Appendix A – Data and Model Parameters

Table A-1: Actual and planned bed capacity

Year	(A) Bed capacity (total)	(B) Planned bed openings with known opening years	(C) Estimated total known bed capacity (A+B)	(D) Distrubution of new beds over 4 years (of unknown opening years) with more emphasis on later years (2019: 10%, 2020: 20%, 2021: 30%, 2022: 40%)	(E) Estimated total bed capacity with known and unknown openings, assuming opening distribution of (D) (A+B+D)	(F) Distrubution of new beds over 4 years (of unknown opening years) with equal distribution (2019: 25%, 2020: 25%, 2021: 25%, 2022: 25%)	(G) Estimated total bed capacity with known and unknown openings, assuming opening distribution of (F) (A+B+F)	(H) Distrubution of new beds over 4 years (of unknown opening years) with more emphasis on earlier years (2019: 40%, 2020: 30%, 2021: 20%, 2022: 10%)	(I) Estimated total bed capacity with known and unknown openings, assuming opening distribution of (H) (A+B+H)
1972	280								
1973	768								
1974	888								
1975	908								
1976	940								
1977	1.034								
1978	1.300								
1979	1.690								
1980	2.402								
1981	3.915								
1982	5.050								
1983	5.722								
1984	5.463								
1985	5.936								
1986	6.414								
1987	7.324								
1988	8.015								
1989	8.643								
1990	8.729								
1991	9.046								
1992	9.662								
1993	10.351								
1994	11.638								
1995	12.312								
1996	13.508								
1997	14.031								
1998	16.096								
1999	17.531								
2000	18.730								
2001	18.765								
2002	18.827								
2003	19.110								
2004	19.595								
2005	21.174								
2006	20.505								
2007	22.187								
2008	23.464								
2009	25.068								
2010	25.591								
2011	26.896								
2012	28.120								
2013	30.133								
2014	31.673								
2015	34.105								
2016	37.224	2.526							
2017e	42.598	5.374	42.598		42.598		42.598		42.598
2018e	48.857	6.259	48.857		48.857		48.857		48.857
2019e	49.777	920	49.777	882	50.659	2206	51.983	3530	53.307
2020e	49.777	0	49.777	1765	52.424	2206	54.189	2647	55.954
2021e	49.777	0	49.777	2647	55.071	2206	56.395	1765	57.719
2022e	49.927	150	49.927	3530	58.751	2206	58.751	882	58.751

Sources: Actual data until 2016; planned data until 2022.

1980-2014: Table 9.3 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/;
2015-2016: Table 10.3 in Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/;

2017e-2022e: Table 10.11 in Statistical Yearbook 2016 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2016/tourism/

In addition to these published opening dates, the Maldives government plans the opening of 56 additional resorts, but without mentioning the number of beds. Considering 236 beds per resort to be opened, this translates into another 13,200 beds until 2022.

Note that the bed capacity in 2016 is higher and growing faster than planned in 2016 (planned openings published in the Statistical Yearbook 2016 is 2,526 beds for 2016. Yet, actual openings for 2016 were 3,119 beds (37,224-34,105 beds)).

Table A-2: Acronyms

Acronym	Written out
AC	Annual bed capacity
ATR	Annual tourism revenues
A	Attractiveness of the Maldives
AOD	Available operational days in the year
ANS	Average number of nights stay
ANS_N	Average number of nights stay normal
AT	Average Tax
C	Bed capacity
CU	Bed capacity utilization
BpR	Beds per resort
CU*	Desired bed capacity utilization
CUD	Bed Capacity utilization - data
E_{CU}	Effect of bed capacity utilization
Ep	Effect of pollution
E_P	Effect of price
E_{CUA}	Effect of bed capacity utilization
E_{PA}	Effect of price on average number of nights stay
E_{CUP}	Effect of bed capacity utilization on price
E_T	Effective of tourists' word of mouth
ET	Expected tourists (forecasted number of tourists)
GR	Gap in resorts
GCU	Gap in bed capacity utilization
IR	Indicated number of resorts
IP	Indicated price
gN	Normal tourist growth rate
P	Price
P_R	Reference pollution
RC	Required capacity utilization
R	Resorts
TR	Tourism receipts
T_R	Tourism receipts
T	Tourists
WgM	Waste generation on the Maldives

WgR	Waste generation on the resorts
WpPd	Waste per day generated by local population - data
WpTd	Waste per day generated by tourists - data
WpT	Waste per day
τ	Time

Table A-3: Data sources of the Maldives waste management model

Domain	Variable	Source
Population		
	Population data	1977, 1985, 1990, 1995, 2000, 2006, 2014 Consensus Data: Table PP 1 in Statistical Release I: Population and Households: http://statisticsmaldives.gov.mv/population-and-households/
	Population fractional growth rate data	1977, 1985, 1990, 1995, 2000, 2006, 2014 Consensus Data: Table PP 1 in Statistical Release I: Population and Households: http://statisticsmaldives.gov.mv/population-and-households/
Maldives Tourists & Perceived Pollution		
	Annual tourists data	1979-2015: Table 9.1 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/ 2014-2016: Table 10.5 in Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/
	Tourism receipts data	1995-2015: The World Bank, International Tourism, Receipts, Current US$: https://data.worldbank.org/indicator/ST.INT.RCPT.CD?end=2015&locations=MV&start=1995&view=chart
	Tourism revenue data[a]	2006-2016 Table 10.6 in Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/
Pollution		
	Waste ferried to Thilafushi data[b]	2004-2014: Table 2.4 (Waste transported to Thilafushi from Male) and 2010-2014: Table 2.5 (Wastes transported to Thilafushi) in Statistical Yearbook 2015 of the Maldives Government: http://planning.gov.mv/yearbook2015/index.html
Resorts & Their Profitability		
	Resorts	1977-2003: Table 9.3 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/ 2000-2016: Table 10.4* in Statistical Yearbooks 2006-2016 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/
	Average duration of stay[c]	2009-2016: Table 10.3* in Statistical Yearbooks 2010-2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/
	Bed capacity data	1980-2014: Table 9.3 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/ 2015-2016: Table 10.3 in Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/
	Beds in operation data[d]	2005-2016: Table 10.3* in Statistical Yearbooks 2006-2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/
	Bed capacity utliziation data	1980-2014: Table 9.6 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/ 2015-2016: Table 10.3 in Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/
	Bed capacity openings data	2016-2022: Table 10.11 in Statistical Yearbook 2016 http://statisticsmaldives.gov.mv/yearbook/2016/tourism/

Notes:

* Each table provides only two or three years in a yearbook. The composit of the dataset is achieved by compiling the data from multiple annual statistical reports. Table 10.4 in the Statistical Yearbook of 2006 comprises data on resorts from 2000 until 2005.

[a] Tourism revenue is only reported from 2006 on by the Maldives Government

[b] Waste ferried to Thilafushi was only reported between 2004 and 2014.

Table A-4: Parameters for the Maldives waste management model

Domain	Subview	Parameter	Value	Units	Comment	Source
Population		-				
Maldives Tourists & Perceived Pollution						
	Price	Time to change prices	0.25	Year		Estimated from partial model calibration to fit past data
		Reference price	10000	$/(day*tourist)		Estimated from partial model calibration to fit past data
		Normal slope price	12	Dmnl	The normal slope of the function capturing the effect of price on Maldives attractiveness.	
		Inflection price	0.95	Dmnl	The inflection point of the function capturing the effect of price on Maldives attractiveness.	Arbitrarily set.
		Max Efct of Price	0.5	Dmnl	The maximum effect of price on Maldives attractiveness.	Judgmentally set.
		Min Efct of Price	-0.5	Dmnl	The minimum effect of price on Maldives attractiveness.	Judgmentally set.
		Fraction High effect CapUtil on price	0.18	Dmnl	The high effect of capacity utilizazion tables serve as polar extremes for the calibration of the fraction effect of capacity utilization on price.	Estimated from full model calibration to fit past data
	Tourists	Normal annual tourist growth rate	0.11	1/Year	Normal fractional growth rate	Estimated from partial model calibration to fit past data
		Reference # of tourists	380565	Tourists	The reference value for normalizing the input of tourists into the function capturing the effect of tourists on Maldives attractiveness.	Estimated from full model calibration to fit past data
		Reference tourism tax	0.12	Dmnl	Average tax on tourism receipts	Estimated from partial model calibration to fit past data
		Fraction High effect Tourism Tax on price	0.10	Dmnl	The low and high effect of capacity utilizazion tables serve as polar extremes for the calibration of the fraction effect of capacity utilization on price.	Estimated from partial model calibration to fit past data
		Normal slope tourists	4	Dmnl	The normal slope of the function capturing the effect of tourists on Maldives attractiveness.	Estimated from full model calibration to fit past data
		Max Efct of Tourists	1	Dmnl	The maximum effect of tourists on Maldives attractiveness.	Estimated from partial model calibration to fit past data
		Min Efct of Tourists	-0.3	Dmnl	The minimum effect of tourists on Maldives attractiveness.	Estimated from partial model calibration to fit past data
		Inflection tourists	0.50	Dmnl	The inflection point of the function capturing the effect of tourists on Maldives attractiveness.	Estimated from full model calibration to fit past data
		Average tourism tax	0.14	Dmnl	Average tax on tourism receipts	Estimated from partial model calibration to fit past data
	Perceived Pollution	Normal Reference perceived pollution	3.50E+10	Tons	This parameter sets the reference pollution for the pollution perception.	Estimated from partial model calibration to fit past data
		Time for perception to fade	2	Year	Tourists' perception of pollution fades after a couple of years.	Arbitrarily set to 2 years.
		Max Efct of Pollution	0.5	Dmnl	The maximum effect of Pollution on Maldives attractiveness.	Judgmentally set.
		Min Efct of Pollution	-0.5	Dmnl	The minimum effect of Pollution on Maldives attractiveness.	Judgmentally set.
		Normal Slope Pollution	14	Dmnl	The normal slope of the function capturing the effect of pollution on Maldives attractiveness.	Judgmentally set.
		Fraction of tourists in range of waste	0.01	Dmnl	Tourists located in resorts within 30 km of Thilafushi. Takes into consideration the fraction of beds available in the closer resorts.	Judgmentally set based on data in Table 9.3 of Statistical Archive of the Maldives: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/wp-content/uploads/sites/3/2017/03/table9.3.pdf
Pollution						
	Malé	Kilos of waste per Maldive inhabitant per day	1.2	kg/people/day		Peterson, 2015; http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-eine-Insel-aus-Muell.html
		Kilos of waste per tourist per day	3.6	kg/people/day		Estimated from full model calibration to fit past data
		Waste composition in Malé	0.22, 0.53, 0.03, 0.18, 0.05	Dmnl	Food, Yard, Plastics, Inorganic, Other (construction debris and paper)	Peterson, 2015
	Resorts	Waste composition in resorts	0.4, 0.38, 0.05, 0.11, 0.06	Dmnl	Food, Yard, Plastics, Inorganic, Other (construction debris and paper)	Peterson, 2015, p. 32
		Fraction of waste at resorts dumped in ocean	0.4, 0, 0, 0, 0	Dmnl/Year	Food, Yard, Plastics, Inorganic, Other (construction debris and paper)	Peterson, 2015, p. 32
		Fraction of waste incineration on resorts	0, 1, 0, 0, 0.33	Dmnl/Year	Food, Yard, Plastics, Inorganic, Other (construction debris and paper). All of garden and yard waste (38% of total waste) is incinerated at the resorts. One third of other waste (paper products) (other waste accounts for 6% of total waste) is also incinerated at resorts.	Peterson 2015, p. 36 for comments and p. 31 for overall composition
		Fraction of waste incinerated that can be perceived	0.1	1/tourist	Assumes that 10% of the total waste incinerated will be perceived by tourists. Tourists can see the smoke that is coming out of inadequate incineration facilities on the resorts.	Estimated from the number of beds in closer range of Malé airport, which is 4km away from Thilafushi, based on Table 9.3 Statistical Yearbook 2017 of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/2017/tourism/
	Thilafushi	Fraction of waste burned from 1993	0.79	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste burned from 2006	0.73	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste burned from 2013	0.68	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste ferried leaking to ocean	0.01	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste stored leaking to ocean	0.01	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste burned on Thilafushi	0.4	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste burned that can be perceived	0.15	Dmnl		Estimated from partial model calibration to fit past data
		Fraction of waste leaked that can be perceived	0.75	Dmnl		Estimated from partial model calibration to fit past data
Resorts & Their Profitability						
	Bed Capacity Utilization	Time to form expectations on tourists	1	Year		Estimated from partial model calibration to fit past data
		Max change in resorts	5.5	resorts/Year	Maximum number of resorts that can be opened in a year.	Arbitrarily set to 5.5 resorts/year.
		Time to build resorts	2	Year		Arbitrarily set to 2 years.
		Normal average beds per resort	194	Tourists/resort		Estimated from full model calibration to fit past data
		Normal slope bed capacity	4	Dmnl	The normal slope of the function capturing the effect of bed capacity utilization on Maldives attractiveness.	Estimated from full model calibration to fit past data
		Inflection bed capacity	0.80	Dmnl	The inflection point of the function capturing the effect of bed capacity utilization on Maldives attractiveness.	Estimated from partial model calibration to fit past data
		Min Efct of BedCap	-0.35	Dmnl	The minimum effect of bed capacity utilization on Maldives attractiveness.	Judgmentally set.
		Max Efct of BedCap	0.90	Dmnl	The maximum effect of bed capacity utilization on Maldives attractiveness.	Judgmentally set.
		Time to perceive gap capacity utilization	0.5	Year	It takes half a year to perceive the gap of capacity utilization.	Arbitrarily set to 0.5 years.
		Desired bed capacity utilization	0.65	Dmnl		Estimated from full model calibration to fit past data
		Available Operational Days in Year	356	days/Year		There are 365 days per year.
		Time to perceive bed capacity	2	Year		Estimated from partial model calibration to fit past data
	Profit	Historical Ave length of stay	9.7	days/Year		Estimated from full model calibration to fit past data
		Average cost per tourist per day	250	$/(day*tourist)		not active in model
		Time to perceive profits	3	Year		not active in model
		Required investment per resort	2.00E+07	$/resort		not active in model
		Desired ratio of profits	0.25	1/Year		not active in model

Note: Many of the parameters are estimated from calibration to fit past data. Some are retrieved from statistical yearbooks and archive of the Government of the Maldives or from Peterson (2015). A few are arbitrarily set.

Table A-5: Initial values for the Maldives waste management model

Domain	Stock	Initial value	Units	Initial year	Source
Population					
	Population in Maldives	142,832	people	1977	1977 Consensus data point: Table PP 1 in Statistical Release I: Population and Households: http://statisticsmaldives.gov.mv/population-and-households/
Maldives Tourists & Perceived Pollution					
	Annual # of tourists	33,124	Tourists	1979	1979 data point: Table 9.1 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/
	Price	195	$/(day*tourist)		Estimated from full model calibration to fit past data
	Accumulated pollution perceived by tourists	100	Tons		Arbitrarily set to 100 tons for initial simulated year.
Pollution					
	Waste stored in resorts	0	Tons		Judgmentally set based on small number of resorts (11) in initial year of simulation
	Waste in Male and Island Communities	0	Tons		Arbitrarily set to 0 tons for initial simulated year.
	Waste in Thilafushi	0	Tons		Waste was transported to Thilafushi since the beginning of the 1970s (Peterson, 2015), and was officially announced as a waste disposal site in 1992 was only opened in 1992 (Evans, 2015; Ramesh, 2009)
	Accumulated waste leaked to ocean	0	Tons		Judgmentally set based on Peterson, 2015
Resorts & Their Profitability					
	Resorts	25	resorts	1979	1979 data point: Table 9.3 in Statistical Archive of the Maldives Government: http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/

Note: Most initializations of stocks are taken from the statistical archive of the Government of the Maldives and from Peterson (2015). A few are judgmentally or arbitrarily set.

Table A-6: Sensitivity analysis

Domain	**Parameter**	**Units**	**Min**	**Base**	**Max**
Pollution	Inflection pollution	dmnl	0.85	0.95	0.99
Pollution	Normal slope pollution	dmnl	6	14	24
Pollution	Reference perceived pollution	tons	5e9	3.5e10	5e10
Price	Inflection price	dmnl	0.85	0.95	0.95
Price	Normal slope price	dmnl	6	12	24
Price	Reference price	$	4,000	10,000	15,000
Resorts	Max change in resorts	resorts/year	5	5.5	20
Resorts	Bias size	dmnl	0	1	3

Appendix B – Functional form of Attractiveness Functions

We use four s-shaped logistics functions (f_1, f_2, f_3, f_4) to determine the additive effect of attractiveness to the Maldives. Each nonlinear function (f_i) takes the form of an s-shaped logistics function following closely the formulation proposed by Repenning (2002). The functional form is such that each function $f_i\{.\}$ takes the general form:

$$f_i\{\cdot\} = (B^U + B^L) \cdot g_i\{\cdot\} - B^L,\ 0 \leq g_i\{\cdot\} \leq 1$$

which, given the constraint on $g_i\{.\}$, is bounded from above by B^U and below by B^L.

In terms of upper and lower bounds, a high value in one area (e.g., high prices, high levels of pollution) is assumed to dominate any positive effects of other effects of attractiveness. Hence, the lower bound (i.e., minimum value) associated with a high parameter value should be larger (in magnitude) than the higher value of the other additive effects.

In addition, the effect of price, pollution, bed capacity utilization and tourists on attractiveness is monotonically decreasing ($f_i'\{x\} \leq 0$). In the neighborhood of x=0 and x=2 the first derivative is assumed to be zero. Also, in the neighborhood of x=1 the first derivative is assumed to be negative. These conditions restrict the function to being s-shaped and decreasing. The logistic curve to capture our functions:

$$f_i\{x\} = (B^U + B^L) \cdot \left\{1 - \frac{\exp(slope \cdot (x - inflection))}{1 + exp(slope \cdot (x - inflection))}\right\} - B^L$$

This specification for the logistics function establishes four parameters for each function: (1) the upper bound (B^U), a maximum value; (2) the lower bound (B^L), a minimum value; (3) the slope of the function; and the inflection point. A fifth parameter, a reference value, serves to normalize the input parameter.

Appendix C – Partial Model Calibration

To perform the partial calibration on Annual Bed Capacity (AC), we started with the total bed capacity, given by the product of the number of Resorts (R) and Beds per Resort (BpR), adjusted by the fraction of days that such capacity is operational. Resorts (R) is determined by an anchoring and adjustment process, with the gap between the indicated number of resorts (IR) and resorts (R) adjusted over time (τ), and a control for the maximum change in Resorts (McR). The gap in resorts (GR), equal to the indicated number of resorts (IR) minus resorts (R), is given by the Gap in Bed Capacity (GC) divided by the Beds per Resort (BpR) and the correction for operational days. The Gap in Bed Capacity (GC) is given by the product between the Gap in Bed Capacity Utilization (GCU) the Expected number of Tourists (ET). The gap in Bed Capacity Utilization (GCU) is determined by the positive differences between Bed Capacity Utilization (CU) and its desired level (CU^*). The Expected number of Tourists (ET) is given by an exponential smooth of the actual Tourists Data (TD) with a Time to form expectations on tourists (τ_T).

The partial estimation of bed capacity minimizes the sum of squared differences between Annual Bed Capacity Data (ACD) and its simulated behavior (AC), subject to the structure of the partial model and driven by data on bed capacity utilization (CUD) and actual number of tourists (TD).

$$\underset{CU^*,\tau_T,AOD,McR,BpR}{Min} \sum_{t=1}^{n}\left(AC(t) - ACD(t)\right)^2 \qquad \text{(Eq. 1)}$$

$$Subject\ to:$$

$$AC(t) = (AOD/365) * (R(t) * BpR)$$

$$\frac{dR}{dt} = MIN(McR, (IR - R(t))/\tau)$$

$$IR(t) = R(t) + GR$$

$$GR(t) = \frac{GC(t)}{BpR*(AOD/365)}$$

$$GC(t) = ET * GCU(t)$$

$$\frac{dET(t)}{dt} = (TD(t) - ET(t))/\tau_T$$

$$GCU(t) = MAX(0, CUD(t) - CU^*)$$

All data series were publically available and obtained electronically from government supported sites. Table C1 shows the estimated values for the calibrated parameters and their 95% confidence intervals. All estimated values have reasonable magnitudes. Partial calibration suggests that there are about 200 average beds per resort (BpR); almost 5 resorts that can be added per year; an annual desired Bed Capacity Utilization (CU^*) of about 0.56; and a time to form expectations on tourists (τ_T) short of one and three quarter years.

Parameter	Estimate	95% Confidence Interval	
Average beds per resort (*BpR*)	199.11	189.4	211.21

Time to form expectations on tourists (τ)	1.73	1.653	1.854
Max change in resorts (*McR*)	4.84	4.596	5.013
Desired Bed Capacity Utilization (CU^*)	0.56	0.481	0.692

Table C1: Estimates for the Adjustment of Bed Capacity

Figure C1 presents the fit between the simulated series and the data. Theil inequality statistics capture the fraction of the mean square error between the simulated series and the data due to unequal bias, variance, and correlation {Theil, 1966 #75}. The low values for bias and variance suggest unsystematic error (Sterman, 1984). The high R^2 suggests that the model explains a large fraction of the mean square errors.

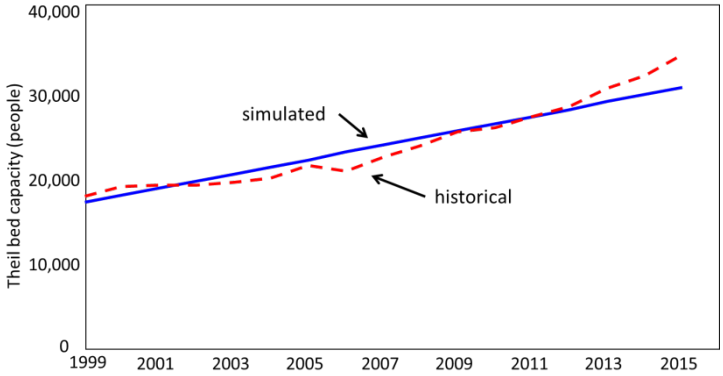


Figure C1: Partial model estimation for Bed Capacity

Summary Statistics for Historical Fit	
N	38
R^2	0.973
Mean Abs. Percent Error	0.16%
Theil's Inequality Statistics	
Bias	0.000
Variation	0.003
Covariation	0.997

Table C7: Summary statistics for partial model calibration for Bed Capacity

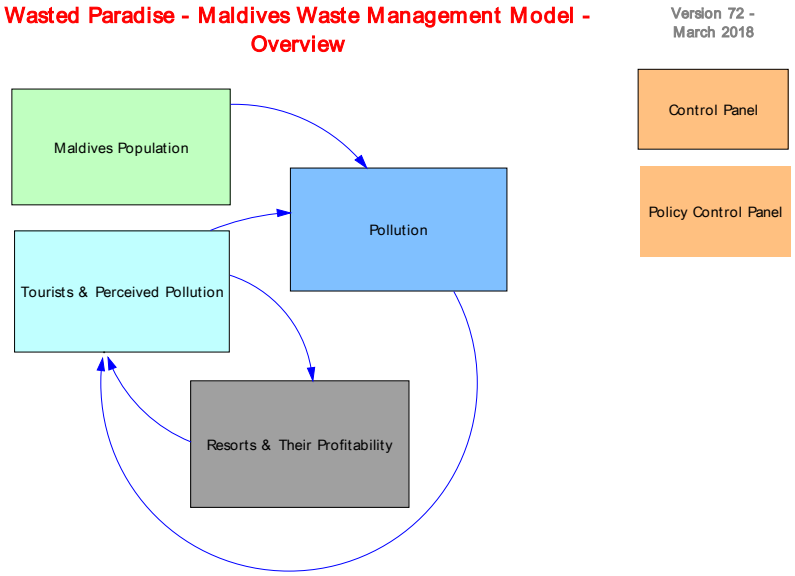
We used partial model calibration to estimate other parameters and initial conditions in the model. In total, we conducted six partial model calibrations comparing simulated and actual data series for Bed Capacity Utilization (CUD), Waste (WTD), Tourists (T), Tourism Receipts (TR) and Tourism Revenues (TRR). Through partial model calibration, we gained a deeper understanding of the impact of different parameters in the simulation. We used such insight to retain a small subset of parameters that could be used to calibrate the model in the Full Model Calibration.

Bibliography

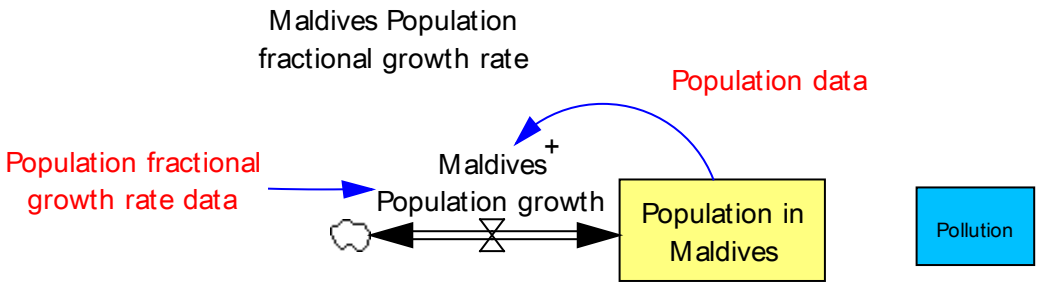
Sterman JD. 1984. Appropriate summary statistics for evaluating the historical fit of system dynamics models. *Dynamica* **10**(Winter): 51-66.

Appendix to the manuscript "Wasted Paradise?": System dynamics model

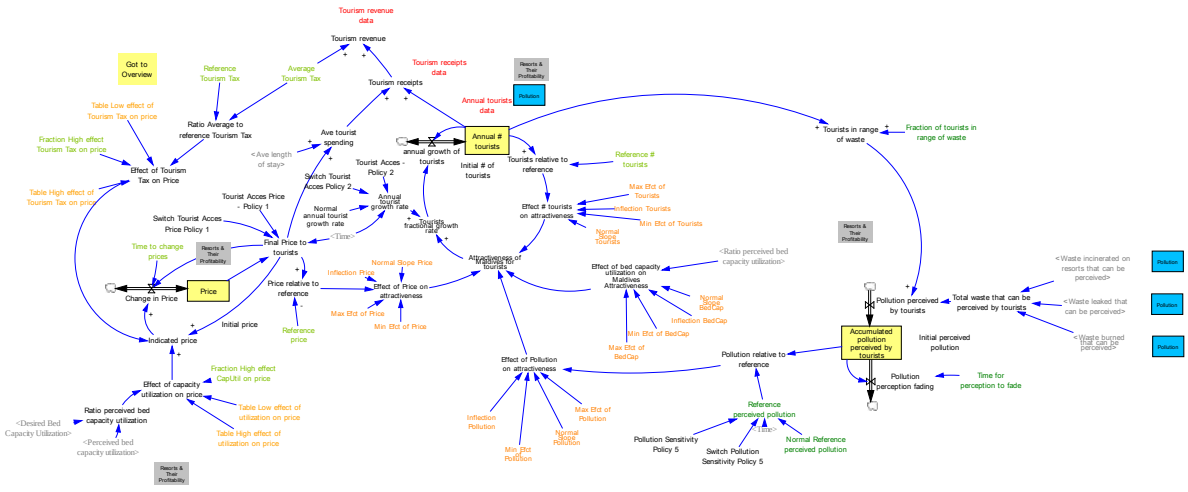
Model overview



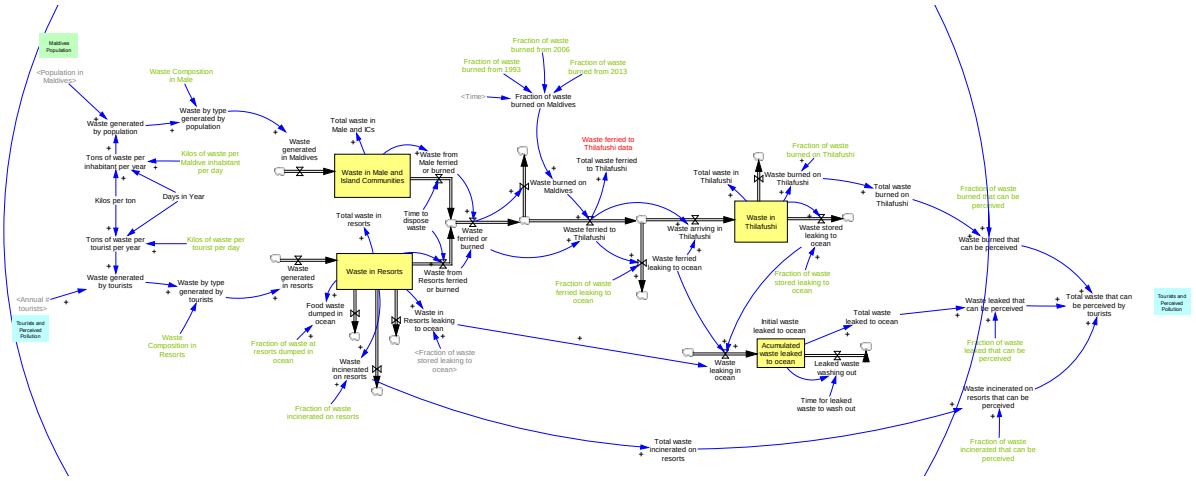
Sub structure Population



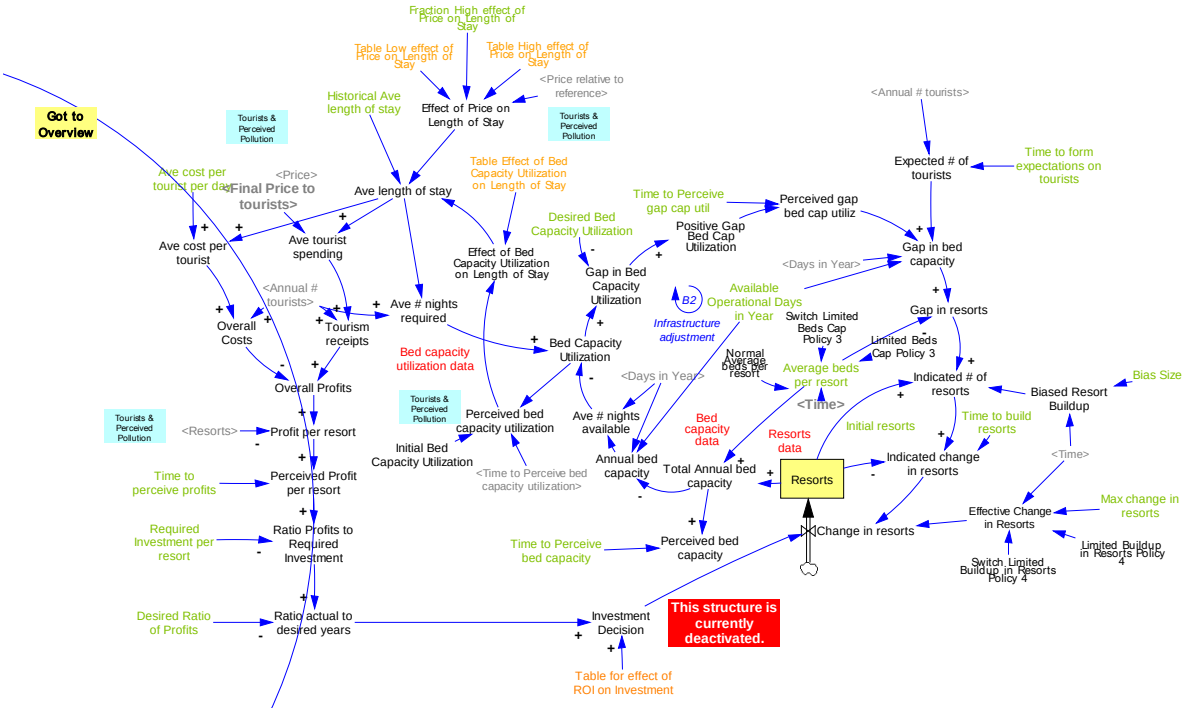
Sub structure: Tourists, Price, Perceived pollution



Sub structure: Pollution



Sub structure Resorts and their profitability



Model equations

Limited Buildup in Resorts Policy 4=
5.5
~ resorts/Year
~ This variable captures a value for maximum number of beds in Policy 3.
|

Normal Reference perceived pollution=
3.5e+010
~ Tons
~ This parameter sets the reference pollution for the pollution perception.
|

Pollution Sensitivity Policy 5=
3.5e+010

~ Tons
~ This variable captures a value for Pollution Sensitivity in Policy 5.
|

Switch Limited Beds Cap Policy 3=
0
~ Dmnl
~ This variable switches on the limited number of beds in Policy 3.
|

Switch Limited Buildup in Resorts Policy 4=
0
~ Dmnl
~ This variable switches on the limited number of beds in Policy 3.
|

Switch Pollution Sensitivity Policy 5=
0
~ Dmnl
~ This variable switches on the Pollution Sensitivity in Policy 5
|

Normal Average beds per resort=
194.221
~ Tourists/resort
~ Average number of beds per resort (194.221 from calibration).
|

Effective Change in Resorts=
IF THEN ELSE(Time < 2016, Max change in resorts, Limited Buildup in Resorts Policy 4\
) * Switch Limited Buildup in Resorts Policy 4 + (1 - Switch Limited Buildup in Resorts Policy 4\
) * Max change in resorts
~ resorts/Year
~ |

Reference perceived pollution=
IF THEN ELSE(Time < 2016, Normal Reference perceived pollution, Pollution Sensitivity Policy 5\
) * Switch Pollution Sensitivity Policy 5 + (1 - Switch Pollution Sensitivity Policy 5\
)*Normal Reference perceived pollution
~ Tons
~ This parameter sets the reference pollution for the pollution perception.
|

Limited Beds Cap Policy 3=
194.221
~ Tourists/resort
~ This variable captures a value for maximum number of beds in Policy 3.
|

Average beds per resort=
IF THEN ELSE(Time < 2016, Normal Average beds per resort, Limited Beds Cap Policy 3\
) * Switch Limited Beds Cap Policy 3 + (1 - Switch Limited Beds Cap Policy 3) * Normal Average beds per resort
~ Tourists/resort
~ Average number of beds per resort (194.221 from calibration).
|

Normal Slope Pollution=
14
~ Dmnl

~ The normal slope of the function capturing the effect of pollution on \
Maldives attractiveness.
|

Change in resorts=
Investment Decision * MIN(Effective Change in Resorts ,Indicated change in resorts)
~ resorts/ Year
~ This flow changes the stock of resorts.
|

Change in Price=
(Indicated price - Final Price to tourists) / Time to change prices
~ $/(day*tourist*Year)
~ |

Price relative to reference=
Final Price to tourists/ Reference price
~ Dmnl
~ This variable calculates the relative pollution.
|

Switch Tourist Acces Policy 2=
0
~ Dmnl
~ This variable switches on the tourist acces in Policy 2
|

Switch Tourist Acces Price Policy 1=
0
~ Dmnl
~ This variable switches on the tourist acces price in Policy 1.
|

Annual tourist growth rate=
IF THEN ELSE(Time < 2016, Normal annual tourist growth rate, "Tourist Acces - Policy 2"\
) * Switch Tourist Acces Policy 2 + (1-Switch Tourist Acces Policy 2)*Normal annual tourist growth rate
~ 1/Year
~ The normal fractional growth rate.
|

"Tourist Acces - Policy 2"=
0.05
~ 1/Year
~ This variable captures a value for maximum tourist access in Policy 2.
|

Normal annual tourist growth rate=
0.1075
~ 1/Year
~ The normal fractional growth rate.
|

Indicated change in resorts=
("Indicated # of resorts" - Resorts) / Time to build resorts
~ resorts/Year
~ This variable is the sum of all resorts plus the required resorts. \
Indicated resorts can be influenced by biased intention to build resorts.
|

Ave tourist spending=

Ave length of stay * Final Price to tourists
~ $/(Year*tourist)
~ This variable captures the average spending per tourist per year.
|

"Tourist Acces Price - Policy 1"=
100
~ $/(day*tourist)
~ This variable captures a tourist access price in Policy 1.
|

Final Price to tourists=
IF THEN ELSE(Time < 2016, Price, Price + "Tourist Acces Price - Policy 1") * Switch Tourist Acces Price Policy 1\
+ (1-Switch Tourist Acces Price Policy 1)*Price
~ $/(day*tourist)
~ This variable calculates the final price to tourists after adding policy \
tax.
|

Indicated price=
Final Price to tourists* Effect of capacity utilization on price * Effect of Tourism Tax on Price
~ $/(day*tourist)
~ The indicated price changes fractionally the Price by multiplying it with \
the Effect of capacity utilization on price.
|

"Indicated # of resorts"=
(Resorts + Gap in resorts) * Biased Resort Buildup
~ resorts
~ This variable is the sum of all resorts plus the required resorts. \
Indicated resorts can be influenced by biased intention to build resorts.
|

Ave length of stay=
Historical Ave length of stay * Effect of Price on Length of Stay * Effect of Bed Capacity Utilization on Length of Stay
~ days/Year
~ Average lentgh of tourists stay (in days/year) on the Maldives.
|

Perceived bed capacity utilization=
SMOOTHI(Bed Capacity Utilization, Time to Perceive bed capacity utilization , Initial Bed Capacity Utilization\
)
~ Dmnl
~ It takes time to perceive bed capacity utilization - we capture this with \
an information smooth.
|

Bias Size=
0
~ Dmnl
~ Time for buildup bias to take effect.
|

Table Effect of Bed Capacity Utilization on Length of Stay(
[(0.8,0.4)-(1,1)],(0,1),(0.8,1),(0.825,0.995),(0.85,0.94),(0.95,0.56),(0.975,0.505),\
(1,0.5))
~ Dmnl
~ The higher the price, the more expensive the Maldives as a tourist \

```
        destination. the shorter tourists' length of stay. This is the  high \
        effect table.
    |

Effect of Bed Capacity Utilization on Length of Stay=
    Table Effect of Bed Capacity Utilization on Length of Stay ( Perceived bed capacity utilization\
        )
    ~   Dmnl
    ~   Bed Capacity Utilization influences length of stay of tourists in a \
        nonlinear way
    |

Initial Bed Capacity Utilization=
    0.2
    ~   Dmnl
    ~   Initial bed capacity utilization.
    |

Biased Resort Buildup=
    IF THEN ELSE( Time < 2016, 1, 1+ Bias Size)
    ~   Dmnl
    ~   The bias for the buildup of resorts can increase the indicated number of \
        resorts.
    |

Resorts= INTEG (
    Change in resorts,
        Initial resorts)
    ~   resorts
    ~   Number of initial resorts operating in 1979.
    |

Resorts data
    ~   Dmnl
    ~   This is the DATA for bed capacity utilization.
    ~   :SUPPLEMENTARY
    |

Initial resorts=
    25
    ~   resorts
    ~   Initial number of resorts.
    |

Effect of Price on attractiveness=
    (Max Efct of Price * (1- EXP(Normal Slope Price*(Price relative to reference -Inflection Price
    ))/(1+EXP(Normal Slope Price*(Price relative to reference-Inflection Price))))+Min Efct of Price\
        )
    ~   Dmnl
    ~   The higher the price, the lower the attractiveness of Maldives as a \
        tourist destination.
    |

Tourism receipts=
    ("Annual # tourists"* Ave tourist spending)
    ~   $/Year
    ~   This variables captures the tourism receipts by multiplying the number of \
        tourists with the average spending of a tourist.
    |

Effect of Pollution on attractiveness=
```

(Max Efct of Pollution * (1- EXP(Normal Slope Pollution*(Pollution relative to reference
-Inflection Pollution))/(1+EXP(Normal Slope Pollution*(Pollution relative to reference\
-Inflection Pollution))))+Min Efct of Pollution)
~ Dmnl
~ The higher the price, the lower the attractiveness of Maldives as a \
tourist destination.
|

Initial price=
195.293
~ $/(day*tourist)
~ This parameter sets the reference price per day.
|

Price= INTEG (
Change in Price,
Initial price)
~ $/day/tourist
~ Average daily price per person to stay in the Maldives
|

Maldives Population growth=
Population fractional growth rate data * Population in Maldives
~ people/Year
~ This flow changes the stock of Maldives population.
|

Reference Tourism Tax=
0.12
~ Dmnl
~ Average tax on tourism receipts
|

Table High effect of Price on Length of Stay(
[(0,0.8)-(2,1.2)],(0,1.15),(0.25,1.15),(0.5,1.13),(0.75,1.09),(1,1),(1.25,0.91),(1.5\
,0.87),(1.75,0.85),(2,0.85))
~ Dmnl
~ The higher the price, the more expensive the Maldives as a tourist \
destination. the shorter tourists' length of stay. This is the high \
effect table.
|

Table High effect of Tourism Tax on price(
[(0,0.9)-(2,1.1)],(0,0.95),(0.25,0.95),(0.5,0.955),(0.75,0.97),(1,1),(1.25,1.03),(1.5\
,1.045),(1.75,1.05),(2,1.05))
~ Dmnl
~ The higher the tourism tax, the more expensive the Maldives as a tourist \
destination.This is the high effect table.
|

Effect of capacity utilization on price=
Fraction High effect CapUtil on price * Table High effect of utilization on price (Ratio perceived bed capacity utilization
) + (1-Fraction High effect CapUtil on price) * Table Low effect of utilization on price\
(Ratio perceived bed capacity utilization
)
~ Dmnl
~ Capacity utilization influences price of resorts in a nonlinear way
|

Table Low effect of Price on Length of Stay(

```
        [(0,0.9)-(2,2)],(0,0.999),(1,1),(2,1.001))
        ~       Dmnl
        ~       The higher the price, the more expensive the Maldives as a tourist \
                destination. the shorter tourists' length of stay.
        |

Table Low effect of Tourism Tax on price(
        [(0,0.9)-(2,2)],(0,0.999),(1,1),(2,1.001))
        ~       Dmnl
        ~       The higher the tourism tax, the more expensive the Maldives as a tourist \
                destination.\!\!\!
        |

Effect of Price on Length of Stay=
        Fraction High effect of Price on Length of Stay * Table High effect of Price on Length of Stay\
                (Price relative to reference) + (1-Fraction High effect of Price on Length of Stay\
                ) * Table Low effect of Price on Length of Stay (Price relative to reference)
        ~       Dmnl
        ~       Price influences length of stay of tourists in a nonlinear way
        |

Effect of Tourism Tax on Price=
        Fraction High effect Tourism Tax on price * Table High effect of Tourism Tax on price\
                (Ratio Average to reference Tourism Tax) + (1-Fraction High effect Tourism Tax on price\
                ) * Table Low effect of Tourism Tax on price ( Ratio Average to reference Tourism Tax\
                )
        ~       Dmnl
        ~       Tourism Tax influences price of resorts in a nonlinear way
        |

Fraction High effect Tourism Tax on price=
        0.1
        ~       Dmnl
        ~       The low and high effect of capacity utilizazion tables serve as polar \
                extremes for the calibration of the fraction effect of capacity \
                utilization on price.
        |

Fraction High effect of Price on Length of Stay=
        1
        ~       Dmnl
        ~               |

Ratio Average to reference Tourism Tax=
        Average Tourism Tax/ Reference Tourism Tax
        ~       Dmnl
        ~       This variable calculates the ratio of average to reference tourism tax.
        |

Total waste in Male and ICs=
        SUM(Waste in Male and Island Communities[waste type!])
        ~       Tons
        ~       This variable calculates the total waste in Male and Island Communities \
                (all waste types).
        ~       :SUPPLEMENTARY
        |

Waste in Male and Island Communities[waste type]= INTEG (
        Waste generated in Maldives[waste type]-Waste from Male ferried or burned[waste type\
                ],
                0)
```

~ Tons
~ This stock indicates the total waste on the Maldives.
|

Waste ferried or burned[waste type]=
Waste from Male ferried or burned[waste type] + Waste from Resorts ferried or burned\
[waste type]
~ Tons/Year
~ Total waste ferried or burned in the Maldives
|

Waste ferried to Thilafushi[waste type]=
Waste ferried or burned[waste type] - Waste burned on Maldives[waste type]
~ Tons/Year
~ An average of 330 tonnes of rubbish are brought to Thilafushi every day, most of \
which are from Male.
Source: \
https://globalvoicesonline.org/2014/10/24/theres-an-island-made-of-toxic-tr\
ash-rising-out-of-the-sea-in-the-maldives/
|

Waste burned on Maldives[waste type]=
Waste ferried or burned[waste type] * Fraction of waste burned on Maldives
~ Tons/Year
~ This flow indicates the waste burned on the Maldives.
|

Waste in Resorts[waste type]= INTEG (
Waste generated in resorts[waste type]-Food waste dumped in ocean[waste type]-Waste from Resorts ferried or burned\
[waste type]-Waste in Resorts leaking to ocean[waste type]-Waste incinerated on resorts\
[waste type],
0)
~ Tons
~ This stock indicates the total waste on resorts by waste type.
|

Waste from Resorts ferried or burned[waste type]=
Waste in Resorts[waste type] / Time to dispose waste
~ Tons/Year
~ This flow captures all waste burned, or shipped to a disposal site.
|

Waste in Thilafushi[waste type]= INTEG (
Waste arriving in Thilafushi[waste type]-Waste burned on Thilafushi[waste type]-Waste stored leaking to ocean\
[waste type],
0)
~ Tons
~ This stock indicates the total waste on Thilafushi by waste type.
|

Inflection BedCap=
0.795152
~ Dmnl
~ The inflection point of the function capturing the effect of bed capacity \
utilization on Maldives attractiveness.
|

Inflection Pollution=
0.95

~ Dmnl
~ The inflection point of the function capturing the effect of pollution on \
Maldives attractiveness.
|

Inflection Price=
0.95
~ Dmnl
~ The inflection point of the function capturing the effect of price on \
Maldives attractiveness.
|

{UTF-8}
annual growth of tourists=
Tourists fractional growth rate * "Annual # tourists"
~ Tourists/Year
~ The annual growth of tourists changes the stock of Annual tourists.
|

Normal Slope BedCap=
4
~ Dmnl
~ The normal slope of the function capturing the effect of bed capacity \
utilization on Maldives attractiveness.
|

Attractiveness of Maldives for tourists=
"Effect # tourists on attractiveness" + Effect of bed capacity utilization on Maldives Attractiveness\
+ Effect of Price on attractiveness + Effect of Pollution on attractiveness
~ Dmnl
~ Attractiveness is the sum of four effects: Effect of tourists, Effect of \
bed capacity utilization, Effect of pollution, and Effect of price.
|

Effect of bed capacity utilization on Maldives Attractiveness=
Max Efct of BedCap* (1- EXP(Normal Slope BedCap*(Ratio perceived bed capacity utilization\
-Inflection BedCap))/(1+EXP(Normal Slope BedCap*(Ratio perceived bed capacity
utilization\
-Inflection BedCap))))+Min Efct of BedCap
~ Dmnl
~ The higher the bed capacity utilization, the more attractive the Maldives \
as a tourist destination.
|

Max Efct of Price=
0.5
~ Dmnl
~ The maximum effect of price on Maldives attractiveness.
|

Tourists fractional growth rate=
Annual tourist growth rate * (1+ Attractiveness of Maldives for tourists)
~ 1/Year
~ Actual tourist fractional growth rate is the product of the Normal annual \
tourist growth rate and the Attractiveness of the Maldives as tourist \
destination.
|

Min Efct of Pollution=
-0.5
~ Dmnl

~ The minimum effect of Pollution on Maldives attractiveness.
|

Min Efct of Price=
-0.5
~ Dmnl
~ The minimum effect of price on Maldives attractiveness.
|

Min Efct of Tourists=
-0.309
~ Dmnl
~ The minimum effect of tourists on Maldives attractiveness.
|

Inflection Tourists=
0.500423
~ Dmnl
~ The inflection point of the function capturing the effect of tourists on \
Maldives attractiveness.
|

Normal Slope Price=
12
~ Dmnl
~ The normal slope of the function capturing the effect of price on Maldives \
attractiveness.
|

Normal Slope Tourists=
4
~ Dmnl
~ The normal slope of the function capturing the effect of tourists on \
Maldives attractiveness.
|

Max Efct of Tourists=
0.721
~ Dmnl
~ The maximum effect of tourists on Maldives attractiveness.
|

Min Efct of BedCap=
-0.347
~ Dmnl
~ The minimum effect of bed capacity utilization on Maldives attractiveness.
|

Max Efct of BedCap=
0.9
~ Dmnl
~ The maximum effect of bed capacity utilization on Maldives attractiveness.
|

Max Efct of Pollution=
0.5
~ Dmnl
~ The maximum effect of Pollution on Maldives attractiveness.
|

Waste generated by population=

Population in Maldives * Tons of waste per inhabitant per year
~ Tons/Year
~ This variable caculates the total waste generated by the Maldives \
population
|

"Effect # tourists on attractiveness"=
Max Efct of Tourists * (1- EXP(Normal Slope Tourists*(Tourists relative to reference\
-Inflection Tourists))/(
1+EXP(Normal Slope Tourists*(Tourists relative to reference-Inflection Tourists))))+\
Min Efct of Tourists
~ Dmnl
~ The more tourists travel to the Maldives, the more they talk about it, \
kicking off the Word-of-Mouth loop. Below a threshold point for the number \
of tourists visiting this effect increases attractiveness. Above a \
threshold point this effect decreases attractiveness.
|

Waste generated by tourists=
"Annual # tourists" * Tons of waste per tourist per year
~ Tons/Year
~ |

Ratio perceived bed capacity utilization=
Perceived bed capacity utilization / Desired Bed Capacity Utilization
~ Dmnl
~ This variable calculates the ratio of perceived bed capacity utilization \
by dividing the perceived by the desired bed capacity utilization.
|

Annual bed capacity=
Total Annual bed capacity * (Available Operational Days in Year/Days in Year)
~ Tourists
~ This variable translates the annual bed capacity into the nights available \
for tourists.
|

Historical Ave length of stay=
9.74082
~ days/Year
~ Average tourists stay days on the Maldives.
|

"Ave # nights available"=
Annual bed capacity * Days in Year
~ Tourists*day/Year
~ This variable translates the annual bed capacity into the nights available \
for tourists.
|

Available Operational Days in Year=
365
~ days/Year
~ These are the number of days in a year that resorts are operational.
|

Fraction High effect CapUtil on price=
0.178644
~ Dmnl
~ The high effect of capacity utilizazion tables serve as polar extremes for \
the calibration of the fraction effect of capacity utilization on price.

```
	|

Table Low effect of utilization on price(
	[(0,0.9)-(2,2)],(0,0.999),(1,1),(2,1.001))
	~	Dmnl
	~	The higher the bed capacity utilization, the more expensive the Maldives \
		as a tourist destination.\!\!\!
	|

Table High effect of utilization on price(
	[(0,0.6)-(2,1.4)],(0,0.875),(0.25,0.875),(0.5,0.877),(0.75,0.91),(1,1),(1.25,1.09),(\
		1.5,1.123),(1.75,1.125),(2,1.125))
	~	Dmnl
	~	The higher the bed capacity utilization, the more expensive the Maldives \
		as a tourist destination.This is the  high effect of capacity utilizazion \
		on price table.
	|

Fraction of waste burned from 2006=
	0.73
	~	Dmnl
	~		|

Fraction of waste burned from 2013=
	0.68
	~	Dmnl
	~		|

Fraction of waste burned on Maldives=
	IF THEN ELSE( Time>=2013, Fraction of waste burned from 2013, IF THEN ELSE(Time>=2006\
		, Fraction of waste burned from 2006, IF THEN ELSE( Time>=1993, Fraction of waste burned
from 1993\
		 , 1)))
	~	Dmnl
	~	Prior to 1992 no waste was sent to Thilafushi. From 1993, the fraction of waste \
		burned was 85% (15% shipped to Thilafushi). Then in 2006 it was decreased \
		to 75%, amount shipped increased to 25%). Then, from 2013 it was decreased \
		to 60% (amount shipped was increased to 40%). With respect to resorts in \
		2015, Peterson estimates that 68% of them ship their waste to waste \
		disposal sites (e.g., Thilafushi). All food waste is dumped in the ocean.
		Yard and paper waste are incinerated. The remaining ashes can be also \
		shipped to waste disposal. (Peterson 2015, page 35).
	|

Fraction of waste burned from 1993=
	0.79
	~	Dmnl
	~		|

Waste ferried leaking to ocean[waste type]=
	Waste ferried to Thilafushi[waste type] * Fraction of waste ferried leaking to ocean
	~	Tons/Year
	~	Some of the waste leaks into the ocean during transport to Thilafushi as \
		the boats are not covered with a net or other device to prevent the \
		spillage or blowing of waste into the sea (Peterson, 2015, p. 35).
	|

Waste arriving in Thilafushi[waste type]=
	Waste ferried to Thilafushi[waste type] - Waste ferried leaking to ocean[waste type]
	~	Tons/Year
	~	The waste arriving in Thilafushi equals the waste ferried to Thilafushi \
```

minus the waste leaking into the ocean.
|

Total waste ferried to Thilafushi=
SUM(Waste ferried to Thilafushi[waste type!])
~ Tons/Year
~ This variable indicates the sum of all waste types ferried to Thilafushi.
~ :SUPPLEMENTARY
|

Tons of waste per inhabitant per year=
Days in Year * Kilos of waste per Maldive inhabitant per day / (Kilos per ton)
~ Tons/people/Year
~ Each inhabitant of Maldives generates 1.2 kg of garbage per day. Source: \
http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-ein\
e-Insel-aus-Muell.html
|

Waste generated in resorts[waste type]=
Waste by type generated by tourists[waste type]
~ Tons/Year
~ This is the waste that is actually produced on the tourist atolls.
|

Waste generated in Maldives[waste type]=
Waste by type generated by population[waste type]
~ Tons/Year
~ This flow changes the stock of waste generated in Maldives.
|

Food waste dumped in ocean[waste type]=
Waste in Resorts[waste type] * Fraction of waste at resorts dumped in ocean[waste type\
]
~ Tons/Year
~ Food waste is currently dumped into the ocean. "The food discards are \
taken at about 06:00 in a resort boat about 4 to 5 km out to sea and then \
are dumped into the water. The food is consumed by fish" (Peterson, 2015: \
32).
|

Total waste that can be perceived by tourists=
Waste burned that can be perceived + Waste leaked that can be perceived + Waste incinerated on resorts that can be perceived
~ Tons/(Year*tourist)
~ This variable adds the burned waste, the incinerated waste, and the waste \
leaked into the oceans that can all be perceived by tourists.
|

Fraction of waste incinerated that can be perceived=
0.1
~ 1/tourist
~ Assumes that 10% of the total waste incinerated will be perceived by \
tourists. Tourists can see the smoke that is coming out of inadequate \
incineration facilities on the resorts.
|

Total waste incinerated on resorts=
SUM(Waste incinerated on resorts[waste type!])
~ Tons/Year
~ Summs of the waste incinerated on resorts by waste type.
|

Waste incinerated on resorts that can be perceived=
	Total waste incinerated on resorts * Fraction of waste incinerated that can be perceived
	~	Tons/(Year*tourist)
	~	This is the waste incinerated on the tourist resorts that can be perceived \
		by tourists.
	|

Fraction of waste incinerated on resorts[waste type]=
	0, 1, 0, 0, 0.33
	~	1/Year
	~	All of garden and yard waste (38% of total waste) is incinerated at the \
		resorts. One third of other waste (paper products) (other waste accounts \
		for 6% of total waste) is also incinerated at resorts. (see Peterson 2015, \
		page 36 for comments and page 31 for overall composition).
	|

Fraction of waste at resorts dumped in ocean[waste type]=
	0.4, 0, 0, 0, 0
	~	Dmnl/Year
	~	Assumes that 40% of food waste is dumped into the ocean.
	|

Waste leaking in ocean[waste type]=
	Waste ferried leaking to ocean[waste type] + Waste stored leaking to ocean[waste type\
		] + Waste in Resorts leaking to ocean[waste type]
	~	Tons/Year
	~	This flow captures the waste that leaks into the ocean.
	|

Waste in Resorts leaking to ocean[waste type]=
	Waste in Resorts[waste type] * Fraction of waste stored leaking to ocean
	~	Tons/Year
	~	This outflow captures the waste leaking from the resorts into the ocean, \
		multiplying total waste times the fraction of waste stored leaking to \
		ocean.
	|

Total waste in resorts=
	SUM(Waste in Resorts[waste type!])
	~	Tons
	~	This variable calculates the total waste on the tourist resorts (all waste \
		types).
	~	:SUPPLEMENTARY
	|

Waste incinerated on resorts[waste type]=
	Waste in Resorts[waste type] * Fraction of waste incinerated on resorts[waste type]
	~	Tons/Year
	~	This flow indicates the waste burned on resorts (incineration of "other \
		waste" tye only) (Peterson, 2015: 32).
	|

Gap in bed capacity=
	("Expected # of tourists" * Perceived gap bed cap utiliz) / (Available Operational Days in Year\
		/Days in Year)
	~	Tourists
	~	This variable calculates how many beds are needed in the near future.
	|

Time to Perceive gap cap util=

0.5
~ Year
~ It takes a quarter of a year to perceive the gap of capacity utilization.
|

Perceived gap bed cap utiliz=
SMOOTHI(Positive Gap Bed Cap Utilization, Time to Perceive gap cap util , Positive Gap Bed Cap Utilization\
)
~ Dmnl
~ It takes time to perceive the bed capacity utilization - we capture this \
with an information smooth.
|

Perceived bed capacity=
SMOOTHI(Total Annual bed capacity, Time to Perceive bed capacity , Total Annual bed capacity\
)
~ Tourists
~ It takes time to perceive the bed capacity - we capture this with an \
information smooth.
~ :SUPPLEMENTARY
|

Time to Perceive bed capacity=
2
~ Year
~ We assume it takes two years to perceive bed capacity (until bed capacity \
is tracked).
|

Perceived Profit per resort=
SMOOTHI(Profit per resort, Time to perceive profits, Profit per resort)
~ $/Year/resort
~ Profits are not perceived instantaneously, but with a time delay.
|

Ratio Profits to Required Investment=
Perceived Profit per resort / Required Investment per resort
~ 1/Year
~ This variable calculates the ratio of the perceived to the required profit \
per resort.
|

Time to perceive profits=
3
~ Year
~ It takes time to perceive profits.
|

Time to Perceive bed capacity utilization=
0.72382
~ Year
~ |

Profit per resort=
Overall Profits / Resorts
~ $/Year/resort
~ This variable breaks down the overall profits to profits per resort.
|

Accumulated pollution perceived by tourists= INTEG (

Pollution perceived by tourists - Pollution perception fading,
Initial perceived pollution)
~ Tons
~ This is the accumulated pollution that the tourists perceive.
|

Acumulated waste leaked to ocean[waste type]= INTEG (
Waste leaking in ocean[waste type] - Leaked waste washing out[waste type],
Initial waste leaked to ocean[waste type])
~ Tons
~ This is the accumulated waste leaked into the ocean around the resorts.
|

Fraction of waste leaked that can be perceived=
0.75
~ 1/tourist/Year
~ Assumes that 75% of the total waste leaked will be perceived by tourists. \
This needs to also take into account the time component that tourists will \
see it.
|

Fraction of waste stored leaking to ocean=
0.01
~ Dmnl/Year
~ Assumes that 1% of waste ferried leaks to the ocean
|

Reference price=
10000
~ $/(day*tourist)
~ This parameter sets the reference price per day.
|

Required Investment per resort=
2e+007
~ $/resort
~ The required investment per resort in million USD.
|

Pollution perception fading=
Accumulated pollution perceived by tourists / Time for perception to fade
~ Tons/Year
~ A fraction of pollution fades, decreasing the stock of accumulated \
pollution perceived by tourists.
|

Ave cost per tourist=
Ave length of stay * Ave cost per tourist per day
~ $/(Year*tourist)
~ This variable captures the average cost per tourist per year.
|

Ave cost per tourist per day=
250
~ $/(day*tourist)
~ This parameters captures the average cost per tourist per day on the \
Maldives.
|

Waste burned that can be perceived=
Total waste burned on Thilafushi * Fraction of waste burned that can be perceived

~ Tons/(Year*tourist)
~ This variable calculates the burned waste that can be perceived by the \
tourists.
|

Investment Decision=
Table for effect of ROI on Investment (Ratio actual to desired years)*0 +1
~ Dmnl
~ As actual ROI is above required ROI investors are more likely to \
investment. Required ROI is 2 years.
|

Average Tourism Tax=
0.144416
~ Dmnl
~ Average tax on tourism receipts
|

Table for effect of ROI on Investment(
[(0,0)-(1,1)],(0,0),(0.02,0.02),(0.98,0.98),(1,1))
~ Dmnl
~ |

Leaked waste washing out[waste type]=
Acumulated waste leaked to ocean[waste type] / Time for leaked waste to wash out
~ Tons/Year
~ This outflow calculates the leaked waste that washes out, thus disappears \
(washed away in other regions, hidden under ocean bed, etc.).
|

Tourism revenue=
Tourism receipts * Average Tourism Tax
~ $/Year
~ Tourism revenues are calculated by multiplying Tourism receipts with the \
tourism tax.
~ :SUPPLEMENTARY
|

Time for perception to fade=
2
~ Year
~ Tourists' perception of pollution fades after a couple of years.
|

Overall Costs=
"Annual # tourists" * Ave cost per tourist
~ $/Year
~ This variable captures the overall costs from tourism.
|

Time to change prices=
0.25077
~ Year
~ Average time to adjust resort prices.
|

Desired Ratio of Profits=
0.25
~ 1/Year
~ Investors would like annual profits to be at least 0.25 of the total \
required investment to launch a new resort.

|

Total waste burned on Thilafushi=
SUM(Waste burned on Thilafushi[waste type!])
~ Tons/Year
~ This variable adds up the waste burned on Thilafushi.
|

Total waste leaked to ocean=
SUM(Acumulated waste leaked to ocean[waste type!])
~ Tons
~ This variable sums up all the waste leaked into the ocean.
|

Fraction of tourists in range of waste=
0.01
~ Dmnl
~ Tourists located in resorts within 30 km of Thilafushi. Takes into \
consideration the fraction of beds available in the closer resorts. Table \
9.3 of Statistical Archive of the Maldives: \
http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/
|

Tourism receipts data
~ $/Year
~ This is the DATA for tourism receipts of the Maldives.
~ :SUPPLEMENTARY
|

Fraction of waste ferried leaking to ocean=
0.01
~ Dmnl
~ Assumes that 1% of waste ferried leaks to the ocean
|

Time for leaked waste to wash out=
2
~ Year
~ Tourists' perception of pollution fades after a couple of years.
|

Tourists in range of waste=
"Annual # tourists" * Fraction of tourists in range of waste
~ Tourists
~ This variable calculates the number of tourists that are in close distance \
to Thilafushi.
|

Overall Profits=
Tourism receipts - Overall Costs
~ $/Year
~ Overall profits are calculated by subtracting the costs from the receipts.
|

Pollution perceived by tourists=
Tourists in range of waste * Total waste that can be perceived by tourists
~ Tons/Year
~ This flow measures the pollution inflow perceived by the tourists.
|

Waste leaked that can be perceived=

Total waste leaked to ocean * Fraction of waste leaked that can be perceived
~ Tons/(Year*tourist)
~ This is the waste that leaked into the ocean that can actually be \
perceived by the tourists.
|

Waste stored leaking to ocean[waste type]=
Waste in Thilafushi[waste type] * Fraction of waste stored leaking to ocean
~ Tons/Year
~ This outflow captures the waste leaking into the ocean, multiplying total \
waste times the fraction of waste stored leaking to ocean.
|

Initial waste leaked to ocean[waste type]= INITIAL(
0)
~ Tons
~ This parameter assumes an initial pollution of the oceans (at beginning of \
simulation).
|

Positive Gap Bed Cap Utilization=
MAX (0, Gap in Bed Capacity Utilization)
~ Dmnl
~ This variable calculates the gap in bed capacity utilization.
|

Tourism revenue data
~ $/Year
~ This is the DATA for tourism revenue of the Maldives.
~ :SUPPLEMENTARY
|

Ratio actual to desired years=
Ratio Profits to Required Investment / Desired Ratio of Profits
~ Dmnl
~ Investors require actual ROI to be above required ROI to decide to \
investment. Required ROI is 2 years.
|

Pollution relative to reference=
Accumulated pollution perceived by tourists / Reference perceived pollution
~ Dmnl
~ This variable calculates the relative pollution.
|

Total waste in Thilafushi=
SUM(Waste in Thilafushi[waste type!])
~ Tons
~ This variable calculates the total waste on the Thilafushi (all waste \
types).
~ :SUPPLEMENTARY
|

waste type:
Food, Yard, Plastics, Inorganic, Other
~ Dmnl
~ |

Waste Composition in Resorts[waste type]=
0.4, 0.38, 0.05, 0.11, 0.06
~ Dmnl

~ The percentage composition of waste refer to: Food, Yard, Plastics, \
Inorganic, Other (Construction debris and paper), respectively. (Peterson \
2015, page 32)
|

Waste by type generated by population[waste type]=
Waste generated by population * Waste Composition in Male[waste type]
~ Tons/Year
~ This variable calculates the waste generated by the population - by waste \
type.
|

Waste by type generated by tourists[waste type]=
Waste generated by tourists * Waste Composition in Resorts[waste type]
~ Tons/Year
~ This variable calculates the waste generated by tourists - by waste type.
|

Waste Composition in Male[waste type]=
0.22, 0.528, 0.025, 0.18, 0.047
~ Dmnl
~ Thie parameter indicates the waste composition in Male.
|

Max change in resorts=
5.5
~ resorts/Year
~ Maximum number of resorts that can be opened in a year.
|

Bed Capacity Utilization=
MAX (0, "Ave # nights required"/"Ave # nights available")
~ Dmnl
~ Bed capacity utilization puts the nights required and the nights available \
into relation with each other.
|

"Ave # nights required"=
"Annual # tourists"* Ave length of stay
~ Tourists*day/Year
~ This variable caclulates the number of nights required to host all \
tourists staying in the Maldives.
|

Population fractional growth rate data
~ 1/Year
~ This is the DATA for polulation fractional growth rate.
|

Annual tourists data
~ people
~ This is the DATA for annual tourists traveling to the Maldives.
~ :SUPPLEMENTARY
|

Waste ferried to Thilafushi data
~ Tons/Year
~ This is the DATA for waste ferried to Thilafushi.
~ :SUPPLEMENTARY
|

```
Population data
        ~       people
        ~       This is the DATA for population.
        ~       :SUPPLEMENTARY
        |

Bed capacity data
        ~       people
        ~       This is the DATA for bed capacity.
        ~       :SUPPLEMENTARY
        |

Bed capacity utilization data
        ~       Dmnl
        ~       This is the DATA for bed capacity utilization.
        ~       :SUPPLEMENTARY
        |

"Annual # tourists"= INTEG (
        annual growth of tourists,
                "Initial # of tourists")
        ~       Tourists
        ~       The number of tourists traveling to the Maldives per year.
        |

Time to form expectations on tourists=
        1
        ~       Year
        ~       Time (in years) to form expectation on tourists traveling to the Maldives.
        |

{UTF-8}
"Expected # of tourists"=
        SMOOTH3I( "Annual # tourists" , Time to form expectations on tourists , "Annual # tourists"\
                )
        ~       Tourists
        ~       This variable calculates how many tourists are expected to travel to the \
                Maldives. It is a SMOOTH3 function.
        |

"Initial # of tourists"=
        33124
        ~       Tourists
        ~       These are the initial number of tourists in 1979 (Table 9.1 in Statistical Archive \
                of the Maldives Government:
                http://statisticsmaldives.gov.mv/yearbook/statisticalarchive/).
        |

"Reference # tourists"=
        380565
        ~       Tourists
        ~       The reference value for normalizing the input of tourists into the \
                function capturing the effect of tourists on Maldives attractiveness.
        |

Initial perceived pollution=
        100
        ~       Tons
        ~       We assume the initial perceived pollution to be 100 tons.
        |
```

Tourists relative to reference=
"Annual # tourists" / "Reference # tourists"
~ Dmnl
~ This variable puts the actual number of tourists in relation to the \
carrying capacity.
|

Total Annual bed capacity=
Resorts * Average beds per resort
~ Tourists
~ This variable calculates the number of beds available for tourists.
|

Maldives Population fractional growth rate=
0.023
~ 1/Year
~ Normal fractional growth rate is 0.023.
~ :SUPPLEMENTARY
|

Fraction of waste burned on Thilafushi=
0.4
~ 1/Year
~ Assumes that 40% of the waste is burned on Thilafushi.
|

Time to dispose waste=
0.08
~ Year
~ Average time to dispose waste in the island. We assume about 1 month to be \
the time that waste sits around before it is shipped to a disposal site.
|

Days in Year=
365
~ days/Year
~ There are 365 days in a year.
|

Desired Bed Capacity Utilization=
0.645481
~ Dmnl
~ This is the desired bed capacity utilization by the resorts.
|

Fraction of waste burned that can be perceived=
0.15
~ 1/tourist
~ Assumes that 15% of the total waste burned will be perceived by tourists. \
This is separate (and different) from the number of tourists close to \
Thilafushi and those that can see the smoke.
|

Gap in Bed Capacity Utilization=
Bed Capacity Utilization - Desired Bed Capacity Utilization
~ Dmnl
~ This variable calculates the gap in bed capacity utilization.
|

Gap in resorts=
Gap in bed capacity / Average beds per resort

~ resorts
~ This variable calculates the resorts needed in the near future.
|

Kilos per ton=
1000
~ kg/ton
~ There are 1,000 kilograms in a ton.
|

Waste from Male ferried or burned[waste type]=
Waste in Male and Island Communities[waste type] / Time to dispose waste
~ Tons/Year
~ Part of the waste is ferried to Thilafushi or burned.
|

Time to build resorts=
2
~ Year
~ Average time to build a resort in years.
|

Tons of waste per tourist per year=
Days in Year*Kilos of waste per tourist per day/ (Kilos per ton)
~ Tons/tourist/Year
~ Each tourist of Maledives generates 3.5 kg of garbage per day.
Source: \
http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-ein\
e-Insel-aus-Muell.html
|

Waste burned on Thilafushi[waste type]=
Waste in Thilafushi[waste type] * Fraction of waste burned on Thilafushi
~ Tons/Year
~ This flow indicates the waste burned on Thilafushi.
|

Kilos of waste per tourist per day=
3.55687
~ kg/tourist/day
~ Each tourist of Maledives generates 3.5 kg of garbage per day.
Source: \
http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-ein\
e-Insel-aus-Muell.html
|

Kilos of waste per Maldive inhabitant per day=
1.2
~ kg/people/day
~ Each inhabitant of Maldives generates 1.2 kg of garbage per day. Source: \
http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-ein\
e-Insel-aus-Muell.html
|

Population in Maldives= INTEG (
Maldives Population growth,
152143)
~ people
~ 394.000 people in 2014
Source: \
http://www.welt.de/vermischtes/article131144033/Im-tuerkisblauen-Wasser-ein\

```
                e-Insel-aus-Muell.html
        |

********************************************************
        .Control
********************************************************~
                Simulation Control Parameters
        |

FINAL TIME  = 2050
        ~       Year
        ~       The final time for the simulation.
        |

INITIAL TIME  = 1979
        ~       Year
        ~       The initial time for the simulation.
        |

SAVEPER  = 1
        ~       Year [0,?]
        ~       The frequency with which output is stored.
        |

TIME STEP  = 0.015625
        ~       Year [0,?]
        ~       The time step for the simulation.
        |
```