

Scheduling Renewal of Water Supply Distribution System – A Case Study in Portugal

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Approach Methodology:

1. Pipe failure analysis in two diameters segments
2. Definition of a deterioration model for each diameter segment and pipe material.
3. Each unit area (DMA) was classified according their behavior age.
4. According to the expected behavior an evaluation of the pipe whole life cost is made, for different asset life-time periods.
5. Renewal decision based on the using of the residual asset-life time that minimize the total expected costs.

DN<400

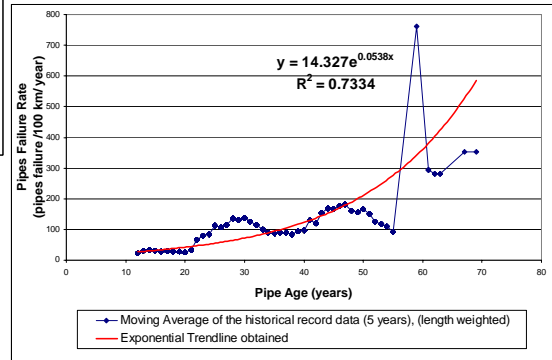
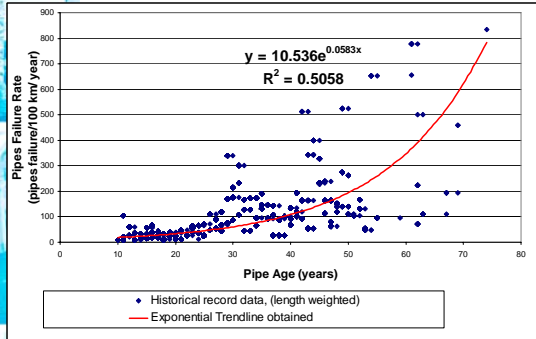
DN>=400

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DEFINITION OF A DETERIORATION MODEL

Failure analysis of Asbestos Cement pipes (DN<400)



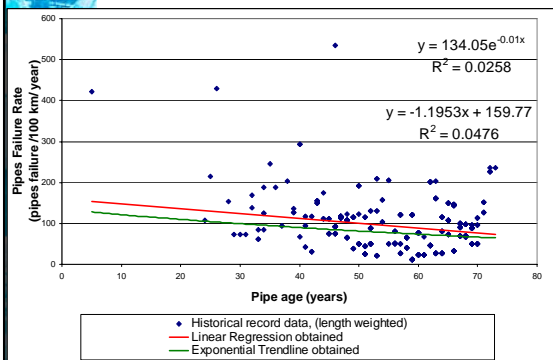
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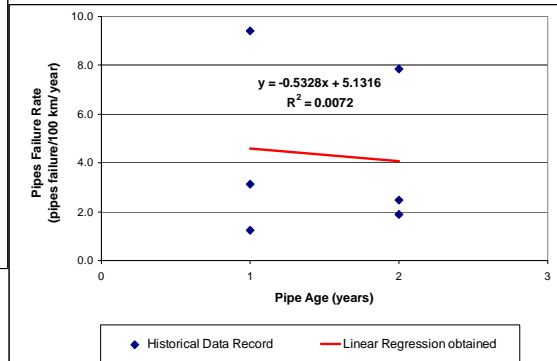
DEFINITION OF A DETERIORATION MODEL

Pipe Failure analysis (DN<400)

Grey Iron pipe (DN<400)

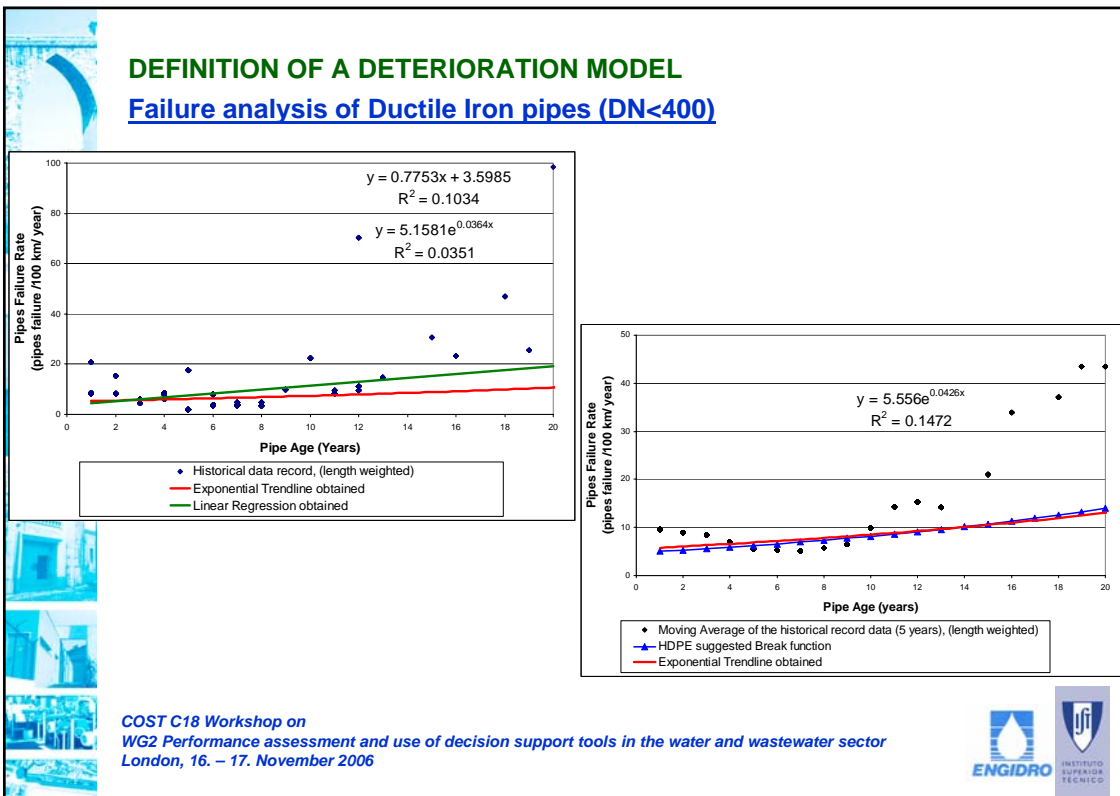
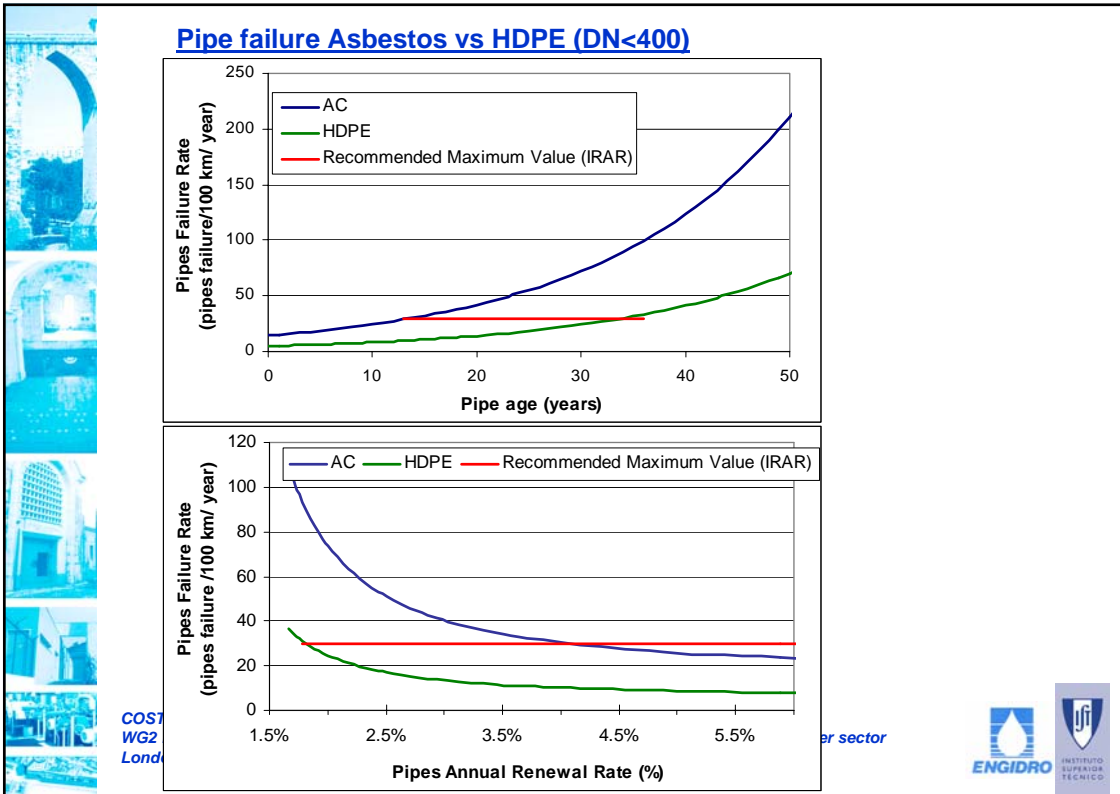


HDPE pipe (DN<400)



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Life Cycle Analysis:

Costs considered:

- Unplanned emergency intervention for pipe failure repair;
- Water volume leakage from the pipe burst;
- Indirect costs to the client caused by the water supply suspension;
- Risk of direct damages to other entities;
- Renewal investment;
- Fiscal benefits for the investment annual payment (in Portugal 27,5% of the annual amortization value).

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Life Cycle Analysis (Discounted Cash-flows)

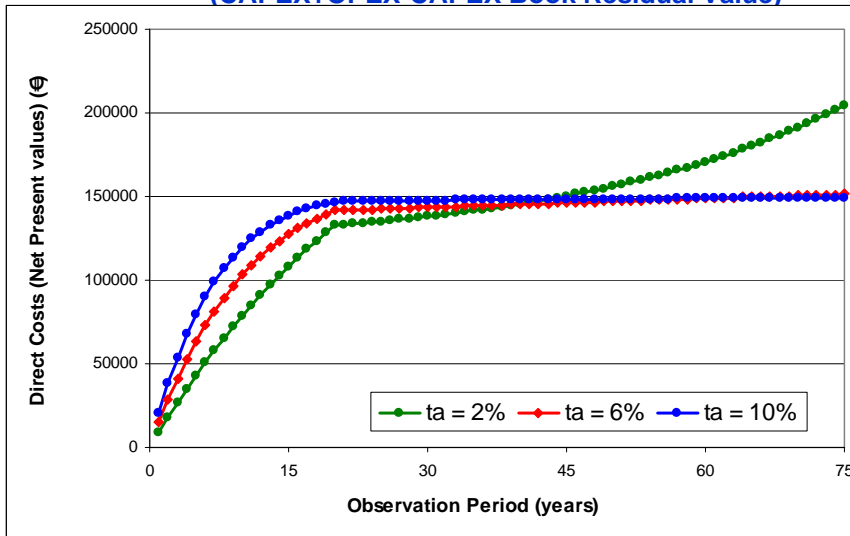
Discount Rate (effective, net of inflation) =	6.5%												
Fiscal Benefit Rate of annual depreciation =	27.5%												
Break Repair cost =	3 087 €/break												
Water Marginal Cost =	0.0701 €/m ³												
Water average sale price =	1.069 €/m ³												
Failure social cost/ Cost of affecting clients =	925 €/failure 50% GDP/capita												
	163 €/m												
Fiscal depreciation period of the Investment =	20 years												
Length of Asbestos Cement (AC) Pipes =	1.00 km												
Length of Ductile Iron (DI) Pipes =	0.00 km												
Equivalent Average Age of Asbestos Cement Pipes in the year 0 =	19 600 year												
Leakage Volume in year 0 =	19 600 m ³												
Number of Critical connections =	50 connections												
Renewal Investment =	163 000 €												
Annual Investment depreciation =	8 150 €												
	Year	1	2	3	4	5	6	7	8	9	10	11	12
Pipes Equivalent Average Age	0	1	2	3	4	5	6	7	8	9	10	11	12
Number of pipe breaks =	0.89	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.09
Leakage Volume / year (10 ³ x m ³) =	20	1	1	1	1	1	1	2	2	2	2	2	2
Number of Plomb or Niquel Connections	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational and Maintenance Costs													
Breaks Repair Costs =	2 755	156	164	173	183	193	204	215	227	239	253	266	
Water Sale Income reduction =	15	1	1	1	1	1	1	1	1	1	1	1	1
Leakage Costs =	1 374	78	82	86	91	96	102	107	113	119	126	133	
Other Costs													
Annual Cost of Plomb Connections =	0	0	0	0	0	0	0	0	0	0	0	0	0
Social Costs =	825	47	49	52	55	58	61	64	68	72	76	80	
Investment or Residual Value													
Investment =	163 000												
Annual Depreciation =	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150	8 150
Residual Value of the Investment =	163 000	154 850	146 700	138 550	130 400	122 250	114 100	105 950	97 800	89 650	81 500	73 350	
Annual Fiscal Benefit with depreciation =	0	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241	-2 241
Annual Cash Flow - Direct Costs =	163 000	-2 007	-1 994	-1 981	-1 966	-1 951	-1 935	-1 918	-1 900	-1 881	-1 861	-1 840	
Annual Cash Flow - with Externalities =	163 000	-1 961	-1 945	-1 929	-1 911	-1 893	-1 874	-1 854	-1 832	-1 810	-1 786	-1 761	
Net/ Discounted Annual Cash Flow - Direct Costs =	163 000	-1 885	-1 758	-1 640	-1 528	-1 424	-1 326	-1 234	-1 148	-1 067	-992	-921	
Net Annual Cash Flow - with Externalities =	163 000	-1 841	-1 715	-1 597	-1 486	-1 382	-1 284	-1 193	-1 107	-1 027	-951	-881	
Net Present Value - Direct Costs =	0	15 716	30 018	43 019	54 826	65 537	75 242	84 025	91 963	99 126	105 580	111 386	
Net Present Value - Costs with Externalities =	0	15 760	30 105	43 149	54 999	65 752	75 499	84 323	92 302	99 506	106 001	111 847	
Equivalent Annual Constant Payments (Direct Costs),	0	16 738	16 488	16 243	16 004	15 770	15 543	15 320	15 104	14 892	14 687	14 486	
Equivalent Annual Constant Payments (Direct Costs),	0	16 784	16 535	16 292	16 054	15 822	15 596	15 375	15 159	14 950	14 745	14 546	
Increase of the Equiv. Annual Constant Payments (Direct Costs) =	16 738	-250	-245	-239	-233	-228	-222	-217	-211	-206	-200	-199	
Increase of the Equiv. Annual Constant Payments (D. Costs + Externalities) =	16 784	-249	-243	-238	-232	-226	-221	-215	-210	-204	-199	-199	

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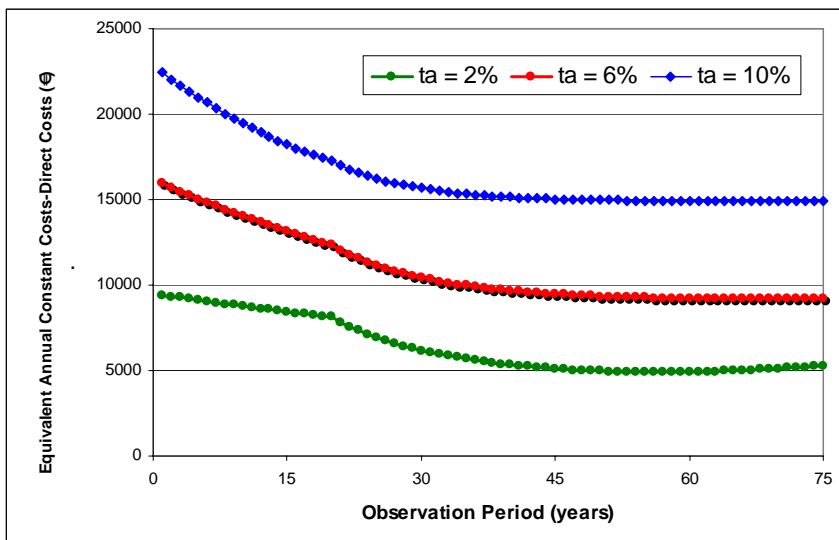
Net Present Value for different Observation Periods and discount rate (CAPEX+OPEX-CAPEX Book Residual Value)



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Equivalent Annual Constant Payments for different Observation Periods

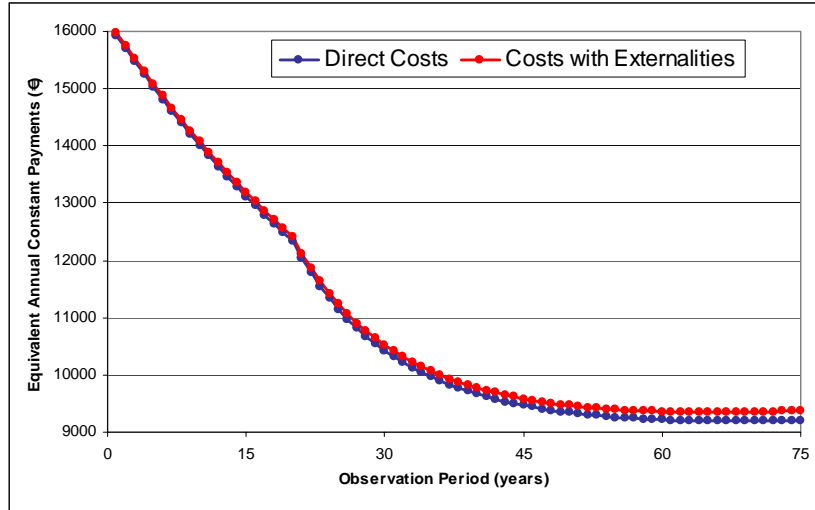


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Equivalent Annual Constant Payments (Discount rate = 6%)



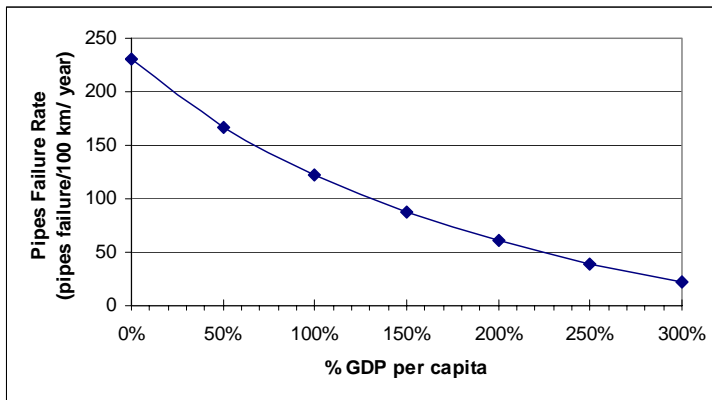
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Economic Pipes Failure Rate function Cost of affecting Clients

Ta = 6,5%

Portuguese GDP per capita



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Average Annual Pipes Renewal Effort

(Cost of affecting clients = 50% Portuguese GDP of clients affected)

T= 6.5%

AC and GI Pipes Renewal Schedule	Lenght (km)	Investment (€)	Accumulated Difference of the Pipes failure Rate (breaks /100 km/ year)	Accumulated Difference of Number of Critical Connections	Annual Renewal Lenght	
					(km/year)	(%/year)
Years 1 to 5	28.1	4 582 657	3.1	-981	7.0	0.49%
Years 6 to 10	90.8	14 815 433	2.7	-3 458	18.2	1.27%
Years 11 to 15	257.1	41 958 788	-7.9	-11 195	51.4	3.60%
Total - 15 Years	375.9	61 356 878			Annual average value	25.1 1.76%

T= 5.0%

AC and GI Pipes Renewal Schedule	Lenght (km)	Investment (€)	Accumulated Difference of the Pipes failure Rate (breaks /100 km/ year)	Accumulated Difference of Number of Critical Connections	Annual Renewal Lenght	
					(km/year)	(%/year)
Years 1 to 5	47.2	7 707 889	1.5	-1 804	11.8	0.83%
Years 6 to 10	116.4	19 008 077	-0.5	-4 599	23.3	1.63%
Years 11 to 15	212.2	34 640 911	-7.8	-11 284	42.4	2.97%
Total - 15 Years	375.9	61 356 877			Annual average value	25.1 1.76%

T= 3.5%

AC and GI Pipes Renewal Schedule	Lenght (km)	Investment (€)	Accumulated Difference of the Pipes failure Rate (breaks /100 km/ year)	Accumulated Difference of Number of Critical Connections	Annual Renewal Lenght	
					(km/year)	(%/year)
Years 1 to 5	91.6	14 949 259	-2.5	-2 825	22.9	1.60%
Years 6 to 10	131.0	21 382 189	-4.5	-7 383	26.2	1.84%
Years 11 to 15	165.2	26 967 826	-8.5	-11 821	33.0	2.32%
Total - 15 Years	387.8	63 299 275			Annual average value	25.9 1.81%

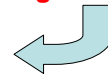
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Impact of the Annual Pipes Renewal Effort in Failure Pipes Rate:

Annual renewal extension		Accumulated difference in global pipe failure rate indicator (Pipe failure/100 km)	
		5 years	10 years
(%/year)	(km/year)		
2,0%	28,4	-5,9	-8,4
2,5%	35,5	-8,2	-13,3
3,0%	42,6	-10,5	-16,8
3,5%	49,7	-12,6	-19,7

Regulator target



Economic Annual Pipes Renewal Effort :

(Cost of affecting clients = 50% Portuguese GDP of clients affected)

T= 3.5%

AC and GI Pipes Renewal Schedule	Lenght (km)	Investment (€)	Accumulated Difference of the Pipes failure Rate (breaks /100 km/ year)	Accumulated Difference of Number of Critical Connections	Annual Renewal Lenght	
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Thank you for your attention.

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