

## Design and Implementation of a GIS Model for Evaluating Iran Ecological Capabilities



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### Abstract

Ecological and potential capability of the land is frequently evaluated to create suitable bases for decision making. Environmental managers and city planners need the results of such assessments to observe the environmental sustainable development. Experiences have shown that the lack of knowledge about land potential capabilities may damage the environment severely. Various procedures have been proposed to determine the ecological and potential capabilities of lands.

This paper reviews the current models of environmental capabilities, evaluate them, and propose a new model to overcome the previous shortcomings. The governing factors of the model are first identified. Proper questioners are structured and disseminated to 750 users. The weights of the factors are identified by statistical analysis of the questionnaires and Delphi method that is a branch of phase theory. The model is then introduced to a GIS package to visualize the environmental unit maps. Sensitivity analysis is performed to determine the level of parameter sensitivity on any changes.

In order to assess the model, District 22 of Tehran, Capital of Iran, has been chosen. Ecological capability of the area for service and civil development are determined. Restricting factors such as; environmental units along rivers, flood passages, and rough terrain that hinder the areas of being developed for service and civil development usages are properly taken into account. The results showed that the points given to environmental units vary from zero to sixty five. Detail discussion on the results is presented in the paper.

**Key Words:** Ecological capabilities, Ecological map unit, GIS, Linear mathematical model, Phase theory.

## **Introduction**

Ecological and potential capability of the land is evaluated with predetermined and specific standards. These studies are considered as a basis for decision-making and planning on the land all over the world. The reason for this is the necessity of choice and desired utilization of land ecological potential in the form of environmental management and planning studies in harmony with the sustainable development principle. Evaluation of Land ecological capability is so significant that application of the design may not only prevent the improvement of the region environmental conditions but also damage the environment severely if the land potentially lacks suitable ecological capability to carry out a special usage (even in the case of great economic and social need for that usage). In recent years, evaluation of ecological capability has also been highlighted as a necessity in land use planning in Iran and this has been manifested in national social, economic and cultural programs of Islamic republic of Iran. In this research, great attempt was made to design a new model for ecological capability evaluation of Iran in order to establish service and civil development usage using general Delphi method. This new model was planned using linear mathematical model.

## **Materials and Methods**

To design the new model for service and civil development usage, first of all the required information regarding Iran ecological resources were collected according to library research. Design & analysis team prepared primary questionnaires. These questionnaires were tested for accuracy, possible errors and completion with an eye to other experts' views. While preparing questionnaires, synergic effects of ecological factors especially in Iran were noted. From among 24 types of prepared questionnaire, one of the questionnaires were edited with the purpose of coefficients determination or significance of 23 effective parameters in establishment of required usage and rest of the questionnaires were completed for value determination of each stage or frequency of these factors in establishment of service and civil development usage. Finalized questionnaires were completed by estimation of statistical universe size and according to general Delphi method principles. For this purpose 750 questionnaires were completed from Delphi group. Respondents included people with PHD (%23.09), people with MA degrees (%44.12) and people with BA degrees (%22.79). After completing the questionnaires, obtained information were analyzed using statistical software Spss 11.0 and parameters such as mode, average, variance and standard deviation in each type of questionnaires were specified. To ensure the statistical correctness in the study, the questionnaires were refilled and Delphi items were repeated in %20 Delphi group randomly. To use new linear model in evaluation of ecological capability and mapping, this model was introduced to database and geographical information system using ArcInfo GIS software. To insure the sensitivity level of desired replies to specific changes in main model, sensitivity analysis of designed model was examined using Lingo software. Ecological capability evaluation of Tehran region no. 22 to establish service and civil development usage as a case study in order to ensure the effectiveness of the new model was studied using Arcview GIS 3.2A software. For this purpose topographic map of the region was prepared from Tehran municipal GIS center. Sustainable and unsustainable ecological sources maps were prepared at a scale of 1:25000 using the Meteorological Office data, sampling and satellite pictures and was introduced to geographical information system after quantification

## Results

Various methods of ecological capability evaluation are different in type of ecological models used in them. The purpose of designing a new method for Iran service and civil development usage is gaining access to a linear mathematical model in order to study ecological capability evaluation. The most important process in designing this model is choosing a scientific approach for recognition and evaluation of effective parameters in evaluation of ecological capability. Consequently in this research Delphi method was used. Indeed this method was derived from phase methods, the most important feature of which is quantification of quality data. Questionnaires are suitable tools in this method. Delphi method is very reliable, comprehensive and easy-to-use, which can predict the effectiveness of a system by examining its conditions. The name of the method is derived from an oracle in ancient Greece, where was a forum for great thinkers of that time. This method is achieved in two ways: general and advanced. In this research, general method is chosen. Two groups perform this method: analyzer and designer team and Delphi group. First group creates questions and questionnaires and analyzes them and Delphi group merely answers the questionnaires. This method is also known as operative Delphi or traditional Delphi. The different stages of general Delphi method in this research are as follows:

1-Research: The aim of research is to study about the specific subject matter and to find a suitable research method for the desired field.

2-Forming the analysis and design team: This team is aimed to design and edit the primary and final questionnaires, reply instructions, to guide Delphi group and ultimately to analyze Delphi group replies. In this research, this team prepared 24 questionnaires and made 750 copies considering the statistical correctness.

3-Forming Delphi group: It is referred to respondent group answering the questionnaires. This group involves experts in the related field.

4-Repitition of Delphi courses: After completing the questionnaires, %20 of Delphi group refilled the questionnaires randomly.

5-Analysis of questionnaires data: Questionnaires were analyzed using Spss 11.0 software and factors such as mode, average, variance and standard deviation were calculated.

6-Delphi solution: After analyzing the questionnaires data, the results, referred to as Delphi solution, were shown as follows:

In designing a new model for evaluation of Iran ecological capabilities in order to establish service and civil development usage, the following 23 factors have to be noted:

Height from sea level (Ev), gradient percent (So), geographical orientations (As), annual humidity percent (Ch), annual average rainfall (Cp), annual average temperature (Ct), wind speed (Cw), soil changeability (Pl), soil drainage (dr), soil depth (ds), soil pebbles percent (Ps), soil granulation (Pg), soil composition (Ts), geomorphology (Gp), petrology (Mr), rock resistance coefficient to erosion (El), surface waters hydrology (Hw), underground waters hydrology (Wr), water resources quantity (liter/day) (Wl), soil hydrologic groups (Hs), preservation value of natural tree species (Tn), field condition regarding environmental authorities preservation (Cn), value of animal species (mammals) Fv.

To make these factors realizable for the geographical information system, they were introduced in code. The model for Iran ecological capability evaluation tailored to the service and civil development usage (URB) was suggested as follows: This model specifies the coefficients of factors affecting this usage:

$$URB = 0.0591 Ev + 0.0735 So + 0.0523 As + 0.0098 Ch + 0.0167 Cp + 0.0083 Ct + 0.042Cw + 0.0121 Pl + 0.0583 dr + 0.0515 ds + 0.0205 Ps + 0.0424 Pg + 0.0447 Ts +$$

$$0.0356 GP + 0.0265 Mr + 0.0326 EI + 0.0636 Hw + 0.0553 Wr + 0.0674 Wl + 0.0235 Hs + 0.0530 Tn + 0.0720 Cn + 0.0523 Fv$$

As the above model is shown, value of factors affecting Iran ecological capability evaluation is quite different. Value of factors affecting Iran ecological capability evaluation model (service and civil development usage) is shown in Fig.1. The results of questionnaires analysis, which specifies the value of each ecological factor affecting the service and civil development usage, are shown in Table1. As we see in this table, some possible restricting factors in the field under study may prevent the establishment of service and civil development usage in that location. Table1 shows these factors with the value of zero. In an environmental unit, one of the restricting factors listed below can reduce the points required for service and civil development usage:

- Each of the categories no.8, 9, 10 and 11, height from the sea level: higher than 2200 meters from sea level in every environmental unit.
- Categories no.7, 8, 9, 10, gradient percent factor: more than %20
- Category no.3, wind speed factor: more than 50 km/h
- Each of the categories no.1, 9, 13, and 14, petrology factor: original rocks of Marn types (I, II), torrential desert, sandy hill or Gypsy dome.
- Each of the categories 1, 2, 7,9, 10, 11or 24-geomorphology factor: straight and narrow lines, smooth or jagged lines with steep gradient, hill, wavy hills with steep or circular gradient, A-formed hills with steep gradient, terraced parallel hills with steep or mild gradient or riverbed.  
Each of the categories 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or 11 surface waters hydrology factor: river dry bed, torrential desert, fold, Marn(I, II), and river dry bed and fold, river dry bed and Marn, torrential desert and fold, torrential desert and Marn, fold and Marn, salty structures(salty domes and evaporation Marens) and erosion sensitive structure (deposit production in resources)
- One of the categories no.1 or 11, soil texture factor: sandy or clay texture.
- Category 1 soil granulation factor: soil with very fine granulation
- Category 4 soil changeability factor: unchanged soil
- Category 5 soil drainage factor: soil with poor drainage
- Category 1 water resources quantity factor: less than 50 liter/day per person.
- Category 1 preservation value of natural tree species factor: existence of trees such as zelcova carpinifolia, bucus hyrcana, taxus baccata, populus caspica, cupressus sempervirens in the area under study.
- Category 1 value of animal species (mammals): existence of animals such as acinonix jubatus, equus hemionus, cervus dama, panthera pardus, gazella dorax, selenarctos thibetanus in the area under study.
- Each of the categories no.1, 2, 3, 4, 5, 6, 7, 10 or 12 the area under study from protection point of view: national park, protected area, wild life sanctuary, natural landmark, biosphere reserve, forest store, global heritage or monuments.

Ecological capability evaluation using the new model will be begun after environmental units map in the area under study is prepared. First of all, land form unit map is prepared by combining maps of categories like height from sea level, gradient and geographical orientations. Then environmental units map is prepared in geographical information system by overlapping soil type and floral coverage condensation maps with land form unit map. Environmental units map represents small ecosystems in the area under study and is the basis of decision-making for Iran ecological capability evaluation. In the meantime,

ecological resources characteristics, which are effective in ecological capability evaluation of service and civil development relating to every environmental unit, are introduced to geographical information system in code. Every environmental unit potentiality is shown in a data range between 0 and 100 at the scale 1:10000 considering designed model for the data. Geographical information system can categorize the environmental units according to obtained points with desired range. It can produce final usage map. After obtaining the desired reply, sensitive analysis test was done in order to examine the possible parameters effect on the desired reply by Simplex method using Lingo software.

The results of Tehran region no.22 ecological capability evaluation study in order to establish service and civil development usage is shown in map no.1. To apply this model for this region with 5700 hectares, first of all sustainable and unsustainable ecological resources were known. Then ecological resources maps were prepared at the scale of 1:25000 and were introduced to geographical information system after being numbered. In the next step, maps according to height from sea level, gradient, geographical orientations, land form unit and environmental units were prepared using Arc View GIS 3.2a software. To continue the process, ecological resources data relating to 515 environmental units were introduced to geographical information system and designed model was applied to each environmental unit data and specific points of each unit were calculated. As we see in the map, the calculated points were categorized to five groups regarding aim of study and evaluator request. The units shown in black have the highest point for service and civil development usage. On the contrary, units shown in the brightest colors are not suitable for service and civil development usage (point zero). Restricting factors such as river path, hilly grounds and fold are factors which reduces the points to zero.

### **Discussion and conclusions**

This research was aimed at designing a linear mathematical model for Iran service and civil development usage. One of the most significant characteristics of this model is its ability at assessing the quantity of ecological parameters value, which is effective at service and civil development usage. Furthermore, this model can evaluate environmental parameters with different coefficients. To design this model, Delphi method was used which is a derivative of phase theory method. Questionnaires are the main tools and the necessary information including ecological factors, significance of 23 factors effective in evaluating ecological capability of service and civil development usage was obtained by filling 750 questionnaires of Delphi group. Questionnaires data were analyzed using Spss 11.0 software. Then the model was designed in geographical information system. After sustainable and unsustainable ecological resources in the field under study were analyzed systematically and environmental unit maps were prepared, ecological capability was evaluated using this model. The designed model in geographical information system can categorize environmental units on the basis of obtained point range, prepare the usage map according to aim of study and evaluators' request and calculate points of each unit at the scale of 1:10000. Model sensitivity was analyzed with the Simplex method using Lingo program. More than 293 possible conditions are predicted in Iran, which are considered unsuitable for establishment of expected usage regarding restricting factors in some effective ecological factors. To assess the proposed model capability, Tehran region no.22 ecological potential was evaluated as a case study to establish service and civil development usage. Results of the study on 5400 hectares field show that points given to environmental units to establish usage vary between zero and 65. However, restricting factors such as river path, hilly grounds and folds in some environmental units prevent the establishment of service and civil development on these units.

**Table 1: Results of ecological factors various categories analysis effective in Iran ecological capability evaluation in order to establish service and civil development usage**

(Cn) Field condition regarding preservation		Value of animal species (Mammals) Fv		Preservation value of natural tree species		Ecological factors
Value	Frequency	Value	Frequency	Value	Frequency	Frequency categories
	National park		Acinonyx jubatus, Equus hemionus, Cervus dama, Gazella doracs and Selenarctos thibetanus		zelcova carpinifolia, buxus hyrcana, taxus baccata, populus caspica, cupressus sempervirens	1
	Protected area	7	Capra aegagrus, Ovis sp., Canis lupus, Panthera pardus, Felis sp., Martes foina, Ursus arctus –	17	Juniperus, Thuya orientalis, Acer monspessulanum, Cerasus avium and Quercus sp.	2
	Wild life sanctuary	30	Vulpes sp. Meles, Hyaena, Mustela nivalis	45	Other species	3
	Natural landmark	37	Sus scrofa, Hystrix indica, Sciurus anomalus, Canis aureus and Ochotona rufescens		*	4
	Biosphere reserve	59	Other species			5
	Forest store					6
	Forest park					7
8	General artificial forest					8
7	Nature park					9
	Global heritage					10
	National historical and religious works					11
	Archeological works					12
97	Other areas					13

**Table: 1. Results of physiography and climate factors in various categories analysis effective in Iran ecological capability evaluation**

Ecological factors Frequency categories	Wind speed (Cw)		Annual average rain fall (Cp)		Annual average temperature (Ct)		Average humidity percent (Ch)		Geographical aspects (As)		Gradient percent (So)		Height from sea level (Ev)	
	Value	frequency	value	Frequency	Value	Frequency	Value	Frequency	Value	Frequency	Value	Frequency	value	Frequency
1	92	1-35 km/h	6	0-50 mm in year	14	less than 18 C°	36	Not more than 40 percent	5	North	97	0-2 percents	39	0-100 meters
2	3	36-50 km/h	23	51-200 mm in year	89	18/1-21 C°	79	40/1-60 percents	27	Northeast	92	21/1-5 percents	47	101-200 meters
3	0	more than 50 km/h	48	201-500 mm in year	87	21/1-24 C°	85	60/1-80 percents	53	East	92	5/1-8 percents	68	201-400 meters
4	*N.M.	N.M.	86	501-800 mm in year	65	24/1-30 C°	13	More than 80/1 percents	64	Southeast	27	8/1-12 percents	89	401-600 meters
5	N.M.	N.M.	74	801-1200 mm in year	12	More than 30/1 C°	N.M.	N.M.	90	South	14	12/1-15 percents	92	601-1200 meters
6	N.M.	N.M.	57	1201-2000 mm in year	N.M.	N.M.	N.M.	N.M.	87	South west	45	15/1-20percent	23	1201-1800 meters
7	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	75	West	0	20/1-25 percents	3	1801-2200 meters
8	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	75	North west	0	25/1-40 percents	0	2201-2600 meters
9	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	98	plate	0	40/1-65 percents	0	2601-3000 meters
10	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	More than 65 percents	0	3001-3400 meters
11	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	More than 3400 meters
12	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.*

\*N.M.= not measured

**Table 2. Results of soil factors in various categories analysis effective in Iran ecological capability evaluation**

Ecological factors Frequency categories	Soil grainity (Pg)		Geomorphology (Gp)		Soil texture (Ts)		Soil Changeability (Pl)		Soil depth (Ds)		Hydrologic groups in soil (Hs)		Soil drainage (Dr)		Percent of pebbles in soil (Ps)	
	Value	Ferquency	Value	Ferquency	Value	Ferquency	Value	Ferquency	Value	Ferquency	Value	Ferquency	Value	Ferquency	Value	Ferquency
1	0	Tiny	0	Straight, narrow lines	0	Sandy	92	Changed	3	0-30 cm	89	A	96	Complete	87	2-15 percents
2	73	Spiller	0	Smooth or jagged line with steep gradient	68	Lomay-sandy	77	Semi-changed	29	31-60 cm	77	B	87	Middle to good	69	16-50 percents
3	84	Middle	45	Mountainside	59	Clay-sandy	12	Changing	63	61-120 cm	32	C	20	Incomplete to average	41	51-90 percents
4	65	Coarse	72	Upper cone	66	Lomay-clay-sandy	0	Unchanged	93	121-180 cm	5	D	2	Poor to incomplete	0	More than 90 percents
5	N.M.	N.M.	67	Middle cone	67	Clay-lomay-sandy	N.M.	N.M.	96	More than 180 cm	N.M.	N.M.	0	Poor	N.M.	N.M.
6	*N.M.	N.M.	71	Old cone	82	Loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
7	N.M.	N.M.	0	Hill	13	Clay-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
8	N.M.	N.M.	4	Domical hills	74	Sandy-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
9	N.M.	N.M.	0	Wavy hills with steep hills and circular hills	52	Clay-sandy-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
10	N.M.	N.M.	0	A-shaped hills with steep hills	73	Sandy-loamy-clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
11	N.M.	N.M.	0	Terraced parallel hills	0	Clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
12	N.M.	N.M.	3	Hills with gentle gradient	73	Sandy-clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
13	N.M.	N.M.	57	High desert	24	Loamy-clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
14	N.M.	N.M.	76	Alluvial middle plate	37	Sandy-clay-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
15	N.M.	N.M.	74	Desert like	32	Loamy-sandy-clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
16	N.M.	N.M.	78	Continental alluvial	24	Silty	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
17	N.M.	N.M.	44	Parallel layers with gentle gradient	68	Silty-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
18	N.M.	N.M.	65	Fanlike	39	Silty-clay-loamy	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
19	N.M.	N.M.	8	Middle land	15	Silty-clay	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
20	N.M.	N.M.	89	Dolian	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
21	N.M.	N.M.	12	Carest with Dolian	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
22	N.M.	N.M.	27	Carest with Dolin	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
23	N.M.	N.M.	71	Youth basalte	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.
24	N.M.	N.M.	0	Riverbed	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.

• N.M. =not measured

**Table: 3. Results of geology and hydrology factors in various categories analysis effective in Iran ecological capability evaluation**

Ecological factors Frequency categories	Resistance coefficients of rocks to corrosion (El)		Hydrogeology (Wr)		Water resources (Wl)		Petrology (Mr)		Surface waters hydrology (HW)	
	Value	Frequency	Value	Frequency	Value	Frequency	Value	Frequency	Value	Frequency
1	3	0.7-2	93	Quaternary and alluvial formation	0	Less than 50 liter/day for persons	0	Marl (type I and II)	0	Dry river bed
2	9	2.1-5	23	Quaternary, cretaceous and oiligense formation	22	50-100 liter/day for persons	52	Limestone	0	Flooding desert
3	59	5.1-9	46	Marl, schil and igneous rocks	54	100-150 liter/day for persons	69	Volcanic rocks	0	Fold
4	79	9.1-13	N.M.	N.M.	79	150-225 liter/day for persons	82	Sandstone	0	Marn (type I and II)
5	88	13.1-15	N.M.	N.M.	96	225-300 liter/day for persons	53	Alluvial Volcanic and cone like	0	Dry riverbed and fold
6	*N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	28	Schist and Conglomerate	0	Dry riverbed and Marl
7	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	7	Genesis and Amphibolites	0	Flooding desert and fold
8	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	8	NaCl in the form of salty domes	0	Flooding desert and Marl
9	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	0	Flooding desert	0	Salty structure
10	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	48	Alluvial bulb	0	Corrosion – sensitive structures
11	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	77	Aphiolite	0	Fold and Marl
12	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	65	Dolomite and Calcite marble	0	Others
13	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	0	Sandy gips	94	N.M.
14	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	0	Diapir gips	N.M	N.M.
15	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	83	Loose	N.M	N.M
16	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	72	Continental shelf deposits	N.M	N.M
17	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	46	Quartzite	N.M	N.M
18	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	31	Conglomerate		N.M
	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	65	Tuff	N.M	N.M

\*N.M=not measured

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