Technical Appendix

This appendix provides full documentation used in Vensim.

(01) average plot ratio=2.5
Units: Dmnl

(02) completed areas of residential areas=
(105.841*investment on projects completed*investment on projects completed +194.54*investment on projects completed+1280.27)*(1-STEP(0.014,1991)+STEP (0.086,1994)+STEP(0.02,1995)-STEP(0.029,1996)-STEP(0.003,1997)-STEP(0.028, 1998)-STEP(0.072,1999)-STEP(0.01,2000)-STEP(0.134,2001)-STEP(0.088,2002)-STEP (0.009,2003)+STEP(0.051,2004)-STEP(0.06,2005)+STEP(0.044,2006)-STEP(0.037, 2009)+STEP(0.138,2010))*
effect of investment on projects completed(investment on projects completed)
Units: thousand m2

(03) construction cost(
[(1991,0)-(2020,3000)],(1991,1065.48),(1992,1123.54),(1993,1180.76),(1994 ,1257.72),(1995,1297.84),(1996,1325.26),(1997,1341.33),(1998,1328.47),(1999 ,1310.61),(2000,1315.49),(2001,1305.69),(2002,1317),(2003,1314),(2004,1304),(2005,1302),(2007,1316),(2008,1330),(2009,1364),(2010,1336))
Units: euros/m2

(04) delivering quantity of domestic waste=
(0.3*Urban population)+(-4e-005*environmental regulation investment* environmental regulation investment +0.00728*environmental regulation investment-0.13016)*(1-STEP(0.581,1991)+ STEP(0.041,1992)+STEP(0.08,1993)+STEP(0.095,1994)+STEP(0.073,1995)+STEP(0.066 ,1996)+STEP(0.08,1997)+STEP(0.073,1998)+STEP(0.054,1999)+STEP(0.052,2000)+ STEP(0.033,2001)+STEP(0.064,2002)+STEP(0.031,2003)-STEP(0.073,2004)+STEP(0.037 ,2005)+STEP(0.017,2006)+STEP(0.003,2007)-STEP(0.067,2008)+STEP(0.113,2009) -STEP(0.003,2010))
Units: million to

(05) distribution proportion of GDP(
[(1991,0)-(2020,1)],(1991,0.577447),(1992,0.588552),(1993,0.615768),(1994 ,0.603154),(1995,0.591674),(1996,0.59358),(1997,0.591207),(1998,0.589509), (1999,0.588482),(2000,0.592582),(2001,0.59101),(2002,0.596586),(2003,0.601174),(2004,0.608081),(2005,0.62735),(2006,0.602094),(2007,0.580905),(2008,0.590868),(2009,0.595917),(2010,0.595229),(2011,0.594477),(2012,0.593665),(2013,0.592799),(2014,0.591884),(2015,0.590925),(2016,0.589927),(2017,0.588892),(2018,0.587826),(2019,0.586732),(2020,0.585612))
Units: Dmnl

(06) domestic water consumption=
((Urban population*41/1e+006)+(-0.0225*urban GDP*urban GDP+5.0291*urban GDP -223.512)*(1+STEP(0.067,1991)-STEP(0.117,1992)-STEP(0.015,1993)-STEP(0.069 ,1994)-STEP(0.056,1995)-STEP(0.039,1996)+STEP(0.011,1997)+STEP(0.013,1998) -STEP(0.002,1999)-STEP(0.003,2000)+STEP(0.013,2001)-STEP(0.034,2002)-STEP(0.014,2003)-STEP(0.025,2004)-STEP(0.065,2005)+STEP(0.065,2006)+STEP(0.137, 2007)-STEP(0.088,2008)-STEP(0.333,2009)))*(1-line loss rate(Time))
Units: million cubic meters

(07) economic growth=
urban GDP*economic growth rate(Time)
Units: billion

(08) economic growth rate(
[(1991,-0.1)-(2019,0.1)],(1991,0.042562),(1992,-0.03137),(1993,0.042628),
(1994,0.03536),(1995,0.014976),(1996,0.036114),(1997,0.027175),(1998,0.029598
),(1999,0.021673),(2000,0.04986),(2001,0.00027),(2002,0.016721),(2003,0.005703
),(2004,-0.0052),(2005,0.068846),(2006,0.055769),(2007,0.009432),(2008,-0.074
),(2009,0.047501),(2010,0.024999))
Units: Dmnl

(09) effect of housing price to income ratio(
[(0,0)-(20,2)],(0,0),(3,1.12),(5,1.1),(6,1.08),(6.5,1),(7,0.95),(8,0.92),(20,0.9))
Units: Dmnl

(10) effect of investment on projects completed(
[(0,0)-(20,1)],(0,1),(4,1),(7,1.1),(15,1))
Units: Dmnl

(11) effect of loan rate(
[(0,0)-(14,10)],(0,0),(5.25,1.05),(14,0.9))
Units: Dmnl

(12) effect of new investment(
[(0,0)-(1,2)],(0,0),(0.011,1),(1,1.1))
Units: Dmnl

(13) effect of people live in poverty(
[(0,0)-(0.1,10)],(0,1),(0.02,1.05),(0.024,1),(0.1,0.95))
Units: Dmnl

(14) effect of supply to demand ratio(
[(0,0)-(15,2)],(0,1.5),(0.5,1.15),(1,1.1),(1.2,1),(1.5,0.95),(5,0.8))
Units: Dmnl

(15) effect of unemployment rate(
[(0,0)-(0.1,10)],(0,0),(0.03,1.05),(0.04,1),(0.1,0.95))
Units: Dmnl

(16) effect of urban family size(
[(0,0)-(5,10)],(0,0),(2,1.5),(2.2,1),(5,1))
Units: Dmnl

(17) effect of rent-price index(
[(0,0)-(10,10)],(0,1),(1,0.7),(1.2,0.8),(1.3,0.9),(1.6,0.7),(2,0.5))
Units: Dmnl

(18) environmental regulation investment=
urban GDP*proportion of environmental investment(Time)*1000
Units: million

(19) FINAL TIME = 2020
Units: Year
The final time for the simulation.

(20) GDP per capita=
urban GDP*1e+009/Urban population
Units: euros

(21) green coverage=
(per capita area of public green land(Time)*Urban population/1e+009)/urban area
Units: Dmnl

(22) housing price to income ratio=
living space per capita*urban housing price index*400/urban disponsible income per capita

Units: Dmnl

(23) INITIAL TIME = 1991
Units: Year
The initial time for the simulation.

(24) investment on new residential projects=
urban GDP*proportion of new investment(Time)
Units: billion

(25) investment on projects completed=
urban GDP*proportion of investment on projects completed(Time)
Units: billion

(26) land price(
[(1991,0)-(2020,400000)],(1991,11958),(1992,12085),(1993,12485),(1994,13773
),(1995,12836),(1996,14114),(1997,17285),(1998,14692),(1999,15245),(2000,
15060
),(2001,16905),(2002,17498),(2003,17941),(2004,19341),(2005,21189),(2006,
18217
),(2007,19859),(2008,16353),(2009,17764),(2010,21246))
Units: euros/m2

(27) land price per floor areas=
land price(Time)/average plot ratio*effect of new investment(proportion of new investment
(Time))
Units: **undefined**

(28) line loss rate(
[(1991,0)-(2020,1)],(1991,0.214),(1992,0.205),(1993,0.197),(1994,0.189),(
1995,0.182),(1996,0.176),(1997,0.167),(1998,0.161),(1999,0.155),(2000,0.151
),(2001,0.148),(2002,0.146),(2003,0.145),(2004,0.144),(2005,0.146),(2006,0.148
),(2007,0.15),(2008,0.154),(2009,0.159),(2010,0.164))
Units: Dmnl

(29) living space per capita=
(1.933*(urban disponsible income per capita/1000)*(urban disponsible income per
capita
/1000)-66.8135*(urban disponsible income per capita/1000)+603.815)*(1-STEP
(0.49,1991)+STEP(0.146,1992)+STEP(0.074,1993)+STEP(0.103,1994)+STEP(0.082,
1995)+STEP(0.084,1996)+STEP(0.107,1997)+STEP(0.071,1998)+STEP(0.04,1999)+STEP
(0.005,2000)-STEP(0.089,2001)+STEP(0.016,2002)-STEP(0.065,2003)-STEP(0.045
,2004)-STEP(0.099,2005)-STEP(0.103,2006)-STEP(0.065,2007)-STEP(0.097,2008)
+STEP(0.324,2009)-STEP(0.208,2010))
Units: m2

(30) loan rate=5
Units: Dmnl

(31) meet the housing demand=
residential sale areas*0.1*(1-STEP(0.042,1991)-STEP(0.034,1992)-STEP(0.16
,1993)+STEP(0.021,1998)-STEP(0.004,2000)-STEP(0.037,2001)-STEP(0.078,2002)
-STEP(0.074,2003)-STEP(0.045,2004)-STEP(0.5,2005)+STEP(0.6,2006)-STEP(0.31
,2007)+STEP(0.1,2008)+STEP(0.211,2009)-STEP(0.3,2010))
Units: thousand m2

(32) newly sold areas=
(-6.4595*investment on new residential projects*investment on new residential projects
+179.513*investment on new residential projects-175.622+6000)*(1-STEP(0.04,
1993)-STEP(0.03,1994)-STEP(0.09,1995)-STEP(0.09,1996)+STEP(0.2,1998)+STEP

(0.03,2000)+STEP(0.1,2001)+STEP(0.06,2002)-STEP(0.01,2003)-STEP(0.01,2004)
+STEP(0.035,2005)-STEP(0.14,2006)-STEP(0.14,2008))
Units: thousand m2

(33) per capita area of public green land(
[(1991,800)-(2020,1000)],(1991,883.539),(1992,873.593),(1993,870.925),(1994
,871.681),(1995,870.174),(1996,864.875),(1997,870.105),(1998,869.451),(1999
,865.233),(2000,861.275),(2001,854.974),(2002,850.469),(2003,848.34),(2004
,846.644),(2005,848.434),(2006,848.858),(2007,848.434),(2008,848.646),(2009
,849.707),(2010,849.282))
Units: m2 per capita

(34) population below the poverty line(
[(1991,0)-(2020,0.1)],(1991,0.0189),(1992,0.0189),(1993,0.0189),(1994,0.0189
),(1995,0.0215),(1996,0.0229),(1997,0.0241),(1998,0.0231),(1999,0.0211),(2000
,0.0189),(2001,0.0188),(2002,0.0201),(2003,0.021),(2004,0.0216),(2005,0.00125
),(2006,0.00125),(2007,0.0013),(2008,0.00115),(2009,0.001))
Units: Dmnl

(35) population density=Urban population/(urban area*1000)
Units: inhabits per km2

(36) population growth=Urban population*population growth rate(Time)
Units: people

(37) population growth rate(
[(1991,-0.004)-(2019,0.02)],(1991,0.014929),(1992,0.006567),(1993,0.00261
),(1994,0.005206),(1995,0.005179),(1996,0.001803),(1997,0.002314),(1998,0.004874
),(1999,0.004595),(2000,0.00737),(2001,0.005298),(2002,0.002509),(2003,0.002003
),(2004,0.000999),(2005,-0.0005),(2006,0.000499),(2007,-0.00025),(2008,-0.00125
),(2009,0.0005),(2010,-0.001))
Units: Dmnl

(38) population of married=0.017
Units: Dmnl

(39) proportion of environmental investment(
[(1991,0)-(2020,1)],(1991,0.956),(1992,0.906),(1993,0.923),(1994,0.87),(1995
,0.824),(1996,0.794),(1997,0.747),(1998,0.707),(1999,0.665),(2000,0.628),(
2001,0.574),(2002,0.549),(2003,0.899),(2004,0.597),(2005,0.578),(2006,0.541
),(2007,0.512),(2008,0.507),(2009,0.548),(2010,0.523))
Units: Dmnl

(40) proportion of investment on projects completed(
[(1991,0)-(2020,0.8)],(1991,0.023152),(1992,0.027523),(1993,0.03348),(1994
,0.037214),(1995,0.032214),(1996,0.028757),(1997,0.026734),(1998,0.025957)
,(1999,0.023909),(2000,0.023134),(2001,0.017802),(2002,0.016121),(2003,0.015385
),(2004,0.016472),(2005,0.01523),(2006,0.015162),(2007,0.012587),(2008,0.010272
),(2009,0.010357),(2010,0.010357))
Units: Dmnl

(41) proportion of new investment(
[(1991,0)-(2020,0.1)],(1991,0.031042),(1992,0.034434),(1993,0.038522),(1994
,0.040352),(1995,0.030682),(1996,0.027293),(1997,0.026292),(1998,0.025672)
,(1999,0.023806),(2000,0.019536),(2001,0.015346),(2002,0.015768),(2003,0.017796
),(2004,0.016409),(2005,0.015727),(2006,0.014986),(2007,0.010209),(2008,0.010026
),(2009,0.011346),(2010,0.011346))
Units: Dmnl

(42) "rent-price index"(

[(1991,0)-(2020,10)],(1991,1),(1992,1.049),(1993,1.108),(1994,1.156),(1995
,1.201),(1996,1.227),(1997,1.251),(1998,1.264),(1999,1.274),(2000,1.296),(
2001,1.318),(2002,1.348),(2003,1.367),(2004,1.387),(2005,1.403),(2006,1.424
),(2007,1.445),(2008,1.453),(2009,1.465),(2010,1.475))
Units: Dmnl

(43) residential sale areas=
The demand for housing*0.5*
effect of housing price to income ratio(housing price to income ratio)
*effect of supply to demand ratio(supply to demand ratio)
Units: thousand m2

(44) road traffic accidents=
(total motor vehicles*1e+006*0.006)+(0.1568*(Urban population/1e+006)*(Urban population
/1e+006)-1.2459*(Urban population/1e+006)+2.4798)*(1-STEP(0.43,1991)+STEP(
0.135,1992)-STEP(0.032,1993)-STEP(0.088,1994)-STEP(0.022,1995)-STEP(0.072,
1996)+STEP(0.179,1997)+STEP(0.145,1998)+STEP(0.203,1999)+STEP(0.059,2000)-
STEP(0.048,2001)-STEP(0.186,2002)-STEP(0.309,2003)-STEP(0.122,2004)+STEP(0.089
,2005)-STEP(0.127,2006)-STEP(0.065,2007)+STEP(0.066,2008)-STEP(0.22,2009)-
STEP(0.03,2010))
Units: people

(45) supply to demand ratio=The supply for housing/The demand for housing
Units: Dmnl

(46) The demand for housing= INTEG (+the demand growth-meet the housing demand,70710.6)
Units: thousand m2

(47) the demand growth=
effect of housing price to income ratio(housing price to income ratio)*effect of loan rate
(loan rate)*effect of unemployment rate
(unemployment rate(Time))*effect of people live in poverty(population below the poverty line
(Time))*((-0.0003*(population growth/1000)*(population growth/1000)+30*population growth
/1000+3.457)*(1+STEP(0.8,1992)-STEP(0.361,2010))+(Urban population*0.05+
Urban population*population of married)*0.001)*
living space per capita*effect of urban family size(urban family size)*(1+STEP(0.6,1993)
- STEP(0.825,1994)-STEP(0.094,1995)+STEP(0.548,1996)-STEP
(0.34,1997)-STEP(0.396,1998)-STEP(0.063,1999)-STEP(0.151,2000)+STEP(0.05,2001
)+STEP(0.186,2002)+STEP(0.03,2004)+STEP(0.736,2005)-STEP(0.448,2006)+STEP(
0.2,2007)+STEP(0.5,2008)-STEP(0.33,2009)+STEP(0.4,2010))
Units: thousand m2

(48) the housing supply completed=
residential sale areas*0.15*(1-STEP(0.682,1991)-STEP(0.032,1992)-STEP(0.038
,1993)+STEP(0.005,1994)+STEP(0.137,1995)+STEP(0.028,1996)+STEP(0.137,1997)
+STEP(0.185,1998)+STEP(0.045,1999)-STEP(0.002,2000)-STEP(0.008,2006)-STEP(
0.0214,2009))
Units: thousand m2

(49) The supply for housing= INTEG (+the supply growth-the housing supply completed,71682)
Units: thousand m2

(50) the supply growth=
newly sold areas+completed areas of residential areas*(1-STEP(0.29,1992)-
STEP(0.1,1993)-STEP(0.143,1994)+STEP(0.296,1995)+STEP(0.297,1996)+STEP(0.242
,1997)-STEP(0.2,1998)+STEP(0.234,1999)-STEP(0.034,2000)+STEP(0.17,2001)-STEP
(0.03,2003)-STEP(0.116,2004)+STEP(0.046,2005)-STEP(0.085,2006)-STEP(0.022,
2007)+STEP(0.191,2008)+STEP(0.24,2009)-STEP(0.105,2010))

Units: thousand m2

(51) total cost=
(construction cost(Time)+land price per floor areas)*(1+0.7*2*loan rate/100)
Units: thousand m2

(52) total motor vehicles=
(-16.1832*(Urban population/1e+006)*(Urban population/1e+006)+128.443*(Urban population /1e+006)-252.248)*(1+STEP(0.217,1991)-STEP(0.164,1992)-STEP(0.035,1993)-STEP (0.003,1994)-STEP(0.014,1995)-STEP(0.008,1996)+STEP(0.005,1997)+STEP(0.003 ,1998)+STEP(0.01,1999)+STEP(0.012,2000)+STEP(0.017,2001)+STEP(0.023,2002)+ STEP(0.012,2003)+STEP(0.099,2004)+STEP(0.014,2005)+STEP(0.005,2006)+STEP(0.011 ,2007)-STEP(0.121,2008)+STEP(0.007,1999)+STEP(0.007,2010))
Units: million

(53) unemployment rate(
[(1991,0)-(2020,1)],(1991,0.044986),(1992,0.061694),(1993,0.083416),(1994 ,0.085864),(1995,0.087359),(1996,0.095962),(1997,0.097222),(1998,0.087649) ,(1999,0.078995),(2000,0.067205),(2001,0.070871),(2002,0.079696),(2003,0.084568),(2004,0.0864568),(2005,0.091735),(2006,0.067861),(2007,0.059226),(2008, 0.057227),(2009,0.070755),(2010,0.060356))
Units: Dmnl

(54) "urban air pollution NOx,SO2,PM10"=
(0.1185*(Urban population/1e+006)*(Urban population/1e+006)-0.9507*(Urban population /1e+006)+1.9184)*1000*(1-STEP(0.284,1991)+STEP(0.135,1992)+STEP(0.061,1993)+STEP(0.021,1994)+STEP(0.046,1995)+STEP(0.029,1996)-STEP(0.001,1997)-STEP (0.001,1998)+STEP(0.013,1999)-STEP(0.013,2000)+STEP(0.02,2001)-STEP(0.02,2002)-STEP(0.035,2003)-STEP(0.041,2004)-STEP(0.046,2005)-STEP(0.049,2006)-STEP (0.176,2007)-STEP(0.001,2008)-STEP(0.01,2010))+(25.9005*total motor vehicles *total motor vehicles-185.37*total motor vehicles+358.311)*(1+STEP(0.001,1995)-STEP(0.001,1996)-STEP(0.003,2000)+STEP(0.003,2000)+STEP(0.002,2006)-STEP (0.016,2007)+STEP(0.016,2008))
Units: thousand ton

(55) urban area=10.558
Units: thousand km2

(56) urban disponsible income per capita=
GDP per capita*distribution proportion of GDP(Time)
Units: euros

(57) urban family size=2.2
Units: **undefined**

(58) urban GDP= INTEG (economic growth,96.776)
Units: billion

(59) urban housing price index=
(0.0072*(total cost/1000)*(total cost/1000)-0.00967*(total cost/1000)+1.38)*effect of supply to demand ratio(supply to demand ratio)*effect of rent- price index ("rent-price index"(Time))
Units: Dmnl

(60) Urban population= INTEG (population growth,3.751e+006)
Units: people