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# Harrington Desirability Function for Multi-Attribute Outdoor Space Quality Assessment

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**Abstract.** The current economy of public utilities makes it imperative for property management companies and apartment owners (landlords) to assess the quality of outdoor space near the house. This is a multidimensional phenomenon, which means it requires a special mathematical toolkit based on the Harrington desirability function. The goal hereof is to devise inputs to use the Harrington desirability function for multi-attribute outdoor space quality assessment. The research identifies the acceptable limits of outdoor space quality metrics and defines the effective range of all particular assessment parameters. One finding is that in most cases, it is appropriate to use a four-grade parametric assessment, i.e. to render each particular assessment as normative, unacceptable, acceptable, or best. The paper summarizes the inputs for multi-attribute outdoor space quality assessment by encoding the values of particular parameters into five cumulative metrics in a tabular format. Testing the proposed method shows it offers a rather easy-to-use toolkit suitable for professional and domestic use.

## 1. Introduction

Outdoor space quality is a relevant problem for the today's economy, as it affects people's social interests. Outdoor space is crucial to the urban environment each urban resident needs; as such, it is a key factor of urban development. The current economy of public utilities makes it imperative for property management companies and apartment owners (landlords) to assess the quality of outdoor space near the house.

Outdoor space quality is an integrated concept [1] that features numerous metrics: availability of playgrounds for children, cleanliness and greenspaces, sidewalk and access road condition, etc. The need to take into account such diverse set of criteria complicates any effort to generalize and quantify outdoor space quality.

Multi-attribute quality assessment of outdoor space as a multidimensional object requires special mathematical toolsets for integral assessment. The best-known tool therefor is the Harrington desirability function. The function is a widely used assessment and optimization tool in a variety of fields [2]. However, it has yet to be applied to the problems of public utilities, as the desirability function requires specific inputs: the quantitatively and qualitatively rendered quality metrics to be assessed (the particular assessment parameters); such inputs have never been sampled to date.



## 2. Statement of problem

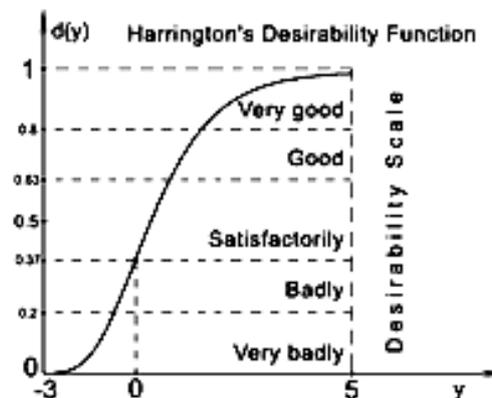
The goal hereof is to devise inputs to use the Harrington desirability function for multi-attribute outdoor space quality assessment.

This requires:

1. defining the limits of particular outdoor space assessment parameters;
2. defining the effective range of particular parametric values;
3. encoding the particular outdoor space assessment parameters in a tabular format.

## 3. Theory

The single assessment is based on a generalized desirability function (the desirability curve), which maps the natural values of the particular assessment parameters onto a dimensionless desirability scale, which is a psychophysical scale, see Figure 1. The scale aligns physical parameters (e.g. the traits of an object) with the subjective expert assessment of how desirable this or that trait is [3].



**Figure 1.** Harrington desirability function on the desirability scale.

Values on the scale are denoted as  $d$ . The desirability scale ranges from 0 to 1.  $d_i = 0$  corresponds to the 'unacceptable' value of a trait;  $d_i = 1$  is the 'best' value of the trait.  $d_i = 0.37$  is usually taken for the lowest acceptable limit.

To use the scale, set the most desirable values of the individual qualitative and quantitative metrics taken to analysis, then convert these specific particular assessment parameters into abstract numeric (encoded) values in the range of effective values  $[-2; +5]$ . Each encoded  $d_i$  value corresponds to a graduation on the desirability scale. To get a generalized metric, first set the acceptable limits ( $y$ ) for each particular assessment parameter. After converting all ( $y_i$ ) into particular desirability values ( $d_i$ ), calculate the generalized desirability factor  $D$  by the formula (1):

$$D = \sqrt[n]{d_1 \times d_2 \times \dots \times d_i \times \dots \times d_n} \quad (1)$$

The calculated generalized desirability factor is a comprehensive description of an object; it is a quantitative, unambiguous, universal, adequate, and 'neutrally' generalized metric. This effectively and easily converts a variety of metrics to a single graph that covers all the criteria.

Thus, an important step towards comprehensive assessment of outdoor spaces lies into mapping the particular parameters to a single scale and setting the acceptable limits. In other words, applying the Harrington function to the assessment of outdoor space means the input must contain the acceptable limits for all the particular assessment parameters while also specifying their effective (intermediate) values.

Earlier studies [4] identified the following cumulative outdoor space quality metrics: sidewalk and access road condition, playground condition, outdoor lighting, greenspaces, and sanitation. Each

cumulative metric combines multiple singular metrics, which are essentially the particular assessment parameters, i.e. the assessment criteria.

Acceptable limits herein are based on the regulatory framework for outdoor space maintenance and improvement [5]. For the metric of Children's Playground Availability, Clause 3.5.11 of the Rosstroy Regulations No. 170 dd. September 27, 2003 notes that each homeownership shall have playgrounds for children with sufficient greenspace and the necessary improvements for children to play at and with in summer and in winter. For this study, the requirements are encoded as follows. The 'best' value is encoded as +5, the 'worst' value is encoded as -2. The best value stands for a full compliance with the specified requirements. The worst value stands for the absence of any playground for children. Any other case will be mapped in-between to make a scalable sequence of effective values on the scale of particular assessment parameters. The codes may vary from the best to the worst value (5, 4, 3, 2, 1, 0, -2).

The interviewed officers of property management companies noted that in most cases, it would be a better solution to limit the encoding to four values: normative, unacceptable, acceptable, and the best. One factor behind such limited scaling is that regulatory framework mainly sets forth a single condition without any variance in it. For the metric above, there are two non-boundary values: 0 (normative), which means a playground is there, but it lacks improvements and greenspace; and 1, which means the playground has improvements, but no greenspace. Codes 1 to 5, which the desirability function assigns to 'good' and 'excellent' values, are impractical, as they map to the smoothed saturation segment ( $d \rightarrow 1$ ) of the desirability curve.

Pursuant to the goal hereof, analyze the process the data on each particular assessment metric. Table 1 below summarizes the encoded inputs.

**Table 1.** Particular outdoor space assessment parameters: encoded.

PAP name and number	Encoded PAP value	
	Code	Value
Dumpsters in place	5	Dumpsters are in place, stand on a concrete or asphalt platform, sheltered by standard fence of reinforced concrete or other materials, surrounded with shrubs. Repainted twice a year.
	1	Dumpsters are in place and comply with all the requirements except that they lack shrubbery
	0	Dumpsters are in place and comply with all the requirements except that they lack shrubbery. Repainted once a year.
	-1	Dumpsters are in place, are not sheltered by standard fence of reinforced concrete or other materials, not surrounded with shrubs. Repainted once a year.
	-2	Non-compliant or no dumpsters in place
Shrubbery height, m	5	Shrubs reach the lower edge of ground-floor windows
	0	Shrubs slightly above the lower edge of ground-floor windows, do not obscure sunlight
	-2	Shrubs high above the lower edge of ground-floor windows, obscure sunlight
Building-to-shrub center distance	0	1.5 m
	-2	< 1.5 m

The researchers have developed five encoding tables for each cumulative metric.

#### 4. Applicability

Research has produced inputs that can be used by the Harrington desirability function for multi-attribute outdoor space quality assessment.

Tests involved property management officers, apartment owners, and the building's Board members. For tests, the team researched the Sanitation of three apartment blocks in Vladivostok using the developed inputs, i.e. the tabular-encoded particular assessment parameters. The team further devised auxiliary tables to facilitate expert assessment; the tables had fields for rating the outdoor space quality metric by metric. For experts, the description of each field was clear, unambiguous, complete, and adequate.

This proves the feasibility of applying the Harrington desirability function to assess the quality of outdoor space; the research thus lays the foundation for a future outdoor space quality assessment method.

#### 5. Conclusions

The research identifies the acceptable limits of outdoor space quality metrics on the basis of the regulatory framework for outdoor space maintenance and improvement. The upper limit stands for a full compliance with the regulatory requirements ('the normative'). The lower limit is unacceptable.

The paper defines the effective range of particular parametric values; One finding is that unlike in other applications of the Harrington desirability function, which makes use of a full range of codes, the most appropriate solution for outdoor space quality assessment is to use a four-grade parametric assessment, i.e. to render each particular assessment as normative, unacceptable, acceptable, or best.

The paper summarizes the inputs for multi-attribute outdoor space quality assessment by encoding the values of particular parameters into five cumulative metrics in a tabular format. This is a rather easy-to-use toolkit suitable for professional and domestic use.

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