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Understanding the impacts of electric mobility in the transportation patterns of the Azores using a spatial interaction model with alternative transportation modes

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Viability of Electric Cars in the Azores through stakeholder consultation

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Abstract. The Green Islands project, aiming at alleviating the energetic dependence of the Azores Archipelago, Portugal, involves the implementation and monitoring of a pilot study to test innovative solutions of electric mobility.

To determine the type of vehicle and system to be selected for this study, we scoped the market for hybrid and electric vehicles, which could be used in either of three application scenarios: general public, urban centres and by converting 20% of the car fleet of a smaller island into one innovative solution of electric mobility. We invited stakeholders from several sectors, such as auto and gas sales, public transportation, electricity production and distribution and urban planning. Resorting to Q Methodology, we asked them to sort the several options of vehicles/systems. The results were presented after they had the chance to hold an informal discussion over lunch. After the presentation we stimulated further discussion by asking them to choose one of the best rated vehicle/systems and defend their option. We held the experiment in the major two islands of the Azores, Terceira and São Miguel. In both sessions three distinct groups were formed, one that favours a family car that resembles as much as possible the current gas cars in autonomy and charging time, one that favours public transportation and a third that favours innovation in the transportation system by investing in small two-seat cars. Finally we undertake a preliminary Cost-Benefit Analysis for electric cars in the Azores for different contexts of income and average mobility.

Key words

Electric vehicles, hybrid vehicles, pilot study, Q Method, stakeholder consultation, Cost Benefit Analysis.

1. Introduction

The Azores Archipelago, Portugal, is a group of nine islands located in the mid-Atlantic ridge, some 2000 miles away from Mainland Portugal. The remoteness and insular nature of this territory made it appealing to the MIT-Portugal Program as the location for implementing a renewable energy project, which took the form of the Green Islands project (check <http://www.mitportugal.org/ses/research-projects.html>).

In the project, MIT-Portugal and the Regional Government of the Azores are strategic partners in the design and implementation of sustainable energy systems and economic development for the islands. The aims of the project are to identify robust, long-term sustainable energy strategies for the Azores, to design policies, projects and business opportunities to implement the long-term strategy; to create partnerships with local governmental agencies and interested public and private agents; and to coordinate with potential investors.

The objectives of the Azores Strategic Energy Plan are:

- 1) Increase the use of electricity in the overall energy mix;
- 2) Increase the use of renewable electricity in the overall electricity mix;
- 3) Increase the use of renewable energy in non-electric energy supplies.

One of the energy heavy sectors targeted is the transportation/mobility sector. The trends and patterns in vehicle fleet composition and use, including public transport and freight, land, maritime and air are being analysed, and a pilot-study will be conducted with alternative vehicles.

In this paper we conducted a process of stakeholder consultation and a cost benefit analysis to determine which type of electric vehicle is the overall favourite and for which context of income and mobility.

2. Q Method in stakeholder consultation

There are several methods available for deciders and policy makers to use in assessing the role and motivations of stakeholders [1]. One of these is Q Methodology [2] in which participants are asked to rank several statements by order of importance or agreement. These Q Statements are gathered beforehand through interviews with prominent stakeholders and/or from media and other sources. The results are analysed through a Principal Component Analysis where each respondent (Q Sort) is a variable. Respondents are grouped into factors according to the degree of similarity of their rankings.

Thus, this method allows not only to gather a measure of the subjectivity of the respondents, but also to determine the similarities and divergences between factors or groups, establishing a basis for dialogue and discussion [3].

There are a few examples of Q Methodology as a basis for consultation and participatory decision in the literature. One example is given by Sweeden [4], who resorted to this method to “find a common basis for cooperation among groups with a long history of conflict over forest management issues (...)” Her argument for Q Methodology is that participatory decision methods are preferable to a more limited monetary valuation in ecosystem decision processes. In her words, “Understanding the attitudes of groups involved in conflict over ecosystem use is crucial for designing policies that have a chance of being implemented, as well as being equitable and sustainable. Thus, the use of Q method is an essential step for supporting successful public participation in decisions affecting ecosystem sustainability.”

Other examples are Rajé’s [5] work with Q methodology to explore the different perspectives people have of transports in their lives and how these affect their social inclusion, and Hawthorne and colleagues [6], who used photos instead of statements to assess the relation between spatial proximity and opposing reaction to the development of recreational trails in abandoned railways.

An example even closer to what we aimed to do in this paper was presented by Doody et al. [7] who used Q Method to analyse the discourse, combining public opinion with technical expertise to select sustainable development indicators

3. Methodology

Two meetings were held, one in Terceira (December 29th 2009) and one in São Miguel (December 30th 2009). These islands were selected as they have the largest populations and economies, and in several cases, the companies providing services in smaller islands such as gas and electricity sales are located in these larger islands. São Miguel has a much larger territory and therefore a larger road network than Terceira, and for this reason, we opted for two separate meetings instead of attempting to hold a videoconference and treat the respondents as a uniform group.

Before the actual meetings, a pilot meeting was held with researchers of the University of the Azores from several areas so as to fine tune the questionnaire.

A. Participants

Twelve stakeholders from the most important companies and institutions of the relevant sectors in the Azores attended the meeting in each island (Table I).

Table I. – Stakeholders

STAKEHOLDERS	TERCEIRA	SÃO MIGUEL
Gas and fuel sales	1	-
Electricity production	1	1
Auto sales, rental, other	1	2
General businesses	2	2
Public transportation	1	-
Urban planning	3	1
Regional Government	1	2
Research	1	3
Renewable energies	1	1

B. Concourse and Q Statements

Instead of following the traditional steps of concourse gathering from discourse analysis, we performed a market analysis to define what the real vehicle options were and used those as Q Statements, presented in a table to the participants after a brief oral presentation (Table II).

Prices were deliberately omitted so as to avoid skewing the results towards more financially accessible alternatives in detriment of those that were truly preferred by the participants. The question was not to know what vehicle /system was more appropriate for each one of them in terms of individuals but in terms of the institutions they were affiliated.

C. Analysis

Results were analysed with PQMethod software (<http://www.lrz-muenchen.de/~schmolck/qmethod/>) to run a PCA with varimax factor rotation. The number of factors was selected based on the ratio of questions/respondents, with at least three defining sorts per factor, which resulted in three factors for each of the meetings but also when all the participants were grouped together.

After the discussion of the results (see section D), participants were asked to chose and rank three of the choices defended previously. We calculated the modes for each ranking (1, 2, and 3) and for all the votes polled together.

D. Generating discussion

The participants were invited for a light lunch while the results were being analysed, as a way to start an informal discussion.

After lunch, the relevant Q Method results were presented in two slides, one where the participants were grouped by factor, and one where the 4 top ranking Q Statements were listed for each factor, as well as the top consensus statements.

Each participant was then asked to select a Q Statement from his own factor or from the consensus and justify why he found that choice appealing, addressing five issues:

- a) What problems does this solution solve?
- b) What values and objectives underlie this course of action?
- c) Which solutions do you reject upfront and why?
- d) Are there unspoken values behind these choices?
- e) What are the risks of your choice?

Table II. – Q Statements

MARKET SOLUTIONS					APPLICATION SCENARIOS		
					General Public	Urban Centres	20% of the island with electric cars
Type	No. of seats	Battery solutions (*)	Range	Top speed			
Electric	4+1 seats	Bat. - 6 hours	+ 100 km	+ 50 km/h	1	15	29
			- 100 km	- 50 km/h	2	16	30
		Bat. + 6 hours	+ 100 km	+ 50 km/h	3	17	31
			- 100 km	- 50 km/h	4	18	32
		Bat. Change	- 100 km	- 50 km/h	5	19	33
	2 seats	Bat. - 6 hours	+ 100 km	+ 50 km/h	6	20	34
				- 50 km/h	7	21	35
		Bat. + 6 hours	+ 100 km	+ 50 km/h	8	22	36
				- 100 km	+ 50 km/h	9	23
				- 50 km/h	10	24	38
	Bat. Change	+ 100 km	+ 50 km/h	11	25	39	
	Over 10 seats				12	26	40
Hybrid	5 seats				13	27	41
	Over 10 seats				14	28	42

* Battery charging time refers to a full charge at 220v.

4. Results and Discussion

Overall, the results were statistically sound, with low correlation between factors and a fairly high percentage of variance explained by each factor and model (Table III).

Table III – Correlations between factor scores and percentage of variance explained by factor

FACTORS	<i>1</i>	<i>2</i>	<i>3</i>
<i>Terceira</i>			
<i>1</i>	1.0000	-0.0910	0.3132
<i>2</i>	-	1.0000	0.0843
<i>3</i>	-	-	1.0000
<i>% expl. var.</i>	22	20	19
<i>São Miguel</i>			
<i>1</i>	1.0000	-0.0140	-0.0265
<i>2</i>	-	1.0000	0.0469
<i>3</i>	-	-	1.0000
<i>% expl. var.</i>	21	19	18
<i>Terceira and São Miguel</i>			
<i>1</i>	1.0000	0.0349	0.1094
<i>2</i>	-	1.0000	-0.0130
<i>3</i>	-	-	1.0000
<i>% expl. var.</i>	20	19	12

A. Terceira Island

In a normal Q study the complete rankings for each factor are analyzed to gain a complete understanding of the perspective regarding likes and dislikes but in this case we were only interested in the higher rated Q Statements. Since the objective here was merely to detect if there were natural groups within the stakeholders and which alternatives these favoured. Furthermore, with only one hour to process the data and examine the results before the discussion, we only looked at the higher rankings, selecting the four Q Statements with the highest z-scores for each factor and the high ranking consensus statements.

There were five consensus statements, of which only Q Affirmation [28] (Hybrid over 10 seats in urban centres) ranked high (scoring 4 for factors 1, and 3 and 5 for factor 2). Other statements were [7], [24], [35] and [37] (check table II for vehicle and system).

Factor 1 grouped stakeholders from academia, gas sales and general businesses. The elements of this group were somewhat disgruntled with the results as they were grouped more for their lower preferences than their highest. In this factor the highest ranking statements markedly favoured hybrids:

- [13] Hybrid, 5 seats, general public (z-score 2.032);
- [41]: Hybrid, 5 seats, small island with 20% penetration (z-score 1.946);
- [27]: Hybrid, 5 seats, urban centres (z-score 1.844);
- [42]: Hybrid, over 10 seats, small island with 20% penetration (z-score 1.738).

The second highest loading participant was in gas sales, which, coupled with the high agreement on the lower extreme (-6, -5 positions) could explain the hybrid preponderance in this group.

Factor 2 gathered stakeholders from the regional government, general commerce, electricity production and urban planning. They clearly favoured vehicles that could offer the same level of comfort and usability as the present combustion vehicles, regardless of the application scenario, as we can see in from their highest ranking statements:

- [1]: Electric, 5 seats, large autonomy, high velocity, fast charging, general public (z-score 2.565);
- [3]: Electric, 5 seats, large autonomy, high velocity, slow charging, general public (z-score 1.544);
- [28]: Hybrid, over 10 seats, urban centres (z-score 1.339);
- [15]: Electric, 5 seats, large autonomy, high velocity, fast charging, urban centres (z-score 1.284).

Not surprisingly, the highest loading Q Sort here was from the electricity production and sales stakeholder.

Factor 3 gathered stakeholders from urban planning, public transportation and car sales. They clearly favoured public transportation solutions:

- [26]: Electric, over 10 seats, urban centres (z-score 2.404);
- [14]: Hybrid, over 10 seats, general public (z-score 1.542);

- [42]: Hybrid, over 10 seats, small island with 20% penetration (z-score 1.422);
- [28]: Hybrid, over 10 seats, urban centres (z-score 1.371).

Q Statement [42] was high ranked both in factor 1 and factor 3 (hybrid, over 10 seats, small island with 20% penetration).

During the discussion, electric and hybrid buses were defended as a way to show the quality of these vehicles to the public without letting the initial investment fall on them, which could be a deterring factor. These buses would also provide much needed relief to urban congestion and pollution problems. The risk in adopting one of the bus solutions, defended in the after lunch meeting ([26], [28] and [14]) for the pilot study, was that, later on, individuals of the general public might not feel compelled to adopt a private electric or hybrid solution for their private transportation.

Five seat electric cars with fast charging and high autonomy and velocity for the general public ([15], [1] and [4]) were also defended by several participants, because they are versatile, easy to use, comfortable and the closest option to the current means of transportation, which would contribute to lessen the objections buyers might have.

During the discussion two other options were defended by the a gas sales stakeholder; he defended the hybrid car by, under the grounds that “good is the enemy of great” and that hybrid technology was well developed whereas electric car technology, although optimal in theory, still had major hurdles to overcome to be able to satisfy the public.

Another alternative defended was by a stakeholder from the academia, who argued that there was a need to shift the current transportation paradigm pervading Europe (5 seat cars with 1 occupant), akin to the American system, to one more adapted to the urban structure and needs of Europe. The way to achieve this transformation would be to adopt a 2 seat electric car.

After the discussion, when asked to chose and rank their 3 favourite options, the most voted choice in the first place was [26], with [1] in the second place. When all the votes for all the positions were polled together, [1] was the most chosen option, thus indicating a heavy interest in a family cars close to the current combustion model.

B. São Miguel Island

Unlike in the Terceira meeting, in São Miguel there was no high ranking consensus Q Statements: all were neutral or negative. Consensus statements were [5], [17], [19], [21], [24], [30], [32], [36], [37] and [38] (check table II).

Factor 1 gathered stakeholders from electricity production and sales, general commerce and urban planning. Their choices were oriented to public transportation and to electric family cars:

- [26]: Electric, over 10 seats, urban centres (z-score 2.132);
- [29]: Electric, 5 seats, large autonomy, high velocity, fast charging, small islands with 20% penetration (z-score 2.042);
- [28]: Hybrid, over 10 seats, urban centres (z-score 1.450);
- [16]: Electric, 5 seats, low autonomy, low velocity, fast charging, urban centres (z-score 1.422).

Factor 2 gathered stakeholders from academia and the renewable energies sector. Their preferences went to electric cars, both family and smaller sized, with characteristics close to the current combustion vehicles for ease of use.

- [3]: Electric, 5 seats, large autonomy, high velocity, slow charging, general public (z-score 1.904);
- [1]: Electric, 5 seats, large autonomy, high velocity, fast charging, general public (z-score 1.789);
- [6]: Electric, 2 seats, large autonomy, high velocity, fast charging, general public (z-score 1.717);
- [15]: Electric, 5 seats, large autonomy, high velocity, fast charging, urban centres (z-score 1.561).

Factor 3 gathered stakeholders from academia, and car sales and car rental, who markedly preferred an innovative solution for transportation by heavily voting on small electric cars:

- [20]: Electric, 2 seats, large autonomy, high velocity, fast charging, urban centres (z-score 2.110);
- [6]: Electric, 2 seats, large autonomy, high velocity, fast charging, general public (z-score 1.709);
- [34]: Electric, 2 seats, large autonomy, high velocity, fast charging, small islands with 20% penetration (z-score 1.655);
- [11]: Electric, 2 seats, large autonomy, high velocity, battery changing, general public (z-score 1.606).

It is interesting to keep in mind the geographical and accessibility differences between Terceira and São Miguel islands as we look into the results. Most São Miguel stakeholders defended electric public transportation in urban centres ([26] and [28]) for basically the same reasons as the Terceira stakeholders had: to promote public trust, and to demonstrate their effectiveness, durability and robustness.

On the other hand, electric cars for the general public and/or in small islands with 20% penetration, similar to the current combustion models in flexibility and usability ([29], [1], [3], [15]), were also defended for the pilot study on the same grounds: to demonstrate the durability and robustness of electric vehicles, while, counting on word of mouth, to spread the praise of these solutions and rapidly change their degree of acceptance.

A shift in the transportation paradigm by using small cars was again defended, this time by two participants, one from academia, the other from car sales and car rentals.

When ranking their three most preferred solutions, after the discussion, the most voted choice in the first place was [26], and [1] in the second place again. But when all the votes for all the positions were polled together, [26] was the most voted, which is probably a reflection of the heavier urban transportation burden that is felt in São Miguel.

C. Terceira and São Miguel Islands

There were several consensus statements for this analysis ([12], [16], [21], [22], [26], [33], [34], [35], [36], [37]), most of which ranked as fairly neutral Q Statements, safe for [26] and [16] which ranked high.

Factor 1 gathered stakeholders from gas sales, general commerce, urban planning, electricity production, and car sales and car rental. The best ranking vehicle is an electric bus, but the group trend seems to be a family electric car that offers as much comfort of use as the current combustion vehicles:

- [26]: Electric, over 10 seats, urban centres (z-score 1.828);
- [29]: Electric, 5 seats, large autonomy, high velocity, fast charging, small islands with 20% penetration (z-score 1.606);
- [13]: Hybrid, 5 seats, general public (z-score 1.540);
- [1]: Electric, 5 seats, large autonomy, high velocity, fast charging, general public (z-score 1.189).

Factor 2 gathered stakeholders from academia, regional government, urban planning, general commerce, electricity production, renewable energies and car rental. As for Factor 1, they favoured electric cars close to the current model, but also ranked high electric public transportation and a small, versatile, electric vehicle – the emphasis of this factor was on visibility by the general public:

- [3]: Electric, 5 seats, large autonomy, high velocity, slow charging, general public (z-score 1.918);
- [1]: Electric, 5 seats, large autonomy, high velocity, fast charging, general public (z-score 1.908).
- [26]: Electric, over 10 seats, urban centres (z-score 1.526);
- [6]: Electric, 2 seats, large autonomy, high velocity, fast charging, general public (z-score 1.443).

Factor 3 gathered stakeholders from urban planning, car sales and public transportation. Unlike the precedent factors, they much favoured hybrids, which, judging by some of the comments made by the participants, was due mainly to their interest in public transportation combined with readily available technology, free of the drawbacks of electric cars:

- [28]: Hybrid, over 10 seats, urban centres (z-score 2.221);
- [14]: Hybrid, over 10 seats, general public (z-score 1.934);
- [42]: Hybrid, over 10 seats, small island with 20% penetration (z-score 1.799);
- [40]: Electric, over 10 seats, small island with 20% penetration (z-score 1.603).

While the number of Q Sorts would have allowed for the characterization of 4 factors in a classic Q study, here, 2 of these 4 factors, while not highly correlated, ranked high the same solutions, making this analysis pointless for our purposes. As such, we decided on maintaining the 3 factor analysis, obtaining again: one faction for electric family cars that must be flexible and easy to use; one mixed faction that favoured the electric family car but also less popular solutions, such as the 2 seat electric car; and, finally, faction for public transportation mostly on hybrids.

5. Conclusion

Q Methodology is not designed and does not intend to devise the most popular views for a given problem but rather to reveal the different discourses, being thus useful to gain perspective on the situation and eventually favour an open discussion, and ultimately to inform decision.

As such, from this study we conclude that there is a considerable stakeholder interest in three very different scenarios when making choices for a pilot study on alternative transportation: a group defends public transportation, electric or hybrid, is the way to go, as it is very visible and removes the burden of the initial investment from the general public; then there is a group

that defends hybrid or electric cars that are very similar in autonomy, velocity and ready use to conventional cars; and finally there is a group advocating a deep change in the transportation paradigm, by adopting vehicles much more suited to the needs of the average urban dweller – smaller, more economic and versatile (keeping in mind that most Azorean islands are smaller than the average city in area to travel).

The purpose of this study was to inform decision on the selection of pilot projects. We consider that the present information on three preferred scenarios achieves this goal. Further works involves a choice experiment to assess the specificities of those three vehicle/systems and, along the implementation of the pilot projects, a suitable monitoring system.

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