EarthSystemScience

Climate Change and Futureproofing Infrastructure: Etimesgut, Ankara Case Study

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Outline

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- ❑ Objectives
- ❑ Methodology
- ❑ Land Use/Land Cover Change Analyses
- ❑ Pilot Study - Application
- ❑ Summary and Conclusions

Motivation: Climate Change and Extreme Events : Urban Floods & Consequences

http://www.radikal.com.tr/turkiye/melih-gokceke-fotografli-balikadam-yaniti-1162862/ - 2011

Radikal: On June 16 heavy rains in 2011 Ankara - Çetin Emeç Boulevard underpass.

20.05.2018-Hürriyet: The downpour in Ankara, dozens of people in the underpass were stranded.

http://www.hurriyet.com.tr/ankarada-saganak-onlarca-kisi-alt-gecitte-mah-40842931 - 2018

http://www.hurriyet.com.tr/yerel-haberler/ankara/9-dakika-yagdi-mamaki-sel-aldi-40827222 - 2018

05.05.2018-Hürriyet: Rainfall, which lasted for 9 minutes, caused flooding in Mamak - Ankara, four people were injured in the flood. The flood waters dragged the vehicles, over 20 workplaces and over 150 vehicles were damaged.

Problem Statement

- There are many implications of extreme rainfall events, including issues related to water quality, infrastructure management and public safety. Older systems have not been designed to accommodate extreme rainfall events, while increasing urbanization is creating more impervious surfaces. Inadequate infrastructure investment and maintenance further increases exposure of urban communities to flooding.

- In the last decades, heavy rainfall and flash flooding caused various damages in Turkey; for example settlements were damaged, road transportation and vehicles are disrupted, and life was negatively affected in Ankara.

Objectives

- To examine the type and rate of change for the land use-land cover situation and investigate the possible effects of these variations on urban flood.
- To analyze the capacity of a pilot stormwater network considering land use/land cover and climate change.
- To gather data in order to propose potential infrastructure design and alternative options for stormwater infrastructure design and management.

Methodology: Data and Pilot Study Area

Figure 1.1. Pilot Study Area - Railway Maintenance Complex in Etimesgut-Ankara

Analyses are conducted for the capital city of Ankara, which is a highly urbanized city. A population of 5.3 million people (TURKSTAT, 2016) are living in the capital Ankara, 88% of the population lives in the city centre. The information obtained from the analyses is transformed and applied to test the runoff and hydraulic performance of an actual stormwater network of a Railway Maintenance Complex (Figure 1.1) located in Etimesgut Ankara Province as a specific critical infrastructure (Turkish State Railways, 2018)

Figure 1.2. Urban Transformation of Pilot Study Area- Left 2003 and Right 2018

- Observed Precipitation Data; (1950-2015 - State Meteorological Services)
- Projected Precipitation Data; (2015-2098 - State Meteorological Services)
- Land Use/Cover Data; digitized data of maps obtained from General Command of Mapping for Ankara for late 1950s, early 1980s, mid 1990s and 2013

Methodology:

Methodology of this study consists of three parts; precipitation analysis, land use/cover analysis and application of the precipitation and land use/cover analysis results by Rational Method.

The methodology of precipitation analysis in this study consists of;

(1) Projected data is disaggregated into finest scale (5 minutes) and then it is aggregated to next analysis time scales (such as 10, 15, and 30 minutes)

(2) Trend analysis is carried out for observed and projected data.

(3) Stationary GEV (St) models are developed; return levels are derived for desired return periods for observed and projected data.

(4) Non-stationary GEV (NSt) models are developed; return levels are derived for desired return periods for observed and projected data

*** Detailed analyses were presented in previous presentation of the authors' for the precipitation data.**

The methodology of land use/cover analysis in this study consists of;

(1) Data digitalized and classified as urban and green area and also transportation networks such as, road, rail, etc. for Ankara

(2) Area of urban and green and length of road network computed in ArcGIS for Ankara

(3) Change and trend of urban and green area together with road network is investigated for Ankara; a potential development rate and developable part of the pilot study area assessed

(4) Land use/cover types of pilot study area is calculated for Pilot Study area

(5) Composite runoff coefficient is calculated for Pilot Study area

Methodology:

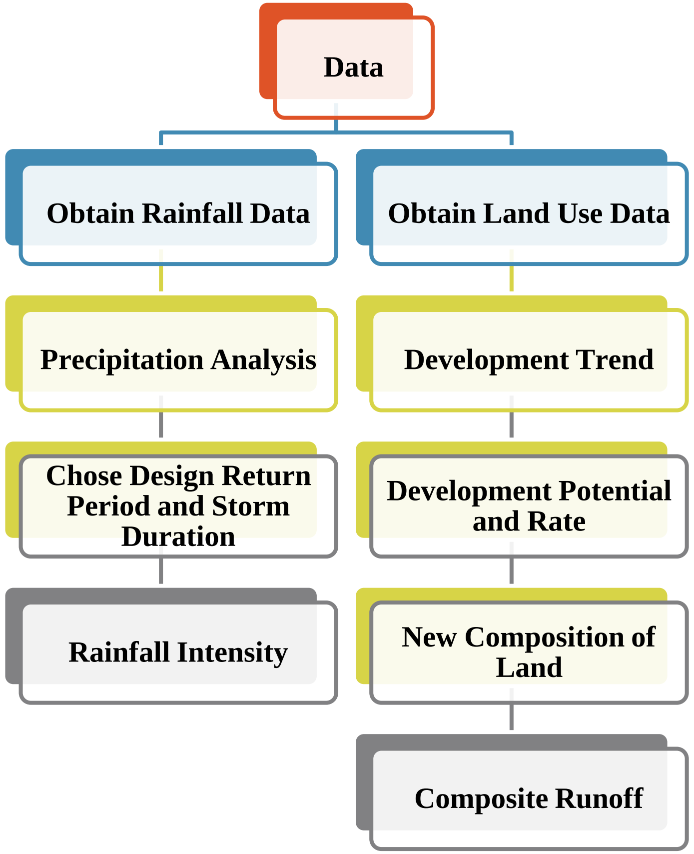

Figure 1.3. Parameter Derivation for Rational Method

Analysis conducted for the following cases;

Case 1; only the design intensity has changed and the behavior of existing stormwater network is observed

Case 2; only design runoff coefficient has changed and the effect is observed

Case 3; both design intensity and runoff coefficient have changed and the changes in pipe capacities (percent fullness) of existing network is observed

Case 4; design intensity has changed and pipe diameters are optimized

Case 5; design intensity and runoff coefficient have changed and pipe diameters are optimized

Land Use/Land Cover Change

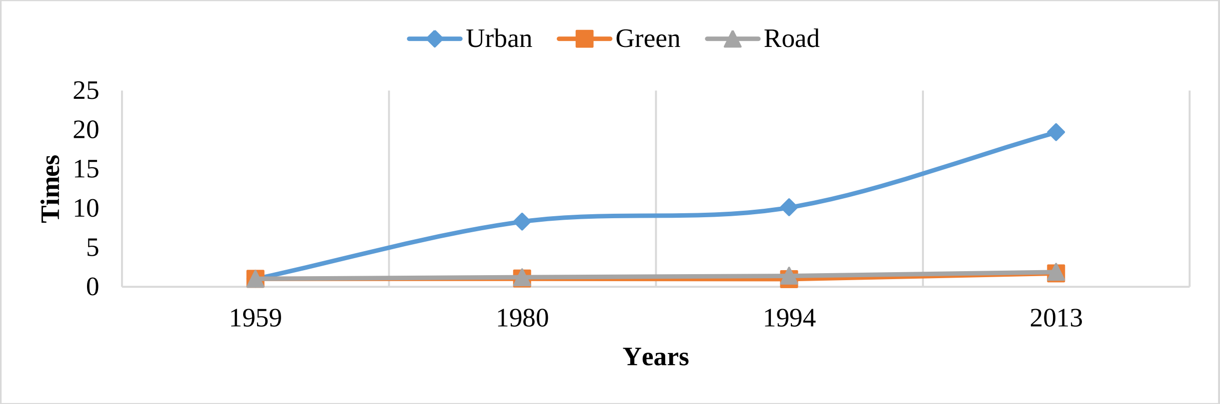

Figure 1.4. Areal Ratio with Respect to Late 50s

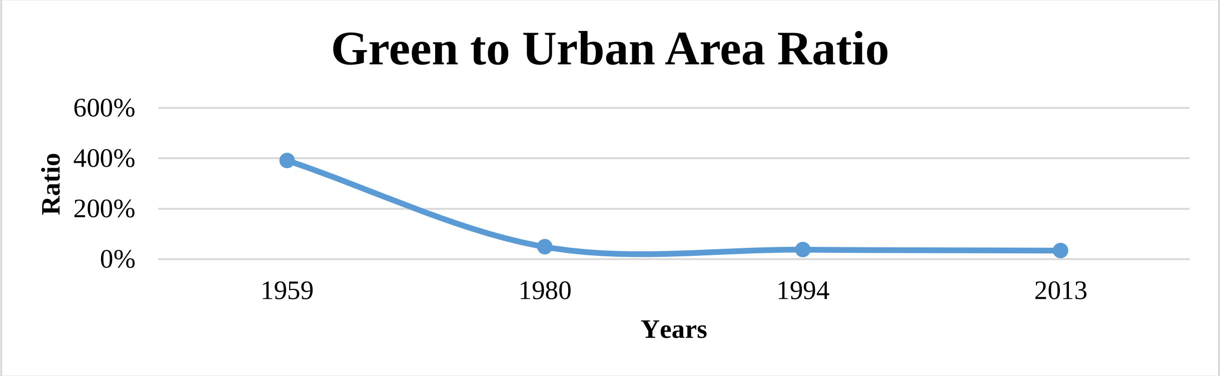

Figure 1.5. Ratio of Green Area with Respect to Urban Area

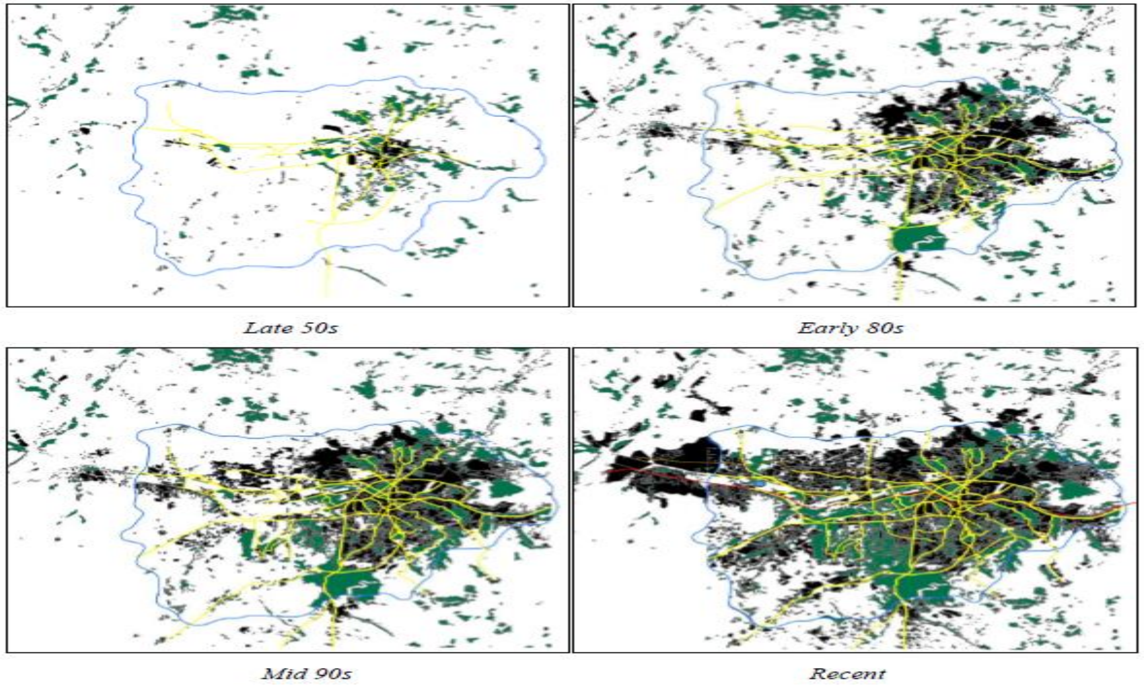

Figure 1.6. Last 60 Years Urban Transformation of Ankara (Black=Urban, Green=Green Areas)

Type	Area m²	Runoff Coefficient
Building (Roof)	51,629	0.95
Car Park	18,500	0.95
Landscaped Area	4,650	0.50
Green Area	16,500	0.30
Asphalt-Sub-Ballast	149,000	0.95
Slab on Grade	49,000	0.95
Undevelopped	5,272	0.30
Potential Development Area	47,449	0.95
Composite Runoff Coefficient		**0.90**

Table 1.1. Cover Types and Runoff Coefficient – Pilot Study Area

- The outputs produced from the land cover change maps showed that urban areas exhibited a very high rate of increase, especially after 1960s for Ankara.
- After 80s, the rural population started to decline and for the recent years the rural population is almost became negligible for the demographic statistics. This decline in the rural population is one of the significant reasons that cause an increase in the urban population.

Pilot Study (Etimesgut Complex)

	%0-%20	%20-%40	%40-%60	%60-%80	%80-%100
St Mpi 4.5	87%	12%	0%	0%	0%
St Gfdl 4.5	85%	13%	1%	0%	0%
St Hg 4.5	83%	15%	2%	0%	0%
Nst Mpi 4.5	87%	12%	0%	0%	0%
Nst Gfdl 4.5	86%	13%	1%	0%	0%
Nst Hg 4.5	83%	15%	2%	0%	0%
St Mpi 8.5	80%	14%	6%	0%	0%
St Gfdl 8.5	98%	2%	0%	0%	0%
St Hg 8.5	97%	3%	0%	0%	0%
Nst Mpi 8.5	80%	14%	6%	0%	0%
Nst Gfdl 8.5	98%	2%	0%	0%	0%
Nst Hg 8.5	97%	3%	0%	0%	0%
St Obs 2 Years	69%	18%	9%	4%	0%
Nst Obs 2 Years	69%	18%	8%	4%	0%
Baseline Design	69%	19%	8%	4%	0%

Table 1.2. Percent Fullness of Models without Pipe Revision - **Case 1**

	%0-%20	%20-%40	%40-%60	%60-%80	%80-%100
St Mpi 4.5	85%	13%	1%	0%	0%
St Gfdl 4.5	83%	14%	3%	0%	0%
St Hg 4.5	81%	13%	6%	0%	0%
Nst Mpi 4.5	85%	13%	1%	0%	0%
Nst Gfdl 4.5	83%	14%	3%	0%	0%
Nst Hg 4.5	81%	13%	6%	0%	0%
St Mpi 8.5	76%	16%	7%	1%	0%
St Gfdl 8.5	97%	3%	0%	0%	0%
St Hg 8.5	97%	3%	0%	0%	0%
Nst Mpi 8.5	76%	16%	7%	1%	0%
Nst Gfdl 8.5	97%	3%	0%	0%	0%
Nst Hg 8.5	97%	3%	0%	0%	0%
St Obs 2 Years	66%	19%	9%	6%	1%
Nst Obs 2 Years	66%	19%	9%	6%	1%
Baseline Design	65%	20%	9%	4%	2%

Table 1.3. Percent Fullness of Models Without Pipe Revision-Climate Change and Land Use Change (C=0,90) - **Case 3**

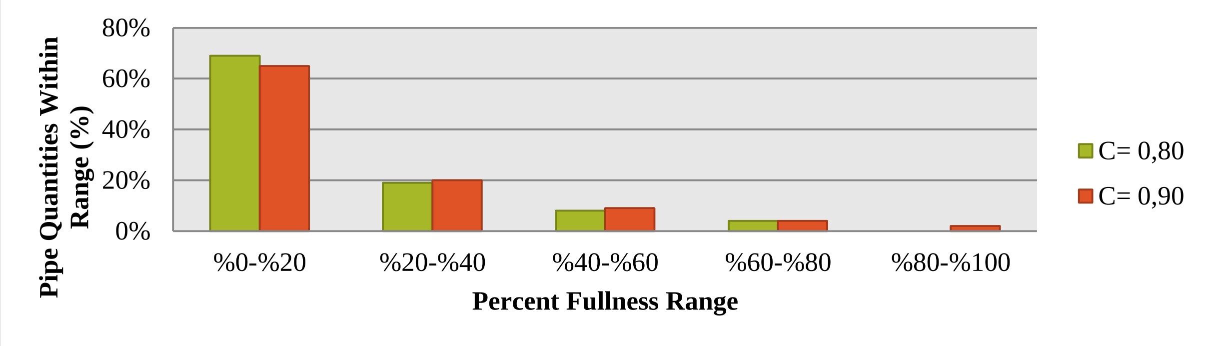

Figure 1.7. Baseline Design Percent Fullness – C=0.8 and C=0.9 - **Case 2**

Pilot Study (Etimesgut Complex)

	%0-%20	%20-%40	%40-%60	%60-%80	%80-%100	#of >90
St Mpi 4.5	67%	11%	10%	10%	2%	1
St Gfdl 4.5	67%	6%	11%	11%	5%	1
St Hg 4.5	67%	6%	11%	11%	6%	1
Nst Mpi 4.5	68%	12%	10%	9%	1%	0
Nst Gfdl 4.5	67%	6%	11%	11%	5%	1
Nst Hg 4.5	67%	6%	12%	10%	5%	0
St Mpi 8.5	64%	7%	15%	11%	2%	1
St Gfdl 8.5	71%	7%	11%	9%	2%	0
St Hg 8.5	70%	6%	10%	10%	4%	2
Nst Mpi 8.5	64%	8%	15%	11%	2%	1
Nst Gfdl 8.5	71%	7%	11%	9%	2%	0
Nst Hg 8.5	70%	6%	10%	10%	4%	2
St Obs 2 Years	59%	8%	15%	14%	4%	1
Nst Obs 2 Years	60%	7%	16%	14%	3%	0
St Obs 5 Years	52%	10%	16%	15%	7%	2
Nst Obs 5 Years	53%	11%	14%	17%	6%	1

Table 1.4. Percent Fullness of Models with Pipe Revision-Climate Change - **Case 4**

	%0-%20	%20-%40	%40-%60	%60-%80	%80-%100	>%90	>%100
St Mpi 4.5	67%	8%	11%	9%	5%	2%	0%
St Gfdl 4.5	66%	6%	9%	9%	10%	4%	1%
St Hg 4.5	65%	6%	9%	10%	10%	6%	1%
Nst Mpi 4.5	67%	9%	11%	8%	4%	1%	0%
Nst Gfdl 4.5	67%	5%	9%	10%	9%	4%	1%
Nst Hg4 .5	65%	7%	10%	9%	9%	5%	0%
St Mpi 8.5	62%	7%	9%	14%	7%	2%	0%
St Gfdl 8.5	70%	6%	10%	10%	4%	1%	0%
St Hg 8.5	69%	6%	10%	7%	7%	4%	1%
Nst Mpi 8.5	62%	8%	10%	14%	6%	2%	0%
Nst Gfdl 8.5	71%	6%	9%	10%	5%	2%	0%
Nst Hg 8.5	69%	6%	10%	7%	7%	4%	1%
St Obs 2 Years	56%	11%	9%	13%	11%	4%	0%
Nst Obs 2 Years	56%	10%	10%	13%	10%	4%	0%
St Obs 5 Years	50%	11%	12%	14%	11%	7%	3%
Nst Obs 5 Years	50%	11%	12%	13%	12%	6%	0%

Table 1.5. Percent Fullness of Models with Pipe Revision-Climate Change and Land Use - **Case 5**

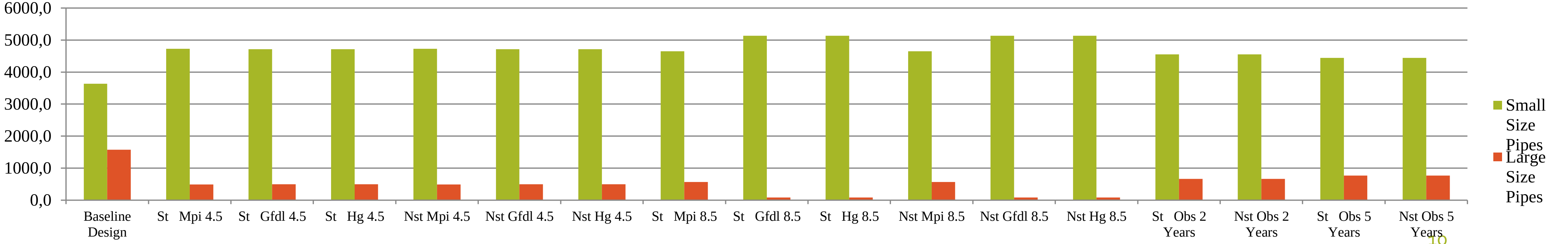

Figure 1.8. Small (Thin) vs. Large (Thick) Size Pipe Quantities – Baseline and Revised System Pipe Lengths in Meters

Pilot Study (Etimesgut Complex)

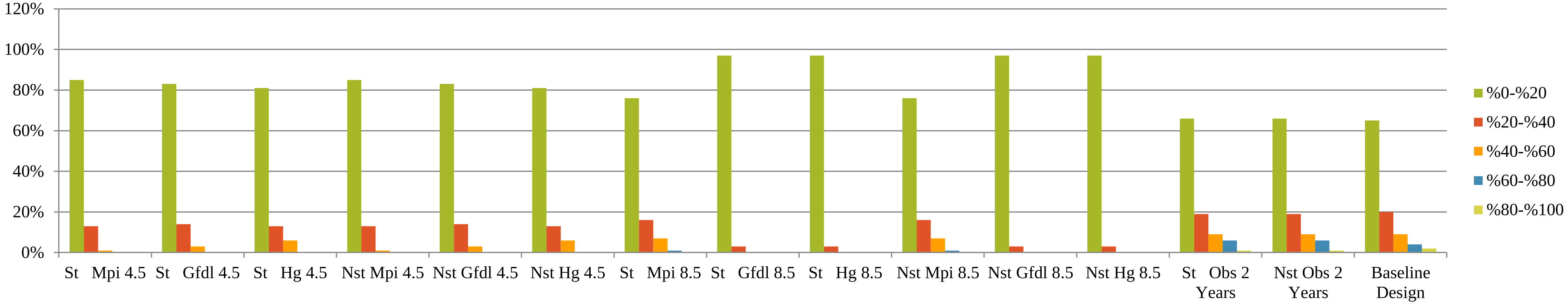

Figure 1.9. Capacity Ratio of Models Without Pipe Revision-Climate Change and Land Use Change (C=0,90)

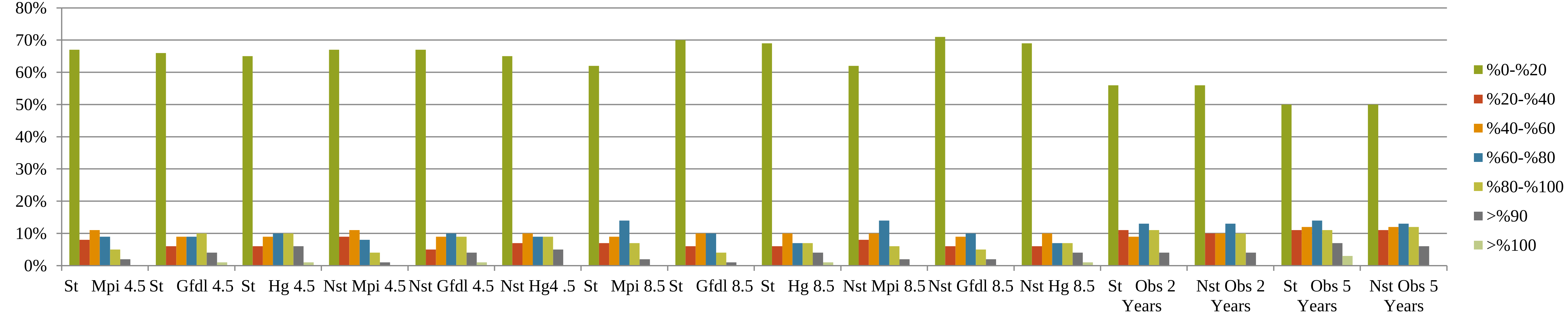

Figure 1.10. Capacity Ratio of Models With Pipe Revision-Climate Change and Land Use Change

Pilot Study (Etimesgut Complex)

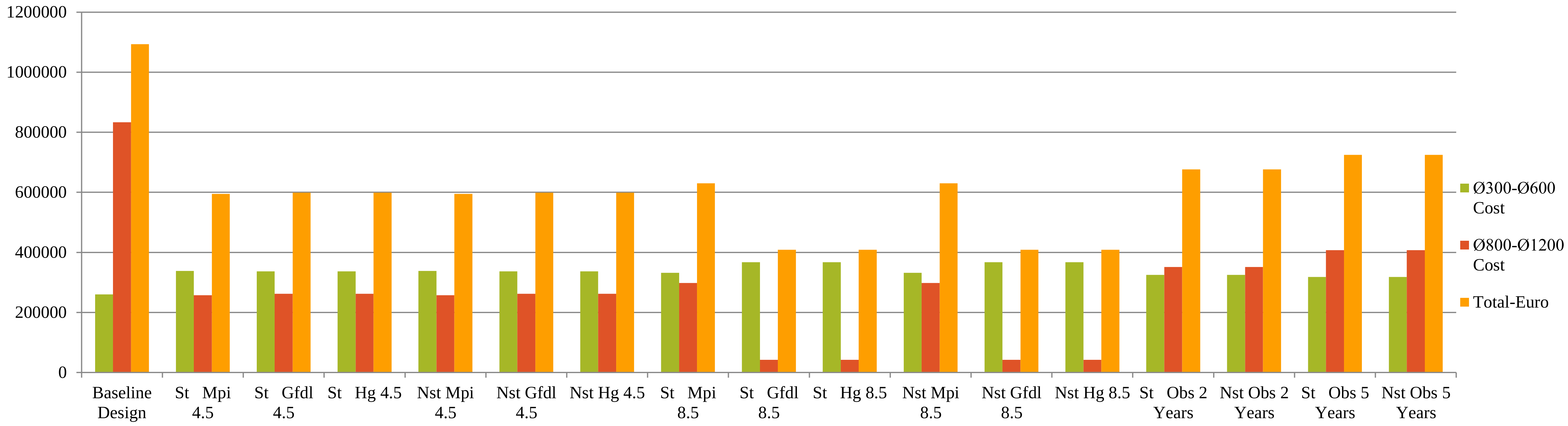

Figure 1.11. Cost Comparison of Models after Revision (in Euros)

- Total cost of models that reveal lower rainfall intensity has the lowest ones such as stationary GFDL model RCP8.5 or HG model RCP8.5.
- In general RCP4.5 results reveal higher total cost than RCP8.5 results probably because of the increasing temperature and decreasing precipitation, besides MPI model stationary and nonstationary results.
- Observed data driven design alternatives have the higher cost among the all alternatives, yet they are still lower than the existing design.

Summary and Conclusions:

- The urban area increased about 8 times in 80s compared with the late 50s and about 20 times in early 2010s when compared with the late 50s while green area increased only 2 times with respect to late 50s in Ankara province.
- The current network system in Etimesgut pilot study area can sustain its performance hence stationary observation period analyses results can be used for the design values.
- Yet nonstationary results allow to make a risk based design, by using quantiles of nonstationary return level results.
- The framework applied in this thesis can be applied anywhere (e.g. for Ankara province) since enough data is available if the extremes are the concern.

References

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