Introduction to the GIS-based Priority Mapper

Integrating InfoHarvest's Priority Analyst with ESRI's ArcMap® GIS

Background

In 2003, InfoHarvest worked with ESRI to integrate InfoHarvest's commercial multi-criteria decision analysis (MCDA) product, Criterium DecisionPlus (CDP), with the USDA Forest Services' Ecosystem Management Decision Support (EMDS) system. The EMDS runs as an extension under ESRI's ArcMap® product and combines InfoHarvest's MCDA technology with a fuzzy logic rules engine and a scenario analysis approach.

The core of the implementation of our MCDA engine in the EMDS is the Priority Analyst engine. We are now making the Priority Analyst directly available for use in ArcMap, with a focus on prioritizing actions and visually displaying budget implications on a map. We call this integrated solution the Priority Mapper. It is implemented as an extension to ArcMap and as a geo-processing tool for use with ArcGIS's ModelBuilder.

This document provides an overview of this extended implementation by walking through a (fictitious) damage recovery example.

System Overview

The Priority Mapper supports the user in applying MCDA decision models to prioritize features on a map. Using it involves the following steps

A) Create an MCDA model using Criterium DecisionPlus
   a. Identify what is the goal in prioritizing the features
   b. Identify what criterion you need to prioritize the features
   c. Enter how import each of those criteria are in prioritizing the features
B) Obtain a Map of the area loadable in ArcMap
C) Obtain a feature class of the features you wish to prioritize – e.g., schools, river reaches
D) Create a Priortization using the Priority Mapper
   a. Associate the MCDA model with the feature set
   b. Map the attributes in the feature set to lowest criteria in the MCDA model
   c. Run the MCDA model against the feature set to prioritize the features
E) Show the prioritized features on the original map
F) Explore how changing the weights
G) Optionally see how many of these tasks could be funded when resources are finite
   a. specify a budget constraint field and
   b. the amount available to expend, and
   c. assuming highest priority features would be addressed first, have the Priority Mapper calculate which features fall within the budget
   d. see on the map which features fall within the budget
   e. Generate Budget Action list

In the next section, we follow these steps through prioritizing a fictitious dataset from New Orleans.

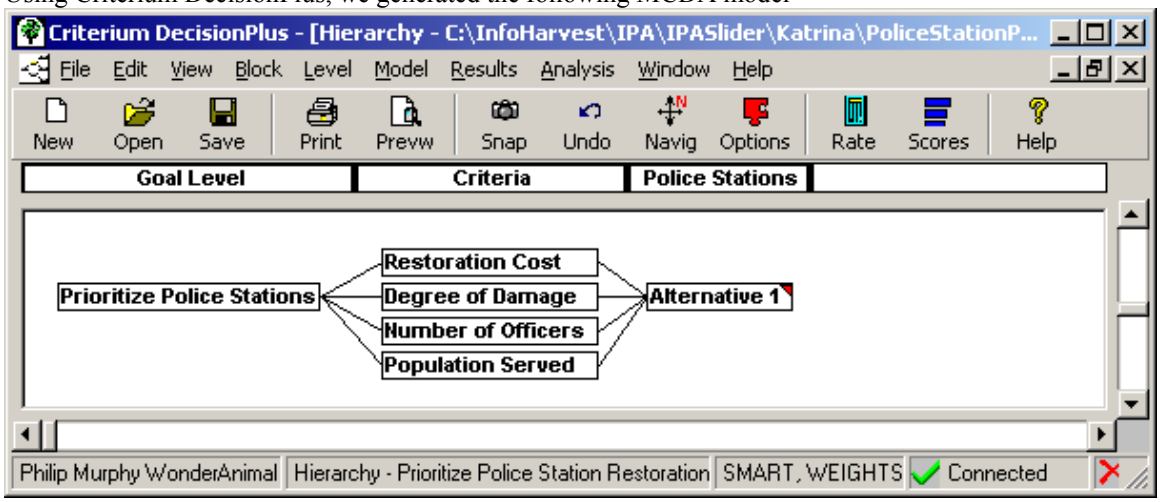
Priority Mapper Example – Prioritizing Restoration of Police Stations in New Orleans

There are over 30 police stations in downtown New Orleans that were affected by the recent hurricane. We obtained a map of their locations in New Orleans, then generated fictitious data that we imagine could easily obtained for each station. The goal is to establish a list of the stations that should be restored first, given a finite budget, and validate the list based on reviewing the locations on a map.

Note: While the location of the police stations is derived from actual maps, the data we associated with them was artificially created to show the main steps in map-based prioritization.

A) Create an MCDA model to prioritize the restoration

Using Criterium DecisionPlus, we generated the following MCDA model



The goal is identified to be to prioritize the police stations for restoration. The prioritization will be based on the number of people each station served, the number of officers supported at each station, estimates of the degree of damage received from the hurricane, and estimates restoration costs. The Criteria and the scales used to measure them are:

Criterion	Scale Units	Low	High
Restoration Cost	$K	3000	0
Degree of Damage	Degree of Damage	Undamaged	Destroyed
Number of Officers	Officers	0	100
Population Served	People	0	10000

The Criteria

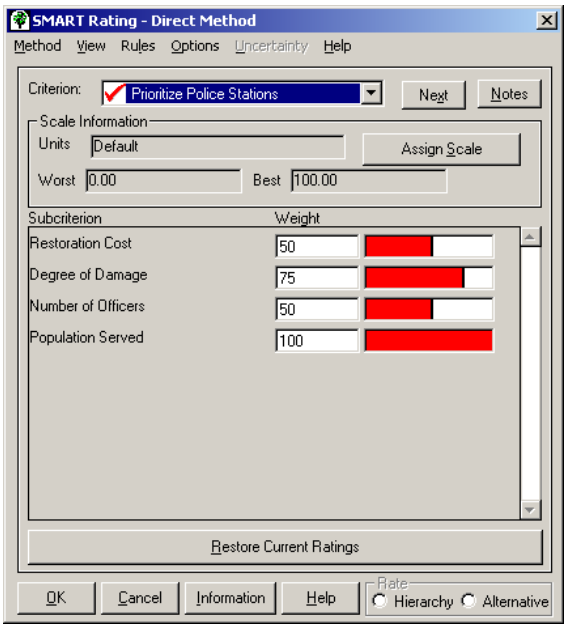
Restoration Costs represent estimates of how much money will be required to restore each police station's physical infrastructure to working order. Estimates are in thousands of dollars ($K).

The Degree of Damage criterion is assessed against an ordered qualitative scale measuring the degree of damage sustained by the buildings in the police station: {undamaged, wet, damaged, structural, destroyed}.

The Number of Officers counts the number of police officers that are based in each police station.

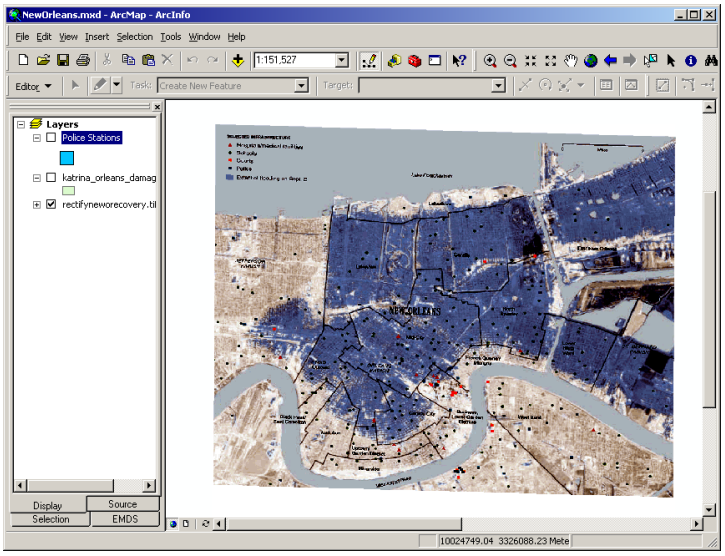
The Population Served criterion is an estimate of the number of people in the community served by the police station. This field data would typically be generated by doing a GIS analysis based on census data.

Weighting the Criteria



The importance of these criteria in prioritizing the stations for restoration was then entered. In this example the Population Served criterion was deemed the most important criterion with respect to which the Degree of Damage was considered to be 75% as important, etc.

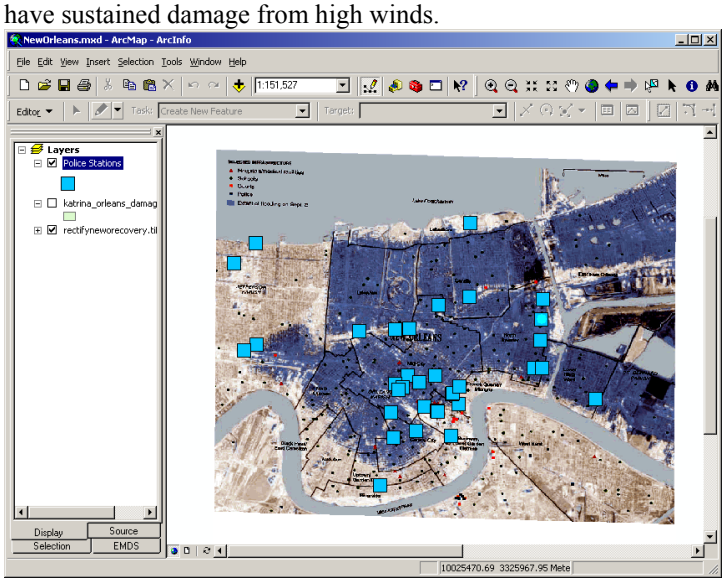
B) Obtain a Map of the area loadable in ArcMap



Using ArcMap, an aerial picture of downtown New Orleans taken on September 2nd, 2005 was geo-referenced using FEMA damage data. The flooding is shown in blue.

C) Obtain a feature class of the features you wish to prioritize

A feature class showing the location of 34 downtown police stations was obtained and overlaid on the map of New Orleans. Some stations are clearly within the flood zone, while other are clear of it, though they still may have sustained damage from high winds.



Still in ArcMap, we then added a number of attribute fields corresponding to the criteria we had identified when creating the MCDA model. We then entered sample data to populate those fields. Using ArcMap's extensive data import or table join capabilities, this data could easily have been imported from actual data sources.

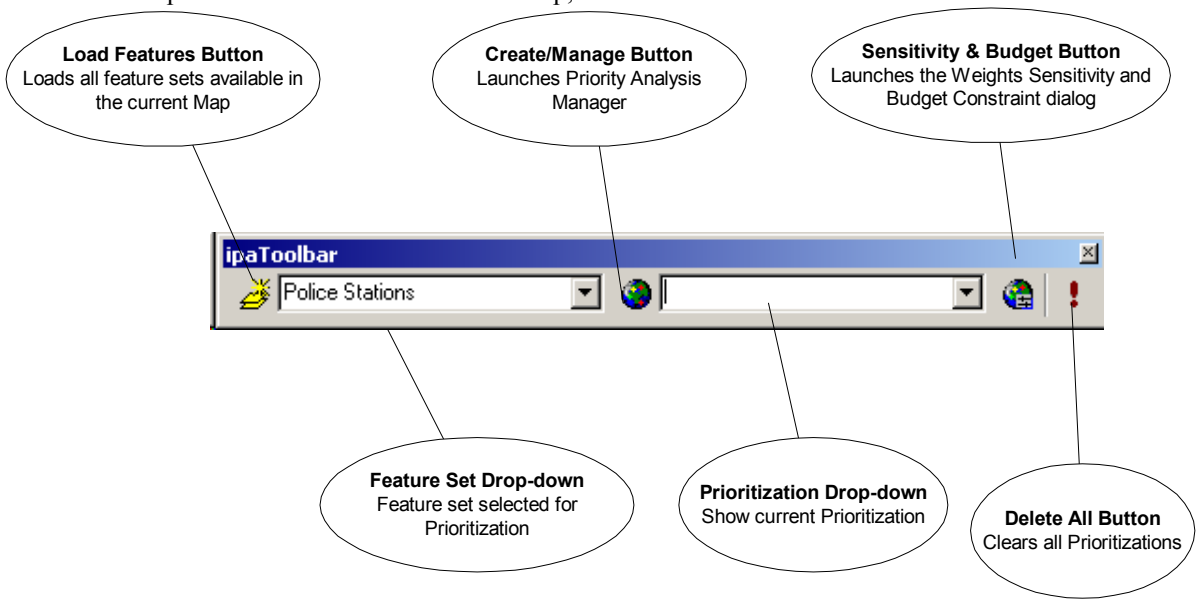
Attributes of Police Stations

OBJECTID*	SHAPE*	DamageDegree	NumberOfficers	RebuildCost	PopulationSer
6	Point	Undamaged	55	0	7500
7	Point	Undamaged	30	0	5000
8	Point	Wet	40	500	7500
9	Point	Undamaged	50	0	6000
10	Point	Undamaged	40	0	5000
11	Point	Wet	30	50	4000
12	Point	Wet	45	40	3500
13	Point	Wet	60	30	4500
14	Point	Damaged	70	750	4000
15	Point	Wet	40	60	3500
16	Point	Undamaged	30	0	4000
17	Point	Wet	25	40	1700
18	Point	Wet	20	30	1800
19	Point	Wet	40	70	2900
20	Point	Undamaged	50	0	3300

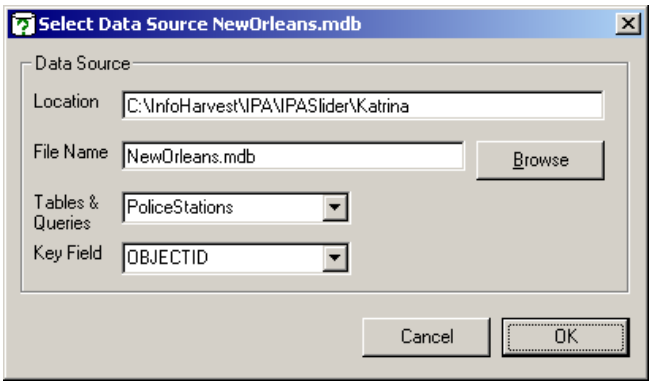
Record: 1 Show: All Selected Records (1 out of 34 Selected.) Options

D) Create a Priortization using the Priority Mapper

To start the Map-based Action Prioritizer in ArcMap, make the IPAToolbar visible.

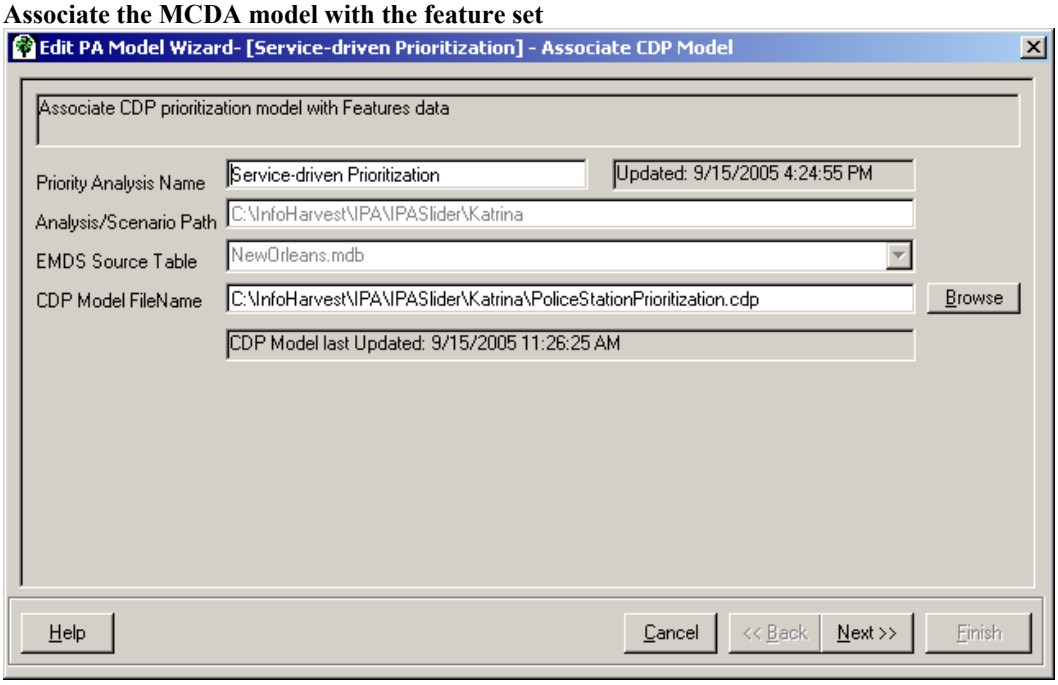


Pressing the Load Features button on the left loads all feature sets available in the map into the drop down list and selects the first available – in this case the Police Stations feature set.



Clicking the Priority Mapper Create/Manage button launches the Priority Analysis manager. The Manager first obtains the attribute database table underlying the selected feature sets, and queries the user as to which field it should use to uniquely identify each feature (Police Station). In this example the ObjectID field is created by ArcMap and its uniqueness enforced, and so is a good candidate field.

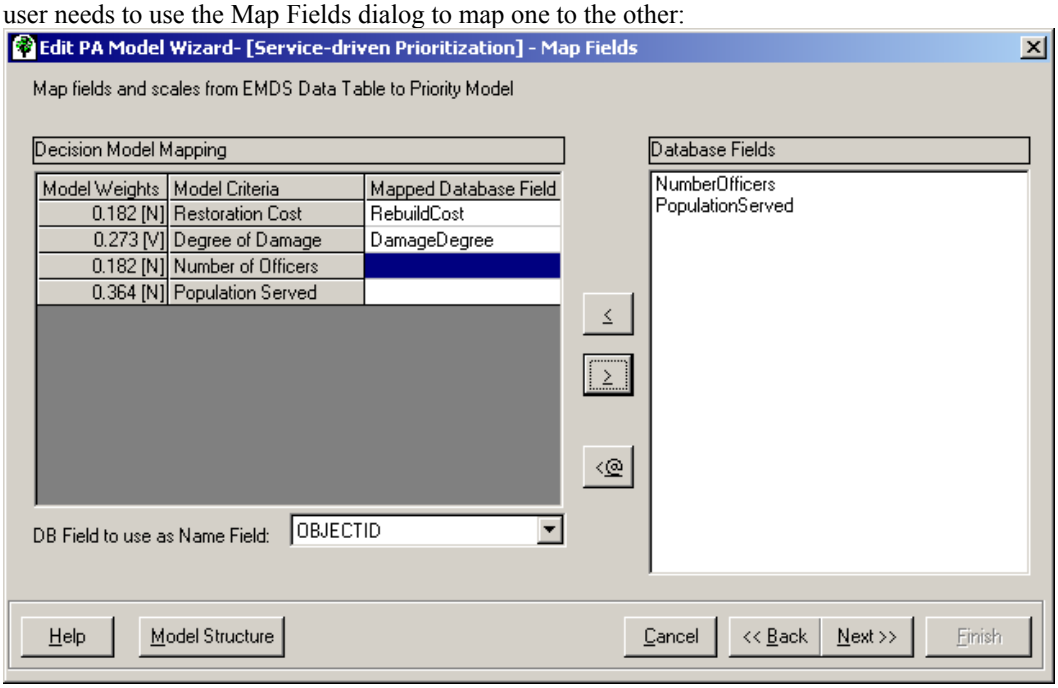
Associate the MCDA model with the feature set



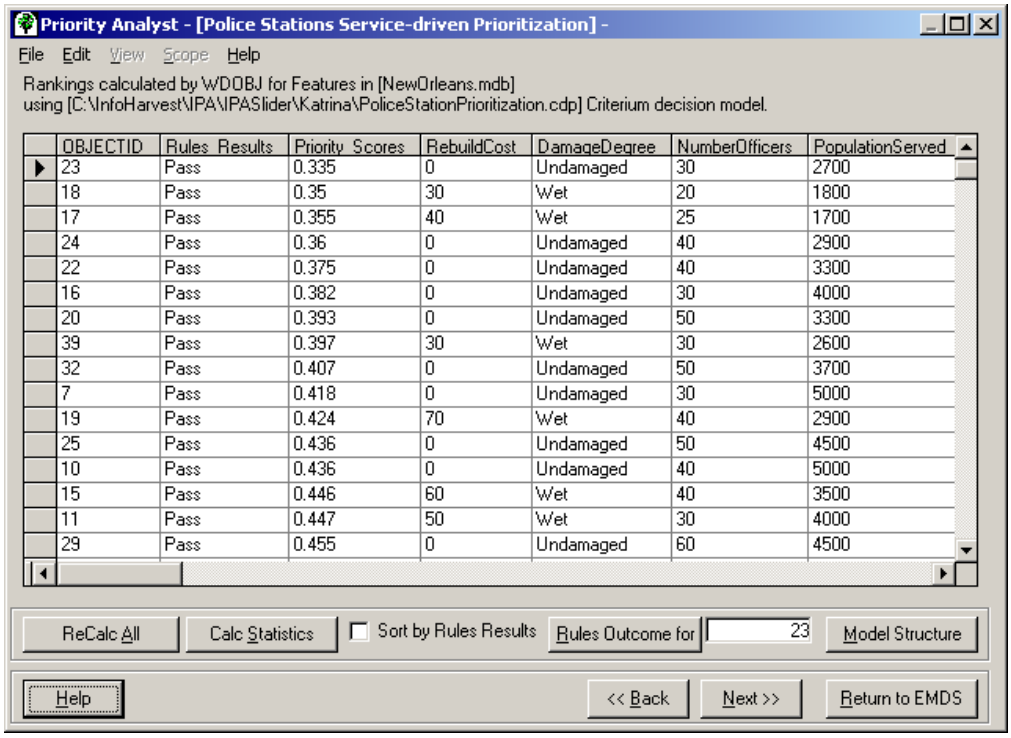
With the Police Station Feature set chosen, the systems asks you to enter a name for the prioritization, and browse for the MCDA model you wish to use for the prioritization. Knowing that the MCDA model we created gives greatest weight to the number of people served by the Police Station, we enter the name "Service-driven Prioritization".

Map the attributes in the feature set to lowest criteria in the MCDA model

As is often the case, the name of the attribute fields may differ from those in the selected MCDA model, so the user needs to use the Map Fields dialog to map one to the other:

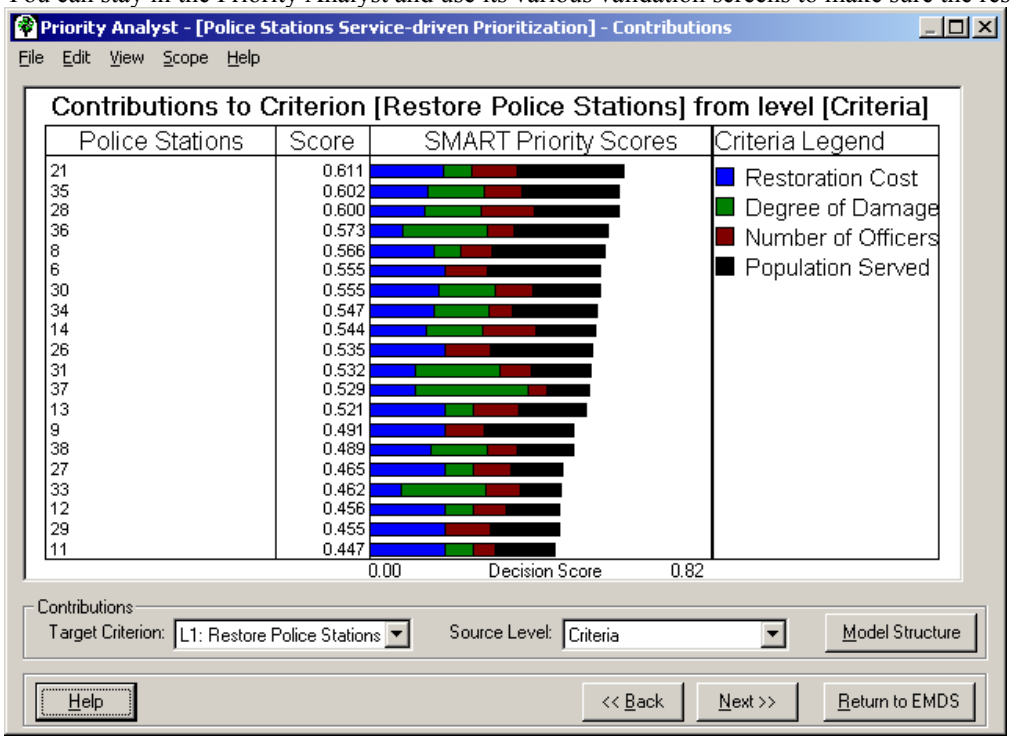


Run the MCDA model against the feature set to prioritize the features



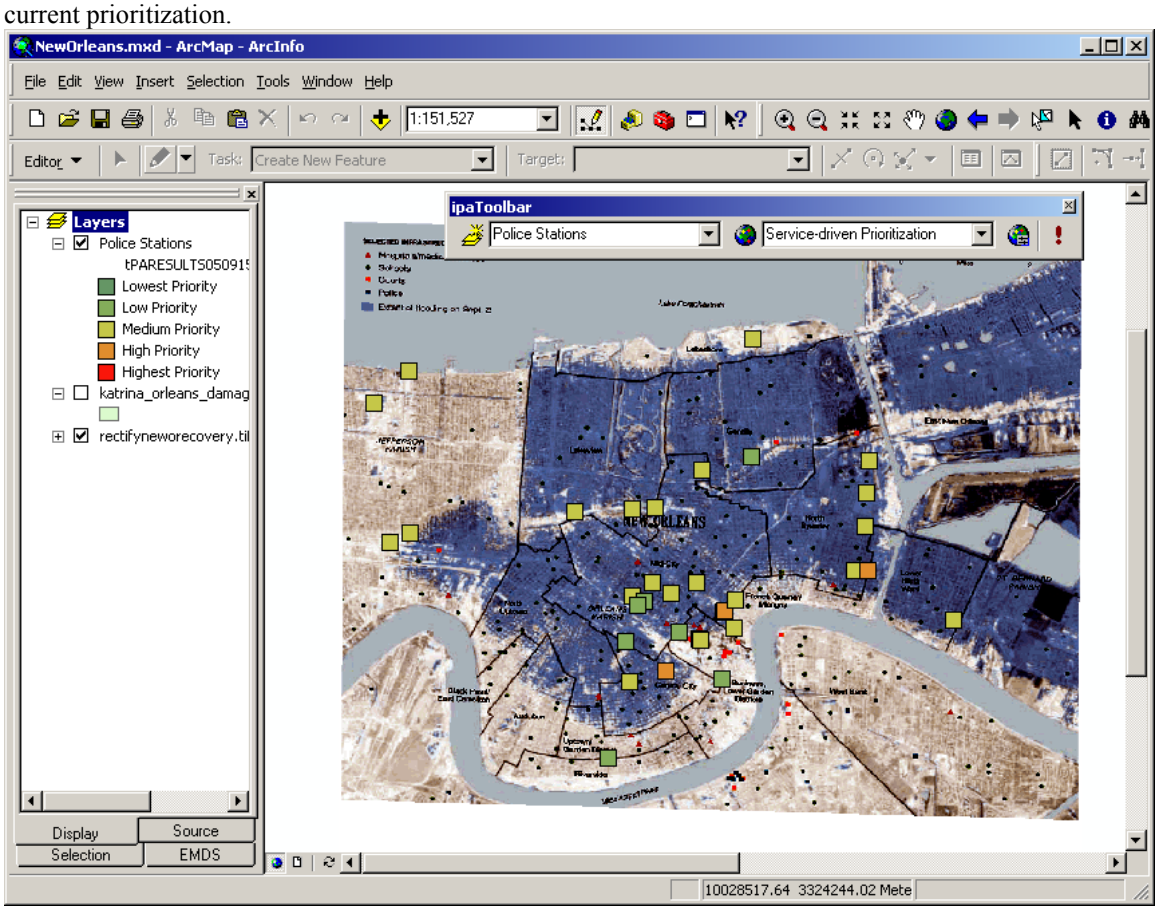
OBJECTID	Rules Results	Priority Scores	RebuildCost	DamageDegree	NumberOfficers	PopulationServed
23	Pass	0.335	0	Undamaged	30	2700
18	Pass	0.35	30	Wet	20	1800
17	Pass	0.355	40	Wet	25	1700
24	Pass	0.36	0	Undamaged	40	2900
22	Pass	0.375	0	Undamaged	40	3300
16	Pass	0.382	0	Undamaged	30	4000
20	Pass	0.393	0	Undamaged	50	3300
39	Pass	0.397	30	Wet	30	2600
32	Pass	0.407	0	Undamaged	50	3700
7	Pass	0.418	0	Undamaged	30	5000
19	Pass	0.424	70	Wet	40	2900
25	Pass	0.436	0	Undamaged	50	4500
10	Pass	0.436	0	Undamaged	40	5000
15	Pass	0.446	60	Wet	40	3500
11	Pass	0.447	50	Wet	30	4000
29	Pass	0.455	0	Undamaged	60	4500

You can stay in the Priority Analyst and use its various validation screens to make sure the results make sense.



E) Show the prioritized features on the original map

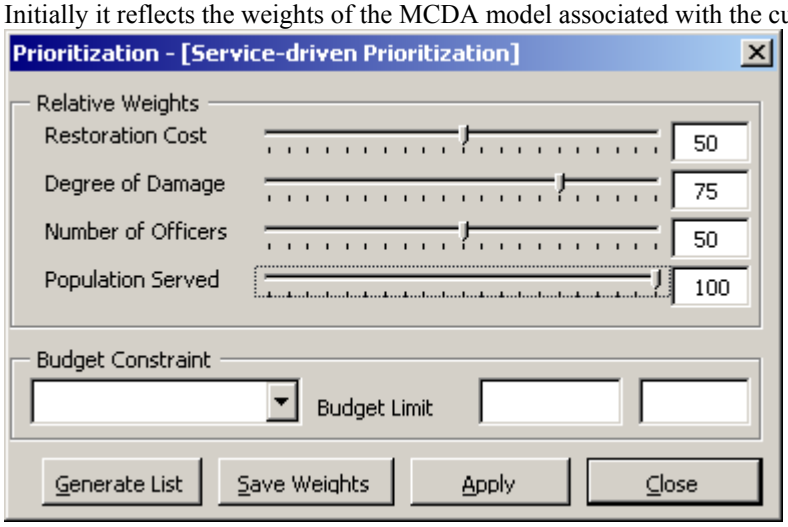
On closing the Priority Analyst Manager, the Police Station Feature set is redrawn to show the results of the current prioritization.



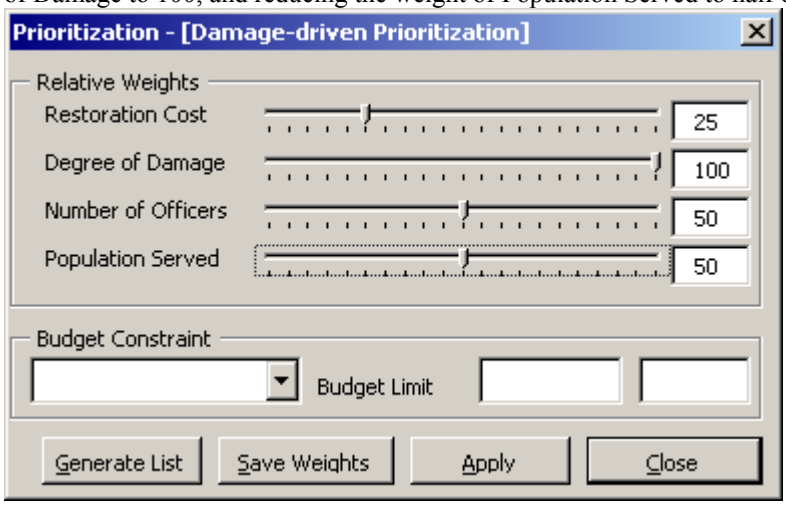
With this fictitious data, the higher priority stations appear in the flooded, more populous areas.

F) Explore how changing the weights affects Prioritization

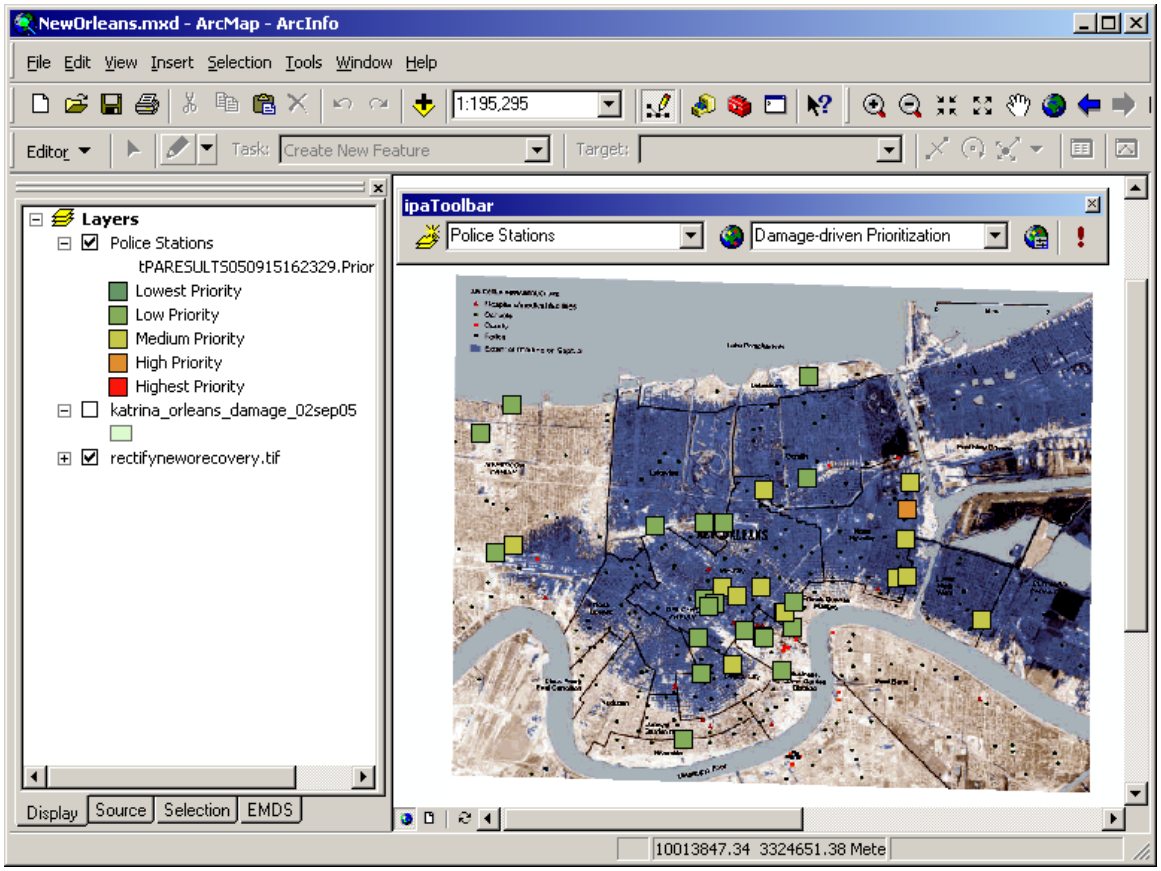
On clicking the Sensitivity and Budget Button, a dialog appears in which you are able to vary the weights. Initially it reflects the weights of the MCDA model associated with the current prioritization.



Changing the weights to a more damage-driven prioritization, could be achieved by setting the weight of Degree of Damage to 100, and reducing the weight of Population Served to half of that.



Clicking the Apply button would produce the following Prioritization on the map:



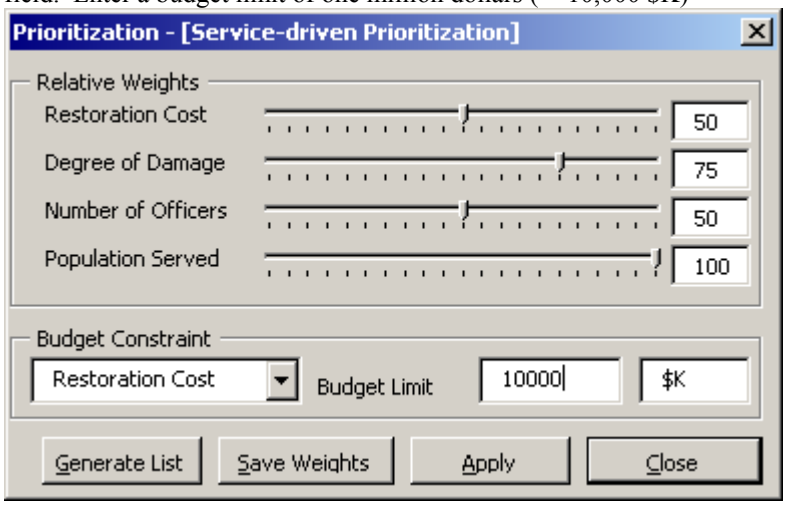
Most stations would be of medium priority, and more scattered throughout the flood area, with less correlation with populations served.

G) Optionally see how many of these tasks could be funded when resources are finite

In many cases we are prioritizing features in anticipation of taking action with respect to them (e.g., disaster recovery, habitat restoration, threat reduction, school building improvements). But usually there are constraints in terms of resources available. The Map-based Action Prioritizer supports budget development visually on a map.

Identify the Constraint field and enter budget limit

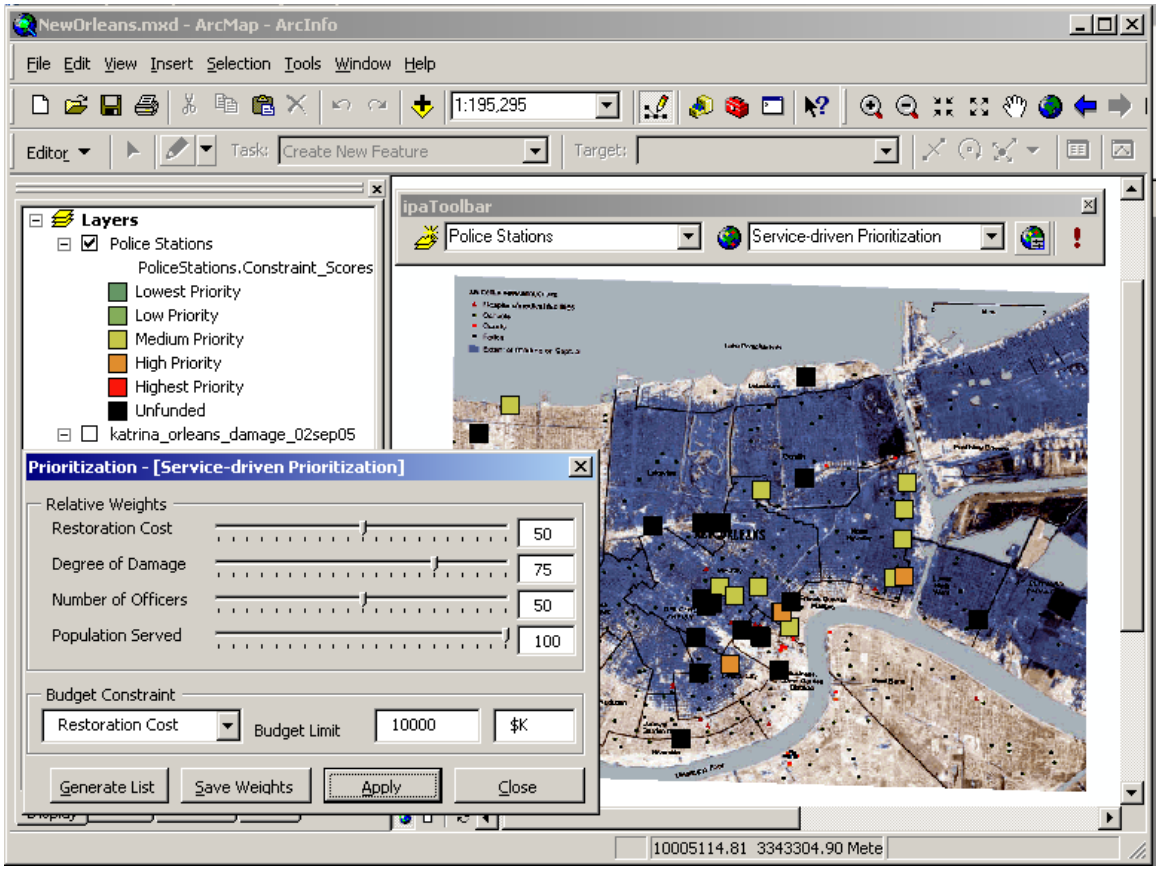
Click on the Sensitivity and Budget button again and select Restoration Cost as our constraint (limited resource) field. Enter a budget limit of one million dollars (= 10,000 $K)



Calculate which features fall within the budget

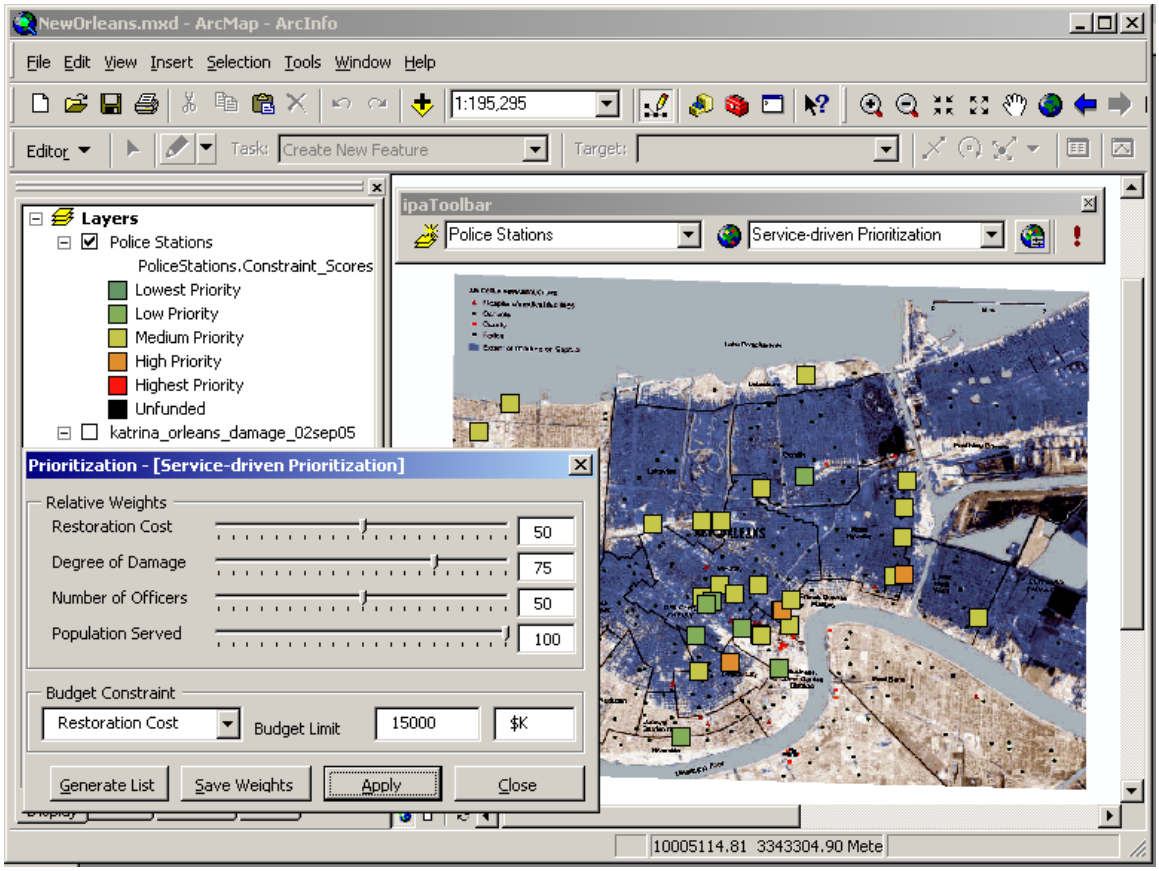
Click the Apply button to have Priority Mapper run down the list of features from high priority to low, until the budget limit is reached.

See on the map which features fall within the budget



Police Stations whose is priority is sufficiently low that they do not make the budget cut are indicated in black.

Were the budget cap to be increased to $1.5 million, all of the low priority stations could also be restored:



Generate Budget Action Report

Clicking the Generate List button copies the prioritized list and budget information to the clipboard.

Police Stations Included in a budget of 10000 $K

OBJECTID	Restoration Costs	Priority_Scores	Resource Usage (K$)
21	100	0.61	100
28	800	0.6	900
35	700	0.6	1600
36	1700	0.57	3300
8	500	0.56	3800
6	0	0.55	3800
30	300	0.55	4100
14	750	0.54	4850
34	500	0.54	5350
26	0	0.53	5350
31	1200	0.53	6550
13	30	0.52	6580
37	1200	0.52	7780
9	0	0.49	7780
38	600	0.48	8380
27	40	0.46	8420

Police Stations Excluded in a budget of 10000 $K

OBJECTID	Restoration Costs	Priority_Scores	Resource Usage (K$)
33	1800	0.46	10220
12	40	0.45	10260
29	0	0.45	10260
11	50	0.44	10310
15	60	0.44	10370
10	0	0.43	10370
25	0	0.43	10370
19	70	0.42	10440
7	0	0.41	10440
32	0	0.4	10440
20	0	0.39	10440
39	30	0.39	10470
16	0	0.38	10470
22	0	0.37	10470
24	0	0.36	10470
17	40	0.35	10510
18	30	0.35	10540
23	0	0.33	10540

Summary

InfoHarvest's Priority Mapper supports users in quickly applying the science of multi-criteria decision making to features on a Map. It helps the user understand the effects of the weightings they entered in the MCDA model on the resulting prioritization. When resources are finite, it helps the user visualize the geographic impact of both the prioritization and the resource limits. It is particularly useful in helping prioritize large numbers of features for inclusion in a budget. By providing a quick, transparent approach to prioritization, Priority Mapper supports timely, even-handed way for non-programmers to develop and communicate prioritizations of actions, assets or tasks.