CITY OF CAPE TOWN
COST SURFACE MODEL

USER MANUAL - VOLUME I
VOLUME II OF II
ALGORITHMS FOR COST CALCULATIONS

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1. Sewage Module

In the cost surface shapefile attribute table, there are three cost fields relating to the sewage module:

Field Name	Attribute Description & Calculation
S_convcost	The cost per site to provide "conveyance" infrastructure (i.e. sewer pipes and sewage pumpstations) for the hexagon under consideration. The conveyance cost is calculated using the following formula: S_convcost = (D x UC x F + PS) / NS Where, D = the straight line Distance from the centre of the hexagon to the nearest sewer pipe within the same treatment system. This distance is derived from a shapefile of 100m buffers that has been developed for each treatment system. UC = the Unit Cost in Rands per meter of the selected diameter pipe. The diameter used in the initial calculations was 300ND with a unit cost of R1 950 per meter. This value can be changed on Dialog 4.1: Sewage Cost Surface Generation (pg 38 of the User Manual - Volume I) F = a Factor to increase the pipe length that is being costed as a straight line length has been derived from the buffers. This value can be changed on Dialog 4.1: Sewage Cost Surface Generation (pg 38 of the User Manual - Volume I) PS = the cost of a Pump Station if required. This value can be changed on Dialog 4.1: Sewage Cost Surface Generation (pg 38 of the User Manual - Volume I). If the field is disabled then the User must change the attribute in the field "Type" in the shapefile PIPEWORK ZONES from "Gravity" to "Pumped". NS = the Number of Sites of low cost housing per Hexagon. The default value is 500.

Field Name	Attribute Description & Calculation
S_treacost	The cost per site to provide treatment capacity for the low cost housing units in the hexagon under consideration. The treatment cost is calculated using the following formula: S_treacost = (RM x SG) / 1 000 000 Where, RM = the cost in Rands per Megalitre per day of treatment capacity to construct 1Ml/day treatment capacity. The value used in the inital calculations is R7 000 000 per Ml/day treatment capacity. This value can be changed on Dialog 4.1: Sewage Cost Surface Generation (pg 38 of the User Manual - Volume I). SG = the Sewage Generation per dwelling unit in litres per day. The value used in the inital calculations is 350 litres/day. This value can be changed on Dialog 4.1: Sewage Cost Surface Generation (pg 38 of the User Manual - Volume I). Note that a treatment cost is only calculated if there is no available spare hydraulic capacity at the treatment works that services the treatment system under consideration. The capacity parameters (installed capacity, current loading and spare capacity) of the treatment systems can be defined using the fields “Installed”, “Current” and “Spare” in the attribute table of the shapefile “TREATMENT SYSTEMS”.
S_totcost	The sum of the conveyance cost and treatment cost.

2. Water Module

In the cost surface shapefile attribute table, there are four cost fields relating to the water module:

Field Name	Attribute Description & Calculation
W_truncost	The cost per site to supply water via water trunk infrastructure to the hexagon under consideration. The trunk cost is calculated using the following formula: W_truncost = (D x UC x F) / NS Where, D = the straight line Distance from the centre of the hexagon to the nearest water reticulation pipe within the same reservoir zone if there is storage capacity in the reservoir, or the straight line Distance from the centre of the hexagon to the nearest water trunk if there is no storage capacity in the reservoir. This distance is derived from a shapefile of 100m buffers that has been developed for the reticulation network or a shapefile of 100m buffers around the trunk network. UC = the Unit Cost in Rands per meter of the selected diameter pipe. The diameter used in the initial calculations was 200ND with a unit cost of R1 250 per meter. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I) F = a Factor to increase the pipe length that is being costed as a straight line length has been derived from the buffers. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I) NS = the Number of Sites of low cost housing per Hexagon. The default value is 500.
W_rescost	The cost per site to provide water storage capacity (i.e. reservoirs) for the low cost housing units in the hexagon under consideration. The storage cost is calculated using the following formula: W_rescost = (RM x WC x ND) / 1 000 000 Where, RM = the cost in Rands per Megalitre of storage capacity to construct 1Ml storage capacity. The value used in the inital calculations is R3 000 000 per Ml storage capacity. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I). WC = the Water Consumption per dwelling unit in litres per day. The value used in the inital calculations is 450 litres/day. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I).

Field Name	Attribute Description & Calculation
	ND = the Number of Days of storage capacity required. The value used in the inital calculations 2 days. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I). Note that a storage cost is only calculated if there is no available spare storage capacity in the reservoir zone under consideration. The storage capacity parameters (installed capacity, current loading and spare capacity) of the treatment systems can be defined using the fields “Capacity”, “Load” and “Spare” in the attribute table of the shapefile “RESERVOIR ZONES”. Alternatively (and as is the case for Cape Town’s model), the attribute field “Cap_Status” in the same shapefile can be populated with either “Has Spare Capacity”, “No Spare Capacity” or “Unknown Spare Capacity” as the case may be. In the later 2 instances, a storage cost will be calculated.
W_treacost	The cost per site to provide treatment capacity for water consumed by the low cost housing units in the hexagon under consideration. The treatment cost is calculated using the following formula: W_treacost = (RM * WC) / 1 000 000 Where, RM = the cost in Rands per Megalitre per day of treatment capacity to construct 1Ml/day treatment capacity. The value used in the inital calculations is R7 000 000 per Ml/day treatment capacity. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I). WC = the Water Consumption per dwelling unit in litres per day. The value used in the inital calculations is 450 litres/day. This value can be changed on Dialog 4.2: Water Cost Surface Generation (pg 44 of the User Manual - Volume I). Note that a treatment cost is only calculated if there is no available spare hydraulic capcity at the treatment works that services the water works zone under consideration. The capacity parameters (installed capacity, current loading and spare capacity) of the treatment systems can be defined using the fields “Capacity”, “Load” and “Spare” in the attribute table of the shapefile “WATER WORKS ZONES”.
W_totcost	The sum of the trunk cost, reservoir cost and treatment cost.

3. Roads Module

In the cost surface shapefile attribute table, there is one cost field relating to the roads module:

Field Name	Attribute Description & Calculation
R_totcost	The cost per site to provide an access road from the existing road network to the hexagon under consideration. The algorithm searches for the lowest cost access road by considering a route in 8 directions from the centre of the hexagon to connect into specified roads (the "Collectors" in the FEATURES shapefile. The number of rivers, railways and non-accesible roads that need to be crossed in each direction add to the cost of the road. The trunk cost is calculated using the following formula: R_totcost = the Minimum of: (RL x UC + RIC + RAC + HCC + IC) / NS x F, in northerly direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in north-westerley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in westerley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in south-westerley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in southerley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in south-easterley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in easterley direction (RL x UC + RIC + RAC + HCC + IC) / NS x F, in north-easterley direction Where, RL = the straight line Length of Road from the centre of the hexagon to the nearest "Collector" road in the direction under consideration. UC = the Unit Cost in Rands per meter of the new access road. A unit cost of R3 000 000 per km has been used. This value can be changed on Dialog 4.3: Roads Cost Surface Generation (pg 51 of the User Manual - Volume I). RIC = the cost of Crossing Rivers in order to construct the access road in the direction under consideration. Each river feature can have a a unique "crossing cost" (i.e. the cost of a bridge across the river) which can be entered in the field "Crosscost" in the attribute table of the FEATURES shapefile. An amount of R1 500 000 has been assigned as a crossing cost to each of the river features. RAC = the cost of Crossing Railway lines in order to construct the access road in the direction under consideration. Each railway line feature can have a a unique "crossing cost" (i.e. the cost of a bridge across the railway line) which can be entered in the field "Crosscost" in the attribute table of the FEATURES shapefile. An amount of R1 500 000 has been assigned as a crossing cost to each of the railway line features.

Field Name	Attribute Description & Calculation
	HCC = the cost of Crossing Highways in order to construct the access road in the direction under consideration. Each highway feature can have a a unique "crossing cost" (i.e. the cost of a bridge across the highway) which can be entered in the field "Crosscost" in the attribute table of the FEATURES shapefile. An amount of R2 500 000 has been assigned as a crossing cost to each of the highway features. IC = the Cost to construct an Intersection where the access road ties into the "Collector" feature. This cost (of R1 500 000) is only added to the total cost if RL < 1km. Both the cost and the minimum length values can be changed on Dialog 4.3: Roads Cost Surface Generation (pg 51 of the User Manual - Volume I). NS = the Number of Sites of low cost housing per Hexagon. The default value is 500. F = a Factor to modify the cost of the access road based on the terrain that the road is to be constructed over. The cost surface attribute table contains a field "Avg_Grade" that holds the average grade in percent of the hexagon under consideration. The category values for flat, rolling or mountainous terrain, together with their related factors can be changed on Dialog 4.3: Roads Cost Surface Generation (pg 51 of the User Manual - Volume I).

4. Stormwater Module

In the cost surface shapefile attribute table, there is one cost field relating to the stormwater module:

Field Name	Attribute Description & Calculation
SW_totcost	The cost per site to remove stormwater via stormwater pipe infrastructure from the lowest point of the hexagon under consideration to the nearest discharge point. The pipe cost is calculated using the following formula: SW_totcost = (D x UC x F1 x F2 x F3) / NS Where, D = the straight line Distance from the lowest point of the hexagon to the nearest discharge point (a stormwater pipe, a river or the coast line) with an elevation less than the low point of the hexagon. Should the pipe be longer than a user-specified value (entered when recalculating pipe lengths (button **d** on Dialog 4.4, pg 55 of Volume I)) then the algorithm will search for the nearest major road on the route of the generated pipe and discharge at the intersection of the pipe and road, where it is assumed that there will stormwater drainage infrastructure in place. UC = the Unit Cost in Rands per meter of the selected diameter pipe. The diameter used in the initial calculations was 450ND with a unit cost of R2 400 per meter. This value can be changed on Dialog 4.4.1: Stormwater Drainage Infrastructure(pg 56 of the User Manual - Volume I) F1 = a Factor to increase the pipe length that is being costed as a straight line. This value can be changed on Dialog 4.4.1: Stormwater Drainage Infrastructure(pg 56 of the User Manual - Volume I) F2 = a Factor to increase the cost of infrastructure due to the age / condition of surrounding infrastructure. This value can be changed on Dialog 4.4.2: Stormwater Infrastructure Condition Factor (pg 58 of the User Manual - Volume I) F3 = a Factor to increase the cost of infrastructure if discharge of stormwater is to ecologically sensitive rivers. This value can be changed on Dialog 4.4.3: Stormwater Discharge Point Sensititvity Factor (pg 59 of the User Manual - Volume I) NS = the Number of Sites of low cost housing per Hexagon. The default value is 500.

5. Electricity Module

In the cost surface shapefile attribute table, there are three cost fields relating to the electricity module:

Field Name	Attribute Description & Calculation
E_lines	The cost per site to construct electrical transmission line infrastructure to the hexagon under consideration. The transmission line cost is calculated using the following formula: E_lines = (D x UC x F) / NS Where, D = the straight line Distance from the centre of the hexagon to the nearest existing transmission line. This distance is derived from a shapefile of 100m buffers that has been developed around the transmission line network. UC = the Unit Cost in Rands per meter to construct overhead transmission lines. A unit cost of R1 000 per meter (or R1 000 000/km) has been used. This value can be changed on Dialog 4.5: Electricity Cost Surface Generation (pg 61 of the User Manual - Volume I) F = a Factor to increase the transmission line length that is being costed as a straight line length has been derived from the buffers. This value can be changed on Dialog 4.5: Electricity Cost Surface Generation (pg 61 of the User Manual - Volume I) NS = the Number of Sites of low cost housing per Hexagon. The default value is 500. Transmission line costs are only calculated in areas in which there is no existing substation coverage. The substation coverage is a theoretical area to which the substation can provide electricity based on it's firm capacity, the density of dwelling units and the load density (i.e. kVA per hectare).

Field Name	Attribute Description & Calculation
E_subs	The cost per site to provide electrical substation capacity for the low cost housing units in the hexagon under consideration. The substation cost is calculated using the following formula: E_subs = CC / 30 000 000 * LD * 1 000 Where, CC = the Capital Cost in Rands of a new substation with a 30 MVA transformer (30 000 000 VA transformer). The value used in the inital calculations is R15 000 000 for the substation. This value can be changed on Dialog 4.5: Electricity Cost Surface Generation (pg 64 of the User Manual - Volume I). LD = the Load Density per dwelling unit in kVA per day. The value used in the inital calculations is 2 kVA / unit. This value can be changed on Dialog 4.5: Electricity Cost Surface Generation (pg 64 of the User Manual - Volume I). New substation costs are only calculated in areas in which there is no existing substation coverage. The substation coverage is a theoretical area to which the substation can provide electricity based on it's firm capacity, the density of dwelling units and the load density (i.e. kVA per hectare).
E_totcost	The sum of the transmission line cost and substation cost.

6. Transportation Cost Module

In the cost surface shapefile attribute table, there is one cost field relating to the transportation costs module:

Field Name	Attribute Description & Calculation
Trans_cost	The average cost per person to travel to their place of work is calculated using the following methodology: Each of the 6 560 hexagons is considered with each of the 52 macro traffic zones and the following calculation is performed for each of the resultant 340 000 routes. Trans_cost = ((D x PP x MS x CM) for Private Vehicles + (D x PP x MS x CM) for Buses + (D x PP x MS x CM) for Taxis + (DS x PP x MS x CM) for Trains + IZC for Trains) / 100 Where, D = the straight line Distance from the centre of the hexagon under consideration to the centre of the macro traffic zone under consideration. PP = the Percentage of People in the hexagon travelling to the macro traffic zone. MS = the Modal Split of people travelling from the hexagon under consideration (i.e. the percentage using private vehicle, bus, taxi and train) to the traffic zone. CM = the Cost per km to travel on each of the transport Modes. (bus and train – 40c/km, taxi – 80c/km & private transport – 160c/km) DS = the approximate distance between railway stations utilised when travelling from hexagon to traffic zone. IZC = the Intra Zone Cost to travel by taxi or bus to the nearest railway station when interzone travel is via train (which itself comprises a distance, a modal split and a cost per mode).