

Results

Metrics

- Results stored at a micro-level in the database
 - Raw changes in flight and connection data
- Post processing of those results to obtain macro-level
 - Key performance metrics

Metrics

- 140 Flight indicators (e.g., input_delay, selected speed, ARCT)
- 22 Performance indicators per scenario
 - Features (e.g., average, count)
 - Aggregations (e.g., all flights, only full service carriers flights)
 - 381 metrics in total

P1	Gate-to-gate passenger trip time
P4	Missed connections
P5a	Flight departure delay
P5b	Flight arrival delay
P6	Airlines cost all
P7	Airlines cost hub
P9	Airlines cost non-hub
P11	Speed variations incurred
P13	Pax delay
P14	Emissions
P15	Departure delayed flights

P17	Arrival delayed flights
P19	Holding
P20	Arrival delayed passengers
P21	Pax overnight stays
P22	Extra fuel cost
P23	Flight passenger costs (to airline)
P24	Direct flight cost per minute of delay
P25	Wait for passenger flights waiting
P25	Wait for passenger flights all
P26	Delay recovered at cruise
P27	Waiting time in connections

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Grouped in categories

Delay

Cost

Efficiency

Sub-categories

Flight

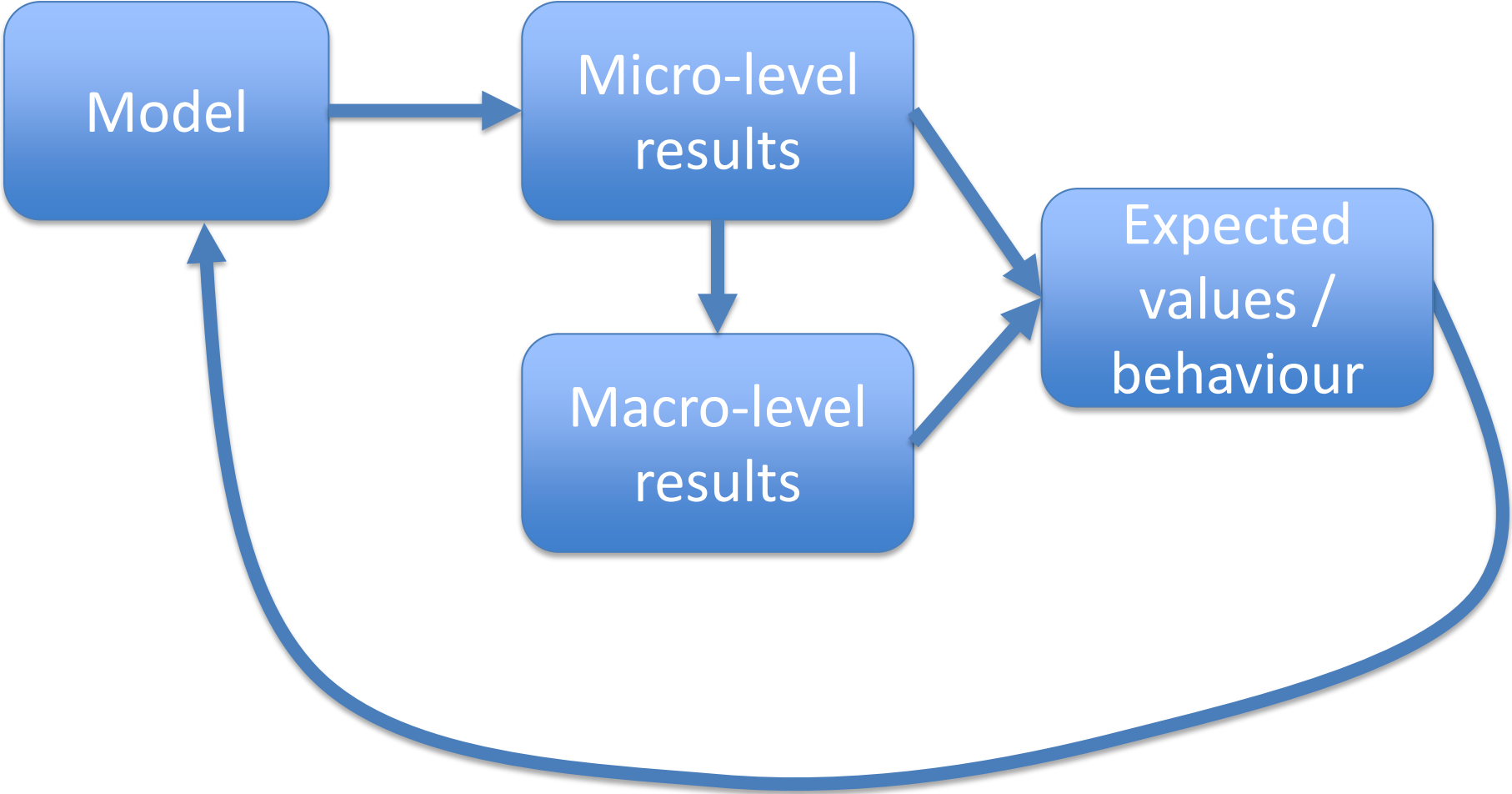
Passenger

Complexity of solution

Emissions

Flight performance

Validation



Validation

- Incremental process

Fuel models

Cost models

Delay models

Optimisation
mechanism

Validation

- Example

Id_dec	time_point	Id_sim	expected_arrival	expected_arr_delay	nom_pax_costs	nom_crew_costs	opt_speed	estimated_arrival	estimated_arr_delay	opt_consumption	opt_fuel_costs	opt_pax_costs	opt_crew_costs	opt_conn_fuel_costs	opt_conn_pax_costs	opt_conn_crew_costs	optimal	outbound_wait_count	outbound_not_wait_count
879406	ARCT	1723	05:09	49.52	149.71	1178.14	14.48	05:09	49.52	0	0	149.71	1178.14	47.5	3711.54	3438.32	0	21	13
879407	ARCT	1723	05:09	49.52	149.71	1178.14	14.51	05:08	48.52	295.18	147.59	142.65	1161.47	47.5	3650.05	3909.36	0	23	11
879408	ARCT	1723	05:09	49.52	149.71	1178.14	14.54	05:07	47.52	622.96	311.48	135.71	1144.8	47.5	3695.81	2917.93	0	22	12
879409	ARCT	1723	05:09	49.52	149.71	1178.14	14.57	05:06	46.52	972.63	486.31	128.91	1128.13	47.5	3641.32	2640.74	1	23	11
879410	ARCT	1723	05:09	49.52	149.71	1178.14	14.6	05:05	45.52	1345.45	672.72	122.24	1111.46	47.5	4077.84	2886.92	0	22	12
879411	ARCT	1723	05:09	49.52	149.71	1178.14	14.64	05:04	44.52	1742.72	871.36	115.73	1094.79	47.5	3670.12	3177.88	0	24	10
879412	ARCT	1723	05:09	49.52	149.71	1178.14	14.67	05:03	43.52	2165.81	1082.9	109.37	1078.12	47.5	3543.79	2540.43	0	24	10
879413	ARCT	1723	05:09	49.52	149.71	1178.14	14.7	05:02	42.52	2616.13	1308.06	103.18	1061.45	47.5	3665.29	3035.42	0	26	8
879414	ARCT	1723	05:09	49.52	149.71	1178.14	14.74	05:01	41.52	3095.17	1547.59	97.17	1044.78	47.5	3773.93	2533.43	0	26	8
879415	ARCT	1723	05:09	49.52	149.71	1178.14	14.77	05:00	40.52	3604.49	1802.24	91.33	1028.12	47.5	3226.45	2613.49	0	26	8
879416	ARCT	1723	05:09	49.52	149.71	1178.14	14.78	05:00	40.25	3749.7	1874.85	89.76	1023.54	47.5	5167.79	2985.93	0	26	8
879657	AMAN	1723	05:01	41.34	0	0	12.97	05:09	49.14	-359.72	-179.86	146.96	1210.47	47.5	4380.85	2326.84	1	19	15
879658	AMAN	1723	05:01	41.34	0	0	13.54	05:06	46.14	-312.68	-156.34	126.31	1145.54	47.5	4226.13	2668.38	0	19	15
879659	AMAN	1723	05:01	41.34	0	0	12.46	05:12	52.14	-278.63	-139.32	168.67	1275.4	47.5	4333.85	2796.87	0	19	15
879660	AMAN	1723	05:01	41.34	0	0	14.17	05:03	43.14	-76.18	-38.09	106.96	1080.6	47.5	5933.89	2568.45	0	20	14

Model executions

- Use of batch executions
 - 50 executions per scenario
- Batch executions on elastic cloud instance AWS
- Vertical scalability
- Horizontal scalability possible evolution
- Execution time 4-7 min on Intel Xeon E5 2509, 16Gb RAM
- Validation
- Post-processing

Results

- Micro and macro level results stored in databased
- Extracted from database in CVS format
 - Flexibility to use other tools (Matlab, Excel, R)
- Post-processing to produce graphical representation of results

Results

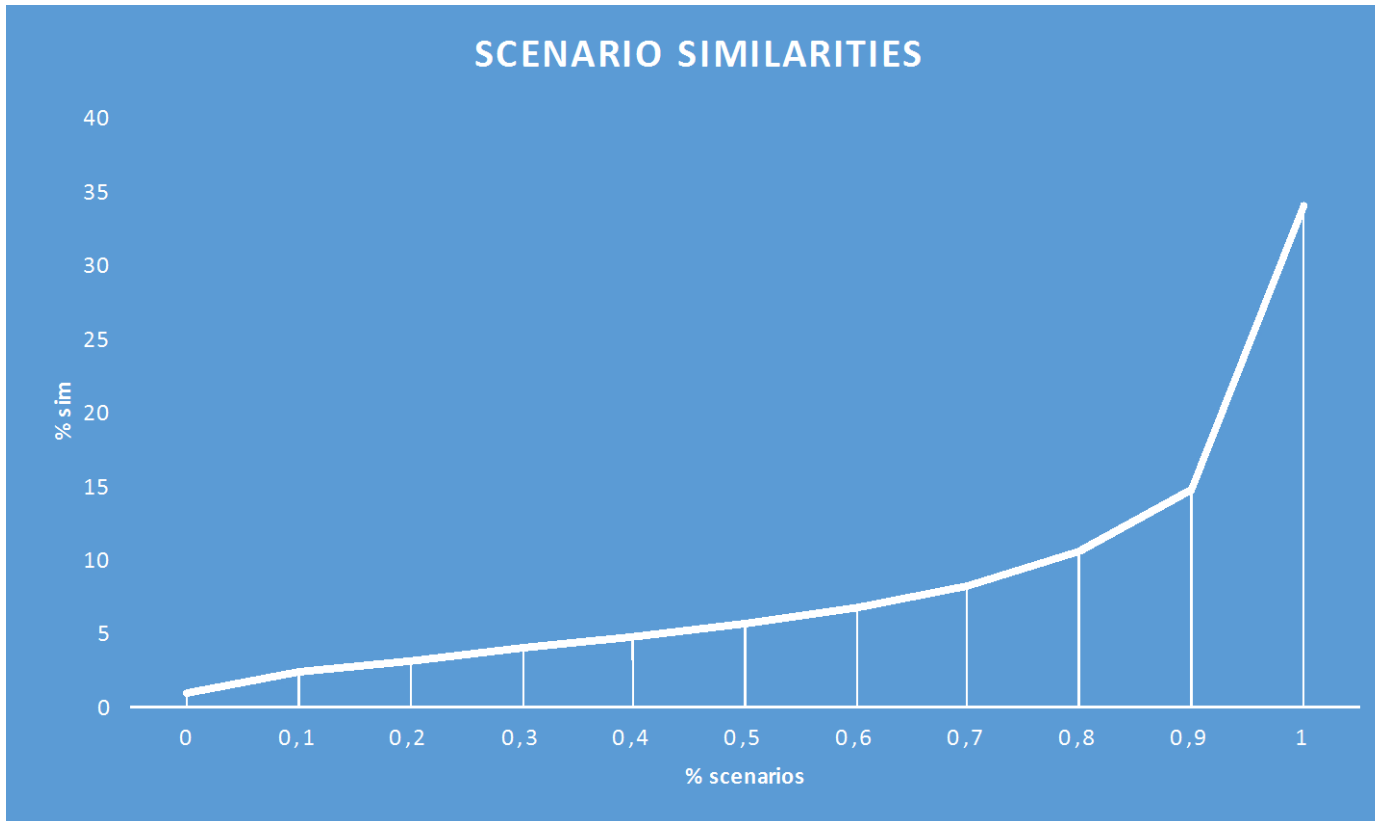
Stochastic simulator



Outputs are considered samples of random variables with unknown distribution

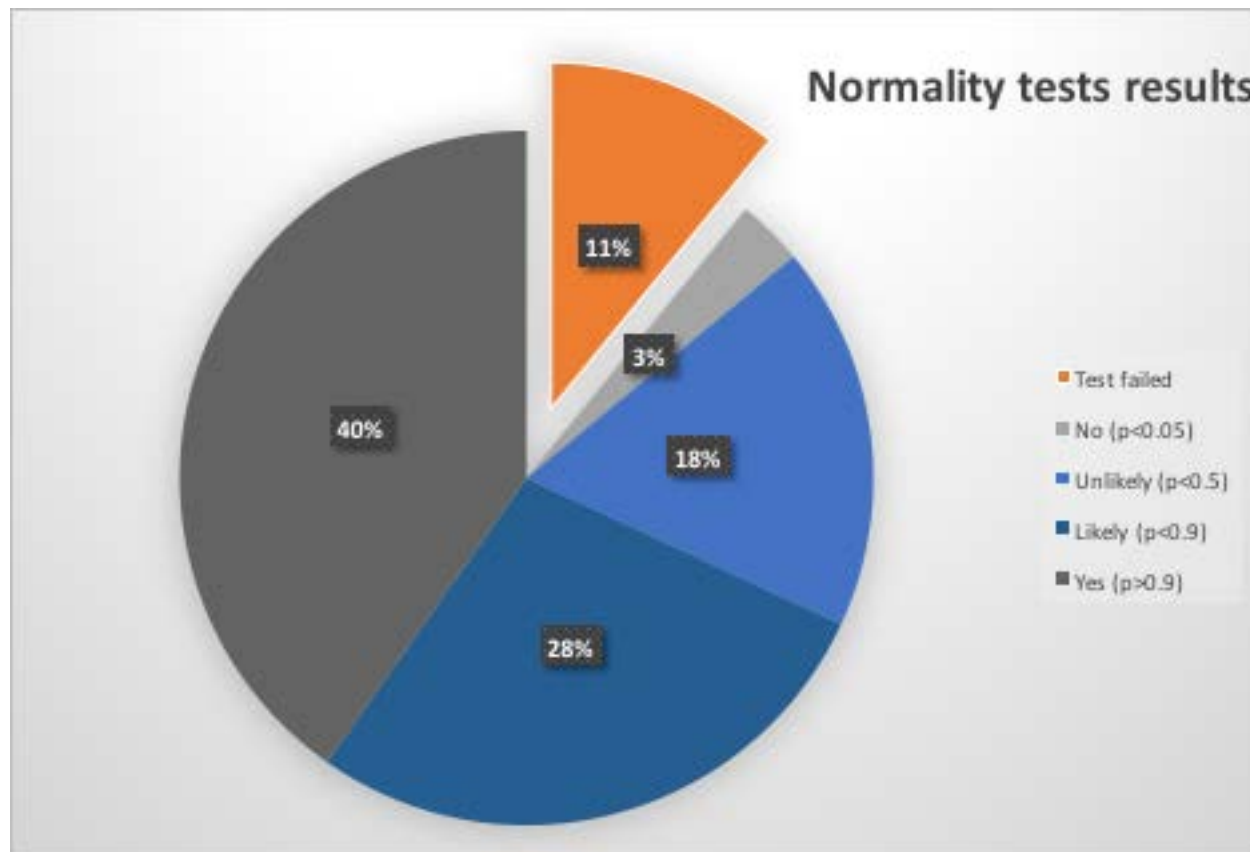
Kolmogorov-Smirnov tests

H_0 : “Samples X and Y share the same distribution”



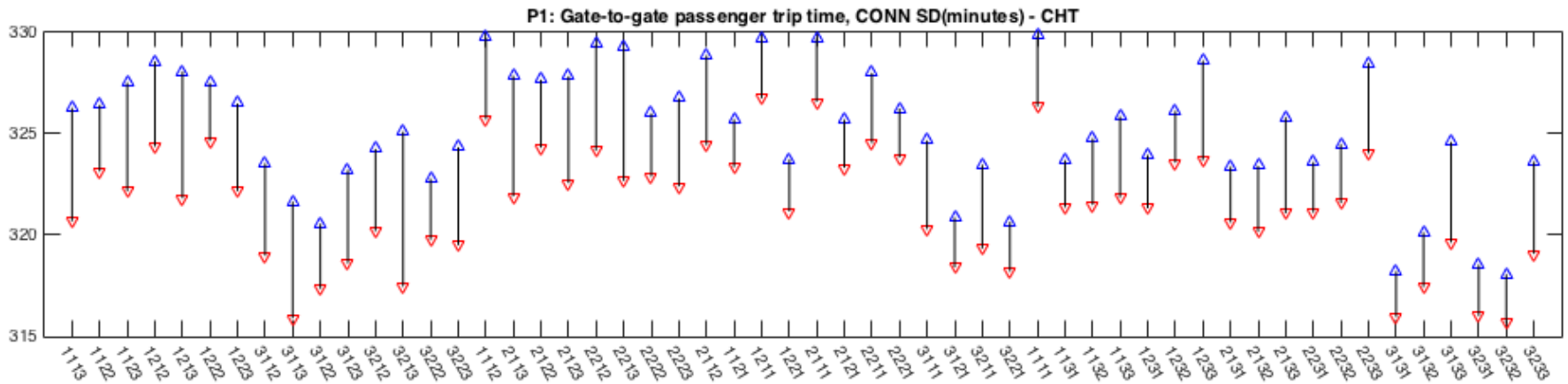
Chi² tests

H₀: “Sample X follows a Normal distribution with mean and deviation unknown”



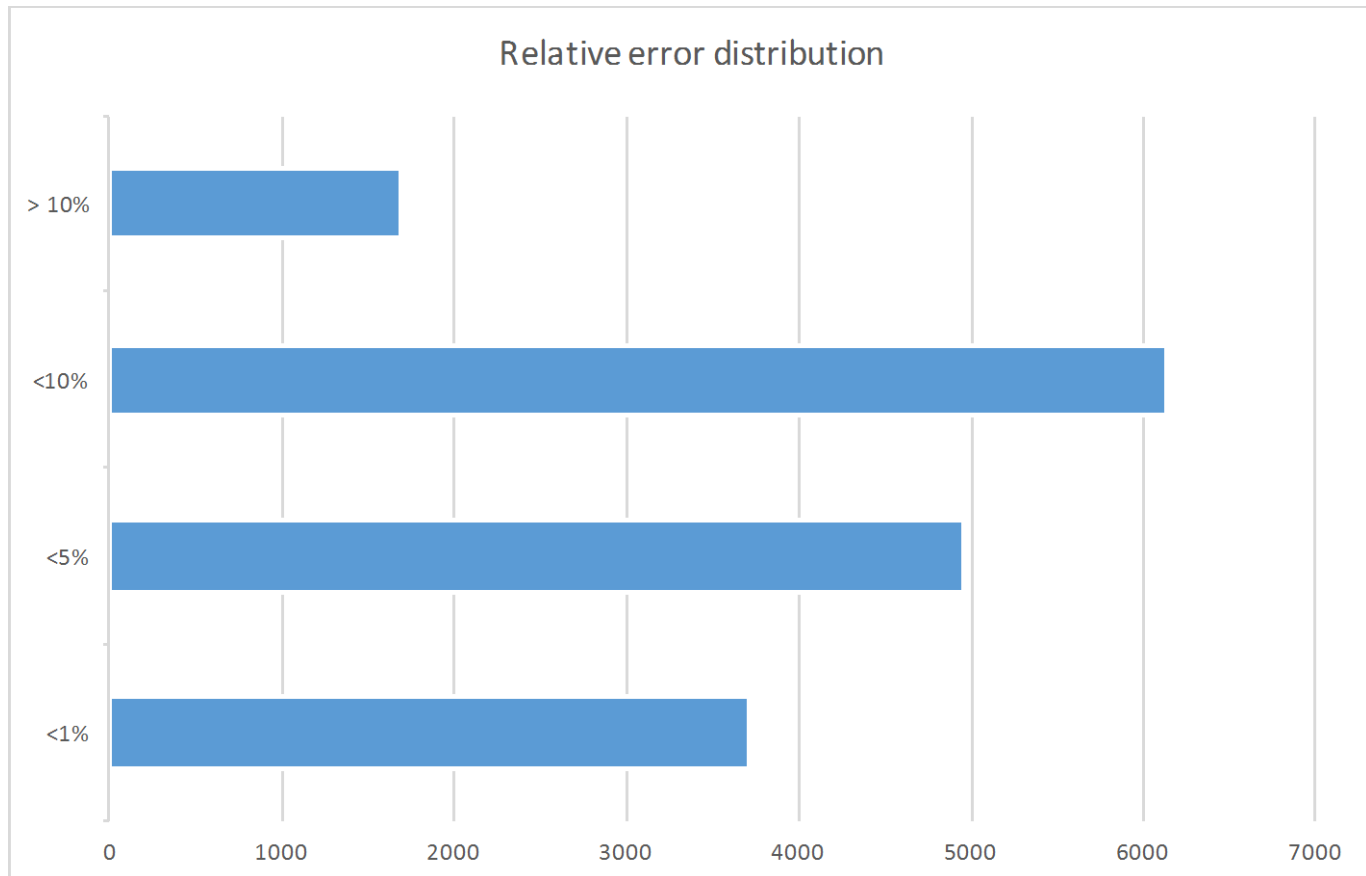
Confidence Interval

Interval in which a parameter is more likely to be.



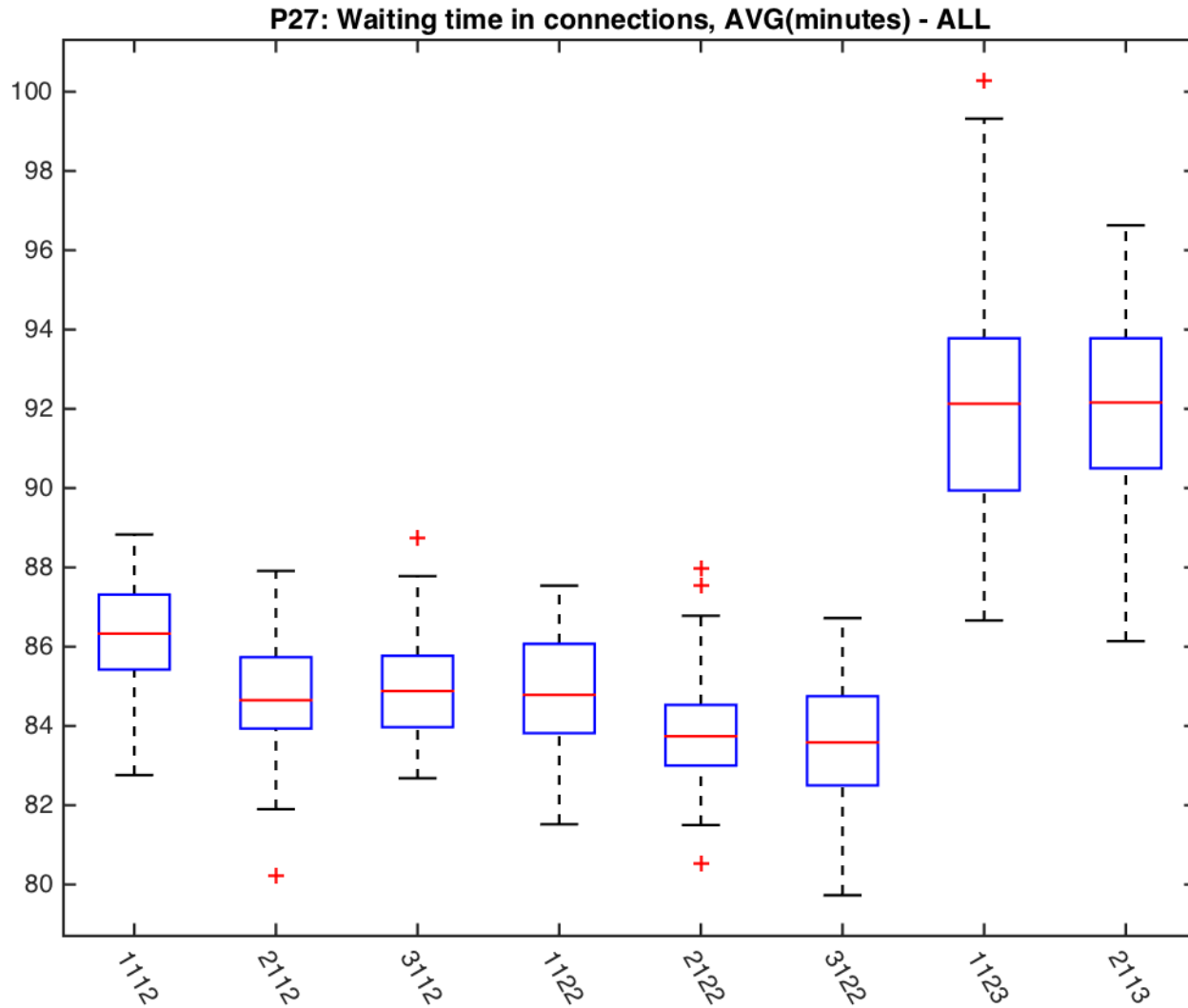
Confidence Interval

Can be interpreted as the error by not doing infinite simulations*

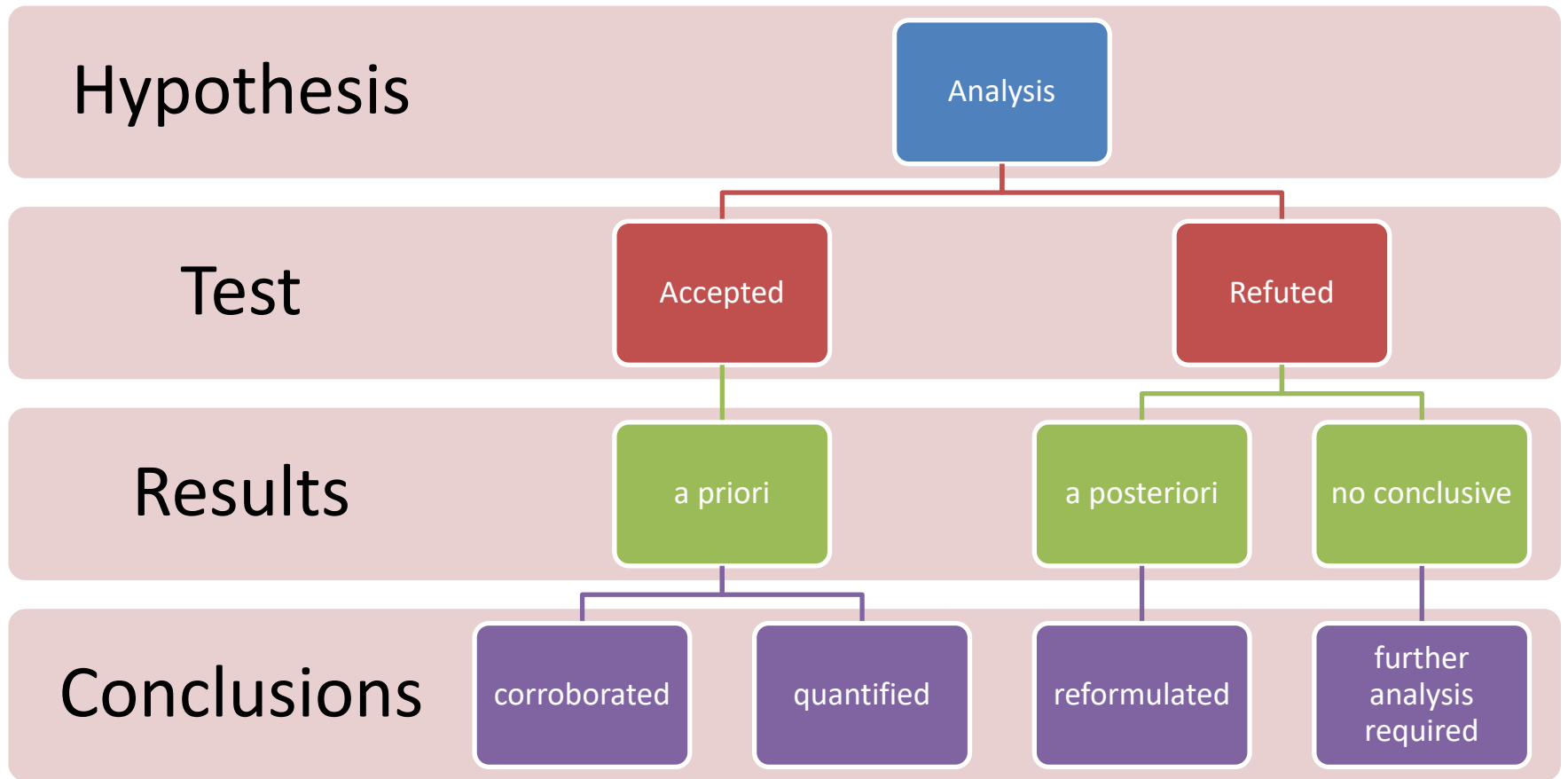


*assuming normality and finite variance

Plot Boxes



Methodology Analysis Results



Methodology

Hypothesis

Analysis

- Hypothesis design:
 - Based on team expertise, common knowledge or just formalizing research questions
 - Only qualitative hypothesis, no need to make numerical estimates
 - Divided into three categories: Delay, Costs and Efficiency

Methodology

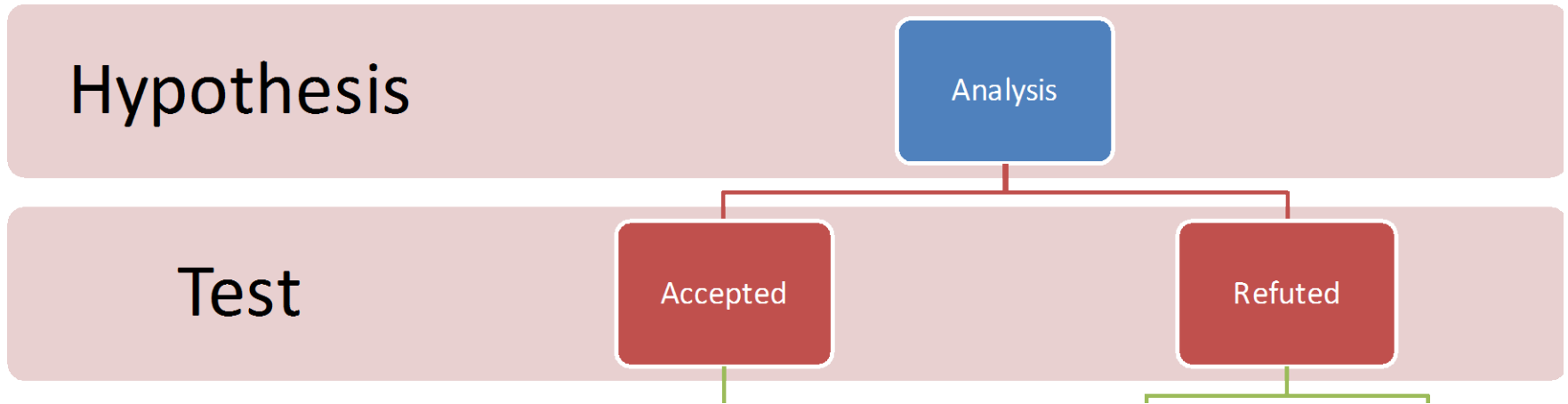
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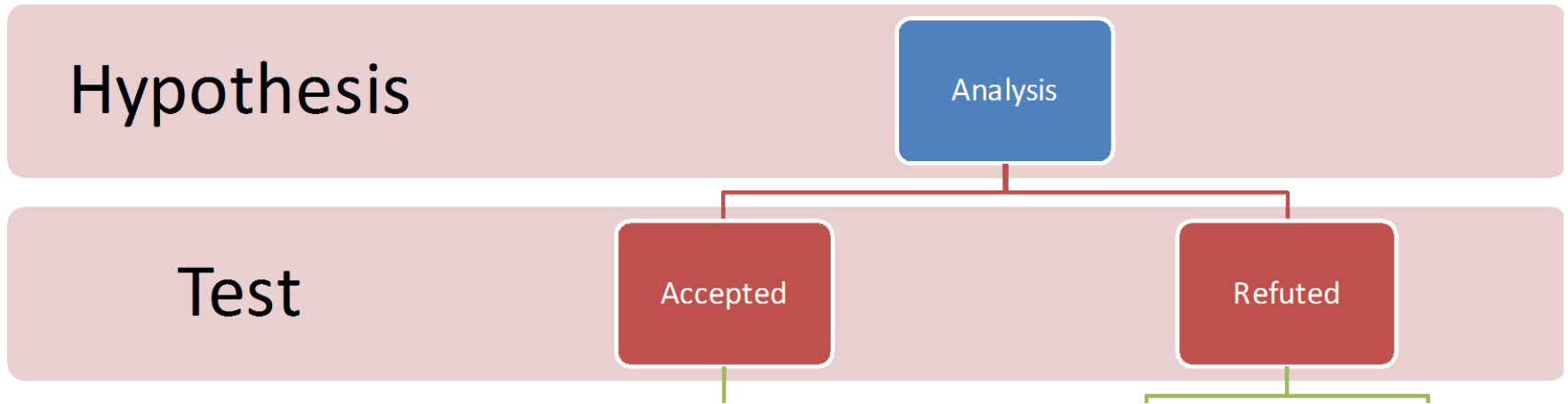
Higher claims on passenger compensation (strategy 3) might lead to less connections missed and a reduced gate-to-gate time

Methodology



- Hypothesis testing
 - Select representative variables
 - Select which scenarios to compare
 - Generate ad-hoc reports to compare scenarios

Methodology

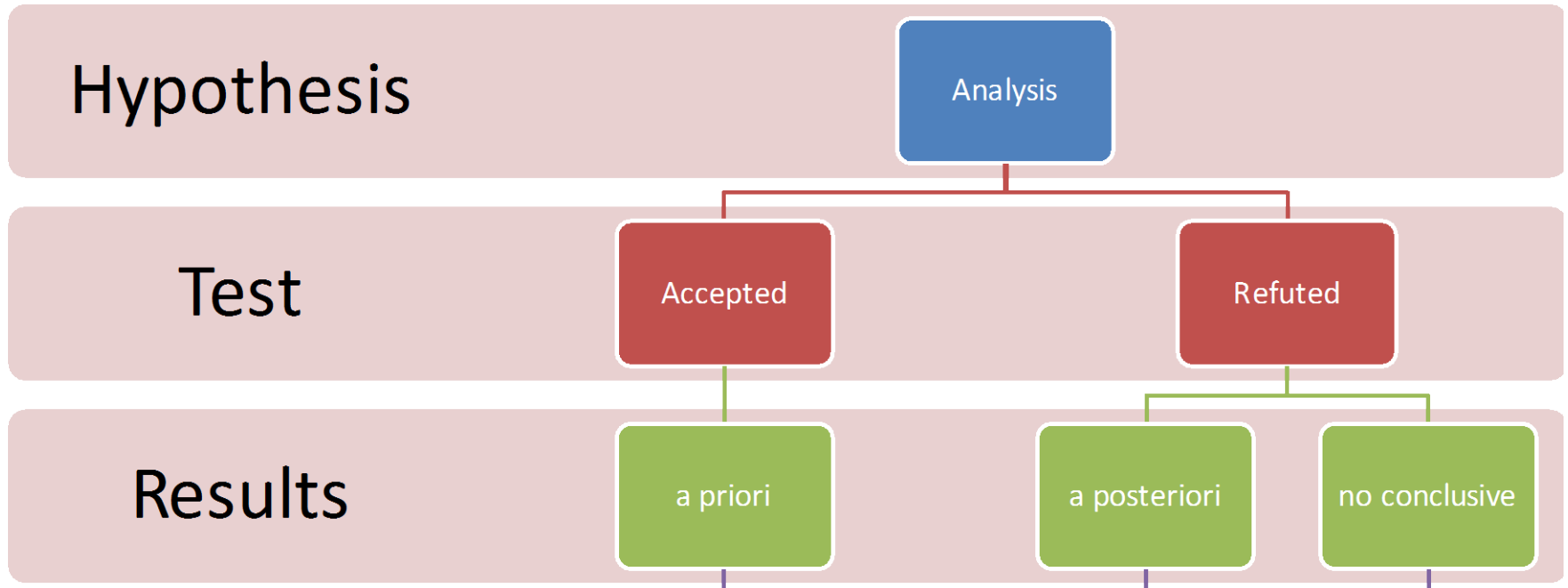


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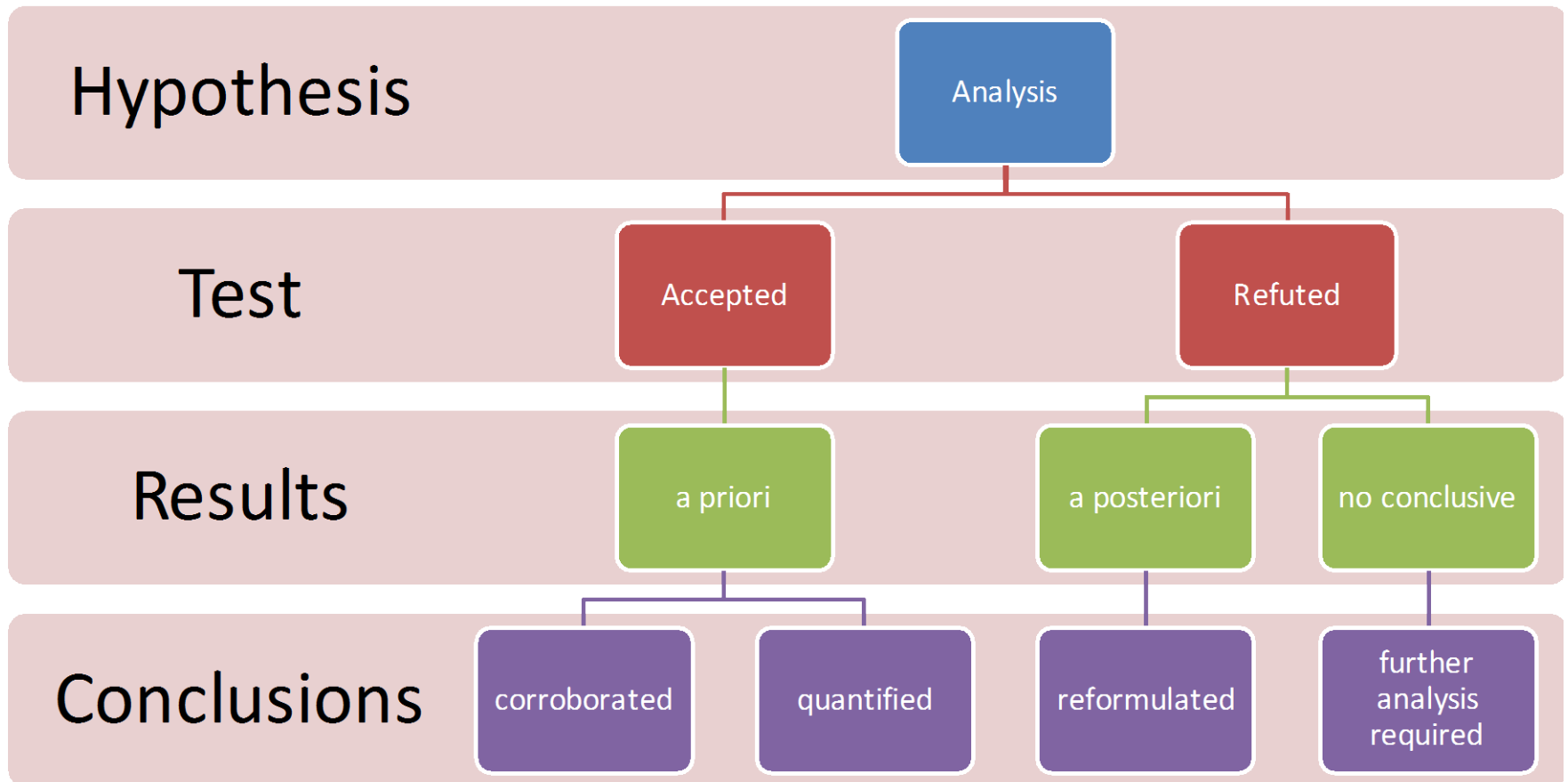
- passengers gate-to-gate time
- number of missed connections
- Strategy 3 scenarios in contrast to Strategy 2 scenarios

Methodology



- A priori: known to be true, now corroborated
- A posteriori: new results, sometimes unintuitive
- No conclusive: data can not support the hypothesis

Methodology



Conclusions are final statements made of confirmed or quantified hypothesis, in some cases reformulated to make more clear remarks

Emergence behaviour

- Interaction between agents decisions
- Behaviour derived from the model