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HELLENIC REPUBLIC
MINISTRY OF DEVELOPMENT
GENERAL SECRETARIAT FOR RESEARCH AND INNOVATION
HELLENIC FOUNDATION FOR RESEARCH AND INNOVATION

Greece 2.0 NATIONAL RECOVERY AND RESILIENCE PLAN
"BASIC RESEARCH FINANCING" (Horizontal support for all Sciences)
ID 16618 – Subproject 1 (MIS: 5163923)

Interim Report

Function-oriented, multi-material design of sustainable mechanical systems

Fun4Design

15672

INTERIM REPORT SUBMISSION GUIDELINES

The Interim Report is the pre-condition for receiving interim payment and must be submitted when a minimum of 40 % of financial resources have being used. In the case of Collaborating (multi-beneficiary) projects the Report is submitted by the Coordinator.

The Report must be written in English and submitted in electronic format, and includes the following three (3) sections:

Part A:

A1. General Project Information
A2. Abstract
A.3.1. Amendments & Modifications
A.3.2. Amendment & Modification Table
A.4. Project Implementation
A.5. Work Package Table
A.6. Deliverables Table
A.7. Milestones Table
A.8. Risks Table
A.9. Communication and Dissemination Activities
A.10. Project Impact
A.11. Follow-Up of Recommendations from Previous Review(s) (*If applicable*)
A.12. Use Of Resources

Part B: Annexes

B1. Other Information
B2. Project Deliverables

Part C: Interim Financial Report

The Interim Financial Report is submitted as a separate document (in Excel format) **in Greek**. A template for the Interim Financial Report is available on the H.F.R.I. Project Management Platform.

PART A	
A1. GENERAL PROJECT INFORMATION	
SUB-ACTION	Sub-action 1. Funding New Researchers – RRF: Basic Research Financing (Horizontal support for all Sciences)
SCIENTIFIC/THEMATIC AREA	SA2. Engineering Sciences & Technology
PROJECT TYPE	MULTI-BENEFICIARY PROJECT
PROJECT TITLE	Function-oriented, multi-material design of sustainable mechanical systems
PRINCIPAL INVESTIGATOR	Angelos Filippatos
HOST INSTITUTION	University of Patras
COLLABORATING ORGANISATIONS (BENEFICIARIES)	-
COLLABORATING ORGANISATIONS (NON-BENEFICIARIES)	TU Dresden
PROJECT START DATE (DD/MM/YY)	20/11/2023
PROJECT DURATION (IN MONTHS)	24
APPROVED BUDGET	187,500.00 €
AMENDMENTS (number)	
DATE OF LATEST VERSION OF THE PROJECT'S TECHNICAL DOCUMENT	-
PROJECT WEBSITE ADDRESS (*if applicable*)	Fun4Design - IDEAS
REPORTING PERIOD (DD/MM/YY)	20/11/2023 έως 11/03/2025

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A2.1 ABSTRACT (*maximum 500 words*)

The overall goal of **Fun4Design** is the function-oriented, multi-material design of sustainable mechanical systems. It investigates the engineering process to describing and integrating the functions of sustainability and recyclability during the conceptual design phase of multi-material systems without hindering the main structural function. During the reporting period of M01-M15, we started to focus on the following three major objectives of the project:

1. The **first key objective** is **method-oriented** and focuses on **how to design** and develop sustainable multi-functional systems fulfilling the structural functions and the functions of recyclability and sustainability. To approach this, we took as a design demonstrator a structure typical for automotive applications, such as **A-pillars**. This example was selected due to its high variability of design parameters, material composition (multi-material structure) and complex loading conditions, which lead to a high effort for design case studies and simulations. This is included in Phase I of the project called Design and Development (M01-M12) performing the fundamental tasks required for the conceptual design phase through WP 2, WP 3 and WP 4.
2. The **second key objective** is **function-oriented.** In this stage, we investigate the relationship between the a-pillar geometries, including material properties and functions requirements in order to identify application limits. This is also included in Phase I through WP 2, where we explored different a-Pillar geometries and materials, investigating the basic design requirements and identifying the resulting functions. Based on the derived functions, different families of functions were identified, specifically the structural, sustainability and recyclability functions, moving from lower to higher complexity. This procedure is presented in Deliverable 2.1: List of requirements and functions, where the appropriate requirements and functions are summarized and proposed in details.
   Additionally, in WP4, parametric FEM simulations are in progress with different material configurations for the selected functions of WP2. These parametric simulation models are applied to different automotive and aircraft designs, integrating sustainability and recyclability functions. Some results are presented in Deliverable 4.2: *Conference Disseminating Parameterized Test-Benchmark*, which includes two submitted conference publications.
3. The **third key objective** is **system-oriented** and was initiated during this period (between M10 and M12). This corresponds to Phase II of the project, called Synthesis and Validation, carried out through WP 5 and 6. To fulfill this objective, we already have started to design complex loaded a-pillar structures using multiple contradicting functions, e.g. high-structural performance and high-recycling material mix. Here, we will use data-driven engineering methods, where we will develop a hierarchical ML-model, presumably ANN with input nodes representing design parameters and types of functionalities, e.g. structural, recyclable, sustainable, cost functions. This model will be integrated into a GUI-tool for efficient decision-making.

Following the above, in the Interim Report of **Fun4Design**, the following deliverables are provided in Annex B2:

D1.1 Project handbook

D2.1 List of requirements and functions

D4.2 Conference disseminating parametrized test-benchmark

Also, the expalantion of the work in each Work Package is described and some key results is proposed. Also, further actions are involved including the Interim Financial Report as separated file.

A.2.2. LIST OF ASSOCIATED BENEFICIARIES (Consortium)		
INSTITUTION NAME	**ROLE**	**BUDGET**
University of Patras (UPAT)	Host Institution	187,500.00 €

A.2.2. LIST OF RESEARCHERS INVOLVED IN THE PROJECT (*Individual statement for each Beneficiary*)

NAME	CAREER STAGE	Role	Person Months during the reporting period	WPs worked on
Angelos Filippatos	Associate Professor	Principal Investigator	0,89	1,2,7
Dionysios Markatos	Post-doctoral Researcher	Team Member	2,39	2,3,7
Anastasios Zavos	Post-doctoral Researcher	Team Member	1,05	3,4
Charalampos (Harry) Psihoyos	Post-doctoral Researcher	Team Member	1,01	4
George Kouvaras	PhD Student	Team Member	9,52	2,3,5
Vasileios Lazaridis	Master Student	Team Member	4,19	3,5

A.3. MODIFICATIONS/MINOR CHANGES (applied by the beneficiaries without previous approval by HFRI)

Modifications have been made regarding the composition of the Research Team as well as the project timeline.

Specifically, the initial research team, apart from the Assistant Professor and Scientific Coordinator of the project, Angelos Filippatos, consisted of Professor Pantelis Nikolakopoulos, Postdoctoral Researchers Dionysios Markatos and Ilias Bilalis, as well as the non-remunerated Professor Maik Gude and Postdoctoral Researcher George Tzortzinis.

However, due to professional commitments and personal reasons, Dr. Bilalis will not be able to contribute to the project. As a result, he has been replaced by Dr. Charalampos (Harry) Psihoyos, who was added to the research team following a public call.

Additionally, Dr. Markatos was temporarily substituted for a few months by Dr. Anastasios Zavos. His inclusion in the Research Team was based on an evaluation conducted by the Research Committee of the University of Patras, taking into account his professional experience and the relevance of his scientific expertise to the project's objectives.

Furthermore, it was considered imperative to expand the team by incorporating younger researchers and PhD candidates, namely Giorgos Kouvaras and Vasileios Lazaridis, with the aim of optimizing the project's implementation.

The process of forming a research team with the appropriate expertise and experience relevant to the project's objectives, along with the time required for the completion of administrative procedures (public calls, approvals from the Research Committee, contract agreements), led to the necessary modification of the project timeline, as these factors contributed to delays in its execution.

As a result of the above, an extension of the deliverables was essential to ensure that all tasks are completed with the expected level of quality and rigor. This additional time will allow for the proper integration of resources and personnel, ensuring that the project effectively fulfills its objectives.

The extension was approved by ELIDEK-UPAT on 01.03.2024 with protocol number 23345. The corresponding document was attached to the Interim Report.

A.4. PROJECT IMPLEMENTATION (*maximum 2 pages per Work Package*)

WP Number: 1	**WP Title**: Project management and career development
Beneficiaries: University of Patras	
Starting Month: 1	**Ending Month:** 24

WP Objectives

- Ensuring the highest quality of research and innovation activities within the different WPs.
- Ensuring project's implementation within deadlines, budget and quality, meeting all objectives.
- Tracking deviations, identifying risks and providing mitigation measures when required.

WP PMs 0.41

WP Cost 1,509.19 €

In WP1, project coordination and financial management are outlined. The project officially began on November 20, 2023.

The two main activities that took place were:

1. Formation of the complete research team (as already mentioned in Table A2.2)

2. Preparation of D1.1. We have to highlight D1.1, in which the scientific and technical plan details are provided, and several clarifications and scientific changes are made with respect to the initial proposal.

During this period, internal meetings between the PI and research team members were held to gather information about upcoming plans for the project and any delays that have impacted its progress.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP1, the following tasks are included:

T1.1 Project Coordination, Administrative and Financial Management

T1.2 Supervision and career development

The Principal Investigator (PI) oversees the overall project management, including administrative coordination and communication with both internal and external university partners, as well as research team members. The PI ensures the quality and timely delivery of project results while also addressing and resolving potential conflicts. Particularly, the extension of the deliverable's timeline is necessary due to unforeseen delays that have impacted the project's progress. One of the primary reasons for this extension is the delay in the contract's finalization and signing, which postponed the official start of the project. This delay affected the timely allocation of resources and the overall project schedule.

Additionally, the search for researchers with the appropriate expertise and experience relevant to the project's objectives required more time than initially anticipated. So, this extensive search further contributed to the delays in the project's execution. Under these challenges, an extension of the deliverables is necessary to ensure that all tasks are completed with the expected level of quality and rigor. This additional time will allow for the proper integration of resources and personnel, ensuring that the project meets its objectives effectively.

Deliverables

Deliverable D1.1: Project handbook is provided including detailed work plan, Gantt chart, milestone and progress monitoring.

Work package planned Action and Effort for the next reporting period (*if applicable*)

The next planned actions include presenting personalized career development plans for all research members through Deliverable 1.2, ensuring continuity and growth within the academic community. These plans encompass various components, such as future research opportunities abroad with international collaborators and participation in the ILK researchers' seminar program. Additionally, the Career Development Plans will cover research activities, conference presentations, dissemination events, and training activities, providing comprehensive support and contributing to the project's goals.

Furthermore, the preparation and submission of the project's final report as Deliverable 1.3 will also be considered.

WP Number: 2	**WP Title:** Analysis of main and secondary functions for representative geometries
Beneficiaries: University of Patras	
Starting Month: 1	**Ending Month:** 14

WP Objectives

- Identify the envisaged functions and characterize them to enable a performance-estimation of the solutions.
- Define the final specification of the requirements of the selected geometries.
- Set the basis for future desktop studies and the conceptual design phase.

WP PMs 6.49

WP Cost 19,788.31 €

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In WP2, the definition of the requirements and the functions that will be used as input to the conceptual sustainable design of the A-pillar automotive structure were determined. As a result, the submission of D1.2: List of Requirements and Functions has been completed.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP2, the following tasks are included:

T2.1: Function analysis

T2.2: Selection and analysis of representative geometries

During the reporting period, a description of the holistic character of sustainability into the automotive industry was obtained. Subsequently, the reference case of the A-pillar structure was analyzed. For the conceptual design of the A-pillar structure, its stakeholders and their needs were identified, translated into corresponding requirements. In particular, these requirements cover sustainability factors, integrating performance, economic, social, environmental, and circularity aspects. Then, the A-pillar functions and their relations with the design requirements were identified.

To the end, the analysis of different types of A-pillar geometries was studied, with emphasis on rectangular, circular and trapezoidal shapes. This evaluation will be conducted in the next design stage, where Structure-Property-Function (SPF) relationships will be analyzed in WP#3.

Deliverables

Deliverable D1.2: List of Requirements and Functions was submitted, integrating the requirements and the functions of the A-pillar automotive structure.

Work package planned Action and Effort for the next reporting period (*if applicable*)

WP Number: 3	**WP Title:** Identification of required materials and formulation of SPF relationships
Beneficiaries: University of Patras	
Starting Month: 1	**Ending Month:** 18

WP Objectives

- Identification of representative materials suitable for sustainable design
- Physically-based investigations of structure-property-function relationships

WP PMs 8.54

WP Cost 21,864.00 €

In WP3, the desired materials and A-Pillar shapes were identified for sustainable design. These materials were derived from the automotive industry, with mechanical properties obtained from ANSYS Granta, while the representative geometries (rectangular, semi-circular and trapezoidal) were selected based on a literature review. Then, by exploring the materials and representative A-Pillar geometries, 3D FE models were developed to investigate the relationships between (i) their composite Structure (layup, fiber-volume fraction), (ii) the resulting Properties (mechanical and non-mechanical), and (iii) their Functions.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP3, the following tasks are included:

T3.1 Selection and analysis of virgin and recycled metallic and composite materials

T3.2: Investigation and formulation of structure-property-function (SPF) relationships

During the reporting period, the desired materials were examined during the design phase and were intended to meet the defined requirements. In particular, alongside DP500 steel, two metallic alloys, Aluminum 6111 T8x (Al 6111 T8x) and Magnesium-Aluminum-Zirconium AZ91D (Mg-Al-Zn AZ91D), were also considered for the metallic base profile. Additionally, two composite materials were selected for the composite layer (FRP1)

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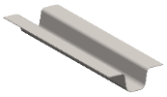
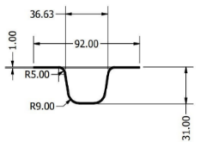
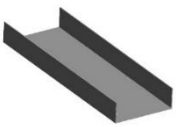
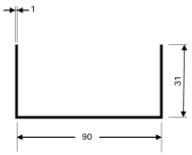
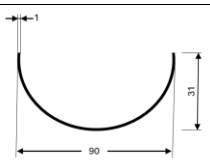
and the rib structure (FRP2). **Table 1** provides the mechanical properties of the examined materials, sourced from the ANSYS Granta Selector dataset. Based on the structural requirement that the outer geometric dimensions of the A-pillar structure must remain unchanged; the focus also lies on the **internal profile shape** of the A-pillar as illustrated in **Table 2.** The CAD models are parametric and were developed in the ANSYS Design Modeler environment. In this step, we have all numerical models with the corresponding A-pillar shapes and materials, and we check for the validation of numerical data through experiments and other published works. After that, the Structure-Property-Function (SPF) relationships are investigated, showing how the internal structure (e.g., material and geometry) affects the set of properties at the component level and the corresponding structural, efficiency, economic, and environmental functions. During the writing of this report, extended experimentation is being conducted to submit these results to a journal.

Table 1. Mechanical properties of the materials.

	Properties	DP500 Steel	Al 6111 T8x	Mg-Al-Zn AZ91D	Glass Fiber (GF) laminate in PA matrix (FRP1)	Polyamide with GF (FRP2)
Mechanical	*E (GPa)*	210	69	44.6	23.2	8
	v	0.3	0.33	0.3	0.15	0.33
	ρ (kg/m^3)	7850	2713	1775	1800	1170
	σ_{yield} (MPa)	385	260	155	485	85
Environmental Impact	Manufacturing process	Roll Forming	Roll Forming	Die Casting	Autoclave	Autoclave
	Disposal	Recycle	Recycle	Recycle	Downcycle	Downcycle
	CO_2 footprint	42.8	52.2	89.3	46.6	46.6
Costs	Part cost (€/kg)	1.205	3.27	10.04	157	157

Table 2. Investigated A-Pillar profile shapes.

Internal Profile Shape			
No	A-pillar type	Base profile	Profile Dimensions
G0	Reference		
G1	Rectangular		
G2	Semi-circular		

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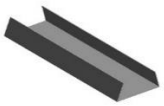
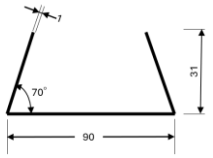
G3	Trapezoidal		

Work package planned Action and Effort for the next reporting period (*if applicable*)

Deliverable D3.1: Paper on SPF relationships is in progress and 80% ready for submission to a high-impact journal. We are reviewing numerical data and structuring the paper according to the journal's instructions.

Additionally, data on recycled materials are gathered from publications regarding automotive A-Pillar analysis in order to find how recycling affects SPFs. At this point, advice and guidance of recycled materials will be provided from Prof. Gude of and Dr. Tzortzinis of Technische Universität Dresden, with whom we have agreed to cooperate on this project.

WP Number: 4	**WP title:** Parametric design and simulations for database generation
Beneficiaries: University of Patras	
Starting Month: 4	**Ending Month:** 18

WP Objectives

- Parametric design and simulations including multiple configurations with mechanical properties
- Generation of a database with design and material configurations, and non-mechanical indexes

WP PMs 1.55

WP Cost 6,110.00 €

In WP4, parametric FEM simulations are in progress with different material configurations for the selected functions of the WP2. These parametric simulation models are applied for multiple scenarios, generating adequate artificial data to different loading conditions. Following the above and to enhance our feedback on sustainability design, two Conference publications were submitted during this reporting period, in accordance with the overall project schedule.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP4, the following tasks are included:

T4.1 Desktop studies with simulation process for representative geometries

T4.2 Generation of a dataset of desktop studies with SPF-related information

Two different desktop studies were conducted using various mechanical components, such as an A-pillar structure and a hat-stiffened panel. Using ANSYS Workbench Environment and Structural analysis solver, a set of data for structural analysis were obtained, including for example stresses, strains and eigenfrequencies. Also, for every simulation, non-mechanical properties were calculated, for example the sustainability indexes, environmental impact and cost.

Numerical results from both desktop studies were presented, in **MO9**, at the Tenth International Conference on Engineering Failure Analysis (ICEAFX) and in **M15**, at the ''Towards Sustainable Aviation'' Summit (TSAS2025), employing sustainability into the early design phases. All these results were combined with a test-benchmark set for further data analysis.

Deliverables

Deliverable D4.2: *Conference Disseminating Parameterized Test-Benchmark* was submitted. For both conferences, a dataset of materials describing SPF relationships in the automotive and aviation industries was included, achieving our milestone (M1).

Work package planned Action and Effort for the next reporting period (*if applicable*)

During the writing of this report, we are creating FE models to simulate the real anisotropic behavior of composite materials in order to generate a dataset with a large number of design points. Additionally, different types of composite materials, with or without recycled fibers, will be modeled and compared to assess how these configurations affect the required functions. Here, the collaborating researcher from TU Dresden, Dr. Tzortzinis, will assist with scripting the parametric simulations and generating the database through multiple numerical simulations.

The next planned actions include the preparation of Deliverable D4.1: *Scripts for Parametric Simulations*, where the interaction of the model with the optimization technique will be integrated into the A-pillar structure.

WP Number: 5	**WP Title:** Data-driven mapping of SPF relationships via ML-algorithm application
Beneficiaries: University of Patras	
Starting Month: 10	**Ending Month:** 18

WP Objectives

- Identification of SPF-relationships through data-driven approaches, which are too complex to be identified through traditional physically-based approaches
- Generation of a user-friendly, open-access tool for decision making during conceptual design

WP PMs 1.56

WP Cost 3,360.00 €

The starting month of WP5 is M10, and significant progress has been made. In particular, supervised Machine Learning (ML) algorithms have begun to be developed to train models on the generated dataset. ML models are trained with an emphasis on selecting suitable material composition and geometry for the A-pillar structure to fulfill the required functions such as performance, environmental impact, and cost. This procedure is implemented in a user-friendly, open-access tool, which can be expanded with new materials and geometries for different mechanical components.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP5, the following tasks are included:

T5.1 Data-driven mapping and analysis of SPF-relationships

T5.2 Development of a GUI-tool for Conceptual Design

During this period, the results, generated from the previous FE models, were used for the generation of two types of datasets: one with numerical values and one composed of images. The numerical results from different A-Pillar geometries were grouped together as shown in **Figure 1**. Also, a python code was written for the automated capture and save of the images to the corresponding folders (see **Figures 2 and 3**). PyWorkbench and PyMechanical libraries of python were used to interact specifically with the respective ANSYS environments facilitating the automation of repetitive tasks. This code was executed externally in Jupyter Notebook platform allowing the trigger of processes and the visualization of them in real-time within the ANSYS environment. Then, ML models are trained for sustainable performance prediction of A-Pillar Structures.

This is ongoing work that progresses alongside FE modeling.

total deformation (mm)	AVERAGE total energy (mJ)	x-deformation min (mm)	x-deformation max (mm)	y-deformation min (mm)	y-deformation max (mm)	z-deformation min (mm)	z-deformation max (mm)	σ1 Maximum
0.0853	14.945	-0.0178	0.0178	-0.0006	0.0850	-0.0056	0.0056	148.86
0.0696	12.040	-0.0131	0.0131	-0.0004	0.0693	-0.0050	0.0050	121.54
0.0581	9.952	-0.0099	0.0099	-0.0003	0.0578	-0.0046	0.0046	100.87
0.0496	8.401	-0.0077	0.0077	-0.0002	0.0493	-0.0042	0.0042	84.92
0.0430	7.218	-0.0060	0.0060	-0.0001	0.0427	-0.0039	0.0039	72.40
0.0378	6.296	-0.0048	0.0048	-0.0001	0.0375	-0.0037	0.0037	62.37
0.0337	5.562	-0.0041	0.0041	-0.0001	0.0334	-0.0034	0.0034	54.16
0.0303	4.966	-0.0038	0.0038	-0.0001	0.0300	-0.0032	0.0032	47.43
0.0274	4.476	-0.0036	0.0036	-0.0001	0.0272	-0.0030	0.0030	41.86
0.0251	4.067	-0.0034	0.0034	-0.0001	0.0248	-0.0029	0.0029	37.20
0.0230	3.721	-0.0031	0.0031	-0.0001	0.0228	-0.0027	0.0027	33.28
0.2131	36.494	-0.0388	0.0389	-0.0014	0.2122	-0.0154	0.0154	129.83
0.1779	30.175	-0.0294	0.0295	-0.0010	0.1770	-0.0141	0.0141	107.52
0.1515	25.480	-0.0228	0.0228	-0.0007	0.1506	-0.0130	0.0130	90.60
0.1311	21.898	-0.0179	0.0180	-0.0005	0.1303	-0.0120	0.0120	77.57
0.1143	18.978	-0.0144	0.0144	-0.0004	0.1135	-0.0111	0.0111	62.96
0.1018	16.775	-0.0125	0.0125	-0.0003	0.1011	-0.0104	0.0104	54.66
0.0916	14.987	-0.0116	0.0116	-0.0003	0.0909	-0.0098	0.0098	47.86
0.0831	13.514	-0.0108	0.0109	-0.0003	0.0824	-0.0092	0.0092	42.22
0.0759	12.284	-0.0101	0.0101	-0.0003	0.0752	-0.0087	0.0087	37.52
0.0698	11.243	-0.0095	0.0095	-0.0002	0.0691	-0.0083	0.0083	33.55
0.2766	47.071	-0.0463	0.0464	-0.0015	0.2752	-0.0219	0.0219	105.73
0.2356	39.747	-0.0358	0.0359	-0.0010	0.2343	-0.0202	0.0202	89.14
0.2038	34.140	-0.0282	0.0282	-0.0007	0.2025	-0.0187	0.0187	76.35
0.1776	29.568	-0.0226	0.0226	-0.0006	0.1764	-0.0172	0.0172	62.46
0.1581	26.123	-0.0194	0.0194	-0.0005	0.1570	-0.0161	0.0161	54.24
0.1422	23.329	-0.0181	0.0181	-0.0005	0.1411	-0.0152	0.0152	47.50
0.1290	21.028	-0.0168	0.0168	-0.0005	0.1279	-0.0143	0.0143	41.92
0.1178	19.107	-0.0158	0.0158	-0.0004	0.1167	-0.0135	0.0135	37.25
0.1046	17.408	-0.0893	0.0893	-0.0009	0.1046	-0.0036	0.0047	57.42
0.0927	15.425	-0.0778	0.0778	-0.0008	0.0927	-0.0034	0.0045	53.05
0.0826	13.754	-0.0681	0.0681	-0.0007	0.0826	-0.0032	0.0043	50.12
0.0741	12.335	-0.0600	0.0600	-0.0007	0.0741	-0.0030	0.0041	47.35
0.2122	35.785	-0.1771	0.1771	-0.0022	0.2122	-0.0085	0.0085	46.95
0.1924	32.680	-0.1573	0.1573	-0.0020	0.1924	-0.0079	0.0086	75.35
0.1739	29.594	-0.1398	0.1398	-0.0019	0.1739	-0.0075	0.0082	70.12
0.1579	26.925	-0.1247	0.1247	-0.0018	0.1579	-0.0072	0.0078	66.01
0.1443	24.632	-0.1118	0.1118	-0.0016	0.1443	-0.0070	0.0074	62.06

Figure 1. Preview of Value Dataset

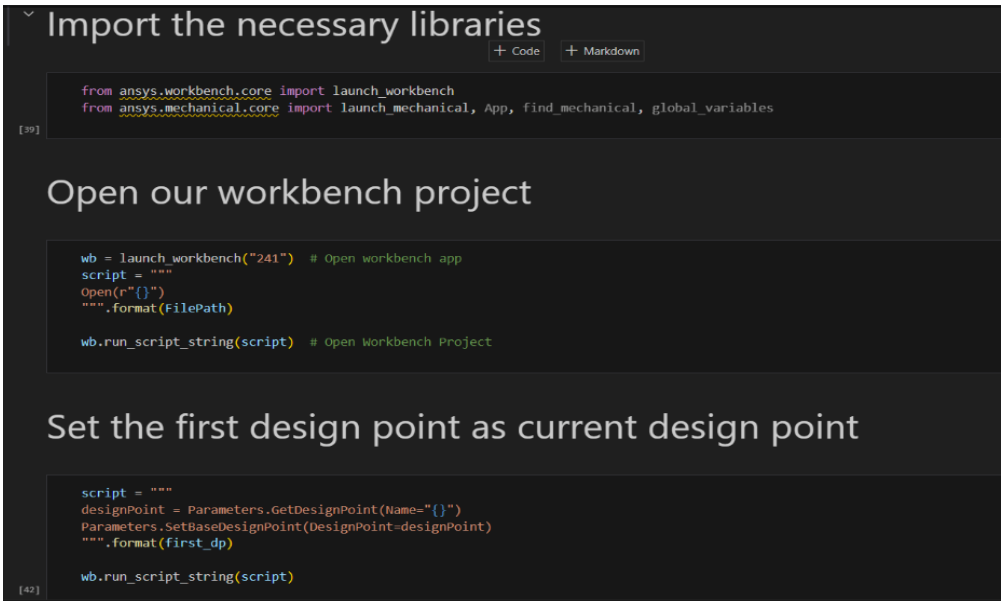


Figure 2. Python Code for Image Dataset Generation (1/2)

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Repetitive loop for capturing all the images

```
for i in range(first_dp,number_dp+first_dp):

    # Calculate thickness for each case based on the thickness of the first design point and the step that it increases
    thickness = t_first_dp + a * increment_t  # for G0 DP_500 starts from 1.0 mm to 2.0 mm
    a += 1


    # Define the folder where images will be saved for this design point
    save_adress = r"{0}\\{1} mm".format(save_dir,round(thickness, 1))

    # System name retrieval for mechanical launch
    sys_name = wb.run_script_string(
        r"""
import json
system = GetSystem(Name="SYS")
wb_script_result = json.dumps(system.Name)
    """
    )

    # Start Mechanical server and launch instance
    server_port = wb.start_mechanical_server(system_name=sys_name)
    mechanical = launch_mechanical(start_instance=False, ip="localhost", port=server_port)

    # Python script to run in Mechanical, modified for each design point
    mech_script = """
save_adress = r"{save_adress}"

#location of each screenshot
iso_loc = r"{{}}\\iso_td.png".format(save_adress)
top_loc = r"{{}}\\top_view_td.png".format(save_adress)
[45]  side_loc = r"{{}}\\side_view_td.png".format(save_adress)
```

Figure 3. Python Code for Image Dataset Generation (2/2)

Work package planned Action and Effort for the next reporting period (*if applicable*)

The next planned actions include the preparation of the following Deliverables:

D5.1: Trained ML-Models that map the SPF-relationships

D5.2: GUI tool for assistance and decision-making at the conceptual design phase

Additionally, the following milestone is planned:

M2: GUI-tool for assistance on decision making during the conceptual design phase

WP Number: 6	**WP Title:** Design and synthesis of demonstrator
Beneficiaries: University of Patras	
Starting Month: 12	**Ending Month:** 24

WP Objectives

- Proof-of-concept at the conceptual design phase
- Verification of the method and the tool at an exemplary demonstrator

WP PMs 0.0

WP Cost -

The starting month of WP6 is M12; therefore, no progress was expected at this stage. However, the first version of the demonstrator, utilizing metals as well as virgin and recycled fibers—based on the proposed solutions from the previous phase—will be implemented. As a result, during the first months of the project's second year, the research team is expected to begin data collection to verify the method. At this point, Prof. Nikolakopoulos will provide support with access to the software infrastructure and consultation on metallic materials through system design theory.

Work Description – Degree of Work Package Objectives Implementation

Description of Work and Tasks

In WP6, the following tasks are included:

T6.1: Conceptual design of demonstrator using the developed tool

T6.2 Basic design of demonstrator for method verification

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This is ongoing work that progresses alongside FE modeling of A-pillar structure. A first version of the demonstrator will be presented at the International Conference of Engineering Against Failure (ICEAF) VIII.

Work package planned Action and Effort for the next reporting period (*if applicable*)

The next planned actions include the preparation of the following Deliverables:

D6.1: Conference publication on the conceptual design of an A-frame design demonstrator

D6.2: Paper submission on basic design of a demonstrator and virtual verification of the developed method

Also, the following milestone is planned:

M3: Virtual demonstration of the developed method on the case of an A-frame design demonstrator

WP Number: 7	**WP Title:** Dissemination and Communication Management
Beneficiaries: University of Patras	
Starting Month: 1	**Ending Month:** 24

WP Objectives

- Develop an online web platform for the awareness and visibility of the project results
- Determine a dissemination plan of the project and communication strategy for maximum impact

WP PMs 0.50

WP Cost 2,289.98 €

In WP7, the development of an online web platform is provided for the visibility of the project results and the dissemination activities are presented.

Work Description – Degree of Work Package Objectives Implementation

Description of Work

In WP7, the following tasks are included:

T7.1: Project website and communication activities

T7.2: Dissemination activities

During this period, a project webpage was launched on the laboratory's website and a dedicated project logo was created to establish a visual identity. The homepage of the Fun4Design website (**Figure 4**) includes the official title of the project, strong messages to disseminate the project's research aims, and key features, and informs the visitor that the project is funded by the framework of H.F.R.I Call "Basic research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0". This section will be updated over the duration of the project related to the project research activities. Also, the research activities in two International Conferences were promoted through the LinkedIn page and project website. All this material can be found in **Annex B1**.

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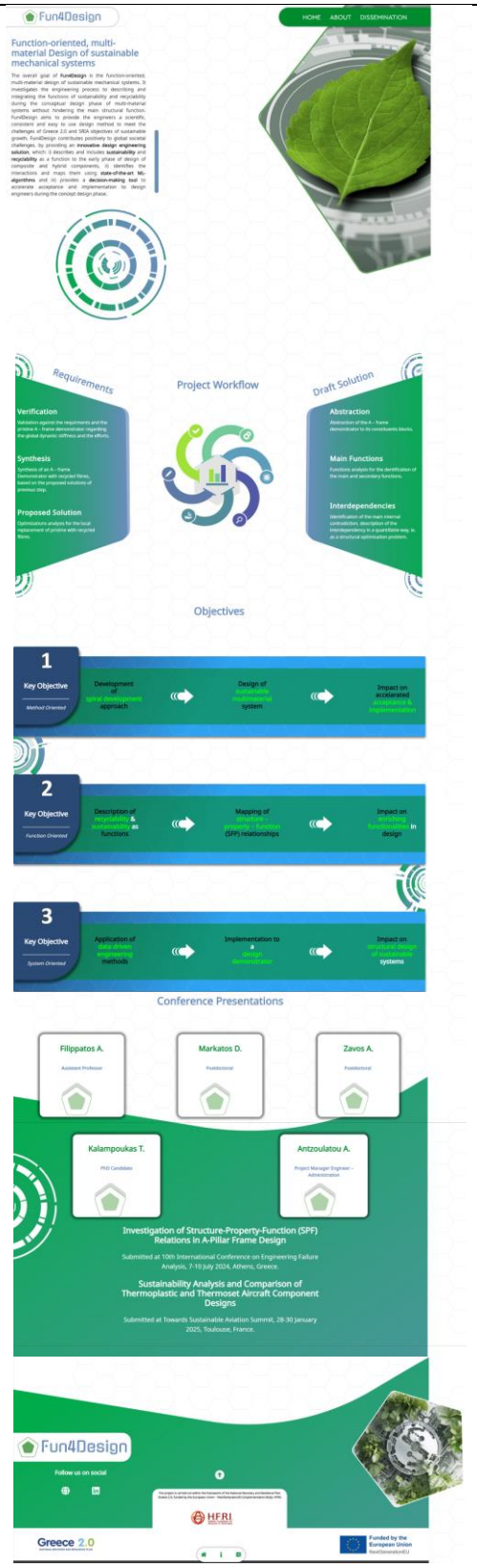

Figure 4. Fun4Design website homepage

Work package planned Action and Effort for the next reporting period (*if applicable*)

The next planned actions include the preparation of the following Deliverables:

D7.1: Periodic update of project website with dissemination and communication results

D7.2: Report on Communication Strategy, Journal and Conference Publications, Project Website and Promotional Material

Additionally, periodic updates on our research activities will be announced on the project website and the laboratory's LinkedIn page.

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A.5. WORK PACKAGE TABLE

WP Number	WP Title	Lead Beneficiary	Starting Month	Ending Month	Completed (Yes/No)	Brief Comments
1	**Project management and career development**	**UPAT**	**1**	**24**	**No**	
2	**Analysis of main and secondary functions for representative geometries**	**UPAT**	**1**	**14**	**Yes**	
3	**Identification of required materials and formulation of SPF relationships**	**UPAT**	**1**	**18**	**No**	
4	**Parametric design and simulations for database generation**	**UPAT**	**4**	**18**	**No**	
5	**Data-driven mapping of SPF relationships via ML-algorithm application**	**UPAT**	**10**	**18**	**No**	
6	**Design and synthesis of demonstrator**	**UPAT**	**12**	**24**	**No**	
7	**Dissemination and Communication Management**	**UPAT**	**1**	**24**	**No**	

A.6. DELIVERABLES TABLE

A/A	WP no.	Deliverable Name	Deliverable Type	Dissemination Level	Lead Beneficiary	Due Delivery Date (in months)	New Due Date (if delayed)	Actual Delivery Date (in months)	Brief Comments
1	1	D1.1 Project handbook	Document	Confidential	UPAT	02		16	Submitted in Interim Report
2	7	D7.2 Communication Strategy	Document	Confidential	UPAT	24			
3	7	D7.1 Periodic update of project website	Website	Public	UPAT	24			
4	1	D1.3 Career development plan	Document	Confidential	UPAT	24			
5	2	D2.1 List of requirements and functions	Document	Public	UPAT	14		16	Submitted in Interim Report
6	3	D3.1 Paper of SPF relationships	Paper	Public	UPAT	18			
7	4	D4.1 Scripts for parametric simulations	Demonstrator	Confidential	UPAT	18			
8	4	D4.2 Conference disseminating parametrized test-benchmark	Conference	Public	UPAT	18		16	Submitted in Interim Report
9	5	D5.1 Trained ML-Models	Publication	Public	UPAT	18			
10	5	D5.2 GUI tool for decision making	Demonstrator	Public	UPAT	18			
11	6	D6.1 Conference disseminating conceptual design of demonstrator	Conference	Public	UPAT	20			
12	6	D6.2 Paper with basic design of demonstrator	Publication	Public	UPAT	24			
13	1	D1.2 Annual report to ELIDEK	Document	Public	UPAT	15, 24			Interim Report submitted to ELKE-UPAT (M15)28.02.2025

A.7. MILESTONES TABLE

A/A	WP	Milestone Title	Lead Beneficiary	Means of Verification	Due Delivery Date (in months)	New Due Date (if delayed)	Actual Delivery Date (in months)	Brief Comments
1	3	Dataset of materials with described SPF-relationships	UPAT	Completion of T3.2, T4.2 and issuance of D3.1, D4.2	12		12	Achieved with issuance of D4.2
2	5	GUI-tool for assistance on decision making during conceptual design	UPAT	Completion of T5.2 and issuance of D5.2	18			
3	6	Virtual demonstration of developed method	UPAT	Completion of T6.2 and issuance of D6.2	24			

A.8. RISKS TABLE

A/A	WP	Risk Description	(Foreseen-Unforeseen) (Yes/No)	Contingency Plan	Risk Actually Encountered (Yes/No)	Mitigation Measure/es	Brief Comments
1	2,3,4	Specific task or work package delays, and issues arise on achieving the milestones	Yes	Re-planning of the affected parts	Yes	PI steps in and increases own effort at the project	
2	2,3	Verification of numerical method	No	Testing different numerical models with numerical and experimental data from TU Dresden	Yes	Assumptions based on relevant researchers working on automotive a-pillar analysis	
3	3	Lack of composite material properties and recycled materials	Yes	Assumptions based on trends at literature	Yes	Searching relevant publications regarding automotive A-Pillar analysis	

A.9. COMMUNICATION AND DISSEMINATION ACTIVITIES (*maximum 1 page*)

Communication activities

Within two months of the project's start, a dedicated project logo was created to establish a visual identity and support dissemination efforts. Additionally, a project webpage was launched on the laboratory's website at the following link: Fun4Design - IDEAS . This page serves to inform both the general and scientific community about the project's activities and progress while strengthening its connection with the Lab. The project logo, shown in **Figure 5**, is also attached as a separate file.

Figure 5. Project logo

Dissemination activities

During the reporting period, numerical results representing the conceptual design methodology using parametric numerical models in an A-pillar structure and an aviation component (Hat-Stiffened Panel) were presented and disseminated scientifically through participation in two (2) International Conferences. More specifically, in **MO9**, the first database of materials and A-pillar geometries was created and presented at the Tenth International Conference on Engineering Failure Analysis (ICEAFX). This research focuses on exploring and establishing Structure-Property-Function (SPF) relationships integrating Environmental Impact for Sustainable Design.

In **M15**, a research framework for a fuselage component made by thermoset and thermoplastic composites was presented at the ''Towards Sustainable Aviation'' Summit (TSAS2025) employing sustainability into the early design phases. This desktop study is performed for a hat-stiffened panel by developing a simulation model using Finite Element Analysis in order to determine the mechanical properties with the candidate composite and metallic materials and for typical loading conditions. The simulation models are then parametrised to generate different material configurations with emphasis on the sustainability design. Particularly, Response Surface Model from ANSYS provided the desired metrics for I) Performance, II) Cost; III) Environmental Impact; IV) Circularity and V) Social Impact were imported manually into the dataset, as they are independent of the geometry, but dependent on the material. Following the above, the normalization of the metrics followed, and the Sustainability Index was calculated for an equal weights scenario. All these results are combined with a test-benchmark set for further data analysis and design studies, following the main objective of **Fun4Design**.

The conference events were also promoted through the LinkedIn page of the involved laboratory, which is provided in **Annex B1.**

A.10. IMPACT (*maximum 2 pages*)

Fun4Design assembles a team of researchers with the necessary expertise to tackle the identified gaps by proposing an innovative engineering solution. This solution integrates sustainability as a core function in the early stages of design—specifically, the conceptual design phase—for composite and hybrid components used in complex mechanical systems within the automotive and aviation industries.
Sustainability is one of the greatest challenges of our time, addressing the urgent issues of climate change and resource scarcity. Based on this holistic consideration of sustainability, ‘‘Engineering of Sustainability ’’ concept has been proposed by the Mechanical Engineering and Aeronautics Department (MEAD) at the University of Patras (UPATRAS), and it has been further developed through this research project, as demonstrated by following conferences:

[1] Zavos, A, Markatos, D, Kalampoukas, T, Pantelakis, S, Filippatos, A. Investigation of Structure Property-Function (SPF) Relations in A-Pillar Frame Design. In: Proceedings of 10th International Conference on Engineering Failure Analysis (ICEFA X), 7-10 July 2024, Athens.

[2] Markatos, D, Filippatos, A, Theochari, A, Pantelakis, S. Sustainability Analysis and Comparison of Thermoplastic and Thermoset Aircraft Component Designs. In: Proceedings of "Towards Sustainable Aviation" Summit 2025 (TSAS2025), 28-30 January 2025, France.

During the reporting period, through the aforementioned international scientific conferences, the research group at UPAT exchanged knowledge, opinions, and comments with other scientists from various Universities. Discussions focused on sustainable design and the development of novel and efficient design solutions, including recycled materials and sustainability index as a tool for prediction. As a result, our research team gained a deeper understanding of the following:

- Developing methodologies for the structural design of sustainable mechanical systems
- Defining the requirements and functions to be used as inputs for the conceptual sustainable design of mechanical components, such as the A-pillar structure in automotive applications and the hat-stiffened panel in aircraft design
- Modeling multi-materials structures (including metals and composite materials) to predict various performance parameters such as stresses, strains, and eigenfrequencies. This is further enhanced by the use of ANSYS Granta software, a valuable tool for identifying material properties related to mechanical performance, processing costs, and recyclability—an innovative aspect of Fun4Design.

In addition, education and training were significantly enhanced through the Fun4Design project. More specifically, the research activities within the curriculum of the Department of Mechanical Engineering and Aeronautics (MEAD) at UPAT, as well as those of ILK at TU Dresden were promoted through new PhD theses related to sustainability in the conceptual design phase. During the reporting period, PI began supporting PhD student Ms. Jenny Madia, with an emphasis on the Structure-Property-Function relationships in multifunctional elements. Through this collaboration, our research team generated new ideas for sustainable design and recyclability.

The overall project advances the generated knowledge in the design of multi-functional technical systems, shifting from a property-oriented to a function-oriented design approach. In the second year of the project, the focus will be on:

- Advancing design and machine learning technologies to identify the added value in ‘‘Engineering of Sustainability ’’
- Addressing global societal challenges by providing a decision-making tool that fosters new ideas for sustainable design

Overall, the knowledge and support provided by Fun4Design will pave the way for the development of green, sustainable technical systems.
These systems will support applied research, leaving a lasting impact in Greece by enhancing the competitiveness of Greek academic institutions.

A.11. FOLLOW-UP OF RECOMMENDATIONS FROM PREVIOUS REVIEW(S) (*if applicable*)

Describe how recommendations from previous reviews have been addressed (if applicable).

A.12. USE OF RESOURCES (*Individual statement for each Beneficiary*)

Provide, where deemed necessary, any information regarding the use of resources during the reporting period. Include explanations on deviations of the use of resources between actual and planned use of resources based on the Funding Decision Document (if applicable). Include explanations on transfer of costs between categories (if applicable).

- For the purchase of the required software licenses for the scheduled 24 months of the project, with a total funding of 10,000 EUR, a transfer was made at the beginning of the program from the category "Other costs (5.2.6 Λοιπές δαπάνες)" to the zero-budget expenditure category "Subcontracting (5.2.5 Δαπάνες για υπηρεσίες τρίτων)" without modifying the Technical Report, in order to proceed with the software purchase. The transfer was accepted as it constituted a budget correction, provided that it would be included in a future modification request.

- Transfer of 2039.22 EUR to "Subcontracting (5.2.5 Δαπάνες για υπηρεσίες τρίτων)" from the category "Other costs (5.2.6 Λοιπές δαπάνες)." The reduction of the initially approved amount in the category from which the amount is transferred cannot exceed 10% of its original budget.

- Transfer of 29.02 EUR from “Equipment (5.2.4 Δαπάνες απόσβεσης εξοπλισμού)” to the category "Other costs (5.2.6 Λοιπές δαπάνες)." The reduction of the initially approved amount in the category from which the amount is transferred cannot exceed 10% of its original budget.

- The category "Dissemination & Travel (5.2.3 Δαπάνες διάχυσης και μετακινήσεων)" also includes the development of the website, which will be maintained online for at least five (5) years after the completion of the project.

FINANCIAL STATEMENT BENEFICIARY [UPAT]	
Cost Category	**Total (€)**
1. Personnel Costs	
1.1 Principal Investigator	**4.999,98 €**
1.2. Post-doctoral Researchers	**20.462,00 €**
1.3. Scientific Associate, (PhD Students, Postgraduate students), Technical Associate & other staff	**29.460,00 €**
1.4. Personnel of beneficiaries (HIs and COs - Beneficiaries) employed under a Public Law relationship or Private Law Open/Closed Term relationship	
2. Consumables	
3. Dissemination & Travel	**4.141,98 €**
4. Subcontracting	
5. Equipment	**1.470,98 €**
6. Other Costs	**7.960,80 €**
7. Indirect Costs	**7.958,19 €**

PART B

ANNEX B1 (Other Information)

The project and conference presentation at ICEFAX were promoted through the LinkedIn page of the laboratory (**Figure 6**).

LinkedIn link : https://www.linkedin.com/posts/ideasmdl_fun-4-design-activity-7203420652383408128-kLxd?utm_source=share&utm_medium=member_ios&rcm=ACoAABKZKe8BzFULRstmKgJJpMRiARqrSYSjhVM

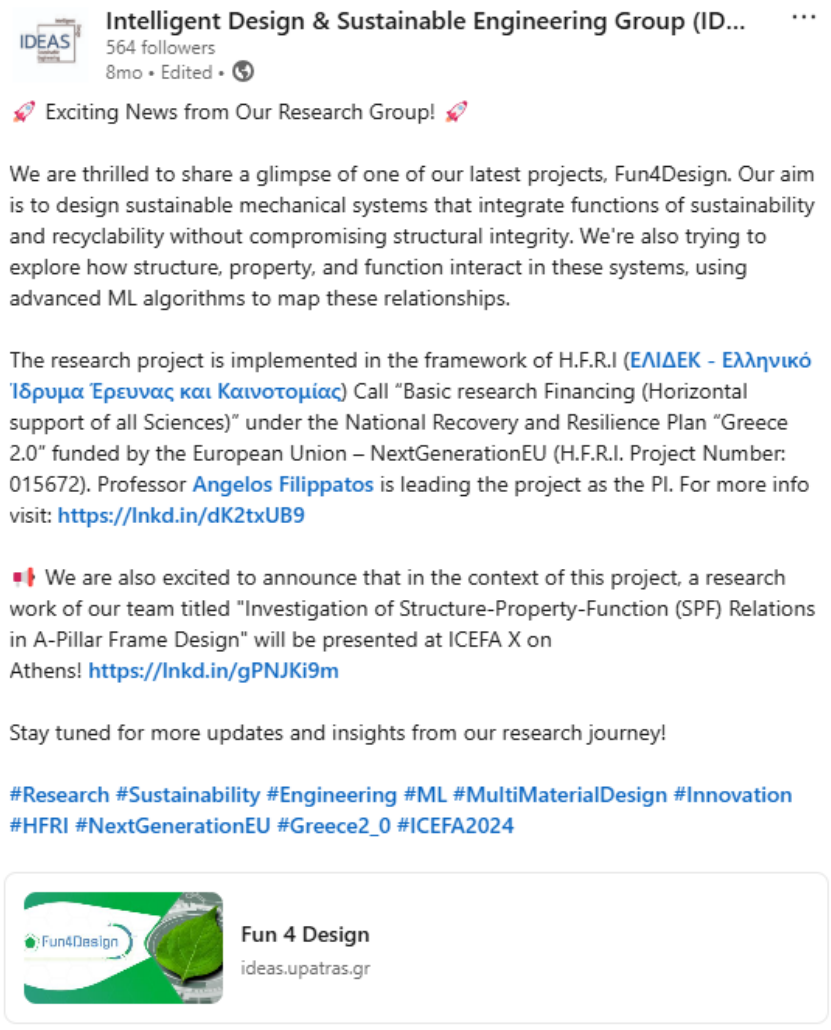

Figure 6: Communication of the project website and conference presentation on the involved laboratory's LinkedIn account.

The conference event in the ‘’Towards Sustainable Aviation’’ Summit 2025 was also promoted through the LinkedIn page (**Figure 7**).

LinkedIn link : https://www.linkedin.com/posts/ideasmdl_ideasgroup-nextgenerationeu-sustainabilityinengineering-activity-7291016838677716992-Puk4?utm_source=share&utm_medium=member_desktop&rcm=ACoAABKZKe8BzFULRstmKgJJpMRiARqrSYSjhVM

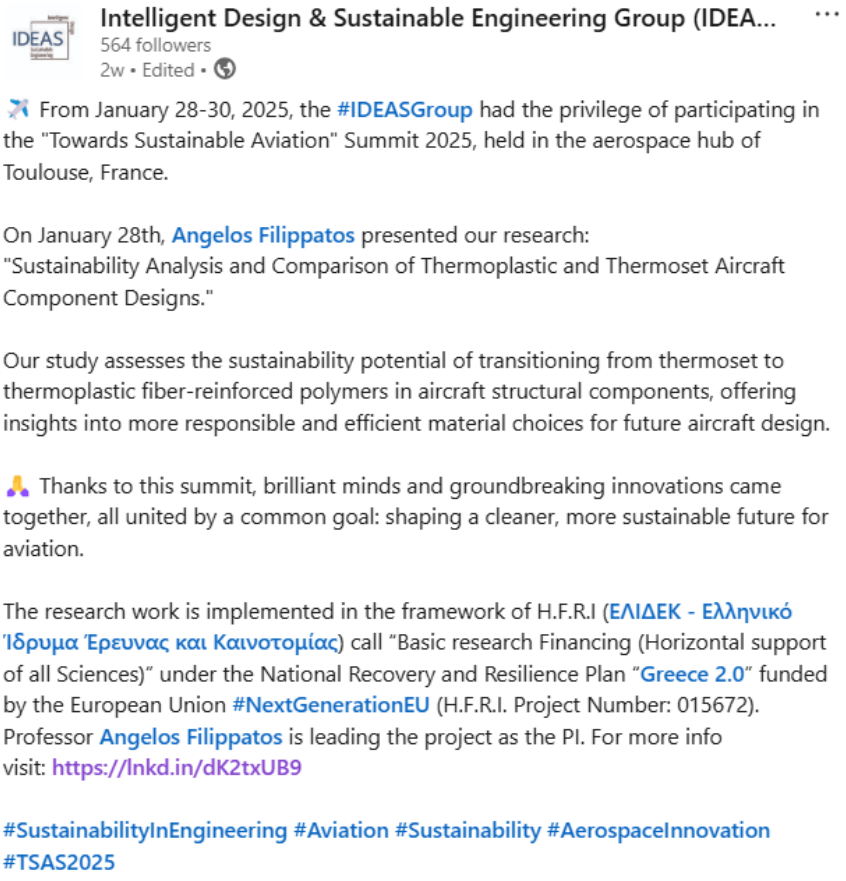

Figure 7: Conference presentation on the involved laboratory’s LinkedIn account regarding Fun4Design project.

ANNEX B2 (Project Deliverables)

D1.1 – Project Handbook

Document Author(s)	Angelos FILIPPATOS
Document Contributor(s)	Dionysios MARKATOS, Anastasios ZAVOS

Abstract

The overall goal of **Fun4Design** is the function-oriented, multi-material design of sustainable mechanical systems. It investigates the engineering process to describing and integrating the functions of sustainability and recyclability during the conceptual design phase of multi-material systems without hindering the main structural function. **Fun4Design** aims to provide the engineers a scientific, consistent and easy to use design method to meet the challenges of Greece 2.0 and SRIA objectives of sustainable growth in two project phases. Phase I, WP2, WP3 and WP4, focuses on the Design and Development of the method performing the basic, fundamental tasks required for the conceptual design phase and selecting suitable virgin and recycled materials, both metallic and composite. Phase II, WP5 and WP6, focuses on the Synthesis and Validation of the method. **Fun4Design** selects as a design demonstrator a structure typical for automotive A-frames consisting of steel and composite materials. It implements data-driven solutions for the design phase compares it against typical design approaches. **Fun4Design** brings together a new team of researchers with the necessary experience to achieve three key objectives: i) how to design with the method-oriented spiral development approach, ii) how to describe and map the relationship between material properties and the functions of sustainability and recyclability, and iii) how to integrate these functions to a system with multiple contradicting functions.

Fun4Design contributes positively to global societal challenges, by providing an innovative design engineering solution, which: i) describes and includes sustainability and recyclability as a function to the early phase of design of composite and hybrid components, ii) identifies the interactions and maps them using state-of-the-art ML-algorithms and iii) provides a decision-making tool to accelerate acceptance and implementation to design engineers during the concept design phase.

Keywords: sustainable engineering, conceptual design, recycled composites, machine learning, multi-criteria decision making, mechanical systems, function-integration, design-from-recycling, recyclability, sustainability

File: WP1_Fun4Design_D1.1#_Project Handbook#.pdf

D2.1 – List of Requirements and Functions

Document Author(s)	Angelos FILIPPATOS
Document Contributor(s)	Anastasios ZAVOS, Dionysios MARKATOS

Abstract

The present deliverable focuses on the collection of requirements and functions for the conceptual design phase at the example of an A-pillar design demonstrator from the automotive sector, as described in WP#2 of Fun4Design Project. WP#2 belongs to Design and Development phase which contributes to enhance the sustainability in automotive sector through the use of multi-functional materials. Specifically, this report focuses on: a) Defining the technical requirements of the a-pillar, (b) Identifying the primary functions and characterize them to enable a sustainable performance and (c) Creating the main simulations for future desktop studies. The present report also demonstrates that choosing a sustainable a-pillar structure necessitates balancing various factors including performance, environmental, economic, social impact, and circular economy considerations.

Keywords: Conceptual design, Sustainability, A-pillar, Automotive, Requirements, Functions

File: WP2_ Fun4Design_D2.1#_List of requirements and functions#.pdf

D4.2 – Conference disseminating parametrized test-benchmark

Document Author(s)	Angelos FILIPPATOS
Document Contributor(s)	Dionysios MARKATOS, Anastasios ZAVOS

Abstract

Deliverable D4.2, titled *"Conference Disseminating Parametrized Test-Benchmark"*, as part of WP#4 of the Fun4Design project, aims to present two different parametric studies, with an emphasis on mechanical components such as an A-Pillar structure and a hat-stiffened panel. These numerical studies were presented at two International Conferences.

This deliverable provides a brief introduction to the conference papers and includes the presentation slides.

Keywords: Numerical studies, Parametric, A-Pillar, Hat-Stiffened panel, Conference papers

File: WP4_ Fun4Design_D4.2#_Conference disseminating parametrized test-benchmark #pdf

- ***ICEFAX_Conference paper***
  - ***ICEFAX Presentation_Fun4Design***
  - ***ICEFAX_Abstract with Acknowledgement***
- ***TSAS2025_Conference***
  - ***TSAS2025_Abstract with Acknowledgement***
  - ***TSAS2025_AF_20240124_with Acknowledgement Fun4Design***

ΥΠΕΥΘΥΝΗ ΔΗΛΩΣΗ/DECLARATION

Ο Επιστημονικός Υπεύθυνος του Έργου και ο Νόμιμος Εκπρόσωπος του Φορέα Υποδοχής δηλώνουν υπεύθυνα ότι:

1. Τα αντίγραφα των παραστατικών που υποβάλλονται είναι ακριβή αντίγραφα των πρωτοτύπων.
2. Τα πρωτότυπα παραστατικά είναι πάντα στην διάθεση του ΕΛ.ΙΔ.Ε.Κ.
3. Τα παραστατικά δεν αντιστοιχούν σε δαπάνες που έχουν χρηματοδοτηθεί από άλλο χρηματοδοτικό οργανισμό (δημόσιο ή ιδιωτικό).
4. Οι δαπάνες του έργου παρακολουθούνται λογιστικά σε ξεχωριστό λογαριασμό και είναι εις γνώση των υπογραφόντων ότι όσες από αυτές δεν έχουν καταχωρηθεί στο λογαριασμό αυτό θα κριθούν μη επιλέξιμες.
5. Όλα τα στοιχεία που περιλαμβάνονται στην Έκθεση Προόδου είναι ακριβή και αληθή
6. Τηρούνται όλοι οι όροι και οι περιορισμοί της Προκήρυξης και του Οδηγού Διαχείρισης της παρούσας Δράσης.

	Επιστημονικός Υπεύθυνος	**Ο Νόμιμος Εκπρόσωπος του Φορέα Υποδοχής**
Ονοματεπώνυμο	Άγγελος Φιλιππάτος	Χρήστος Μπούρας
Ημερομηνία		
Υπογραφή		

This document is complemented with the Financial Report (Part C).