

A DECISION SUPPORT SYSTEM FOR THE PRIORITIZATION OF PROJECTS AND INVESTMENTS TO MAXIMIZE IMPACT ON REGIONAL DEVELOPMENT

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ABSTRACT

Funding specific projects and actions may be used to boost a region's economic growth, but maximizing impact requires making wise, well-informed investment allocation decisions. Multiple-criteria analysis provides a means for comprehensively considering and carefully weighing the financial, environmental, political, regulatory, and practical aspects involved in such complex decisions. Designing methodologies that take these variables into account, as well as software tools to effectively manage and support data associated with the various alternatives under consideration can greatly help with this process. This paper presents a methodology for the prioritization of projects aimed at regional development and the decision support tool developed for its implementation. This methodology was used for the elaboration of the Investment Master Plan (IMP) for the PRODEPRO project in Brazil.

Keywords: regional development, decision support system, multiple-criteria decision analysis.

1. INTRODUCTION

Multiple criteria decision analysis (MCDA) is an advanced field of operations research and management science, devoted to the development of decision support tools methodologies to address complex decision problems involving multiple criteria goals or objectives of conflicting nature (Financial Times 2015). Numerous multi-criteria decision making methods (MCDM) have been developed to help with decision problems by evaluating a set of alternatives given a set of criteria. Examples of MCDM include the Analytical Hierarchy Process (Saaty 1980), the Multi-Attribute Utility Theory (Keeney and Raiffa 1993), outranking techniques (Roy 1996), fuzzy techniques (Fuller and Carlsson 1996) and weighting techniques (Keeney 1999).

The application of these techniques within the context of regional development and funding programs is well known and they are found to be very useful for policy decision making (Huang et al. 2011). Abundant literature can be found reporting either the ex-post assessment of the impact of regional development funds (Křupka et al. 2011) or aiming at informing fiscal equalisation of development funds (Hajkowicz 2007). Additionally, multi-criteria analysis is employed both

for the comparison of alternatives and for monitoring of implemented actions (Garfi et al. 2011).

In this paper, we focus on the description of a methodology designed for the prioritization of projects aimed at regional development, as well as the decision support system developed to implement that methodology.

In the following section more information on the use-case is presented. Section 3 describes the methodology and general approach whereas in Section 4, the decision support system is precisely explained. In Section 5, the results obtained within the PRODEPRO use-case are outlined. This paper concludes with a summary of the corresponding conclusions.

2. PRODEPRO PROJECT IN BRAZIL

Brazil is the largest country in the Latin American region and the world's fifth largest country, both by geographical area and population. The Brazilian economy is the world's seventh largest by nominal GDP and the seventh largest by purchasing power parity (CIA 2014). In spite of being one of the world's fastest growing major economies in the last few years, further efforts are required in order to reduce the socio-economical inequalities between Brazilian regions. At present, Brazil is developing specific strategies for the economic and social enhancement of the five macro-regions of which it is composed, i.e., Northern, Northeast, Central-West, Southeast and Southern.

The Northeast Region (NE) is the country's poorest and least developed region where 58% of the total population and 67% of the rural population lives on less than \$2/day (IFAD 2014). The NE is the third largest of the five geopolitical regions of Brazil and is composed of nine states: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. With an area of more than 1.5 million km²—more than twice the area of Spain— it represents 18% of Brazilian territory; it has a population of 53.6 million people—28% of the total population of the country— and a contribution of 13.4% of Brazil's GDP (IBGE 2011).

In pursuing a specific NE regional development strategy, the Banco do Nordeste de Brasil (Brazilian Northeast Bank, BNB) and the Inter-American Development Bank (IDB) agreed in 2012 the provision of financial and technical resources for structuring the

Northeast Region Productive Development Programme (PRODEPRO). The main strategic goal of PRODEPRO is increasing the capacity of the NE Region to promote sustainable and competitive growth of its manufacturing sector contributing to economic and social development of the region, creating jobs, and reducing inequalities (IDB 2013).

For the effective launching of PRODEPRO, an Investment Master Plan (IMP) was developed. The IMP allowed the identification and the prioritized proposal of the infrastructures, projects and actions required to achieve the aforementioned strategic objectives. The IMP entailed the following series of goals, among others:

1. Characterising production sectors within the NE Region and detecting their technical, financial, infrastructural, legal, environmental, and institutional needs.
2. Estimating growing and economic contribution of production flows for a time span of ten years.
3. Identifying and prioritizing investment opportunities in infrastructures for the region's production units, including their logistic inter-dependencies.
4. Identifying and improving the capacity of the integrated production flows axis by means of new infrastructures elements for the national and international trade.
5. Developing an Executive Plan describing the investment proposals supporting the development of production flows within the NE region and its hinterland aimed at achieving maximum physical and economic integration between States and Regions.

The IMP was carried out by a joint venture made up by two Spanish engineering SMEs (Proyfe S.L. and Teirlog Ingeniería S.L.) and one local Brazilian partner (ASTEP Engenharia Ltda.).

3. METHODOLOGICAL APPROACH

An MCDM was specially developed for the prioritization of a series of investments in the NE of Brazil but it can be generalized and applied to other cases.

The proposed methodology is partially based on the fundamental principles of the analytical hierarchy process (AHP) - i.e. decomposition of the structure of the problem, comparison of judgments, and hierarchical composition of priorities- and its main goal was to aid decision making by providing the client with a solution for effective evaluation of the projects and investments under consideration within the IMP.

The AHP enables decision makers to structure decisions hierarchically: the strategic goal(s) at the top, evaluation criteria and subcriteria in the middle, and alternative choices at the bottom (as shown in Figure 1). Decision-makers and/or the analysts can define as many

subcriteria as deemed necessary. However, a large number of subcriteria might drag out the evaluation process. Provided that some parameters will be more relevant than others for achieving the strategic goals, the final analysis will only consider a set of relevant criteria which will in turn be weighed in relation to its importance. Therefore, those alternatives that perform well on the most relevant criteria will likely get higher scores.



Figure 1. Hierarchical Decision Structure

The methodology proposed in this paper is developed along two main phases and consists of the following steps:

Phase I

1. *Define the problem and the strategic goals.* This step is critical because all prioritization efforts have to be guided by the goals stated here.
2. *Determine judgement criteria.* In order to break down the decision problem, the strategic goals must be translated into relevant aspects (e.g. environmental criterion) which may be used to measure the level of performance of each alternative.
3. *Determine judgement parameters.* Criteria are defined as general assessment dimensions which represent and evaluate the goodness of projects regarding the objectives set. However, each criterion needs to be broken down into a set of relevant sub-criteria (also called parameters) that should have a much more specific meaning.
4. *Determine parameter indicators and scales.* For each parameter, a specific variable (or set of variables, in the case of so-called "compounds parameters") must be identified. Alternatives will be evaluated against each

parameter according to their “indicator” (value of the variable) and a pre-defined “scale”.

Phase II

5. *Determine each parameter and criteria relative weight.* The weights assigned to the various criteria and subcriteria show the relative importance of each one in the multi-criteria under consideration.
6. *Evaluation of the alternatives.* This is the core of the solution process. Input data associated with each alternative and parameter is required for their corresponding assessment.
7. *Determine global scores and rank the alternatives.* Once the scores of each alternative for each parameter have been obtained, parameter weights are taken into account to calculate each project’s global score.
8. *Generation of reports.* Executive Plans are generated based on the ranking of alternatives, budget constraints, and practical or political considerations.

Five main criteria (step 2) were considered for the PRODEPRO project, namely, (i) Social and Territorial Impact, (ii) Production Chain Performance, (iii) Transport and Logistic Improvements, (iv) Environmental Impact, and (v) Project Economic Characteristics.

Amongst the sixteen parameters considered for the PRODEPRO project are the following: Number of states affected, Number of microregions affected, Indigenous territories affected; Number of production chains, companies, and employees benefited; Reduction in logistic costs and times; Contamination and consumption of resources; Time to deployment, and Alignment with state policies and priorities.

The AHP was used to determine the weight assigned to both the criteria and the parameters (step 5). However, the high number of alternatives made it impossible to evaluate them using pairwise comparisons (step 6). Instead, each alternative is given a score for each parameter. In order to do so, the methodology integrates geographic information systems (GIS) and transportation modelling to obtain a set of Key Performance Indicators (KPIs) which are employed throughout the evaluation process. In this methodology, all partial scores are integer values ranging from 1 to 5. The global score (step 7) is the dot product of the vector of partial scores and the array that contains the weights of the parameters. A linear transformation is used to convert global scores to a 0-100 scale.

Results must be explained to and discussed with the client to select a list of alternatives (step 8) that will exploit synergies and maximize impact. This list has to take into account both budgetary constraints and practical considerations.

In addition, sensitivity analysis shall be conducted to measure the robustness and consistency of the results, in

terms of variations in the ranking of the projects assessed under changes in the weights assigned to the criteria.

Finally, it should be noted that discerning and selecting the alternatives is another problem that should be solved (at least partially) in a previous stage.

4. IMPLEMENTATION

A tool named COLMEIA (*colmeia* is the Portuguese word for hive) was developed in Microsoft Excel to handle large amounts of information and perform all the intermediate calculations necessary to carry out the MCDM developed for the PDI PRODEPRO.

The tool is able to perform the following key tasks:

- Simultaneous analysis and comparison of up to 1000 projects. This includes: storing all data associated with these projects (data from TransCAD transport analysis, generic project profile information such as type, infrastructure budget and location, environmental data from GIS tools, econometric models, etc.), calculating the 1000 individual scores of 1000 projects for each parameter, applying exclude filters to discard projects that should not be eligible for funding, and combining each vector to calculate the overall individual score of each projects.
- Automatic application of the AHP pairwise comparison to calculate the weights of up to 5 criteria (groups of parameters).
- Automatic application of the AHP to calculate the weights of up to 30 parameters (divided into five groups of six parameters). In addition, one or more parameters can be enabled or disabled at any time, if the end-user of the tool so wishes (global scores are recalculated consistently).
- Sort projects by score and priority level to generate action plans based on the total budget available for funding.

The tool allows reviewing and analysing at any time the reasons why some projects have achieved higher ratings than other projects, making all results “traceable”. In addition, it is possible to modify at any time the values considered to apply exclude filters, to calculate the importance of parameters and / or criteria against each other (AHP input data), etc.

Along with an effective implementation of the multi-criteria analysis, an extra effort to improve the efficiency of the code was carried out to avoid computation speed issues. On the other hand, a number of applications were implemented in COLMEIA to increase the tool’s usability and automate certain processes. These applications were developed using Visual Basic and created ad hoc to be used by the officers of the BNB and IDB, with a Portuguese user interface. The most important applications implemented are the following:

- Hyperlinks to relevant cells and spreadsheets.
- A wizard to modify key configuration values used in COLMEIA, such as eligibility thresholds (exclude filters) and available budget.
- A wizard for the introduction of new parameters.
- A wizard for the introduction, modification and/or removal of projects (see Figure 2).
- A routine to generate Executive Plans based on the ranking obtained and the budget constraints.

Figure 2. Screenshot of one of the windows implemented for the introduction of new projects.

To complete the description of the tool, the alternatives considered, the input data used, and the output data obtained in the context of the PRODEPRO project are now presented.

4.1. Alternatives under consideration

In order to meet the general objectives of a regional development program, it is necessary to define and propose projects and actions that may be very different in nature but must contribute to satisfy those goals. The origin of the projects considered in the PDI PRODEPRO was diverse, spanning transportation plans developed by different organizations at national or regional level and requests from different public administrations from the Northeast Region of Brazil. As transportation infrastructures are crucial for regional development, a significant portion of these projects consisted of new (or expansion of) logistic and transportation infrastructures which will channel the present and forecasted production flows in order to improve the productivity and competitiveness of the NE companies. These projects are also expected to enhance the physical integration between the nine states within the region and with the rest of the country; expanding the regional trade; and fostering exports and attracting foreign investment. Additionally, other type of

investments included new transportation, energy, and telecommunications projects.

4.2. Input data

A simulation model implemented in TransCAD was developed to first analyse the present capacity of the network in order to cope with the increase in production-consumption flows expected for the next 10-year period. Second, the impact of the forecasted infrastructures in the modal split accounting for the percentage of freight absorbed by the targeted modes - rail, river and maritime feeder transport- was assessed. The simulation model had a fundamental role for determining, for each project under consideration, parameters such as the reduction in logistic costs and times, the number of production chains, and the number of states and microregions benefited.

The model methodology is based on an adaptation of the four steps model (Ortúzar and Willumsen 2011) and the simulation model itself is based on a previous TransCAD model developed within the Brazilian National Plan for Logistics and Transport.

The model network was obtained from that study and updated with the latest links as well as the investment projects studied in PRODEPRO.

Figure 3 shows the full model network which contains road links (represented in black), rail links (red), sea (blue), and waterways (light blue). Each mesoregion border is depicted in light green and state borders with thick green lines.

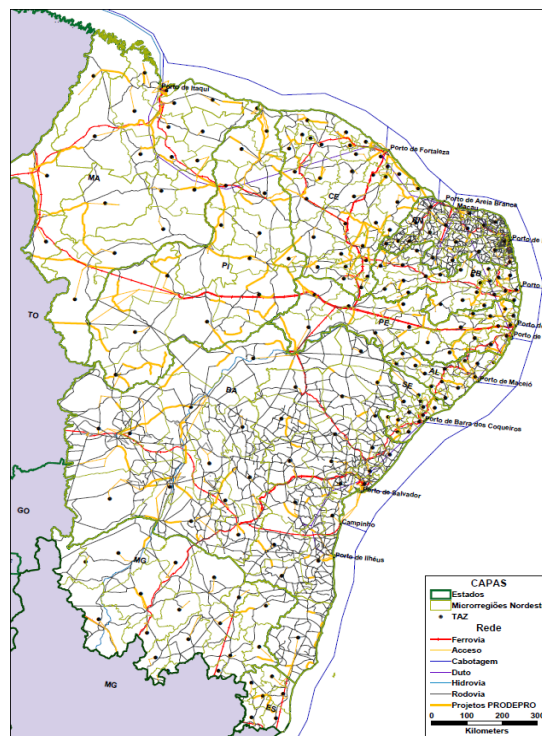


Figure 3. Model network. Investment projects to be analysed are remarked in yellow.

A thorough description of this transport model can be found in (Crespo et al. 2014).

4.3. Output data

The most relevant output data provided by COLMEIA is the ranking of alternatives, which includes their global and partial scores. This ranking is the foundation of the Executive Plan that contains the set of projects finally selected for funding. As explained in Section 3, results must be analysed and discussed with the client. In addition, COLMEIA generates a number of matrices and graphics (see Figure 4) to report key information such as budget distribution between states, most benefited chains, types of alternatives frequently chosen, and number of eligible projects by state and type, among others.

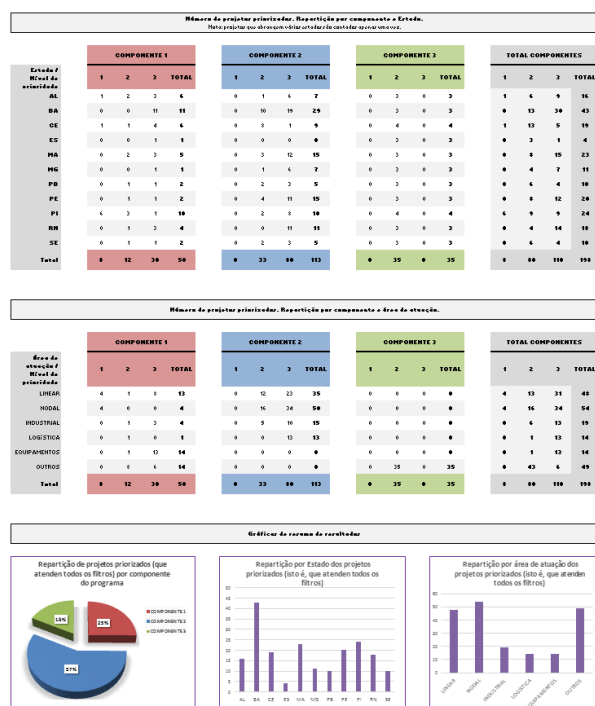


Figure 4. Example of reports generated by COLMEIA.

In the following section a summary of the results and conclusions drawn from the study carried out for the PDI PRODEPRO project can be found.

5. USE-CASE RESULTS

As stated by the client (BNB 2014), PRODEPRO's Investment Master Plan (PDI) is not only the program's major planning mechanism but also identifies the most important production sectors in the 11 states covered by PRODEPRO (in the Northeast, Minas Gerais and Espírito Santo), the related bottlenecks and priority investments for each sector and each state. Within this study, an initial set of 948 projects were considered. By means of an exhaustive filtering and pre-analysis process –which took into account, for each project, its estimate total cost, its current status, and political preferences, among many others- the initial set of projects was reduced to a list of approximately 350, from which 75% were analysed in a comprehensive manner with the criteria and parameters discussed in

previous chapters. The remaining projects were analysed under the same methodological framework but using a simplified set of parameters since they were feasibility studies and capacity building projects, and thus still far from certain implementation.

The analysis of the results ultimately led to the proposal of a prioritized set of investments constituting the infrastructure pillar of the PRODEPRO programme.

6. CONCLUSIONS

The methodology and the decision support system used for the elaboration of the Investment Master Plan (IMP) for the PRODEPRO development project in Brazil have been presented.

Whereas the AHP is used to determine the weight assigned to both the criteria and the parameters, the high number of alternatives made it impossible to evaluate them using pairwise comparisons. Instead, each alternative is given a score for each parameter. In order to do so, the methodology integrates geographic information systems (GIS) and transportation modelling to obtain a set of Key Performance Indicators (KPIs) which are employed throughout the evaluation process. An easy to use, adaptable, and flexible tool has been specifically designed to implement this methodology, as well as to manage and provide decision-makers access to all relevant economic information. By generating new evidence in support of a decision, this tool allows end-users to make more informed decisions, and improves transparency since it provides documentation for future reference and review (traceability).

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