

# Confronting Project Conflicts into Success: a Complex Systems Design Approach to Resolving Stalemates

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## ARTICLE HISTORY

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## ABSTRACT

In today's complex projects development, stakeholders are often involved too late. There is also in many cases a one-sided technical focus that only focuses on the system's behaviour and does not integrate the individual stakeholder preferences. This locks stakeholders into a 'technical' conflict instead of being able to emerge from it 'socially'. Moreover, stakeholders are often involved a-posteriori in a multi-faceted development process which is untransparent, leading to stalemates or even artefacts that nobody ever wants. There is thus a need for a purely associative and a-priori design-supported approach that integrates both system's reality and stakeholder's interests within a joint agreement and technical framework. The state-of-the-art Preferendus, the computer-aided design engine embedded within the proven Open Design Systems (Odesys) methodology, is a neutral tool in confronting complexity into success. The Preferendus is deployed to co-creatively generate a best-fit-for-common-purpose solution for a number of wind farm related degrees of freedom, project constraints and given a number of stakeholder objective functions. Since, the Preferendus design potential for a stalemate depends strongly on stakeholder interest, importance and trust, in this paper an structured stakeholder judgement approach is introduced to transparently arrive at individual stakeholder weights using a choice-based conjoint analysis (CBCA) method. This method also allows for obtaining an initial estimate for the individual stakeholder preference functions. By modelling disputable exogenous factors as endogenous design parameters, it is also shown for which factors the stalemate problem is indeed both technically and socially (un)solvable, while interests and reality are conjoined.

## KEYWORDS

generative & participatory design, computer-aided design and decision modelling, multi-objective design optimization, Conjoint Analysis, preference function modelling, preference elicitation, IMAP optimization, open design & decision systems, conflict management

## 1. Introduction

### *Context*

Why do we often build what nobody wants? Because in complex developments, we involve stakeholders too late, or sometimes not even at all <sup>1</sup>, the decision-making pro-

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<sup>1</sup>In this context, note Lucebert's famous line of poetry: 'everything of value is defenceless'

cess is not transparent and the creative process is not best-fit for common purpose. In fact, the stakeholder is often only allowed to choose after the fact, as a kind of ‘cosmetic dressing’, from variants conceived by someone else that are not certain to be optimal but allow room for manipulation. And, why are stakeholders digging themselves ever deeper into a ‘technical-scientific swamp’ while failing to get out of these stalemates conjointly? Actually, in this way they keep battling for a presumably biased and sub-optimal alternative. And, why do (political) decision-makers usually hold the cards to their chests without allowing all stakeholders to participate equivalently and objectively? As such, planning and development processes often end in a deception for stakeholders and synthesis will not emerge. Would it be not great to associatively arrive at a best-fit and integrative socio-technical solution, aided by open and neutral computer glass-box modelling? But now, how do we take a co-creative route to a conjoint ideal within reach?

Until recently, science also offered no solace for this route of open design and decision-making, because decision models either focus only on what people desire or only on what is feasible, and often focus only on the technique of mathematical optimisation rather than integrating it into the art of human-centred design. The state-of-the-art Open Design Systems (read Odesys and see Wolfert (2023)) methodology however does offer an opportunity to openly overcome conflicts of socio-technical interest. This multi-objective design optimisation (MODO) methodology Odesys ideally unites wishful thinking (‘desireability’: ‘what one wants’) and realism (‘capability’: ‘what it can do’). Odesys makes all interests count, resulting in a co-created best-fit solution, where value is more than money or technology alone. Through an open glass-box modelling in which this integration is maximised for the associated group preference (IMAP), Odesys determines a best-fit synthesis using its solid mathematical design engine the Preferendus, which acts as an extra ‘perceptual organ’ in the development process. Odesys and its IMAP/Preferendus is a pure form of complex systems integration and design participation to enable an optimal co-creative synthesis unlocking from the beginning rather than sub-optimal compromises after the fact. In other words, from insight outwards and from outlook inwards, Odesys has a way out to a conjoint ideal within reach.

Odesys works from the design principle of associative & integrative *diaduction*<sup>2</sup> and is able to resolve a design freedom paradox. In fact, designing is solving a freedom paradox in which from the individual human freedom<sup>3</sup> and the artefact’s design

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<sup>2</sup>Diaduction (compare words dialogue, dialectic) as opposed to the specific Eekels&Roozenburg term ‘induction’ (see Wolfert (2023)) : i.e., it is not the innovation from the design process which is predominant but the transformation of a socio-technical conflict into co-creative success. One can consider this process as a diaduction of spiritual mind, physical matter, outer observation and inner experience. In other words, from the social participation and technical performance point of view both subject and object are integrated and individual stakeholder preferences are associated. Note: the term diaduction is a completely new term linked to the specifics of a design process, which relates to the concepts of dialogue and dialectics (with a link to the term diacracy, see next section), but which indicates a pure open and dynamic engineering approach aimed at a best-fit value, as a ‘contramal’ / counterpart to the dialectical induction within research which pursues unique truth. Design enables an integrative way out (ie., duction) of a congregate of multiple (ie., dia) ‘interests’ and ‘degrees of freedom’ (compare terms as induction, deduction and see Wolfert (2023))

<sup>3</sup>When we describe creative activity, we speak of freedom of style or freedom of self-expression in a way that indicates an inner conquest of outer constraints. An inner degree of freedom implies something granted or imposed from outside’s degrees of freedom and constraints. Designing is thus an inner-outer spiritual activity, on action, on thinking and feeling that emerges from the human inner self to materialise in the outer world the maximum potential of a the system freedom is found. Here, this maximum can be synthesised when the individual makes less claim to his own self-interest in the interest of the well-being and potential of the whole, see Odesys’ social-technical threefolding principles (see Wolfert (2023))

freedom are maximized for the highest associated <sup>4</sup> group value. Moreover, Odesys computer-aided design-support methodology aligns also with Wolfert (2023) "thinking slow" (or 'deliberative thinking') using simulation and optimization models to explore numerous solutions systematically, reducing cognitive biases, enhancing efficiency, and acknowledging results no longer conceivable for humans. It thus facilitates a shift within complex systems design management from unsubstantiated 'thinking fast' to transparent 'thinking slow' glass-box modelling. This mode of a-priori and joint decision support modelling is one of deliberation (which means literally: to free as a whole). Thereby, both the social and technical cycles are supported to open a best-fit-for common purpose.

These advances culminate in a holistic and open design methodology which integrates the system degrees of freedom ('object') and the individual freedom of the project stakeholder ('subject') seeking for a group maximisation of the associated preferences of the stakeholders involved, within a constrained design space. This generative design freedom maximisation can be seen as an open design aggregation of 'vertical' integration and 'horizontal' association and aligns with Odesys' open social-technical threefolded design principles and its transformative U-model (see Wolfert (2023)). Herewith Odesys takes the next step in computer-aided operations <sup>5</sup> management confronting complex design freedom into success.

### ***Contribution***

Projects where stakeholders (politicians, residents, environmental organisations, project developers etc.) find it difficult to reach a synthesis are the complex development challenges of onshore windfarms. Here, energy returns and long-term effects for people's well-being and a healthy living environment are at odds. The plan developers responsible are municipalities and other government bodies that present preconceived 'preferred alternatives' at public consultation evenings and try to push these through, without the stakeholders really being heard from their usual NIMBY syndrome. Engineering consultants and other advisors to these projects cash in on a stalled process and are willing to generate new alternatives indefinitely, not realising enough that they are missing opportunities for even better best-fits. Odesys and its IMAP based Preferendus can open up this process and effectively and efficiently turn this conflict of interest into a co-creative 'yes'. Based on a real-life demonstration project of a wind farm in the Dutch municipality of Oss, the Odesys methodology will further elucidate how to structure a stalemate problem and enable it to be unlocked. The specific contributions of this paper are (1) translating and resolving a stalemate problem into a multi-objective socio-technical threefolding design problem in which uncontrollable variables can be converted to controllable variables to smooth the problem from a purely single-side technical stalemate; (2) a conjoint analysis based preference elicitation for determining individual global and local stakeholder weights as well as a first estimation of their preference functions. Finally, this stalemate design application (DA) can be seen as a complement to the summative Odesys DAs from Wolfert (2023).

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<sup>4</sup>Associated originates from the term 'association', which is similar terms are covenant, alliance (UK, French) or Bündnis (GER). It indicates co-existence and fraternity in which individual interests are aggregated. A pure association presupposes holding on to each other out of trust and a willingness to 'cross over in a common boat despite not knowing exactly where you are going end up.

<sup>5</sup>Both projects delivery and assets services management.

## ***Structure***

First, in Section 2, the mathematical Odesys threefold formulation will be used to formulate a socio-technical problem as an a-priori design problem. This requires an integrative set of performance, objective and preference functions which will be addressed in Section 3 for the wind farm problem. The design variables and the related design space constraints are also introduced. Next in Section 3, a new structured stakeholder judgement approach is introduced for preference elicitation, using the a choice-based conjoint analysis (CBCA) method. In Section 4, the results and a conspection will be presented for three cases: (1) a simplified linear 2x2 multi-objective and single interest design problem (MODO) explaining a compromise solution for equal global weights within a plottable solution space; (2) a linear 4x4 multi-objective and single interest design problem (MODO) explaining a synthesis solution for both an equal and uneven distribution of the global weights; (3) a non-linear 4x4 multi-objective and multiple interests design problem (MODO) explaining a synthesis solution having both global and local weights and interests. Section 5 summarises the main conclusion and next steps for further developments.

## ***Outreach***

Despite the presented 4x4 multi-objective and multiple interests modelling being a direct reflection of the actual complex design problem, achieving real results requires iterative collaboration with all actual stakeholders. In addition to the serious game results as presented here, this requires the use of the Odesys U-model that facilitates the technical, social and purpose process by going through open design loops (Wolfert, 2023). This is beyond the scope of this paper. The focus of this paper is therefore on providing and demonstrating a design loop for several cases, rather than a specific and detailed treatment of participatory decision-making of the complex wind farm project as such. The authors are convinced that the approach presented here makes it possible to renew the current ‘pseudo-democratic’<sup>6</sup> form of decision-making towards a design diacracy for the common well-being from the future (Bérard, 2023). This includes a shift from a Referendum (ex-post) towards a Preferendum (ex-ante) based decision making resulting in healthy solutions for all concerned making use of socio-technical threefolding principles (Wolfert, 2023). Finally, this is also a call to the many different engineering consultants and contractors supporting complex projects to broaden their horizons and further improve their current best practices to achieve transparent, effective and efficient decision-making. From this basic open design attitude, the Odesys approach be of added value in complex projects to confronting conflicts into co-created success by informed decision-making that eliminates biases.

## ***Reading note***

For the reader here are two more important general notes (1) this article contains only additional references to those in the Open Design Systems book, see Wolfert (2023). However, we would like to draw the reader’s attention specifically to a number

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<sup>6</sup>Actually, the word pseudo-democracy is used because nowadays the ‘stakeholders’ are kept happy but not really involved. That is why, as a counter-movement, all kinds of forms such as ‘deep- or direct-democracy’ are emerging. However, none of them has an operationalisation of decision support modelling based on their ‘well-intentioned’ principles. Therefore, it is time to adopt a socio-technical threefolding design modelling approach that fuses freedom, fraternity and equivalency.

of works from this extensive list which are: Ackoff, Glasl, Roozenburg& Eekels and Scharmer. This article contains new developments with respect to their work. (2) the three case results are only a subset of the real-life design process and therefore only serve to qualitatively explain the Odesys methodology and the open-ended U-process rather than discussing the quantitative results as such. The design outcomes are the result of a serious game which took place within Boskalis. The actual outcomes are confidential, but the subset as presented here are illustrative.

## 2. Odesys' mathematical threefold formulation

The purpose of this section is to enable stand-alone reading of this paper. To this end, the Odesys is summarised here (for more info see Wolfert (2023); Teuber et al. (2024); Van Heukelum et al. (2024)). The core of Odesys' methodology is the following mathematical statement of a multi-objective design optimisation (MODO) problem, which integrates subject desirability and object capability and generates a feasible solution with the maximised aggregated group preference: i.e. the IMAP method, and reads as

$$\begin{aligned} \text{Maximise } U = A [P_{k,i} (O_i (F_1(\mathbf{x}, \mathbf{y}), F_2(\mathbf{x}, \mathbf{y}), \dots, F_J(\mathbf{x}, \mathbf{y}))), w'_{k,i}] \text{ for} \\ k = 1, 2, \dots, K \\ i = 1, 2, \dots, I \end{aligned} \quad (1)$$

constrained by:

$$g_p(O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})), F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})) \leq 0 \text{ for } p = 1, 2, \dots, P \quad (2)$$

and where:

- $U$ : Utility function that needs to be maximized for a best-fit design configuration, where the Preferendus Genetic Algorithm is used for (Wolfert, 2023) or Van Heukelum et al. (2024).
- $A$ : An algorithm that determines the aggregated preference score as part of the IMAP optimisation operation (see Teuber et al. (2024) or the A-Fine-Aggregator (2024)).
- $P_{k,i}(O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})))$ : Preference functions that describe the preference stakeholder  $k$  has towards objective function  $i$ , which are functions of different design performance functions  $j$  and dependent on controllable design and/or non-controllable physical variables (  $i \leq k$  and  $K$  is maximum number of stakeholders).
- $O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y}))$ : Objective functions that describes the objective  $i$ .
- $F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})$ : Design performance functions  $j$  that describe the physical object behavior.
- $\mathbf{x}$ : A vector containing the (controllable endogenous) design variables  $x_1, x_2, \dots, x_N$ . These variables are bounded such that  $lb_n \leq x_n \leq ub_n$ , where  $lb_n$  is the lower bound,  $ub_n$  is the upper bound, and  $n = 1, 2, \dots, N$ .
- $\mathbf{y}$ : A vector containing the (uncontrollable exogenous) physical variables  $y_1, y_2, \dots, y_M$ .

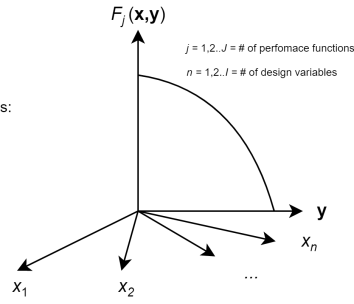
- $w'_{k,i}$ : Weights for each of the preference functions. The global weights for the relative importance of stakeholders is defined as  $w_k$ . The local weight stakeholder  $k$  gives to objective  $i$  is defined as  $w_{k,i}$ . The following formula holds:  $w'_{k,i} = w_k \cdot w_{k,i}$ , given that  $\sum w'_{k,i} = \sum w_{k,i} = \sum w_k = 1$ . Note that: (1) in case of equivalent stakeholder decision-making  $w_k = 1/K$ , (2) these global/local weights within our MODO problem are similar to main and sub-criteria in an MCDA evaluation, see Wolfert (2023) and (3) the maximum number of preference functions equals  $K * I$ .
- $g_p(O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})), F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y}))$ : Inequality constraint functions, which can be either objective function and/or design performance function constraints. Note: should there be any equality constraints in the stalemate problem, these will be rewritten as an inequality constraint  $g_p$ .

To better understand and further detail this specific social-technical systems integration, the different functions as part of the mathematical formulation are conceptualised in the Odesys threefold modelling framework, as shown in Figure 1.

**Capability- Object**

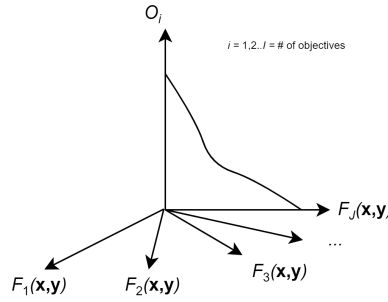
*Design performance functions*  
(supply)

subject to Design performance constraints:  
 $g_p = F_j(\mathbf{x}, \mathbf{y}) \leq 0$

**Integration Subject-Object**

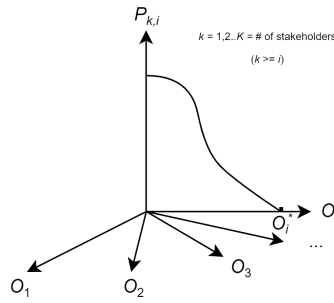
*Objective functions*  
(conciliation)

subject to Objectives constraints:  
 $g_p = O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})) \leq 0$  and/or  
 $g_p = O_i(F_{1,2,\dots,J}(\mathbf{x}, \mathbf{y})) - O_i^* \leq 0$

**Desirability - Subject**

*Preference functions*  
(demand)

where  $0 \leq P_{k,i} \leq 100$



**Figure 1.** Conceptual threefold framework of the Odesys mathematical statement, where subject desirability and object capability are integrated, see Wolfert (2023). Note that: (1) the shapes of the curves are arbitrary; (2) the different functions are linked (an ordering principle) and that maximisation is not yet part of this threefold.

### 3. Wind farm development - a stalemate case

First we will describe here the socio-technical wind farm design stalemate problem qualitatively, as a basis to translate into a mathematical MODO formulation with corresponding quantitative IMAP design outcomes.

**Technical context** This wind farm design project is to generate renewable energy for the city Oss. To meet its energy goals, the municipality wants to develop a wind farm with a number of turbines, which should ideally be as close to the center as possible to minimize energy losses. It is estimated that no more than 12 turbines are needed. Energy generation depends not only on the number and location of the turbines but also on the turbine height and the average wind speed required, among other factors. These four design variables can still be controlled. The current search c.q. preferred

area is located on a (radius) line from the center of Oss to the west and extends to 10km inside the municipal border. The wind farm should be located at least 2km outside the center of Oss. The height of the turbines will not exceed 150m (hub height). Typical uncontrollable variables are: rotation diameter, type of power converter, specific local environmental data etc. The different design performance functions depend on the aforementioned design variables. Below are the relations for three performance functions between power generation; noise hindrance and bird mortality on the one hand and the four design variables on the other.

**Social context** This wind farm design as part of sustainable polder development, demonstrates a multi-stakeholder design optimisation approach for the decision on the number and type of turbines at a certain location. The creative conflicts of interests are : (a) energy - profit for the energy service provider; (b) health- noise hindrance for the local residents; (c) environment - bird mortality for the ecologists; (d) health - particle pollution for regulator RIVM; amongst others such as health & environment - magnetic cable radiation, horizon-pollution, and shadow cast. The energy service provider's objective is to maximise the energy power and it's profit within a positive business-case. The objectives of all other stakeholders should be minimised. From its contribution to the national energy transition, the municipality of Oss has a minimum supply requirement of renewable energy ('RES-bijdrage').

**Stalemate Context:** Here are two actual quotes which clearly describes the stalemate (see 'Wind farm rage Oss' BkbbxTV (2024))

Municipality : "The current preferred alternative is the "best plan" according to the Municipality, but it remains a "compromise": it will never succeed in satisfying everyone. It remains a balancing of interests. We will all have to contribute to the energy objective, and as we have now made the calculations we will need 9?"

Other Stakeholders : "The alternative does not fit in any way: not within the framework, not within the energy objective. It is wishful thinking, without realism. The current plan has only losers. According to other Stakeholders there will be actions. We are 6-0 behind, and we do not have the resources like the Municipality, developers or a collective of farmers. We will take action unless the Municipality really comes to talk to us now. We have nothing against windmills in principle.

Based on this contextual description, we will now describe the integrative MODO problem by running through the Odesys threefold mathematical statement framework (see Section 2), resulting in design performance-, objective-, and preference functions (see Section 3), including the design degrees of freedom (design variables and stakeholder's preference and importance).

### 3.1. Design performance functions

In this section, we will introduce all the relevant design performance functions for a wind farm. These functions describe the wind farm behaviour as a function of design variables or other physical non-controllable variables and they will be integrated into the objective functions in Section 3.2. Here, we have used EngineeringToolBox (2009) and Kalmikov (2017) generically and refer to additional specific references per performance function. The following design variables and their design space bounds are considered.

- (1)  $F_1 = x_1$  ( $2 \leq x_1 \leq 10$ ): distance to city centre
- (2)  $F_2 = x_2$  ( $0 \leq x_2 \leq 12$ ): number of turbines

- (3)  $F_3 = x_3$  ( $50 \leq x_3 \leq 150$ ): turbine (hub) height  
 (4)  $F_4 = x_4$  ( $3 \leq x_4 \leq 15$ ): required wind speed

3.1.1.  $F_5 = P_{dt}$  = power generated per day per turbine

To calculate the power generated per day per turbine, we start with the blade diameter calculation. The diameter  $D$  is given by:

$$D = x_3 \times 1.3 \quad (3)$$

where  $x_3$  is the turbine (hub) height and the constant (1.3) is a scaling factor. This factor is derived from empirical data and/or industry standards to account for certain physical characteristics or performance metrics of the turbine.

Next, the swept area  $A$  of the wind turbine blades is calculated using the formula:

$$A = \pi \left( \frac{D}{2} \right)^2 \quad (4)$$

The power  $P$  generated per day is then calculated using the following equation:

$$P = 0.5 \times A \times \rho \times e \times (x_4)^3 \quad (5)$$

where  $A$  is the swept area,  $\rho$  is the air density ( $1.225 \text{ kg/m}^3$ ),  $e$  is the efficiency (0.3), and  $x_4$  is the average rated wind speed. The power  $P$  is in Watts.

Finally, to convert the power from Watts to kilowatt-hours (kWh) per day, we use:

$$P_{dt} = P \times \frac{24}{1000} \quad (6)$$

Note one could introduce an inequality constraint here, e.g.,  $g_1 \geq 50000 \text{ kWh/day}$  (minimum energy supply requirement).

3.1.2.  $F_6 = SP$  = sound power per turbine

First of all we have to introduce two adjustments: 1. Wind Speed Adjustment:

$$\text{wind\_adj} = x_4 - \text{wind\_base\_speed} * 0.2 \quad (7)$$

where  $\text{wind\_base\_speed} = 3 \text{ m/s}$ . This adjustment accounts for an increase in noise by 0.2 dB per m/s over the base wind speed. 2. Height Adjustment:

$$\text{height\_adj} = x_3 - \text{height\_base} * 0.1 \quad (8)$$

where  $\text{height\_base} = 50 \text{ meters}$ . This adjustment accounts for an increase in noise by 0.1 dB per meter over the base height. Then, the general inverse square law for sound pressure level describes the decrease in intensity of a sound wave as it propagates away from a point source in a free field. From this a general formula for calculating the sound pressure level (SPL) at a distance is calculated by:

$$SPL_{dist} = SPL_{source} - 20 \cdot \log_{10} \left( \frac{dist}{ref\_dist} \right) \quad (9)$$

where:

- $SPL_{dist}$  is the sound pressure level at the observation point,
- $SPL_{source}$  is the sound pressure level at a reference distance from the source,
- $dist$  is the distance from the source to the observation point,
- $ref\_dist$  is a reference distance from the source, often taken as 1 meter.

and adapted for our specific problem:

$$L_{d,single} = L_W + \text{wind\_adj} + \text{height\_adj} - 20 \log_{10} \left( \frac{x_1 * 1000}{1} \right) \quad (10)$$

Here  $L_W = 104$  dB is the example sound power level of a turbine. This formula calculates the noise level at a distance considering the adjustments for wind speed and height. Now we have to convert the single turbine noise level to power using a relationship between sound pressure level and sound power that is expressed as:

$$Power = 10^{\frac{SPL - SPL_{ref}}{10}} \quad (11)$$

where:

- $Power$  is the sound power ratio relative to a reference power,
- $SPL$  is the sound pressure level in decibels,
- $SPL_{ref}$  is the reference sound pressure level, typically 0 dB at the threshold of human hearing (20 micropascals).

and adapted for our specific problem:

$$SP = 10^{\frac{L_{d,single}}{10}} \quad (12)$$

This converts the single turbine noise level from decibels to power. Note one could introduce an inequality constraint here, e.g.,  $g_2 \leq 42$  dB (on the facade).

### 3.1.3. $F_7 = M = \text{bird mortality}$

For the derivation of the design performance function related to bird mortality we refer to Nilsson et al. (2023). For the blade diameter  $D$ , we use Equation (3), which is a function of  $x_3$ . Moreover, the swept area of the wind turbine blades is calculated by

$$A = \pi \left( \frac{D}{2} \right)^2 \quad (13)$$

Then, the bird mortality ( $M$ ) is estimated as:

$$M = \left( \frac{A}{30000} \right) * C * \begin{cases} 800 & \text{if } 8 < x_1 < 9 \\ 200 & \text{otherwise} \end{cases} \quad (14)$$

where:

- A rotor diameter ( $D$ ),
- A collision probability factor ( $C$ ) of 0.005 (or 0.5%),
- A maximum swept area of 30000.

Note that there is a bird breeding area located somewhere between 8 and 9 kilometres from the city centre

#### 3.1.4. $F_8 = E = \text{erosion rate}$

For the derivation of the design performance function related to the erosion rate we refer to Zhang and Liu (2023) and Rimereit et al. (2021). For the blade diameter  $D$  and the swept area  $A$ , we use Equations (3) and (13), which are both a function of  $x_3$ . Then the erosion rate is estimated by:

$$E = w * f * r * \left( \frac{A}{30000} \right) \quad (15)$$

where:

- $A$ : swept area (with  $A < 30000$ ),
- $w$ : wind impact equal to  $(x_4)^3$ ,
- $r$ : rain impact equal to 1 (negligible),
- $f$ : pollution probability factor of 0.001 (or 0.1%).

So, this integrates the hub height, wind speed, and number of turbines to calculate the erosion rate on turbine blades due to particle pollution, expressed in terms that are specific to the definitions provided.

### 3.2. Objective functions

Within the stalemate wind farm design problem, there are four conflicting objectives of interest. These functions will now be described as a function of the design variables and the performance functions from Section 3.1.

#### 3.2.1. $O_1 = \text{Energy Profit}$

The energy efficiency depends on the so-called resistance factor, which is determined as follows:

$$R = \frac{x_3 + x_4}{12} \quad (16)$$

where  $x_3$  is the turbine height and  $x_4$  is the average rated wind speed. Using the equations for  $R$  and the design performance function  $F_5$ , the final objective function which represents the energy profit reads as:

$$O_1 = O_P = (P_{dt} \cdot \text{EP} \cdot x_2) - (R \cdot x_1) \quad (17)$$

where:

- EP is the price of electricity per kWh (0.01),
- $P_{dt}$  is the wind turbine profit per day,
- $x_2$  is the number of turbines,
- resistance is as calculated above,
- $x_1$  is the distance to the city centre.

### 3.2.2. $O_2 = \text{Noise Disturbance}$

Making use of the design performance function  $F_6$ , and converting the total noise power back to dB, the final objective function which represents the noise disturbance (also sometimes called noise pollution) reads as:

$$O_2 = O_N = 10 \cdot \log_{10}(x_2 \cdot SP) \quad (18)$$

### 3.2.3. $O_3 = \text{Bird Mortality}$

Making use of the design performance function  $F_7$ , the final objective function which represents the bird mortality reads as:

$$O_3 = O_M = M \cdot x_2 \quad (19)$$

where:

- $M$  is the bird mortality per day,
- $x_2$  is the number of turbines.

### 3.2.4. $O_4 = \text{Particle Pollution}$

Making use of the design performance function  $F_8$ , the final objective function which represents the particle pollution reads as

$$O_4 = O_{PP} = E * x_2 \quad (20)$$

where:

- $E$  is the erosion rate.
- $x_2$  is the number of turbines.

## 3.3. *Preference functions & weights distributions*

To make the open design systems approach executable, the last step is to determine the preference functions and weights of the different stakeholder interests. This is a dynamic open-ended approach in reality in which the social and purpose cycles are run through in iterative open loops using the socio-technical Odesys U-model. The conjoint preference elicitation approach, also called structured stakeholder judgement (compare structured expert judgement for engineering) is an important part of this process. Here, stakeholders define and adjust their individual preference curves and (global/local) weight distributions in relation to their actual 'idealised design' purpose 'in the now'. In this article we can only show some main steps (and corresponding case results in the next Section 4). To this end, the three following steps within the integrative open-ended design system approach are proposed here: i.e.,

- (1) a *linear 2x2 single-interest* case in which only two stakeholders: the energy provider  $S_1$  and the local residents  $S_2$ , each represent a single objective ( $O_1$  and  $O_2$  respectively) with equal importance, making the global weights both  $w_k = 0.50$  and the local weights both  $w_{k,i} = 1.0$ . So, each stakeholder has a 100% single interest in one objective and participates equally. This can build

confidence for the working of the system while a compromise solution can (still) be visualised the solution space (2x2 'plottable' space). This results in the following conjoint weight table (note: linear preference curve are introduced in the next section):

**Table 1.** Step 1 - Weights for each of the preference functions, according to  $w'_{k,i} = w_k \cdot w_{k,i}$ .

Stakeholder $k$	$w'_{O1}$	$w'_{O2}$	$w_k$
S1	0.5	0.0	0.5
S2	0.0	0.5	0.5
Total	0.5	0.5	1.0

- ;
- (2) a *linear 4x4 single-interest* case in which two stakeholders  $S_1, S_2$  (the same as in the previous step (1)) are joined by two other stakeholders, the ecologist  $S_3$  and the RIVM health organisation  $S_4$ , reflecting the objective  $O_{1..4}$  respectively. We assume the following two group decision making cases (a) the energy provider  $w_{S1} = 0.50$  "against" a coalition of the other three stakeholders  $S_{2..4}$  who have weights of  $w_{S2} = 0.20$ ;  $w_{S3} = 0.15$ ;  $w_{S4} = 0.15$  respectively and (b) all stakeholders do have equal global weights of  $w_k = 0.25$ . In both case the each stakeholder has a 100% single interest in one objective, which means that all local weights are  $w_{k,i} = 1.0$ . This results in the following conjoint weight tables (note: we model their preference curves again linearly, see next section):

**Table 2.** Step2a - Uneven global weights for each of the preference functions, according to  $w'_{k,i} = w_k \cdot w_{k,i}$ .

Stakeholder $k$	$w'_{O1}$	$w'_{O2}$	$w'_{O3}$	$w'_{O4}$	$w_k$
S1	0.50	0.0	0.0	0.0	0.50
S2	0.0	0.20	0.0	0.0	0.20
S3	0.0	0.0	0.15	0.0	0.15
S4	0.0	0.0	0.0	0.15	0.15
Total	0.50	0.20	0.15	0.15	1.00

**Table 3.** Step2b - Equal global weights for each of the preference functions, according to  $w'_{k,i} = w_k \cdot w_{k,i}$ .

Stakeholder $k$	$w'_{O1}$	$w'_{O2}$	$w'_{O3}$	$w'_{O4}$	$w_k$
S1	0.25	0.0	0.0	0.0	0.25
S2	0.0	0.25	0.0	0.0	0.25
S3	0.0	0.0	0.25	0.0	0.25
S4	0.0	0.0	0.0	0.25	0.25
Total	0.25	0.25	0.25	0.25	1.00

- ;
- (3) a *non-linear 4x4 multiple-interests* case in which the four stakeholders  $S_{1..4}$  (same as in the previous step (2)) are again the represented in the group decision making problem. Here again all there global weights are equal and thereby  $w_k = 0.25$ , but they can all have individual interest and preferences for multiple objectives  $O_{1..4}$ . In other words, each stakeholder can have multiple interests in different objectives, which means that the local weights are are no longer equal to 1.0 (the sum of the local weights per stakeholder should equal 1.0 instead). This results in the following conjoint weight tables (note: we model their preference curves again non-linearly, see next section):

**Table 4.** Step 3 - Local Weights for each of the preference functions per stakeholder

Stakeholder $k$	$w_{O1}$	$w_{O2}$	$w_{O3}$	$w_{O4}$
S1	1.00	0.00	0.00	0.00
S2	0.30	0.40	0.00	0.30
S3	0.40	0.00	0.40	0.20
S4	0.30	0.10	0.10	0.50

**Table 5.** Step 3 - Conjoint weights distribution per preference function, according to  $w'_{k,i} = w_k \cdot w_{k,i}$ . Note that stakeholders may have different individual interests in all four objectives (max. 16), while the overall weights are equally distributed.

Stakeholder $k$	$w'_{O1}$	$w'_{O2}$	$w'_{O3}$	$w'_{O4}$	$w_k$
S1	0.250	0.000	0.000	0.000	0.25
S2	0.075	0.100	0.000	0.075	0.25
S3	0.100	0.000	0.100	0.050	0.25
S4	0.075	0.025	0.025	0.125	0.25
Total	0.500	0.125	0.125	0.250	1.00

For the preferences elicitation in step (3) above, an conjoint and deliberative analysis within a Boskalis confidential serious game (Vander Stee (2024)) was used to elicit preference functions and weight estimations by means of standard choice based conjoint analysis (CBCA) software Sawtooth-Software (2007). CBCA is a well-known and proven quantitative concept (see e.g. Raghavarao et al. (2010) here applied for estimating both preference functions and weights distributions. This first quantitative step in preference elicitation gives the individual stakeholder insight into the importance of his interest in the different objectives and also provides an initial shape of the associated preference functions. An example for this CBCA application for this case are found in the Odesys Toolbox Odesys-Toolbox (2024) or with more background details in Vander Stee (2024). This first quantitative preference elicitation estimate is followed by a qualitative step in which the stakeholders can freely adjust the CBCA estimates so that he recognizes his idealized design as good as possible in the weights and preferences. Combining the CBCA with with a freely adapted construct of preference functions and weights (for more info for the second part, see Mol and Schriever

(2024)), both quantitative and qualitative approaches are used to ensure an optimal structured stakeholder judgment process as a reflection of the open design.

#### 4. Results & conspection

In this section, we aim to solve the three cases described above as part of the dynamic and open-ended MODO problem. For this, we use the Preferendus tooling in which a best-fit for common purpose design point is generated within the IMAP method using an inter-generational Genetic Algorithm (GA). In other words, the Preferendus finds a point in the solution space what given the specific case parameters and technical reality with the maximum integrative and aggregated preference value for the stakeholder involved. In this way the Preferendus takes us to a common ideal within reach. In reality, the Preferendus is a dynamic tool that transparently and objectively supports the iterative design and decision-making process consisting of open technical-, social- and purpose loops. We have shown only three 'design snapshots' here as a result. These three were not chosen for the specific outcomes and results but to demonstrate the possibility of breaking open a stalled design, while balancing desirability and capability. The explanation of the results is therefore brief and the reader is further urged to use dynamic toolbox modelling alongside these three 'extreme' cases to dynamically 'play' with the model so that it starts 'talking back', see Odesys-Toolbox (2024).

A specific note is made regarding the wind speed design variable . Normally, this is not modelled as an endogenous variable  $x$ , but as an exogenous one  $y$ . Since the Odesys modelling aims to avoid as much technical debate and analysis as possible to generate a socio-technical design solution instead, we choose to retrospectively verify that this found wind speed occurs on average in practice (i.e., verification against past wind profiles). This design approach, including the wind speed reversal, avoids a possible technical stalemate and this can be adjusted at a later design stage. Moreover, it gives therefore an incentive to open stalled technical analyses and conflicts to explore if they might leave design freedom space unexploited.

Two final notes are made regarding the values of the various parameters and the IMAP outcomes: (1) Despite the fact that all socio-technical functions qualitatively reflect reality as well as possible, the values used still need to be verified in practice. This may still influence the current results. (2) Because of the non-linearity of the problem, *the* global IMAP design point cannot be found. It will always be *a* best-fit, and there may be more that are close to such a best-fit. Therefore, we recommend performing an a-posterior MCDA on these possible different best-fit Preferendus IMAP outcomes (note you have to use at least 3 outcomes within this MCDA, see Wolfert (2023)).

##### 4.1. Case 1: linear 2x2 single-interest

In these case 1 results, see the quantitative charts and data in the next subsection, we can notice the following high over:

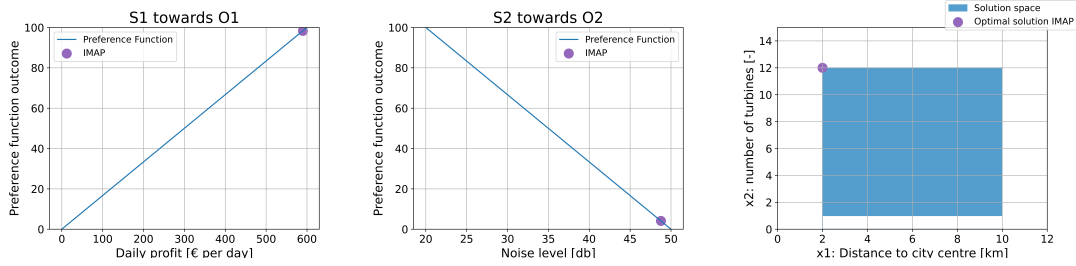
- The first two plots of the solution space and design outcomes generated by the Preferendus show the so-called SODO (single-objective design optimisation) 'corner-points' for a linear 2x2 problem, best for  $O_1$  or  $O_2$  and their respective stakeholder.
- The third solution space plot shows the so-called compromise solution, which

is a third and different MODO 'corner-point', reflecting a maximum number of turbines at a maximum distance from the city centre. Note: with an a-posterior MCDA it can easily be shown that a MODO design point has a higher group value than the SODO points. In other words, relinquishing the pure self-interest, ultimately enables an optimal design solution that benefits the whole group.

#### 4.1.1. 100% S1

**Table 6.** A best-fit design point

Variable	IMAP outcome
$x_1$	2 km
$x_2$	12 #

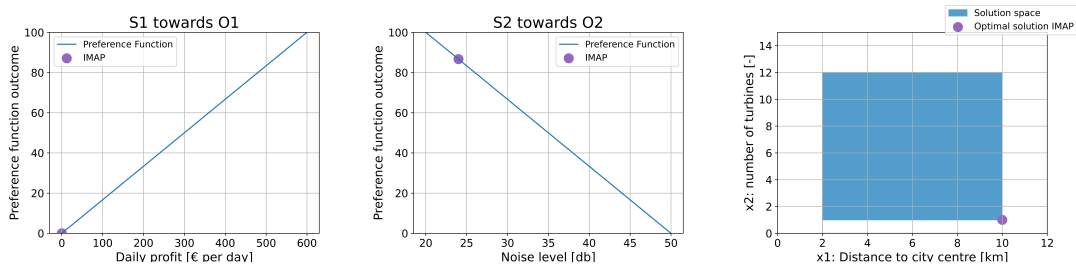


**Figure 2.** The preference functions including best-fit design point and solution space.

#### 4.1.2. 100% S2

**Table 7.** A best-fit design point

Variable	IMAP outcome
$x_1$	10 km
$x_2$	1 #

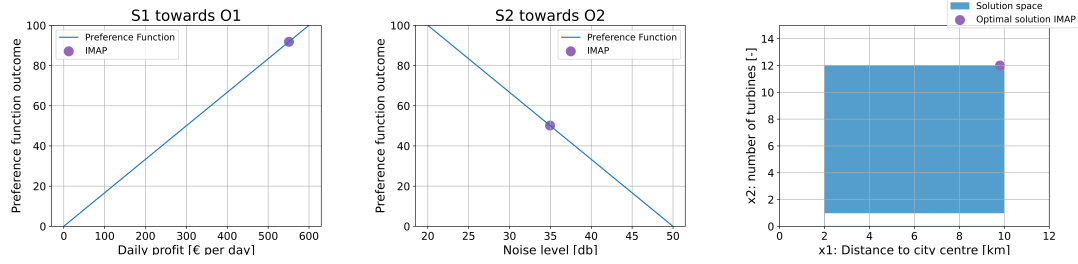


**Figure 3.** The preference functions including best-fit design point and solution space.

#### 4.1.3. 50/50% for $S1..S2$

**Table 8.** A best-fit design point.

Variable	IMAP outcome
$x_1$	10 km
$x_2$	12 #



**Figure 4.** Preference functions including best-fit design point.

#### 4.2. Case 2: linear $4 \times 4$ single-interest

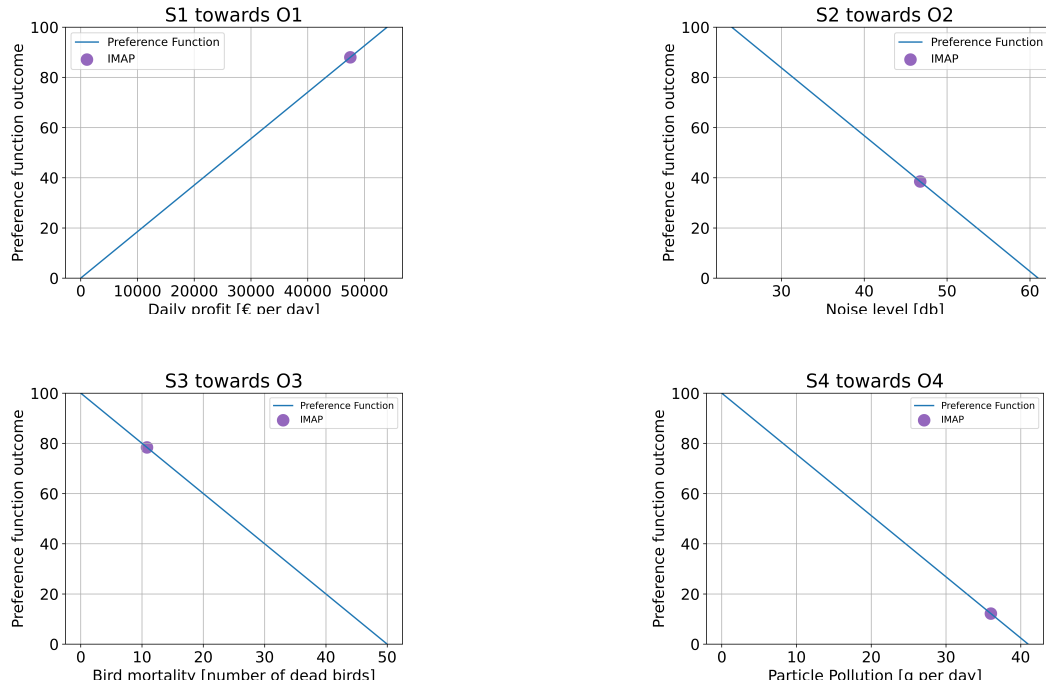
In these case 2 results, see the quantitative charts and data in the next subsections, we can notice the following high over:

- In case 2a, it can be seen that a design synthesis of socio-technical conflicts of interest generated by the Preferendus is most driven by 'desirability'. Because there are 3 stakeholders together 'against' and only the energy provider is with 50% 'in favour' of a windfarm development, a best-fit seems viable with balanced preference function results. However, the windspeed required shows that the solution is physically unfeasible.
- Case 2b shows that a design synthesis of the socio-technical conflicts of interest design outcomes generated by the Preferendus is most strongly driven by 'capability'. Because the four stakeholders participate equally, the importance of the service provider has declined compared to 2a, making the best-fit see a non-viable wind farm and the design point falls on the endpoints of the preference functions (completely 'satisfied' or 'dissatisfied').

##### 4.2.1. Uneven 50/20/15/15% for $S1..S4$

**Table 9.** A best-fit design point

Variable	IMAP outcome
$x_1$	10 km
$x_2$	11 #
$x_3$	140 m
$x_4$	14.8 m/s

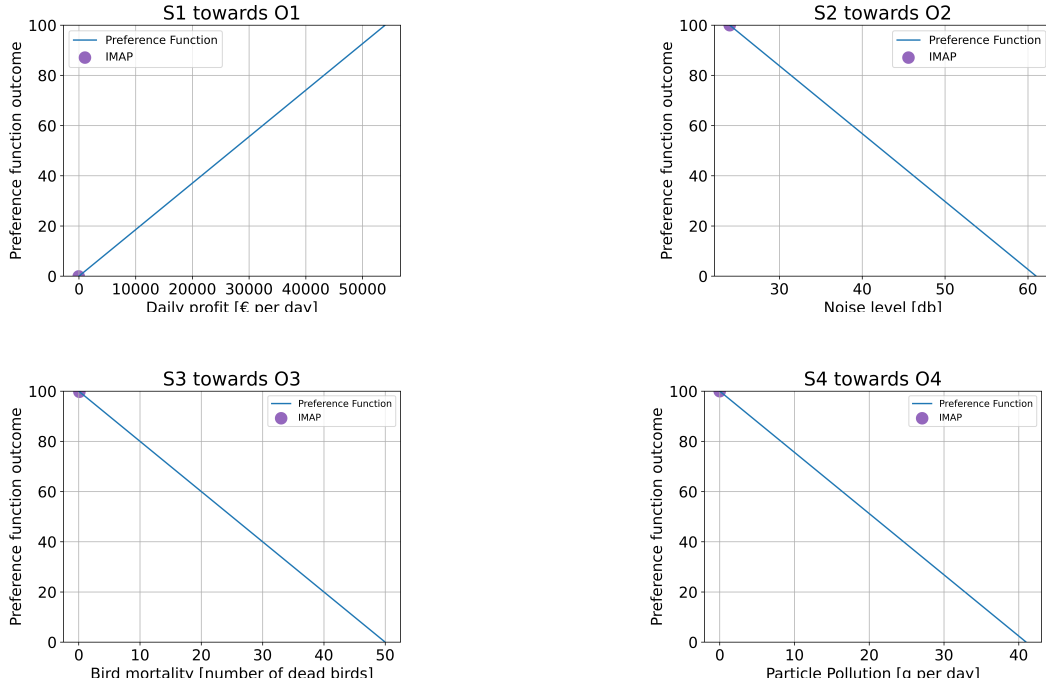


**Figure 5.** Preference functions including best-fit design point.

4.2.2. Equal 25/25/25/25% for  $S1..S4$

**Table 10.** A best-fit design point.

Variable	IMAP outcome
$x_1$	10 km
$x_2$	1 #
$x_3$	50 m
$x_4$	3.0 m/s



**Figure 6.** Preference functions including best-fit design point.

#### 4.3. Case 3: non-linear 4x4 multiple-interests

In these case 3 results, see the quantitative charts hereafter, we can notice the following high over :

- Case 3 shows that a design synthesis of socio-technical conflicts of interest generated by the Preferendus is driven most strongly by ‘desirability’, in that there is a ‘coalition’ that seems to be in favour of wind energy revenues (‘we will always be better off for that seems to be the credo’ and/or ‘the desire of this thought seems greater than the reality and its side effect’). However, the required wind speed shows that the solution is actually physically unfeasible.
- Case 3, due to the distribution of individual weights and the different preference function shapes, shows a balanced outcome where mostly the design point generated by the Preferendus lies on the function rather than on an endpoint. This case shows similarities with case 2a, partly because the summed weights per objective are rather similar to the global (and uneven) distribution in case 2a.

**Table 11.** Solution of 4x4 case where the energy provider has a weight of 50% “against” the coalition of the other stakeholders.

Variable	IMAP outcome
$x_1$	10 km
$x_2$	10 #
$x_3$	145 m
$x_4$	15.0 m/s

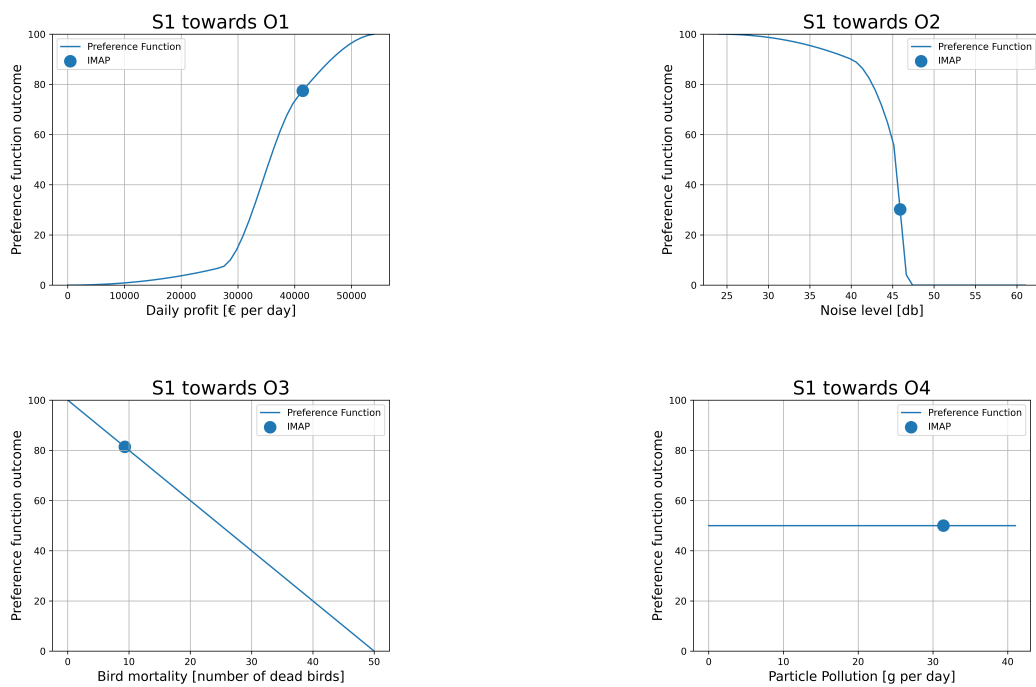


Figure 7. Preference curves for  $S_1$  towards  $O1..4$ .

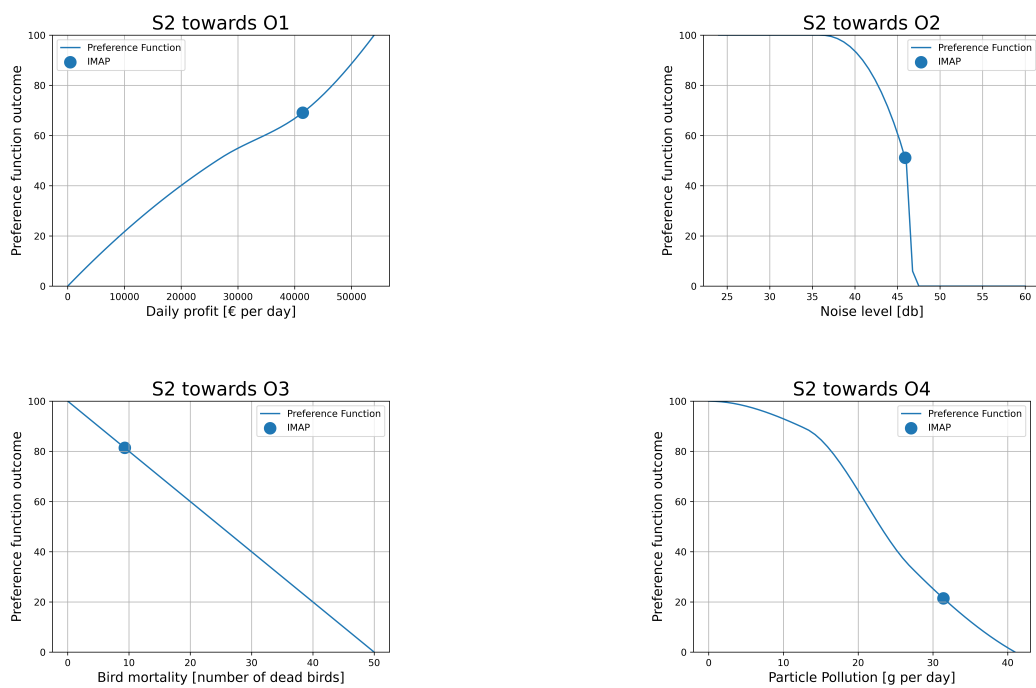


Figure 8. Preference curves for  $S_2$  towards  $O1..4$ .

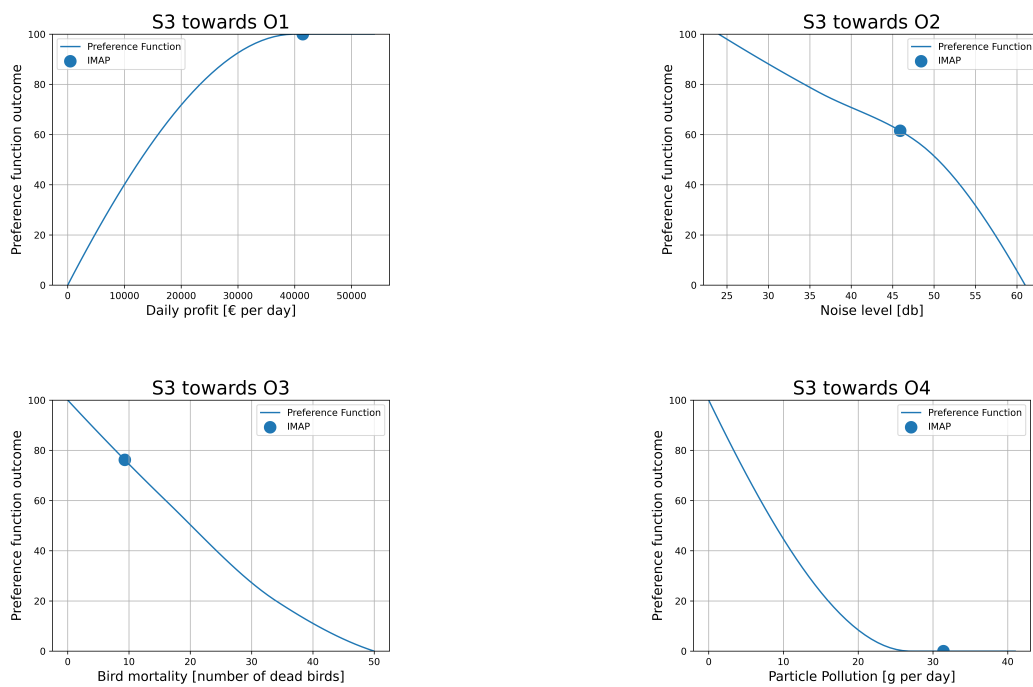


Figure 9. Preference curves for  $S_3$  towards  $O1..4$ .

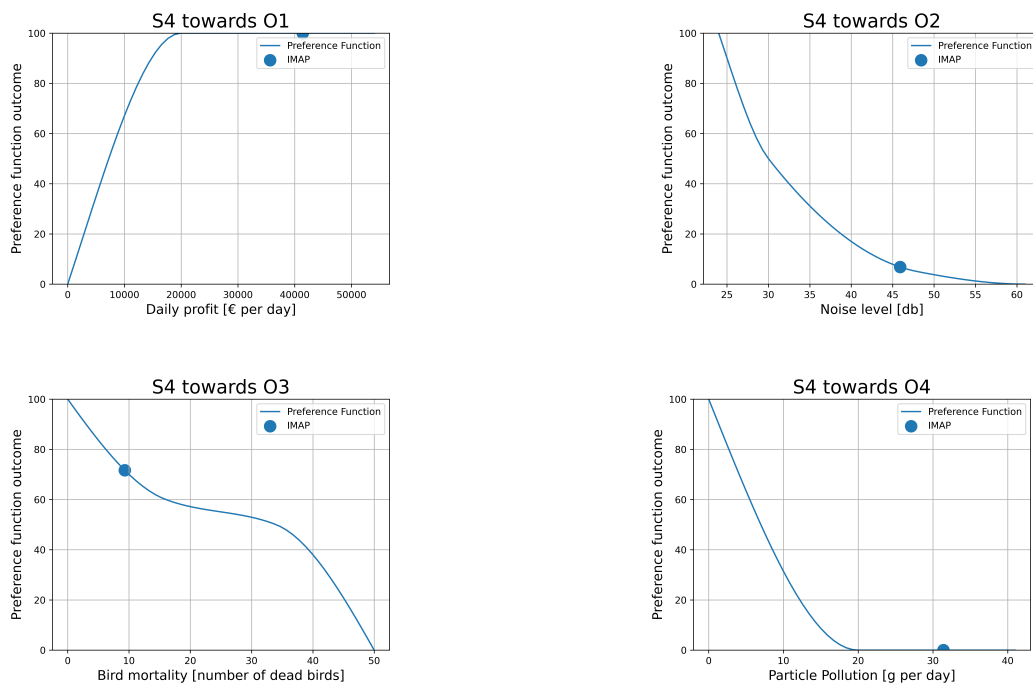


Figure 10. Preference curves for  $S_4$  towards  $O1..4$ .

## 5. Conclusion & further development

The working and added value of the complex systems design methodology Odesys has been demonstrated for a stalemate windfarm development problem. A dynamic tool called Preferendus has been used to confront the socio-technical conflicts into success. Depending on the specific technical parameter setting and the combined interests of the stakeholders, this has been partly possible. The following high-level conclusions can be drawn:

- Following Odesys' associative and integrative design principle of diaduction, it was possible to translate a stalemate problem into an IMAP problem. This problem turned out to be resolvable using the Preferendus to confronting the socio-technical conflicts into co-created success, where interests and reality are conjoined.
- More specifically, through Odesys' "vertical" integration, desirability ('subject') and capability ('object') are united so that desired purpose and realistic performance are synthesised. In some cases, we have shown that wishful thinking seemed to take precedence over realism to break open the stalemate. However, physical feasibility returned this to reality (note here the free translated quote of the well-known natural scientist Richard Feynman: 'For a successful technology, reality must take precedence over stakeholder relations, for nature cannot be fooled').
- More specifically, through Odesys' "horizontal" (chain) association, individual stakeholder interests are aggregated to a maximum highest preferred value. This is because when individual stakeholders are willing to give up their pure self-interest a fair bit, it becomes possible to create a best-fit for common purpose that benefits the whole group the most (note here the free translated quote of the well-known spiritual scientist Rudolf Steiner: 'The well-being of a group of people working together is greater the less the individual claims the work outcome of only his individual interest').

In addition to these conclusions, the following are specific recommendations for further development:

- The technical parameters and design performance functions that describe the behaviour of this wind farm need to be further tested in practice to make the Preferendus results more reliable and usable in a real stalemate negotiations (i.e., improve structured expert judgment).
- The social input, the preference functions describing the stakeholders interests and the steps in the social cycle should be studied in more detail (i.e., improve structured stakeholder judgment). It is also recommended to synchronize these with Friedrich Glasl's model of conflict escalation and with Roger Fisher's Getting to Yes principles (see Wolfert (2023)).
- A specific Preferendus stalemate solver module could be developed that can be used to determine where in the design problem the least amount of concession should be made to achieve a desired and achievable result. This could include the addition of negotiable constraints or preference elicitation.
- The process of going through an integrated socio-technical cycle needs to be further developed, tested and validated in real-life practice. It is recommended to using the latest insights from Otto Scharmer's U-model theory and practice. In particular, the concepts of 'dialoguing in the now' and 'idealised design' deserve

specific process improvements for the Odesys U-model and its open-loop learning approach (i.e., a DIII approach moving a step beyond the single DI and double DII loops learning from Chris Argyris and Donald Schön).

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## Disclosure statement

The authors report that there are no competing interests to declare.

## Data availability statement

Separate Deepnote links are available for each of the three case parts. This allows the reader to dynamically ‘play’ with the model so that it starts ‘talking back’. These three app-links are:

- (1) 2x2 single-interest & linear: <https://deepnote.com/app/odesys-toolbox-2/Windfarm-basic-6a6010c5-ebd0-4c0f-8892-ec833cfead85>
- (2) 4x4 single-interest & linear: <https://deepnote.com/app/odesys-toolbox-2/Windfarm-4x4-linear-d60d004f-68fe-4046-9e69-2887324d6760>
- (3) 4x4 multiple interest & non-linear: <https://deepnote.com/app/odesys-toolbox-2/Windfarm-extended-13678eab-714e-487c-a68a-934298a161dc>

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