Advanced Design Tools for Ocean Energy Systems Innovation, Development, and Deployment

Deliverable D3.3

Testing and verification results of the Structured Innovation tool – Beta version

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EXECUTIVE SUMMARY

DTOceanPlus will accelerate the commercialisation of the Ocean Energy sector by developing and demonstrating an open-source suite of design tools for the selection, development, deployment, and assessment of ocean energy systems (including sub-systems, energy capture devices, and arrays). The suite of tools will include a Structured Innovation tool, for technology concept selection, a Stage Gate tool, for the technology development process, and a set of Deployment Design and Assessment tools for the design of the system and its evaluation.

The Structured Innovation (SI) design tool comprises innovation methodologies that can enhance concept creation and selection in ocean energy systems, enabling a structured approach to address complex ocean energy engineering challenges where design options are numerous. Thus, it can facilitate efficient evolution from concept to commercialisation. The tool is one of a kind beyond the current state-of-the-art, that will enable the transfer and adaptation of the QFD/TRIZ and FMEA methodologies to the ocean energy sector.

Deliverable D3.3 "Testing and verification results of the Structured Innovation design tool – Beta version" of the DTOceanPlus project includes the details of the verification activities carried out to test the SI tool to verify that it meets the requirements defined in WP2 and the technical requirements defined in T3.1. This report describes:

- the Verification Cases (VCs), Software Evaluation Forms and associated Key Performance Indicators (KPIs) and their creation,
- the demonstration and training sessions that were provided to the verifiers of the tool,
- the results of the verification, including quantitative and qualitative assessments of each VS and
- recommended changes or additional functionality that would add value to the tool.

At the end of this round of testing, a stable version (beta) of the tool is available, fully documented with a technical manual and a user manual, which will be further validated and demonstrated using real data from the first pilot experiences in WP7.

According to the quantitative results, the end-users involved in evaluating the SI tool are satisfied with the usability, user-friendliness, performance, and value of the software. The qualitative assessment feedback gathered some improvements compiled and categorised by functionality, evaluation characteristics, and the frequency of comments. As a result of this, 15 high priority improvement areas were selected to be implemented in the final release of the DTOceanPlus suite of design tools.

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ABBREVIATIONS AND ACRONYMS

AD	Assessment Design
BL	Business Logic
BV	Bureau Veritas
CA	Commercial Attractiveness
CR	Customer requirement
DD	Deployment Design tools
DET	Detection
DO	Design Objectives
DOE	U.S Department of Energy
DR	Design Requirement
D&A	Deployment and Assessment tools
EC	Energy Capture
ECR	Evaluation Criteria
ED	Energy Delivery tool
EDP	Energias de Portugal
ESA	Environmental Social Acceptance tool
ESC	Energy Systems Catapult
ET	Energy Transformation tool
FMEA	Failure Mode Effects Analysis
FR	Functional Requirement
HoQ	House Of Quality
ID	Identifier
KPI	Key Performance Indicator
LCOE	Levelised Cost of Energy
LMO	Logistics and Marine Operations
MC	Machine Characterisation
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
OCC	Occurrence
OCC	Open Cascade
OEC	Offshore Energy Converter (an aggregate term for WEC & TEC)
OES	Ocean Energy Sector
OMP	Orbital Marine Power
OPEX	Operational Expenditure
PTO	Power Take-Off
QA	Quality Assurance
QFD	Quality Function Deployment
R&D	Research and Development
RAMS	Reliability, Availability, Maintainability, Survivability too
RM	Reference Models
RPN	Risk Priority Number
rRPN	Revised Risk Priority Number
SC	Site Characterisation
SEF	Software Evaluation form
SEV	Severity
SG	Stage Gate design tool

SI	Structured Innovation tool
SK	Station Keeping tool
SLC	System Lifetime Costs tool
SoTA	State of The Art
SPEY	System Performance and Energy Yield tool
SR	Software routes
TA	Technical Achievability
TEC	Tidal Energy Converter
TRIZ	*Teoriya Resheniya Izobretatelskikh Zadatch*, (theory of inventive problem solving)
TRL	Technology Readiness Level
TS	Technical Solution
UEDIN	University of Edinburgh
UI	User Interface
VC	Verification Case
VOC	Voice of the Customer
VS	Verification Scenarios
WEC	Wave Energy Converter
WES	Wave Energy Scotland
WP	Work Package

DEFINITION OF TERMS

Features — The functionality provided by the software to the user and relates to the identified requirements from the user consultation exercise captured in WP2

Software route — Each of the possible trajectories to cover all the business logic of the tool (e.g., new concept/improvement cycle, …)

Verification Scenarios — A set of independent input/output data to be provided to the end-user for the verification. It comprises of the Design Objective, Verification Cases and User Stories.

User stories — Short, simple descriptions of a feature. A partial design objective (e.g., As a <type of user>, I want <some goal> so that <some reason>).

Verification Cases — Design variants covering one trajectory and ending up in one or multiple Features/User Stories.

Design Objectives — Short descriptions of a relevant design case for ocean energy, non-confidential, which has been addressed by other tools/methods, and applicable to part or all the Verification Cases.

Structured Innovation Methodology — A technique to stimulate rigour, organised and consistent innovative thinking, technology selection and impact assessment. This technique combines functions such as understanding the mission, the future vision, the market (including the potential for commercial exploitation, competition, differentiation, social value etc.) and the development of potential solutions. This is broadly described in British Standard BS7000-1, "Design Management Systems, Part 1 – Guide to Managing Innovation" amongst others. The methodology is following the concept shown in Figure 0-1.

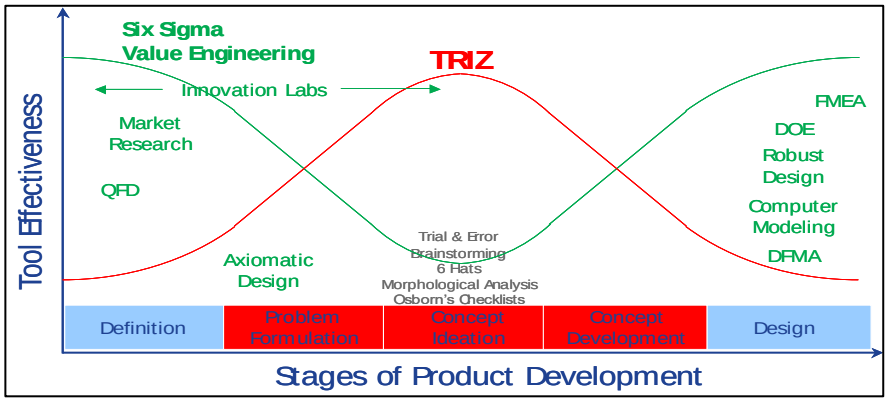

FIGURE 0-1: TOOL EFFECT VS PRODUCT DEVELOPMENT STAGE [1]

Quality Function Deployment (QFD)	A structured methodology used to identify, prioritise customers' requirements and translate them into suitable technical requirements for each stage of product development and production. It is achieved using the House of Quality (HoQ), which is a matrix used to describe the most important product or service attributes or qualities.
Theory of Inventive Problem (TRIZ)	A systematic problem-solving approach based on universal principles of creativity, patents, and research. The methodology looks to identify the generic concept problems and solutions and to eliminate the technical and physical contradictions.
Failure Modes and Effects Analysis (FMEA)	A methodology used as risk analysis and mitigation tool to improve development ventures. At concept and design phases, the concept or design FMEA mitigates risks associated with the various concept selections.
Customer requirements	Quality can be defined as meeting customer needs or requirements. These requirements, also known as 'the voice of customers,' are captured in a variety of ways such as customer specifications, surveys, interview.
Design parameters	The design parameters are technical characteristics or functional requirements defined to meet the customer requirements. These parameters are measurable, and meaningful, stated in such a way that particular solutions are implied.
Target values	The target values of the design parameters provide the quantitative technical specifications for these parameters to satisfy the customer requirements.
Ideality	Ideality is best defined as the aspirational State-of-the-art parametric values, that can drive innovation and identify opportunity, and newness relative to current capability. In other words, an ideal state of a system is a system where all its functions are achieved with no harm caused.
Contradictions/ Conflicts	Contradictions occur between two or more features, with one feature to be improved, and the other worsened. An example of this could be- to generate more electricity for a turbine, a bigger turbine might be required (improved features), but this will result in a heavier machine, increasing its costs (worsened features).
Art-of-the-possible	These are the values of ideal technology (ideal solutions beyond constraints-competing interests). The art-of-the-possible rather than the state-of-the-art takes into consideration the ideality of devices or processes only limited by physics (e.g., the Betz limit, yield strength) and extreme conditions to provoke new concepts

Occurrence	In FMEA, the occurrence is defined as a ranking number associated with the likelihood that the failure mode and related causes will be present in the function being considered
Severity	In FMEA, severity is the ranking associated with the extremely severe effect of failure modes.
Detection	The current controls of the systems determine the probability of detecting a failure before the effect is realised. Detection raking is associated with how likely a failure can be detected.
Risk Priority Number (RPN)	The RPN, the product of occurrence, severity, and detection rankings is a measure used when assessing risks to help identify critical failure modes. Caution is required when assessing risks using RPN values.
Solution Hierarchy	A multi-level list of potential solutions for ocean energy systems that starts with the energy trilemma as requirements: delivering secure, affordable, and environmentally sustainable energy; and lists potential solutions for each requirement. The intention is to offer this hierarchy as a structured set of prompts, and to help the user to consider multiple solutions to different QFD levels – the user can then understand the potential for ideality and innovation, and thoroughness.

1. INTRODUCTION

1.1. SCOPE AND OUTLINE

This report documents the methodology and results of the verification of the **Structured Innovation (SI)** tool beta version. The verification tasks described in this report were designed to assess whether the tool:

- responds correctly to a varied set of inputs,
- performs its functions in an acceptable time and with reasonable use of computational resource,
- is adequate in terms of usability,
- can be verified against control data.

Verification is a critical step in software development – it determines whether the software satisfies the functional requirements and is essential to ensure that the development phase is being carried out accurately.

Four verification scenarios (VSs) were created to evaluate the functionalities of the Structured Innovation tool. Demonstration and interactive training sessions were conducted to illustrate how to use the Structured Innovation tool. The technical verifier (TECNALIA) and the industrial verifiers (OMP, IDOM, Sabella, WES, EDP CNET) were given access to an online version of the beta version of the Structured Innovation tool. They were then asked to run through each of the VS and complete a Software Evaluation Form (SEF) designed to perform the verification. This report describes:

- the Verification Cases (VCs), the SEF and associated Key Performance Indicators (KPIs) and their creation,
- the demonstration and training sessions that were provided to the verifiers of the tool,
- the results of the verification, including quantitative and qualitative assessments of each VS and any recommended changes or additional functionality that would add value to the tool

The remainder of this report is structured as follows:

- The remainder of **Section 1** provides short summaries of the DTOceanPlus project and the Structured Innovation tool. For further information and background on the project, the reader is directed towards previous deliverables [1] [2] [3].
- **Section 2** illustrates the methodology adopted for the Verification activities, starting from the software routes and the user stories approach intended to delineate the tool's functionalities. Then, attention was focussed on the data used to run the Verification cases. The training sessions organised both for the technical and the industrial partners are also illustrated in this section. Finally, the Evaluation Criteria used to evaluate the tool's functionalities are presented.
- **Section 3** illustrates in detail, the verification cases, the steps to the testing of SI tool's features, and the approach adopted to define the user stories. In this section, an evaluation of the tool's functionalities according to the Evaluation Criteria previously defined is also presented.
- **Section 4** analyses the results of the evaluation activities, and finally, conclusion and future work are discussed in **Section 5.**

1.2. SUMMARY OF DTOCEANPLUS PROJECT

The Structured Innovation design tool belongs to the suite of tools "DTOceanPlus" developed within the EU-funded project DTOceanPlus [4]. DTOceanPlus aims to accelerate the commercialisation of the Ocean Energy sector by developing and demonstrating an open-source suite of design tools for the selection, development, deployment, and assessment of ocean energy systems (including subsystems, energy capture devices and arrays) and at various levels of complexity (Early/Mid/Late stage).

At a high level, the suite of tools developed in DTOceanPlus will include:

- **Structured Innovation tool (SI)**, for concept creation, selection, and design.
- **Stage Gate tool (SG)**, using metrics to measure, assess and guide technology development.
- **Deployment tools**, supporting optimal device and array deployment:
  - Site Characterisation (SC): to characterise the site, including metocean, geotechnical, and environmental conditions.
  - Machine Characterisation (MC): to characterise the prime mover;
  - Energy Capture (EC): to characterise the device at an array level;
  - Energy Transformation (ET): to design PTO and control solutions;
  - Energy Delivery (ED): to design electrical and grid connection solutions;
  - Station Keeping (SK): to design moorings and foundations solutions;
  - Logistics and Marine Operations (LMO): to design logistical solutions and operation plans related to the installation, operation, maintenance, and decommissioning operations.
- **Assessment tools** to evaluate projects in terms of key parameters:
  - System Performance and Energy Yield (SPEY): to evaluate projects in terms of energy performance.
  - System Lifetime Costs (SLC): to evaluate projects from the economic perspective.
  - System Reliability, Availability, Maintainability, Survivability (RAMS): to evaluate the reliability aspects of a marine renewable energy project.
  - Environmental and Social Acceptance (ESA): to evaluate the environmental and social impacts of a given wave and tidal energy projects.

These will be supported by underlying common digital models and a global database. Linkages between DTOceanPlus modules are outlined in Figure 1-1.

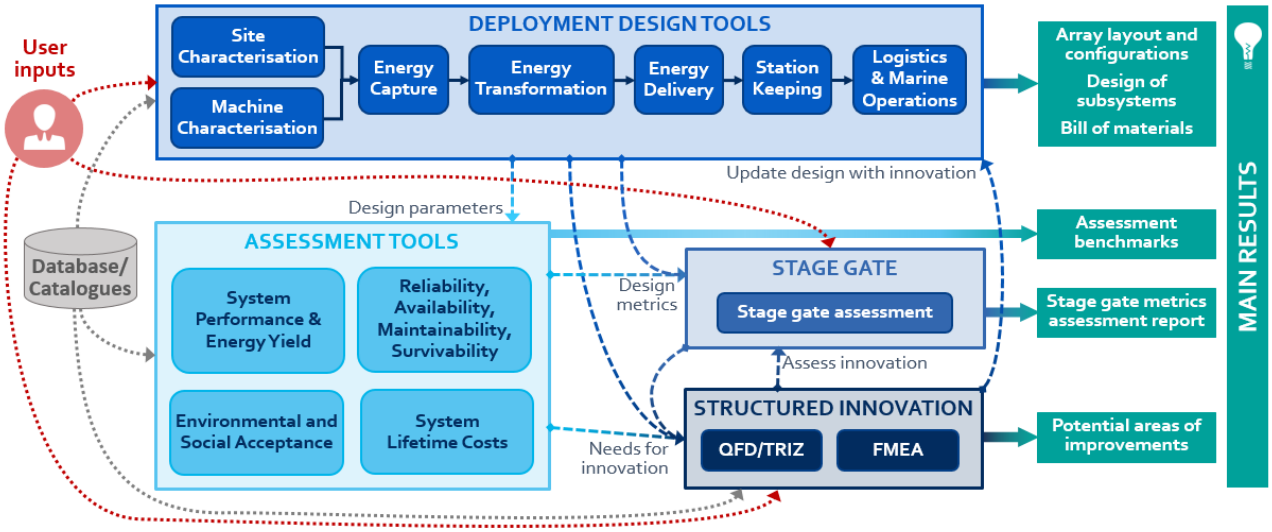

FIGURE 1-1: DTOCEANPLUS MODULES, MAIN LINKAGES AND OUTPUTS

1.3. STRUCTURED INNOVATION TOOL

The **Structured Innovation design** tool within the DTOceanPlus suite is one of a kind beyond the current state-of-the-art, that will enable the transfer and adaptation of the QFD/TRIZ and FMEA methodologies to the ocean energy sector. For a sector such as ocean energy, where the number of design options is still very high, the open-source Structured Innovation design tool is needed to help users to understand the complexity and interdependencies of the engineering challenge – resulting in a more efficient evolution from concept to commercialisation.

- The Quality Function Deployment (QFD) methodology defines the innovation problem and identifies trade-offs in the system.
- The Theory of Inventive Problem Solving (TRIZ), a systematic inventive problem-solving methodology, generates potential solutions to the often-contradictory requirements raised from the QFD.
- The output from the integrated QFD/TRIZ component comprises of design requirements along with target engineering metrics.
- The Failure Modes and Effects Analysis (FMEA) assesses the technical risks associated with the proposed design concepts, specifications, and gap analyses.

The SI tool produces a set of metrics and assessments; conflicts and impact report; and a design report. The metrics and assessments include both ideality (a measure of what might be theoretically possible to achieve) and development values (how difficult it would be to implement the selected solution), relevant to the benchmark assessments of ideal innovative concepts for wave and tidal renewable energy projects at different stages of development. The design report then includes requirements [2] [3].

2. METHODOLOGY

2.1. OVERVIEW

The main aim of the verification tasks was for the technical and industrial verifiers to evaluate the Structured Innovation (SI) tool's functionalities. To achieve this, the following actions were completed:

- **Definition of the *VCs* and *VSs*** – this was achieved by analysing the key features of the SI tool and the associated *use cases* accounting for the technology types (wave/tidal), the aggregation levels (array/device/subsystem), the running mode (new concept/ improvement cycle), the design objectives, and the targeted user group. (refer- Section 2.2).
- **Definition of data** –the required input/output (I/O) data for the verification cases were defined and collected. (refer- Section 2.3)
- **Delivery of training sessions** – training sessions on the tool's use were provided to both the technical verifiers and the industrial partners. A technical note was provided as a guide to support the task (refer- Section 2.4).
- **Definition of Evaluation Criteria** – a Software evaluation form was developed and used to verify all DTOceanPlus modules. The software evaluation form is divided into sections assessing Usability, User-friendliness, Performance and Accuracy, and the tool's perceived value (refer- Section 2.5).

After the training sessions' delivery, the technical and industrial verifiers were provided with the software evaluation form and a technical note that includes the details of each VSs and reference data. They then assessed each of the VCs in turn, testing the software's appropriate features and completing the software evaluation forms.

The quantitative and qualitative results from the evaluations completed by each verifying partner were collected, collated, and analysed. The results of this analysis are presented in **Chapter 4**.

2.2. DEFINITION OF THE VERIFICATION CASES

The overarching use case for the Structured Innovation design tool is for concept creation and design improvement. The Structured Innovation tool has three major functionalities:

- Scanning the design space and assess attractive areas for innovation
- Identify and solve the contradictions arising from the proposed solutions
- Mitigate the potential technical risks associated with the attractive concepts

These functionalities are shown in Figure 2-1, highlighting the high-level software route of the SI tool.

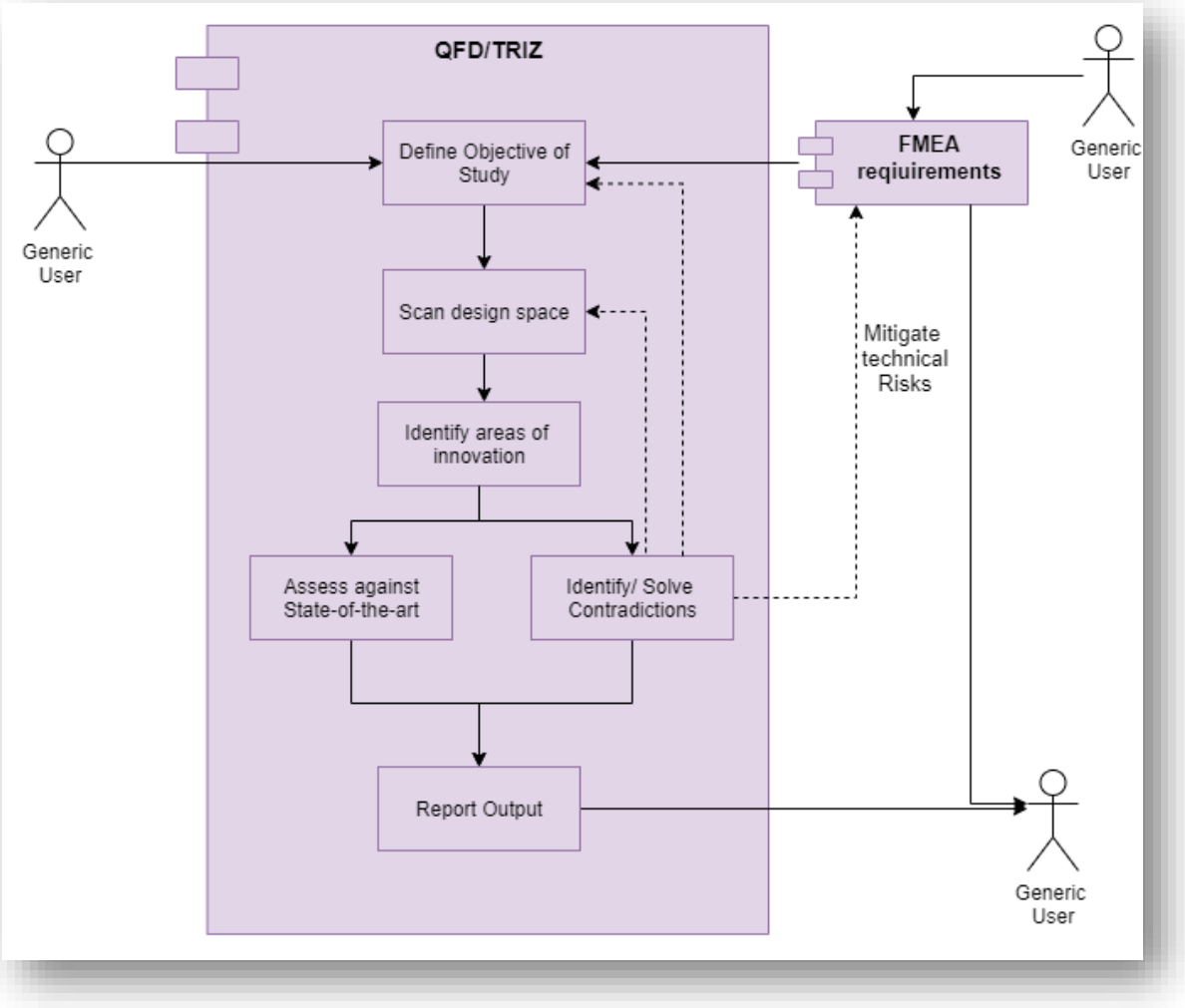

FIGURE 2-1: HIGH-LEVEL SOFTWARE ROUTE FOR SI TOOL

For each of these key functionalities and features (as shown in

TABLE 2-1), a set of *user stories* was defined, outlining all potential use cases of that functionality. User stories are generally formulated in users' everyday language; they should help the reader understand what the software can accomplish.

TABLE 2-1: SI TOOL MAIN FUNCTIONALITIES AND FEATURES

MODULE	Main Functionalities	Feature(s) tested
QFD/TRIZ	To scan the design space and identifying attractive areas for innovation	Objectives of the study Assessment of areas of innovation Correlation of functional requirements Ideality definition (art-of-the-possible) State-of-the-art assessment
	To identify and solve contradictions	Interactions between functions Identifications Implementing TRIZ alternative solution
FMEA	To mitigate technical risks of implementing proposed concepts	Identify potential failure modes, Reduce the likelihood and impact of failure
QFD/TRIZ/ FMEA	To generate a complete report:	To output: Achievable innovative concepts (assessed impact, ideality & difficulty of innovation) Conflict assessment and alternative solutions Assessment of Ideality and development impacts

The scope of the user story is to define roles ("As a user / as a developer"), prove the utility of a specific feature ("I would like to calculate the efficiency of a tidal energy array of five turbines…"), and define its purpose ("…to get the following ideal values…").

A related concept is that of the *Software routes* of each module in DTOceanPlus. Most of the individual Deployment and Assessment (D&A) modules will operate differently at different complexity levels (Low-1, Medium-2, or High-3) and technology type (wave or tidal). It was important to identify all the different input permutations that lead to slightly different calculation methods or functions in the Business Logic of these tools. Each of the individual permutations and corresponding methods is referred to as software routes. The assessment of these software routes is less applicable to the SI tool because the key features and functionalities operate independently of the complexity level and technology type. In other words, for the SI tool, there is a one-to-one mapping between the Software routes and the key functionalities.

The SI tool can be used either as a standalone tool or within the framework of design tools of the DTOceanPlus project. As such, the tool offers two main design modes: a new concept mode – to give an estimate of costs and performance at an early stage in the concept creation/design process and an improvement cycle mode – for a more detailed assessment of innovation within an existing device/project development path. The VS needed to ensure the two running modes of the SI tool were evaluated.

For these reasons, the VSs were developed using the three major functionalities of the SI tool as the basis, including two scenarios in the new concept assessment mode and two improvement assessment scenarios of existing designs. Besides, a permutation of aggregation levels resulted in 4 VCs as detailed in **Chapter 3.** For each *VC*, critical use cases associated with the tested functionalities were also extracted and provided to the verifiers as extra guidance of what precisely needed to be tested. These sub-tasks within each *VC* are also described in **Chapter 3**.

While the SI tool operates in the same manner regardless of the technology type, it was still essential to verify that it is compatible with the wave and tidal energy assessments. It was also important to ensure that the tool provided value to each user group expected to use the SI software (funders, investors, technology developers, and project developers). Each *VS* was thus associated with a technology type and user group. Furthermore, a short description was written to add a broader context and background to each scenario. All these additional details are shown in TABLE 3-1. The *User stories and Software routes* were also used as the basis for the development of tutorials, training sessions, and user manual (see the Annex for the tutorials and user manual for the SI tool).

2.3. DATA DEFINITION

The verification scenarios were adapted following available data from literature, publicly available research projects. The data used for the verification of the Structured Innovation tool were obtained from:

The Reference Model Project sponsored by the U.S Department of Energy (DOE) Wind and Water Power Technologies Program. This project's goal was to produce non-proprietary Reference Models (RMs) of marine hydrokinetic technology designs as study objects for open-source research and development programs [5]. The RMs used as part of DTOceanPlus' verification activities are RM1 and RM3: for both of them, power performance and velocity measurements were collected to assess their interaction with the surrounding environment. The outputs of the tests have been used as inputs for the modules developed under DTOceanPlus, as showed in FIGURE 2-2. These data were provided to the verifiers, as a resource if needed, to run the verification scenarios VS2 and VS3. The Tidal Reference Model (RM1) data were used for the verification activities in VS3, as shown in FIGURE 2-2.

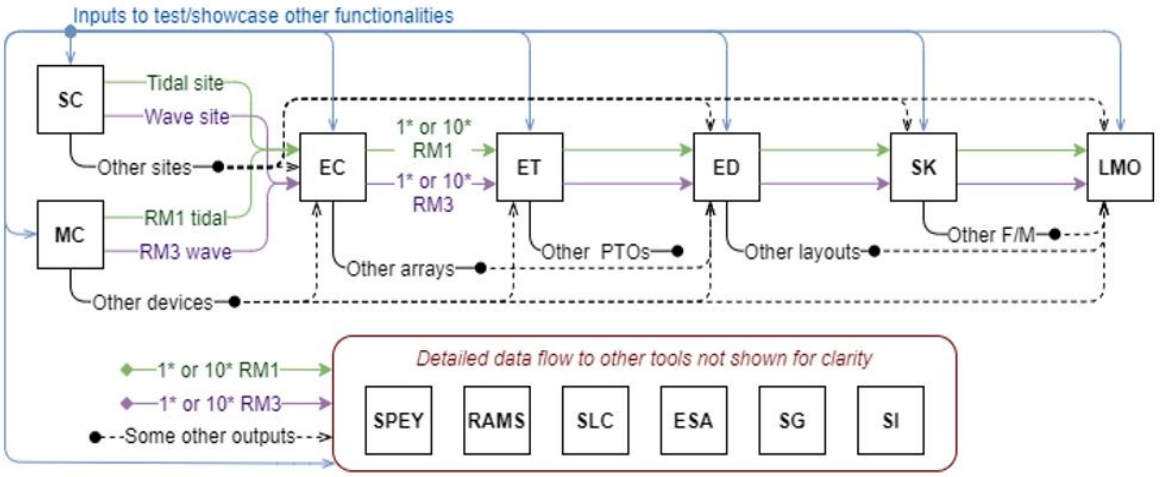

FIGURE 2-2: FLOW OF REFERENCE CASES/DATA BETWEEN THE TOOLS

The SI tool will provide the user with a structured and logical approach to generating new concepts. To help with this process, the SI tool was supported in the verification task by the **Scenario Creation tool**, developed by Wave Energy Scotland [6]. The purpose of the Scenario Creation tool is to generate wave energy scenarios and rank them in order of Commercial Attractiveness (CA) and Technical Achievability (TA), and use the ranking to explore wave energy technology development activities. Data from the tool were provided to the verifiers to run the verification scenario VS1.

The scenarios provided included combinations of the following:

- Degree of freedom the wave energy device moves in
- Shape of the prime mover
- Material
- Scale (m)
- Average resource (kW/m)
- Average efficiency (%)
- CAPEX (£)

These scenarios supported the user of the SI tool as they can be used for the Target Values or State of the Art values in the QFD module. In addition to the above project's data, **Open-access publications** were used to obtain data on innovations such as the negative spring concept that fed into the target/ideal values in VS2 [7] [8] [9]; the star-radial cabling configuration that fed into VS3 [10] [11], and the ReDAPT data into the failure modes section in VS4 [12] [13] [14].

It is important to emphasise that the verification activities are being carried out by running the SI tool in standalone mode, meaning that the user will provide all the critical input parameters required to run the SI tool. However, when the SI tool is run in integrated mode, the user will be prompted to open each of the relevant Stage Gate, Deployment, and Assessment tools to obtain the SI assessment metrics.

2.4. DEMONSTRATION AND TRAINING SESSIONS

2.4.1. TRAINING SESSIONS FOR THE TECHNICAL PARTNER

Before running the VCs, the technical partner (TECNALIA) was trained on using the tool, given access to the tool on a server, and training material and tutorials. The main form of the training was provided through a set of video conference calls where a walkthrough of all the tool's features was given. The conference calls facilitated technical discussions between the developers and the technical verifier. The *VSs* were also presented and discussed thoroughly during these training calls.

A comprehensive guide to understanding all the potential of the Structured Innovation tool is provided in the 'Deliverable D3.2-Structured Innovation design tool-Alpha version', where the main functionalities of the SI tool (1- Scanning the design space and assess attractive areas for innovation, 2- Identify and solve the contradictions arising from the proposed solutions, 3- Mitigate the potential technical risks associated with the attractive concepts, 4- Reporting outputs are explained in [3]. This document also presents technical aspects such as implementing the software architecture, several examples of module inputs and outputs, and a user- guide to the front-end of the tool.

A webinar on how to use the Structured Innovation tool is also available on the project website[1], focusing on the tool functionalities and its potential for the different stakeholders. The education activity culminated with technical discussions between the developers and the technical verifier, during which a live demonstration of the flow to be followed when running the tool has been held, and the Verification scenarios presented.

Before running the first round of Verification Cases, the technical partners (in the case of Structured Innovation tool- TECNALIA) received comprehensive training material and tutorials.

2.4.2. TRAINING SESSIONS FOR THE INDUSTRIAL PARTNERS

A similar walkthrough of the tool was provided to the industrial partners on a separate video conference call. The industrial partners were also provided with the relevant published documentation on the Structured Innovation tool, access to the previously recorded webinar, and a technical note. The technical note provides a general user guide to the verifiers, detailing what each verification case will cover in terms of requirements and user stories and describing each step within the tool. A description is given of the verification cases chosen, including information of the design objectives and the full list of inputs (e.g., the relationships, ratings) and the corresponding results.

2.5. EVALUATION CRITERIA

At the start of the project, a consultation of potential users and other stakeholders for the DTOceanPlus tools was conducted to identify and clarify their needs and requirements on the functionality and use of the Structured Innovation tool [15]. Of the overall software characteristics considered, usability followed by flexibility & expandability, modularity was most important. Additionally, transparency of

[1] https://www.dtoceanplus.eu/Publications/Training/Webinar-4-Structured-innovation-design-tool-for-ocean-energy

how the tools work is critical, including documentation referenced to background research and version control or parameter tracking.

The outcome of this analysis translated these user requirements into detailed functional requirements for the development of the DTOceanPlus tools and subsequently set out the evaluation criteria.

The survey highlighted the need for the **Structured Innovation tool** to be **flexible,** both for the public and private investors, who will use the SI tool to identify attractive areas of innovation for investment and design of funding call and for technology/project developers- to identify or create new or improved concepts for their technologies. A general **Problem-solving** tool used to identify and quantify: innovative challenges, enabling technologies, ideas of optimisation of the system, and areas of investment opportunities. A **Structured approach** provokes the designer to consider the concept of ideality- not to constrain opportunistic innovation created by systematic thinking of the art-of-the-possible rather than state of the art; a tool that compares the assessment of potential versus **technical risks.**

The inputs from the user-groups consultation and the **technical requirements** set out for the SI tool [2] delineated the evaluation criteria used throughout the verification activities. These criteria include a numeric (see TABLE 2-2) and qualitative assessment for each SI tool's functionality.

Regarding the numeric assessment, a scale ranging from 1 to 5 was used, where 1 represents the most negative assessment and 5-the most positive assessment.

TABLE 2-2: NUMERIC ASSESSMENT OF THE TOOL'S FUNCTIONALITIES

Score	(1)	(2)	(3)	(4)	(5)
Description	Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

A common Software evaluation form was developed and used in the verification of every DTOceanPlus module. The Software evaluation form was divided into four sections assessing the

- usability,
- user-friendliness,
- performance and accuracy and
- perceived value of the tool.

The evaluation criteria included in the Evaluation form are shown in the evaluation results in Chapter 4, categorised under these four headings. Each technical or industrial verifier was required to assign a score of 1 – 5 when completing the Software evaluation form for the individual evaluation criterion (see TABLE 2-2).

The *Performance and accuracy* section evaluates each functionality of the software, as shown in TABLE 2-3. For example, evaluation criteria 3.a.1 and 3.b.1 are the same criterion but applied to 'Scanning the design space' and 'Identifying and solving the contradictions' functionalities.

TABLE 2-3: FUNCTIONALITIES AND FEATURES OF THE SI TOOL

Functionalities of the tool		Feature(s) tested
QFD	To Define the objective of the study, scan the design space & assess areas of innovation	Determine attractive areas of innovation Define interactions & Correlation functional requirements Defining ideality Organisation Impact Specify and assess SoTA achievements
TRIZ	To identify and solve the contradictions arising from the proposed solutions	Identifying correlations between functions Implementing TRIZ alternative solution
FMEA	To mitigate the potential technical risks associated with the attractive concepts	Identify potential failure modes, Reduce the likelihood and impact of failure
Reporting	To determine & output achievable innovative concepts (assess impact, ideality & difficulty of innovation)	Generate an exportable report that summarises: - A set of functions for concept creation - A conflict and impact report - Assessment of Ideality and development impacts

The completed Solution Evaluation forms are included as an Annex to this report.

3. VERIFICATION CASES

The verification scenarios for the Structured Innovation tool are described below and compiled in TABLE 3-1.

1. VS1 - ARPA-E, the Advanced Research Projects Agency-Energy, would like to advance high-potential, high-impact wave energy converters that are too early for private-sector investment but with great techno-economic potential. As such, ARPA-E wants to assess early-stage wave energy concepts as part of its TRL-1 programme.
2. VS2 - A Wave energy technology developer would like to design WEC equipped PTO that can absorb and convert ocean wave energy more efficiently (with a negative spring mechanism for Phase control)
3. VS3 - A tidal energy project developer with an Array of 20 tidal turbines (Sandia's Reference Model (RM1)) would improve the device layout and power cabling architecture.
4. VS4 - A private investor would like to identify and quantify challenges in investing in a single novel tidal turbine concept.

TABLE 3-1: SUMMARY OF VERIFICATION CASES FOR THE SI TOOL

Verification Scenarios	VS1	VS2	VS3	VS4
Verification case	QFD/TRIZ/FMEA	QFD/TRIZ	QFD/TRIZ	FMEA
Design objectives	Identifying potential areas of opportunity	Creating new or improving a sub-system for an existing device	Creating new or improving an array concept	Identifying and quantifying challenges
Targeted user group	Funder/Investor	Technology/Project developer	Technology/Project developer	Funder/Investor
Technology	Wave	Wave	Tidal	Tidal
Aggregation level	Device	Sub-system (PTO)-RM3 (Negative spring)	Array- 10 x RM1	Device
Running Mode	New concept	Improvement cycle	Improvement cycle	New concept

3.1. USER FLOW AND EXPERIENCE

The user would deploy the Structured Innovation tool to create or improve sub-systems, devices, or array designs at a higher maturity level and different aggregation levels. The process of using DTOceanPlus for innovation can be articulated as follows:

- **Define the objectives and relative priorities:** the user would initiate the QFD/TRIZ to define the top-level objectives and relative priorities that trigger the innovation potential. These objectives are the result of design needs (Design limitations from design or assessment tool, or Stage Gate process), the art-of-the-possible of the designs (ideality only limited by physics), and threshold values from the Stage Gate tool.
- **Assess the potential innovative solutions:** the user will assess the potential solutions to the objectives by:
  - Selecting or adding solutions, solution descriptions, and direction of improvement requirements for each stakeholder's requirement.
  - Assessing the potential conflicts between the solutions and their impacts
  - Defining the TRIZ classes that can resolve the conflicts with alternative solutions
  - Defining the strength of relationships between the objectives and solutions
  - Assessing the quality and impact of the solutions
- **Assess the technical risks**: The user would initiate the FMEA module to systematically assess and mitigate potential risks associated with the proposed new or improved concept(s):
  - By defining the scope and the system boundaries of the study: Interfaces, elements within the system, and elements outside the system
  - By providing the functional requirements of the system under study
  - By completing the FMEA steps to identify the potential failure modes/effects and define the system's current design and control process.
- **Generate the report:** one of the main outputs of the SI design tool is a standardised report that summarises all the input and output data of the module.

It is important to emphasise that, even though the Verification activities have been carried out by running the SI tool in *standalone mode* (i.e., the tool is not integrated within the suite of tools), it is intended work in cooperation with the other tools developed within DTOceanPlus. For example, the Stage Gate tool can identify improvement areas as the basis for a new improvement cycle analysis that enables innovation of an existing concept. The user will be prompted to launch the Structured Innovation tool and will be asked to provide critical input parameters about the technology being assessed. Once the user has completed the innovation assessment, he will be prompted to return to the Stage Gate to reassess their technology stage. Another example, running the **SI tool in integrated mode**, the user will be prompted to open each of the relevant deployment and Assessment design tools to obtain (or input) the relevant metrics (target values or state-of-the-art achievements).

3.2. USER STORIES

As mentioned previously, the *user stories* were used as the basis for the verification cases. The four scenarios are listed below, along with the critical user stories selected from each feature. These sub-tasks within each VS describe the SI tool from an end-user perspective and provide additional guidance to the functionalities' verifiers to be tested.

Step 1. **Define the objective of the study-** capture the project objectives and the list of the customer needs (WHATs) broadly defined. In the context of developing a new product, this is a list of customer requirements. These requirements – often general, vague, and difficult to implement directly – are prioritised in order of importance

1.1. **Define Project Objectives**. As an SI user, I would like to define my top-level objectives based on the innovation study.
1.2. **Define Customer requirements (CRs)**: As an SI user, I would like to capture the voice of the customer by inputting the customer requirements
1.3. **Prioritise requirements**: As an SI user, I would like to prioritise the requirements and rank these CRs by their relative importance

Step 2. **Scan the design space**: - map options for each of the key parameters that make up ocean energy concepts or projects, then rank these options' attractiveness through high-level physical and economic assessments.

2.1. **Define functional requirements (FRs)** As an SI user; I would like to specify the functional requirements (and direction of improvement) that meet my top objectives by either inputting or selecting from the aide-memoire (solution hierarchy) the functional requirements (FRs).
2.2. **Define Ideality:** As an SI user, I would like to set target/ideal values for each potential innovation area, i.e., functional requirement. Compliance with the FRs will be assessed through key metrics; for instance, if Capture Energy is considered an FR, "Capture Length Ratio" might be used as the key metric. The SoTA and ideality are then quantified for those metrics.
2.3. **Determine & assess organisation development impact:** As an SI user, I would like to assess and rank how much effort is required for the organisation to implement the ideal innovations (FRs). This function rates the organisation's difficulty in engineering and delivering (make, supply, deliver) these ideal functional requirements using a pre-defined rating.
2.4. **Define Impacts:** As an SI user, I would like to define the strength of the relationships between the CRs and the FRs using the SI tool's pre-defined scale. The strength relationships are determined based on the (team of) designers' knowledge on fundamental relationships of ocean energy parameters.
2.5. **Define interactions between FRs:** As an SI user, I would like to establish the interdependencies between the FRs to identify areas where trade-off decisions, conflicts, and innovation may be required. The tool provides a pre-defined correlation ranking (high ±9, medium ±4, low ±1 and, positive or negative meaning synergies or conflicts).

Step 3. **Understand the art-of-the possible for concept targets:** compares the existing competitive technologies or solutions against the proposed solutions

3.1. **Specify SoTA achievement**: As an SI user, I would like to specify the State-of-the-art (SoTA) data to be used for comparison. Note the SoTA data refer to leading-edge technology or design data, including the newest ideas and features.

Step 4. **Identify and solve contradictions:** The correlation (interdependencies) between the FRs is determined to identify areas where trade-off decisions, conflicts, and innovation may be required.

4.1. **Identify the requirements with the worst impacts:** As an SI user, I would like to assess further the conflicts between the FRs, defined in §2.3, and identify the FRs having the worst impacts (Sum of negatives, worst conflicts)

4.2. **Identify generic TRIZ conflicts:** As an SI user, I would like to obtain potential alternative solutions to the contradictive requirements (conflicts) by selecting the most relevant generic contraction (known in the tool as TRIZ classes).

Step 5. **Reporting QFD/TRIZ outputs: Attractive areas of innovation (Assess impact, ideality, and difficulty of innovations)-** define the innovation problem space representing the voice of the customer and make an immediate objective assessment of the best solutions which fit the customer requirements.

5.1. **Assess organisation/development impact:** As an SI user, I would like to assess and rank how much effort is required for the organisation to implement the ideal innovations (FRs). This function rates the organisation's difficulty in engineering and delivering (make, supply, deliver) these ideal functional requirements using a pre-defined rating.

5.2. **Assess the solutions to meet the requirements:** As an SI user, I would like to re-assess and rank the impact of the proposed functionalities and customer values, to understand and prioritise the innovation areas of importance based on the CRs development impacts.

5.3. **Assess SoTA achievement against targets**: As an SI user, I would like to assess ideality against the SoTA by determining the deviation of the existing technology developments against the target (ideal) values. This determines if the competitive technologies meet the target criteria and their compliance.

5.4. **Solution ideality:** As an SI user, using the SoTA achievement against targets (§5.2), I would like to check if the competitive technologies meet the target criteria and their compliance by considering each solution's importance to meet the CR (§3.2). The higher the solution's value, the more achievable it is for the proposed solution to reach the ideal target set based on the deviation from the ideal targets and the degree of importance of the solution to meet the customer requirement.

5.5. **Development ideality:** As an SI user, from the organisational impact (§3.1), I would like to check the likelihood that competitive technologies can meet the target criteria with more development. The higher the value of the development ideality-the most difficult it is for the organisation to achieve the target/ideal values set based on their current engineering and 'make & deliver' state.

5.6. **Obtain proposed alternative solutions:** As an SI user, I would like to be presented with suggested alternative solutions (also known as inventive principles) to the contradictive requirements identified in § 4.1 and § 4.2

Step 6. **Mitigate technical risks of proposed concepts:**

6.1. **Define the study:** Depending on which module (QFD/TRIZ or FMEA), I would like to follow the steps described in §1 to create, edit, or import a study to assess and mitigate the technical risks of the functions considered. Also, I would set the Risk Priority Number (RPN) action level and occurrence limit as threshold values beyond which I should be notified that an intervention/mitigation is needed.

6.2. **Define the functional requirement:** Similar to §2.1; I would like to define, edit, view, or delete the functional requirements for the study

6.3. **Define Failure Mode**: As an SI user, I would like to define the potential failure modes for each requirement

6.4. **Define Effects of failure**: As an SI user, I would like to define the effect of each failure mode, and in turn, rank the severity of the effect(s) using the pre-defined severity ranking.

6.5. **Define Potential causes:** As an SI user, I would like to determine the potential causes or problems of failure modes. Since a failure mode may have more than one cause, I would like to input or select (FMEA database) all probable causes. Besides, I would like to choose an Occurrence ranking, which is the likelihood that the failure mode and the associated cause will happen.

6.6. **Define Design control:** As an SI user, I would like to describe/input all the detection and control measures considered for the concept or design and establish, using the pre-defined detection rating, the controls' likelihood to detect that a failure has occurred.

6.7. **Display results and actions:** Having defined the potential failure modes and determined the potential root causes, effect, and detection measures, the team will be presented with the resulting RPNs for all the failure modes, and highlighting risks where mitigations are required for the specific failure modes. Note that the Risk Priority Number (RPN) is calculated by multiplying the Severity (SEV), Occurrence (OCC), and Detection (DET) rankings associated with each failure: RPN = SEV*OCC* DET

Note that trigger for action is highlighted when RPN is greater than the given threshold value (example >70) and if Occurrence is greater than the given value (e.g., OCC>4). In the SI tool, a warning symbol is provided for the user of the tool to act:

- The red symbol indicates that the final RPN value is higher than the Action Level
- The green symbol indicates that the RPN value is lower than the action level,
- An orange symbol indicates that the RPN is below the action level, but the Occurrence limit is higher than the limit.

These can be mitigated by clicking on the 'Mitigation' button, allowing the user to go through the analysis again and make changes where possible.

6.8. **Mitigate actionable failure modes:** To mitigate the failure modes with the highest risks, the SI user will propose suitable corrective actions for the actionable failure modes (mitigated severity, Occurrence, detection ranking). These corrective actions can be obtained from QFD alternative solutions, specific actions for the system (e.g., proposed design review, enhanced material properties), and background literature (e.g., measures implemented in other sectors).

6.9. **Review the revised risks:** The revised RPN (rRPN) will be displayed for the user to establish if all the functions are within the acceptable limits. A display of the report page will enable the team to amend the relevant failure modes as they see fit

6.10. **Reporting FMEA outputs**- All the data provided by the user and calculated by the SI tool are outputted as a standardised report in PDF format using the Report page of the SI tool's GUI

Step 7. **Report generation:** generate a standardised report summarising the results of a SI analysis

7.1. **Export QFD/TRIZ report:** As an SI user, I would like to generate and export a standardised report in PDF format that summarises all the information regarding the objectives and priority assessment, the list of functional requirements, their metrics, conflicts and impacts, the design briefs (includes requirements, specifications, and gaps), the ideality assessment, the optimum solutions, and the technical mitigation measures.

7.2. **Export FMEA report:** As an SI user, I would like to produce a standard report in PDF format that captures all the inputs, the RPN assessment, and the mitigation measures proposed.

4. ANALYSIS OF RESULTS

A Software Evaluation Form has been used to gather all the insights from the first round of VCs by the technical verifier (TECNALIA). The same document has been filled by the industrial partners, who performed the second round of VCs. With the information coming from both the technical verifier and the industrial partners, a completed version of this document is available at the end of this report (Annexes II and III). In this section, however, only the most relevant information is presented.

Four characteristics have been evaluated while running the VCs for the SI tool, namely:

- Usability, which deals with the high-level software experience;
- User-friendliness, to assess how much the software is easy to use;
- Performance and Accuracy, to determine the quality of results in terms of accuracy, robustness, and performance for each one of the main functionalities (features) of the software;
- Value to assess the value perceived by the user.

The following subsections present the quantitative and qualitative results.

4.1. QUANTITATIVE ASSESSMENT

A total of eight organisations (ESC, TECNALIA, EDP, OMP, Sabella, IDOM, WES/UEDIN, and BV) completed the verification process for the different functionalities of the Structured Innovation tool. Their feedback was provided using the software evaluation form. The scores for each response are shown anonymised in ANNEX III: ANONYMOUS FEEDBACK. A small number of the respondent's scores (<5%) were related to the technical issues with the host server (OCC) of the SI tool. These scores were excluded from this analysis as the final version of the tool will not use this server. The mean ratings for the four characteristics evaluated during the verification activities is shown in Figure 4-1.

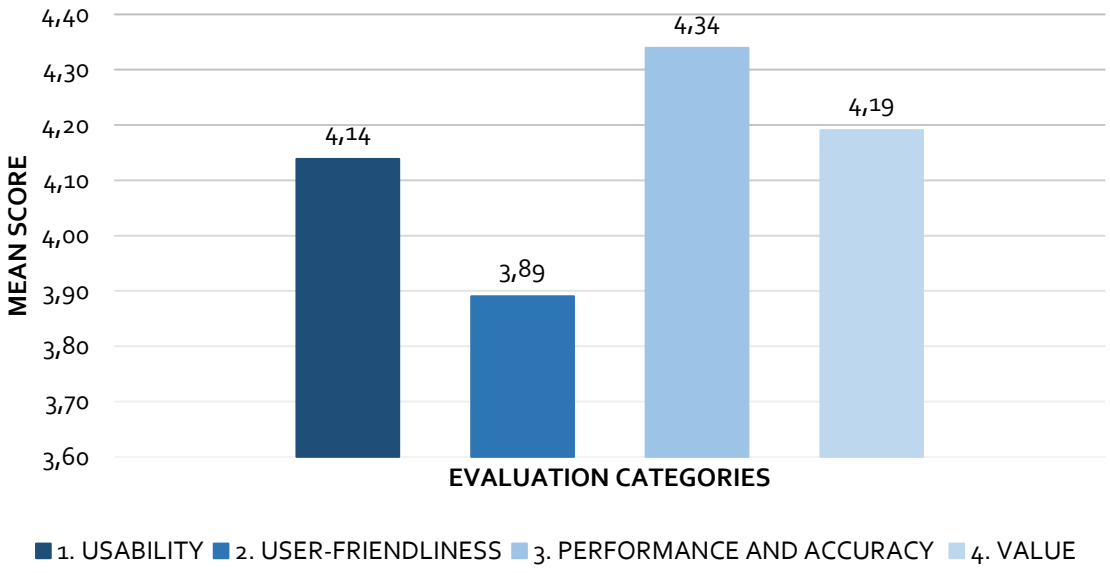

FIGURE 4-1: MEAN RATINGS OF THE EVALUATED CHARACTERISTICS

It is worth noting that all the characteristics have a mean value of around 4 out of 5, which indicates a high or very high user satisfaction. The majority of the respondents see the SI tool's performance and accuracy as more satisfied characteristics (average score of 4.34). However, there is room for improvement in which the tool interface is concerned to enhance its user-friendliness (mean score 3.89).

As shown in Figure 4-2, most of the verification participants (76%) were satisfied with the SI tool's usability. The majority of (69%) the respondents agree or strongly agree that the tool is generally user friendly. Around 82% (on average) of the respondents considered that the tool shows performance and accuracy. More than 80% of the users considered that the tool is valuable, while around 20% are undecided. Further analysis of the results is described in the following sections.

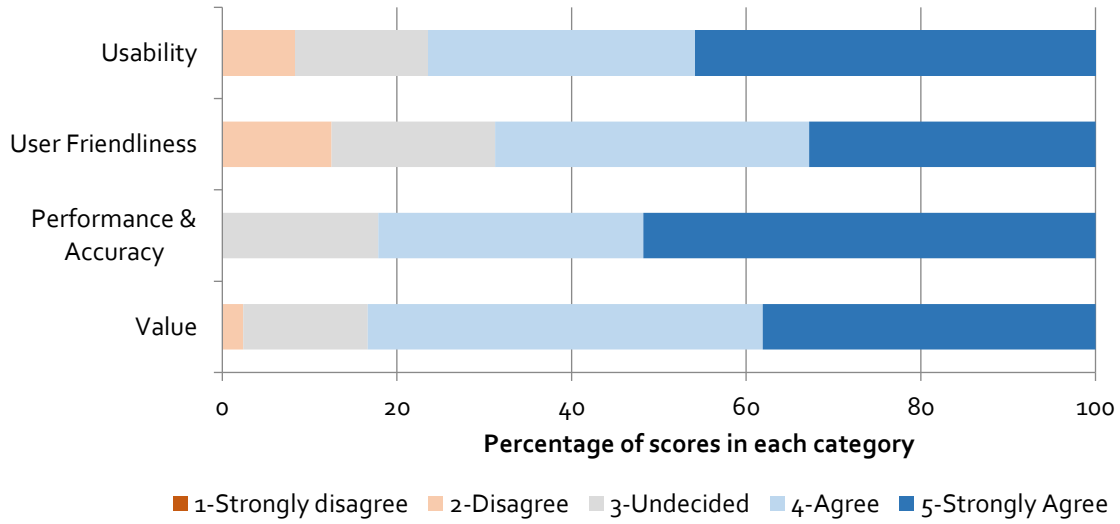

FIGURE 4-2: PERCENTAGE OF SCORES FOR THE FOUR KEY CATEGORIES

4.1.1. USABILITY

The following statements have been assessed in the *Usability* category:

TABLE 4-1: ASSESSED USABILITY CRITERIA

Id	Statement
1.1	The software is intuitive and easy to use in general
1.2	It is easy to create and delete a Study
1.3	It is easy to edit, save and export a Study
1.4	The process of inputting data is clear and efficient
1.5	Results are meaningful, easy to interpret, and use
1.6	I could complete the process without errors
1.7	I am satisfied with the overall speed of computation
1.8	The software can be run from my computer without any issue
1.9	The training sessions and documentation are useful for learning how to use the software

Figure 4-3 presents, in the form of stacked bars, the user scores per each statement listed in the previous table. The same results are presented in Figure 4-4, using a spider chart in order to highlight the mean, maximum and minimum values.

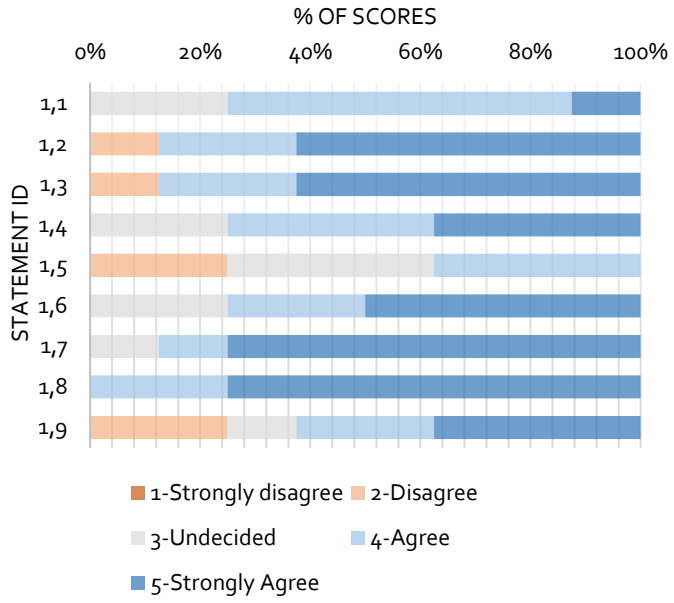

FIGURE 4-3: DISTRIBUTION OF USER SCORES PER USABILITY STATEMENT

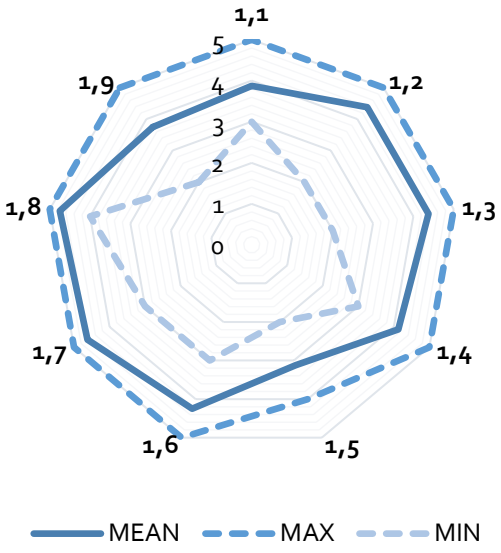

FIGURE 4-4: SCORES PER USABILITY STATEMENT

In view of the results (Figure 4-3 and Figure 4-4), it can be said that the tool is, in general, easy to use and intuitive (ID-1.1). It is easy to create, save, edit, export, and delete a Study (ID-1.2 and 1.3). The user finds it easy to understand where to insert data (ID-1.4), and the speed of the computation is adequate to the level of complexity of the operations processed by the software (ID-1.7). Moreover, most users

have completed the process without errors (ID-1.6), and the tool has run from users' computers without any issues (ID-1.8).

Nearly a quarter of the evaluations forms (25%) suggested it is difficult (score 2) to interpret and use the results (ID-1.5) and that the training sessions led by software developer and documentation do not make the flow through the tool as smooth as they expected (ID-1.9).

4.1.2. USER FRIENDLINESS

The following statements have been assessed in the *User-friendliness* category:

TABLE 4-2: ASSESSED USER FRIENDLINESS CRITERIA

ID	Statement
2.1	The user interface is simple, easy to navigate and well-organised
2.2	The user interface looks professional
2.3	It responds promptly to user actions (inputs, selections, clicks…)
2.4	It provides the user with enough help, indications, and guidance throughout each process
2.5	The meaning of each data input/user selection is clear
2.6	The meaning of each data output is clear
2.7	Visualisation of results is clear and informative
2.8	The user can add further information to the Study through the interface

The user scores per statement are shown in Figure 4-5 with stacked bars. Figure 4-6 presents the same results with a spider chart's help to highlight the mean, maximum and minimum values.

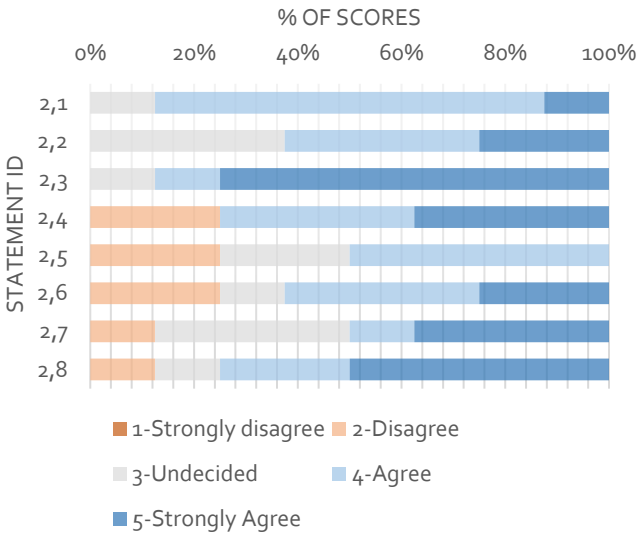

FIGURE 4-5: DISTRIBUTION OF USER SCORES FOR USER-FRIENDLINESS STATEMENT

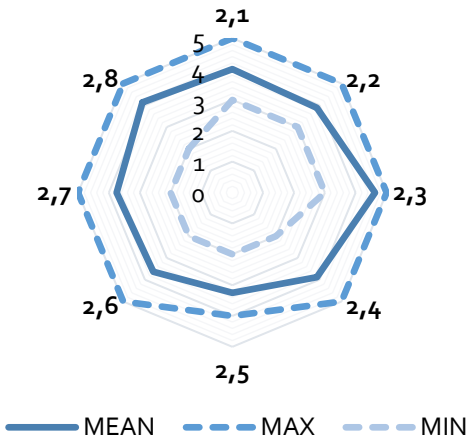

FIGURE 4-6: DISTRIBUTION OF USER SCORES FOR USER-FRIENDLINESS STATEMENT

Nearly all evaluations (87.5%) agree (score 4-5) that the user interface is overall simple, easy to navigate, and well organised (ID-2.1). It responds promptly to user actions (ID-2.3), which actually is the best-rated statement (4.625 out of 5).

Related to the interface's appearance, a significant part of the responses (62.5%) agree that the user interface looks professional (ID-2.2), and the rest is undecided.

A quarter of the answers (25%) shows that it would be great if more help, indication, and/or guidance throughout each process could be provided to the user (ID-2.4). Moreover, the same percentage of people indicated that the meaning of each data input/user selection (ID-2.5) and data output (ID-2.6) is not clear enough (score 2). It is worth pointing out that the lack of clearness in the meaning of each data input/user selection is the statement that has obtained the worst score (mean value of 3.25 out of 5).

Half of the responses (50%) find the visualization of results (ID-2.7) not clear and informative enough (score 2-3).

Finally, nearly all responses (75%) are satisfied (scores 4-5) with the information that can be added to the Study through the interface (ID-2.8).

4.1.3. PERFORMANCE AND ACCURACY

This section aims at evaluating the accuracy, robustness, and performance of the software considering the following features:

- Definition of the objective of the study (QFD/TRIZ)
- Understand the art-of-the possible for concept targets (QFD/TRIZ)
- Identification and solve contradictions (QFD/TRIZ)
- Mitigation technical risks of proposed concepts: FMEA
- Report generation

The following statements have been assessed in the performance and accuracy category:

TABLE 4-3: ASSESSED PERFORMANCE AND ACCURACY CRITERIA

ID	Statement
3.1	Results are robust and not sensitive to small changes of inputs
3.2	Results are credible and trustworthy for the audience
3.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used
3.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity
3.5	The computational time is adequate for the level of accuracy provided
3.6	The software did not suffer from any sort of data shortage/lack of memory during the test
3.7	The software can handle errors without crashing

Figure 4-7 presents the user scores per each statement listed above. The same results are presented in Figure 4-8 using a spider chart, to highlight the mean, maximum and minimum values.

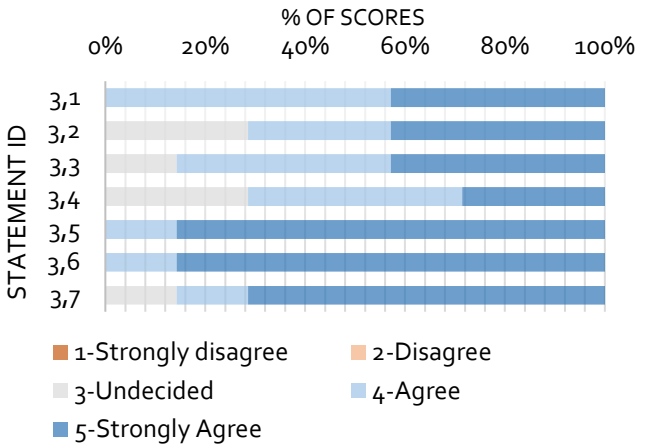

FIGURE 4-7: DISTRIBUTION OF USER SCORES FOR PERFORMANCE AND ACCURACY STATEMENT

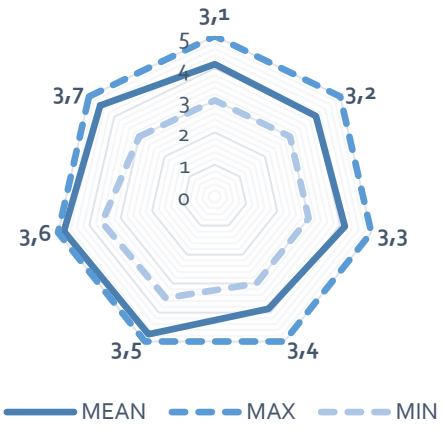

FIGURE 4-8: MEAN, MAXIMUM AND MINIMUM SCORES PER PERFORMANCE AND ACCURACY STATEMENT

In view of the results, it can be said that the results provided by the tool are, in general (100% of the responses with score 4-5) robust and not sensitive to small changes of inputs (ID-3.1). Nearly all respondents (75%) agree (score4-5) that the results obtained are trustworthy (ID-3.2) and that the accuracy of them corresponds to the user expectation for the stage of technology maturity (ID-3.4). In addition, the majority (87.5%) find the accuracy of results acceptable (score 4-5) considering the granularity/complexity of data inputs used (ID-3.3).

All the responses (100%) agree that the computational time is adequate (score 4-5) for the level of accuracy provided (ID-3.5) and that the software did not suffer from any sort of data shortage/lack of memory during the test (ID-3.6).

Additionally, 87.5% of the responses agree (score 4-5) that the software can handle errors without crashing (ID-3.7).

As it is shown Figure 4-8 all the statements assessed show a mean score greater than 4 except the 3.4, so it can be said that some users expected greater accuracy of the results for the technological maturity.

4.1.4. VALUE

The following statements have been assessed in the *Value* category:

TABLE 4-4: ASSESSED VALUE CRITERIA

ID	Statement
4.1	The software allows the user full control of the design process
4.2	It produces results that allow easy comparisons
4.3	It provides a large range of alternatives to create/assess technologies
4.4	The user is informed about the internal processing (e.g., remaining time, log) and warned about potential inconsistencies
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality
4.6	I would recommend the use of this software

Figure 4-9 presents in the form of stacked bars the user scores per each statement listed above. The same results are presented in Figure 4-10 using a spider chart, to highlight the mean, maximum and minimum values.

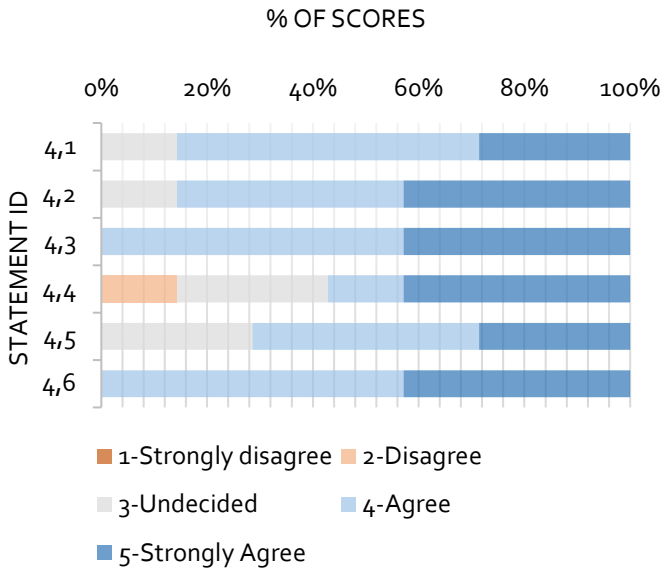

FIGURE 4-9: DISTRIBUTION OF USER SCORES PER VALUE STATEMENT

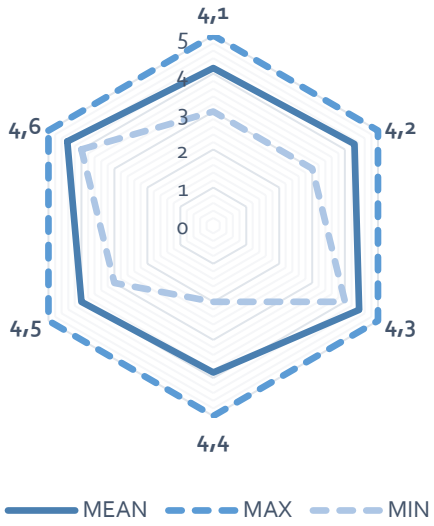

FIGURE 4-10: MEAN, MAXIMUM AND MINIMUM SCORES PER VALUE STATEMENT

- The majority of the respondents (86%) agree (score 4-5) that the software allows the user full control of the design process (ID-4.1).
- The majority of the respondents (86%) show satisfaction (score 4-5) with the tool's capability to produce results that allow easy comparison (ID-4.2).
- All evaluations forms (100%) show that the users agree (score 4-5) that the tool provides a large range of alternatives to create/assess technologies (ID-4.3)

- Less than a half (43%) of respondents detect a lack of information about the internal processing (e.g., remaining time, log) and miss being warned about potential inconsistencies (ID-4.4).
- Nearly all respondents (72%) agree (score 4-5) that the software meets their expectations in terms of results, graphical options, interaction, and functionality (ID-4.5).
- All respondents (100%) of the evaluation form were willing (score 4-5) to recommend the use of this software (ID-4.6).

As it is shown in Figure 4-10, all the statements assessed show a mean score greater than 4 except the 4.4, so it can be said that some users expected more information when running the tool about the internal processing and being warned about potential inconsistencies.

4.2. QUALITATIVE ASSESSMENT

This section presents feedback from both technical and industrial verifiers, gathered from their Software Evaluation Forms, and feedback given outside of the forms from consortium partners.

Comments have been grouped under three main categories: *Overall user satisfaction*, *Unintended tool performance,* and *Proposals for improvement*. The aim of this section, in particular, is to guide the path for improvement of the SI tool.

4.2.1. OVERALL USER SATISFACTION

Generally, the feedback indicated that the Structured Innovation tool is easy to use and straightforward to understand. According to the comments received, the following can be said about the overall user satisfaction:

- The SI tool is different from the Deployment and Assessment (D&A) tools. Its value is driven by the user's information and the user's ability to make innovative decisions based on how this input data is presented back to them. **Accuracy** is not relevant in the same way as in the D&A tools, as many early technology developers are focused on finding paths to innovating or improving their designs. The Value section highlighted the need for the user to be informed about the time and internal processing. This issue is being addressed through the implementation of a Progress indicator bar. This progress bar will be linked to each subprocess related to the main functionalities of the tool.
- Users seem to be more familiar with FMEA methods than QDF or TRIZ. This issue will be addressed by implementing contextual description and guidance for each step and the documentation system's proposed structure that will include: Tutorials, How-to guides, Reference material, and Background & context.
- While the tool is visually simple to read, there is insufficient detail to fully understand the **entry criteria** making it unintuitive to enter the correct data and interpret the relevant results. To resolve this issue, each step will provide a contextual on-screen description, explanatory dialogue boxes, help buttons, and a link to the documentation system that will include: Tutorials, How-to guides, Reference material, and Background & context.
- For some users**, results** were difficult to understand without a precise definition of what they meant. Even with the Verification Cases document, it was not always apparent whether the results were right, and the results' presentation was difficult to interpret. The issue will be resolved by providing

the final version of the SI tool, contextual descriptions, legends, and glossary to improve the QFD/TRIZ and FMEA reports' clarity and readability. In addition, a clear distinction between the sections of the report will be provided, including expected actions and links to additional documentation. The use of delineated sections and tables and will be implemented

- Users found the **Verification Case Document** useful, but some suggested that it would be better to provide it as individual documents or without the separation of data between the main body and the appendices, as it led to a lot of scrolling in attempts to find the required data input. A dynamic and useful documentation system will be provided with the SI tool's final release, including tutorials, how-to-guides, an explanation of features and calculation methods, and background & context for each module within the SI tool.

Overall, the users felt that they had full **control of the process**, and the **processing** seems instant with no issues or lag time when working with the tool, and no relevant crashes when inputting data. Several suggestions were provided to improve the tool's user interface design to be more professional and intuitive (see section 4.2.3).

4.2.2. UNINTENDED TOOL PERFORMANCE

A large part of this verification task was in identifying errors and bugs which could be fixed. The tool seems generally robust when it is working, but some users detected that the **host server was down**, and it prevented them from accessing the tool. These issues originated from the host server and not the tool itself.

Some users detected problems when running the SI Design tool using **Microsoft Edge browser**. It seems that MS Edge is not supported. Due to Internet Explorer's limited usage, a consortium consensus was made to adopt Chrome-based browsers (e.g., Firefox, Chrome, etc.).

Due to some ambiguity regarding proper data input, some users had several **warnings** when carrying out analysis—these warnings related to missing or unsaved data.

- When a previously saved failure mode is removed, an error pops up. However, it disappears as soon as a new text is re-entered. This issue should be better handled as a warning and not as an error.
- In the FMEA module, it is possible to create two studies with the same name, which should be avoided or allowed in both modules (QFD/TRIZ and FMEA) with additional descriptions to differentiate them.
- In the FMEA report, there is a yellow warning on the left-hand side when the occurrence is above the user-defined limit. This yellow warning also displays when the mitigation measure changes the RPN value from an inadmissible value to an acceptable one. However, it should be green as it is solved.
- The users suggested that input **error messages** should be explicit and not look like a code error.

These errors are straightforward to fix and will be addressed in the beta version of the tool.

4.2.3. PROPOSALS FOR IMPROVEMENTS

Proposals for improvement are either related to the user interface or the specific software functionality/feature. These proposals are listed below:

GENERAL USER INTERFACE

- **Description/Help on-screen**

  More contextual help at the side of each input label will improve usability. Most people will not be familiar with the process, so it is best to clearly guide them through the tool.

- **Step bar**

  The progress menu along the top is nice, but it is very temperamental about where to click for it to work (currently just the text, not the numbers). It would be useful to provide visual feedback indicating a link (e.g., with the hand icon, changing the colour, etc.).

- **Entering data**

  It did not seem evident if the data were saved upon entry for some users, and they had to put time and effort in to make sure the add button (click on "+") was clicked and carried out.

- **Appearance**

  SI Home Page allows the user to start a new QFD/TRIZ or FMEA study, but it requires the user to go to each module submenu to see/edit existing studies. It is not intuitive that this is possible; or that each time the user creates a new QFD/TRIZ or FMEA, it is saving the results.

  Having the next and previous buttons floating would be beneficial as users would not have to scroll so much to get to these operations when on a section that has a lot of data. Another possibility may be to have the buttons at the top of the page.

  While using QFD/TRIZ or FMEA, it would be useful to display the respective study's name on the top of the page (as a header), especially at the "Report Page."

  The user also reported that they prefer to have all the information displayed by default rather than hidden.

- **Saving information**

  Once a new entry is created, changes made in the numeric values are automatically saved. This operation saves time for the user; it could create a risk if something is changed unintentionally. A suggestion is to ask the user before saving the updates.

- **Importing information**

  For real innovation cases, inputting and formatting the required parameters may be time-consuming. Some users suggested options to import the information assigned to the Functional requirements (FRs) from one file, for instance, an Excel spreadsheet (e.g., FR = id, description, target

value and unit, the direction of improvement, difficulty to engineer and deliver, interactions, TRIZ classes).

DEFINE OF THE OBJECTIVE OF STUDY

- **Customer Requirements (CRs)**

  The tool allows the user to rank to the top-level objectives from high to low priority. However, users report that it would be great if different weights could be assigned to each objective so that solutions given by the QFD/TRIZ account for the importance given to these CRs by the user.

  Some users propose to rename Step-2 as "Customer Requirements" to avoid misunderstandings. Examples or indication of how many FRs are typically added is sought.

- **Functional Requirements (FRs)**

  It would be helpful if they were linked to the Customer Requirements from the previous page, i.e., "In order to meet these customer requirements, how should the technology function?"

  Examples or indication of how many FRs are typically added is sought.

- **Impacts**

  Some users propose to rename Step-3 to "Level of Impact of Functional Requirements on Customer Requirements."

  The Solution Quality Assurance (QA) check should briefly explain what to do to fix the error (lots of users had problems identifying the reasons for the QA check.)

  When the user does not define the level of impact for a particular CRs vs FRs, the cell is set by default to a shaded "None." It may be better to highlight the cell has not been modified in a visible way to avoid omission from the user (which may lead to hard to track).

- **Interactions**

  Even if the "High negative" to "High positive" ranking system is not that hard to understand, it could be useful to add in the Help section an explanation of the ranking these refer too: "The tool provides a pre-defined correlation ranking (strong ±9, medium ±4, weak ±1 and, positive or negative meaning synergies or conflicts).", or even more meaningful information to an early user about what is intended by "High negative" or "High positive" correlation.

  Having the interaction page visible by default will allow the user to see what interactions have been defined. An instance is if the interaction between FR1 and FR2 is defined, FR2 and FR1 interaction is also defined. The current setting of the tool is not evident to the user that this is the case. The user must be aware that he has previously defined these interactions, especially when the input is by default "None," or if multiple users are to work on the same study simultaneously (and change the "No" to another value if he thinks it was not previously defined). Either a visual help to have a progression bar, or a "half matrix" could be adequate: -In a general manner, this kind of progression status could be useful for the user to ensure they defined all the necessary sections.

UNDERSTAND THE ART-OF-THE POSSIBLE FOR CONCEPT TARGETS

Practically no feedback on this functionality has been received. Some users indicated that they were unsure what to put in "Description" (solutions page of QFD/TRIZ). It would be helpful to rename this step "State-of-the-art Assessment and provide a clear description of the operation such as: 'Examples of state-of-the-art."

IDENTIFY AND SOLVE CONTRADICTIONS

This feature is implemented using long **drop-down menus of the 39 contradiction parameters**, making it hard to find the right one. The users suggest having filters or a multiple-step selection of TRIZ classes (e.g., it can be structured in 4 categories: Design properties (e.g., weight, length, area, etc.), design qualities (e.g., reliability, accuracy, etc.), losses (e.g., Energy, substance, etc.) and harms (e.g., object-affected, object-generated, etc.). An alternative would be the contradiction parameters can be displayed in alphabetic order. When the user clicks on a letter, moves to the first item's position that starts with that letter.

The users would like to be suggested where to concentrate their innovation efforts, so more **guidance** is needed. In FR, the combination of importance and organisational impact would indicate its potential impact. Likewise, when the users turn to the suggested inventive principles, an indication of where to focus their attention would be valuable by providing suggested routes (e.g., Go to the FR with the highest potential impact and select the most repeated inventive principle, etc.).

MITIGATE TECHNICAL RISKS OF PROPOSED CONCEPTS

- **Edit saved study**

  In the FMEA module, the users cannot edit saved studies and would like to have this option available. The design requirements (page-2) can be edited, the initial thresholds defined on page-1 cannot be amended, and there is no possibility to add Effects, Causes, etc., in the subsequent pages. When the users click Edit on a saved study, they can add text into the boxes to add a new item, but the green "+" button appears to be blocked (no entry sign appears), so they cannot edit.

- **Home Page**

  Once a new FMEA study is created, the user can only define its name. It is impossible to add a description of the design objective or modify the thresholds for the action level and occurrence. The users suggest that this module work in a similar way to QFD, where it is possible to return to the first step.

  To help the users to define "Action Level" and "Occurrence limit," contextual definitions (and examples) are needed.

  When users access FMEA from the SI home page "Start here," they cannot load previously saved studies. This gave the impression there was no such facility until they had completed it. It was suggested that the users could navigate straight from the SI Home page to the FMEA Home page

where a list of existing studies is provided, and operations such as create a new study, delete, import, export are accessible.

- **Design Requirements (DRs)**

  The users do not understand the difference between the DRs and FRs in the SI tool. They propose to use the same terminology if there is no difference.

  The users proposed that the SI tool provides a link to import features (e.g., FRs from a QFD/TRIZ study to the FMEA module, or vice versa) so that the requirements for FMEA are the same in QFD/TRIZ.

- **Failure Modes & Effects of failure**

  A dropdown list with generic failure modes - same for effects of failure - would be useful (as well as having a free entry field option if required). Another proposal is to change sub-headings to "Please enter all Failure Modes for the design requirement: #####."

  The severity scale focuses on the consequences of the loss of primary function. There might be other consequences for environmental impacts, injuries, or repair costs to assess the severity. The users also propose to consider these aspects in the assessment of severity.

- **Causes of failure & Design Controls**

  The drop-down menu listing the causes is too extensive for the user to navigate it. It seems it is structured by component type. Perhaps it is worth rearranging it into two levels to facilitate finding the causes faster.

  When there are multiple effects for a failure mode, the tool does not guarantee that the causes match the relevant effects and, in turn, failure mode. The interface asks about the lists of failure modes, whereas it should be better to ask for the list of effects. Clarity is required in the description of this page to ensure that the users are on these links (e.g., For Effects ###, "Please enter the cause(s) and Probability of occurrence(s)).

- **FMEA mitigations**

  It would help keep the table header fixed to facilitate the visualisation of the results as they do not fit on a single page (i.e., many rows). Moreover, the text can be quite close to the next cell down, so the visual display would benefit from some extra row separation or shading difference between rows to visually separate the contents.

  It is possible to edit the Mitigation measure provided by clicking on the text (and to delete it with the red basket), but the editing function may be highlighted more clearly.

  It would be great to allow the user to mitigate all design requirements with RPN's independence and the occurrence limit. Also, alerting the user if the decision on the mitigation action is enough to reduce the risk under the established level or not.

  The RPN resulting from a mitigation action can still exceed the RPN threshold. However, the tool does not highlight or warn the user about this issue on the report page.

A direct link could be provided between the Action Level defined by the user, the obtained RPN, and the revised RPN (rRPN) to have a more direct view on the acceptance for the element considered. A suggestion to review the legend used (The current warning works, but could be improved with larger icons with more vibrant Red-Orange-Green colours)

It would be good if these icons on the left could be hovered over to tell the user what they mean, in addition to contextual description/help to describe the meaning of SEV, OCC, DET, RPN, rRPN, etc.

When the Mitigation window pops up, it is initially populated with the unmitigated assessments. As soon as the users have changed it, they cannot compare their new situation against the unmitigated status, which could be interesting.

REPORT GENERATION

- **Export results**

The users would like to have the option to export the results in a readable report format (e.g., pdf, excel, etc.).

- **Compare studies**

The users would find it interesting to have a way to compare various studies or compare the detailed phases of one study (e.g., Phase-1 and Phase-4).

- **Display of results**

On the web browser, the display of results lacks table lines in FMEA, making it difficult to understand. It would be beneficial to add table lines and colour-coded results.

Adding graphs to the report page will significantly facilitate the interpretation of results (e.g., visual representation of the HoQ matrix).

In the report page, the users also recommend formatting data outputs (e.g., 2.35544% to 2.35%, €120000 to €120,000).

In the case of QDF/TRIZ, some users find it useful to have the CRs and FRs reported.

- **Description and guidance**

The QFD/TRIZ tool is based on concepts that are relatively easy to understand, but the exploitation of the results may be hard for inexperienced users. For this reason, some efforts are required in providing **conceptual help or extra guidance** on how to exploit the "Potential for disruption" and "Suggested TRIZ inventive principles" sections. For example, it could be interesting to highlight (with colours, or comments) areas in these tables of interest to orientate the user.

The inexperienced users might find it hard to know the difference between solutions of "High" importance and "Low" organisational impact. Hence, highlighting areas that could easily be implemented, the "low hanging fruits" might help.

Giving information about the meaning of "solutions achieving/missing" columns is also important for some users. Moreover, some users would appreciate the definition of inventive principles and examples given.

4.3. TASK LIST

This section expands on the qualitative assessment from the Software Evaluation Forms. The feedback was compiled and categorised by functionality, evaluation characteristics, and by the frequency of comments. From the 146 qualitative comments received, initial results suggested:

- Forty-eight areas proposing improvements to the tool's usability, performance, and user experience
- Five comments relating to the host server (OCC)
- Ten comments relating to the positive features of the tool

These comments were grouped into the three following categories:

- Proposed improvements that require a change
- Features to maintain (as per positive feedback)
- Out-of-scope functionalities/features

The priority allocation of the proposed improvements was based on the criticality of the functionality, the value-added user benefits, the features required for integration, and the frequency of the received comments in the feedback forms. The following quality criteria were used to prioritise the implementation of the design specifications:

- **High (Critical)** priority: was allocated to the proposed improvements that are critical to operating the SI tool as intended (in standalone and integrated mode), have value-added benefits to the user experience, and if a comment was mentioned 15 times or more, as it is likely that the majority of the reviewers encountered the issue and suggested some changes. This was determined to be of high priority.
- **Medium (Should)** priority: was allocated to the proposed improvements that have value-added benefits to the user experience, added features for integration, and if the comment was mentioned 7 times or more, it was determined to be of medium priority.
- **Low (Could)** priority: was allocated to the proposed improvements that nice-to-have without adding significant benefits to the user experience. If the comment was mentioned less than 7 times, seen as a one-off, it was of low priority.

It should be noted that where the frequency of some of the design requirements was lower than the threshold (say >15 for high priority), the critical functionality and value-added benefits were considered first to determine the priority of implementation. This illustration is presented in

TABLE 4-5.

TABLE 4-5: EXAMPLE OF PRIORITISATION OF HIGH IMPACT IMPROVEMENTS

Issue groups	Value-added	Critical Functionality	Integrated features	Occurrence	Priority
Insufficient contextual description, guidance, and background information	X			30	High
Ability to import/ export, or delete study	x	x		1	High
Import data from Other modules	x	x	x	2	High

Of the 48 proposed improvements, the prioritisation was as follows:

- 24 were classed to be of high priority
- 9 classed of medium priority
- 15 classes of low priority

The 24 proposed improvements were further mapped into 15 high impact improvements. A summary of the proposed improvements is presented in TABLE 4-6 with the intended resolutions—more detail in ANNEX IV: FULL TASK LIST.

TABLE 4-6: SUMMARY OF HIGH IMPACT IMPROVEMENTS

Proposed Improved	Resolutions
Insufficient contextual description, guidance, and background information detailing detailed concepts of the modules and step-by-step guide and examples.	As a global approach, each step will provide a contextual on-screen description, explanatory dialogue boxes, help buttons, and additional background information in the final release of the SI tool, including definitions of the terminologies. The SI tool will also provide links to the documentation system.
No uniformity in overall style for all steps indicating input fields and labels, operations available, and allowing ease of navigation	This issue is being addressed, including: ▪ Clear input labels for clarity of operation available, ▪ Adding warnings with description of missing inputs ▪ Adding hovering information to each input field ▪ Better use of tables/matrix for the Interactions Page These options are being considered, and other ideas on how to improve the UX of the SI tool.
Lack of error-handling guidance and warning when steps incomplete	Error handling: Explanatory dialogue boxes, and additional help buttons, will be included in the final release of the SI tool Warnings- The implementation will enable to continue with incomplete data but receive a warning(s) when viewing pages affected by missing information.

Proposed Improved	Resolutions
Inconsistences in autosaving option when adding/editing entry field (+)	Several approaches are considered for saving user-inputted data consistently. The Autosave option with revision is being implemented and tested to ensure that this issue has been tackled adequately in the final version of the tool
Lack of contextual descriptions, legends, glossary for completeness both the QFD/TRIZ and FMEA report	Clarification on how best to present the results is required. ▪ The top objectives and customer requirement priorities will be included in the report ▪ Contextual on-screen description, explanatory dialogue boxes will be provided for each section of the report ▪ Improving how the potential innovative areas are presented, including potential for disruption and ideality of solutions. An option to show the results in a tabular format has also proposed, and graphical representations
Style improvement for completeness and clarity of both the QFD/TRIZ and FMEA report pages.	In future versions of the SI tool, the style and consistency of the SI tool report will be reviewed to improve the clarity and readability of the report A clear distinction between the report sections will be provided, including the description, and expected actions. The use of delineated sections and tables and will be implemented
Inconsistencies in the reported TRIZ alternative solutions	The TRIZ section (TRIZ classes and report section) has been amended to display TRIZ fields for functional requirements with contradictions. Contextual on-screen description, explanatory dialogue boxes will also be provided
Consistency required between the QFD/TRIZ and FMEA	A review of all the steps and input fields, terminology, and data input formats is needed to ensure a consistent process between the QFD/TRIZ and FMEA modules. Consistency in the description of steps is also being reviewed to make sense to all the possible users of the tool (e.g., new, or experienced user.)
Import data from other modules	Currently, the SI tool has been developed in standalone mode. As a consumer to a Work is now underway to implement the integrated features to enable the SI tool to consume from other modules, e.g.: ▪ Import description and values of solutions from the Stage Gate module (target values, state-of-the-art) ▪ Import solution achievements from deployment and assessment modules (failure mode from RAMS, LCOE from the Systems lifetime cost)
Ability to generate a report in PDF/Excel/CSV	Work is underway to develop a standardised report in PDF format that summarises all the QFD/TRIZ and FMEA modules' input and output data. This will be available in the future versions of the SI tool

Proposed Improved	Resolutions
	An option to export the outputs to Excel/CSV has now been implemented
Lack of visibility of system status	These implementation activities are on-going to improving the user experience. For example: Amending the progress bar to indicate where action is needed, the completed steps, links to active pages, and editable/non-editable sections.
Missing connection between the FMEA and QFD/TRIZ results	The future version of the tool will implement the functionality linking the results of an FMEA study to QFD/TRIZ and vice versa. This implementation will enable the user to innovate in areas where failure modes cannot be mitigated and mitigate technical risks of innovative concepts in the FMEA and QFD/TRIZ modules.
Ability to rank and prioritise the Customer requirements	The functionality enabling the user to define the prioritisation of customer requirements has now been implemented.
Lack of default lists of potential solutions to support the analysis (functional requirements, a library of failure modes, causes, effects)	To support the user experience, the SI tool will suggest generic areas where to concentrate on innovation efforts such as: ▪ A solution hierarchy already implemented in the SI tool as a multi-level list of potential solutions for marine energy for each requirement ▪ An FMEA library with generic failure modes – same for effects of failure - would be useful (and the option to enter what the user wants).
Ability to import/ export, or delete study	This functionality has now been implemented, enabling the user to import/export a study in JSON format or delete a study

The developers of the Structured Innovation tool will implement the resolutions of these high priority improvements in the final release of DTOceanPlus. The Medium and Low priority improvements are listed in ANNEX IV: FULL TASK LIST. These improvements will be reviewed with as many implemented as possible in the remaining timeline of the project. These include issues such as:

- The ability to add notes in a commentary box
- Adding graphs to the report page to facilitate the interpretation of results.
- The ability to use bespoke FMEA Severity, Occurrence, and Detection Ratings for the analysis

5. CONCLUSIONS

The objective of Task 3.3 was to carry out the testing of the Structured Innovation tool in order to verify that it meets all the previously defined requirements (in WP2 and T3.1). This report aims to document the outcome of T3.3 "Verification of the Structured Innovation design tool."

The full verification of the tool consisted in the achievement of the following targets:

- the tool responds correctly to a varied set of inputs;
- the tool performs its functions in an acceptable time and reasonable use of computational resource;
- the tool is adequate in terms of usability;
- the tool is verified against control data.

To ensure that all the functionalities and features of the tool are correctly assessed, the following actions were deployed and fully detailed along with this report:

- Definition of the Verification Cases and evaluation criteria;
- Organisation of training sessions (for technical and industrial partners);
- Collection of data for each Verification Case;
- Running the Verification Cases (by technical and industrial partners);
- Analysis of the results based on quantitative and qualitative assessments.

A stable version (beta) of the tool is available, fully documented with a technical manual and a user manual, which will be further validated and demonstrated using real data from the first pilot experiences in WP7.

According to the quantitative results, the end-users involved in evaluating the SI tool are satisfied with the usability, user-friendliness, performance, and value of the software. The qualitative assessment feedback gathers some improvements that were compiled and categorised by functionality, evaluation characteristics, and the frequency of comments. As a result of this, 15 high priority improvement areas were selected to be implemented in the final release of the DTOceanPlus suite of design tools. Once these improvements are implemented, the Medium and Low priority improvements will be reviewed with as many implemented as possible in the remaining timeline of the project

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ANNEX I: USER MANUAL

This annex provides an overview of the user manual being developed alongside the Structured Innovation tool, firstly outlining how this will be produced and providing an early draft of the documentation content.

1. DOCUMENTATION FORMAT

As with the overall suite of tools, there will be an overarching main documentation, with a separate set of documentation for each module. The main documentation will cover areas including installing and running the tools; use cases and user journeys, including linkages between the various parts of the suite; and how to manage projects and studies.

To provide a dynamic and useful documentation system for the DTOceanPlus suite of tools, it is proposed that this will be developed with a linked hierarchical structure that can be viewed in a browser or exported as a document format as required. The documentation will follow an established system[2], split into four main areas preceded by a brief overview of the functionalities and workflow:

- **Tutorials** to give step-by-step instructions on using the tool for new users.
- **How-to guides** that show how to achieve specific outcomes using the tool.
- An **explanation of features and calculation methods** gives technical background on how it works to give confidence in the tools.
- The **API reference section** documents the code of modules, classes, API, and GUI.

The documentation will be produced using the Sphinx Python Documentation Generator[3].

The documentation contents will build on the work done to date within the project and will continue to be updated alongside the code. The tutorials will build on those produced to train the partners for the main report's verification activities. The explanation of features and calculation methods will be based on the comprehensive details outlined in the alpha-version deliverables. Finally, the API reference section will document the modules' code, based on the code docstrings written alongside the module code.

The verification activities' results will be used to improve the documentation; for example, the tutorials and how-to guides could be added or improved to address any shortcomings identified or feedback received.

For brevity reasons, the content from the alpha version deliverables and code docstrings will not be included in this annex but will be published alongside the final software at the end of the project.

[2] The Documentation System, https://documentation.divio.com/
[3] Sphinx Python Documentation Generator https://www.sphinx-doc.org/en/master/

2. DRAFT TUTORIALS FOR THE STRUCTURED INNOVATION TOOL

2.1. INTRODUCTION

The Structured Innovation (SI) is a software aimed to provide a framework for Structured Innovation application to the objective assessment, concept creation, and selection for Ocean Energy sub-systems, energy capture devices, and arrays. The SI tool will enable a structured approach to address ocean energy engineering complexity where design options are numerous, resulting in efficient evolution from concept to commercialisation.

The tool is intended to be used by a wide variety of stakeholders, including these key user groups:

- Technology Developers – to assess areas of improvement and technical challenges,
- Project Developers – to assess novelty in technology at any level of aggregation,
- Public or Private Investors – to identify attractive areas of innovation for investment.

The overarching use case of the Structured Innovation design tool is for concept creation and design improvement. It will enable users to:

1. Scan the design space and identify attractive areas for innovation,
2. Create new concepts and identify areas of opportunities,
3. Identify and solve the contradictions arising from the proposed solutions,
4. Mitigate the potential technical risks associated with attractive concepts, and
5. Improve existing design concepts.

The SI tool operates with close integration to the Stage Gate, Deployment, and Assessment tools, to support consistent innovative assessment processes and ultimately guide decision-making for the tool's users.

2.2. MAIN FUNCTIONALITIES

The Structured Innovation tool has six major functionalities:

1. **Defining objectives of the study:** This stage captures the project objectives, and the list of the stakeholder needs (WHATs) broadly defined. In the context of developing a new product, this is a list of customer requirements. These requirements – often general, vague, and difficult to implement directly – are prioritised in order of importance.

2. **Scanning the design space:** The SI tool's QFD/TRIZ module is used for two purposes. Firstly, to scan the design space by mapping options for each of the key parameters which make up ocean energy concepts or projects, then ranking the attractiveness of these options through high level physical and economic assessments. Secondly, to define the innovation problem space representing the voice of the customer and make an immediate objective assessment of the best solutions that fit the users' requirements.

    2.1. **Definition of functional requirements:** This is when the customer needs are translated into measurable functional requirements (HOWs) that can satisfy the needs.

2.2. **Definition of Impacts:** In this stage, the relationships between the stakeholder needs (WHATs) and the functional requirements (HOWs) are determined using a predefined scale. Many of the HOWs identified affect more than one WHAT.

2.3. **Requirement interactions:** This establishes the interdependencies between functional requirements (HOWs). The purpose is to identify areas where trade-off decisions, conflicts, and innovation may be required.

3. **Identifying attractive areas of innovation:** The SI tool is developed to include fundamental relationships between key parameters in ocean energy concepts, evidence from the first ocean energy arrays, and a standard library of problem solution inter-relationships. QFD uses a set of requirements (WHATs) and answers them with a set of functional requirements (HOWs). There will be various solutions to solve each requirement, with each solution being aimed at producing the best requirement improvement. These solutions may contradict each other, and the QFD/TRIZ methodology allows these contradictions to be identified and their impact assessed.
   The possible concepts will be ranked in order of importance and achievability, highlighting options that would attract attractive investment opportunities. Evaluation of these options will be based on high-level metrics.

4. **Assessing contradictions:** The SI tool's TRIZ component is used to produce solutions to the QFD requirements where an improvement is needed, or if there is no existing solution, or if the key performance indicators are not satisfactorily met. The TRIZ methodology can be used to ensure completeness in the key parameters which define the design space with, for example, the use of the Effects Database and in the series of provocative prompts to provide the well-known forty inventive principles and other tools to solve contradictions contained within the QFD. The QFD and TRIZ components are integrated into a single component within the SI tool to visualise opportunity and risk areas.

5. **Assessing technical risk:** Technical risks are framed using the 'concept' or 'design' FMEA tool. The tool provides ratings for each defect or failure in terms of severity, occurrence, and detection. The FMEA uses a database of validated defect parameters to improve understanding of technical risk during the design assessment process and offer opportunities for both risk mitigation and cost reduction. The structured innovation process will conclude with a visualisation method to represent the process and results obtained and deviation from the key performance metrics in the SI tool. The results will be expressed in terms of a ranking of attractive options and the QFD requirements presentation. The overall result will be an acceptability rating that allows an objective assessment of the design.

6. **Reporting outputs:** This generates a summary page of all the outputs, including a list of proposed innovative functions, metrics, conflicts and interrelationships, and impact. This can be in report format or as a set of data files for further analysis and future updates.

2.3. STRUCTURE

This documentation is divided into four main sections:

- Tutorials to give step-by-step instructions on using the SI tool for new users.
- How-to guides that show how to achieve specific outcomes using the SI tool.
- An explanation of features and calculation methods gives technical background on how the SI tool gives confidence in the tool.
- The API reference section documents the code of modules, classes, API, and GUI.

3. TUTORIAL EXAMPLE- DEFINING OBJECTIVES OF A STUDY

3.1. INTRODUCTION

This functionality enables the user to define the project's top-level objectives that will be the basis of the innovation study. This is also the place where the user defines the list of the customer needs broadly. In the context of developing a new product, this is a list of customer requirements. These requirements – often general, vague, and difficult to implement directly – are prioritised in order of importance.

A default list of customer requirements, referred to as *Solution Hierarchy,* is provided as a structured set of prompts to help the user consider multiple solutions to different QFD levels. This section elaborates the *defining the objectives of a study* functionality in these three tutorials:

1. Access the QFD/TRIZ Page
2. Create a new QFD/TRIZ study
3. Define and Prioritise the Customer requirements

3.2. ACCESS QFD/TRIZ PAGE

The tutorial shows how to access the QFD/TRIZ module via the main SI Home page, currently on the OCC Host web server. After launching the SI tool, Login details (login ID and password) are required to access the tool. On entering the SI tool, the home page is displayed.

In the current version of the tool, the SI home page provides four main options:

- Start a new QFD/TRIZ study by selecting *Start Here* from the QFD section
- Access the QFD/TRIZ home page by selecting *QFD* from the menu bar
- Start a new FMEA study by selecting *Start Here* from the FMEA section
- Access the FMEA home page by selecting *FMEA* from the menu bar

The menu bar also provides access to the SI tool homepage by selecting *SI*. The menu bar always remains visible, so it is possible to return to the module's home pages from any other page.

3.3. CREATE A NEW QFD/TRIZ STUDY

This short tutorial demonstrates how to create a new QFD/TRIZ study:

1. On selection of "Start here" on the SI Home page, the QFD home page is displayed, providing five main options:
   - Start a new QFD/TRIZ study by selecting *New QFD/TRIZ* button
   - Delete an existing QFD/TRIZ study by selecting the red 'bin' icon next to the relevant name
   - Download an existing QFD/TRIZ study by selecting the green 'down arrow' next to the name
   - Load an existing QFD/TRIZ study by selecting the relevant name
   - Import a new QFD/TRIZ study by selecting the + *Import QFD/TRIZ* button
2. To start a new QFD/TRIZ analysis, select *Start Here* under QFD/TRIZ; or select *New QFD/TRIZ* from the QFD/TRIZ home page.
3. From the New study QFD/TRIZ page, Enter the study's name and the overall objective in the text fields.

   Tip: The study's name will be shown on the QFD/TRIZ home page, under the list of existing studies. Chose an appropriate name for the study, unique, and includes useful information that helps identify the study afterwards, e.g., study reference, date, owner, etc.

4. For a new study, the user is able to select the use of the *Solution hierarchy* by switching the toggle if required. When selected, some initial requirements will be prefilled, and suggestions will be available when entering functional requirements.

   Tip: This option is only available when a study is started and cannot be changed once submitted. However, if selected, suggested prefilled requirements can always be deleted. Therefore, if in doubt, select the option.

5. Select *Submit* to proceed to the next step.

   Caution: Both name and objective fields must be completed before *Submit* is selected. An error will be displayed in the event either field is empty, and it will not be possible to proceed to the next step. If an error is displayed, please enter information into the relevant field(s) and try again.

3.4. DEFINE AND PRIORITISE THE CUSTOMER REQUIREMENTS

The Customer requirements can be defined with or without the use of the Solution Hierarchy. The steps to defining and prioritising these requirements are described:

1. From the *Customer Requirements* page, enter the description and importance for each identified Customer Requirement. Select the green + button to enter the requirement into the tool

   Tip: The importance of the requirements should be set relative to one another. For example, a requirement with an importance of 4 is twice as important as a requirement with an importance of 2. The lowest value possible is 1.

2. The Customer requirements can be edited by changing the relevant field or deleted by selecting the red 'bin' icon next to the relevant entry.

   Tip: If *Use solution hierarchy* was previously selected, some requirements might already be populated. These can be edited or deleted in the same way, where necessary

3. Select *Next* to proceed to the next step or *Previous* to return to the last step.

> Caution: Content added into a requirement field must be entered into the tool before *Next* or *Previous* is selected. An error will be displayed if this has not been completed, and it will not be possible to leave the page. If an error is displayed, please enter, or delete the relevant entry(ies) and try again.

4. TUTORIAL EXAMPLE- ASSESSING CONTRADICTIONS

The TRIZ module provides inventive inspiration for the user – encouraging the user to look for existing solutions to similar problems at different scales and times. This allows the user to think of adopting principles that might offer idealised solutions from other industries, countries, and times in history. This example provides four tutorials on *how to identify and assess the contradictions* using the integrated QFD/TRIZ module:

1. Define the functional requirements
2. Define the level of impact of functional requirements on customer requirements
3. Define the correlation between the functional requirements
4. Assessing the conflicts using the TRIZ 39x39 contradiction matrix

4.1. DEFINING THE FUNCTIONAL REQUIREMENTS

This tutorial illustrates how to create multiple solutions to satisfy the customer requirement. The solutions refer to identifying specific functional requirements (i.e., design characteristics, features, or attributes) and showing how they will satisfy the customer requirements. The steps are as follows:

1. From the Functional Requirements page, enter the description, target value, and units for each identified Functional Requirement. Use the drop-down menu to select the improvement direction (lower/ higher) and the difficulty levels (difficulty to engineer and deliver). Select the green + button to enter the requirement into the tool.

> Caution: Target Value must be a number. An error will be displayed if characters are entered, and it will not be possible to enter the requirement or leave the page. If an error is displayed, please amend, or delete the relevant entry(ies).
>
> Caution: A minimum of two Functional Requirements must be entered

2. Requirements can be edited by changing the relevant field or deleted by selecting the red 'bin' icon next to the relevant entry.

> Tip: If *Use solution hierarchy* was previously selected, some requirements may already be populated. These can be edited or deleted in the same way, where necessary. All pre-populated entries will need the difficulty levels set, and target values added as organisation/project-specific.

3. Select *Next* to proceed to the next step or *Previous* to return to the last step.

> Caution: Content added into a requirement field must be entered into the tool before *Next* or *previous* is selected. An error will be displayed if this has not been completed, and it will not be possible to leave the page. If an error is displayed, please enter, or delete the relevant entry(ies) and try again.

4.2. DEFINING THE LEVEL OF IMPACT BETWEEN CUSTOMER AND FUNCTIONAL REQUIREMENTS

To identify how strongly each of the proposed solutions (functional requirements) affects the customer requirements, the user will have to weigh the relationship between the customer requirements and functional requirements. These steps should be followed:

1. From the Impacts page, Enter the impact of each Functional Requirement on each Customer Requirement, using the drop-down list.

   Tip: Impact rankings are predefined as high (9), medium (4), low (1), and none (0). A Functional Requirement with a High ranking has a larger impact on achieving the Customer Requirement than one ranked as Medium.

   Caution: If the rankings selected mean lower importance Customer Requirements are impacted more than those of higher importance, then the warning '(!) Solution QA check' will appear. This may indicate that the defined Functional Requirements are not the most optimal to satisfy the Customer Requirements. At this stage, the Functional Requirements can be reassessed and updated, along with the impact rankings. However, it is still possible to continue the study without making any further changes.

2. Select *Next* to proceed to the next step or *Previous* to return to the last step.

4.3. DEFINING THE CORRELATIONS BETWEEN THE FUNCTIONAL REQUIREMENTS

A correlation matrix, also known as Roof of the House of Quality in a traditional QFD, evaluates how the defined functional requirements help or hinder each other. The steps to determine these correlations are as follows:

1. From the Interactions page, Enter the correlation between each Functional Requirement by selecting each Functional Requirement in turn and specifying the rankings.

   Tip: Correlation rankings are predefined as high negative (-9), medium negative (-4), low negative (-1), no [none], low positive (+1), medium positive (+4) and high positive (+9). Positive correlation implies that increasing one functional requirement will greatly affect increasing the other, and vice versa. Likewise, a negative correlation implies increasing one functionality will hinder decreasing the other, and vice versa. The purpose is to identify areas where trade-off decisions, conflicts, and innovation may be required.

   Tip: As correlation is reciprocal, entries against one Functional Requirement are automatically added for the corresponding Functional Requirement. For example, suppose the Correlation between Functional Requirement A and Functional Requirement B is entered as low negative. In that case, the tool ensures that the Correlation between Functional Requirement B and Functional Requirement A is also low negative.

2. Select *Next* to proceed to the next step or *Previous* to return to the last step.

4.4. ASSESSING THE CONFLICTS USING TRIZ 39×39 CONTRADICTION MATRIX

The TRIZ contradiction matrix is a conventional problem-solving method that looks at generalising the problems and solutions and eliminating the identified contradictions. These contradictive functional requirements were in the previous tutorial- 4.3. the SI tool aims to eliminate them and proposed alternative solutions. The TRIZ problem-solving steps are as follows:

1. Generalise the contradictive functional requirements into relevant TRIZ general problems (known in the tool as TRIZ classes), using the 39 general problems' dropdown list.
2. For each functional requirement, enter all the relevant TRIZ classes, selecting each in turn from the dropdown list.

   Tip: The drop-down list contains the predefined TRIZ classes from the 39×39 contradiction matrix. Multiple classes can be selected for each Functional Requirement.

3. TRIZ classes can be deleted by selecting the 'x' next to any entries.
4. Select *Next* to proceed to the next step or *Previous* to return to the last step.
5. View the proposed TRIZ general solutions to the contradictive functional requirements in the *Suggested TRIZ inventive principles* section of the *Report Page*.

   Tip: Use the toggle switch to add a description of the inventive principle, alongside a generic example and an example from the marine energy sector where available. This depends on TRIZ classes having been appropriately assigned during the TRIZ step.

ANNEX II: SOFTWARE EVALUATION FORM TEMPLATE – STANDALONE VERSIONS

Tool – Module: Structured Innovation Design Tool

Name (user)	
Company	
Date	Pick a delivery date

Instructions

Numeric assessment

Please rate each field in the tables using a scale from 1 to 5, where 1 represents the most negative assessment and 5 the most positive one.

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Qualitative assessment

Please use the box in each section to add comments, overall experience, or other points that may be useful to record.

1. USABILITY

This section aims to assess high-level software experience. A Study is a design case of an ocean energy technology that can be independently managed in DTOceanPlus.

ID	Statement	Rating
1.1	The software is intuitive and easy to use in general	[Select]
1.2	It is easy to create and delete a Study	[Select]
1.3	It is easy to edit, save and export a Study	[Select]
1.4	The process of inputting data is clear and efficient	[Select]
1.5	Results are meaningful, easy to interpret, and use	[Select]
1.6	I could complete the process without errors	[Select]
1.7	I am satisfied with the overall speed of computation	[Select]
1.8	The software can be run from my computer without any issue	[Select]
1.9	The training sessions and documentation are useful for learning how to use the software	[Select]

Comments

[Please add other key points and comments]

2. USER-FRIENDLINESS

This section aims to assess the user interface of the software.

ID	Statement	Rating
2.1	The user interface is simple, easy to navigate and well-organised	[Select]
2.2	The user interface looks professional	[Select]
2.3	It responds promptly to user actions (inputs, selections, clicks…)	[Select]
2.4	It provides the user with enough help, indications and/or guidance throughout each process	[Select]
2.5	The meaning of each data input/user selection is clear	[Select]
2.6	The meaning of each data output is clear	[Select]
2.7	Visualisation of results is clear and informative	[Select]
2.8	The user can add further information to the Study through the interface	[Select]

Comments

[Please add other key points and comments]

3. PERFORMANCE AND ACCURACY

This section aims to assess the quality of results in terms of accuracy, robustness, and performance per software Feature. A Feature is a main functionality of the software that adds value to the user.

a→ Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.a.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.a.2	Results are credible and trustworthy for the audience	[Select]
3.a.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.a.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.a.5	The computational time is adequate for the level of accuracy provided	[Select]
3.a.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.a.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

b→ Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.b.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.b.2	Results are credible and trustworthy for the audience	[Select]
3.b.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.b.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.b.5	The computational time is adequate for the level of accuracy provided	[Select]
3.b.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.b.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

c→ Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.c.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.c.2	Results are credible and trustworthy for the audience	[Select]
3.c.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.c.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.c.5	The computational time is adequate for the level of accuracy provided	[Select]
3.c.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.c.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

4. VALUE

This section aims to assess the perceived value to the user.

ID	Statement	Rating
4.1	The software allows the user full control of the design process	[Select]
4.2	It produces results that allow easy comparisons	[Select]
4.3	It provides a large range of alternatives to create/assess technologies	[Select]
4.4	The user is informed about the internal processing (e.g., remaining time, log) and warned about potential inconsistencies	[Select]
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality	[Select]
4.6	I would recommend the use of this software	[Select]

Comments

[Please add other key points and comments]

5. GENERAL REMARKS

This section aims to record other qualitative aspects not mentioned above.

[Please add any final remarks]

ANNEX III: ANONYMOUS FEEDBACK

SCORES

USABILITY

ID	Statement	RESPONSE-1	RESPONSE-2	RESPONSE-3	RESPONSE-4	RESPONSE-5	RESPONSE-6	RESPONSE-7	RESPONSE-8
1.1	The software is intuitive and easy to use in general	3	4	5	3	4	4	4	4
1.2	It is easy to create and delete a Study	2	4	5	4	5	5	5	5
1.3	It is easy to edit, save and export a Study	2	4	5	4	5	5	5	5
1.4	The process of inputting data is clear and efficient	4	3	5	3	4	5	5	4
1.5	Results are meaningful, easy to interpret and use	2	3	4	2	3	3	4	4
1.6	I could complete the process without errors	3	5	4	3	5	5	5	4
1.7	I am satisfied with the overall speed of computation	3	5	5	4	5	5	5	5
1.8	The software can be run from my computer without any issue	5	4	5	4	5	5	5	5
1.9	The training sessions and documentation are useful for learning how to use the software	2	4	5	2	5	3	4	5

USER-FRIENDLINESS

ID	Statement	RESPONSE-1	RESPONSE-2	RESPONSE-3	RESPONSE-4	RESPONSE-5	RESPONSE-6	RESPONSE-7	RESPONSE-8
2.1	The user interface is simple, easy to navigate and well-organised	4	4	5	3	4	4	4	4
2.2	The user interface looks professional	3	4	4	3	4	5	5	3
2.3	It responds promptly to user actions (inputs, selections, clicks, ...)	5	4	5	3	5	5	5	5
2.4	It provides the user with enough help, indications and/or guidance throughout each process	2	4	5	2	4	5	5	4
2.5	The meaning of each data input/user selection is clear	2	4	4	2	3	3	4	4
2.6	The meaning of each data output is clear	2	4	4	2	3	5	5	4
2.7	Visualisation of results is clear and informative	2	3	5	3	3	5	5	4
2.8	The user can add further information to the Study through the interface	3	2	5	4	5	5	5	4

PERFORMANCE AND ACCURACY

ID	Statement	RESPONSE-1	RESPONSE-2	RESPONSE-3	RESPONSE-4	RESPONSE-5	RESPONSE-6	RESPONSE-7	RESPONSE-8
3.1	Results are robust and not sensitive to small changes of inputs	3	4	4	4	5	4	5	4
3.2	Results are credible and trustworthy for the audience	3	4	5	3	4	3	5	5
3.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	3	4	5	3	5	4	5	4
3.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	3	4	5	3	4	3	5	4
3.5	The computational time is adequate for the level of accuracy provided	4	5	5	4	5	5	5	5
3.6	The software did not suffer from any sort of data shortage/lack of memory during the test	5	5	5	4	5	5	5	5
3.7	The software can handle errors without crashing	5	5	5	3	5	5	5	4

Fully aggregated results have been analysed without differentiating scores between Verification Scenarios and functionalities (One of the responses received gives scores per verification scenario and per individual feature. Other two responses received give scores per simplified feature: FMEA and QFD/TRIZ). In all cases, the average value per statement has been considered.

Outliers values have not been considered to reflect realistic average (The response received that gives scores per verification scenario and per individual feature, give the score of 1 to all the statements in two features associated to two verification scenarios. These valued has not been considered because they are caused by a misunderstanding.)

VALUE

ID	Statement	RESPONSE-1	RESPONSE-2	RESPONSE-3	RESPONSE-4	RESPONSE-5	RESPONSE-6	RESPONSE-7
4.1	The software allows the user full control of the design process	4	4	5	4	4	5	3
4.2	It produces results that allow easy comparisons	5	4	5	5	4	4	3
4.3	It provides a large range of alternatives to create/assess technologies	4	4	5	4	4	5	5
4.4	The user is informed about the internal processing (e.g. remaining time, log) and warned about potential inconsistencies	3	5	4	2	3	5	5
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality	5	3	5	3	4	4	4
4.6	I would recommend the use of this software	5	4	5	4	4	5	4

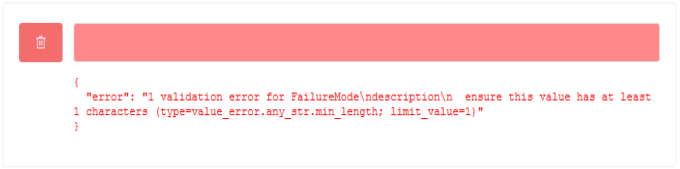
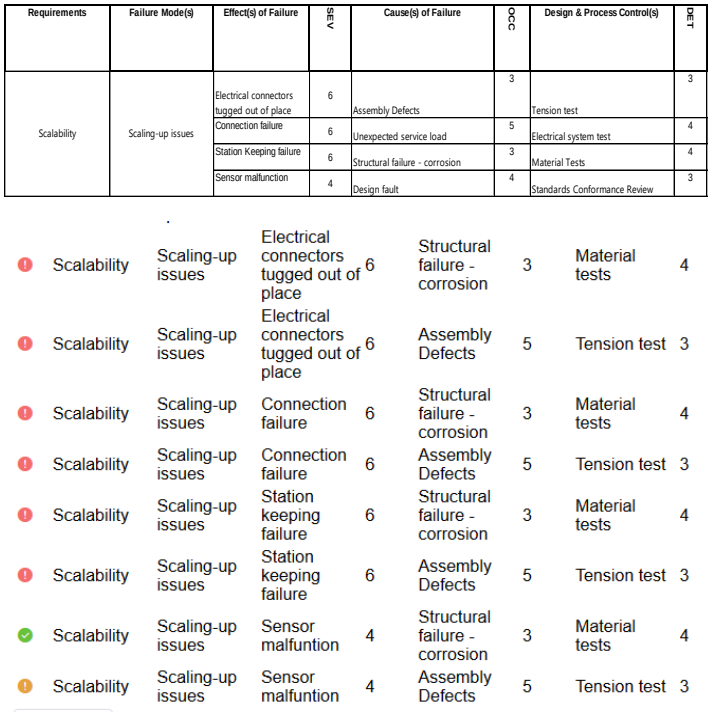
Notice that one of the evaluation forms received has no score in this category.

COMMENTS

ID	Response	Section Assessed	Comments
1	1	Usability	502 Gateway error multiple times: the tool was down for at least 30 mins. Not sure what happens to entered content if this happens mid-assessment?
2	1	Usability	1.1 While the tool is visually simple to read; there is insufficient detail to fully understand the entry criteria making it unintuitive to enter the correct data and interpret the relevant results.
3	1	Usability	1.2 The study appeared to autosave, but I could see no option to delete it
4	1	Usability	1.3 See above, I could see no option to export it
5	1	Usability	1.4 Entering data is ok
6	1	Usability	1.5 Results are difficult to understand without a precise definition of what they mean. Even with the verification case document, it not always easy to read across between the two
7	1	Usability	1.6 The tool seemed generally robust when it was working, but there was an error for half a day that prevented me from accessing it throughout that period
8	1	Usability	1.7 Processing seems instant, but only if results are correct
9	1	Usability	1.8- Computer operation through Chrome Web Browser seemed great
10	1	Usability	Other: SI Home Page allows you to start new QFD/FMEA, but it is necessary to go to the submenu to see/edit existing ones. It is not intuitive that this is possible; or that each time you create a new QFD/FMEA, it is saving the results
11	1	User-friendliness	If no name is inserted and enter is pressed, the following error occurs: Input error messages/checks should be explicit and not look like a code error
12	1	User-friendliness	2.1 Seems fine
13	1	User-friendliness	2.2 Looks basic
14	1	User-friendliness	2.3 Instant responses
15	1	User-friendliness	2.4 Little useful guidance in the tool other than labels for entry points
16	1	User-friendliness	2.5 See above
17	1	User-friendliness	2.6 See above and comments under 1. Usability. Even with the Verification Case document, it is not always obvious whether results are right, and the presentation of results is difficult to interpret as everything is numbered/tables based
18	1	User-friendliness	2.7 See above
19	1	User-friendliness	2.8 Do not know what this means. If you mean the user can edit and existing entry, or return to a previous one, then yes, that is possible if you know where to look for existing studies

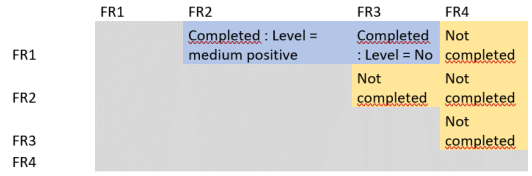
ID	Response	Section Assessed	Comments
20	1	Performance and Accuracy	Overall: It is not clear from the Verification Case Document what the expected values are for the defined inputs given the apparent QA error
21	1	Performance and Accuracy	Step 2; 2.2: following QA error is declared, and it is not clear why priority vs impact does not pass given entered criteria
22	1	Performance and Accuracy	4.b.1 No alternative scenarios are provided in the verification case document, so it is not clear what the results should be if inputs are changed from those defined. 'Small changes' are not defined anywhere
23	1	Performance and Accuracy	4.b.3/4 No accuracies are provided; just absolute numbers based on entries
24	1	Performance and Accuracy	Not all alternative solutions from TRIZ are consistent with the verification case document; names are different, and outputs are not always the same, so it is not clear if the results from the verification test are correct or not
25	1	Performance and Accuracy	Overall: It is not clear from the Verification Case Document what the expected values are given no inputs are prescribed. Therefore outputs/results cannot be checked
26	1	Performance and Accuracy	As for VC1, the output showed QA check issue, not clear why
27	1	Performance and Accuracy	4.b.1 No alternative scenarios are provided in the verification case document, so it is not clear what the results should be if inputs are changed from those defined. 'Small changes' are not defined anywhere
28	1	Performance and Accuracy	4.b.3/4 No accuracies are provided; just absolute numbers based on entries
29	1	Performance and Accuracy	Output reported no data following entries:
30	1	Performance and Accuracy	Suggested inventive principles were provided. However, these were not the same as those shown in Table 5.16. It is therefore not clear if the results from the verification test are correct or not
31	1	Performance and Accuracy	QA check fault, but not clear why
32	1	Performance and Accuracy	The tool is currently not allowing the defined state of the art concepts (Table 5.20) to be entered or edited; the page appears absent
33	1	Performance and Accuracy	Because of issues with Functionality-2, it is not possible to identify and solve contradictions successfully as there is no reference data (or it is null)
34	1	Performance and Accuracy	Although the Verification Case Document provides indicative examples in Tables 7.12-7.14, no inputs are prescribed. Therefore outputs/results cannot be checked.
35	2	Usability	1.4.- For real innovation cases, the collection of information and formatting may take longer. Would it be possible to import information assigned to the FRs from one file or excel spreadsheet? (FR = id, description, target value, unit, the direction of improvement, interactions, TRIZ classes)
36	2	Usability	1.5.- Users might be more familiar with FMEA methods than QDF or TRIZ. Some learning is needed to interpret results
37	2	Usability	1.8.- Problems when running the SI Design tool within Microsoft Edge browser. MS Edge is not supported; other browsers can be used (Firefox, Chrome, ...)
38	2	User-friendliness	2.1.- It is not intuitive that clicking on the upper step bar the user can move, so it would be helpful if when the cursor is over it, the colour changes to indicate that the option is abled.
39	2	User-friendliness	2.3.- Once a new entry is created (click on "+") changes made in the numeric values are automatically saved. This saves time for the user but creates risk if something is changed unintentionally.
40	2	User-friendliness	2.4.- The tool checks validity of inputs and end of the process. It does not let the user continue to the next step if something is missing (e.g., CAPEX = 12,000; The comma is not allowed).
41	2	User-friendliness	2.4.- Contextual help (?) at the side of each input label will improve the usability as implemented in other modules/tools

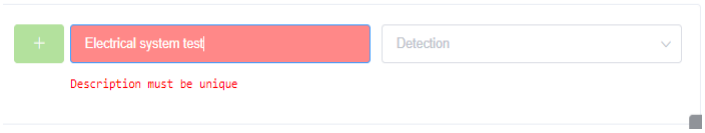
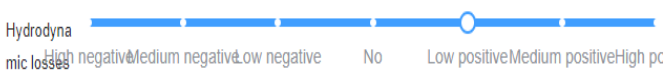
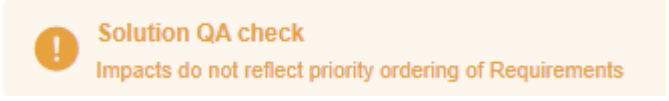
ID	Response	Section Assessed	Comments
42	2	User-friendliness	2.7.- In the report page: • Percentages are not formatted with a comma for thousands. • Not clear what "solutions achieving/missing" columns mean • Are there max-min values for "importance" and "organisational impact"? Not clear if 49 or 20 is "high". A contextual help might clarify the range to the user • Really appreciated the definition of inventive principles and examples given. • Adding graphs to the report page will significantly facilitate the interpretation of results.
43	2	User-friendliness	2.8.- The tool does not allow the user to attach more information about the definition of the Study.
44	2	Performance and Accuracy	Step 2: Requirements 4. a.1.- The tool allows the user to set a priority to the top-level objectives. I would be better if different weights could be assigned to each objective. For instance, the cost could make 60% of the customer requirements, whereas risks 30% and net zero just 10%. It would be great to change the priority score of the customer requirements
45	2	Performance and Accuracy	Steps 3/4/5: FR& Impacts & Interactions 4. a.1.- Not clear how the level of impacts and interactions can change the results of the FR ranking. Same for the organisation impact (very subjective).
46	2	Performance and Accuracy	Step 7: TRIZ 4. a.1.- Not clear how a different mapping of FR to TRIZ classes would lead to other contradictions and therefore different suggested innovation principles. 4. a.1.- Long drop-down menus: List of TRIZ classes (39!!!). Hard to find the right one. It seems that the TRIZ classes can be structured in 4 categories: • Design properties (weight, length, area, volume, speed, force, pressure, shape, stability, strength, duration, temperature, illumination intensity, use of energy, power, the quantity of substance, …) • Design qualities (reliability, accuracy, ease of manufacture, operation, repair, adaptability, detectability, the extent of automation, productivity, …) • Losses (energy, substance, information, time…) • Harms (object-affected, object-generated…) Would it be possible to have filters or a multiple-step selection of TRIZ classes? Alternatively, sort the items of the drop-down lists of the TRIZ classes alphabetically and when the user clicks on a letter, move to the position of the first item that starts with that letter.
47	2	Performance and Accuracy	4.a.1.- In VC2, I would have expected to be suggested inventive principle 36 – Use phase changes. This principle appears in the contradiction matrix in various positions. One of these with applicability to this design problem is "Loss of Energy vs Force". However, this mapping was not evident first. In my opinion, the way the FRs are formulated will have a high impact on the matching of TRIZ classes and therefore, on the sensitivity of results.
48	2	Performance and Accuracy	4.a.7.- Error handling is fine.
49	2	Performance and Accuracy	Step 1: Begin 4. b.1.- Once a new FMEA study is created, we can only define its name. It is impossible to add a description of the design objective or modify the thresholds for the action level and occurrence. This module should work in a similar way to QFD, where it is possible to return to the first step
50	2	Performance and Accuracy	Step 2: Design Requirements 4. b.1.- FRs from a QFD/TRIZ study cannot be imported to the FMEA module. Besides, they are called Design Requirements. Which is the difference from DRs and FRs in the SI tool? If none, the SI features should be linked so that the requirements for FMEA are the same in QFD/TRIZ

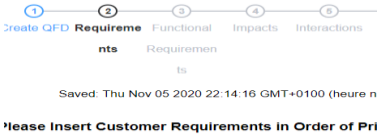
ID	Response	Section Assessed	Comments
51	2	Performance and Accuracy	Step 3: Failure Modes 4. b.3.- I cannot find the link to access the library of failures modes in the SI tool interface (I think the TN mentions it). A dropdown list with generic failure modes – same for effects of failure - would be useful (as well as having the option to enter what the user wants).
52	2	Performance and Accuracy	If a previously saved failure mode is removed, the following error pops up: However, it disappears as soon as a new text is re-entered. It seems that this issue should be better handled as a warning and not as an error • Please enter all Failure Modes for Maintainability 
53	2	Performance and Accuracy	Step 4: Effects 4. b.2.- The severity scale focuses on the consequences for the loss of primary function. There might be other consequences for environmental impacts, injuries, or costs for repair to assess the severity. Shouldn't these aspects also be considered in the assessment of severity? (ref page 38 of the report)
54	2	Performance and Accuracy	4.b.3.- When there are multiple effects for a failure mode, how the tool ensures the causes are matched to each of them? The interface asks about the lists of failure modes, whereas we believe it should ask for the list of effects. Moreover, the implementation of this feature in the SI Tool differs from the excel example: 
55	2	Performance and Accuracy	Step 5: Causes 4. b.1.- The drop-down menu listing the causes is too large for the user to navigate it. It seems it is structured by component type. Perhaps it is worth rearranging it in two levels to facilitate finding the causes faster.
56	2	Performance and Accuracy	Step 7: Mitigations 4. b.1.- It would be helpful to keep the table header fixed to facilitate the visualization of the results do not fit in a single page (a large number of rows).

ID	Response	Section Assessed	Comments
			4. b.3.- It would be great to allow the user to mitigating all design requirements with independence of RPN and occurrence limit. Also, alerting the user if the decision on the mitigation action is enough to reduce the risk under the established level or not. 4. b.7.- The RPN resulting from a mitigation action can exceed the threshold. However, the tool does not highlight or warn the user about this issue in the report page
57	2	Value	3.1.- As a user, I have full control of the process, but the alternatives at each step are so wide that the direction of the innovation effort is blurred
58	2	Value	3.2.- As an end-user, I would like to be suggested the FR where to concentrate my innovation efforts. It seems that the combination of the first column (importance) and the second column (organisational impact) would indicate its potential impact. Likewise, when the user turns to the suggested inventive principles, it would be much appreciated where to focus attention. Can the SI Tool provide a suggested route? (e.g., go to the FR with highest potential impact, select the most repeated inventive principle, ...)
59	2	General remarks	The server was down when running some VCs. However, we understand that this issue was created by the host - OCC- not the tool itself.
60	2	Performance and Accuracy	It would be really appreciated that results were exported in a readable report format (e.g., pdf)
61	3	Performance and Accuracy	I had no problems to be able to verify this feature but had some problems identifying the reasons for the QA check.
62	3	Performance and Accuracy	I had no problems to be able to verify this feature.
63	3	Performance and Accuracy	Depending on the inputs, the results may be more or less trustworthy for the audience, but since this is an innovative process, there is no better way to support the new concept.
64	3	Performance and Accuracy	I had no problems to be able to verify this feature.
65	3	Performance and Accuracy	I had no problems to be able to verify this feature.
66	3	Performance and Accuracy	Depending on the inputs to mitigate the technical risks, the results may be more or less trustworthy for the audience.
67	3	Performance and Accuracy	It should not be possible to create 2 studies with the same name (this is only happening at FMEA) 
68	3	General remarks	While using QFD/TRIZ or FMEA the name of the respective study should be shown in the top of the page (like a header), especially at the "Report Page".

ID	Response	Section Assessed	Comments
69	4	General remarks	Tool format- Overall, it seems to have been developed for a mobile phone interface convention in many places, rather than a desktop programme. Hopefully, this will be easy to rectify as we co-ordinate the GUIs of the different modules.
70	4	General remarks	Help/on-screen guidance: QFD/TRIZ and FMEA are complex processes, and I think the tool should do a lot more hand-holding in guiding the user. Perhaps that is something you still want to add, but despite having been through the process with you and Stuart several times, I would not be able to use this in its current state
71	4	General remarks	Description/Help on-screen: I think the current help items should not be hidden but should appear on the page. E.g., when started entering the customer requirements. The page is 70% blank, so no need to hide the help. Most people will not be familiar with the process, so I think it is best to guide them through it clearly.
72	4	General remarks	Additional help information: If a help menu is used, it should contain much more detailed information, not the basic steps needed to use the tool.
73	4	Performance and Accuracy	Progress bar/menu: The progress menu along the top is nice, but is very temperamental about where I click for it to work, I think it is just the text, not the numbers, but not sure. There is no visual feedback that it is a link (e.g., with the hand icon)
74	4	Performance and Accuracy	Page 2 customer requirements a. There should be guidance on how many to add (typically) b. If I enter a customer requirement and press return nothing happens, I expected to be able to type another entry c. Counterintuitively I have to dd another blank item at the end before I can go to the next page
75	4	Performance and Accuracy	Page 3 functional requirements a. I do not think it is clear enough to someone, not that familiar with QFD what I should be entering on page 3 functional requirements b. There should be guidance on how many to add (per customer requirement?) c. Having the input labels inside the boxes means they are hidden when I type something, this is especially confusing with the difficulty to engineer/deliver d. Again, I have to add a blank row to go to the next step
76	4	Performance and Accuracy	Page 4 - Impacts page (CRs Vs FRs) a. Should the title of this be Level of Impact of Functional Requirements on Customer Requirements b. The Solution QA check should briefly explain what to do to fix the error
77	4	Performance and Accuracy	Page 5- Interactions page (FRs vs FRs) a. I initially had no idea what to do on this page, everything is hidden. b. The midpoint of the correlation scale should probably be "none."
78	4	Performance and Accuracy	Page 6 Insert TRIZ Classes a. Again, guidance on typically how many to consider? One or most of the 39?
79	4	Performance and Accuracy	Page 7 solutions a. Do these inputs have to be the whole width of the page if we are expecting the user to input a short number. It means the units are not so obvious
80	4	Performance and Accuracy	Page 8 Report a. Clicking on the headings at the bottom does not open the detail. I have to click the little > icon b. The highlighting of the rows seems inconsistent. I would expect the parent items on the left to be highlighted, rather than just partial rows. c. Is there another way to display this, as I cannot see it all on the screen (the one area this is an issue) maybe I just chose too many inventive principals
81	4	Performance and Accuracy	FMEA Begin study: 1. If I load an FMEA study, I cannot go to page 1 begin

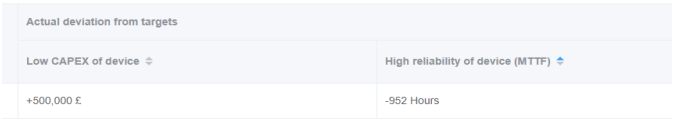
ID	Response	Section Assessed	Comments
82	4	Performance and Accuracy	FMEA design requirement: Page 2 design requirements need some guidance (as I have mentioned elsewhere) and this applies to all pages really
83	4	Performance and Accuracy	Page 3- Failure modes page: a. Nice to see everything is not hidden by default J b. Perhaps the sub-headings should be "Please enter all Failure Modes for the design requirement: #####."
84	4	Performance and Accuracy	Page 7 - FMEA mitigations a. Again, for someone less familiar with FMEA it is not clear what the output is telling me b. What do SEV, OCC, DET, RPN, RPN mean? I can guess… but I should not have to c. It would be good if the icons on the left could have a hover to tell me what they mean i. It looks almost impossible for colour blind people to tell the orange and red icons apart.
85	5	Performance and Accuracy	QFD/TRIZ report generation: Everything works well; however, it seems that the report generation is not available for the moment
86	5	General remarks	GUI improvement: Improving the design of the website to be more professional and intuitive.
87	6	Usability	QFD/TRIZ feature: Relative to 1.1: The steps are well defined (although different from the one in the technical note T3.3), and it is really useful.
88	6	Usability	QFD/TRIZ Relative to 1.3: I completed a study. Then I wanted to modify the name of the study in the "Create QFD" section and encountered some issues (the modification was not considered when clicking on the "Next" button, but it was when I clicked on the QFD/TRIZ button at the top of the page or was not the same as I entered, or I had read error messages such as "Name must be unique").
89	6	Usability	QFD/TRIZ Relative to 1.4: - When defining customer requirements, I expected to give their relative importance with a number immediately after providing their names, as shown in T3.3: I do not know if this functionality will need to be implemented in the future so that solutions given by the CFD/TRIZ account for the importance given to these CRs by the user.
90	6	Usability	QFD/TRIZ in the "Impacts" section: when the user does not define the level of impact, the cell is set to a shaded "None". It may be interesting to highlight in a clearer way that the cell has not been modified, to avoid omission from the user (which may lead to errors that are hard to track), maybe with another word that "None".
91	6	Usability	QFD/TRIZ in the "Interaction" section: Even if the "High negative" to "High positive" ranking system is not that hard to understand, it could be useful to add to the Help section something like in T3.3: "The tool provides a pre-defined correlation ranking (strong ±9, medium ±4, weak ±1 and, positive or negative meaning synergies or conflicts).", or even more meaningful information to an early user about what is intended by "High negative" or "High positive" correlation. As the value will be the same between FR1 and FR2 in the FR1 pulldown section and the FR2 pulldown section, I would find interesting to ensure that the user is aware that he has previously defined the interaction, especially when the input is the default "No," or if multiple users are to work on the same study simultaneously (and change the "No" to another value if he thinks it was not previously defined). Either a visual help to have a progression bar or a "half matrix" could be fine:  -In a general manner, this kind of progression status could be interesting for the user to ensure they defined all the necessary sections Step 4 (from the technical note T3.3) is done before Step 5, which I found surprising but not a real issue for clarity

ID	Response	Section Assessed	Comments
92	6	Usability	QFD/TRIZ Relative to 1.5: -I would find it interesting to remind the values given for CRs and FRs in the Report section and even provide a visual representation of the HoQ matrix. -The QFD/TRIZ tool is based on concepts that are relatively easy to understand, but the exploitation of the results may be hard for inexperienced users. For this reason, I think that some efforts may be put into giving extra guidance on how to exploit the "Potential for disruption" and "Suggested TRIZ inventive principles" sections (even though some guidance is already given in the "Help" menu, with remarks about values for the importance and organisational impact). For example, it could be interesting to highlight (maybe with colours, or comments) areas in these tables of interest to orient the user. It could be interesting to explicitly mention the "low hanging fruits" mentioned in the "Help" menu if the tool can identify it (even if it is dependent on the user expectations), as it can be harsh to know for an unexperienced user what a "High" importance and "Low" organisational impact are (e.g., below with outcomes from VC3  Functional Requirement ⇕ / Importance ⇕ / Organisational Impact ⇕ Manufacturing costs (M€) 19 3 Reliability (years) 25 2 Storage capacity (MWh) 65 12 About the "Suggested TRIZ inventive principles" section of the report, some more information may be given to the user to treat the outcomes (= inventive principles to look at), like a reference to section 2.2.2 from D3.2 (in particular 2.2.2.2, but it is still generic and uneasy about using for inexperienced users). -I added some more elements in the Comment section for 3. a.2.
93	6	Usability	QFD/TRIZ- Relative to 1.9: I found it interesting to read D3.2 and the beginning of T3.3 (which says pretty much the same) to have a technical background and not lose time to understand the various concepts (CRs, FRs, etc....).
94	6	Usability	FMEA feature- Relative to 1.1: Impossible to come back to the "Begin" section to modify it by clicking on the name of the section at the top of the page, while it is possible for the other steps of FMEA analysis
95	6	Usability	FMEA feature- Relative to 1.4: I had this error message  Electrical system test Detection Description must be unique
96	6	User-friendliness	QFD/TRIZ feature: Relative to 2.1: It is possible to navigate through the various steps by clicking on the name of the step at the top of the page, but this may be highlighted to the user (I did not do it on purpose the first time).
97	6	User-friendliness	QFD/TRIZ feature: Relative to 2.2: I had the following issue when displaying with a reduced size for the navigator  Hydrodynamic losses High negative Medium negative Low negative No Low positive Medium positive High pc
98	6	User-friendliness	QFD/TRIZ feature: -I had this warning in the "Impact" section, but I would not find it clear:  Solution QA check Impacts do not reflect priority ordering of Requirements
99	6	User-friendliness	QFD/TRIZ relative to 2.4: It is not convenient at first for an inexperienced user (those who have no time to read D3.2 or content like T3.3) to understand what Requirement, Functional Requirement, or Customer Requirements. Maybe Renaming Step 2 to "Customer Requirement" may avoid misunderstandings

ID	Response	Section Assessed	Comments
			 Maybe the "Help" menu could be made more visible. I missed this small grey button until Step 5
100	6	User-friendliness	FMEA feature: Relative to 2.1: In the "Mitigations" section: It is possible to edit the Mitigation measure provided by clicking on the text (and to delete it with the red basket), but the editing function may be highlighted more clearly: - Maybe pulldown sections, largely deployed on QFD/TRIZ and SG tools, could be used in this section to help the user with this large amount of data, for example, to distinguish between different failure modes or different effects for the same failure mode, etc....
101	6	User-friendliness	FMEA feature: Relative to 2.4: No help section in the "Design requirements" section, but it could be useful if the user did not read the training material. I had this error message 
102	6	User-friendliness	FMEA feature: Relative to 2.7: - There is a yellow warning at the left-hand side when the occurrence is above the user-defined limit, but this yellow warning also displays when the mitigation measure change the RPN value from an inadmissible value to an acceptable one, which is surprising (it should be green as it is solved): 
103	6	User-friendliness	FMEA feature: Reporting/exporting Results can be downloaded from the "Mitigations" section, but the resulting Excel file is not user-friendly: 
104	6	Performance and Accuracy	Relative to 3.a.2: With VC3, I had the following interactions between FRs: TABLE 7.11: VC3- INTERACTIONS BETWEEN FRS

	Define interactions Between FRs	Hydrodynamic losses	Transmission losses	Storage capacity	Manufacturing costs	Installation costs	Reliability
Down	Hydrodynamic losses		+Low	None	+Medium	+Medium	None
Down	Transmission losses	+Low		None	+Low	+Low	None
Up	Storage capacity	None	None		+High	+Low	None
Down	Manufacturing costs	+Medium	+Low	+High		+High	-High
Down	Installation costs	+Medium	+Low	+Low	+High		None
Up	Reliability	None	None	None	-High	None	

ID	Response	Section Assessed	Comments
105	6	Performance and Accuracy	Related to 3.a.2: With VC3 I had the following results in the "Suggested TRIZ inventive principles" section (it may be normal; I cannot judge because I have no experience with TRIZ tools): Hydrodynamic losses Conflict / Worsening / Improving / Inventive Principle Reliability / Reliability / Loss of Energy / Preliminary Compensation; Preliminary action; Physical or chemical properties Storage capacity / Power / Loss of Energy / Local quality; Strong oxidants
106	6	Performance and Accuracy	As there is no interaction (Interactions set to "None" for Reliability and Storage capacity for Hydrodynamic losses), I found surprising to be proposed to solve this conflict (I think that it is done because these are the most negative interactions for Hydrodynamic losses, but I am not sure to report an error). But I had no solution proposed to solve the conflict between Manufacturing cost and Reliability, for which the interaction is Highly negative Manufacturing costs Conflict / Worsening / Improving / Inventive Principle Storage capacity / Power / Ease of manufacture / Cheap disposable; Segmentation; Equipotential; Intermediary On the other hand, I had conflicts resolution suggested for all the FRs, but Manufacturing costs proposed in the Reliability pulldown section Maybe there is a lack of understanding of what is intended to be shown to the user in this report's section
107	6	Performance and Accuracy	About the "Mitigations" section: Maybe a more direct link could be done between the RPN or RPN value and the Action Level defined by the user (as well as with the actual occurrence related to the line we consider and the user-defined threshold) to have a more direct view on the acceptance for the line we consider (I found the coloured warning sufficient, but maybe this could be improved with larger red, orange, and green areas).
108	6	Value	QFD/TRIZ features: Relative to 4.2: Maybe a way to compare various study would be interesting
109	6	Value	QFD/TRIZ features: Relative to 4.4: This is not the case, but as it is really fast, this was not important
110	6	General remarks	About QFD/TRIZ functional requirements: I found references to solution hierarchy in D3.2 (e.g., Figure 3.6) and expected to see this functionality implemented in the QFD/TRIZ tool, but I can imagine that this will only be in the fully integrated SI tool with other design tools.
111	7	Usability	1.1 – easy to use in the web browser, hope that translates over to easy to use in the standalone version
112	7	Usability	1.4 – was not always obvious if the data had been entered, had to put time and effort in to make sure the add button was clicked and carried out
113	7	Usability	1.5 – the display of results on web browser lacks table lines in FMEA, would also be beneficial if the download file for FMEA had colour-coded results. QFD/TRIZ results are more straightforward to understand as in table form, although there is no option to download results.
114	7	Usability	1.6 – Some ambiguity regarding if data was input correctly, had several errors when carrying out analysis. I also had a couple of instances when completing a section used the previous button to go back and would lose data; again, this was not obvious at the time o would throw up an error later.

ID	Response	Section Assessed	Comments
115	7	Usability	1.9 – documentation was useful but maybe been better provided as individual documents or without the separation of data between the main body and the appendices, as it led to a lot of scrolling in attempts to find the required data input. Could almost be structured in a more step by step process, with hold points to check that sections have been completed correctly.
116	7	User-friendliness	2.1 – Relatively straight forward to scroll through, having a save button would be beneficial as not always sure of autosave functions. If the next and previous buttons could be floating would be useful as they do not have to scroll so much to get to them when on a section with a lot of data.
117	7	User-friendliness	2.2 - Not that it does not look professional, just a bit basic at the moment, could do with some clearer separation between sections and input points as all blends into one currently
118	7	User-friendliness	2.4,2.5 and 2.6 –Help sections could do with examples just to show levels of detail required or expected inputs, will inform user more as to what is required
119	7	User-friendliness	2.8 – it is relatively easy and straightforward to make changes and go back and amend data
120	7	Performance and Accuracy	Find it difficult to comment on the results produced with a small sample size of cases I was able to run but see no reason not to believe the outputs and results.
121	7	Performance and Accuracy	Saw no issues or lag time when working with the tool and saw no crashes when inputting data
122	8	Performance and Accuracy	When inputting the 'Objective' into the start of the QFD/TRIZ, it would be good have more guidance, i.e., "Concept creation" / "improvement of a tidal energy device" – The user may not know what to write here
123	8	Performance and Accuracy	QFD/TRIZ Page 2- Customer requirements: Examples of what customer requirements are to help guide the user
124	8	Performance and Accuracy	QFD/TRIZ Page 3 functional requirements: – it would be helpful if they were linked to the Customer Requirements from the previous page, i.e., "To meet these customer requirements, how should the technology function?"
125	8	Performance and Accuracy	QFD/TRIZ Page 3 functional requirements: "Difficulty to engineer" and "difficulty in delivering" are particularly hard to answer for 'Concept creation' because the user may have written "a CAPEX of £1M" but has not decided on a device or material yet, so how to know if this is difficult?
126	8	Performance and Accuracy	QFD/TRIZ Page 4: Impacts page: Should the title of this be Level of Impact of Functional Requirements on Customer Requirements
127	8	Performance and Accuracy	QFD/TRIZ Page 5: I initially had no idea what to do on this page. Everything is hidden –, it should say, "Please slide the marker along to where you think it should lie."
128	8	Performance and Accuracy	QFD/TRIZ classes Page 6: guidance on what a TRIZ class is/ how does the user selects the most relevant one? Maybe some examples to show what kind of thing could be input
129	8	Performance and Accuracy	QFD/TRIZ Solutions page 7: I was unsure what to put in here; what should be in "Description"? Is this where we input examples of existing devices? If so, can it say "Examples of state-of-the-art" at the top?
130	8	Performance and Accuracy	Reports Page: Is the user supposed to click on the blue arrows? My Ideality column just shows "- ", even though one of my solutions exceeds the targets 
131	8	Performance and Accuracy	FMEA Home Page/ Access: If I access FMEA from the SI home page "Start here", I cannot load my own FMEA. This gave me the impression there was no such facility until I had completed it. Perhaps should navigate straight to the list of existing studies, as per the FMEA tab at the top
132	8	Performance and Accuracy	FMEA Home page: Page 1, where you name your study, needs guidance – make the help info immediately shown? (repeat of Donald's comment on other pages)

ID	Response	Section Assessed	Comments
133	8	Performance and Accuracy	FMEA Home Page: Page 1 of FMEA with 'Action Level' and 'Occurrence limit' should have some definitions to help the user define values
134	8	Performance and Accuracy	FMEA Design requirements: needs some guidance- On each page, could the previous and Next buttons appear at the top too? Also, copy Donald's comment one about the progress bar clicking.
135	8	Performance and Accuracy	FMEA Failure modes (page 3): Perhaps the sub-headings should be "Please enter all Failure Modes for the design requirement: #####." Maybe even putting the name of the design requirement in bold or italics would make it visually easier - same for other pages
136	8	Performance and Accuracy	FMEA Page 7 mitigations: When the Mitigation window pops up, it is initially populated with the unmitigated assessments, but as soon as I have changed it, I am not able to compare my new situation against the unmitigated status. I also would like to be able to see the DR, FM, Effects, Causes, Design Controls data for the line being mitigated. Can it all be added to the Mitigation window or the Mitigation window e positioned such that I can see the line in the question above it? Or could I drag without of the way to refer back?
137	8	Performance and Accuracy	FMEA pages Page 4, 5,6, 7: when I click Edit on a saved study, I can add text into the boxes to add a new item, but the green "+" button appears to be blocked (no entry sign appears) so I cannot edit. I can edit pages 2 and 3 to add DRs and FMs, but again cannot add Effects, Causes etc. in the subsequent pages
138	8	Performance and Accuracy	Completion: b) When I completed the mitigation input, I was looking for a "Next" or "Finish FMEA" button to take me back to the home page or on to QFD/TRIZ - user experience felt "uneasy." c) I was also looking for a link from the data I have entered into FMEA and the QFD/TRIZ process – is there a link between the two? (I have not at this point done the QFD/TRIZ and am left wondering what happens next with my FMEA. d) The text in the mitigation box can be quite close to the next cell down – the visual display would benefit from some extra row separation or shading difference between rows to visually separate the contents
139	8	General remarks	Most of our comments relate to Usability user-friendliness and are linked to the 'Statements scored' with 3s and 4s. Not to under-estimate the effort required, but I would say that most of the comments could be easily fixed, given the time to do so. For the Performance and Accuracy section, I have scored five throughout. In this regard, I think the SI tool is different to the D&A tools in that its value is driven by the information entered by the user, and the user's ability to make innovation decisions based on the way this input data is presented back to them. Accuracy is not relevant in the same way as the D&A tools. In the Value section, the only things scored down are those related to the comments on Usability and User Friendliness, and are eminently solvable.
140	9	Usability	TRIZ section help/guidance: "Suggested TRIZ inventive principles" have not been easy for us to interpret.
141	9	User-friendliness	On-screen guidance/help: On "Report page" it is not clear how the "Importance" term in "Potential for disruption" has been obtained
142	9	User-friendliness	TRIZ help/guidance: "Suggest TRIZ inventive principle", the section which proposes a list of TRIZ inventive principles that can solve for any contradictions is not intuitive and a bit laborious when it comes to addressing the output to improve a wave energy technology concept or its sub-system.
143	9	User-friendliness	In general, the "Report page" has a simple and good graphical interface to compare results
144	9	General remarks	TRIZ help/guidance: In general, to carry out an "Identify and solve contradictions" analysis more training would be needed or more exhaustive literature about the concepts behind the TRIZ class principles that maybe could help the user to detect, in a more intuitive way, the suitable classes for each of the functional requirements.

ANNEX IV: FULL TASK LIST

Below is the list of tasks to try and include in the final version of the Structured Innovation tool. It has been derived from the analysis of the qualitative comments provided in the feedback forms. Tasks are presented in order of priority.

TABLE 10-1: HIGH PRIORITY LIST OF TASKS TO IMPLEMENT

Design requirements	Resolutions
Provide contextual description, guidance and background information detailing detailed concepts of the modules and step-by-step guide and examples.	As a global approach, each step will provide a contextual on-screen description, explanatory dialogue boxes, help buttons, and additional background information should be included in the final release of the SI tool, including definitions of the terminologies and legends. The SI tool will also provide links to the documentation system.
Uniformity in overall style for all steps indicating input fields and labels, operations available, and allowing ease of navigation	This issue is being addressed, including: ▪ Clear input labels for clarity of operation available, ▪ Adding warnings with a description of missing inputs ▪ Adding hovering information to each input field ▪ Better use of tables/matrix for the Interactions Page These options are being considered, along with other ideas on how to improve the UX of the SI tool.
Error-handling guidance and warning when steps incomplete	Error handling: Explanatory dialogue boxes, and additional help buttons, will be included in the final release of the SI tool. Warnings- The implementation will enable to continue with incomplete data, but receive a warning(s) when viewing pages affected by missing information
Consistency in autosaving option when adding/editing entry field (+)	Several approaches were considered for saving user-inputted data consistently. The Autosave option with revision is being implemented and tested to ensure that this issue has been tackled adequately in the final version of the tool
Provide contextual descriptions, legends, a glossary for completeness both the QFD/TRIZ and FMEA report	Clarification on how best to present the results is required. ▪ The top objectives and customer requirement priorities will be included in the report ▪ Contextual on-screen description, explanatory dialogue boxes will be provided for each section of the report ▪ Improving how the potential innovative areas are presented, including potential for disruption and ideality of solutions. An option to show the results in a tabular format has also proposed and graphical representations (and expanded in the medium priority)
Style improvement for completeness and clarity of both the QFD/TRIZ and FMEA report pages.	In future versions of the SI tool, the style and consistency of the SI tool report will be reviewed to improve the clarity and readability of the report A clear distinction between the sections of the report will be provided, including the description, and expected actions. The use of delineated sections and tables and will be implemented

Design requirements	Resolutions
Consistent reporting of TRIZ alternative solutions only for conflicts	The TRIZ section (TRIZ classes and report section) has been amended to only display TRIZ fields for functional requirements with contradictions. Contextual on-screen description, explanatory dialogue boxes will also be provided
Consistency required when navigation between QFD/TRIZ and FMEA (operations, description)	A review of all the steps and input fields, terminology, and data input formats is needed to ensure a consistent process between the QFD/TRIZ and FMEA modules. Consistency in the description of steps is also being reviewed to make sense to all the possible users of the tool (e.g., new, or experienced user.)
Ability to import data from other modules	Currently, the SI tool has been developed in standalone mode. As a consumer to a Work is now underway to implement the integrated features to enable the SI tool to consume from other modules, e.g.: ▪ Import description and values of solutions from the Stage Gate module (target values, state-of-the-art) ▪ Import solution achievements from deployment and assessment modules (failure mode from RAMS, LCOE from the Systems lifetime cost)
Ability to generate a report in PDF/Excel/CSV	Work is underway to develop a standardised report in PDF format that summarises all the input and output data of both the QFD/TRIZ and FMEA modules. This will be available in the future versions of the SI tool An option to export the outputs to Excel/CSV has now been implemented
Visibility of system status and ease of navigation between steps and understand the functionality addressed	These implementation activities are on-going to improving the user experience. For example: Amending the progress bar to indicate where the action is needed, the completed steps, links to active pages and editable/non-editable sections.
Provide a connection between the FMEA and QFD/TRIZ results	The future version of the tool will implement the functionality linking the results of an FMEA study to QFD/TRIZ, and vice versa. This implementation will enable the user to innovate in areas where failure modes cannot be mitigated and to mitigate technical risks of innovative concepts in the FMEA, and QFD/TRIZ modules.
Ability to rank and prioritise the Customer requirements	The functionality enabling the user to define the prioritisation of customer requirements has now been implemented.
Provide default lists of potential solutions to support the analysis (functional requirements, a library of failure modes, causes, effects)	To support the user experience, the SI tool will suggest generic areas where to concentrate on innovation efforts such as: ▪ A solution hierarchy already implemented in the SI tool as a multi-level list of potential solutions for marine energy for each requirement ▪ An FMEA library with generic failure modes – same for effects of failure - would be useful (as well as having the option to enter what the user wants).
Ability to import/ export, or delete study	This functionality has now been implemented enabling the user to import/export a study in JSON format or delete a study

TABLE 10-2: MEDIUM PRIORITY LIST OF TASKS TO IMPLEMENT

Design requirements	Resolutions
Ability to easily navigate through the SI tool, not being restrained with incomplete steps, being able to view all the pages with minimal need to scroll, and understand the implications of some of the inputs within the process	A global approach is taken to maximise the screen resolution by implementing: ▪ A collapsible Left-hand side pane to enable the user to access each functionality of the tool (active if complete or inactive) ▪ A collapsible right-hand side pane to access contextual guidance links to documentation and commentary box ▪ An updated SI Home page link to launch the QFD/TRIZ and FMEA home page (rather than their New Study page) ▪ Ability to easily navigate between each step of the process with a warning message if incomplete ▪ Ability to freeze headers of a specific page, with minimal scrolling (if possible) ▪ Ability to navigate through the main functionalities of the tool as sub-processes & view sub-results
Ability to take notes relevant at a particular stage of the process	A commentary box accessible on the right-hand side pane will be available for each step enabling the user to input notes, links to documentation, and commentary box
Ability to import data (functional requirements) from QFD/TRIZ study to FMEA or vice versa	Work is underway to determine the best way of implementing this functionality. One of the options considered is a toggle button similar to the solution hierarchy. This will be implemented in the final version of the tool
Ability to view all the mitigated criteria once mitigation is complete	Currently, the Mitigation table shows Design Requirement, Failure Mode, Effect, Severity, Cause, Occurrence, Design Control, Detection, RPN, and Mitigation status. When mitigation is complete, the revised rRPN is visible, but the value for the revised Severity, Occurrence, and Detection is not displayed. Implementation is underway to include the revised Severity, Occurrence, detection, and rRPN in the result page.
Ability to see the results in smaller sections for better interpretation of results.	The best ways of displaying the results of QFD/TRIZ analysis are investigated on the report page. Suggestions considered are: ▪ Display results in tabular formats (e.g., sub-sections of each main functionality). ▪ Adding graphs to the report page to significantly facilitate the interpretation of results.

TABLE 10-3: LOW PRIORITY LIST OF TASKS TO IMPLEMENT

Design requirements	Resolutions
Ability to be reminded of the Customer requirements when defining Functional requirements	The current implementation of the tool is being updated to enable the user to easily navigate between different pages with warning messages when there are missing data.
Ability to define a project study and provide additional descriptive details.	The user will be able to define multiple analyses with the same name if desired. Also, the user will be able to describe the study (both in QFD/TRIZ and FMEA). The QFD/TRIZ and FMEA home page will display for each study: ▪ The Project study, ▪ The last modified date/time and, ▪ The description of the study
The ability to edit or use bespoke FMEA Severity, Occurrence and Detection Ratings for an analysis	The ability for the user to add/edit the current ratings used, or upload and use bespoke ratings (e.g., other consequences for environmental impacts, injuries, or costs for repair to assess the severity).
Ability to compare multiple studies	The ability to compare multiple studies has been proposed. Currently, this option is seen as out-of-scope due to the implementation effort required in the remaining timeline of the project. The user will be able to compare multiple studies by opening different windows
Ability to import functional requirements files	The ability for the user to import functional requirements files (including target values, difficulty to engineer and deliver, the direction of improvement) A review of the format of the imported files is being considered, however, Currently, this option is seen as out-of-scope due to the implementation effort required to define a 'fit-for-all' format styles for any files imported to coincide with the appropriate step and data structure within the SI tool.

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