New advances in decision making theory under uncertainty and its application in mega projects of hydropower

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ABSTRACT: Hydropower constitutes the main generation apparatus in Colombia, producing 64.2% of all power, so that the country is currently developing three mega projects with an installed capacity above 400 MW and two more hydroelectric construction projects are being considered. In spite of the need to expand electricity service coverage, the social consciousness about necessity of new hydropower generation developments and the expertise teams behind their execution, uncertainty over environmental impact is rarely totally estimated. This study uses the cumulative prospect theory by Kahneman and Tversky, to determine the scenarios in which large organisations tend towards losses among the uncertain environmental impact situations. It also will set prospect theory in an original and practical update arena to modelling the decision-making process and propose a policy, which manages to turn losses, linked to uncertainty, into income opportunities by enforcing the uses of external data.

INTRODUCTION

In 2014, the hydraulic power generation accounted for 64.2% of all power generation in Colombia [1], and during the next decade between building, feasibility and pre-feasibility studies, five more hydroelectric are projected, with an installed capacity that will be above 400 MW [1]. The national picture is a sample of the Latin American tendency to implement mega projects to supply electricity demand, which is corresponding to the economic growth from countries [2].

Despite the wide coverage of hydroelectric projects planned in the current decade and the benefits in terms of population served, there are conflicting opinions from environmental groups who describe this as the plundering of natural resources, configured in parallel [1]. At the same time questioning the inclusion of communities adjacent to the territories of involvement for the joint construction of the various stages of consolidation of the project is proposed.

The construction of hydroelectric power has gone from being a state policy of democratisation of public services, to an integration of private initiatives to promote the development of sustainable energy from large projects, of course, resulting in economic profits and strengthening social concern about the environment [2]. The decisions of the private sector are a response to indicative plans of governments [1]. Large organisations promote hydropower projects supported by the recommendations of highly specialised teams [3] in increasingly uncertain and ambiguous contexts, due to environmental impact assessment [4] and social alternatives studies.

The research presented here provides a novel explanation of one of the sources of conflict currently predictable between local communities and those constructing hydroelectric projects in Colombia, through an endogenous gaze at the large organisations [5] focused on the process of environmental decision-making based on judgment of experts. The study covers the construction of hydroelectric projects (> 350 MW) in Colombia; the participant companies represent all hydropower projects under construction during the study period.

The research employs cumulative prospect theory (CPT) [6] by considering its relevance as a descriptive theory of choice where expert judgment plays a salient role on organisational decision making processes facing conditions of uncertainty. To use this theory, it is necessary to establish the preferences of experts [7] and to identify those dimensions where they experience gains or losses relative to a reference point when choosing.

The field information was obtained from direct interviews with experts in the workplace, taking into account the design of interviews aiming to determine the use of the available heuristic [6] and its quantification, based on the criteria of ease of recall and deliberation time responses. The data are classified in areas of gain or loss, taking into account the cumulative frequency of the categorised responses for each expert. These behavioural studies correspond to *observational* studies category [8].

Various plausible scenarios of the probability function in the multidimensional scale were determined and each risk prospect for each organisation in the defined scenarios was measured [9]. Based on the results, regulatory recommendations for hydropower policy have been identified and organisational adjustments inside decision making process of companies studied. These changes in the current situation aim to overcome bias involving actual models of decision making based on expert judgment within organisations.

According to the behavioural school, one way to overcome these kinds of bias is by finding *external view* style solutions [10] and within that context, the authors propose the adoption of reference class forecasting. To incorporate this adjustment into the mathematical model, environmental and institutional dimensions are set to zero and simulated to obtain the new value function in terms of CPT [6]; thereby, they obtain the impacts of applying organisational adjustments onto the levels of conflict with local communities generated by the bias in the organisational decision-making process based on expert judgment.

This quantification method constitutes an original and effective way to identify opportunities to make organisational adjustment in companies that are fostering new megaprojects and seeking early involvement of local communities. The authors make use of the interpretations derived from the school of heuristics and biases [6] to generate organisational changes aimed at improving decision-making organisational processes to overcome the expert's overconfidence bias and normative environment to overcome the availability bias [11] produced by considering reliable organisation data (field gathering as primary source) instead of institutional data available (public knowledge as secondary source).

The endogenous approach selected by the authors is a novel line of research, which deviates from traditional approaches to the industrial engineering education framework, such as stakeholder theory and power analysis. Organisations adjust in order to identify new policies to reduce conflict levels between local communities; and large organisations involved in these megaprojects constitute an unexplored field in engineering education. Data gathering comes from all four companies that promote large hydroelectric projects in Colombia: EMGESA, CELSIA, EPM and ISAGEN. Selected environmental experts meet the criteria of excellence (high specific knowledge) and professionalism (recognition within an organisation as an expert) [7]. Two plausible and general assumptions were set: homogeneity of expertise and homogeneity of organisation.

METHODOLOGY

The background upon which this research had originated is presented in Figure 1. After a review of decision making schools, it has adopted cumulative prospect theory, because it incorporates expert judgment in the way that was observed in the organisations that promote large hydropower projects in Colombia.

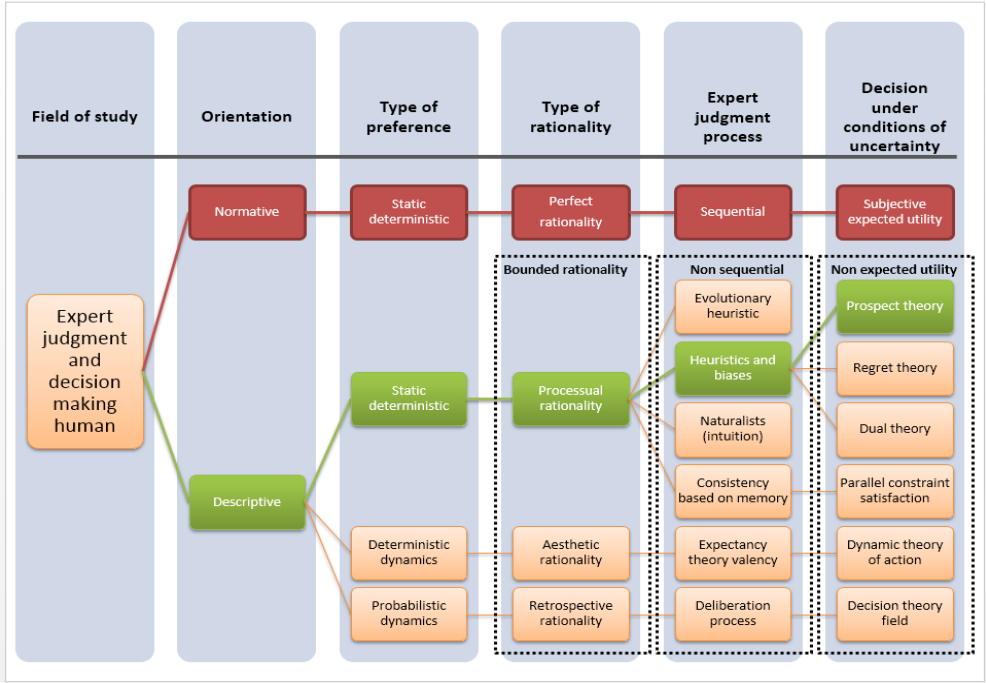

Figure 1. Taxonomy of decision theories under uncertainty (data source: own elaboration [12]).

For prospect theory, the mechanism by which the burden of decision making is assigned to highly qualified staff, is not a surmountable factor at the individual level, however, organisations do not realise this.

Determining the environmental damage of the implementation of a project in one place is often one of the aspects that experts give incidentally. Even those data are exposed to communities in one or another way to get social approval or to

meet the requirement of prior consultation. The picture to the community directly affected by the construction of a mega-project type hydropower cannot be deciphered at the time of decision making. Among the reasons for this is that the effects that will need to be faced will only be known many years, decades or centuries after the development.

However, despite the uncertainty surrounding these kinds of mega-projects, experts (representing the organisations) do not perceive the volatility of the data on which they base their decisions. Human nature aimed at controlling all variables in an uncertain future generates a strong organisation's predispositions to local community requests that at the end exist in controversial and hostile relations during project implementation with those communities.

In order to develop an appropriate descriptive model of decision making, it is necessary to undertake intensive fieldwork observation and capture information directly in the workplace [8][13]. Therefore, to identify the current environmental decision-making process executed for mega hydroelectric projects, the methodological tools adopted were surveys with structured (quantitative data) and unstructured (qualitative data) questions.

The study contemplates projects that exceed 350 MW of generation power and develop in Colombia [1]. To design the methodology tool chosen, it was necessary to identify precise points of inquiry aiming to corroborate or negate the assumptions made.

Furthermore, the tool design must allow for the replication of data from the respondents and generate qualitative inputs useful to validate quantitative results found [13]. At an early stage the organisations entrusted with implementation of projects relevant to the research were identified. It was concluded that organisations are: EPM, ISAGEN, EMGESA, and CELSIA [1]. These are in charge of all mega hydroelectric projects in Colombia between years 2010 and 2020.

These organisations delegated to their environmental experts responsibility for answering the survey designed [7]. The questions were identical for all four experts, and were asked in the same order and with the same procedure, which consisted of providing a maximum response time of five minutes for reply.

The register of answers was conducted through audio recordings and making notes about the first sentence or explanation enunciated by the expert to each question formulated. Such emphases on the expert's first answer ensured that the surveys would reflect the most immediate concerns of experts of organisations in specific work contexts [7]. Moreover, decision making theory indicates that an expert often uses a heuristic approach based on availability in making decisions [11].

Each survey lasted approximately 30 minutes, of which 91% of time was used by experts to answer. The responses had a unique option in most items, nevertheless, to explore how organisations prioritise [7], their two questions that aims to rank given answers from highest to lowest [11]. These attributes come from previously selected environmental impact assessment studies, and previous work done by other research in the study field of mega hydroelectric projects [2][4][6].

RESULTS AND DISCUSSION

The results obtained by applying the cumulative prospect theory model for cases of the organisations studied in Colombia are shown in Table 1.

Table 1: Value function outcomes using CPT model (source: developed by the authors [12]).

CPT model using Colombian coefficients	Value function assessed by case						
	Scenario analysis - CPT model outcomes						
Results by organisation	Colombian more probable case	Social salience case	Environmental salience case	Economic salience case	Institutional salience case	Technological salience case	Equal dimensional case
Organisation A	-16.95	-15.34	-15.74	-16.70	-18.68	-20.15	-17.23
Organisation B	-17.35	-15.34	-18.68	-15.74	-16.70	-20.15	-17.23
Organisation C	-17.25	-16.70	-18.68	-15.74	-15.34	-20.15	-17.23
Organisation D	-16.99	-18.68	-16.70	-20.15	-15.34	-15.74	-17.23
Consolidated all organisations	-17.26	-15.34	-18.68	-16.70	-15.74	-20.15	-17.23

This indicates that decision makers in large organisations associated with hydroelectric projects have a common characteristic, one that refers to loss risk aptitude in the technological dimension requirements. It also indicates the predisposition of organisations to address the most probable requirements of local communities in Colombia.

Experts and organisations that advance large hydroelectric projects in Colombia for the period studied are operating at a loss under all proposed scenarios [9].

Figure 2 summarises the process of environmental decision-making used by the organisations that are in charge of the implementation of mega hydroelectric projects in Colombia. The model indicates stages from deliberation, presentation of recommendations and acceptance by the organisation through the adoption of the proposed recommendation.

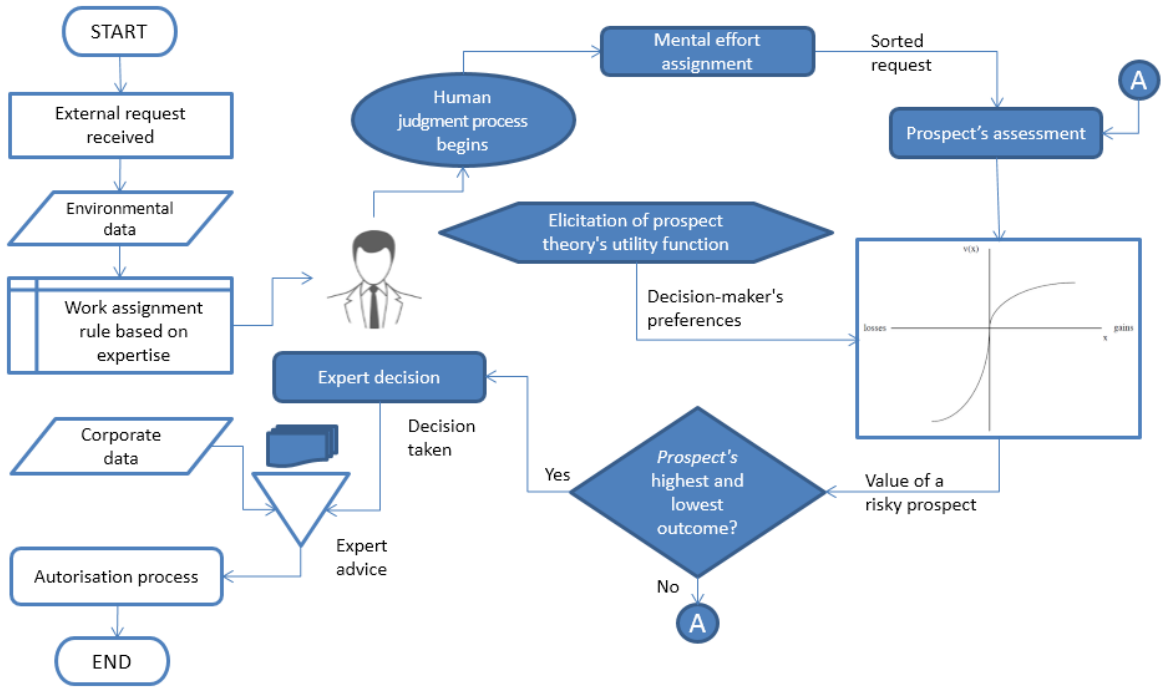

Figure 2: Environmental decision-making under uncertainty observed in work field of large organisations (source: developed by the authors [12]).

The model was built based on the findings from the survey [13] and observation of the work context in which experts develop activities reflecting the dynamics of organisations.

The decision-making process begins with a community requirement to the hydropower project. With this initial request, the organisations evaluate the feasibility of covering this claim, taking into account the degree of impact on environmental assessment already built, the organisational structure rule to deal those issues of each organisation and economic interest in participating in solving unmet demand. To determine project priorities, the organisation is assigned to the internal evaluation unit where experts are assigned. Once the functional area in charge is allocated, the person responsible for leading a group starts with an internal judgment, in which all previous expert perceptions are considered. Previous approaches to similar situations and the questioning of the actual human biases are avoided, because experts do not realise of their biases on decisions.

Likewise, the expert makes an effort to determine the mental shortcuts that will ease the cognitive load of making a decision, a well-known process established to aid decision making in advance, which takes advantage of their curriculum, professional and personal knowledge [11]. At this point, the availability heuristics emerge, that is, the expert arrives at the point of previous knowledge to organise the priorities to be addressed during the process [9]. There is a greater mental effort to recall a dimension, therefore, experts consider it must be less important than alternative dimensions, which have been readily recalled, so they fixed reference point, and any deviations experienced indicate a sure loss located in the value function [6].

The process of multidimensional analysis carried out by the expert occurs like this: a) take each of the social, economic, institutional, technological and environmental scenarios; b) evaluate them from a value function in advance; c) from this, analysis establish the most probable outcome of alternative solutions; d) define the risks function presented by each scenario; e) once the total scenario is seen in a panorama of gain for the expert (who may or may not be consistent with external data on the subject), he/she issues a final recommendation to the organisation to be validated and approved; and f) to complete the process of organisational decision making, the expert recommendation is contrasted with organisational data to ensure compliance with the quality minimum requirements and so on, internally [13]. The recommended decision goes to be adopted or rejected by the organisation; at this stage there is no place to change without notice.

CONCLUSIONS

Applicability of cumulative prospect theory in the Colombian scene implies a new practical way of understanding uncertainty in decision making in large organisations. This research has achieved the proposing of a multidimensional model that allows for estimate predisposition by experts in their mental process to evaluate changes on hydropower

projects when they value in zones of losses or gains because of the requests of the local community. This research will help other academic and everyday studies to decipher decision models where uncertainty is a variable to consider and unleash new engineering's applications based on new decision theories.

The new advances on decision making theories under uncertainty facilitate the comprehension of cumulative prospect theory for scholars interested in analysing organisation internal decision making processes that occur prior to mega projects being built. Results exposed in this text provide tools for identifying heuristics and biases during the decision making process, and will supply a benchmark for organisational changes proposed to fix organisational decision making when doing environmental impact studies and enabling local communities' participation.

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