Non-Technical Barriers

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Abstract

Non-technical barriers to investments in an engineering project can be interpreted as a fuzzy set. The barrier analysis in this lecture note applies fuzzy logic, and it combines a checklist interview with SWOT analysis. As a result a single score indicates the level of barriers. On a higher level, the combination of the level of barriers with the perceived risk indicates the willingness to invest.

Contents

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1 Introduction

An investor's willingness to invest in an engineering project depends not only on economic indicators, such as payback period and internal rate of return, but also on non-technical barriers. Non-technical barriers can threaten an investment project during the planning stage or later, and they can be difficult to measure quantitatively due to their psychological (qualitative) nature.

In order to convey the concept of a non-technical barrier to investors and between project partners, we define it more succinctly as follows (Jantzen, Hermansen and Venetis 2010).

Definition *Non-technical barrier* (NTB). A hindrance to a project due to human concern, as opposed to a technical hindrance. For example, 'I am concerned that the planned biogas plant will spoil the landscape' or 'I am concerned that it will be difficult to find enough local investors'.

If an investor expresses an opinion that can be preceded by the sentence 'I am concerned that ...', then we regard it as a non-technical barrier. Thus any concern, anxiety, or fear qualifies as an NTB.

Several authors have attempted to solidify the concept by taking a scientific approach (e.g., Rösch and Kaltschmitt 1999; Roos, Graham, Hektor and Rakos 1999; Kaya 2006; Lantz, Svensson, Björnsson & Börjesson 2007; McCormick & Kåberger 2007; Mirza, Ahmad, Harijan & Majeed 2007; Painuly 2001; Praserts & Sajjakulnukit 2006). As a general rule, the research studies attempt to identify, and then classify barriers by analysing past projects and interviewing stakeholders. Examples of general NTB classes produced by previous studies include: financial, administrative, organisational, infrastructural, and perceptual barriers.

Intuitively a barrier can be present or not, and it can be large or small. We interpret a given barrier as being a member of a *fuzzy set*, as defined by Lotfi Zadeh (see for instance Zadeh 1994). A non-technical barrier is thus a member to a degree of the fuzzy set of barriers.

As a preliminary step towards an analysis of NTBs, we compose a checklist that we present to potential investors. The aim is to interview potential investors in order to check the presence or absence of a set of anticipated barriers. It is a quantitative approach, with predefined responses to a set of propositions. Notice that we do not attempt a statistical investigation of the issue. We combine the checklist with a SWOT analysis.

Once we have identified a set of barriers, it will guide us to propose relevant actions to overcome the barriers.

2 Theoretical Basis

Lotfi Zadeh observed (Zadeh 1965):

> Clearly, the "class of all real numbers which are much greater than 1," or "the class of beautiful women," or "the class of tall men," do not constitute classes or sets

in the usual mathematical sense of these terms.

For instance, in the fragment "the class of tall men", the concept of tall is an elastic property related to the height of men, not a crisp yes / no type of definition. Parallel to this we observe that in "the class of non-technical barriers to a project", the concept of a non-technical barrier is elastic.

Lotfi Zadeh developed a theory of fuzzy sets based on his observation and from that a fuzzy logic. The following is an extract of the definitions that are necessary and sufficient for our purpose (more in Jantzen 2007).

2.1 Fuzzy Sets

A *membership grade* allows finer detail in the definition of a set, such that the transition from membership to non-membership is gradual. The membership grade for all members of a set defines a *fuzzy set*. Given a collection of objects $\mathcal{U}$, a fuzzy set $\mathcal{A}$ in $\mathcal{U}$ is defined as a set of ordered pairs

$$\mathcal{A} \equiv \{\langle x, \mu_{\mathcal{A}}(x)\rangle \mid x \in \mathcal{U}\} \tag{1}$$

where $\mu_{\mathcal{A}}(x)$ is called the *membership function*for the set of all objects x in $\mathcal{U}$ — for the symbol '$\equiv$' read 'defined as'. The membership function relates to each x a membership grade $\mu_{\mathcal{A}}(x)$, a real number in the closed interval $[0, 1]$. Notice it is necessary to work with pairs $\langle x, \mu_{\mathcal{A}}(x)\rangle$, whereas for classical sets a list of objects is sufficient to signal their membership. An *ordered pair* $\langle x, y\rangle$ is a list of two objects, in which the object x is considered first and y second (note: in the *set* $\{x, y\}$ the order is insignificant).

The term 'fuzzy' (indistinct) suggests a boundary zone, rather than a sharp line. Indeed, fuzzy logicians speak of classical sets being *crisp* sets,to distinguish them from fuzzy sets. As with crisp sets, we decide by intuition which objects are members and which are not; there is no formal basis to determine the membership grade of a fuzzy set. The membership grade is a precise measure, but it rests on personal opinion (arbitrary).

The definition of a fuzzy set extends the definition of a classical set, because membership values μ are permitted in the interval $0 \leq \mu \leq 1$, and the higher the value, the higher the membership. A classical set is consequently a special case of a fuzzy set, with membership values restricted to $\mu \in \{0, 1\}$.

2.2 Fuzzy Logic

Formal logic is based on set theory, and it can be used to judge the correctness of a chain of reasoning. The 'truth' or 'falsity' assigned to a proposition is its *truth-value*. In *fuzzy logic*, based on fuzzy sets, a proposition may be true or false, or even an intermediate truth-value such as *maybe true*. A *proposition* is in fact a declarative statement (assertion) which has a truth-value associated with it. The sentence 'John is a tall man' is an example of a fuzzy proposition having a fuzzy truth-value in the interval $[0, 1]$.

In daily conversation and mathematics, sentences are connected with the words *and*, *or*, *if-then* (or *implies)*, and *if and only if*. These are called *connectives*. A sentence which is modified by the word 'not' is called the *negation* of the original sentence.The word 'and' is used to join two sentences to form the *conjunction* (symbol $\wedge$) of the two sentences.

The word 'or' is used to join two sentences to form the *disjunction* (symbol $\vee$) of the two sentences. From two sentences we may construct one, of the form 'If ... then ...'; this is called an *implication* (symbol: $\Rightarrow$). The sentence following 'If' is the *antecedent*, and the sentence following 'then' is the *consequent.*

2.3 Inference

Logic provides principles of reasoning, by means of *inference*, the drawing of conclusions from assertions. The verb 'to infer' means to conclude from evidence, deduce, or to have as a logical consequence (do not confuse 'inference' with 'in*ter*ference'). *Rules of inference* specify conclusions drawn from true assertions.

One such rule of inference is *modus ponens*. It is often presented in the form of an *argument*:

$$\frac{\begin{array}{l}P\\P \Rightarrow Q\end{array}}{Q}$$

In words: If 1) P is known to be true, and 2) we assume that $P \Rightarrow Q$ is true, then 3) Q must be true. Restricting for a moment to two-valued logic, we see this from the truth-table (Cayley table) defining implication,

Implication

$p \Rightarrow q$

$\downarrow p$ \ $\rightarrow q$	0	1
0	1	1
1	0	1

(2)

Along the vertical axis, symbolized by arrow $\downarrow$, are the possible values 0 and 1 of the first argument P. Along the horizontal axis, symbolized by arrow $\rightarrow$, are the possible values 0 and 1 of the second argument Q. Above the table, the proposition $p \Rightarrow q$ reminds us that the table concerns implication. At the intersection of row i and column j (only counting the inside of the box) is the truth-value of the expression $p_i \Rightarrow q_j$. By inspection, one entry renders $p \Rightarrow q$ false, while three entries render $p \Rightarrow q$ true.

The variable P belongs to the vertical p-axis and Q belongs to the horizontal q-axis. By assuming P true we consider only the second row of the table, and this row contains only a single 1, which is in the second column corresponding to true; therefore Q true is the only possibility. The table depicts that whenever $P \Rightarrow Q$ and P are both true, then so is Q, which is modus ponens.

In such an argument the assertions above the line are the *premises*, and the assertion below the line is the *conclusion*. Notice the premises are assumed to be true, we are not considering *all* possible truth combinations.

As an aside, in a dual fashion, we note that if we assume Q false, we consider only the first column, and this column contains only a single 1; therefore P false is the only valid possibility. This is in fact another rule of inference called *modus tollens*: If 1) Q is known to be false, and 2) we assume that $P \Rightarrow Q$ is true, then 3) P must be false.

Example 1 *Two rules of inference*

(a) Modus ponens. *Let $P \Rightarrow Q$ stand for 'altitude sickness causes a headache'. If John is in a high altitude, and he suffers from altitude sickness, P is true. Therefore the consequent Q is true: John has a headache.*

(b) Modus tollens. *If Jane is in a high altitude, and she does not have a headache, Q is false. We may therefore conclude that Jane does* not *suffer from altitude sickness (the antecedent P is false).*

3 Investigation Method

The aim is to interview potential investors in order to check the presence or absence of a set of anticipated barriers. It is a quantitative approach, with predefined responses to a set of propositions.

3.1 Checklist of Barriers

Investors are presented with a checklist of barriers in the form of propositions. If the respondent answers 'agree' to a proposed barrier, the barrier is present; if 'disagree', then it is not present, considering just the extreme cases for now. All barriers on the list are formulated in terms of a proposition, so they can be answered in a uniform manner. Since each item is a barrier, all items carry a negative connotation. Appendix A has examples of barriers from such a checklist.

We also wish to measure the strength of each barrier. Therefore the answer options in the checklist actually consist of a selection of seven answers arranged on an ordered scale:

agree	1.0
more or less agree	0.8
slightly agree	0.6
maybe	0.5
slightly disagree	0.4
more or less disagree	0.2
disagree	0.0

Each number, invisible to the respondent, is the *agreeability* that we associate with the response in order to process the results by computer. We interpret the agreeability as a degree of membership of the fuzzy set of non-technical barriers. The table above constitutes a membership function. The response indicates the degree of presence of the tested barrier according to the respondent.

A score of 1.0 indicates 'fully present', a score of 0.0 indicates 'not present', and an intermediate score indicates presence to a degree. Notice that a middle score of 0.5 indicates 'maybe present', and apart from the middle point, the numbers on the scale are equally spaced. The membership function and the distance between points is chosen arbitrarily.

We regard the score of 0.5 as neutral, and anything above 0.5 represents a barrier.

Furthermore, we regard scores below 0.5 as an *incentive*. This is because we expect that barriers are at least 'maybe present' in a project, and if a respondent answers that a barrier is *not* present to a degree, it is a relative incentive. Incentives and barriers oppose each other; therefore we assume that the overall barrier level is the average of all respondent scores, a single number.

3.2 SWOT analysis

To accommodate more variety, we apply SWOT analysis to the non-technical barriers. SWOT analysis is a method for analysing success factors of a business proposal, project, or any other objective for that matter. A factor which is *internal* is classified as either a strength (S) or a weakness (W), and a factor which is *external* is classified either as an opportunity (O) or a threat (T). For a brief introduction to the method, see for example Morrison (2008), and for an application to regional planning with respect to renewable energy, see Terrados, Almonacid and Hontoria (2007).

We distinguish between internal and external barriers according to some discriminator, for example the boundary of an organization. Roughly speaking, internal NTBs are susceptible to our actions, while external NTBs are beyond our control. In terms of agreeability scores, we interpret the S, W, O, and T categories in a particular manner:

- Internal barrier: weakness (W) if agreeability > 0.5, strength (S) if agreeability < 0.5
- External barrier: threat (T) if agreeability > 0.5, opportunity (O) if agreeability < 0.5

The barriers may be grouped under sub-categories: administrative barriers, regulatory barriers, economic/infrastructure barriers, financial barriers, product markets/competition/risk perception barriers, public awareness & acceptance barriers, and user defined barriers. Notice that although these sub-categories are broad enough to entail the majority of barriers, their ad hoc nature requires the existence of the sub-category named 'user defined', which is open and could accommodate barriers not anticipated and/or falling outside the aforementioned categories. As a result, we apply the following rule:

- The internal barrier level is the average of all internal NTB scores, and
- the external barrier level is the average of all external NTB scores.

Each average is a number, and given these two numbers we can plot the result as a point in a two-dimensional coordinate system with axes (x, y) corresponding to internal and external, each on the interval [0, 1].

3.3 Willingness to Invest

Even if a project seems risky — say, in terms of payback period — it may still be attractive due to non-pecuniary benefits accrued to residents and/or local authorities. That situation is especially prevalent in public projects, where socio-economic and environmental benefits are weighted higher than in private projects; for instance district heating plants in Denmark must be non-profit according to law. Given an expected life time of 20 years of a plant, it

may be sufficient that the costs balance the income after the 20 years investment lifetime. A cost-benefit analysis is generally laborious, and we may instead have to settle for an interview as follows.

Present the following proposition to a potential investor: If the investment is risky but there are no barriers, then invest. If the answer is 'agree', it indicates a willingness to invest, despite the risk. The answer also indicates that absence of barriers is an incentive (strength) that affects the willingness to invest positively. Possible answers are taken from the same seven point scale of agreeability as previously used for barriers. Form a block of four similar propositions:

$$\begin{array}{ll} \text{P1.} & \text{If the investment is risky and there are barriers, then invest} \\ \text{P2.} & \text{If the investment is risky but there are no barriers, then invest} \\ \text{P3.} & \text{If the investment is not risky but there are barriers, then invest} \\ \text{P4.} & \text{If the investment is not risky and there are no barriers, then invest} \end{array} \tag{3}$$

Proposition P2 is the one mentioned previously, and the remaining three are variations derived by negating the two terms of the conjunctive 'and' on the left hand side of the comma (the antecedent). These propositions query the respondent's willingness to trade profitability for a barrier free project. Propose also a fifth proposition,

P5. The investment is risky

Proposition P5 provides us with an input for inferring the willingness from propositions (3) by means of modus ponens. The level of barriers is the other input needed in order to infer the consequence, and the level of barriers we obtain from the previously mentioned checklist. All calculations can be performed in a spreadsheet, and the result is one single number, which indicates the willingness to invest in a project.

We associate an agreeability α with each of the following three variables:

$$\begin{array}{ll} \alpha_r & \text{the investment is risky} \\ \alpha_b & \text{there are barriers} \\ \alpha_i(k) & \text{invest} \end{array}$$

where k is the sequence number of the proposition $(k = 1, 2, 3, 4)$. We can now represent for instance P1 in symbols, replacing if-then by the symbol $\Rightarrow$ for logical implication and $\wedge$ for the connective 'and',

P1. $\alpha_r \wedge \alpha_b \Rightarrow \alpha_i(1)$

The logical structure is now clear. In order to infer the willingness to invest, we must know agreeability values for the three alphas. The α_r we obtain from proposition P5. The α_b we obtain from the checklist; it is the average of all agreeability values associated with all responses. The agreeability value $\alpha_i(1)$ is associated with the response to proposition P1 in the block (3).

We now adopt the following definitions from fuzzy logic (Jantzen 2007),

$$\begin{array}{ll} \text{Conjunction 'and' } (\wedge) & \text{is defined as multiplication } (*) \\ \text{Negation 'not' } (\neg) & \text{is defined as } 1 - \alpha \\ \text{Inference 'modus ponens'} & \text{is defined as 'and' } (\wedge) \end{array}$$

Example 2 *Single inference*

Assume the average barrier level is $\alpha_b = 0.4$, that is, a slight incentive to invest. Assume further that the investment is perceived as more or less risky, that is $\alpha_r = 0.8$, and we have obtained the following response from P1: $\alpha_i(1) = 0.2$. The resulting willingness to invest is

$$\begin{aligned} \alpha_w(1) &= \alpha_r * \alpha_b * \alpha_i(1) \\ &= 0.8 * 0.4 * 0.2 \\ &= 0.064 \end{aligned}$$

The response $\alpha_i(1)$ is thus weighted by the degree of fulfillment of the left hand side $\alpha_r * \alpha_b$ to produce the result $\alpha_w(1)$.

The willingness to invest α_w is the overall result of all four propositions taken together. They contain an amount of conflict, and we choose to resolve it by computing the weighted average of the responses to each of the propositions. Inserting all the previous definitions, we find

$$\alpha_w = \left[\alpha_r\alpha_b\alpha_i(1) + \alpha_r\left(1-\alpha_b\right)\alpha_i(2) + \left(1-\alpha_r\right)\alpha_b\alpha_i(3) + \left(1-\alpha_r\right)\left(1-\alpha_b\right)\alpha_i(4)\right]/D$$

where D, the denominator of the weighted average, is the sum of the weights occurring in the numerator. Thus,

$$\begin{aligned} D &= \alpha_r\alpha_b + \alpha_r\left(1-\alpha_b\right) + \left(1-\alpha_r\right)\alpha_b + \left(1-\alpha_r\right)\left(1-\alpha_b\right) \\ &= 1 \end{aligned}$$

The willingness to invest is therefore just the numerator, or

$$\alpha_w = \alpha_r\alpha_b\alpha_i(1) + \alpha_r\left(1-\alpha_b\right)\alpha_i(2) + \left(1-\alpha_r\right)\alpha_b\alpha_i(3) + \left(1-\alpha_r\right)\left(1-\alpha_b\right)\alpha_i(4) \quad (4)$$

In summary, given propositions P1 to P4 and agreeability values α_r, α_b and $\alpha_i(k)$, we infer the willingness to invest α_w by Equation (4).

Example 3 *Multiple Inference*

Assume the average barrier level is $\alpha_b = 0.4$, that is, a slight incentive to invest. Assume further that the investment is perceived as more or less risky, that is $\alpha_r = 0.8$, and we have obtained the following responses from P1 to P4: $\alpha_i(1) = 0.0$, $\alpha_i(2) = 0.6$, $\alpha_i(3) = 0.2$, $\alpha_i(4) = 1.0$. Thus

$$\begin{aligned} \alpha_w &= 0.8 * 0.4 * 0.0 + 0.8 * (1 - 0.4) * 0.6 + (1 - 0.8) * 0.4 * 0.2 + (1 - 0.8) * (1 - 0.4) * 1.0 \\ &= 0.4 \end{aligned}$$

The result is an interpolation between the four responses $\alpha_i(k)$ $(k = 1, 2, 3, 4)$ depending on the current values of barrier level α_b and risk α_r.

We regard the special case with $\alpha_i(1) = 0.0$, $\alpha_i(2) = 0.5$, $\alpha_i(3) = 0.5$, $\alpha_i(4) = 1.0$ as a base scenario, where risk and barriers have equal emphasis. Equation (4) thus becomes

simply

$$\alpha_w = 1 - 0.5\alpha_r - 0.5\alpha_b$$

The relationship is bilinear, and the sensitivity of the willingness to invest towards a change in risk is $d\alpha_w/d\alpha_r = -0.5$. The sensitivity towards a change in barriers is $d\alpha_w/d\alpha_b = -0.5$.

This inference method is standard within fuzzy control (see for example Jantzen 2007), where fuzzy membership values are inferred from membership functions and measurements. But acquiring membership values by means of checklists and interviews is non-standard and peculiar to our approach, since it incorporates the membership function directly in the agreeability values.

4 Case Study: Barriers to Biogas in Six Islands

This case study is the result of an EU project named BIORES (2007 - 2010)[2] concerning energy and waste management in islands. The biogas applications are understood as using anaerobic digestion technologies as an alternative to gasification or other digestion procedures. Six European islands — more accurately island clusters or archipelagos — participated: Porto Santo (Portugal), Samos (Greece), Samso (Denmark), Sardinia (Italy), Tremiti Islands (Italy), and Western Isles (Scotland).

Landfill poses a serious problem in all six islands, and one of the major objectives was to reduce the demand for landfill by converting municipal solid waste into biogas. Part of the work was to uncover non-technical barriers that obstruct investments in anaerobic digestion technologies in the islands.

4.1 The Level of Barriers

For the islands we used the geographical boundary of the island to discriminate between internal and external. Appendix A contains the checklist scores from all six islands with barriers partitioned into internal and external barriers and grouped into categories.

Figure 1 is a plot of the barrier levels of the islands, and it summarizes the interviews with experts from all islands. The figure shows that all islands have an incentive (in terms of strength and opportunity) to exploit biogas (level under 0.5), although Samos and Tremiti are close to being neutral (0.5). Sardinia has the largest incentive (lowest score). Some possible explanations follow below.

- Sardinia has in general relatively low internal barriers as well as external. Sardinia has already one biogas plant that exploits biogas from landfill (in Serdiana), the island is large enough to produce economies of scale, and ready it seems, for another biogas plant.
- Tremiti islands, on the other hand, have relatively large administrative, regulatory, and financial barriers (Appendix A). The Tremiti islands have the smallest size of population, with a large influx of visitors during the summer. The local economy depends on the province of Foggia on the mainland. The islands are part of a national park, and there is

[2] www.biores.eu

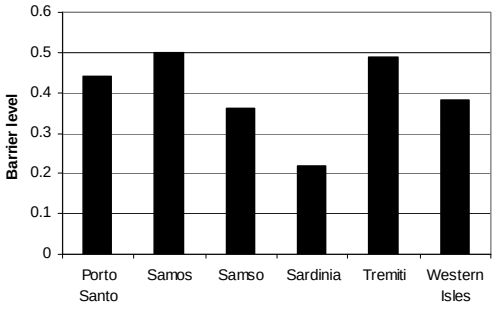

Figure 1. Barrier levels (averages). Level 0.5 is neutral, and a level below 0.5 indicates an incentive; the lower the better.

great concern not to spoil the environment or interfere with tourism development.

- The island of Samos (actually only West Samos participated in the project) is large enough for one or several biogas plants, but the analysis shows that Samos has comparatively large administrative and financial barriers, as well as barriers related to infrastructure, risk perception, public awareness, and farmers' knowledge about biogas by-products (fertilizer).

The strongest barriers across all islands were: lack of awareness among the residents (0.83), farmers have only limited knowledge of the fertilizer products from biogas digestion (0.73), and the authorization process is so slow that investors may loose interest (0.82).

4.2 SWOT analysis

If we look deeper, Figure 2 is a plot of all islands with respect to internal versus external barriers. All islands lie near or inside the lower left hand quadrant, which is an indication of low internal barriers and low external barriers. Sardinia looks exceptionally positive having the lowest levels of barriers of all, while Samos and Tremiti are in the high end, but no worse than 'maybe'.

An imaginary diagonal from the lower left corner (0, 0) to the upper right corner (1, 1) acts as a switching line: above the line, external barriers are higher than internal barriers, and below the line external barriers are lower than internal barriers. Four islands are more or less on the line, indicating a possible correlation; their levels of internal and external barriers are related almost proportionally.

Two islands break the pattern, however. Porto Santo has more external barriers than internal, reflecting its attachment to the island of Madeira, which is where the final political decisions are made. Western Isles have, on the contrary, less external barriers than internal. This may reflect that the Scottish government paid for the existing waste treatment facility (in Stornoway), and financial and political barriers are mostly perceived as internal.

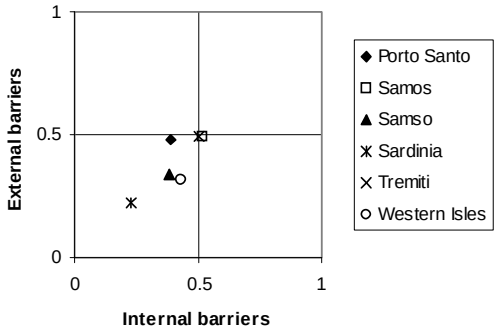

Figure 2. Scores in the SWOT framework. Each island is represented by a point defined by two coordinates: average internal barrier level, and average external barrier level.

4.3 Willingness to Invest

Figure 3 shows the willingness to invest. Here, three islands demonstrate a relatively high willingness to invest, while the Samos score is relatively low.

- Porto Santo scores a high willingness to invest, mainly because they emphasize economic risk more than barriers, and furthermore they think the economic risk is low. This is due to their political administration and organisation, as Porto Santo is under the government of Madeira, which presumably assumes the economic risk if there is a decision to build a biogas plant.
- Tremiti also reckons the risk is low and for similar reasons.
- In the case of Samos, with an exceptionally low willingness to invest, an investment is perceived as more or less risky (0.8, see Appendix B). There is an overall reluctance, because even if there were no barriers and no risk, the willingness to invest is only 0.8, not 1.0.

The sensitivity of the willingness to invest to a change in risk (or barrier level) is -0.5 as a first approximation. For instance, assume that α_r is raised by 0.2 due to uncertainty, then the willingness to invest drops by the amount 0.1.

The previous three figures came out as a result of the analysis phase. Natural questions are now: what do we do about the results, and how do we make use of the data? Figure 2, for instance, is academically interesting, but it is not that clear with respect to what the implications are. When it comes to recommending how to overcome the barriers, the SWOT analysis (Figure 2 and Appendix A) plays a significant role.

The first, major recommendation is to concentrate on the internal barriers, since they are susceptible to actions within the island, while external barriers are beyond immediate island control, by definition. The external barriers should be monitored nevertheless; should

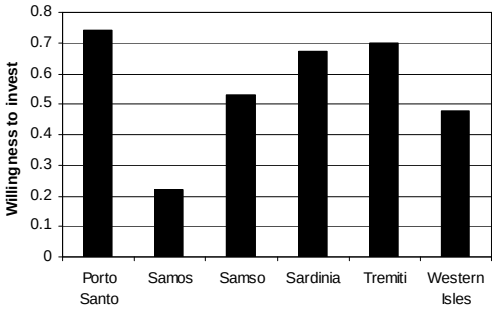

Figure 3. Willingness to invest. A score of 0.5 or higher indicates a willingness to invest. The result for each island is the combination of scores from propositions P1 to P5.

external events resolve those barriers, it will be an incentive, and we must be aware of it. We have thus based our recommendations to the municipality on the internal barriers exclusively.

The BIORES project resulted in action plans for all islands associated with three time-horizons: short term, medium term, and long term. The action plans can be found on the project website.

5 Conclusions

By means of the approach above we are able to process the results of a barrier analysis on a computer. We have linked psychological (qualitative) assessments and computer calculations, and the approach is thus an example of soft computing.

The approach enables us to compare barriers in a quantitative manner, but it also has its shortcomings. We cannot be absolutely sure that we have uncovered all barriers, because we only investigate a predefined set of barriers. To remedy the situation we incorporated an open category of user defined barriers. Some kind of taxonomy of barriers will be necessary in order to ensure that all barriers are investigated, at least all barriers within the framework of the given taxonomy.

The willingness to invest is in our model a consequence of the level of barriers (uncovered by the barrier analysis) and the assessment of risk (based on economic figures such as the discounted payback period). The magnitude of the indicator, a number between 0 and 1, does not in itself give us an absolute measure of the willingness to invest, but its (relative) magnitude is useful in comparisons. It can be used for ranking purposes, and its change after changes in the inputs can be used to quantify sensitivity.

The approach is general, and it can be applied to any engineering project that allows a (fuzzy) checklist with graded responses instead of just yes / no.

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Appendix A. Barriers, Scores from All Islands

No	Category	Internal Barriers	Porto Santo	Samos	Samso	Sardinia	Tremiti	Western Isles
1	Administrative	Too many *internal* agencies and authorities take part in the authorization process (e.g. licensing, environmental assessments, installation permit, operation permit)	0.6	0.8	0.0	0.4	1.0	0.4
2	Regulatory	Local regulations discourage the delivery of industrial waste to a biogas plant (e.g. gate fee)	0.0	0.2	0.6	0.0	0.8	0.0
3		Local regulations discourage the delivery of agricultural waste to a biogas plant (including manure and other animal waste products)	0.0	0.2	0.0	0.0	0.8	0.2
4		Local regulations discourage the delivery of sewage treatment waste in biogas production	0.0	0.2	0.0	0.0	0.5	0.8
5		Local regulations discourage landfill biogas recovery	0.5	0.0	0.0	0.0	0.0	0.4
6	Economic / infrastructure	It is difficult to distribute heat produced at the biogas plant	0.8	1.0	0.0	0.6	1.0	1.0
7		There are restrictions and/or uncertainties in the supply of municipal organic waste to the biogas plant	0.6	0.5	0.8	0.0	0.2	0.0
8		There are restrictions and/or uncertainties in the supply of industrial or agricultural organic waste to the biogas plant	1.0	0.0	0.0	0.0	0.8	0.2
9		The sale of biogas will be limited at times (by inadequate distribution network, storage capacity, demand)	0.2	1.0	0.0	0.5	0.5	0.5
10		The biogas plant will have a negative impact on tourism	0.0	0.6	0.0	0.0	0.0	0.5
11		There are serious land limitations for this type of investment (limited available land, next to tourism industry facilities, or other)	0.0	0.5	0.2	0.0	0.0	0.5
12	Financial	It is difficult to find enough local investors (local investment scheme will not be supported)	1.0	0.8	0.6	0.6	0.2	1.0
13		It is difficult to obtain financial support for items such as: operational costs, maintenance costs, creation of a consumer service office	1.0	0.8	1.0	0.2	0.2	0.0
14	Product markets / competition / risk perception	We have technologies for treating municipal and industrial waste that can compete with a biogas plant	0.0	0.0	1.0	0.4	0.0	0.0
15		We have commercial fertilizers at low cost that can compete with the digestate	0.0	0.5	0.6	0.4	1.0	0.0
16		Local entrepreneurs consider the biogas plant as a high risk investment	0.5	0.8	0.8	0.4	0.0	1.0
17		We can get other biomass fuels (such as wood chip, straw, ethanol) that compete with biogas heat production (if heat option is available)	0.0	0.0	1.0	0.0	0.6	1.0
18		We can grow energy crops, not intended for biogas, that compete with biogas crops	0.0	0.0	0.0	0.0	0.6	0.0
19	Public awareness & acceptance	There is lack of information and awareness regarding biogas plants among our residents (for example low awareness of benefits of biogas energy production)	1.0	1.0	0.6	0.6	1.0	0.8
20		There is lack of social acceptance and local participations towards implementation of renewable energy projects (this type of biogas investment in particular)	0.5	0.6	0.0	0.4	0.4	0.8
21		Our farmers have only limited knowledge about the agricultural by-products from biogas production	1.0	1.0	0.4	0.4	0.8	0.8
22		*Local* authorities or organisations (environmentalist organisation, or other) will oppose to this type of biogas investment	0.0	0.6	0.4	0.0	0.6	0.0
23		There will likely be opposition from the public on the island	0.2	0.8	0.6	0.0	0.5	0.0
24	User defined	Local bad experiences discourage landfill gas recovery			0.8			
25		Local bad experiences from previous projects discourage a biogas project			0.0			
26		8 provinces, 376 local communities, 1 central government can represent a barrier				0.5		
		Average	0.39	0.52	0.38	0.23	0.50	0.43

No	Category	External Barriers	Porto Santo	Samos	Samso	Sardinia	Tremiti	Western Isles
1	Administrative	The authorization process is so slow, that investors may loose interest (for example more than 6 months)	1.0	0.8	0.8	0.5	0.8	1.0
2		Too many *external* agencies and authorities take part in the authorization process (e.g. construction permit, location permit, licensing, environmental assessment, veterinary permit, operation permit)	0.5	0.8	0.6	0.5	1.0	0.0
3	Regulatory	The authorizing agencies are slow to coordinate due to overlap in roles, responsibilities and functions	0.6	0.6	0.2	0.4	1.0	0.5
4		External regulations restrict the supply of organic waste to a biogas plant	0.0	0.0	0.0	0.2	0.2	0.0
5		External regulations discourage cooperation with the private sector (industry, agriculture)	0.0	0.0	0.0	0.0	0.2	0.0
6		External regulations discourage cooperation with the municipality	0.0	0.2	0.0	0.0	0.2	0.0
7	Economic / infrastructure	Investors get limited and/or uncertain guarantees for sales amounts	0.5	0.5	0.4	0.2	0.0	0.0
8		The (selling) price support system for this type of biogas investment is inadequate (feed-in-tariff, quota based support system, or other)	0.5	0.0	0.2	0.0	0.2	0.0
9		Biogas is difficult to sell, because it is more expensive than other biofuels (wood chips, straw, etc.)	0.5	0.0	0.5	0.0	0.0	0.5
10		There is tax on biogas and heat generated from biogas (energy and CO2 taxes)	0.5	0.0	0.0	0.0	0.0	0.0
11	Financial	National support is inadequate (investment cost subsidy, interest rate subsidy, tax reduction or exemption, other)	0.2	0.2	0.6	0.0	0.4	0.0
12		National support through suitable loan mechanisms is weak (for example national funds for environmental protection, waste management, renewable energy development, loan guarantee, etc.)	0.2	0.8	0.5	0.2	1.0	0.0
13		Energy crop cultivation is not subsidised	0.5	1.0	0.6	0.0	0.2	0.5
14		Access to capital and financial products of commercial banks is limited for this type of biogas investment	0.8	0.8	0.2	0.5	0.8	1.0
15		Third party financing for this type of biogas plant investment is limited	1.0	0.6	0.8	0.0	0.8	1.0
16		Project financing for this type of biogas investment is limited	1.0	0.2	0.6	0.0	0.8	1.0
17	Product markets / competition / risk perception	The biogas plant market is immature (few or unavailable existing plants, few or unavailable turn-key construction companies, uncertain cash flows, etc) such that investment costs are high	1.0	1.0	0.2	0.6	0.2	1.0
18		It is difficult to obtain contracts with heat plants	0.6	1.0	0.0	0.2	0.5	0.0
19		It is difficult to obtain contracts with electricity distributors	0.0	0.0	0.0	0.0	0.0	0.0
20		It is difficult to consume all the digestate	0.5	0.5	0.2	0.2	0.8	0.0
21	Public awareness & acceptance	There is a lack of information and awareness among policy makers and regulators regarding biogas potential and benefits (economic, social, environmental, etc)	0.5	0.8	0.0	0.5	0.8	0.0
22		There is a lack of information and awareness among the touristic visitors (for example low awareness of benefits of biogas energy production)	0.0	1.0	1.0	0.5	0.8	0.5
23	User defined	Political strategic and priority resistance	0.6					
24		Contractual problems, competition for waste	0.6					
25		Transportation distances collecting material				0.6		
		Average	0.48	0.49	0.34	0.22	0.49	0.32

Appendix B. Willingness to Invest, Scores from All Islands

No	Proposition	Porto Santo	Samos	Samso	Sardinia	Tremiti	Western Isles
1	If investment is risky and there are barriers, then invest	0.0	0.0	0.0	0.0	0.0	0.0
2	If the investment is risky but there are no barriers, then invest	0.2	0.2	0.6	0.4	0.5	0.8
3	If the investment is not risky but there are barriers, then invest	0.8	0.6	0.2	0.6	0.6	0.4
4	If the investment is not risky and there are no barriers, then invest	1.0	0.8	1.0	1.0	1.0	1.0
5	A biogas plant is a risky investment	0.2	0.8	0.6	0.4	0.2	0.8