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A HIERARCHICAL AND GEOREFERENCED APPROACH FOR FREIGHT TERMINAL LOCATION

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1 – Introduction:

In transportation, decision-making phase has an essential role in the planning context. The actions of planners have to be efficient and dynamic to generate the best management of the resources and consequently maximize benefits. Recently, the intervening factors became more complex and related to political, economical and social interests, which have to be considered in the final decision. However, transportation decisions have been taken under a limited scope as consequence of the application of methodologies and models [1)]. According to Fortes and Paiva [2)], methodologies have been limited to evaluate just travel time and operational costs in a transportation system, which limits and creates incomplete analysis based on cost - benefit evaluations. In this sense, as indicated by Hhakee and Stromberg [3)], a new environment with different conditions has made planners realize that new methods exploring computer's capabilities to simulate complex process are needed.

Computational instruments such as the Geographical Information Systems (GIS) can contribute to overcome the limitations observed in decision-making activities. GIS provides a large variety of tools that allow planners to simulate multiple scenarios and to visualize data / results due to its capabilities to process simultaneously attributes and location data related to geographical reality that can be combined with special functions for spatial analysis [4) 5)]. Many applications of GIS in transportation studies are noticed in recent years exploring mostly the capacity of storage and visualization associated with modelling techniques. Though such applications have generated several benefits to its users, they did not explore completely GIS potential in the sense that traditional transportation models were not conceived to fully incorporate geographical-spatial data and spatial analysis. Additionally and maybe the most important is the fact that transportation models and GIS are not designed to make planning decisions, although they provide better access and manipulation of the data[6)].

In order to combine the information generated by instruments such as GIS and then reach an extensive consideration of the factors influencing the decision-making, some efforts towards the development of Decision Support Systems (DSS) are observed [7) 8)]. In these works, it is clearly observed the intention to focus on the evaluation of variables that are not usually considered in transportation analysis through the manipulation of geographical and spatial elements using the framework of decision techniques. Both studies avoid an operation research modelling, which may be implemented without addressing human values and purposeful human activity [9)], concentrating on the management of geographical-spatial information in order to facilitate group-decision.

Following the same direction of these efforts, in this paper, we present the development and application of the integration of a decision-making technique (Analytic Hierarchy Process), GIS and Remote Sensing (RS) intending to establish a new approach for the determination of a freight terminal location. This new approach is necessary since traditional location theory is based on a particular hypothesis with a small number of location factors usually related to transport and labour costs[10)], and logistic models just focus on the minimization of distances (costs) in the displacements [11)]. In opposition to these conceptions, we propose a hierarchical and georeferenced approach making possible a wider consideration of new variables and the participation of those involved in the decision. In this context, hierarchical stands for the levels of the decision structure using the Analytic Hierarchy Process (AHP), which corresponds to one's understanding of the situation (goals, criteria, subcriteria and alternatives) [12)], and georeferenced is related to the use of information with a reference in a geographical space, respectively.

This paper is divided in four sections. After this introduction (section one), the basic concepts of the AHP-GIS-RS integration are presented in the section two in order to specify the characteristics of each element as well as their role in a decision-making context. Next, we report a case study for the application of the AHP-GIS-RS integration for the location of a freight terminal in Brazil, which is part of a postal transportation system. Finally in section four, it is discussed the relevance of this integration for transportation studies as well as some final considerations are presented.

2 – AHP-GIS-RS integration for decision-making:

In the decision context, planners are responsible to define the variables involved in a problem and to structure and analyze. Dear *apud* Densham [13)] pointed out that one of the main difficulties is related to the definition of these variables, since it is a hard task to capture and represent important spatial dimensions. Such fact may lead to the selection of incorrect variables and consequently deficient decision frameworks and unsatisfactory solutions may be reached. Hence, the participation of the decision-makers becomes an essential issue, since their selection will be the basis for the rest of the process. Nevertheless, the

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knowledge of the decision-group is influenced by the level of information that is provided before and during the analysis. This knowledge becomes a critical issue in transportation studies, which mostly deals with information related to the geographical-spatial reality [14].

In this sense, AHP-GIS-RS integration generates an instrument capable to provide information and computational tools under a decision framework. Developed by Satty [15], AHP is based on human being behavior to decide through the comparison between "objects" until reaching a decision. The comparison is related to the assignment of "weights" according to the relative importance when comparing to pre-established judgment criteria. Using a quantitative scale all the "objects" are compared leading to a prioritization and consequent decision. AHP has a simple structure that directly depends on the knowledge of the decision-group, which is reached through the obtainment of information about the problem.

Additionally, GIS capabilities contribute to provide additional information according to the needs or doubts of the decision-group. The use of RS data (aerial photographs and satellite images) reduces significantly labor-work time for those activities related to the collection of data through surveys *in loco* generating primary data and techniques to process spatial modeling. Hence, information / data related to the spatial location, such as land use patterns, terrain conditions, transportation system, distances and areas can be obtained and manipulated without great amount of investment in data collection [16].

This integration can be divided in four phases as shown in Figure 1. Next, these phases are described in detail:

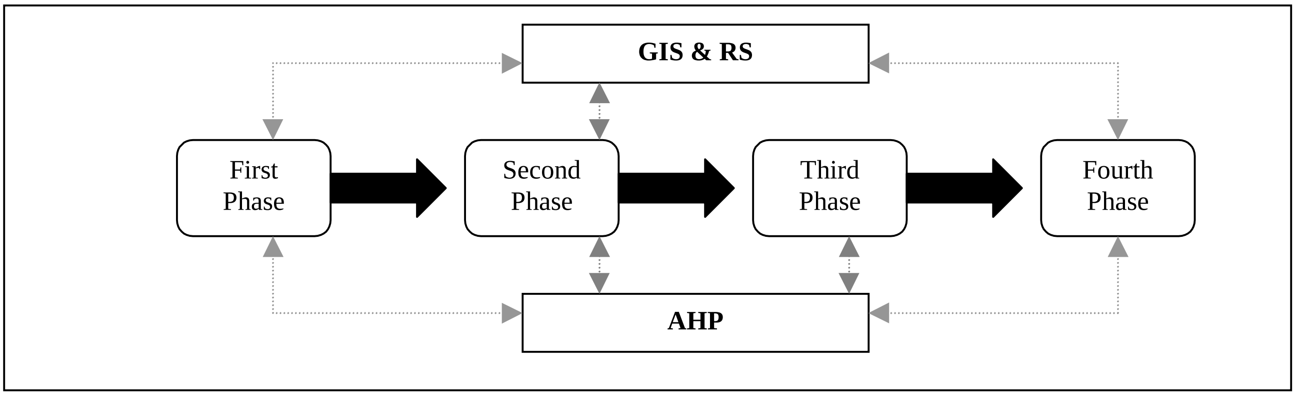

Figure 1: Integration of AHP, GIS and RS

- **First Phase** (Definition of hierarchical structure): concerning on the problem definition, criteria identification and alternative selection for evaluation. AHP establishes theoretical fundamentals, while GIS and RS provide data to diagnose the problem;
- **Second Phase** (Judgements of the criteria): each of the criteria is compared to the others. Decision-group judges according to the fundamental scale defined by Satty [15] , as shown in Table 1, considering data visualized in GIS database;

Table 1: Fundamental Scale for Judgments

Intensity of importance	Definition
1	Same importance
3	Small importance
5	Great importance
7	Very Great importance
9	Absolute importance
2, 4, 6, 8	Intermediary values between adjacent ones
1/x	Inverse comparison
1,1 - 1,9	Comparisons between two next elements

Source: Saaty [15]

- **Third Phase** (Alternative prioritization): the priorities of each alternative, previously identified in the First Phase of this integration, are calculated. Then, be a set of f alternatives, where f=1, 2,…n, we have that each f is related to a priority $P(f)$ within a range of 0 to 1 and obtained through equation 1.

$$P(f) = \sum_{w=1}^{q} \psi_w^f \qquad (1)$$

where f is the alternative number and ψ^f_w is the priority of the last level of criteria w in the AHP hierarchy that is obtained through equation 2 as following:

$$\psi_w^f = \prod_{s=1}^{nl} \Phi_s^w \qquad (2)$$

where Φ^w_s is the relative priority of the criteria w in the level s ($s \in \{1, 2, …., nl\}$) of the AHP hierarchy;

- **Fourth Phase** (Priority Analysis and alternative selection): using thematic maps the decision-group can reach the best decision by analyzing and comparing the different influences of each criteria.

Within this integration, the interaction between GIS and the decision-group is one of the most significant aspects. This interaction occurs in 8 steps as shown in Figure 2. Firstly, the decision group accesses GIS in order to obtain information to be used in the definition of the hierarchical decision structure (step 1). Next, in step 2, the judgements are conducted, but if the decision-group needs additional information then geo-spatial queries can be used as represented in step 3. This step can be repeated as much as needed and complementary data can be retrieved in order to eliminate doubts. In the sequence, the priorities are calculated in step 4 and then they are transferred to GIS database (step 5). Thematic maps are created in step 6 based on the final priorities. In step 7, the decision-group discusses the thematic maps in order to verify eventual problems or inconsistencies. At this point, the decision-group can either reach the final decision (step 8) or restart the process (step 1) or make the improvement of the judgements (step 2 and 3). Along the interaction, it can be noticed that according to the data requirements from the decision-group the whole process can be adjusted and this may lead to a better decision at the end.

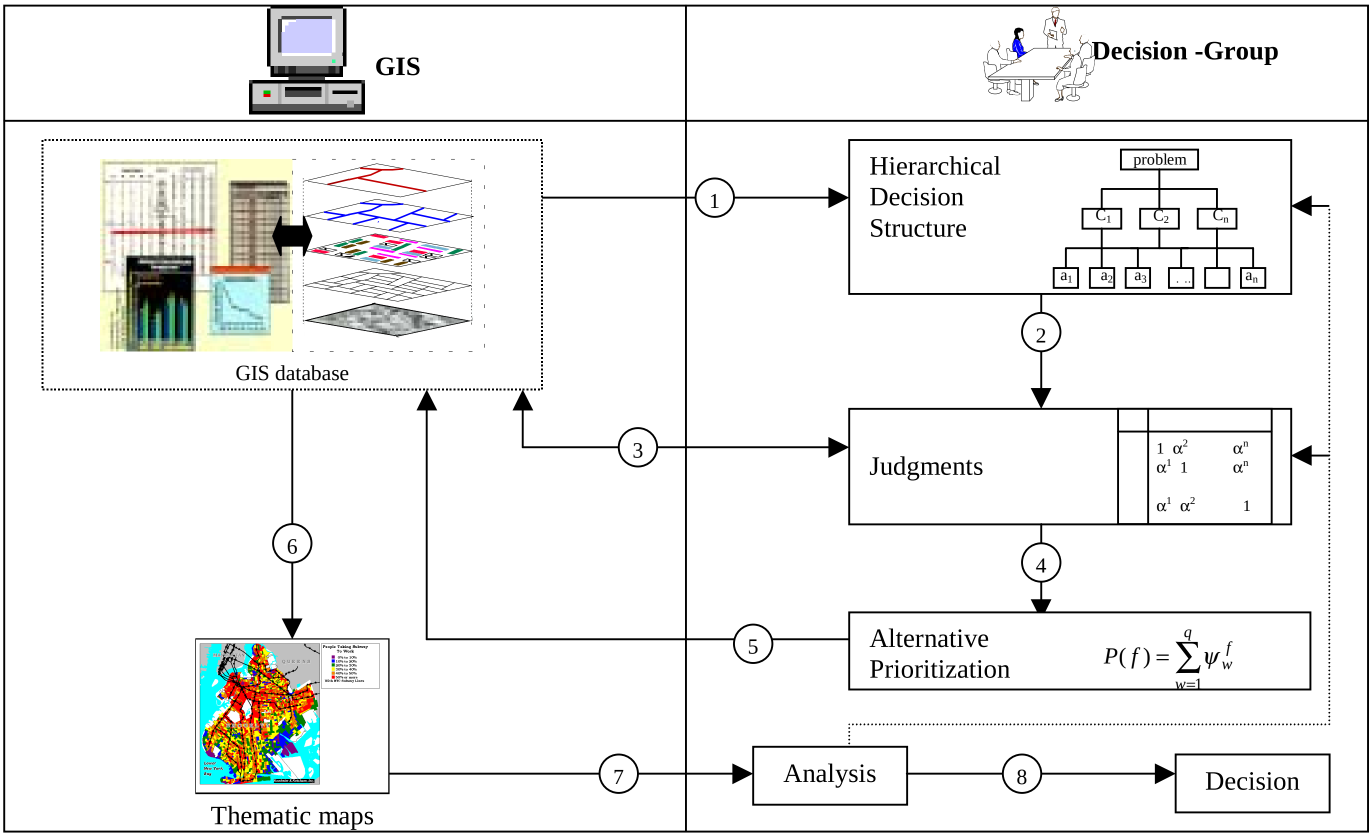

Figure 2: Steps for the interaction between GIS and the decision group

It is important to clarify that the application of this integration depends on previous organization and construction of a GIS database. Such a database can be either a part of a whole project that uses the data for multiple purposes or specifically developed to solve one problem. It is clear that the construction of a specific database will lead to the obtainment of data and consequently generating wasting time and financial resources. We will not be dedicated to the discussion of this matter but one has to be concerned that specific problems do need special data. For instance, the characteristics of the RS data (scale, resolution, cover area, etc.) depend on the objectives of the decision process, i.e., when analyzing regional or local problems the definition of suitable data has to be adequately identified.

3 – Case Study:

In this section, the AHP-GIS-RS integration is applied in solving a real problem related to the selection of a terminal location. We use as an example the location determination of a postal freight terminal in an urban area as part of the Brazilian Postal and Telegraphic Enterprise (ECT). This decision is fundamental in ECT operations since it affects the structure of production and as consequence the cost of the postal service.

In the freight operations of ECT, many types of terminals are used but we concentrate on the analysis in a specific type called Dwelling Distribution Center (DDC). This terminal is a small terminal used in the transshipment of postal freight (letters, small parcels, telegrams, etc) when a large amount of consolidated freight comes from bigger terminals. For instance, in a metropolitan area firstly the postal freight originated from other cities is gather together in main terminals (Operation Center – OC and Selection Center - SC), where they suffer an initial treatment. In the sequence, the postal freight is moved to DDC where it is again organized according to the type of the freight (urgent, special or common) and the destination inside the DDC area. Finally, for each district (zone of collection/distribution on foot) and circuit (route of collection/distribution by motorbikes and small trucks or vans), respectively, postmen and drivers of vehicles process the delivery. In some cases, due to long distances, postmen use public transportation system (bus, subway, train, etc), which allows a faster and economical displacement to reach the district. After the completion of the distribution, the collection activities start in order to continue the whole process of postal freight transportation. So, postmen collect letters from the mailboxes and vehicles are dedicated to transport bigger parcels from the post offices to the DDC. This freight is assembled at DDC and then transferred to the main terminal of the metropolitan area. This collection/distribution (C/D) process is presented in Figures 3 and 4. It is important to make clear that DDCs have a totally different role of post offices, which are dedicated just to receive all types of postal freight and services. This separation is usually necessary since post offices are located in areas of extreme concentration of urban activities in opposition to DDCs that can be located according to logistical definitions.

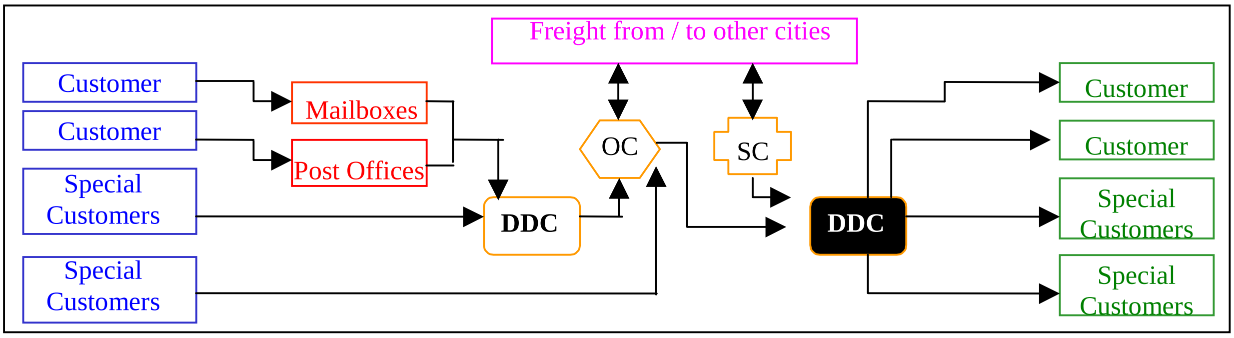

Figure 3: ECT`s freight activities

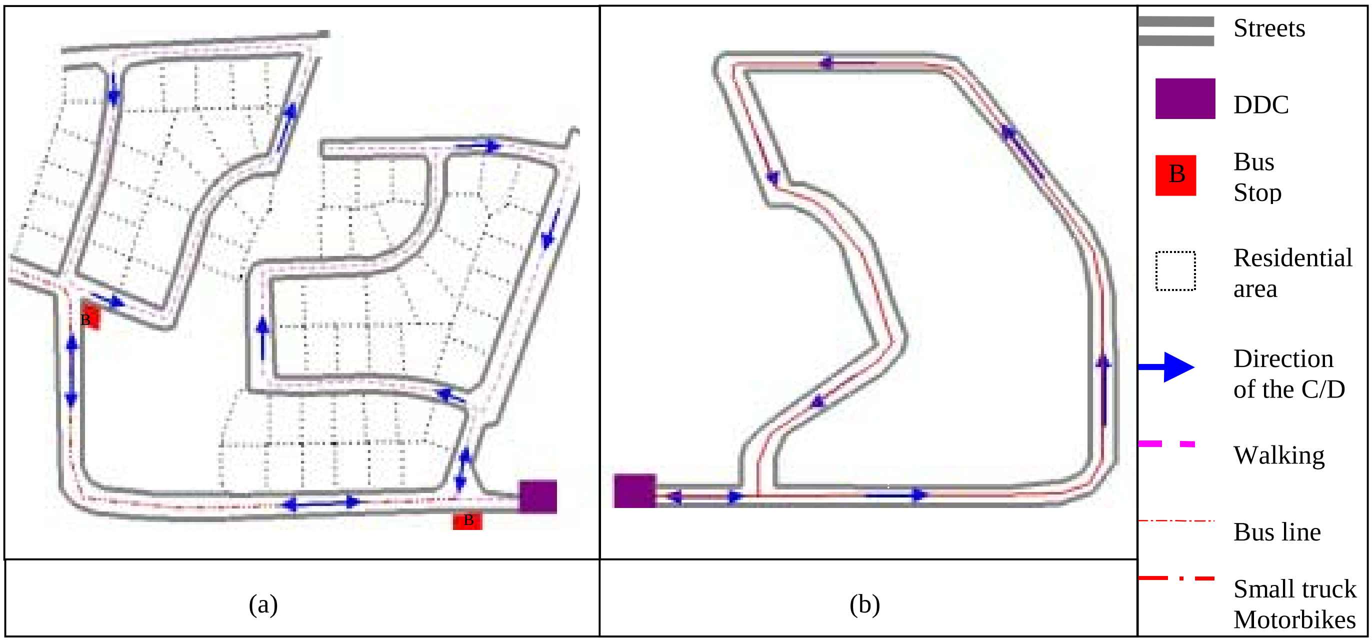

Figure 4: Collection and Distribution activities a) postman b) vehicle

Since DDC provides the necessary facilities to integrate different transportation modes, cost reduction can be obtained through optimal use of resources (staff, gasoline, material, etc) and movements of C/D activities. In this context, DDC location is one of the variables to obtain such optimal cost. If freight demand and / or other external condition suffers variation along the time, the DDC related resources (vehicle and general equipment, personnel and physical space) have to be reorganized in order to reach better services and costs, as well the terminal location [17]. DDC location is affected by rental and delivery (postmen and vehicle) costs, which are dependent on demands and transportation infrastructure (streets, roads, walkways, etc).

According to reports of the company [18], in recent years many variations have been observed in the operational conditions, which its technical staff should evaluate in order to verify, for instance, the DDC location. However, it can be easily verified that there is not an instrument to process such an evaluation considering the most important factors affecting the location of the terminal. The methodology currently used by ECT just analyzes the demands in the service area without using any mathematical model and this analysis is conducted in long-term periods due to the limitations of resources in the technical section [19]. This leads to the necessity to apply not only the correct and frequent evaluation but it is also essential to explore the limited resources without the creation of additional costs.

It would be quite natural to apply location models as described by Novaes [11], but that would not be appropriate. Firstly, these models do not consider important factors such as demand, the conditions of the traffic system and geo-spatial restrictions. Moreover, if it was decided to simulate the network of ECT related to DDC operations, the basic formulation of traditional models is not suitable. Traditional models are devoted to solve the location problem through the minimization of distances (costs) in the displacements from the terminal to points of attendance, which is not the case

Regarding that ECT needs an instrument to process decisions in a strategic level of planning, we propose the application of AHP-GIS-RS integration to identify potential areas to implement DDC in Sobradinho City, Federal District, Brazil. In this city, which is located 24 Km from Brasilia and has a population of 93.000 habitants occupying an area of 569,37 Km^2 [20], ECT's operations cover 15 districts, 1 post office and 2 circuits. The current location of DDC is in the commercial area inside the district 11 as shown in the Figure 5. A decision group was defined with 7 technicians to whom we described our proposal and the integration as an instrument to help in the decision-making. As it was not our purpose to compare with other formulations (location models and methodologies), we did not discuss AHP neither the integration by itself.

To conduct the application without additional costs, a previous GIS database was used. The digital base (coordinate system UTM) containing the transportation system, edification and topography iso-lines and a group of six aerial photographs was also used composes this database. The Development Company of the Federal District (CODEPLAN) provided both sources of data without costs. Additionally, the main characteristics (districts delimitation, location of mailboxes, circuits definition, public transportation by bus, traffic system) of the service area in Sobradinho City were digitalized. GIS database and operations were supported by MSQL and MGE software using a PC-Workstation 300 MHz.

Firstly the interpretation of the aerial photographs was conducted in order to select the potential alternatives. Following the principles described by Avery and Berlin [21], five categories of land use patterns were identified (Residential Simple and Multiple, Commercial, Special and Service areas). In the sequence, we concentrated on the analysis of Commercial areas since DDC can be only implement in such areas. Thus, we verified 19 alternatives (f=19) of Commercial areas that were sub-classified in 3 classes (Local commercial area; Special commercial area; and Mixed commercial area) as shown in Figure 6. To obtain these alternatives, the proximity to streets / avenues, the characteristics of land use patterns and spatial distribution (distance) were geared.

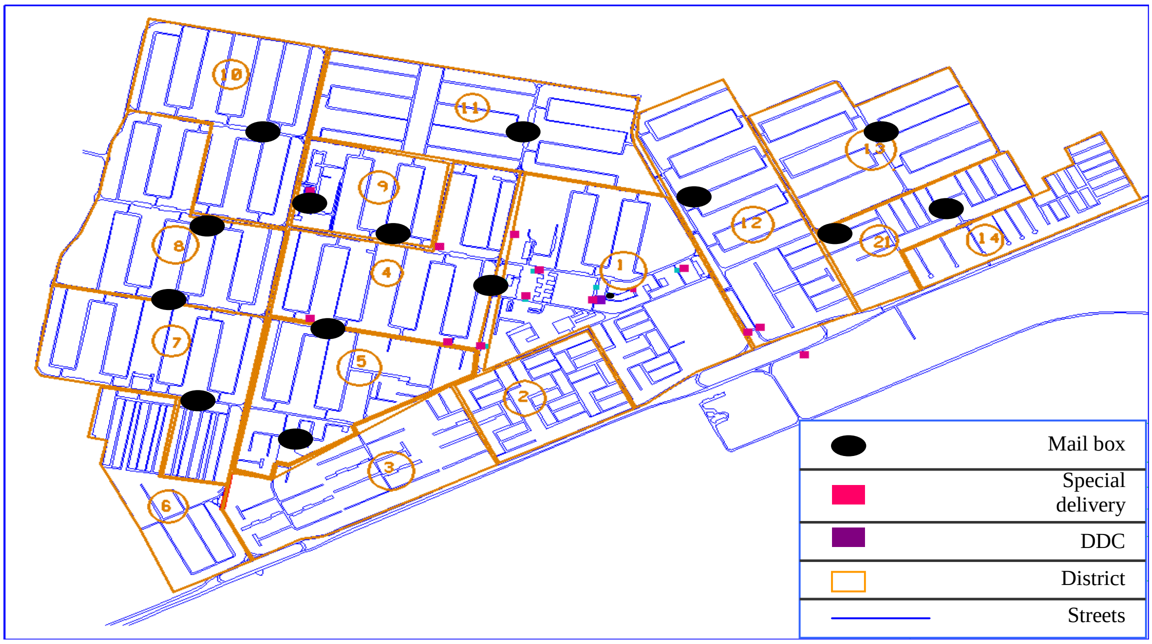

Figure 5: ECT in Sobradinho city

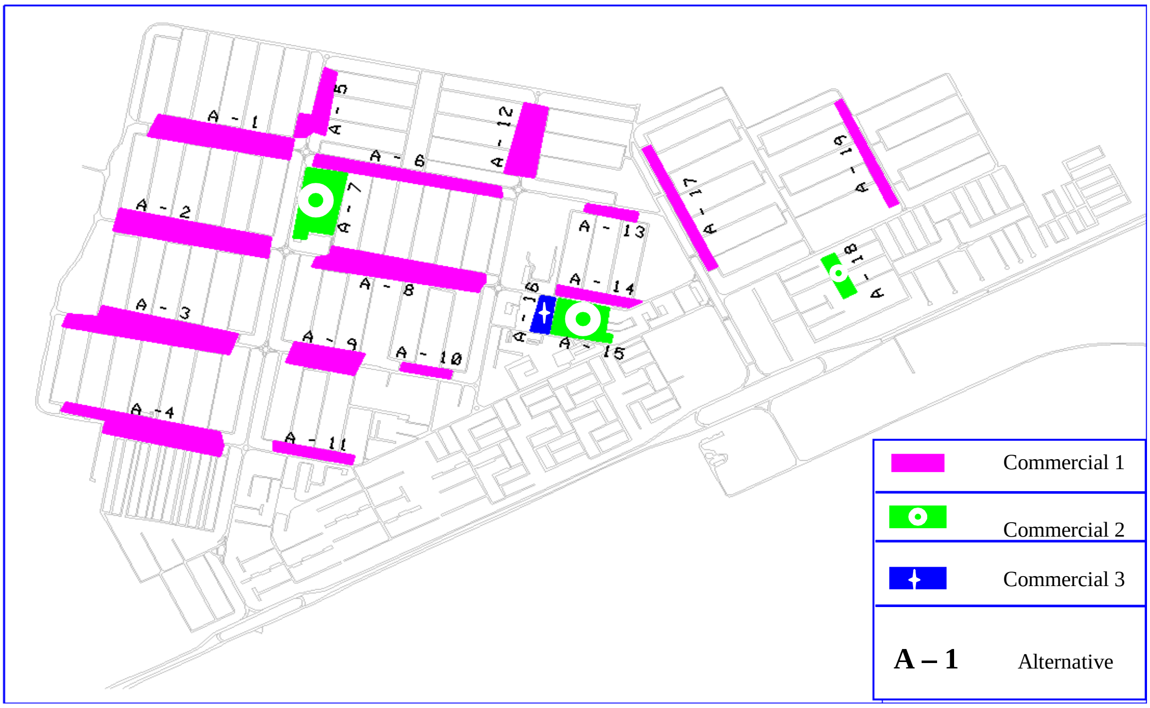

Figure 6: Potential alternatives in commercial areas

Next, the decision hierarchy was defined. Mainly considering the basic concepts of the current methodology of ECT and the information retrieved from GIS database, the decision structure in Figure 7 was reached. The role of GIS database was remarkable, since the decision-group has never experienced such interaction for decision matters and many times they expressed the positive influence in their activities. For instance, when discussing specific criteria such as freight demand, the mosaic of aerial photographs visualized in GIS brought decisive information into their evaluations. The selected criteria are described below:

- **Land Use** – intends to quantify the freight demand around the potential alternative;
- **Topography** – evaluates the conditions of movements in freight operations (postman and vehicles displacements) since the slope variation contributes to generate additional energy requirements;
- **Distances –** quantifies the displacements from the potential alternative to the districts of Collection / Distribution activities;
- **Transportation System** – considers the existence of the system, in special it is evaluated the bus routes and traffic system; and
- **Rental cost** – as the DDC is always rented such cost has to be carefully analyzed.

In this hierarchical decision structure, it can be observed that the criteria reached only one level of sub-criteria. This is due to the consideration by the decision-group that additional levels would not significantly contribute to the final decision. For instance, the transportation system criteria is divided in two sub-criteria, but bus sub-criteria could be analyzed according to the types of bus routes. In the same direction, we could judge the traffic system depending on the functionality of each segment of the network. However, the decision-group opted to establish a simple structure, that is still an hierarchical structure not depending on its complex subdivisions as we can observe in Satty [15]. Obviously, for different applications more detailed decision structures may be necessary, but fortunately this was not the case.

In the sequence, we mediated the discussion and the judgements of all the criteria. During the judgement, it was necessary to obtain more information about the service area, especially those related to the topography criteria. In this sense, we used the Digital Terrain Model (DTM) and a slope map of the city created by a terrain analysis module of the GIS software. Moreover, the decision group asked for the exact distances from potential alternatives to the districts, which was obtained from a network analysis. In the judgment of the Land Use criteria, we applied the methodology developed by Taco *et al.* [22] in order to evaluate the freight demand. This methodology establishes that according to the occupied area of land use patterns the demand can be defined. Finally, rental costs for each alternative were also obtained through rental agencies of Sobradinho City. For each criteria, we constructed thematic maps that were adjusted until the decision-group reached the common sense. Applying the equations 1 e 2, the final priorities $P(f)$ were reached as shown in Figure 7 and Table 2.

Considering the results expressed in Figure 8, some analysis can be conducted on the final priorities and the judgement process. Analyzing the numerical values for each criteria it can be verified that Topography was the greatest value (39.09%) showing its importance in the decision-making. On the other hand, the alternatives 14, 15 and 16 are those with highest priority due to a positive evaluation for almost all criteria excepting only External distance and Rental cost. This best set (14,15,16) is due to the proximity to great freight attraction / generation areas and to its topographical condition (on the highest region of the city). Moreover, it has a great advantage because of the road system and the variety of bus lines as well as the proximity to the city bus terminal. The final priority map leads to the recommendation of the potential alternatives 14, 15 and 16. Despite of understanding of the results, the judgement process was an essential part of the decision-making. The decision-group was able to interact and ask for additional information that was crucial to reach the final decision. This is the case of the Topography criteria, which could not be correctly evaluated without the DTM.

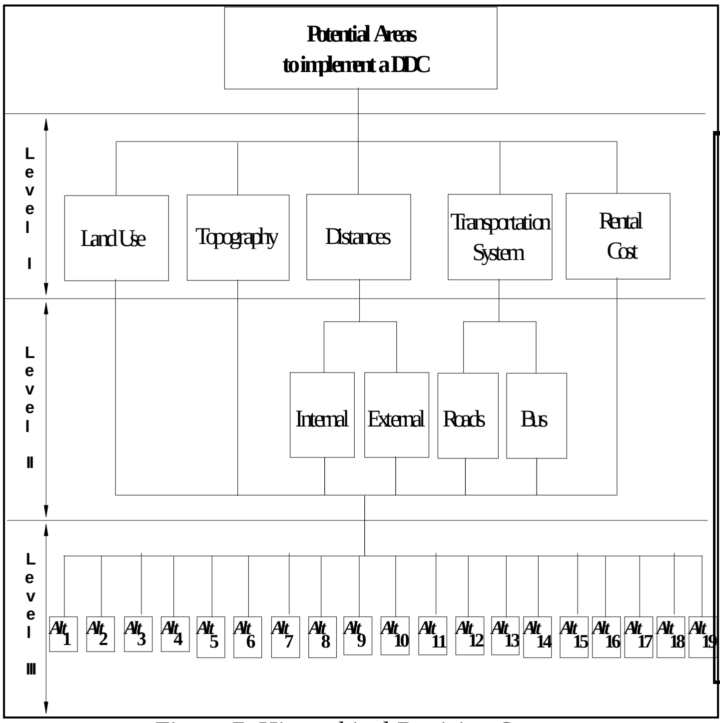

Figure 7: Hierarchical Decision Structure

		Land Use 1.97%	Topography 39.09%	Distances 33.40%		Transport 16.04%		Rental 4.09%	Final Priority
				Int. 83.33%	Ext. 16.67%	Road 16.67%	Bus 83.33%		
	1	1.97%	1.22%	2.40%	3.82%	0.0216	0.0216	0.0689	2.02%
	2	1.97%	1.22%	3.55%	5.19%	0.0216	0.0216	0.0689	2.42%
A	3	1.97%	1.22%	1.55%	12.17%	0.0216	0.0216	0.0689	2.25%
L	4	4.23%	1.22%	1.55%	12.17%	0.0216	0.0216	0.0689	2.30%
T	5	1.97%	1.22%	2.40%	3.75%	0.0216	0.0216	0.0689	2.02%
E	6	1.97%	3.43%	5.87%	3.75%	0.0216	0.0216	0.0689	3.85%
R	7	6.07%	3.43%	5.87%	5.19%	0.0421	0.0421	0.0214	4.15%
N	8	4.23%	6.30%	9.52%	4.79%	0.0421	0.0421	0.0408	6.30%
A	9	7.72%	3.43%	7.11%	12.17%	0.0421	0.0421	0.0426	5.00%
T	10	7.72%	6.30%	7.11%	5.19%	0.0421	0.0421	0.0426	5.73%
I	11	7.72%	3.43%	7.11%	12.17%	0.0421	0.0421	0.0426	5.00%
V	12	1.97%	3.43%	5.87%	2.53%	0.0772	0.0772	0.0689	4.67%
E	13	4.23%	3.43%	5.87%	3.16%	0.079	0.079	0.0612	4.75%
S	14	13.34%	14.40%	9.52%	3.16%	0.1223	0.1223	0.0126	10.73%
	15	13.34%	14.40%	9.52%	3.16%	0.1204	0.1204	0.0126	10.70%
	16	13.34%	14.40%	9.52%	3.82%	0.1204	0.1204	0.0126	10.74%
	17	4.23%	3.43%	3.55%	1.83%	0.0772	0.0772	0.0426	3.93%
	18	1.20%	6.30%	1.55%	1.28%	0.0421	0.0421	0.0296	3.79%
	19	0.81%	7.78%	0.55%	0.69%	0.0216	0.0216	0.1563	4.23%

Table 2: Alternative's priority

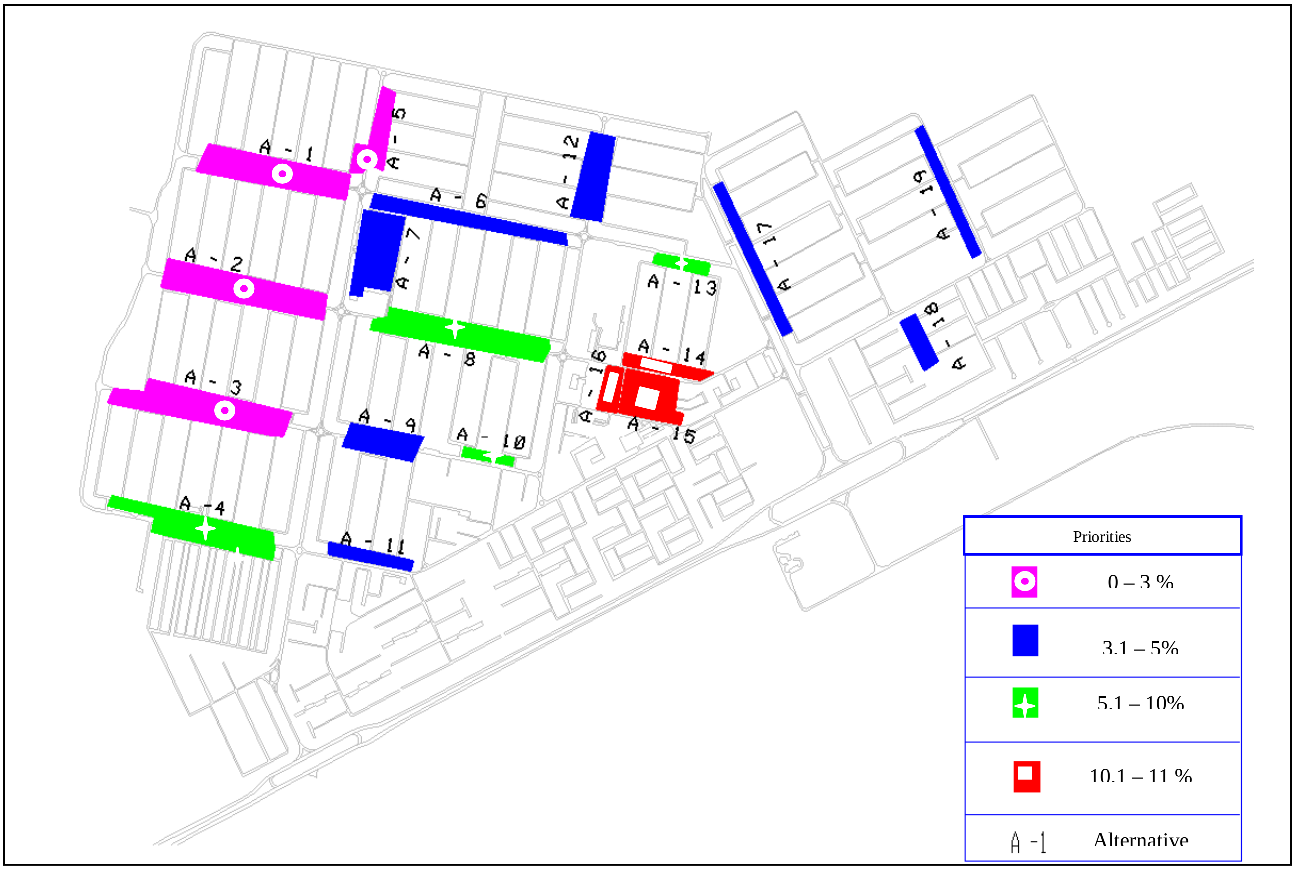

Figure 8: Final priority map for potential alternatives

4 – Discussion and Conclusion:

For a long period, the conception of transportation planning models has been limited by computational capabilities. Basic operations such as storage, organization and mathematical manipulation were often used to process a large amount of data. Nevertheless, they could not contribute with nothing more than this since the geographical-spatial reality was not possible to be considered due to a very restrict conception of database for those application. Consequently, tools could not be developed and models stayed in a conservative stage, just manipulating numeric data and generating a lot of results, which sometimes were meaningless.

The advent of GIS and gradual development of a new frontier is now possible to be seen. Its rare capability to conduct spatial analysis can lead to the reduction of time and money in exploring a rich source of geographical-spatial data: RS. In addition, a new generation of transportation models can be foreseen in opposition to traditional approaches more concerned on the analytical processing than the discussion and solution of problems. Along this direction, it is essential to understand the potential inside new technologies such as GIS and to bring it together to develop efficient and consistent evaluations and modelling. This research tried to follow previous work carried out by Yamashita *et al.*[23)], which already showed promising results in terms of future perspectives.

This paper reported AHP-GIS-RS integration as a hierarchical and georeferenced approach to support decision-making activities. In this integration, AHP contributes to processing geo-spatial data under a decision framework combining the information and an intelligent feature in the decision process. This integration is conducted through the construction of thematic maps generating a simple and efficient instrument of analysis without any complex mathematical formulations and procedures. Specifically about the decision context, it leads to an evaluation that can process both qualitative and quantitative information, which are useful to extrapolate the conception of cost – benefit analysis.

The application of the integration in a location problem proved to be a valid instrument to evaluate areas to implement a DDC terminal. The selection of potential locations by itself is vital not only because it defines a limited number of alternatives to implement the terminal, moreover it computes the most important factors influencing the decision in a strategic planning level. Hence, it generates a satisfactory explanation of the problem and a strong indication regarding the best location. It shows that if a planner needs an instrument to decide quickly and securely about a location, this level of analysis can lead to very interesting result without consuming more time in further analysis.

Besides the success of this application, it is important to highlight the large variety of possible developments in other problems. The integration of AHP-GIS-RS was designed to be general and applicable in any type of problem in transportation planning, since we were mostly concerned with the basic conception in opposition to specific requirements. In this sense, we have worked in totally different applications such as attraction analysis of urban travels and route definition for public transportation. These studies have showed the efficiency and importance of the AHP-GIS-RS integration to solve traditional problems in day-to-day activities of transportation planners.

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References

1) Willis, K.G.; Garrod, G.D.; Harvey, D.R.; *A review of cost-benefit analysis as applied to evaluation of new road proposals in UK;* Transportation Research-D, vol 3, pp.141-146, 1998.

2) Fortes, J.A and Paiva, J.S.; *Uma discussao sobre a metodologia de avaliacao economica de projetos em transportes urbanos*, Proceedings of VII Brazilian Transportation Association for Teaching and Research – ANPET, Sao Paulo, vol 1, pp 93-105, 1990.

3) Khakee, A. and Stromberg, K.; *Applying futures studies and strategic choice approach in urban planning;* Journal of Operational Research Society, vol. 44, n. 3, pp 213-224; 1993.

4) Tsuo, I. *Water Demand Estimation for Water Resources Planning: A Geographically Aproach.* Utah, Estados Unidos (PhD thesis), 1990.

5) Gallimore, W. P.; Hartgen, D.T.; Li, Y. *Aplications of GIS-Transportation Analysis Packages in Super-Regional Transportation Modeling*. Annual meeting of the Transportation Research Board, Washington, USA1992.

6) Harris, B. *Land use Models in Transportation Planning: a review of past developments and current best practice*, Delaware Valley Regional Planning Commision, USA, 1996.

7) Corloni, A.; Laniado, E.; Muratori, S.; *Decision Support System for environmental impact assessment of transport infrastructures;* Transportation Research-D, vol.4, pp.1-11; 1999.

8) Li, X.; Wang, W.; Li, F.; Deng, X..; *GIS based map overlay method for comprehensive assesment of road environmental impact;* Transportation Research-D, vol.4, pp.147-158; 1999.

9) Davies, M. A.P. *A multicretria decision model application for managing group decisions;* Journal of Operational Research Society, vol. 45, n. 1, pp 47-58; 1994.

10) Yurimoto, S.; Masui, T.; *Design of a decision support system for overseas plant location in the EC;* International Journal of Production Economics; vol. 41; pp. 411-418; 1995.

11) Novaes, A. G.; *Logistic Systems: Transportation, Warehouse and Distribution of products*; ed. Edgard Blucher ltd; pp372; Brazil, 1989. (in Portuguese)

12) Harker, P. T. *The art and science of decision making: the Analytic Hierarchy Process;* in The Analytic Hierarchy Process: Applications and Studies; Golden, B.L.; Wasil, E.A., Harker, P.T., (eds); pp. 265; Springer-Verlag; 1989.

13) Densham, P. J : *Spatial Decision Support* in Geographical Information Systems: Principles and Aplication , D.J. Goodclhild, M.F, Rhind, D.W. (eds), England, UK, 1991)

14) Rabbani, S.J.R. and Rabbani, S.R.: *Decisions in Transportation with the Analytic Hierarchy Process*. UFPB, Campina Grande, Brasil, 1996. (in Portuguese)

15) Satty, T. L.: *Metodo de Analise Hierarquica*, McGraw-Hill, Rio de Janeiro, 1991. (in Portuguese)

16) Morain, S.; Baros, S. L.; *Raster Imagery in Geographical Information Systems* (eds); OnWord Press, pp. 495; USA, 1996.

17) Sato, M. *Principles of Mail Processing;* Ministry of Posts and Telecommunications - Building Departament; (internal circulation paper from the Postal and Telecommunications Ministry), pp. 45; Japan, 1974.

18) ECT – Brazilian Postal and Telegraphic Enterprise – Manual de Transporte – DETRA; Brazil; 1991. (in Portuguese)

19) ECT – Brazilian Postal and Telegraphic Enterprise - *Manual de Organizacao – Modulo 21*; Brazil, 1992. (in Portuguese)

20) CODEPLAN - COMPANHIA DO DESENVOLVIMENTO DO PLANALTO CENTRAL (1991) *Pesquisa Domiciliar: Transporte 1990.* Brasília D.F. (in Portuguese)13)

21) Avery, T. E. and Berlin, G. L.: *Fundamentals of Remote Sensing and Airphoto Interpretation*: Maxwell Macmillan International, USA, 1990.

22) Taco, P. W. G., Yamashita; Y., Dantas, A.S., and Souza, N. M., *Trip Model with the Application of Remote Sensing and the Geografic Information Systems*, CD ROM 004 - *68th ITE Meeting*, Canada, 1998.

23) Yamashita, Y.; Dantas, A. S.; Taco, P. W. G., Yamamoto, K.; *Geographical Information Systems and Remote Sensing in Bicycle Planning*; Proceedings of the 21th Annual Meeting of Civil Engineering Planning– Civil Engineers Association of Japan; pp 295 – 299, vol. I; Shiga; Japan, 1998.