

CR-Site: An Infrastructure Siting Tool for Crisis Response

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ABSTRACT

Many crisis response and recovery efforts require choosing locations in order to deliver needed materials and services. Automated methods can help choose optimal locations for relief camps, field hospitals, command centers, and other critical relief infrastructure. However, current information technology tools for siting relief infrastructure suffer from exposing too much complexity to the user. We are developing a tool, CR-Site, which we hope will serve as an exemplar of an emergency siting tool that eliminates unnecessary complexity, while exposing necessary parameters. In this paper, we describe the technical design and user workflow for CR-Site and provide a case study for the functionality provided by CR-Site.

Keywords

Siting Tool, Disaster Relief, Infrastructure, GIS, ModelBuilder, Python

INTRODUCTION

GIS (Geographic Information Systems) analytical tools have proven to be beneficial in many siting tasks, including those with crisis response requirements (Murray, 2010). However, developing complex geospatial procedures in time critical environments can severely reduce the type and quality of analytical products that are produced (Zerger and Smith, 2003). The fundamental goal for the development of this prototype tool, CR-Site, is to provide a simple yet powerful model that will support end users in making informed and objective decisions in selecting the most appropriate locations for infrastructure needed in disaster response and humanitarian relief. CR-Site will be structured for users with limited GIS experience while allowing customization by more advanced users, so that both groups can improve their decision making process by using the geospatial output (Abbas, Srivastava, Tiwari, and Bala Ramudu, 2009). Users will have the option to use pre-loaded global geospatial datasets, or load their own response-specific input layers, and the tool will be set up so that the user can set the criteria and importance of each of the input layers, giving them maximum control for their specific response environment. Once CR-Site has been run, it will produce a single output layer that will highlight the most suitable areas for response infrastructure, including the initial siting and re-siting of humanitarian relief camps, field hospitals, command centers, and other critical relief infrastructure. Once developed, our completed tool will be made freely available in order to stimulate the development of interactive methods of infrastructure siting for disaster response.

TECHNICAL DESIGN AND USER WORKFLOW

CR-Site will be developed so that users with limited GIS experience, as well as more experienced GIS users, will both be able to quickly and effectively use the tool to site critical infrastructure. To accomplish this, the CR-Site interface will only have a limited number of parameters and inputs that will be required, with most inputs having default values that are already populated. This setup will allow the majority of the complex geospatial operations to run in the background once the model has been initiated.

CR-Site will be developed using ESRI's ModelBuilder application, further customized with the Python programming language, and will be run as a geoprocessing tool through ESRI's ArcToolbox interface. CR-Site will be created to allow for maximum flexibility in what input layers can be used, how each of these inputs is analyzed, and how each of the inputs is weighed against the other input layers. The user interface (Figure 1),

will have three main sections: input layers, layer specific criteria, and layer weights. The only input that will be required of the user will be an Area of Interest (AOI) polygon that will dictate where the model will be run geographically. Each of the remaining inputs, criteria, and weights will be optional and will be loaded with default values that can be updated by the user if necessary. CR-Site will be deployed with global datasets that will be used as the default values for the input layers, however, the user will always have the option to replace these with their own more detailed datasets. The default input layers that will be included in this model are elevation (which will be used to generate slope), roads, ports (sea and air), streams (or other water features such as lakes or reservoirs), and land use (or land cover). There will also be two undefined input layers that could be site specific and defined by the user. Some examples of what the undefined input layers could potentially be are hospitals or other medical facilities, floodplains, land ownership, or other key geospatial features that are specific to the response effort. In addition, there will be one optional input for an exclusion layer, which when applied, will allow the user to exclude all areas of the AOI that overlap this layer.

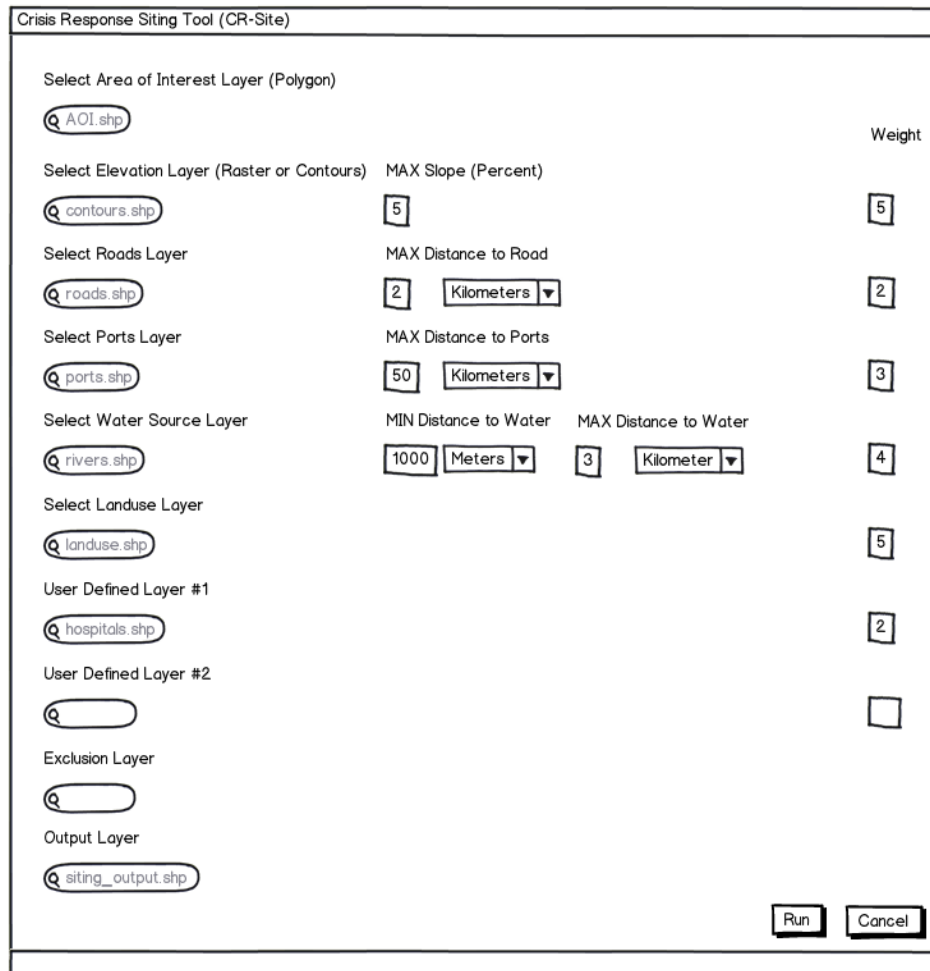


Figure 1. CR-Site User Interface

Each of the input layers (discounting the exclusion input layer) will also have two additional parameters that can be modified by the user before CR-Site is run: a layer specific criteria that will highlight what the user considers to be an acceptable value for that layer, and a weight that will dictate each layer's importance compared to the other input layers. An example of an input parameter that the user might choose to modify could be the acceptable slope of the land; for example, the user might want a slope that is less than 5%. If the user decides to edit the default weights, their inputs will not be constrained by the tool, however they will be normalized before they are applied to the model in order to produce consistent values in the output layer. One aspect of CR-Site that the user will not be allowed to edit are the ranking values that will be assigned to each of input layers; these values will vary between 10, 5, and 1 depending on the specific input layer. The ranking values will be assigned to each feature, in each of the input layers, based on whether that feature meets the user defined (or default) criteria. For example, if the user wants a slope of 5% or less, all areas that meet this condition will receive a ranking value of 10, and all other areas will receive a ranking value of 1. Table 1 highlights the parameters for each input layer, potential criteria values, ranking values, and potential weights.

Input Layers	Parameter	Example Criteria and Ranking Value	Default Weight
Elevation	Slope	Slope \leq 5% Receives Ranking of 10 Slope $>$ 5% Receives Ranking of 1	2
Roads	Distance	Distance \leq 2km Receives Ranking of 10 Distance $>$ 2km Receives Ranking of 1	2
Ports (Sea & Air)	Distance	Distance \leq 50km Receives Ranking of 10 Distance $>$ 50km Receives Ranking of 1	2
Streams	Distance	Distance \leq 3km & $>$ 1km Receives Ranking of 10 Other Distances Receives Ranking of 1	2
Land Use (Land Cover)	Type	Predefined "VALUE" field HIGH values receive ranking of 10 MODERATE values receive ranking of 5 LOW values receive ranking of 1	2
User Defined Input #1	Type	User defined " VALUE " field HIGH values receive ranking of 10 MODERATE values receive ranking of 5 LOW values receive ranking of 1	0
User Defined Input #2	Type	User defined " VALUE " field HIGH values receive ranking of 10 MODERATE values receive ranking of 5 LOW values receive ranking of 1	0
Exclusion Layer	N/A	All features included in this layer will be used to set values of overlapping areas to '0'	N/A

Table 1. Input Layers and Default Values

In order to utilize the functionality of the two undefined inputs, the user will need to load a GIS layer that has a field named 'VALUE', which will need to be populated with one of three values, HIGH, MODERATE, or LOW. The tool will then read the 'VALUE' field and apply the appropriate ranking values so the layer can be incorporated into the model.

Once all the inputs have been set and CR-Site is run, the first process in the model will be to create suitability polygons. The suitability polygons will be created by dividing up the user's AOI input layer into small areas that a total suitability value can then be calculated for. In order to allow the model to run on geographic areas of varying sizes, the size of the suitability polygons will be calculated based on the initial size of the AOI input layer. Once this is complete, the parameters and weights the user selected will be applied to each of the input layers using python programming, and then several buffer, intersect and overlay analysis methods will be applied to determine distance and overlap. When these processes are complete, the total suitability value will be calculated for each cell (suitability polygon). Table 2 highlights how the normalization process and suitability value calculations are made for an example suitability polygon. The suitability value for each of the cells will be calculated by multiplying the normalized weight by the ranking value, then summing all the suitability values to derive the total suitability for that polygon.

Input Layers	Ranking Value	User Defined Weight	Normalized Weight	Suitability Value
Elevation	10	5	0.24	2.4
Roads	1	2	0.10	0.10
Ports (Sea & Air)	10	3	0.14	1.43
Streams	10	4	0.19	1.90
Land Use (Land Cover)	5	5	0.24	1.19
Undefined Input #1 (Hospital $<$ 2 miles)	5	2	0.10	0.48
TOTALS		23	1.00	Total Suitability Value: 7.48

Table 2. Normalization Process and Suitability Calculations for Example Feature

The final output produced by CR-Site will consist of one geospatial layer that will consist of a number of polygons, each of which will have a suitability score. These siting scores will range from 0.0 (unsuitable) to 1.0

(very suitable), and will detail which areas of the AOI are most suitable for the user's infrastructure. The user will be able to identify each of the output cells (polygons) to see the individual suitability values for each of the input layers and the total suitability value for the polygon. At this point, the layer can be symbolized using the standard classification options to help the user visualize the most suitable infrastructure areas. To assist the user with the application of CR-Site, all input layers, parameters, ranking values, and weights will have full help descriptions listed in the CR-Site side panel.

CASE STUDY

A case study was developed to help visualize how each of the input layers will impact the final output layer generated by CR-Site. Since the tool itself is still in the development process, sample data from a small area was manually populated with criteria and weight values to mimic user entered values (Table 3). In this scenario, a large earthquake has just occurred, and the user needs to find locations that would be suitable for temporary housing structures. Sections 1, 2, and 3 of Figure 2 show the input layers that were used in this scenario, a user defined 'Hospital', ports, roads, streams, a user defined 'Dangerous Floodplain', slope, and land use. Section 4 shows the symbolized suitability polygons, which are based on each polygon's calculated suitability value. Section 4 of Figure 2 also shows that based on the input layers and their corresponding criteria and weights, areas near though not directly adjacent to the hospital in the center of the map (area E6), are the most suitable areas for temporary housing. In addition, section 4 of Figure 2 also shows that due to the user providing an exclusion layer (the 'Dangerous Floodplain') the polygons in the area of A8 through E6 have all been giving 0 values and would not be suitable for infrastructure placement.

Input Layers	Criteria and Ranking	Weight	Minimum Value	Maximum Value
Hospital	Within 1 mile - Ranking Value = 10 Within 2 miles - Ranking Value = 5 All other distances - Ranking Value = 1	0.1	0.1	1
Ports	Within 2 miles - Ranking Value = 10 All other distances - Ranking Value = 1	0.13	0.13	1.3
Roads	Within 1 mile - Ranking Value = 10 All other distances - Ranking Value = 1	0.1	0.1	1
Streams	Within 0.5 miles - Ranking Value = 10 All other distances - Ranking Value = 1	0.19	0.19	1.9
Slope	Slope \leq 5% - Ranking Value = 10 All other slope values - Ranking Value = 1	0.24	0.24	2.4
Land Use	Open space area - Ranking Value = 10 All other areas - Ranking Value = 1	0.24	0.24	2.4
Dangerous Floodplain	All areas overlapping floodplain layer receive Ranking Value = 0	N/A	0	0
TOTALS		1	1	10

Table 3. Case Study Criteria and Weights

CONCLUSIONS AND POTENTIAL ENHANCEMENTS

This prototype tool, when completed, will allow staff of varying experience levels to perform critical spatial analysis that can assist with the siting of relief infrastructure. It will provide an interface to allow users to customize various input parameters, set the importance of specific layers, add their own GIS data, and exclude specific regions from the study area. The final product, a geospatial layer, will rank the most suitable locations for relief infrastructure based on the informed inputs of the user. This rapid prioritization of potential infrastructure locations will allow response teams to quickly deploy critical infrastructure and initiate their relief efforts. One key consideration that needs to be kept in mind with the use of CR-Site is that it is limited by the scale and the temporality of the data (Zerger and Smith, 2003). While CR-Site will be provided with global datasets, users might want to identify what other data sources are available and needed for a region, and perform their own data collection and data conversion before an event occurs to improve the usefulness of the model (Kovel, 2000).

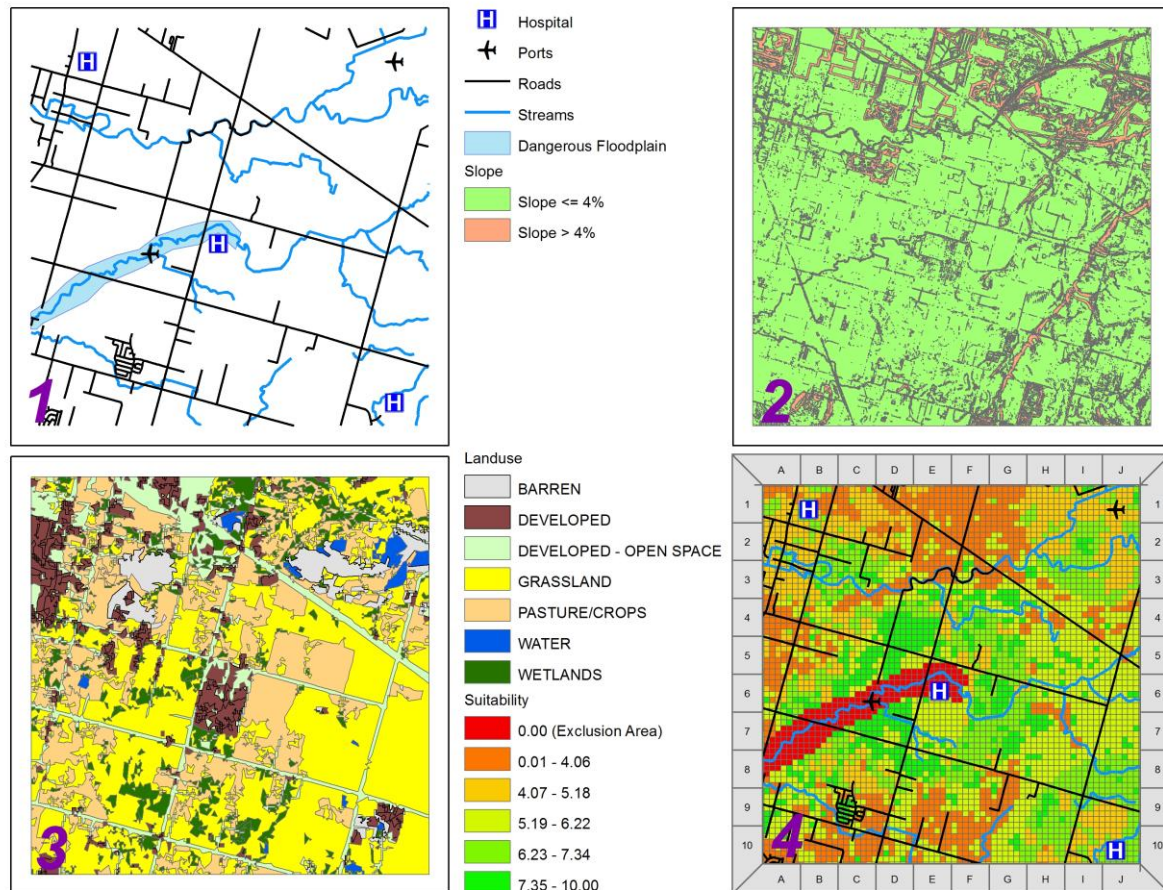


Figure 2. Suitability Case Study

Current plans for CR-Site will result in a useful tool; however, further enhancements could be made to increase the effectiveness and reach of the tool. These future enhancements could include drive-time and walk-time analysis between key geospatial features, the addition of more default geospatial layers, and allowing the user the ability to edit the currently hardcoded ranking values. CR-Site could also be turned into a web based application which would allow it to reach more users who do not have access to ESRI software, and the model could be adapted to allow users to select their AOI interactively, by drawing a point, polyline or polygon. Also, while CR-Site was designed to be run after an event has occurred, it could also be used as a planning tool to help to help assist in disaster planning scenarios. It is understood that in order to create a truly useful model, and to identify future enhancements and alterations of the tool, we will have to work closely with professionals who work in disaster response. We also plan to release CR-Site to the public, in hopes that it can assist in the development of interactive crisis response siting tools.

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