Geotechnical Characteristics of Mass Movements in Manaus – AM

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Abstract

For decades, the urban area of Manaus has been expanding inappropriately, and horizontally, clearing forests and occupying unfit areas for housing. Administrative zones, like the East Zone, did not have the same evolution in their urban infrastructure as this expansion happened. Thus, mass movements arise, mainly due to anthropic factors associated with the presence of geological, topographic and environmental conditions. For the Municipality of Manaus, there is the landslide risk analysis addressed in 2012 by the Geological Survey of Brazil (CPRM) in conjunction with the Municipal Civil Defense. Currently, this risk diagnosis is made through field visits, surface investigation and completion of descriptive form in order to store information of the area under study. This methodology, described by the Ministry of Cities, is widely applied in several Brazilian municipalities with satisfactory results. In this context, the aforementioned procedure was used in the present work, and aiming to reduce subjectivity, the Hierarchical Analysis Process (AHP) was added. In the present study it was observed that this system, besides not modifying the basic approach of the Ministry of Cities method, incorporated a quantitative examination that verified the contribution (in the form of weights) of each danger indicator, besides hierarchizing the slopes with problem. Thus, it was found that the AHP method compared to that applied by the Ministry of the City were similar in the evaluation of the slopes of Jorge Teixeira neighborhood, located in the east zone of Manaus, the region object of the present study, chosen because it was more susceptible to landslide events (CPRM, 2012), aggravated by anthropogenic conditions. It is also verified that the slope stability, employing Bishop's method with the aid of Slope / W software for the slope (S01) in Jorge Teixeira neighborhood, registered results compatible with that found by the AHP method.

Key words: mass movement, slope stability, risk analysis, hierarchical analysis.

1. Introduction

The disordered occupation in urban centers has increased the occurrence of geological accidents, especially in developing countries (BARROSO, 2016). Especially in Brazilian cities, it has been influencing extreme population growth, which is characterized by the lack of planning in relation to natural resources and the well-being of the community (OLIVEIRA, 2010). One of the main causes of this process is the non-distribution of spaces that offer a dignified and healthy quality of life in an equal manner. As a result, the less-favored population becomes more vulnerable with the occupation of unsuitable areas for living and life-threatening, especially on the slopes and river banks. Barroso (2016) points out that this reality generates geological and geomorphological accidents that cause material damage and fatalities. In general, this occupation causes: the removal of vegetation, improper installation of sewage and water, construction of access roads, disposal of rubbish and debris in irregular places, improper cutting and landfill, alteration of the regime stormwater runoff and infiltration (CPRM, 2012). Such interventions in the physical environment trigger geological accidents, which cause social, economic and environmental damage to the population and the public power. According to the Ministry of Cities (2007), settlement in precarious situations on slopes and steep slopes, with no water supply and sewage collection, increases the vulnerability of these naturally fragile areas. Such a succinctly high risk condition that, added to more intense rainy periods (such as the January-May seasons in Manaus), promote serious accidents, as evidenced by Hamdhan et al (2011), Rizzon (2012) and Fernandes (2014). According to Nogueira et al (2007), Manaus, with the implementation of the Free Zone in 1967, began a new economic cycle, with the installation of a large industrial park. This generated the commercial increase, and in the last 30 years with such tax incentives, it attracted a large migratory flow (from the interior of the state, the Northeast and from different regions of the country), resulting in population growth. In the 2014 census of the Brazilian Institute of Geography and Statistics, Manaus recorded a population contingent of 1,405,835 in 2000, rising to 2,182,763 inhabitants in 2019. Consequently, a significant quantitative increase of around 1.74% compared to 2018, showing as one of the fastest growing cities in Brazil. However, due to this rapid development, which generated a horizontal expansion, it showed the occupation of improper regions that affected the city in a disorderly manner, without the proper urbanization and infrastructure work. According to the Brazilian profile study, released by IBGE (2017), in a total of 5,565 municipalities, only 344 (approximately 6.2%) had municipal environmental and geological risk response plans in 2011. The study also showed that 1,812 municipalities (32.5%) were performing landslide risk management and preventive environmental recovery actions. Some have stated, for example, that they perform urban drainage, floodplain reclamation, river and stream restructuring, construction of protective walls and dikes. The IBGE conclusions (2017) also indicate that there is a lack of preparation by the municipalities to deal with urban sanitation policies. Data indicate that 60.5% (3,368) of the municipalities did not perform environmental licensing of sanitation systems, and 47.8% (2,659) failed to monitor water quality. It was also found that 42.7% (2,376) of the municipal administrations had no selective collection program. According to the aforementioned work on the five regions of Brazil, with reference to sanitation planning and policies, we have: a) the Northeast is worse off with only 5.4% (97 out of 1,794 cities); b) the Midwest region presented 8.79% (41 of 466); c) the northern region, in third position, indicated 8.9% (97 out of

449); c) in the case of the South and Southeast regions, they showed 13.46% (160 of 1188) and 16.3% (272 of 1,668 cities), respectively. In total, less than half, 44.5%, of the municipalities have an effective risk action system. In this sense, environmental impact surveys, geotechnical maps and derived products (geotechnical charts, risk charts, second order analysis and others) have been pointed out as instruments of environmental management and municipal planning of paramount importance to the context in which the cities live. According to Alheiros (1998), these procedures allow the hierarchy of problems, the evaluation of investment costs for the execution of preventive and / or corrective interventions in the slopes areas, also contributing to guide the important actions developed by the Municipal Civil Defense. Regarding the study area, the city of Manaus is located between the parallels 03 ° 00 '/ 03 ° 10'.

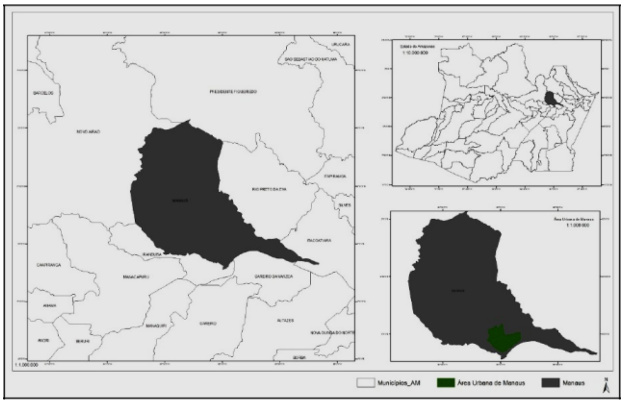

Figure 1. Location of the Municipality of Manaus - AM with an urban area equal to 483 km².
Source: CPRM, 2012.

In another scenario, Manaus is divided, contained in its Master Plan, into six urban areas, totaling 63 neighborhoods. It was chosen to work in the East Zone, as a result of data from the 1st order risk mapping of the Geological Service of Brazil (CPRM, 2012), in partnership with the Municipal Civil Defense. This result indicated that buildings in the city of Manaus are classified, according to risk, as: 5.06% very high, 23.48% high, 43.24% medium and 8.59% low. Notably, the East Zone, and especially the Jorge Teixeira District, was the most susceptible region to landslide events. At this juncture, the area under study is located within the UES Urban Structure Unit, Jorge Teixeira neighborhood, in the city of Manaus. According to the Environmental Master Plan, the mentioned Neighborhood is composed of four Lots / Steps (Arthur Virgílio Filho, Bairro Novo, Jorge Teixeira 3rd Stage and João Paulo), as shown in Figure 2. It has 112,879 inhabitants in a geographical area of 1,557.15 hectares (IBGE, 2010), with a demographic density of 7,249.08 inhab./km². In accordance with the CPRM (2012), these areas are located in high and sloping lands, which added to the horizontal occupation of improper areas, generates unhealthy and quite vulnerable spaces. These characteristics, added to others (specific bibliographic references, topographic and, above all, field analysis), supported the work in question, which is the risk classification in three slopes of Bairro Jorge Teixeira, particularly in irregularly occupied spaces . Thus, the risk analysis was performed, as well as the stability of a slope representative of this condition was determined.

Figure 2. Map of the region under study.

2. Materials and methods

Subsequent to the theoretical construction stage, the phase concerning the choice of locations, that suggested coming from the occupation of risk areas in Manaus-AM, began. Their physical aspects, which were characterized as danger indicators and conditioning factors of mass movements, were investigated. Following the survey of the areas, with the help of Google Earth software and the Mapping of Hazardous Areas produced by CPRM in conjunction with Civil Defense in 2012, there were identified: type and particularities of the slopes; topography; anthropogenic factors such as inadequate discharge of wastewater and sewage, lack of drainage, removal of vegetation cover; overloads in the form of "waste" deposits; and signs of movement. Based on these steps, the Jorge Teixeira neighborhood was chosen, which portrayed a geotechnical constitution unfavorable to safety, aggravated by anthropogenic conditions. In accordance with the method of the Ministry of Cities and Civil Defense, in partnership with CPRM (2012), their slopes were classified, as shown in Figure 3 and Table 1, with the following peculiarities: a) they are in the domain of high and sloping lands. This attribute is marked by high slopes, carved in soils of the Alter do Chão formation; b) the slope on the surface of the terrain is 30% or greater, 17 ° inclination, and prone to geotechnical problems such as landslides, falling blocks; c) they are the most problematic areas in relation to the incidence of geological risk areas (CPRM, 2012); and d) records an average population density of 6,870 inhab./km². This rate is considered high.

Figure 3. Risk classification map, Bairro Jorge Teixeira, Manaus - AM.
Source: CPRM, 2012.

Table 1. Risk classification, Bairro Jorge Teixeira, Manaus - AM.
Source: CPRM, 2012.

Hillside	Rating
S01	R3 - High
S02	R4 – Very high
S03	R2 - Medium
S04	R3 - High
S05	R3 - High

The geological-geotechnical and environmental conditions of the landslide processes were called hazard indicators and were grouped into specific types and classes. The choice for the present work was based on the previously mentioned movement triggers and their characteristics related to the region in question. Following the selection of hazard indicators, weights were assigned for hazard classification by the AHP methodology. Concerning the investigation stages, the problem was initially represented through a hierarchical structure. The first level was the slope, the subsequent ones worked by the danger indicators (criteria), which act to increase or reduce the instability, and the sub-criteria investigated by the divisions of the danger factors. After defining the hazard indicator classes and their subclasses, each of them was analyzed in parts and could be examined in various contexts. Saaty (1990) mentions that one way is to use expert judgment, such as civil engineers, geologists, or mass movement specialists. Another procedure is to use the literature, as mentioned by Farias (2011). In the present study, the judgment process was based on data observed in the field, besides the bibliographic reference. Thus, for the second hierarchical level, each danger indicator was mutually compared, so as to combine 1 to 1 (the pairs) in each judgment. At the third level, the subcriteria of each danger nominee were confronted. It is recorded that the weights and consistency checks were determined by the Hierarchical Analysis - HA process. It is emphasized that the hazard indices and classifications were obtained through the equations in Table 2, which provide the ranges for the classification of the degree of risk. It is important to emphasize that if significant instability features occur, they should be reclassified as very high hazard sectors (R4), in accordance with the recommendations of the Ministry of Cities methodology (2007).

Table 2. Hazard classes.

DANGER INDEX	DANGER DEGREE
$IP < X - 1/2\ \Delta$	LOW
$X - 1/2\ \Delta \leq IP \leq X + 1/2\ \Delta$	MÉDIUM
$IP > X + 1/2\ \Delta$	HIGH
PRESENCE OF INSTABILITY	VERY HIGH

Where:
X – Arithmetic Average of IPs;
Δ – Standard deviation.

Source: Farias, 2011

Specific to the Hierarchical Analysis (AHP) system, its purpose is to examine the danger of slipping in urban areas. Each spreadsheet of this analysis consists of the following main tables: hazard data for each slope studied, weight of each criterion, value and hazard classification. In this way, the hazard indicator classes and their respective weights are stored in tables according to the nature of the slope and the types of landslide processes. In the adjoining stage, the investigative process was carried out with the presence of pre-selected hazard indicators. It was also part of the work in focus field experiments of percussion probing, aiming to determine the granulometry, the structure (consistency and compactness) and the resistance of the layers present in the geotechnical profile, as well as the collection of deformed and undeformed samples. Regarding the slope stability analysis, the Safety Factors (FS) are determined, considering the procedures prescribed in USACE (2003), DAS (2010) and Dutra (2013). Bishop's deterministic method was used, which Ribeiro et al (2010) points out as a tool to determine the critical rupture surface and the respective minimum FS. In this calculation we used the software SLOPE / W - GeoStudioTM software. Slipping risk was typified by the AHP method. These results were compared with the data obtained from the analysis of the Manaus Municipal Civil Defense in partnership with the Geological Survey of Brazil, in 2012.

3. Results

The characterization of the risk areas, in addition to the “office” surveys, was carried out through field investigations, the surface was verified and the natural and / or anthropogenic conditions that could induce sliding processes were identified. The five slopes examined were selected according to their risk classification by the Brazilian Geological Survey in partnership with the Civil Defense, in 2012. Figure 3 shows the location of Jorge Teixeira neighborhood, in relation to Manaus, and the five research areas (Slope I to V).

3.1 Risk Degree - AHP Method

The hierarchical or decisional matrix was determined by the pairwise judgment in their respective classes. From the structuring of this matrix and the results of consistency ratios (RC), the respective values were established for each criterion. Based on the AHP method, the weights for each hazard indicator were obtained. Depending on the decision matrix, it was understood that the most significant criterion, for eventual slippage, was related to movement signs, with a weight of 31.99%. In the case of the following classes, the following were observed: surface water, material type, slope / slope, soil use / occupation, amplitude, groundwater level and last occupation rate, with values equal to 27.54%. , 14.28%, 9.74%, 5.88%, 4.78%, 3.3% and 2.49%, respectively. The value for consistency ratio (RC) equals to 8.92%, resulted as expected. Regarding the slope parameter, by the decision matrix, the most expressive criterion for sliding episode was the class with angle greater than 30 ° and weight of 71.32%. The following classes were those with an angle between 17 ° and 30 °, weight of 22%, and smaller than 17 ° having a weight of 6.69%. Based on these values, a consistent result was certified, since the consistency ratio (CR) was 5.34%, ie, less than 10%. Regarding the use and coverage items, the most relevant criterion for landslide situation is the exposed soil class with a weight of 54.20%. The other classes studied were: urban coverage, field /

crop, shrub and tree, with weights, respectively, expressing values equal to 21.16%, 14.22%, 6.7% and 3.72%, respectively. Again, the result was consistent, since the consistency ratio (OR) of 8.78% is less than 10%. Regarding the water level, it was noted that the most important criterion is related to the slip, being the class with groundwater emerging near the surface, whose weight is 90%. It showed congruence because the consistency (RC) tends to zero. Regarding the material, the most suitable criterion for sliding was the mixed material class, with 47% of weight. The other classes were L / rubble and Solo released, weighing 40% and 11.5%, respectively. Then, a consistency value (RC) of 3.09% was obtained, thus satisfactory. Regarding the amplitude parameter, Table 3 shows the slope class larger than 20 m, with weight equal to 71.32%, while for heights between 10 and 20 m and less than 10 m, have values, respectively, equal to 22% and 6.69%. The result of 5.34%, derived from the determination of the RC parameter, indicated relevance. Depending on the signs of movement, the class with the highest possibility of mass movement, SM3, with a weight of 71.32%, cracks in the ground and houses, as well as slopes in poles or trees with signs, was evidenced from fractures, erosions, and wall embarrassment. Following this class are cracks and signs of depletion in the ground and lastly no evidence of movement, designating weights of 22% and 6.69%, respectively, which resulted in a relevant consistency criterion of 5.34%. . For the surface water indicator, it was found that the class with the highest weight value, with drainage lines on the slope (61.57%), was followed by the high, medium and low concentration classes, with values equal to 24.09%, 9.85% and 4.48%, respectively. The consistency criterion was satisfactory with a value of 9.58% less than 10%. Table 3 shows all weights with their respective classes.

Table 3. Weights of each criterion and subcriterion of the hierarchical analysis.

Hazard Indicators	**(%)**	**Subcriterion**	**(%)**
Amplitude	4.78%	(A1) ≤ 10m	6.69%
		10 < (A2) ≤ 20m	22.00%
		(A3) ≥ 20m	71.32%
Declivity	9.74%	(D1) ≤ 17°	6.69%
		17° < (D2) ≤ 30°	22.00%
		(D3) ≥ 30°	71.32%
Use / Coverage	5.88%	(U1) Arbórea	3.72%
		(U2) Arbustiva	6.70%
		(U3) Campo/Cultura	14.22%
		(U4) Cobertura Urbana	21.16%
		(U5) Solo exposto	54.20%
Water level	3.30%	(NA1) Não Obs.	10.00%
		(NA2) Evidente	90.00%
Surface water	14.28%	(AS1) Conc. Baixa	4.48%
		(AS2) Conc. Média	9.85%
		(AS3) Conc. Alta	24.09%
		(AS4) Linha de drenagem	61.57%

Material	27.54%	(M1) Solo	11.50%
		(M2) Lixo/Entulho	40.55%
		(M3) Misto	47.96%
Motion Signals	31.99%	(S1) Não Observado	6.69%
		(S2) Trinca no solo e abatimento	22.00%
		(S3) Trinca na moradia, solo; Incl. poste, árv.; Erosão.	71.32%
Occupancy rate	2.49%	(TX1) Bx. Dens. / Sist. Sanea. Precário	25.56%
		(TX2) Baixa. Dens. / Sist. Sanea. Adeq.	5.07%
		(TX3) Alta Dens. / Sist. Sanea Precário	57.64%
		(TX4) Alta Dens. / Sist. Sanea Adeq.	11.72%

3.2 Risk Analysis - Civil Defense and CPRM

As mentioned in topic 3.2, the risk analysis carried out in 2005 by Civil Defense in conjunction with the CPRM examined the processes associated with landslides and flooding, as described by the Ministry of Cities. Through this systematization, the slopes were eminent of movement. Therefore, the hierarchical analysis methodology characterized the area with the presence or absence of hazard indicators and their weights. The hazard index of each slope, shown above, and their respective degrees of hazard (Table 2) were obtained. Therefore, for the final calculation of the degree of risk, the arithmetic mean of the hazard index (IP) values for the 4 slopes (S01, S03, S04, S05) surveyed, and the determination of the standard deviation were made. It is noteworthy that the data referring to slope S02 were discarded, since this slope presented evidence of imminent sliding process, ie high risk (R4). These results are shown in Tables 5 and 6.

Table 4. Relationship between HI and Degree of Hazard

Hazard index	**Hazard Degree**
HI < 20,27%	R1
20,27%≤ HI <24,84%	R2
24,84% < HI	R3
Signs of impending motion	R4

Table 5. Field data applied by the AHP method.

SECTOR	**DANGER INDICATORS (DI)**									
	Ampl	**%**	**Decl**	**%**	**Use / coverage**	**%**	**W.L.**	**%**	**Surface water**	**%**
S01	A3	3.412%	D1	0.651%	U1	0.219%	NA1	0.330%	AS2	1.407%
S02	A2	1.052%	D3	6.943%	U4	1.244%	NA1	0.330%	AS3	3.440%
S03	A3	3.412%	D3	6.943%	U3	0.836%	NA1	0.330%	AS1	0.640%
S04	A3	3.412%	D3	6.943%	U3	0.836%	NA1	0.330%	AS1	0.640%
S05	A2	1.052%	D3	6.943%	U1	0.219%	NA1	0.330%	AS4	8.794%

Table 6. Field data applied by the AHP method.

SECTOR	DANGER INDICATORS (DI)							
	Material	%	occupancy rate	%	Instability features	%	Index	%
S01	M3	13.208%	TX2	0.126%	SM1	2.140%	**21.49%**	R2
S02	M2	11.168%	TX1	0.636%	SM3	22.816%	**47.63%**	R4
S03	M2	11.168%	TX2	0.126%	SM2	7.037%	**30.49%**	R3
S04	M2	11.168%	TX3	1.433%	SM2	7.037%	**31.80%**	R3
S05	M2	11.168%	TX3	1.433%	SM2	7.037%	**36.98%**	R3

3.3 Summary of Results - CPRM (Ministry of Cities) and AHP

The joint analysis of the methodology advocated by the Ministry of Cities, applied by the CPRM in 2012, and the Hierarchical Analysis Process (AHP) method in the present work, had investigative and descriptive character of the mass movement conditioning processes, having shown similarity in the evidence and parameters of investigation of slip processes. Table 7 shows the occupation sectors of the selected areas (S01, S02, S03, S04 and S05), where the risk level varies from medium to very high.

Table 7. Comparative table of risk outcomes

SECTOR	CPRM	AHP
	DI	DI
S01	R3	R2
S02	R4	R4
S03	R2	R3
S04	R3	R3
S05	R3	R3

Depending on the determined set of data, we have:

a) S01 presented a Hazard Index (IP) of 21.49%, therefore, a medium degree of hazard (R2), having as most relevant indicators the material deposited on the slope crest and the high amplitude. Alluding to CPRM data, by the Ministry of Cities Method, it was classified as high risk. It should be noted, however, that in the period, there was soil in place without proper compaction, which possibly helped to soften the mass movement process. Therefore, the results by the AHP method are consistent with those expected for sector S01.

b) S02 pointed to an IP of 46.60, so it was classified as very high risk (R4), mainly because it shows very clear signs of movement, such as: gullies at the end of Itaúba Avenue, sloping trees, cracks in the ground. , fractures in the slopes and in the nearby dwellings. Such codes are sufficient for classification in R4. It also exhibited high concentration of water released directly into the slope, which associated with high slope and amplitude of the slope generated great instability, with imminence of sliding. Remember that in this case the IP is not used. The results from the study of CPRM resulted in a very high degree, as well as pointed linear erosions with perpendicular ramps, and high slope edges. Consequently, the methodologies were in agreement.

c) S03 indicated an IP of 29.88%, thus evidencing a high risk of slipping (R3), since the slope has movement constraints such as: high slope and amplitude, crack in the ground and degree of abatement. For CPRM results, this area presented an average risk of landslide (R2) and was not described in detail. It can be concluded that the AHP method explained satisfactory result, due to the mass movement manifestations. It should be noted that the 5 years elapsed between the two surveys possibly aggravated the situation, which led to the difference in results.

d) Slope S04 indicated an IP of 31.80%, with a high degree of risk (R3). According to Tables 5 and 6, the most evident indicators are: high amplitude, high slope, and the presence of banana trees along the slope. In the classification carried out by the CPRM, risk level R3 was determined (Table 7), without, however, detailing the area. Thus, the results expressed correspondence.

e) Slope S05 recorded an IP of 29.59%, with risk grade R3. Tables 5 and 6 show the main danger indicators: high slope, signs of movement, rubble / discarded rubble on the slope, and drainage lines. The CPRM (2012) report cites risk grade R3, but does not add further description. Therefore, the results by the AHP method are in harmony with the method of the Ministry of Cities worked by CPRM.

Regarding the slope hierarchy, which converts part of the subjectivity of the Ministry of the City method into values, the hazard indicators were quantified by means of weights. Thus, the slopes were prioritized in emergency or long-term actions, based on the Hazard Index (IP), which valued the sliding constraints globally. Table 8 indicates the order of priorities for risk mitigation actions.

Table 8. Hazard hierarchy in emergency order

Emergency Hierarchy		
Sector	**DI**	**Hazard Degree**
S02	47.63%	R4
S05	36.98%	R3
S04	31.80%	R3
S03	30.49%	R3
S01	21.49%	R2

From the above, it is emphasized that the hierarchy process consists of a simple and fast methodology, and it is possible to verify the most susceptible slopes, within the same group with the degree of risk. Hence, for slopes grouped into only 4 classes, organizing the priority order becomes easier and more assertive aiming at emergency plans. It is emphasized that the structuring of the Ministry of Cities has a less subjective approach, that is, it quantifies the risk indicators so the slopes are divided into 4 classes (R1, R2, R3 and R4), without having the knowledge of ordination.

3.4 Slope stability

Stability analysis occurred only on slope S01, due to the difficulties in removing undisturbed samples and performing percussion drill tests on slopes with risk grades R3 and R4. Thus, the values of cohesion (c), friction angle (φ) and specific weight (γ) of the soils (layers) representative of slope S01 were determined as a function of the value of penetration resistance (N), derived from the Sounding to Percussion (SPT), and according to NBR 6484/2001. This solution was applied as a result of denting of the undisturbed specimens for the direct and triaxial shear tests. These parameters were estimated according to N, as indicated by Meyerhof (1956), Terzaghi and Peck (1967) and Godoy (1972). In the study of slope stability S01 with Geoslope software, the FS was equal to 1.387. According to NBR 11,681 / 91, FS values between 1.5 and 1.3 indicate medium safety situation. Therefore, comparing this value and the result determined by the AHP method, that is, equal to R3, both point to average insecurity for the referred slope.

4. Conclusions

The Hierarchical Analysis (AHP) methodology, as a way to improve the Ministry of Cities method (2007), proved feasible. It is advantageous to reduce subjectivity in the analysis of indicators of slip hazard, according to the AHP method. This provides more clarity, reliability, flexibility and more practicality in assertive process evaluation. Clarity was shown in the process of hierarchical structuring of hazard indicators, as well as a peer-to-peer assessment of each indicator by experts or the specialized literature. In the AHP methodology, by the analysis and valuation of the motion conditioning system, there was a decrease of subjectivity, therefore, more direct and consistent. Judgment of consistency in the matrix process also affirms the reliability of the method, which makes it easy to analyze and reanalyze by promoting better advice. This reanalysis, by the coherence index, shows another characteristic of the AHP method, that is, it is flexible to changes that are necessary. Therefore, it can be retrofitted for any scenario. The results generally indicated similarity to that determined by the method of the Ministry of Cities, implemented by CPRM. It was possible to rank the sectors according to the knowledge of the areas most needed for more emerging motion containment plans, relative to others of the same class. Comparing the Safety Factor (FS) to the data obtained by the AHP method, there were coincident results for slope S01. Overall, the risk sector analysis was performed satisfactorily. However, it is necessary to apply the study in a larger number of areas, to have a more representative sample. The importance of obtaining soil parameters closer to reality is also emphasized, through undisturbed samples, in order to obtain Safety Factors that more accurately portray the region.

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