Use of fractional factorial design for the sensitivity analysis of a Foot-and-Mouth-Disease - model

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Background:

Increase of international transport and trade (persons, animals, goods)

- Risk of introducing highly contagious diseases
- Simulation models: Elaboration of contingency plans

Switzerland: Application of InterSpread Plus?

Material:

Simulation model: InterSpread Plus Version 1.0.48.9

Data: Iris Bachmann (doctoral thesis 2004, presentation at the SVEPM conference 2005 in Iverness)

Input: Selection of 13 factors responsible for virus transmission ➔ determination of minimum and maximum value each (-1, +1)

Output:

- Number of infected premises (IP), whole dataset and grouped (controllable 1-100 IP vs. uncontrollable outbreaks >100 IP)
- Duration of epidemics in days (TP), maximum possible 200 days (censored)

Methods:

Design Of Experiment: fractional factorial design 2^{k-p}

(Kleijnen Jack P.C. et al., 2005)

- Calculation of a fraction of combinations instead the need of running all 2^{13} = 8‘192 possible combinations
- ➔ 64 scenarios (20 iterations / scen.; max. 200 days / it.)
- Dataset of 1280 experimentally generated outbreaks

Sensitivity analysis:

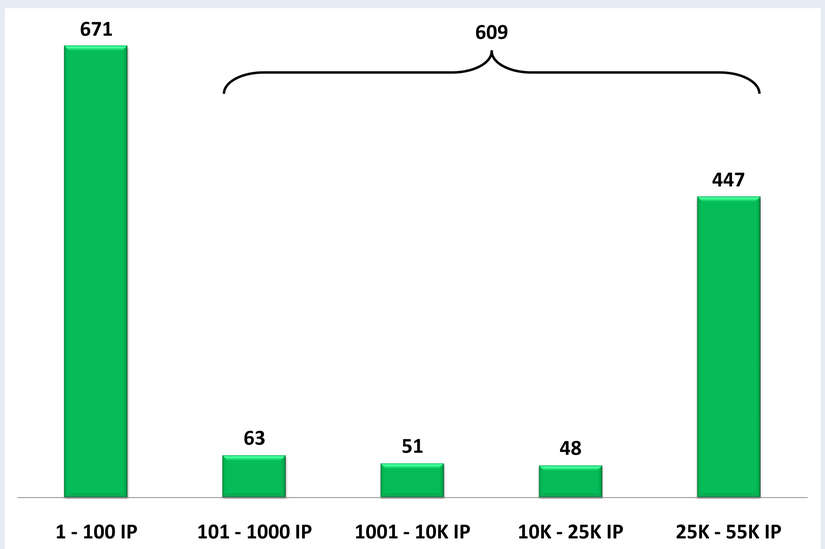
Regression Models: Logistic (IP, TP), Poisson (IP), Cox (TP)

Abstract of the DOE:

factor / scenario	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-	-	-	-	-	+	+	+	+	+	+	+	+
2	+	-	-	-	-	-	-	-	-	+	+	+	+
3	-	+	-	-	-	-	+	+	+	-	-	-	+
etc. to 32	...	...	...	...	...	...	...	...	...	...	...	...	...
33	+	+	+	+	+	-	-	-	-	-	-	-	-
34	-	+	+	+	+	+	+	+	+	-	-	-	-
35	+	-	+	+	+	+	-	-	-	+	+	+	-
etc. to 64	...	...	...	...	...	...	...	...	...	...	...	...	...

Results:

Distribution:
1-100 IP = 671 outbreaks; >100 IP = 609 outbreaks



Logistic Regression whole dataset (main effects): R2 = 0.869, Log Likelihood = -308.20

factor	p-value	Regr.Coeff.	OR	S.E.	95%-C.I.	
1: POPULATION	0.00	0.95	2.59	0.32	1.38	4.84
2: INFECTIVITY	0.00	6.59	727.78	0.39	338.86	1563.06
3: MovHR	0.00	1.90	6.69	0.30	3.71	12.04
4: MovMR	0.01	0.72	2.05	0.28	1.19	3.56
5: MovLR	0.14	0.32	1.38	0.22	0.89	2.12
6: ProbHR	0.08	0.56	1.75	0.32	0.94	3.28
7: ProbMR	0.00	1.07	2.92	0.26	1.75	4.85
8: ProbLR	0.00	2.26	9.58	0.28	5.54	16.59
9: ContHR	0.00	0.91	2.48	0.24	1.55	3.98
10: ContMR	0.04	0.48	1.62	0.23	1.03	2.54
11: ContLR	0.00	1.04	2.83	0.34	1.45	5.51
12: ProbLocal	0.00	1.37	3.94	0.24	2.46	6.30
13: ProbAir	0.00	1.03	2.80	0.28	1.62	4.85

Conclusion:

1. The fractional factorial design is an efficient Design Of Experiment to obtain stable results since the whole range of possible combinations is adequately covered.
2. The fractional factorial design allows to avoid time consuming processes.
3. The fractional factorial design is an useful tool to perform a sensitivity analysis of a simulation model.

Reference:

Kleijnen, Jack P.C. et al., A User‘s Guide to the Brave New World of Designing Simulation Experiments. INFORMS Journal on computing, Vol. 17, No. 3, Summer 2005, pp. 263-289