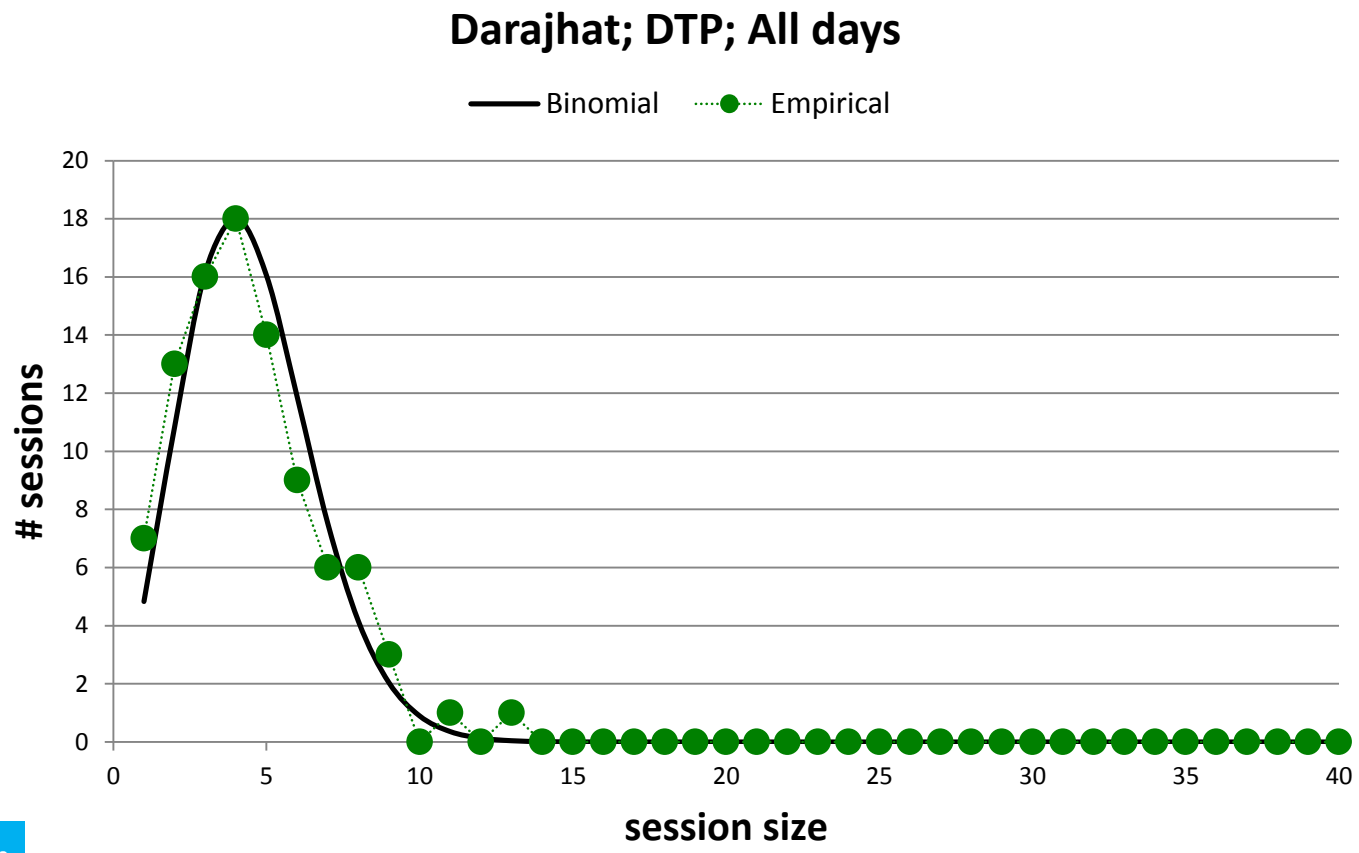
Session size distributions: Bangladesh, DTP, 10 dose vial

In 2004 the Darajhat facility in Bangladesh administered 418 doses of DTP Vaccine.
The facility held 94 immunization sessions that year.

MEAN SESSION SIZE = # DOSES / # SESSIONS = 418 / 94 = 4.4

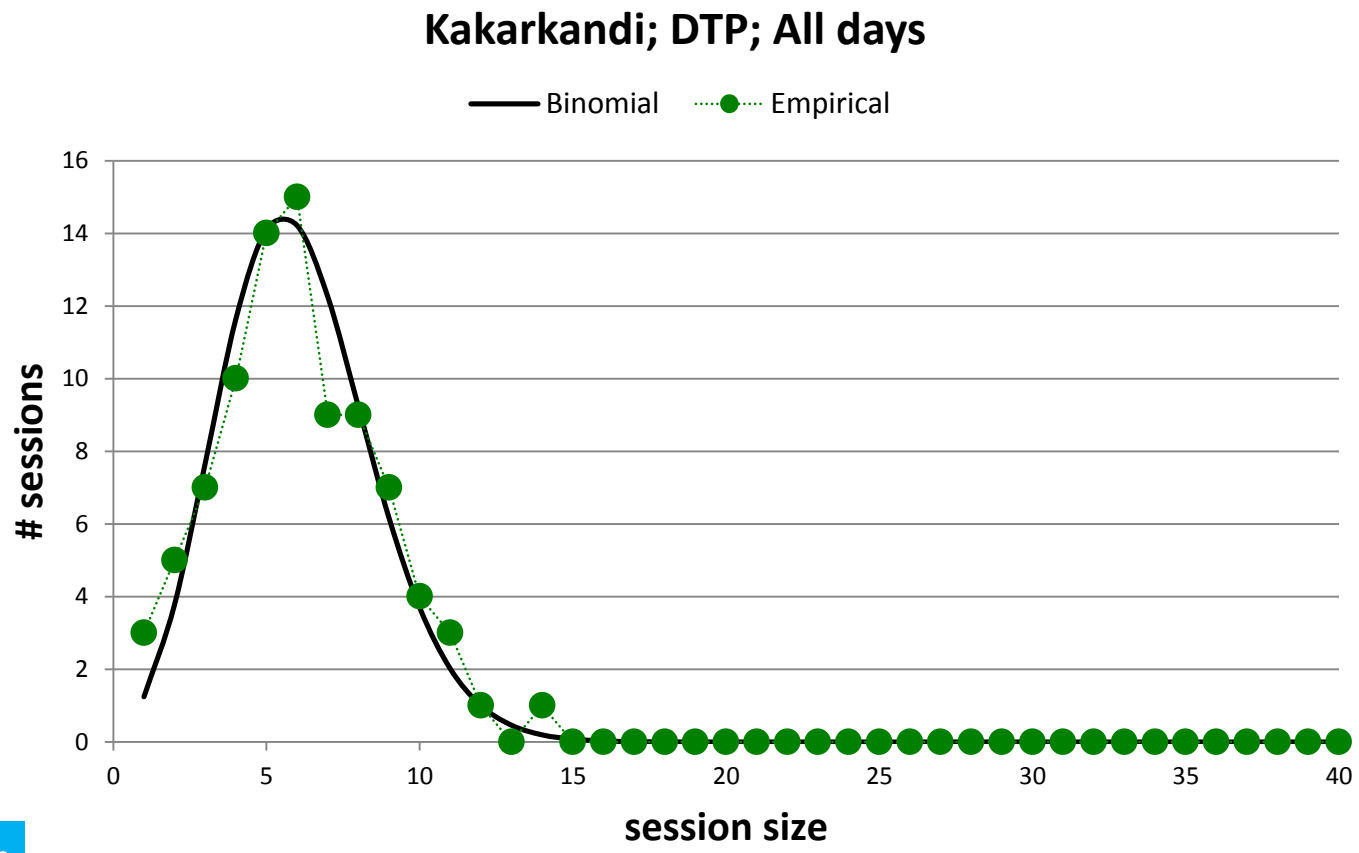
Based on the hypothesis that the session size distribution is Binomial(n; N=418, p=1/94), the expected session size distribution may be generated…



Session size distributions: Bangladesh, DTP, 10 dose vial

In 2004 the Kakarkandi facility in Bangladesh administered 531 doses of DTP Vaccine. The facility held 88 immunization sessions that year.

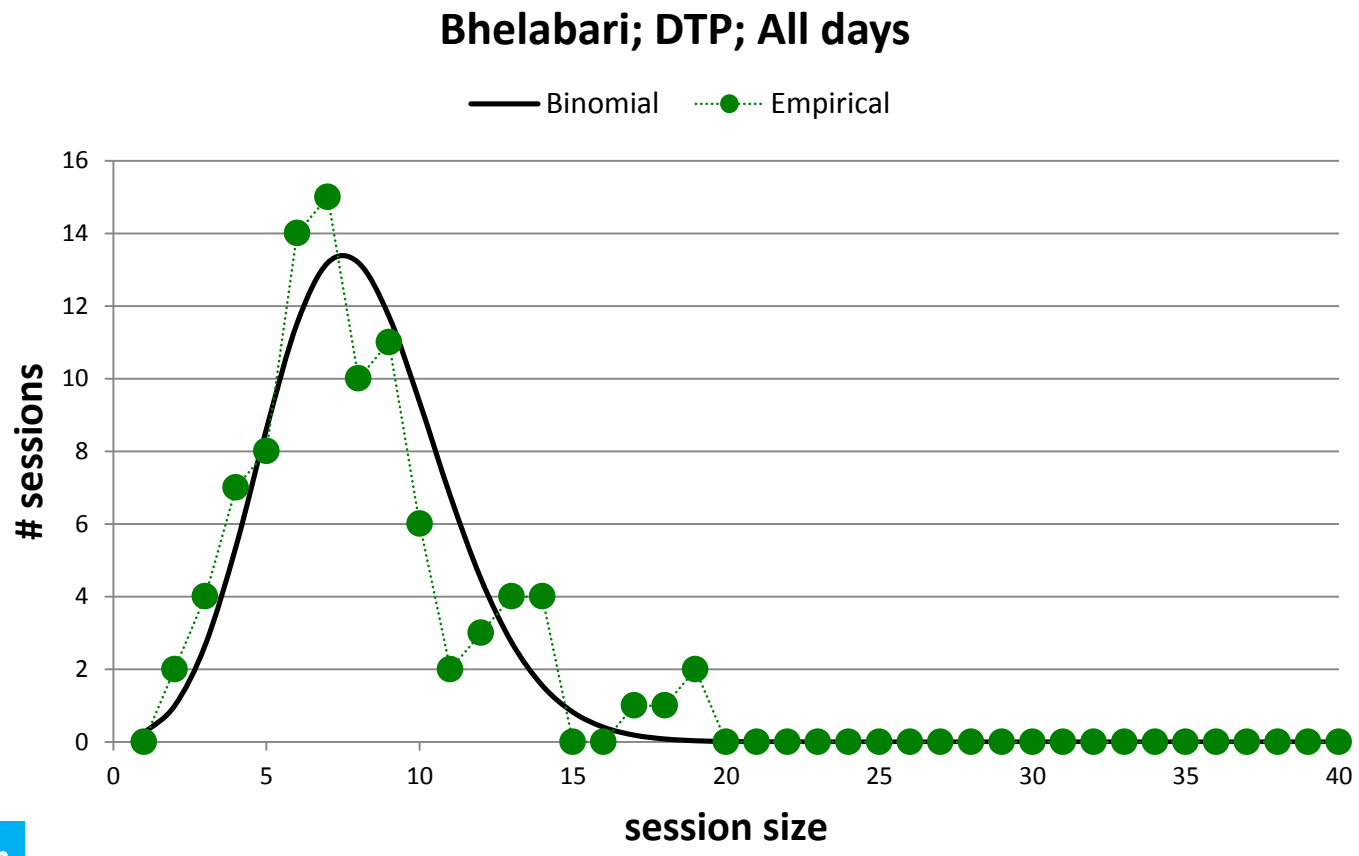
Based on the hypothesis that the session size distribution is Binomial(n; N=531, p=1/88), the expected session size distribution may be generated…



Session size distributions: Bangladesh, DTP, 10 dose vial

In 2004 the Bhelabari facility in Bangladesh administered 751 doses of DTP Vaccine. The facility held 94 immunization sessions that year.

Based on the hypothesis that the session size distribution is Binomial(n; N=751, p=1/94), the expected session size distribution may be generated…



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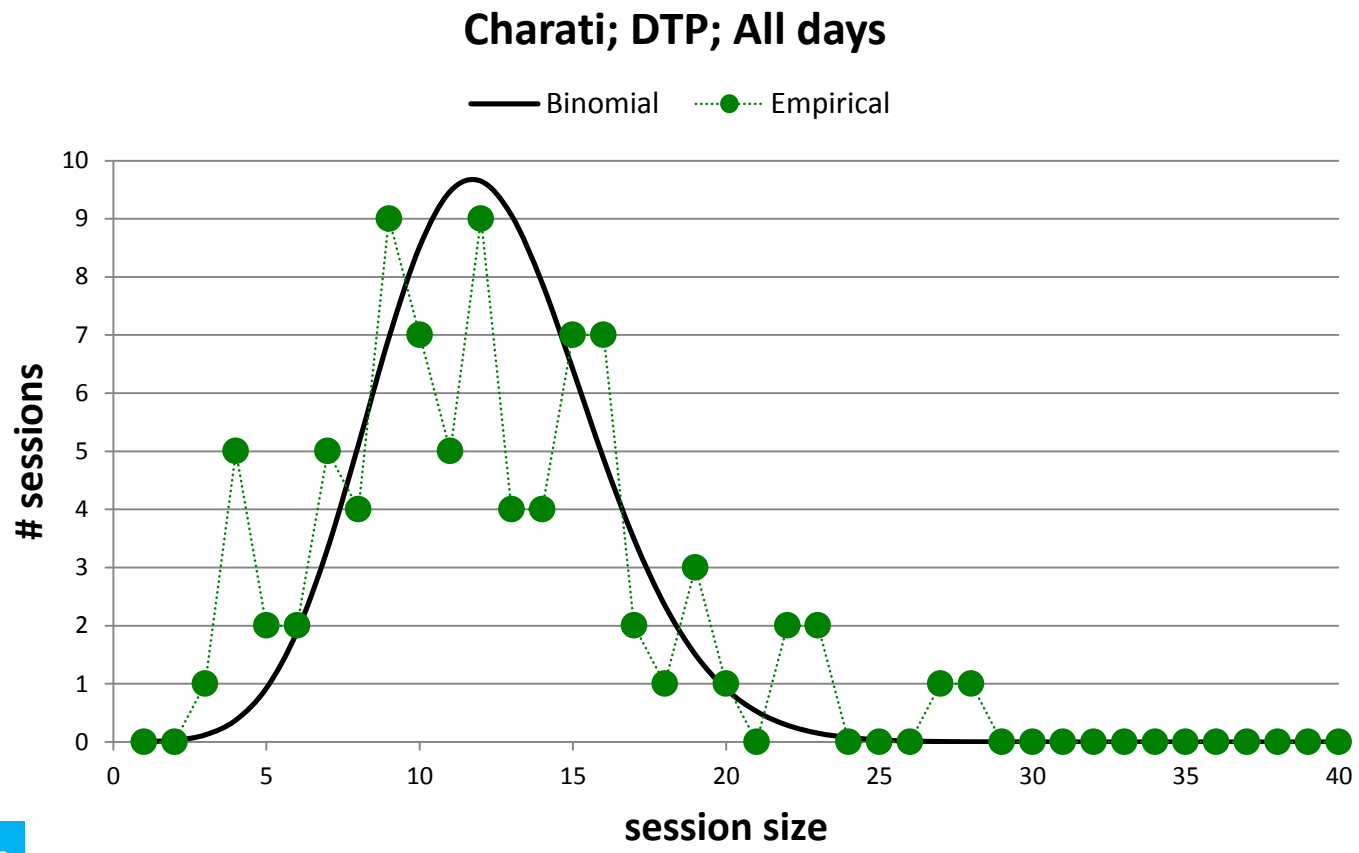
Session size distributions: Bangladesh, DTP, 10 dose vial

In 2004 the Charati facility in Bangladesh administered 1025 doses of DTP Vaccine. The facility held 84 immunization sessions that year.

Based on the hypothesis that the session size distribution is Binomial(n; N=1025, p=1/84), the expected session size distribution may be generated…



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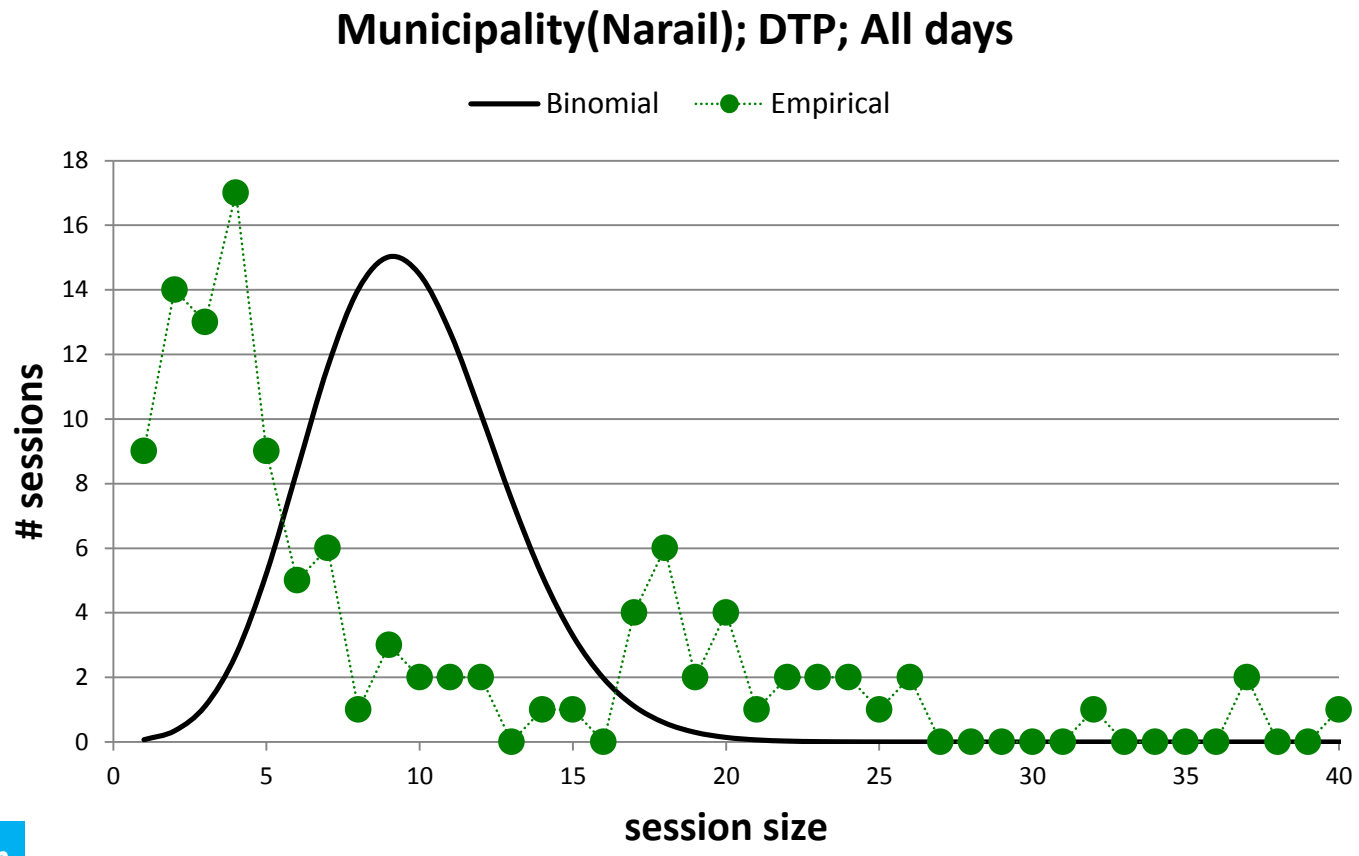
Session size distributions: Bangladesh, DTP, 10 dose vial

In 2004 the Municipality (Narail) facility in Bangladesh administered 1117 doses of DTP Vaccine. The facility held 116 immunization sessions that year.

Based on the hypothesis that the session size distribution is Binomial(n; N=1117, p=1/116), the expected session size distribution may be generated…



Session size distributions: Bangladesh, DTP, 10 dose vial

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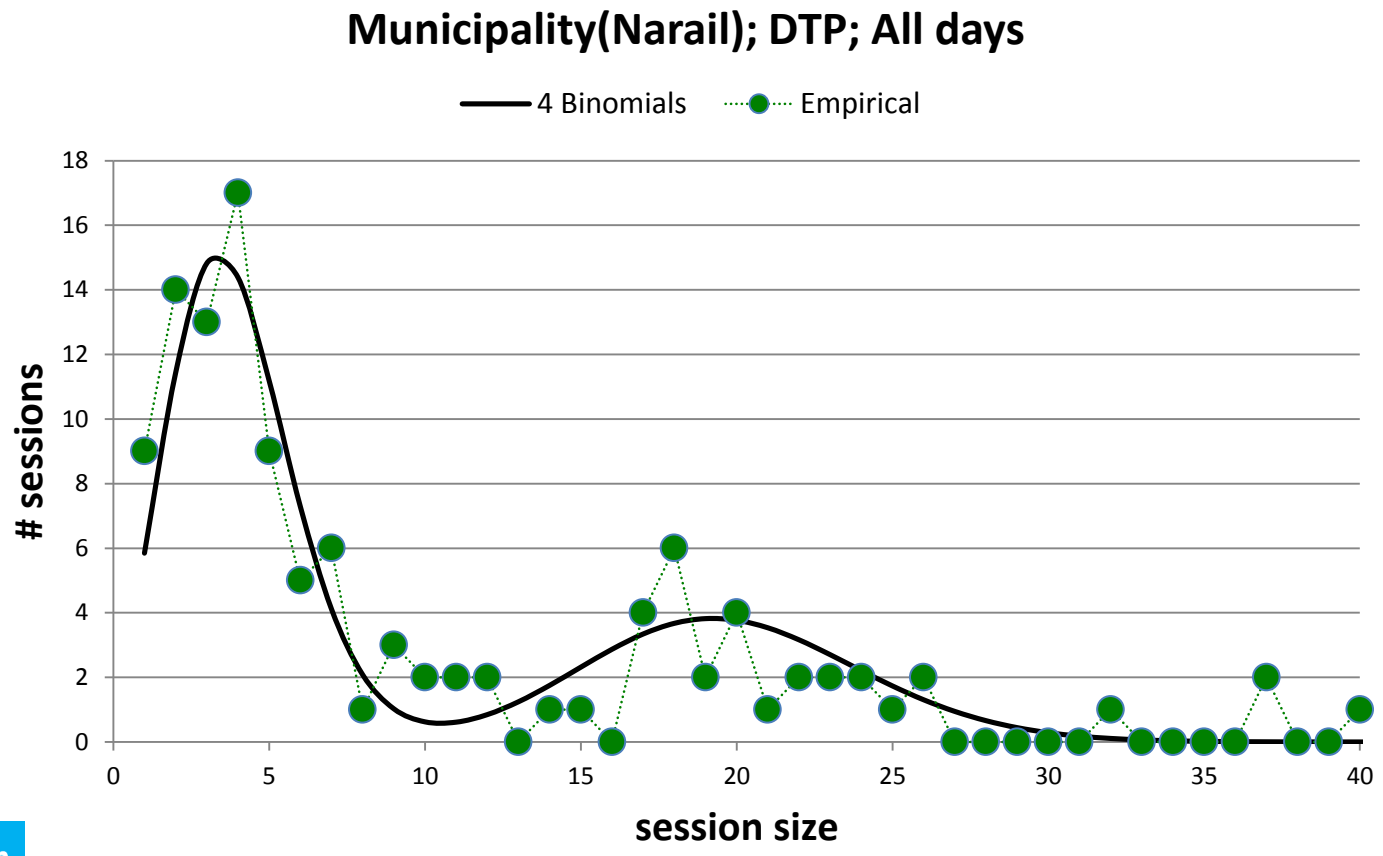
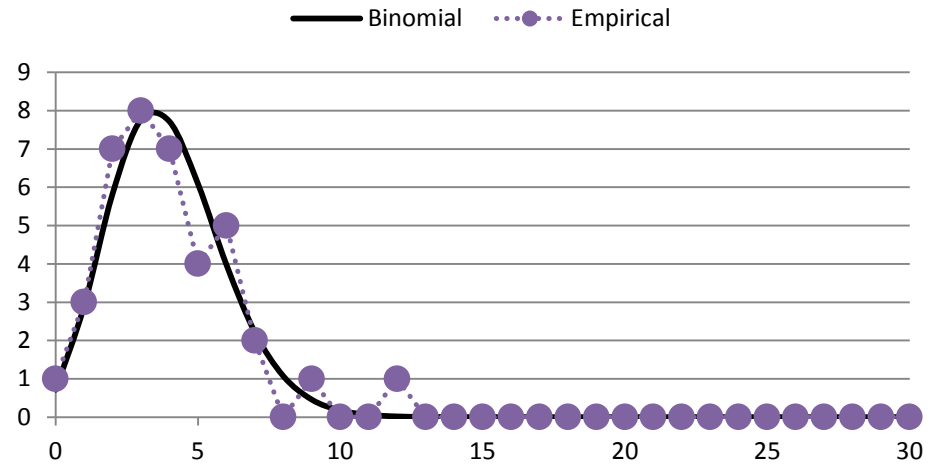
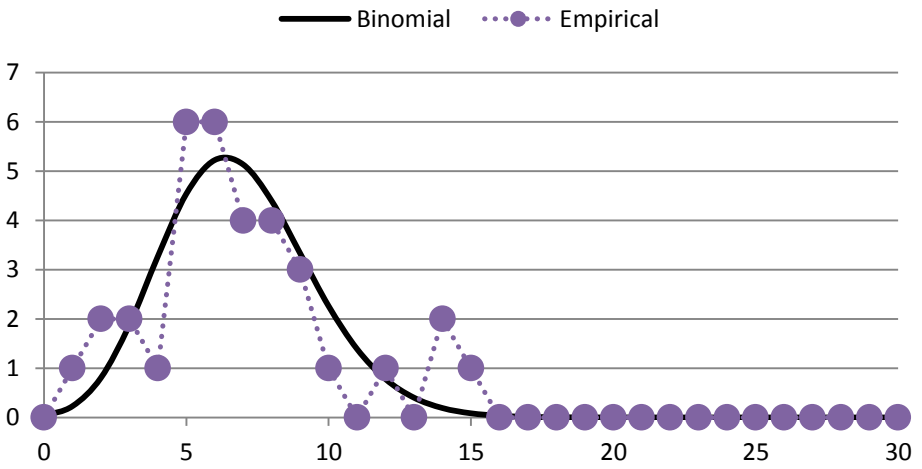


Session size distributions: Cambodia, DTP-HepB, 10 dose vial

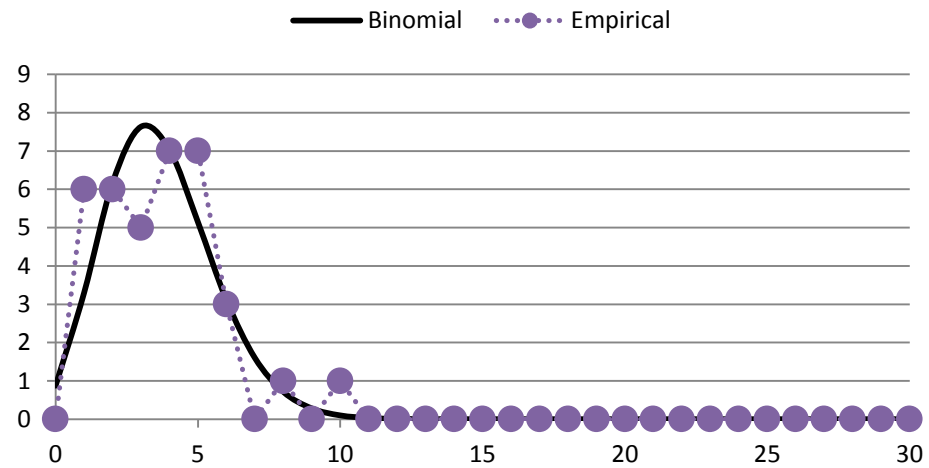
PS.A; outreach; All days



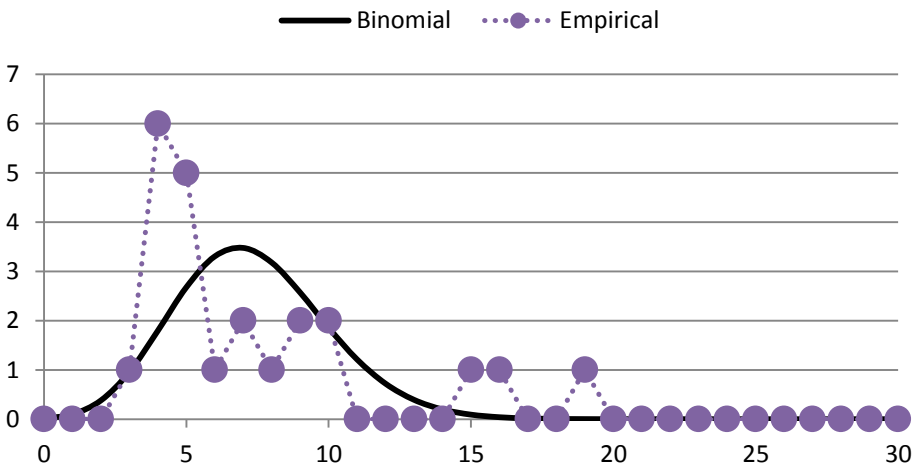
TA.C; outreach; All days



KP.L; outreach; All days



PR.K; outreach; All days



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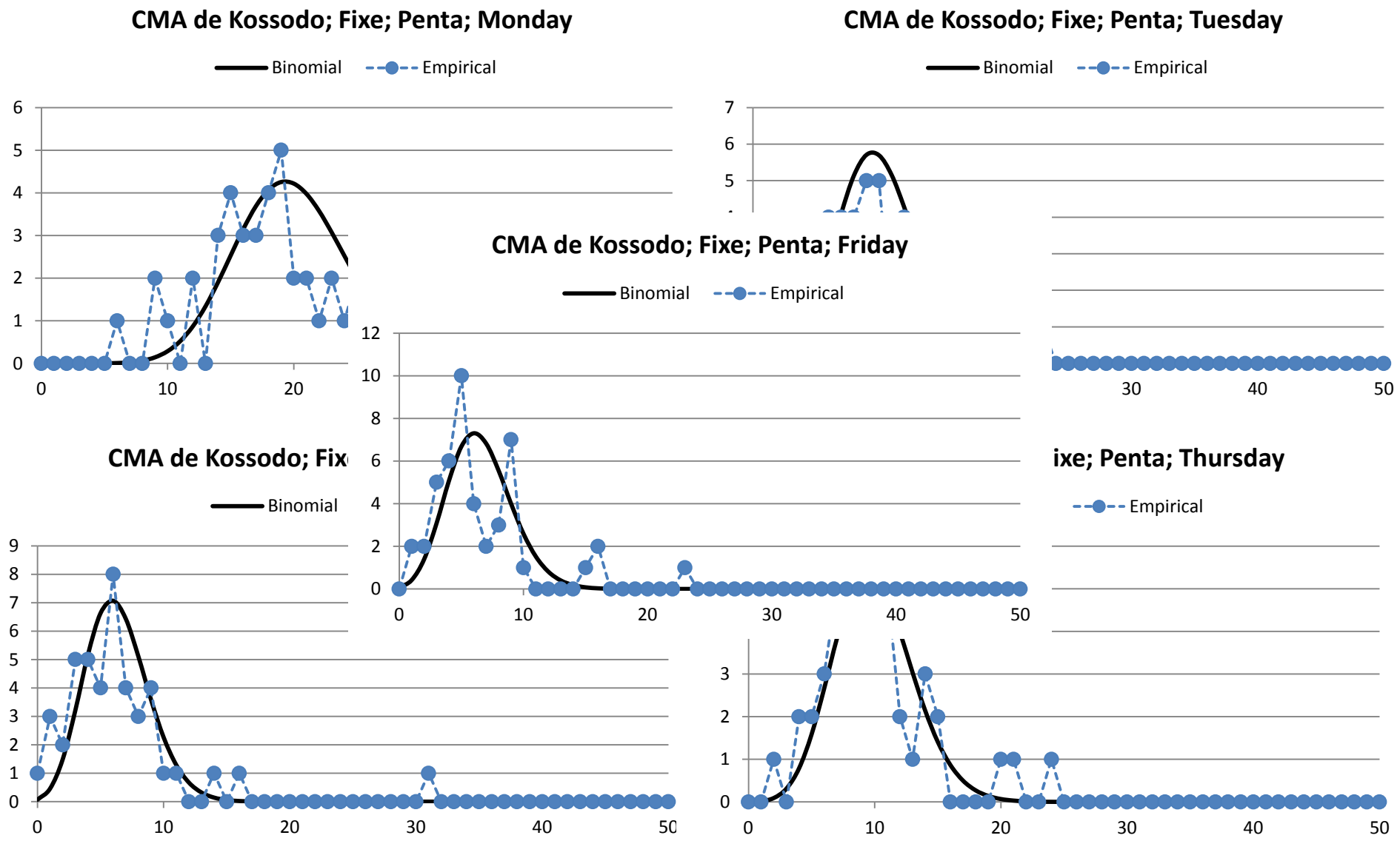
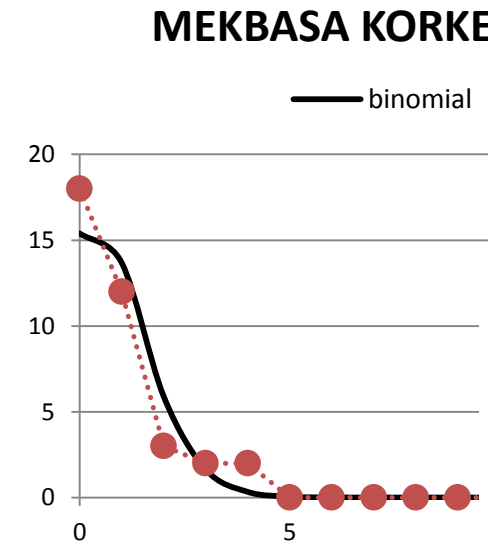
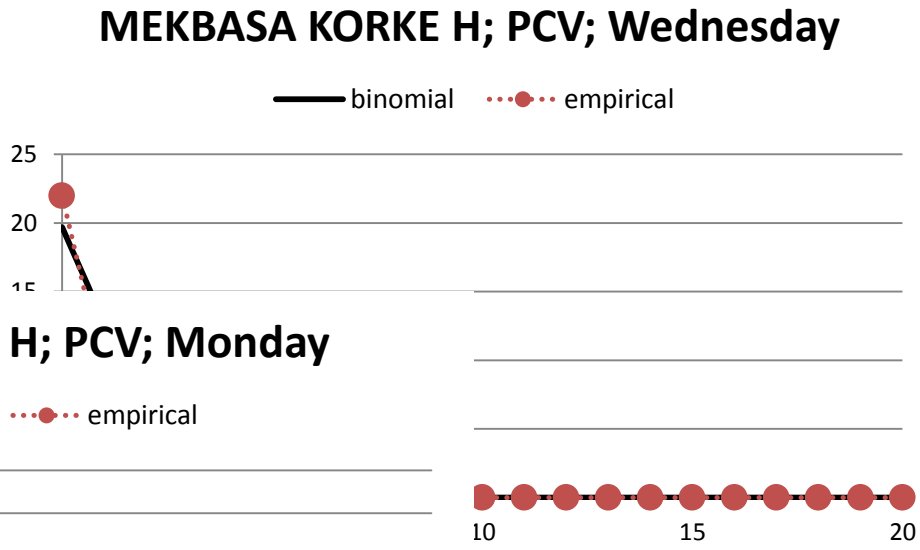
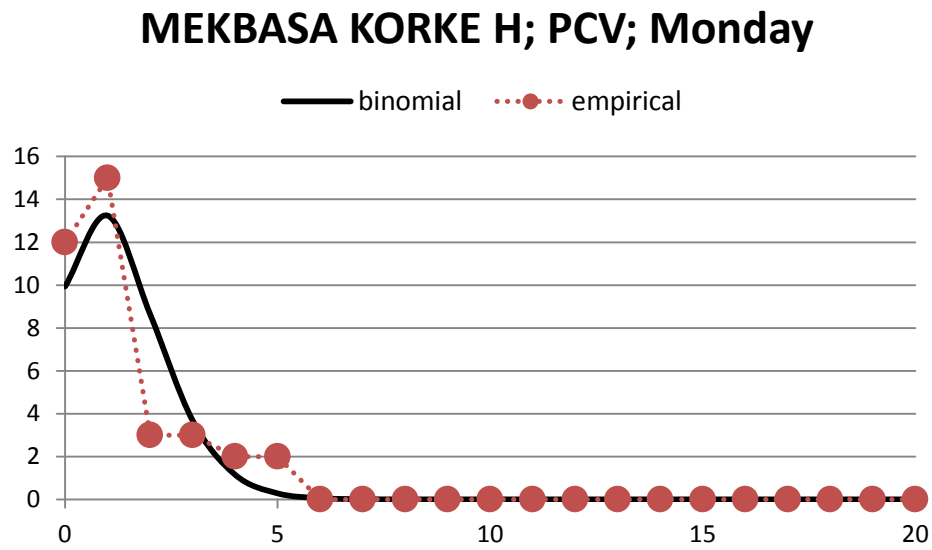
Session size distributions: Burkina Faso, Penta, 1 dose vial

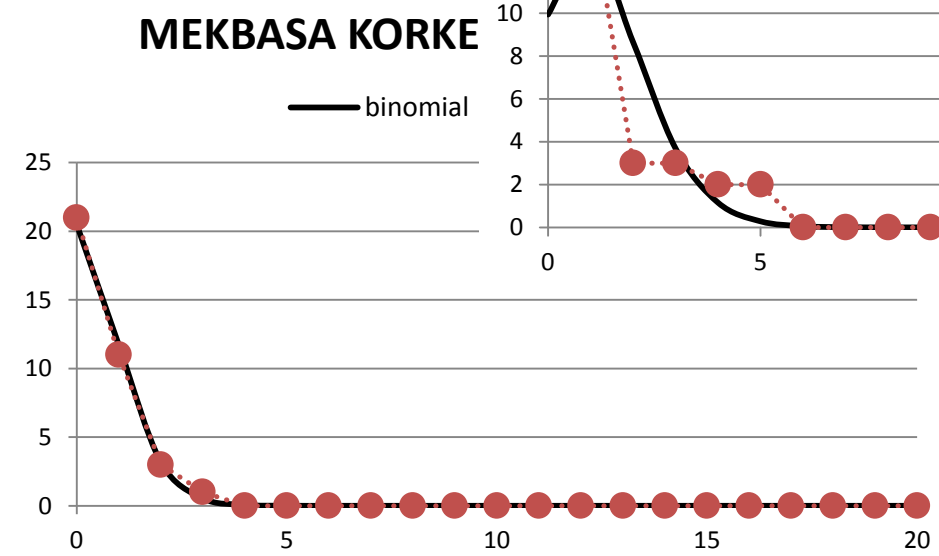


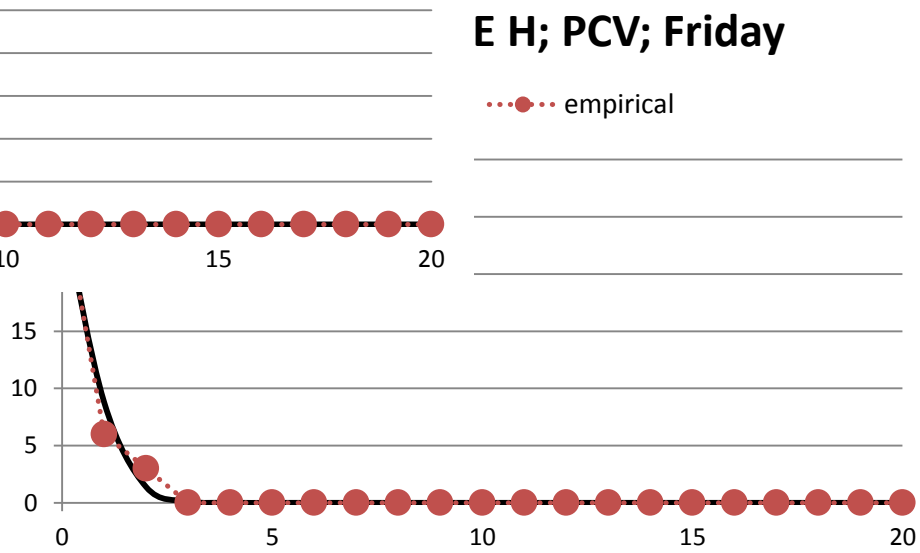
Session size distributions: Ethiopia, PCV, 2 dose vial





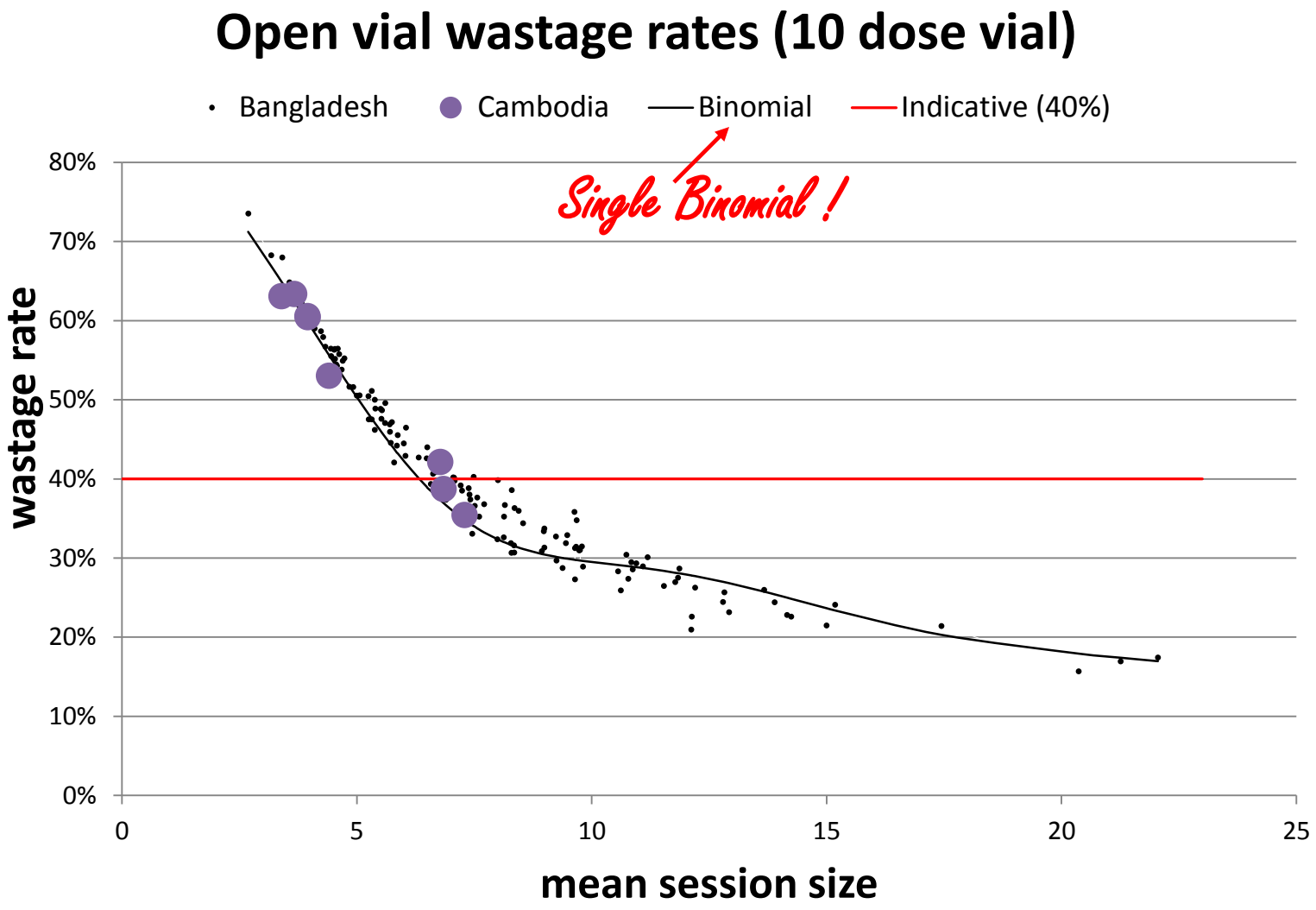






Opened vial wastage data

Open vial wastage data



Open vial wastage: data versus model

Model:

- A1 + A2 $\Rightarrow$ $\mathrm{P}\left(n; N, \frac{1}{S}\right) = \binom{N}{n}\left(\frac{1}{S}\right)^{n}\left(1-\frac{1}{S}\right)^{N-n}$
- A1 + A2 + A3 + A4 $\Rightarrow$ $w(N,S,m) = \frac{\sum_{n=0}^{\infty}\mathrm{P}(n;N,1/S)\times[m-(n\ mod\ m)]}{\sum_{n=0}^{\infty}\mathrm{P}(n;N,1/S)\times[n+m-(n\ mod\ m)]}$

Data:

- A1 + A3 + A4 $\Rightarrow$ $w(N,S,m) \cong \frac{\sum_{n=0}^{\infty}\mathrm{P}(n;N,1/S)\times[m-(n\ mod\ m)]}{\sum_{n=0}^{\infty}\mathrm{P}(n;N,1/S)\times[n+m-(n\ mod\ m)]}$
- That is, for the locations and vial sizes for which we have data, the formula works pretty well, even when A2 is violated.

Sensitivity analyses:

- How sensitive is the model to violations of the assumptions?
- Under what circumstances will the model breakdown?

Assumptions

Assumptions

A1 Births are uniformly randomly distributed throughout the year

- Birth rates do vary throughout the year in most countries.
- Typical variation amplitudes range from 10% to 30%.
- The maximum amplitude observed is ~40%.

⇒ A1 does not hold to varying degrees in most countries.

A2 Children are immunized according to the national immunization schedule

- Session size data from over 250 immunization locations, fixed and outreach, in Bangladesh, Cambodia, Burkina-Faso and Ethiopia, show that for ~10% of locations one day of the week is significantly more popular than other days. For the other 90% of locations, assumption A2 holds.

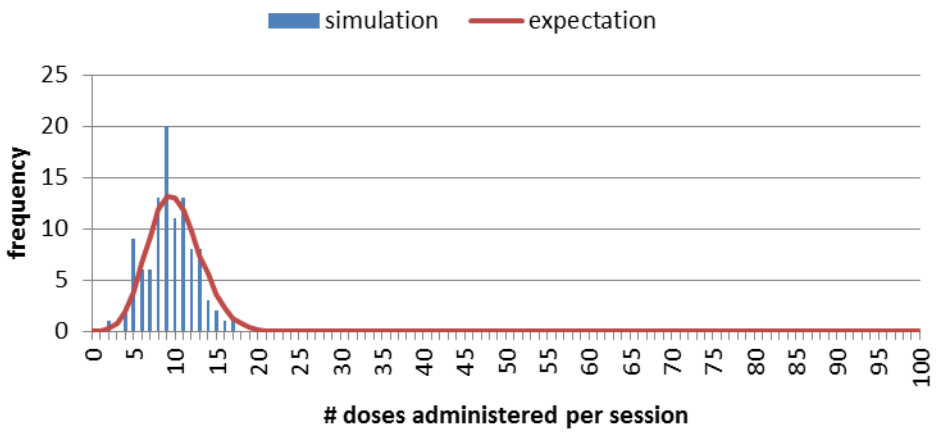
⇒ A2 does not hold in ~10% of the locations for which data is available.

Assumption A2: Children are immunized according to the schedule

Example:

- 5 dose vial, discard after 6 hours
- 1040 doses administered in one year
- 2 sessions per week, Monday and Friday (104 sessions per year)
- Friday session is 4 times more popular than the Monday session (A2 does not hold)

Model (A2 holds – Mon & Fri equally popular)



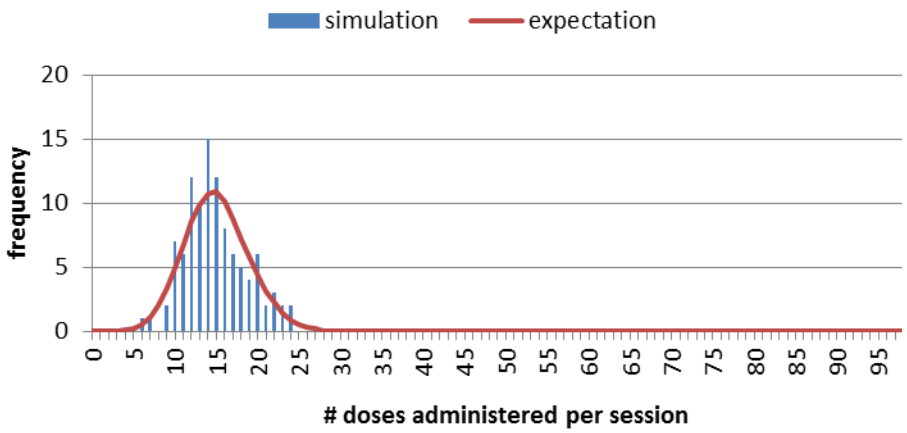
⇒ expected 5-dose vial wastage rate 16.7%

Assumption A2: Children are immunized according to the schedule

Example:

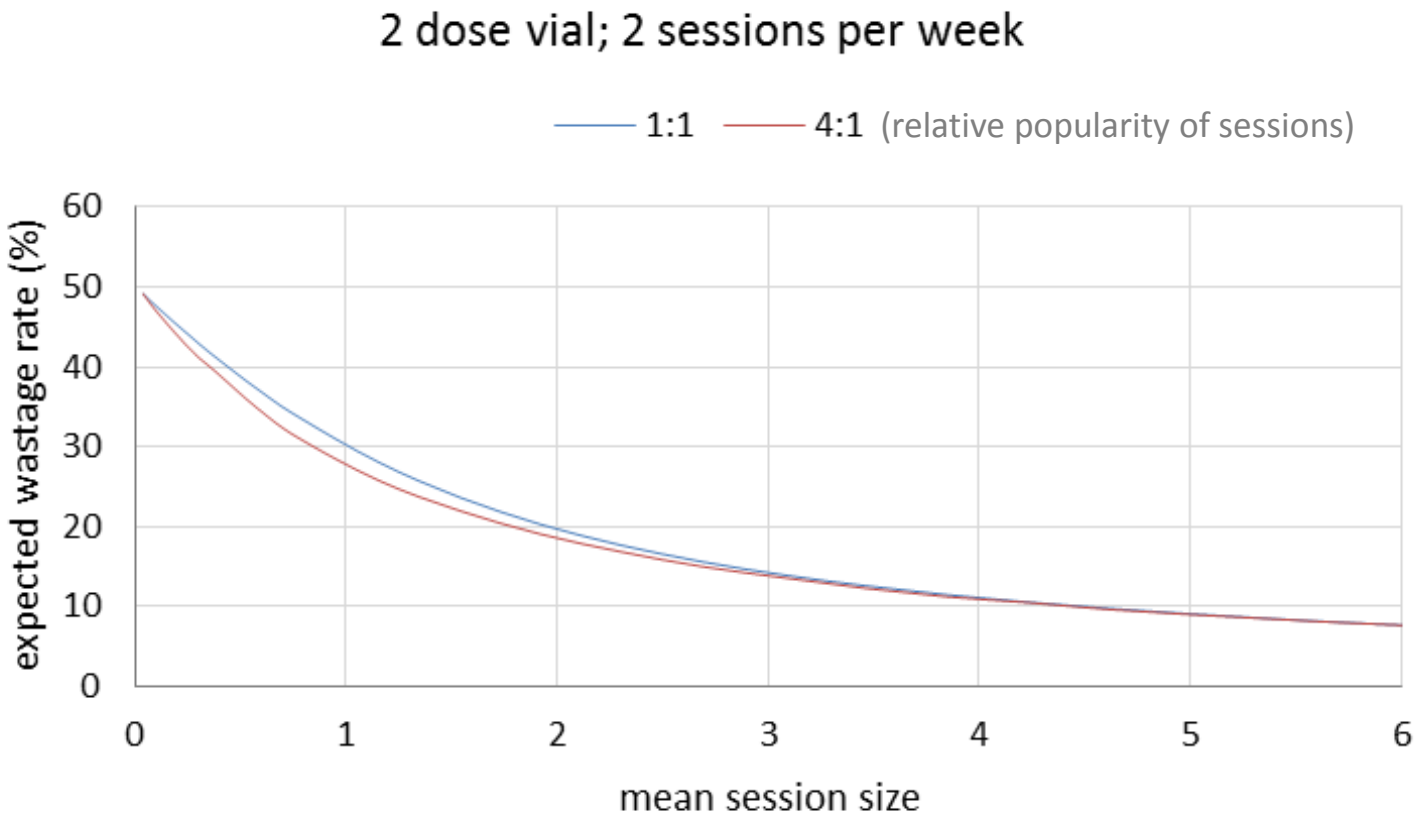
- 20 dose vial, discard after 6 hours
- 1560 doses administered in one year
- 2 sessions per week, Monday and Friday (104 sessions per year)
- Friday session is 4 times more popular than the Monday session (A2 does not hold)

Model (A2 holds – Mon & Fri equally popular)

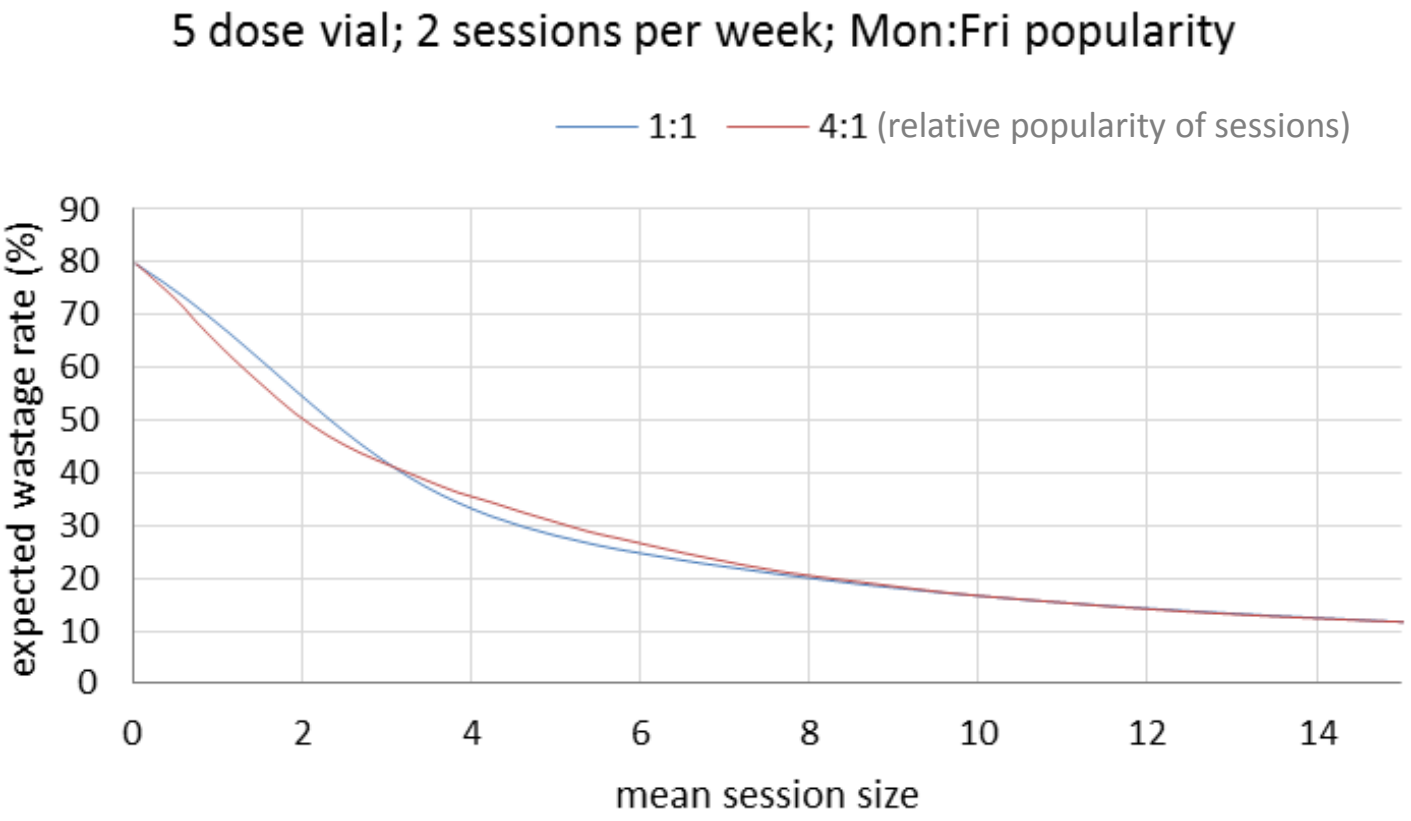


⇒ expected 5-dose vial wastage rate 30.8%

Assumption A2: Children are immunized according to the schedule



Assumption A2: Children are immunized according to the schedule



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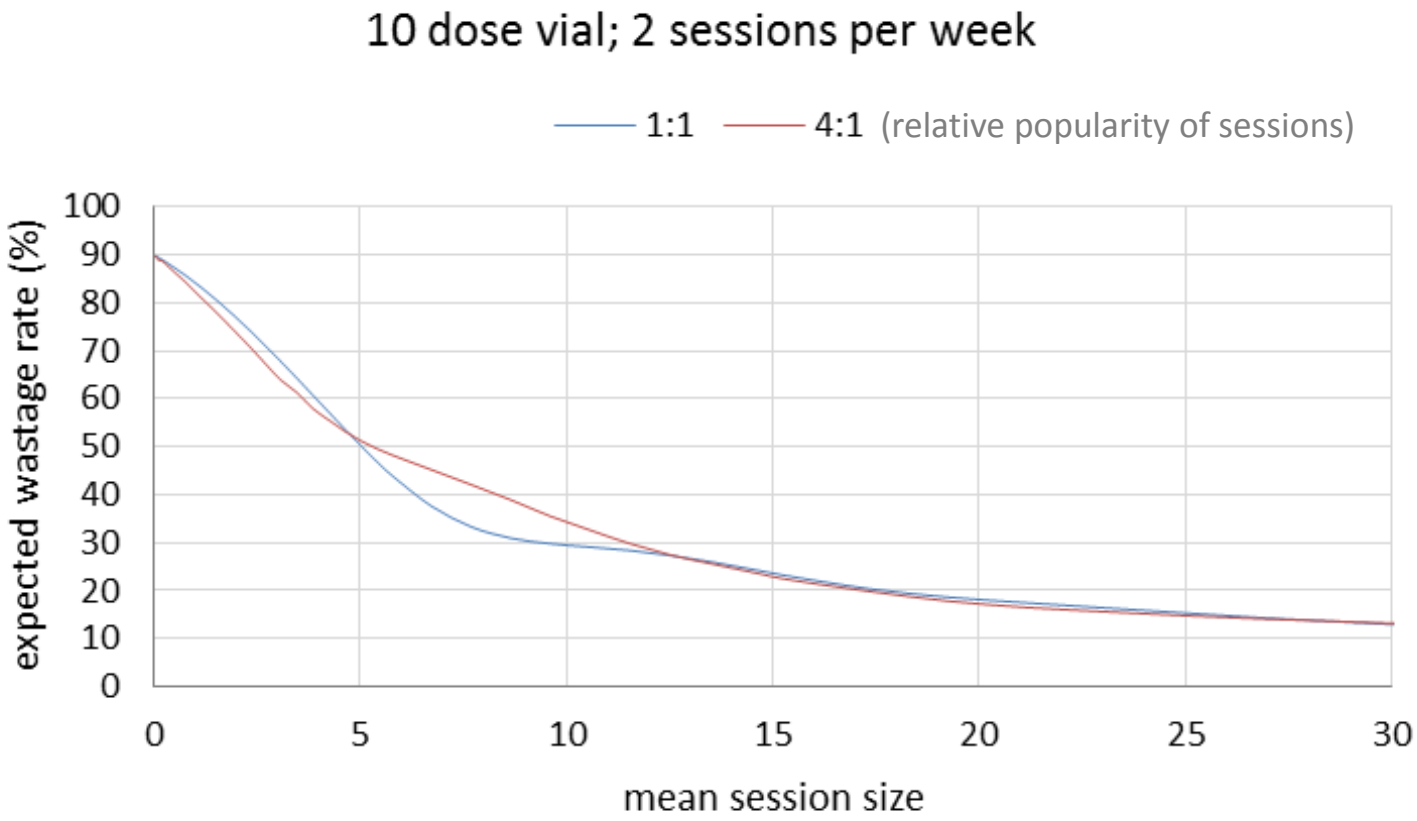
Assumption A2: Children are immunized according to the schedule



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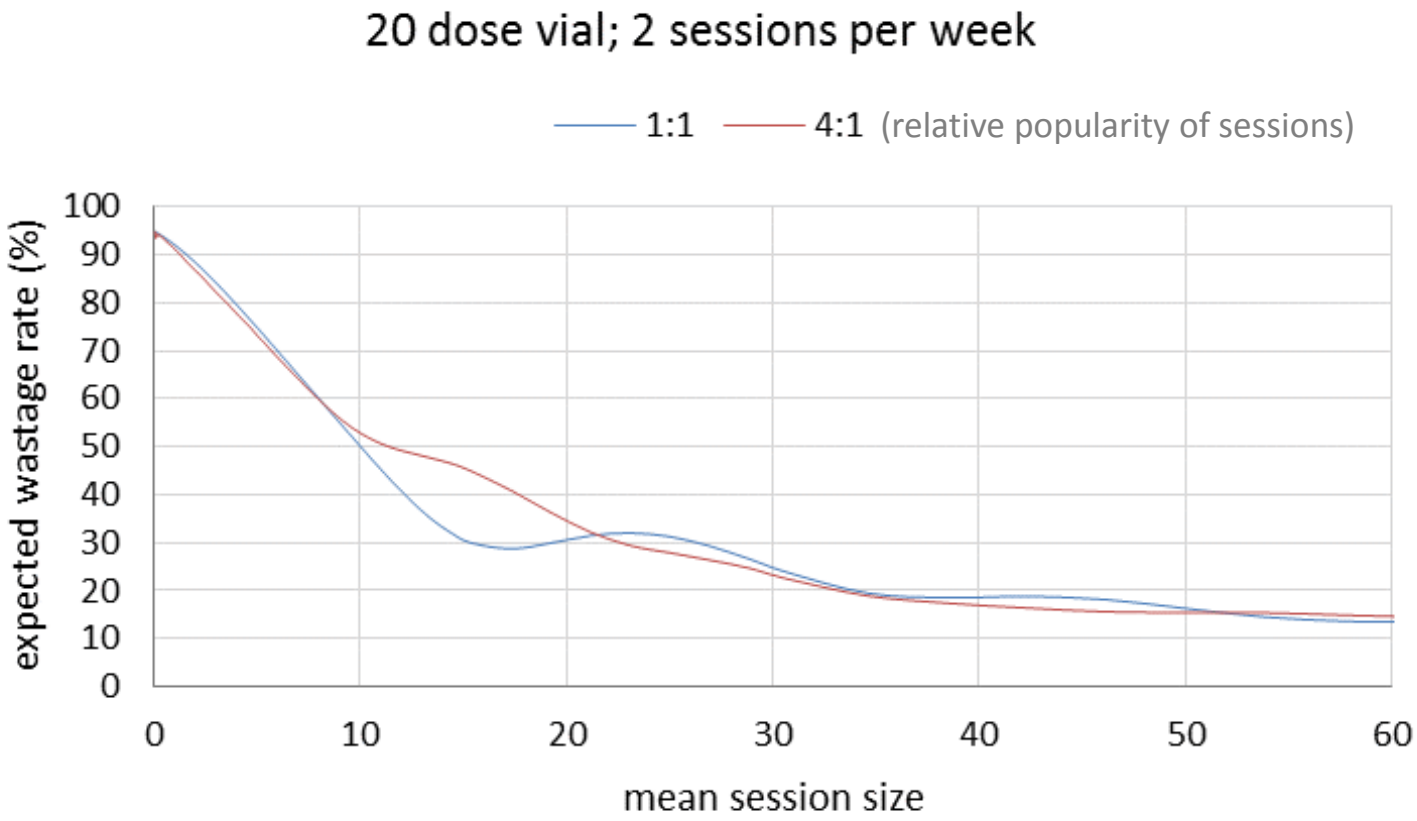
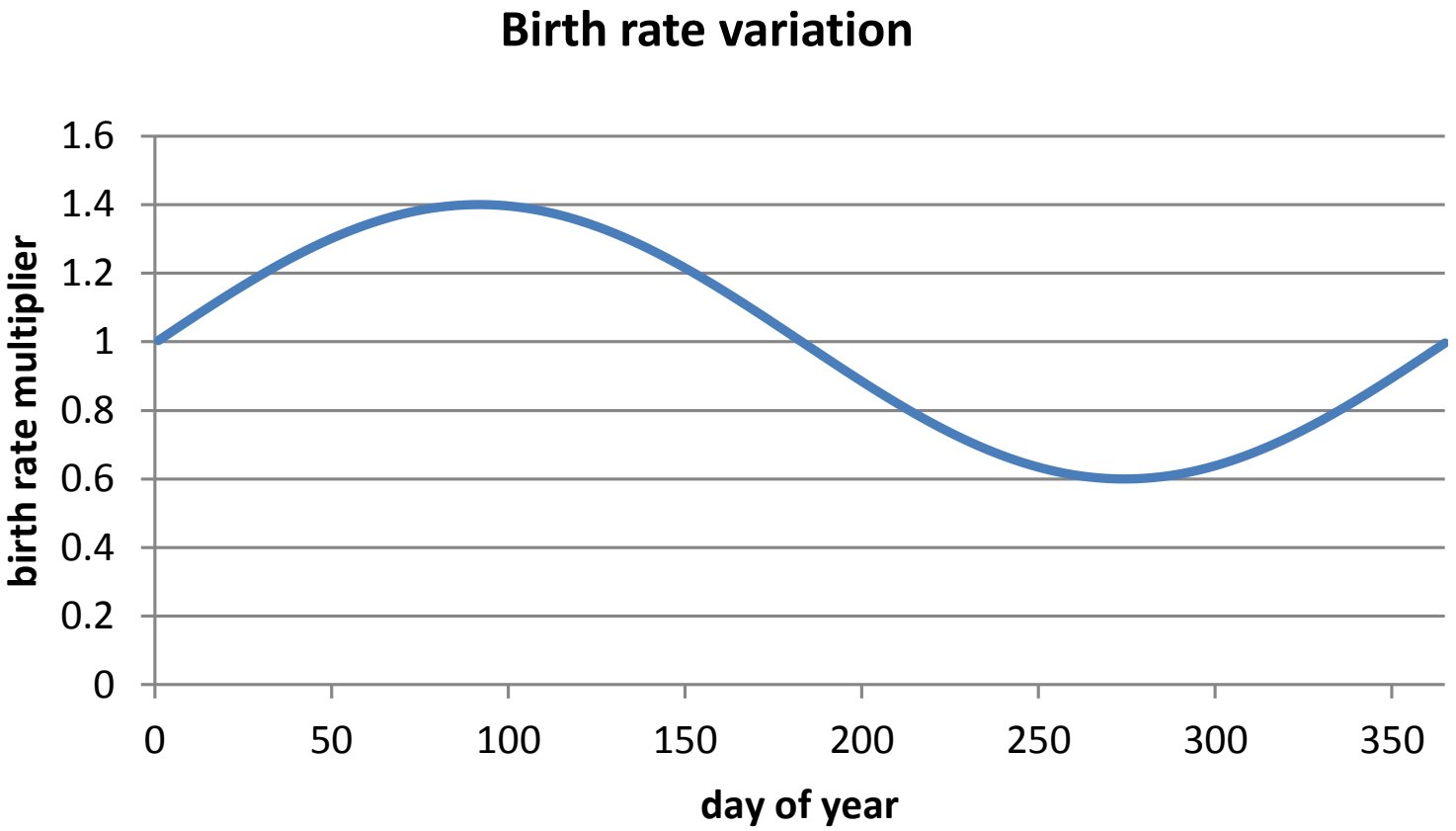


Assumption A1: Births are uniformly randomly distributed throughout the year



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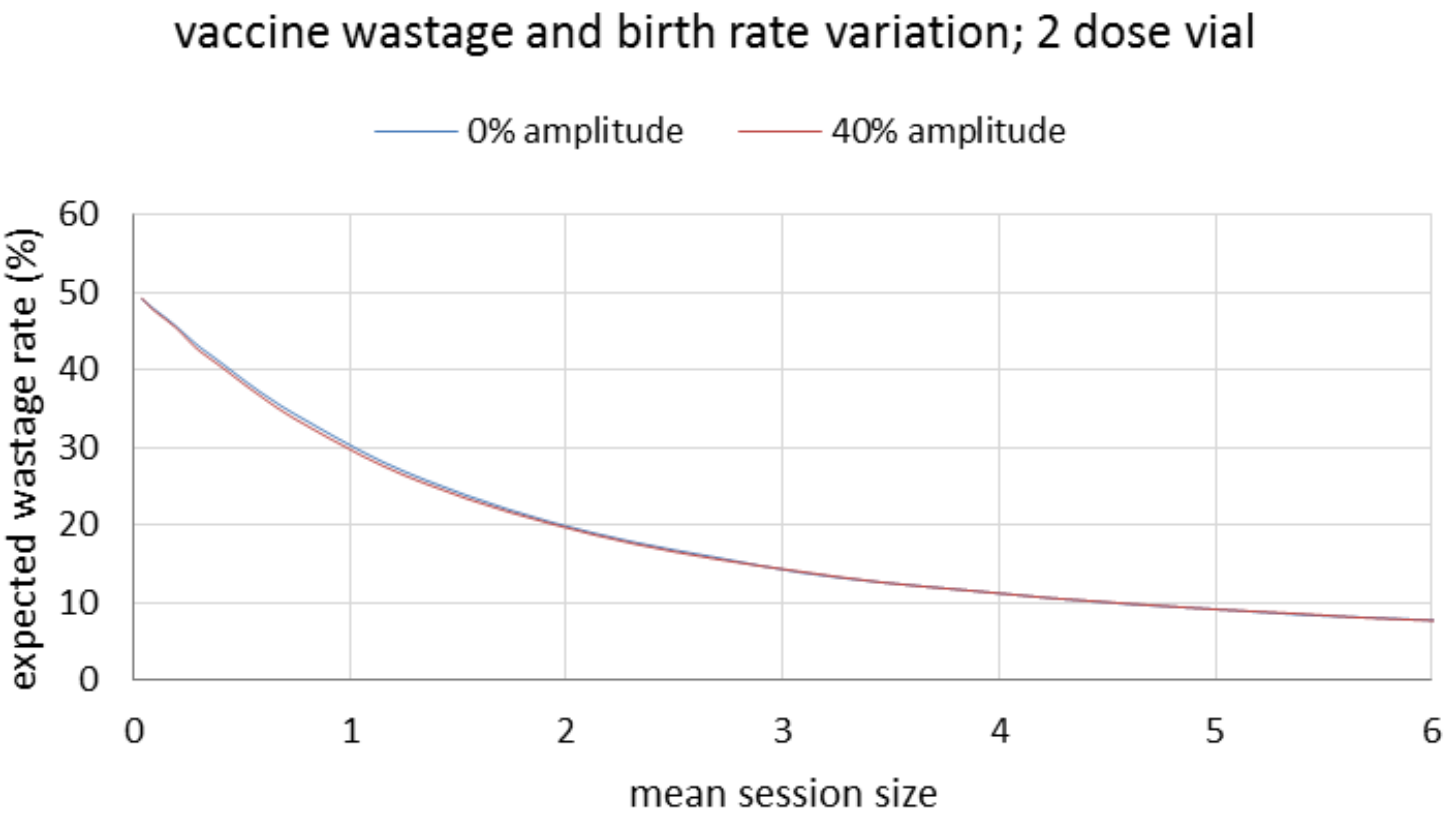

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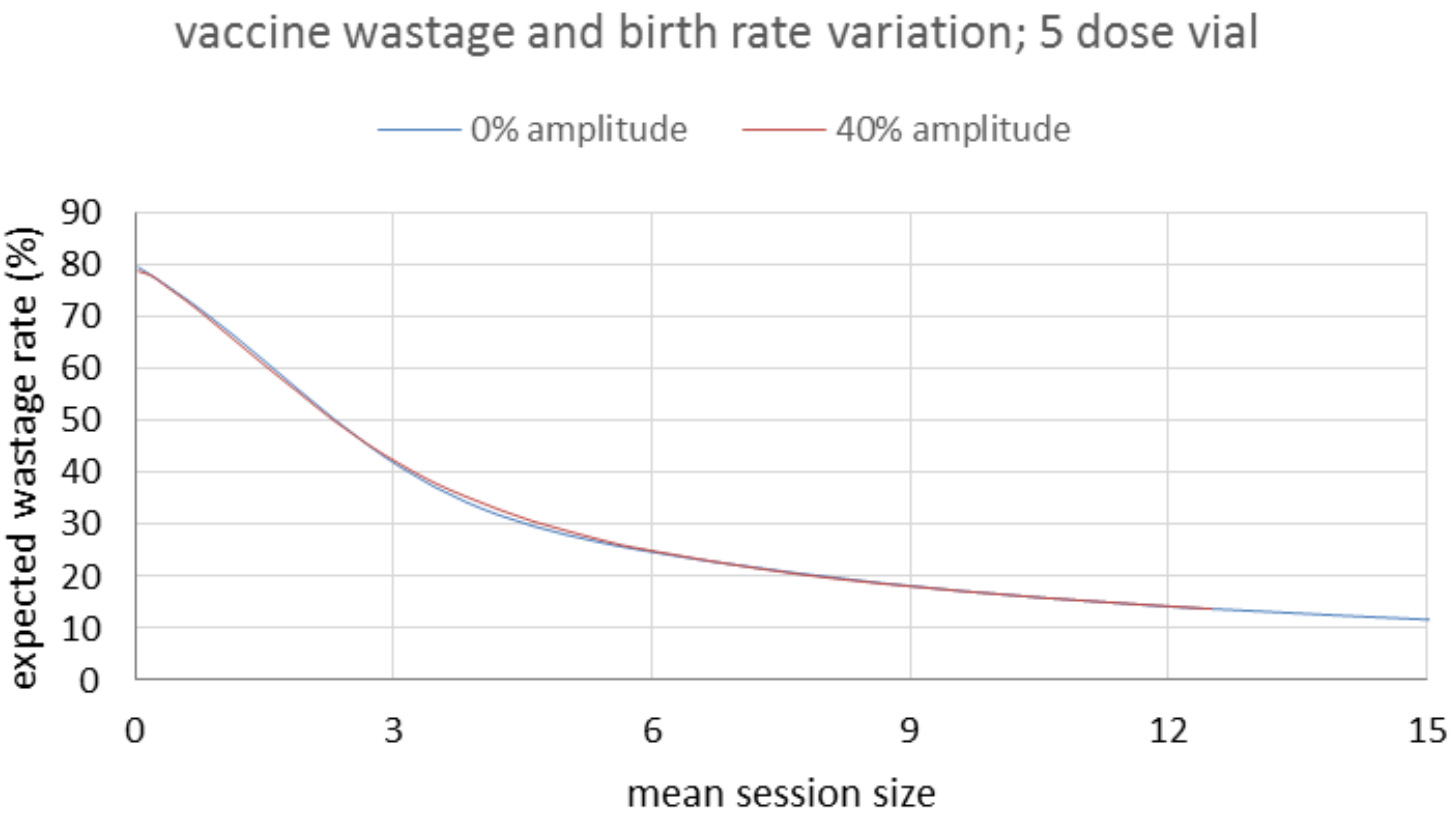

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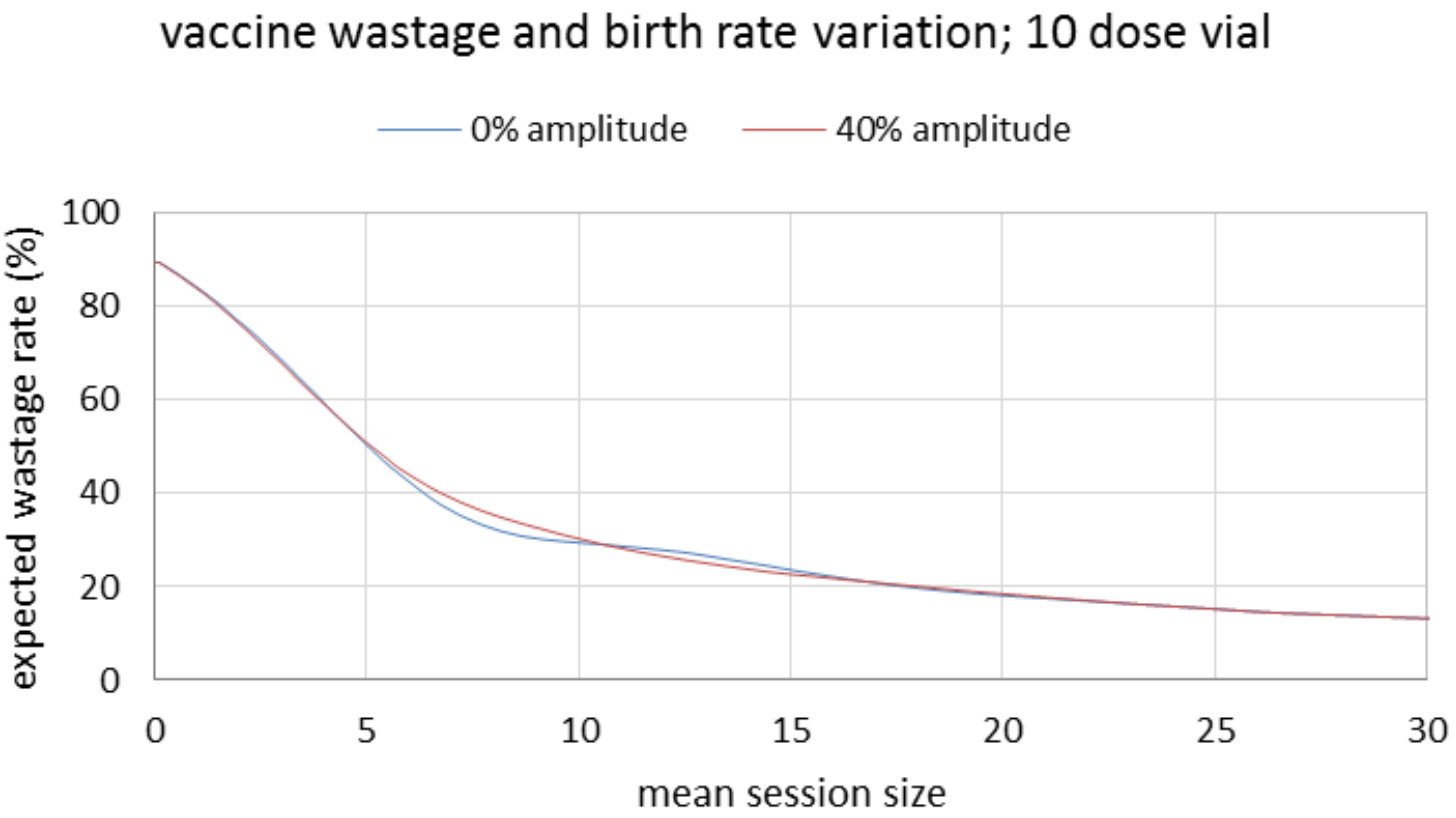

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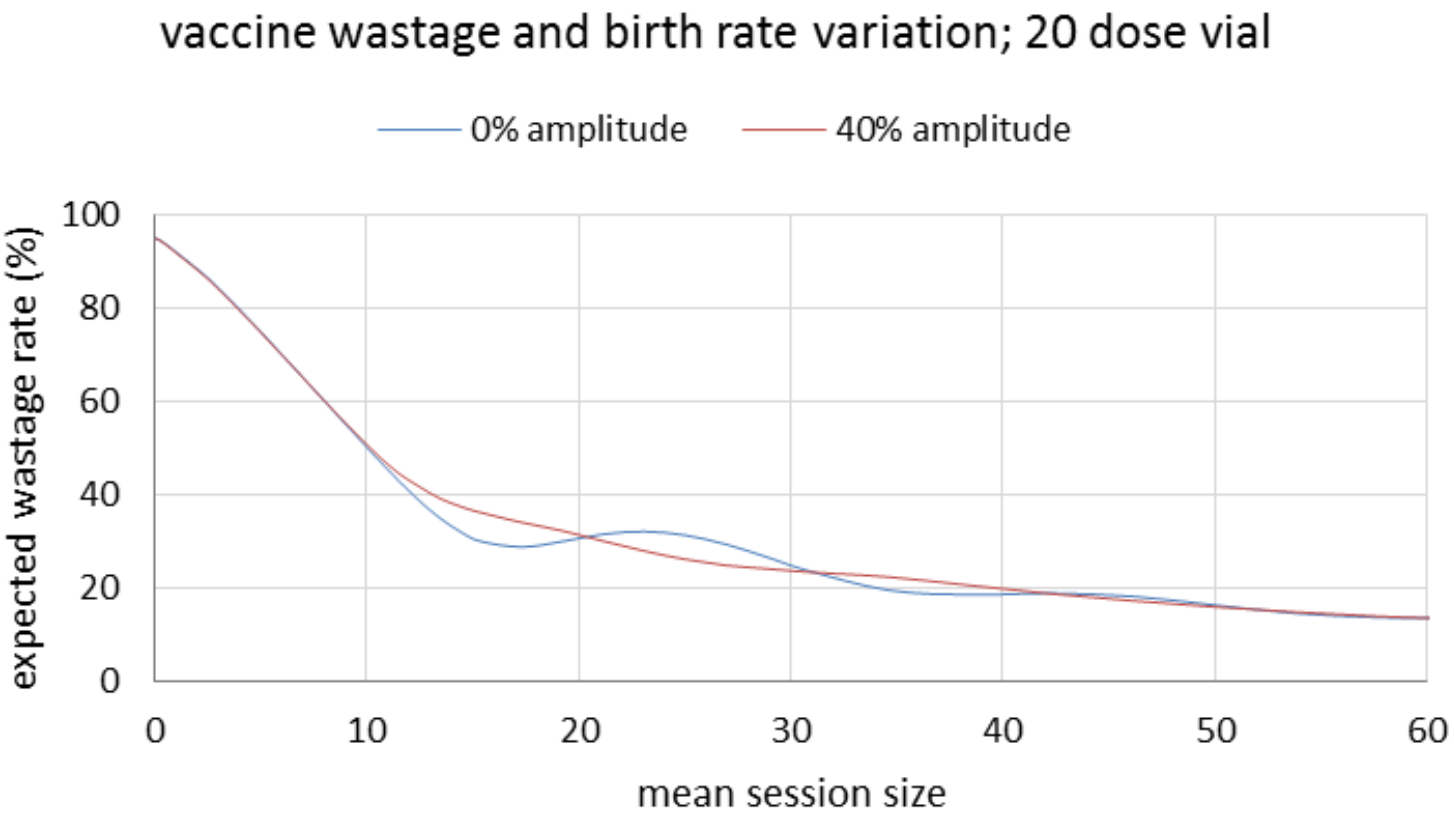

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Assumptions

- When the assumptions do hold, logic tells us:

$$w(N,S,m) = \frac{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [m-(n \bmod m)]}{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [n+m-(n \bmod m)]}$$

- When the assumptions do not hold, logic tells us*:

$$w(N,S,m) \cong \frac{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [m-(n \bmod m)]}{\sum_{n=0}^{\infty} \mathrm{P}(n;N,1/S) \times [n+m-(n \bmod m)]}$$

- Data from more than 250 locations, fixed and outreach, in 4 countries, confirm the logic.

The model works.
Use it!

*The only setting in which the model might be a bit off (more than 10 percentage points):

- a 20 dose vial is used,
- opened vials must be discarded after 6 hours,
- the mean session size is between 12 and 18 doses,
- there are 2 or more sessions per week and one day of the week is 4 or more times more popular than the other days.

Programmatic implications

Immunization session planning

At district level:

The wastage rate implications of *session frequency choice* are now known.

⇒ **More informed choice of immunization session frequency**

⇒ **Reduce wastage**

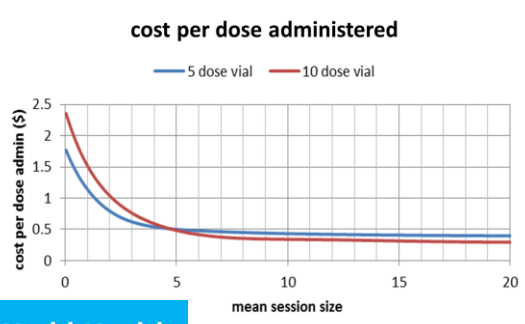
Programme planning

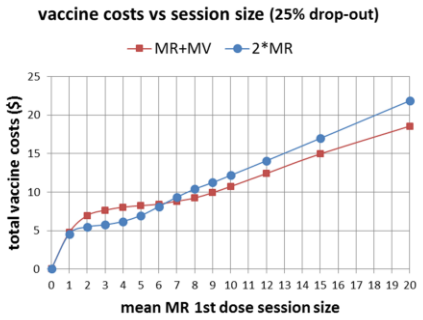
At national level:

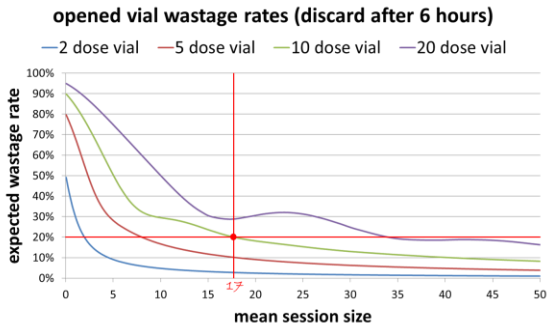
The wastage rate implications of *vial size choice* are now known.

⇒ **More informed choice of vial size**

⇒ **Reduce wastage**







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Vaccine needs forecasting

At district, regional and national levels:

Given the expected number of births *next* year and the planned number of sessions in each immunization location, one can estimate, with reasonable precision and confidence, next year's expected opened vial wastage rates for each location, and then aggregate to higher levels.

⇒ **More accurate forecasting of vaccine needs**

⇒ **Reduce stock-outs and over-stocks**

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Wastage monitoring

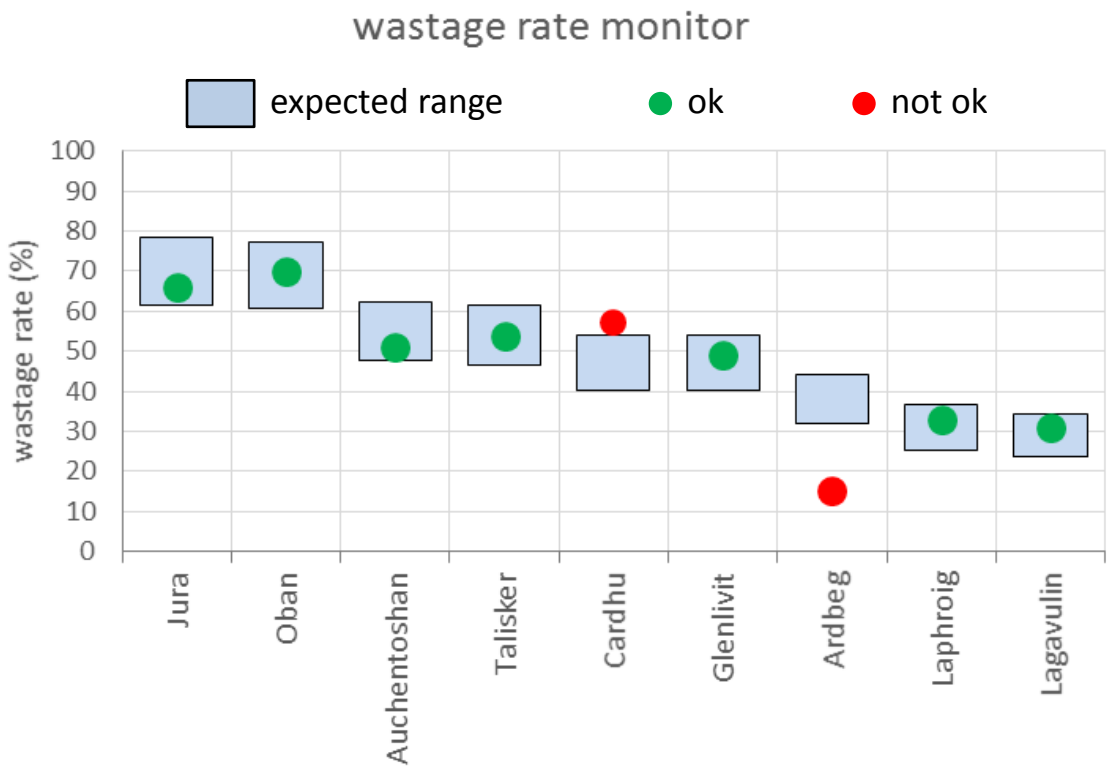
At district level:

Given the number of doses administered *last* year and the number of sessions conducted in each immunization location within a district, one can determine acceptable ranges for last year's opened vial wastage rate for each location.

⇒ **Monitor wastage rates against expected values (not against 0%)**

⇒ **Reduce undue pressure to reduce wastage**

⇒ **Reduce missed opportunities**



Tools

Tools: Look-up table

Expected opened vial wastage rates

discard after 6 hours				
mean session size	vial size			
	2 dose	5 dose	10 dose	20 dose
~0.00	50%	80%	90%	95%
0.10	48%	79%	90%	95%
0.19	45%	78%	89%	95%
0.29	43%	77%	89%	94%
0.38	41%	76%	88%	94%
0.58	37%	74%	87%	93%
0.77	34%	71%	86%	93%
1.15	28%	66%	83%	92%
1.54	24%	61%	80%	90%
1.92	20%	56%	77%	89%
2.31	18%	50%	74%	87%
2.69	16%	46%	71%	86%
3.08	14%	41%	68%	84%
3.46	13%	37%	64%	82%
3.85	11%	34%	61%	80%
4.23	11%	32%	57%	79%
4.62	10%	30%	54%	77%
5.00	9%	28%	50%	75%
5.38	8%	27%	47%	73%
		25%	44%	71%
		23%	38%	66%

discard after 28 days				
mean doses / month	vial size			
	2 dose	5 dose	10 dose	20 dose
~0.00	50%	80%	90%	95%
0.77	33%	72%	86%	93%
1.92	13%	56%	78%	89%
3.85	2%	27%	61%	80%
5.77	0%	9%	42%	71%
7.69	0%	2%	25%	62%
11.54	0%	0%	5%	42%
15.38	0%	0%	1%	24%
23.08	0%	0%	0%	3%
30.77	0%	0%	0%	0%

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Tools: Excel tools

Facility opened vial wastage calculator 

National opened vial wastage calculator 

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Pilot study

WHO are using this model to develop tools and guidance for immunization and supply chain managers to facilitate planning, forecasting and wastage monitoring and plan to pilot the tools in selected countries in the near future.

Thank you

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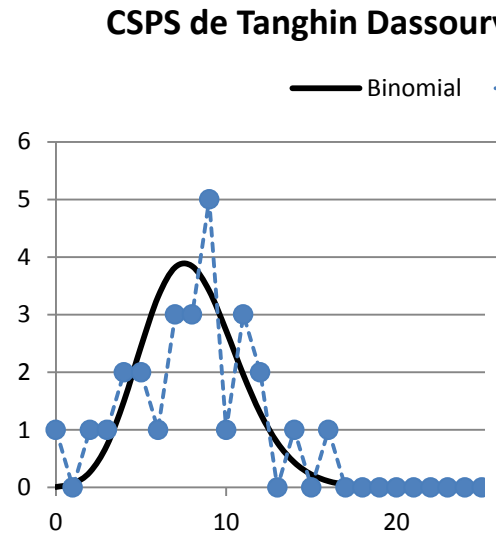
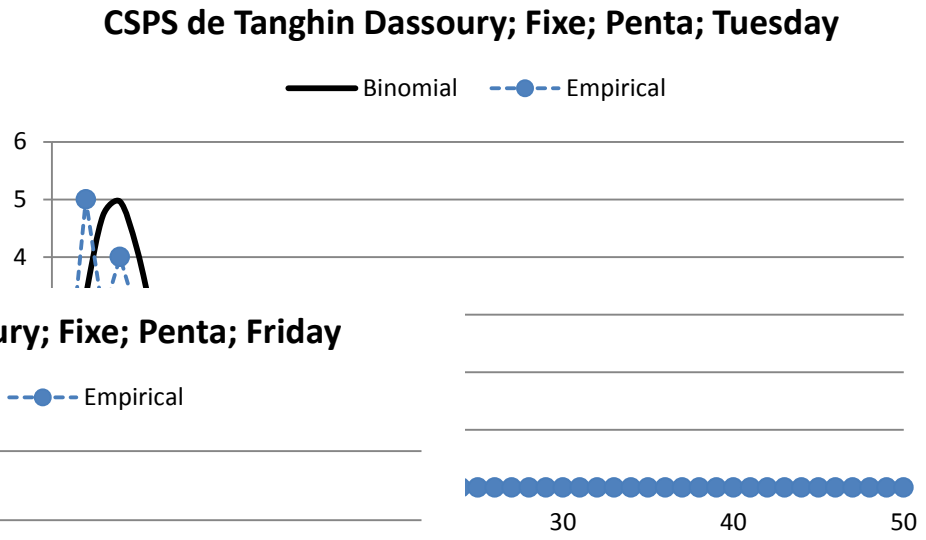
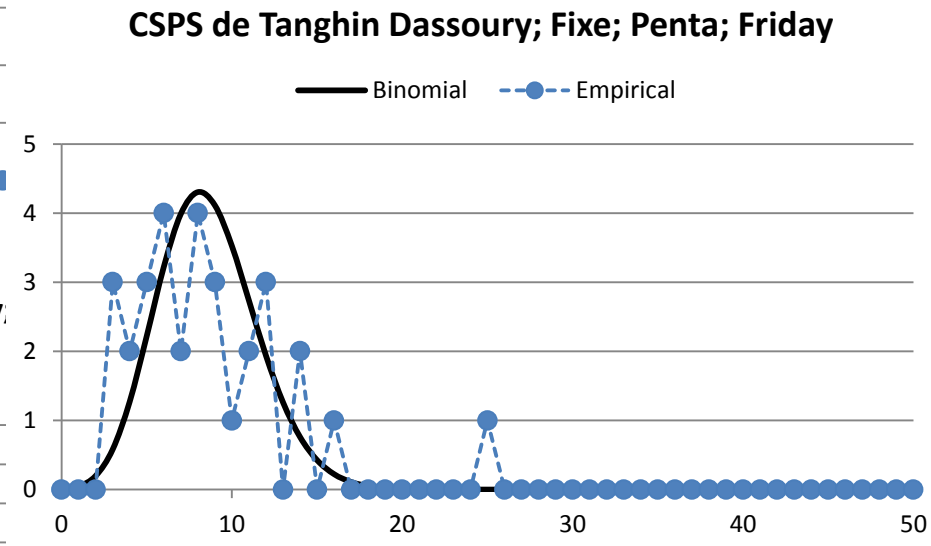
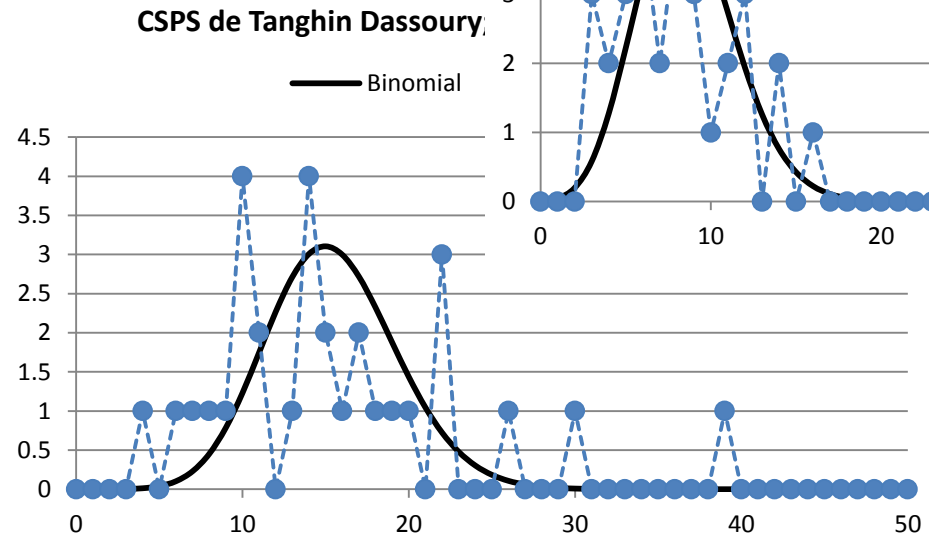
Back-up

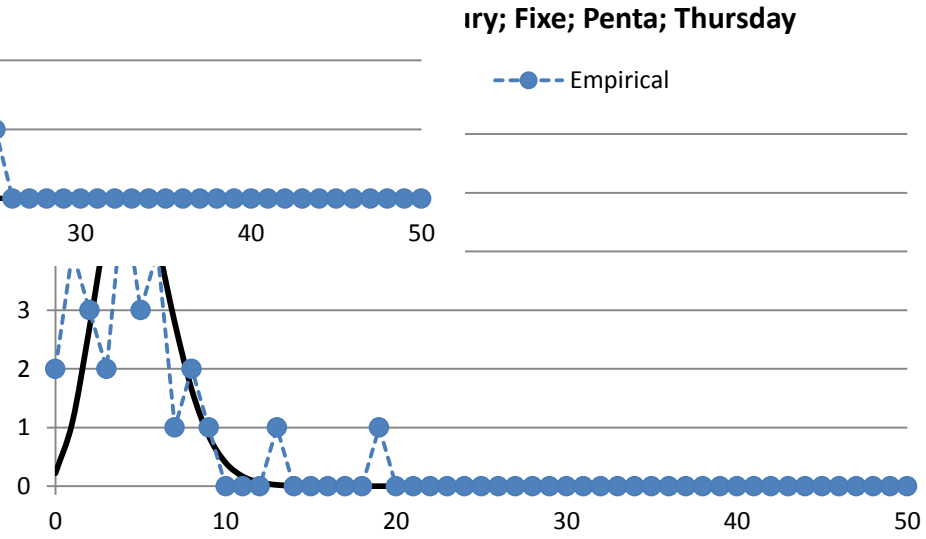
Session size distributions: Burkina Faso, Penta, 1 dose vial











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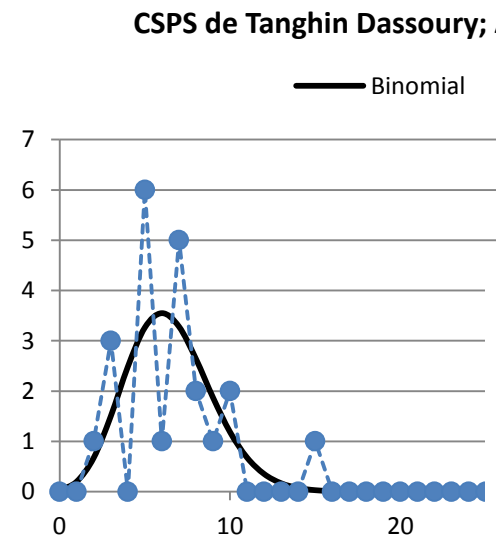
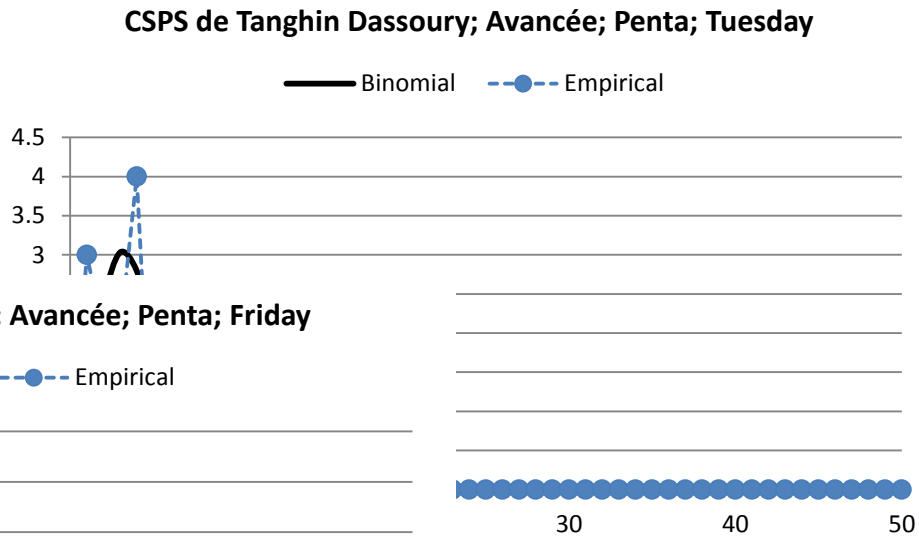
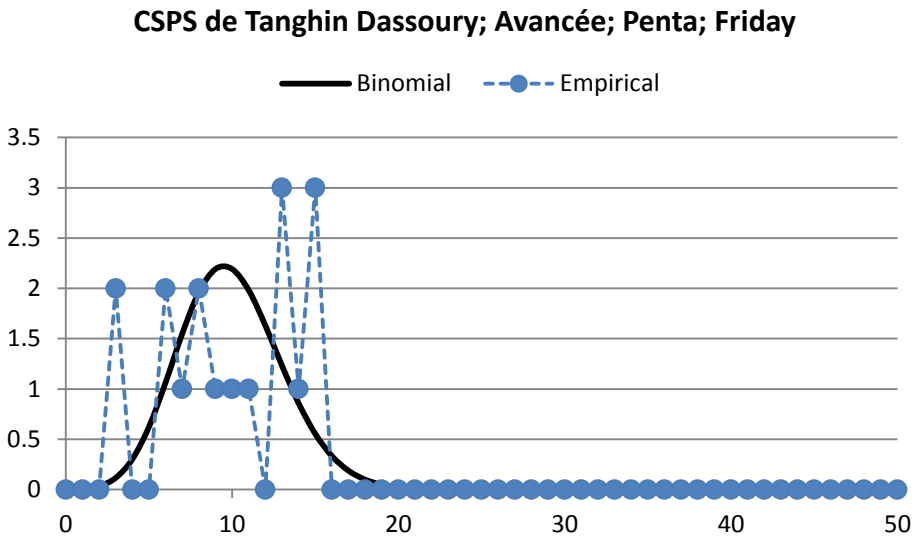
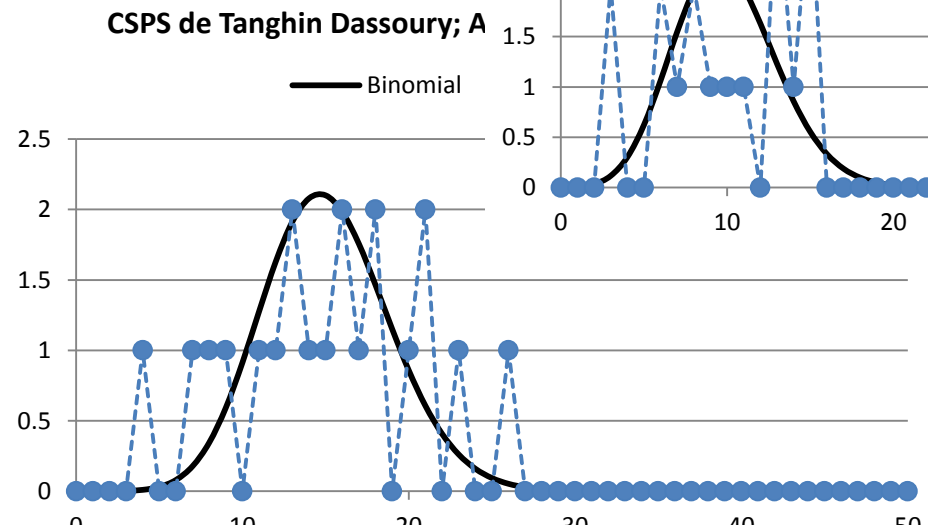
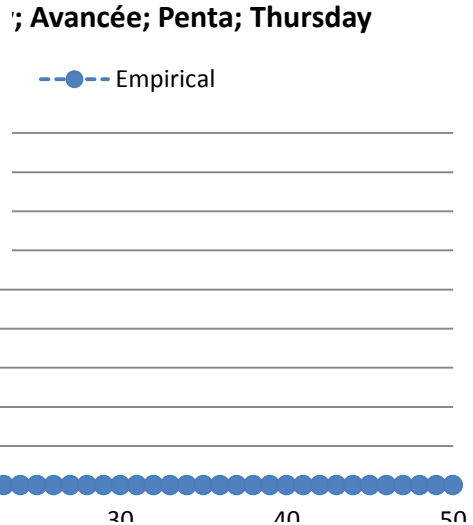
Session size distributions: Burkina Faso, Penta, 1 dose vial



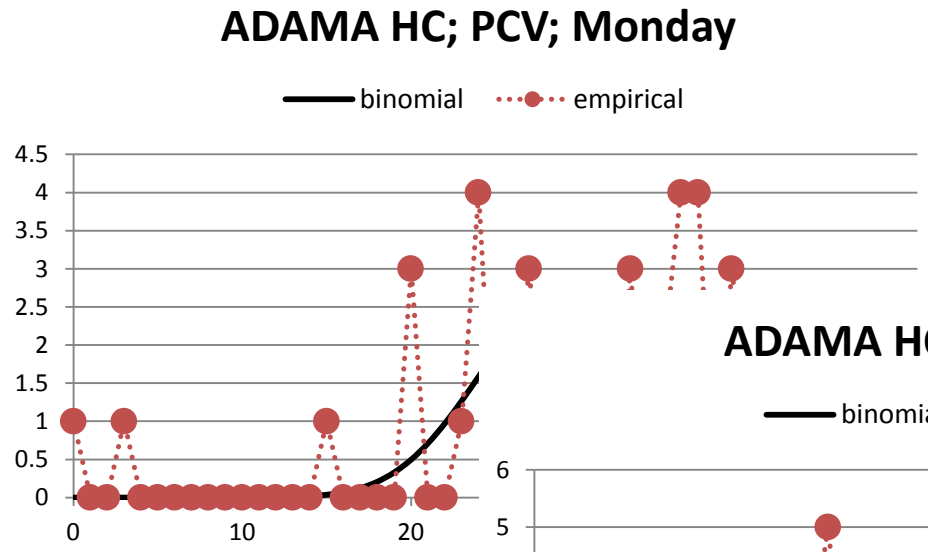


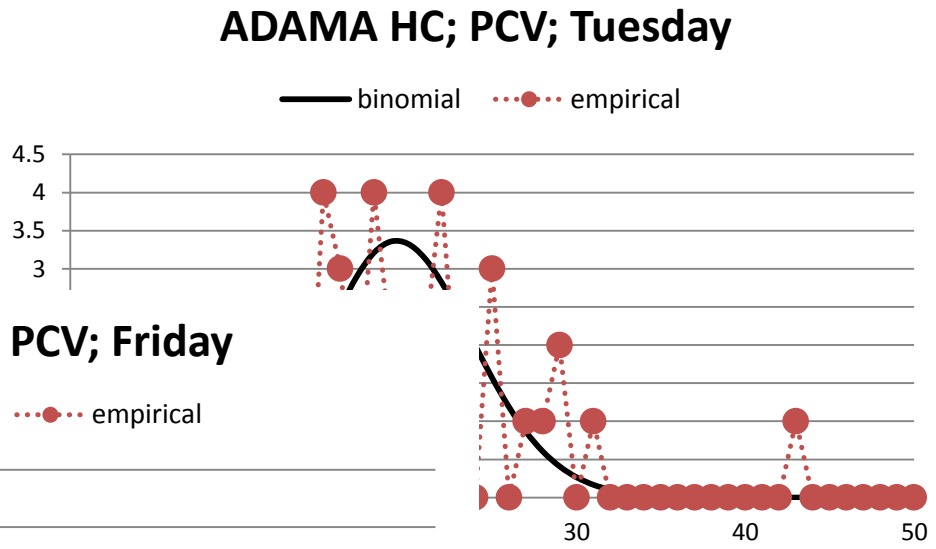


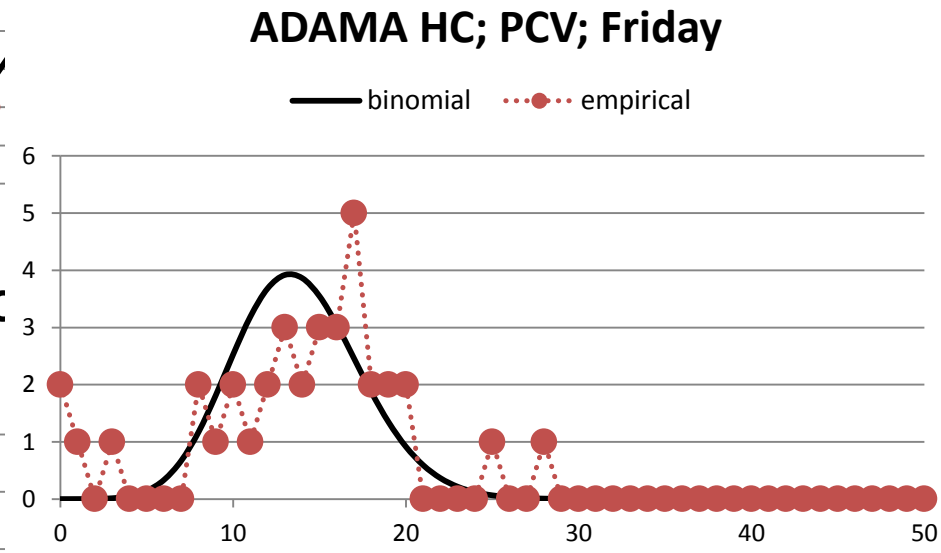


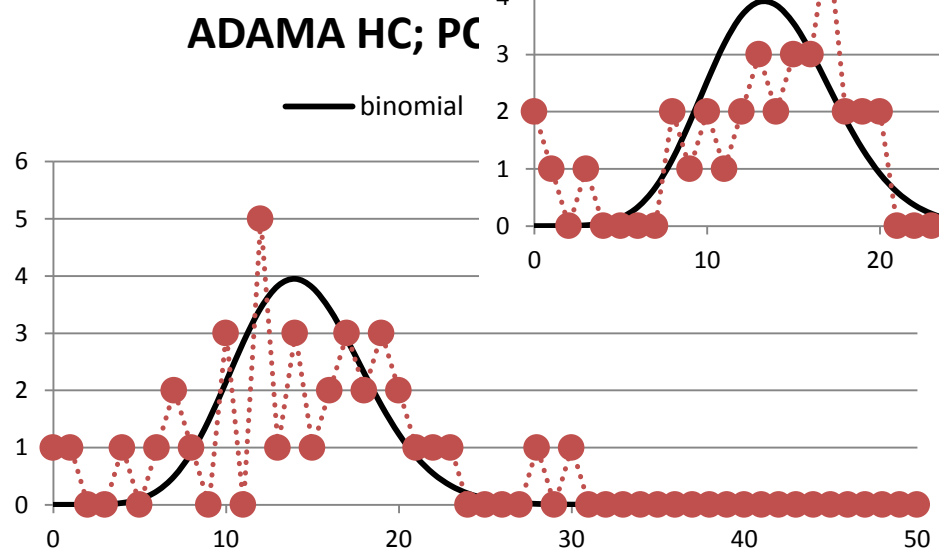


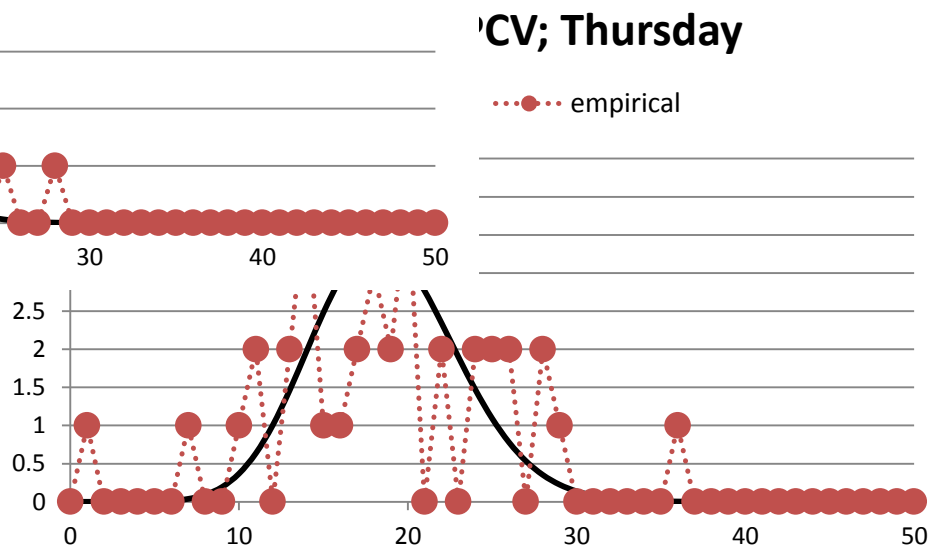
Session size distributions: Ethiopia, PCV, 2 dose vial











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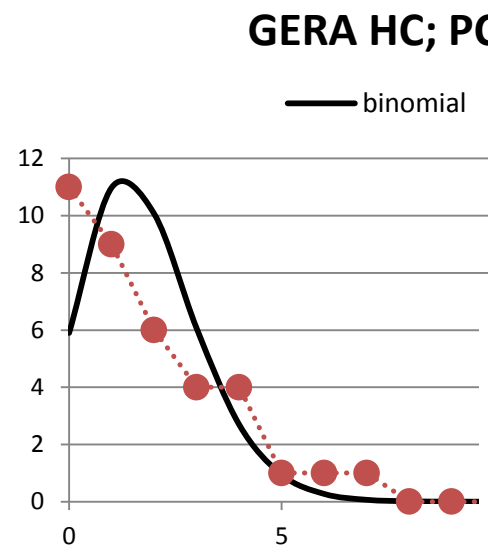
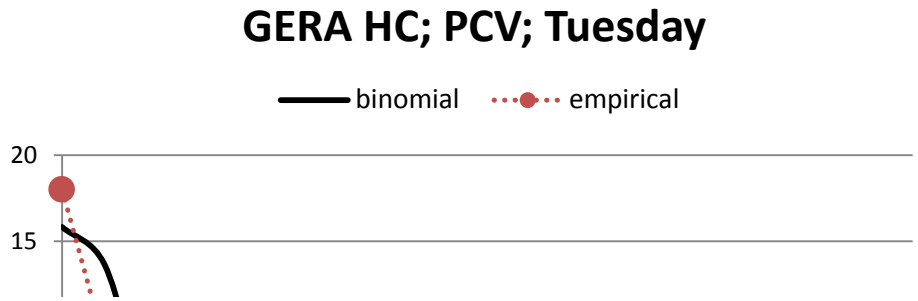
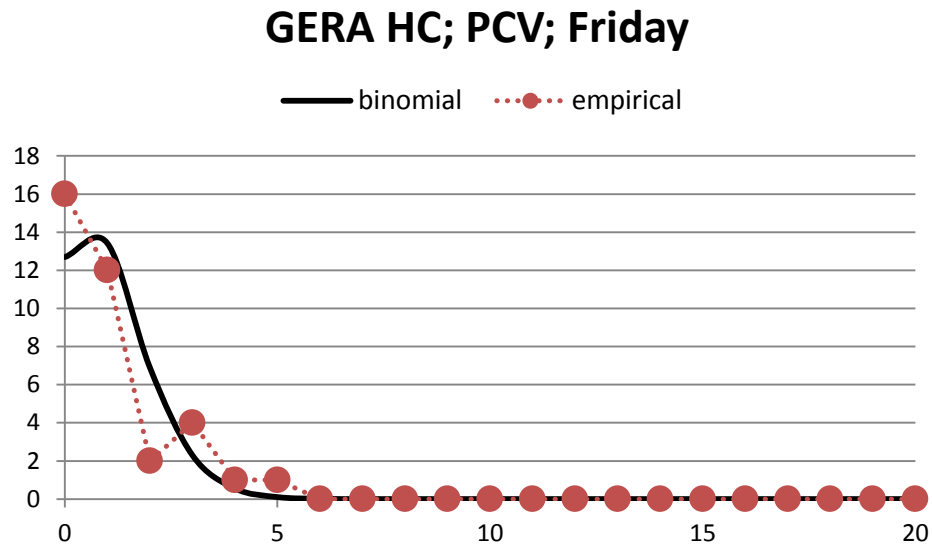
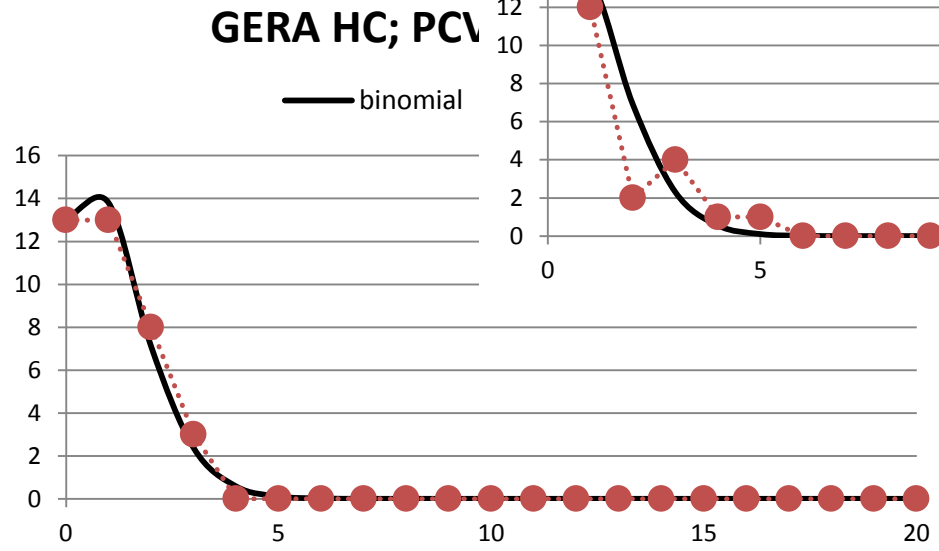
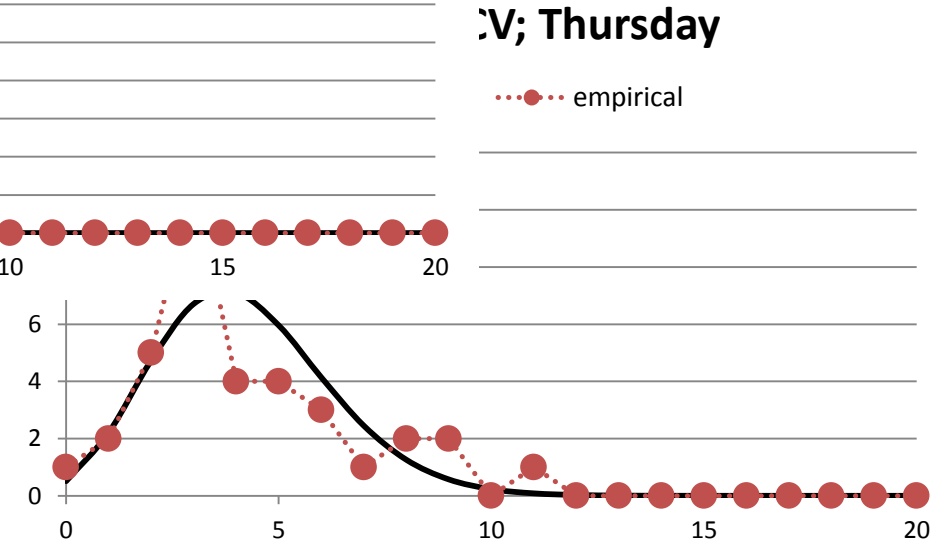
Session size distributions: Ethiopia, PCV, 2 dose vial

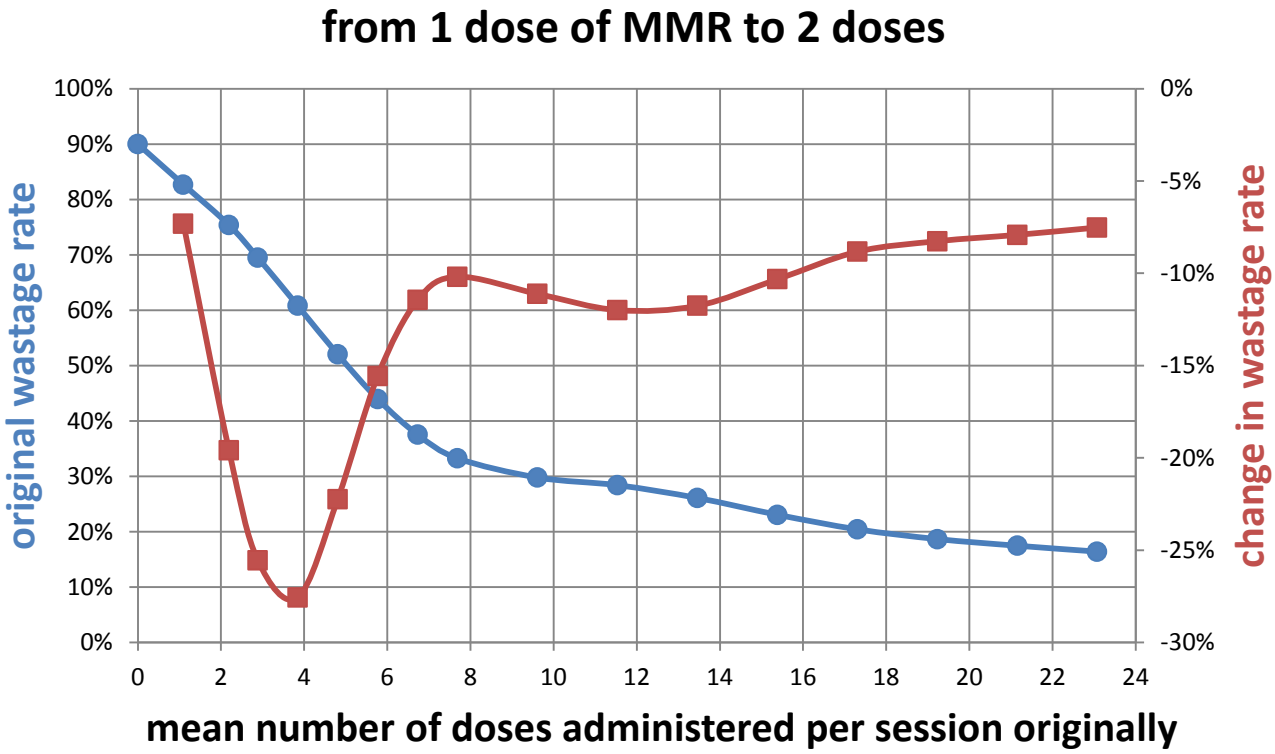






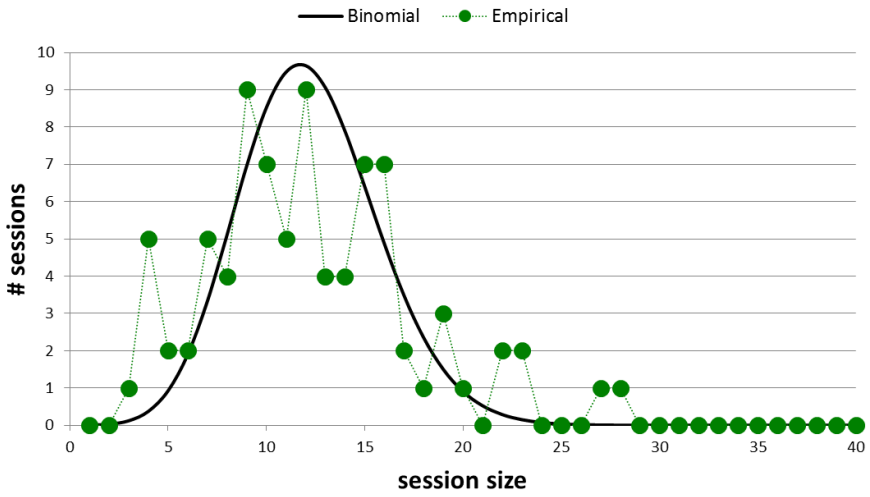





from 1 dose of MMR to 2 doses
original wastage rate
change in wastage rate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
-5%
-10%
-15%
-20%
-25%
-30%
0
2
4
6
8
10
12
14
16
18
20
22
24
mean number of doses administered per session originally

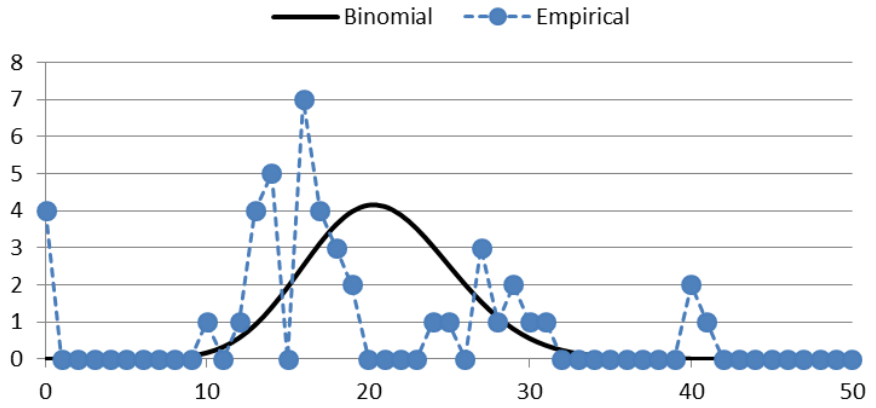
Opened vial wastage: Definition and assumptions

Charati; DTP; 10 dose vial; All days



A no refusal policy is implemented.

CMA de Kossodo; Fixe; BCG; 20 dose vial; Monday



A refusal policy is implemented.

World Health Organization