11th International Conference of
Management and Industrial Engineering

ISSN 2344-0937
ISSN-L 2344-0937
Volume 11
Website: https://icmie-faima-upb.ro

TOWARDS AN INTEGRATED MODULAR SOLUTION FOR MONITORING AND ECOLOGICAL ACTIONS IN DANUBE DELTA

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Abstract: *Wetlands, as ecologically diverse regions that provide a range of important ecosystem services, are under threat from a range of environmental pressures, including floods, fires, and poaching. In addition to these challenges, wetlands face issues related to the health of their fish and bird populations and the stage of their vegetation. Addressing these problems requires an integrated approach that combines advanced monitoring technologies with targeted ecological actions. To effectively monitor and protect the Romanian Danube Delta, an integrated platform of modular solutions is proposed. This paper explores the development of a platform that combines advanced monitoring technologies with targeted ecological actions to preserve and enhance the natural beauty of the Danube Delta. The platform addresses a range of issues, including the occurrence and control of floods, initiation and extinguishing of fires, detection, and control of poaching, monitoring of fish and bird populations and the stage of vegetation - with measures to help their development, monitoring and improving tourist activities, identifying pollution sources, and acting on them.*

Keywords: *wetlands, monitoring, ecological actions, integrated platform, modular solution*

INTRODUCTION

Wetlands are ecologically diverse regions that provide a range of important ecosystem services. These delicate ecosystems are under threat from a range of environmental pressures, including floods, fires, and poaching. In addition to these challenges, wetlands face issues related to the health of their fish and bird populations and the stage of their vegetation. Addressing these problems requires an integrated approach that combines advanced monitoring technologies [1] with targeted ecological actions [2].

The Romanian Danube Delta is one of the most ecologically diverse regions in Europe, home to a wide variety of flora and fauna. However, this delicate ecosystem is under threat from a range of environmental pressures. In order to effectively monitor and protect the Danube Delta, an integrated platform of modular solutions is needed. This paper explores the development of a platform that combines advanced monitoring technologies with targeted ecological actions to preserve and enhance the natural beauty of the Danube Delta [3].

The platform addresses a range of issues, including the occurrence and control of floods, initiation and extinguishing of fires, detection, and control of poaching, monitoring of fish and bird populations and the stage of vegetation - with measures to help their development, monitoring and improving tourist activities, identifying pollution sources, and acting on them. Through this integrated approach, the platform aims to preserve and enhance the natural beauty of these regions. However, these delicate ecosystems are under threat from a range of environmental pressures.

The *Delta ProEco* is the name of the organizational umbrella that through entrepreneurial and technological

developments will provide a platform of integrated modular solutions intended to the monitoring and ecological actions in Romanian Delta, including occurrence and control of floods, initiation and extinguishing of fires, detection, and control of poaching, monitoring of fish and bird populations and the stage of vegetation - with measures to help their development, monitoring and improving `tourist activities, identifying pollution sources and acting on them [3].
As far as we know, such an integrated platform doesn't exist for Romanian Danube Delta. Anyway, where possible, our intention is to use any existing component (web services, applications, physical system etc.) which could be reused from the current market of individual solutions which already solve some of our objectives [4].
In this paper we focus onto a Pilot project, the *FF-RIWER* experiment (founded by *HUBCAP* Horizon 2020 European Project, into the "*Hubcap Open Call EXPERIMENT #2.2*"), which realized a first TRL 4 maturity level Prototype (laboratory tested and validated in 2022), which we will use to develop around it the next levels of complexity and maturity toward the *Delta ProEco* target mention above.
The rest of the paper is organized as follows. Next chapter, EXPERIMENTAL, deals with the design and details of the experiments in the FF-RIWER pilot project, from the perspective of entrepreneurial strategy and technology design. The chapter entitled RESULTS presents the results of the FF-RIWER experiments and their evaluations, from an entrepreneurial and technological perspective. Chapter DISCUSSION describes plans and further developments from an entrepreneurial and technological perspective. The work ends with a series of CONCLUSIONS of the paper, but also of ways to continue the activities started within it.

EXPERIMENTAL

Entrepreneurial and Technological Context

The entrepreneurial vehicle used to realize the first pilot project, for the future *Delta ProEco* platform of integrated modular solutions, is the "*Always Connected Consultants SRL*" (ACC SRL for short in this paper) company, which is a *"Software architectures, development and delivery consulting start-up, created in March 2021, with the aim to be "Always and All Ways Connect.ed/ing." – through agile, innovative and interdisciplinary approaches and initiatives."* [3]. From the technological point of view, the set of components to be developed includes business intelligence and artificial intelligence modules applied on Cyber-Physical Systems (built exploiting both many kinds of sensors and a variety of actuators) [4].

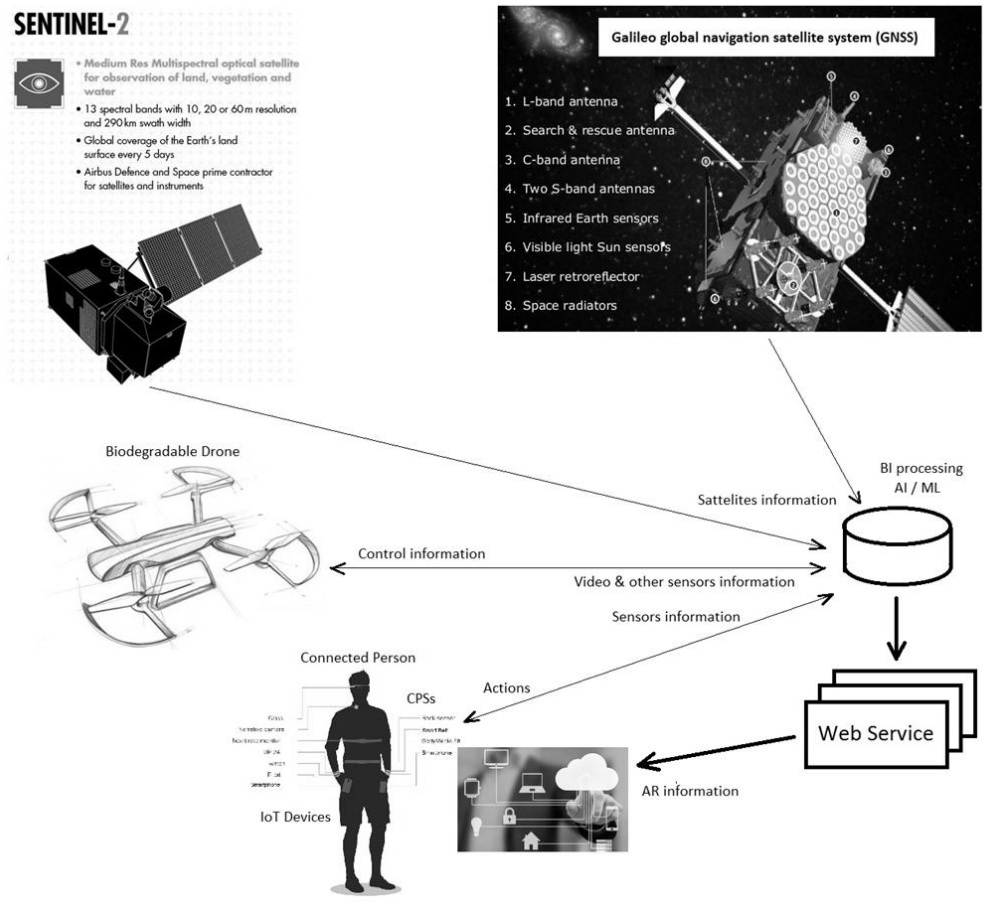

Figure 1: The main components of the monitoring and eco actions solutions [3]

The main components of our solutions are those presented in Figure 1:

- satellites - for high level field data acquisition (processed by our software modules, to extract business intelligence intended to the main goal: monitoring the Romanian Delta),
- various types of coordinated air/water/terrain drones - for lower-level field data acquisition and for some actions from air and water,
- IoT-powered personnel - for detailed field data acquisition and direct human actions,
- augmented reality tools/devices - for augmentation of drones and human data knowledge and actions, and for sandbox simulations necessary in human personnel training.

Each individual target will benefit from our platform integration and from their specific solutions. Such benefits of our specific envisaged solutions are:

- for the floods, fires and pollution sources, the satellites and drones will help local authorities to identify their occurrence, while drones and IoT-powered personnel will enable the eco actions to control their effects.
- for poaching, the drones will help local authorities to detect fraudulent people and actions, while drones and IoT-powered personnel will help to respond to them.
- for the fish and bird populations and the stage of vegetation, the satellites and drones will help local authorities to identify their current situation, while drones and IoT-powered personnel will enable eco actions on them.
- for tourist activities, the satellite, drones and IoT-powered personnel will help specialized agencies to identify and monitor their current situation, while drones and IoT-powered personnel will enable the eco actions etc.

Examples of **application domains** and **customer categories**:

1. Local authorities:
   - for the floods, fires and pollution sources, the satellite and drones will help local authorities to identify their occurrence, while drones and IoT-powered personnel will enable the eco actions to control their effects
   - for the poaching, the drones will help local authorities to detect fraudulent people and actions, while drones and IoT-powered personnel will help to respond to them
   - for the fish and bird populations and the stage of vegetation, the satellite and drones will help local authorities to identify their current situation, while drones and IoT-powered personnel will enable the eco actions on them
2. Specialized tourism agencies:
   - for tourist activities, the satellite, drones and IoT-powered personnel will help specialized agencies to identify monitor their current situation, while drones and IoT-powered personnel will enable the eco actions etc.

The set of components described above will benefit from the usage of the concepts (together with their implementations) of business intelligence and artificial intelligence, applied on an infrastructure Cyber-Physical Systems level (built exploiting both many kinds of sensors and sensing equipment and a variety of actuators and actuating devices). Cyber-Physical Systems [Bologa 2011] [Cernian 2021] [Wang 2020] achieves tight couplings between cyber domain and physical domain by strictly embedding the cyber processes (i.e., communication, computation, and control) into physical devices. Thus, real-time, reliable monitoring and control to physical entities can be conducted, and the efficiency of resource coordination and performance optimization can be improved.

Entrepreneurial Methodology

The vision of the ACC SRL company combines 2 very important concepts for me, the importance of very well-understood Contexts and the importance of the software Architectures (the IT Architectures by extension, comprising both hardware and software) from the point of view of the success of a software (IT) project. In this context, the **Vision** of ACC SRL's company is "Context and Architecture First – A visionary IT Architecture in a very well-understood Context is our key for a sustainable IT Business." [3].

The mission of the ACC SRL is defined in three **Mission** statements, as follows.

- Our **general business** mission statement: "*Tech Advisory – We help organizations define their IT Technology Strategy and Execute their IT Plans with great business value*."
- Our **technical** mission statement: "*Architecture – Through a visionary architecture towards a sustainable business.*"
- Our **soul** mission statement: "*Awareness – One of our missions is to raise awareness about the dangers in wetlands and to prepare and protect such areas."*

The business **Strategy** of my company is to obtain, manage and implement software projects in an **incremental** way, reusing design as much as possible, following **bottom-up** approaches to develop **modular** and **interoperable** solutions which are under visionary **top-down umbrellas**. For instance, the strategy used to develop step by step the "*Delta*

ProEco" umbrella solution (as an integrated "Modular Solution Intended to the Monitoring and Eco Actions in the Romanian Danube Delta", presented in research reports for my master thesis) was to start with a Pilot product.

For this reason we applied to the HUBCAP 2.2 EXPERIMENTS CALL (Horizon 2020 subcontract, see https://www.f6s.com/hubcap-call-2.2-experiment) in February 2022 with "Flood and Fire Risk Mitigation in Wetlands Using MicroWire Sensing" (FF-RIWER, see https://acc.neuroaugmentare.ro/ff-riwer/).
The HUBCAP project was jointly funded by the European Union's (Horizon program) research and innovation program (contract No 872698) and by the Commissioned Research of National Institute of Information (see https://hubcap-portal.eng.it/welcome/).
After the success of the HUBCAP 2.2 EXPERIMENTS CALL competition, the FF-RIWER Pilot Project (which was already described in Research Reports 2 and 3 as partial fulfilment for my final dissertation) started in April 2022. FF-RIWER's **mission** is to raise awareness about the dangers of floods and to help communities prepare and protect themselves. With a state-of-the-art system that integrates advanced sensors, data analytics, and cloud-based communication, we offer real-time monitoring of water levels and alerts to potential flood threats. FF-RIWER's goal was to reduce the impact of floods on communities and help keep people safe. With our innovative technology, we're making a significant contribution to improving flood response and prevention efforts.

An internal organizational analysis of ACC SRL for the **FF-RIWER Pilot project** could involve assessing the **company's strengths, weaknesses, opportunities, and threats (SWOT analysis).** This analysis could help the company to understand its current position and identify areas for improvement:
- Strengths:
  - ✓ The FF-RIWER (product) is a modular solution that could be easily extended and deployed.
  - ✓ The ACC company is an agile one and its team members have multidisciplinary skills.
  - ✓ More and more partner companies and individuals.
  - ✓ The access to the CAMPUS Research Center (where the FF-RIWER experiment was realized).
- Weaknesses:
  - ➢ The distance from Bucharest to the Danube Delta.
  - ➢ The lack of funds at the end of the FF-RIWER project.
  - ➢ The low size of the team.
- Opportunities:
  - ✓ The competitiveness of the miniature sensors that we have for water and temperature.
  - ✓ FF-RIWER is listed as Success Story by HUBCAP.
  - ✓ The existence of the Vacaresti "Delta" inside Bucharest.
  - ✓ New EU and other source funds.
- Threats:
  - ➢ The cashflow (as experienced in FF-RIWER project).
  - ➢ The proximity of the war area (Ukraine, Black Sea, Rep. Moldova) of the Danube Delta area.
  - ➢ A decrease in the interest to rise the Danube Delta from authorities.

We also did a **Stakeholder analysis**, identifying and evaluating the interests and influence of various stakeholders in relation to the ACC SRL company and the FF-RIWER project. By conducting a stakeholder analysis, my company can identify the key stakeholders that are most likely to affect or be affected by the business activities. This information can then be used to develop strategies to engage with these stakeholders and address their concerns.

In the case of ACC SRL, a stakeholder analysis could help the company understand the needs and concerns of its key stakeholders and develop strategies to address them. For example:

- Customers: ACC SRL could conduct surveys or focus groups to gather feedback from its customers on its software architecture, development, and delivery consulting services. This information could be used to improve the company's offerings and better meet the needs of its customers.
- Employees: ACC SRL could conduct employee surveys or hold town hall meetings to gather feedback from its employees on their job satisfaction and engagement. This information could be used to improve the company's work environment and retain top talent.
- Shareholders: ACC SRL could hold regular meetings with its shareholders to provide updates on the company's financial performance and growth prospects. This information could be used to maintain shareholder confidence in the company.
- Suppliers: ACC SRL could work closely with its suppliers to ensure that they are meeting the company's quality standards and delivery timelines. This help improve the company's supply chain efficiency and reduce costs.
- Regulators: ACC SRL could engage with regulators to ensure that it is complying with all relevant regulations and standards. This could help reduce the risk of regulatory fines or penalties.

A separate stakeholder analysis for the *Delta ProEco* umbrella solution could be realized based on the following

business process description:

- The *Delta ProEco* Modular System will be able to Monitor the Delta from the point of view of frequent Hazards (fires, floods, pollution incidents) as well as the Evolution of vegetation, fish and bird populations, etc.
- Various types of Sources - Sensors, fixed or mobile (installed on Drones and IoT-powered Personnel) and European Satellites - will provide Data that, processed by the *Delta ProEco* central system, will be able to generate Alarms and produce different types of Information that will allow Monitoring the mentioned elements
- Alarms and other Monitoring Information will be sent mainly to Local Authority Operators (humans).
- The Reports will be sent to beneficiaries, Local Authorities or interested Companies (e.g., travel agencies).
- Following the receipt of Alarms, local authority Operators will be able to decide to call on *Delta ProEco* to act, through Drones and IoT Personnel (which could also generate field reports), to reduce negative effects.

Starting from this process description we can **identify the following stakeholders of the *Delta ProEco* modular system**:

- Providers of the fixed Sensors data – which could be
- External companies which could lend or sell access to their sensors
- Internal (technical staff which deploys sensors, such as temperature or water level)
- Drones Providers – External companies which could lend or sell the services offered by their drones' fleet
- IoT-powered Personnel Providers – External companies which could lend or sell the services offered by their IoT-powered Personnel
- Local Authorities – External organizations which are the potential Clients of the services offered by us
- Interested Companies (e.g., travel agencies) – External companies which are the potential Clients of the services offered by us.

The stakeholder analysis could continue writing a **Stakeholders' Analysis Matrix** [3]. For each of these stakeholders above, we identified their interests, impact level, main expectations and involvement level, resulting in the following Stakeholder Analysis Matrix (see Table 1).

Table 1: The Stakeholder Analysis Matrix of the monitoring and eco actions solutions [3]

Stakeholder Analysis Matrix				
Stakeholder	**Interests**	**Impact**	**Expectations**	**Involvement**
External Providers of Sensors data	Maximize profit Optimize usage time	Medium	Good communication	Consulting (on monitored areas, on the type of sensors)
Internal Providers of Sensors data	Minimize costs	Low	Good working conditions	Informed (they are internal staff)
Drones Providers	Maximize profit Optimize usage time	Medium	Good communication	Consulting (on monitored or acting areas, on drones' type)
External IoT-powered Personnel Providers	Maximize profit Optimize acting time	Medium	Good communication	Consulting (on monitored or acting areas, on intervention type, etc.)
Local Authorities	Have accurate and timely information Minimize costs (of our services)	High (they also authorize the development of *Delta ProEco*)	Accuracy Availability Readiness Reasonable costs	Consulting (on monitored or acting areas, on intervention type, etc.) Potential partners
Interested Companies	Have accurate and timely information Maximize profit	Medium	Accuracy Availability Reasonable costs	Consulting (on monitored areas, on types of monitored information)

Technological Design Methodology

As we already mentioned, the FF-RIWER Project which is a pilot of a much large modular solution *Delta ProEco* – "The FF-RIWER experiment targeted the integration of a CPS technology, namely MicroWire Sensing technology, offered by RVM and available as a HUBCAP asset, into a new MBD-augmented modular CPS solution (*Delta ProEco*) for flood and fire risk mitigation in wetlands, to be implemented by ACC." [3].

The high-level architecture of a proposed modular solution for fire and flooding monitoring in Danube Delta, resulted from the business analysis briefly presented in Figure 1 is illustrated in Figure 2. A set of sensors will be placed near the riverbank. In case of a flooding accident, an increased water level moves vertically a float with a magnet. The vertical position of the float is precisely detected by the sensor. A similar method will enable sensors to detect high

temperatures that could be a danger for the environment, threatening the dry vegetation with accidental fires.
The first step towards an implementation of the proposed architecture is a testbed that combine environmental sensors with software modules for communication, data storage and processing and visual data presentation (alerts, history etc) to be used in use cases related to wetlands (and envisioned to be first deployed in the Romanian Danube Delta).
Figure 3 presents a detailed architecture of a testbed for the proposed modular solution. For the current version we are developing a testbed with multiple container-encased (Docker) Python scripts for data and alarm simulation, using a similar server-side setup. The entire testbed can be replicated through docker-compose scripts.
The software stack of the testbed we realized for experimental purposes is organized in a dockerized software stack, allowing a rapid automatic restoration of service in case of fault (in case of power failures). It's main components are:

- the **Gateway** (**MQTT broker**), configured for secure TLS communication.
- the **Sensor Connectivity Module simulators** - these virtual devices simulate temperature, humidity and water level and send reports to the gateway, but also threats like wildfires or floods, used as data generators
- the **Server-side MQTT client** reads the reports from the Gateway and stores telemetry and alerts in the database.
- **tools** used for development (**web user interface** for the **database**, **webdebug server, Grafana plotting server**)
- the **user interface** and **its API server**.

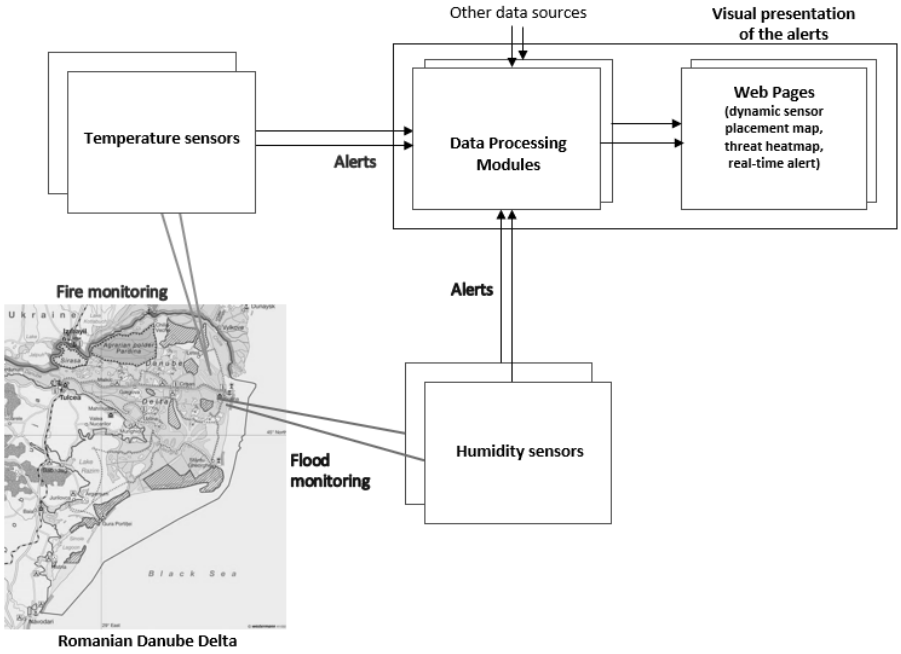

Figure 2: The high-level architecture of a proposed modular solution [3]

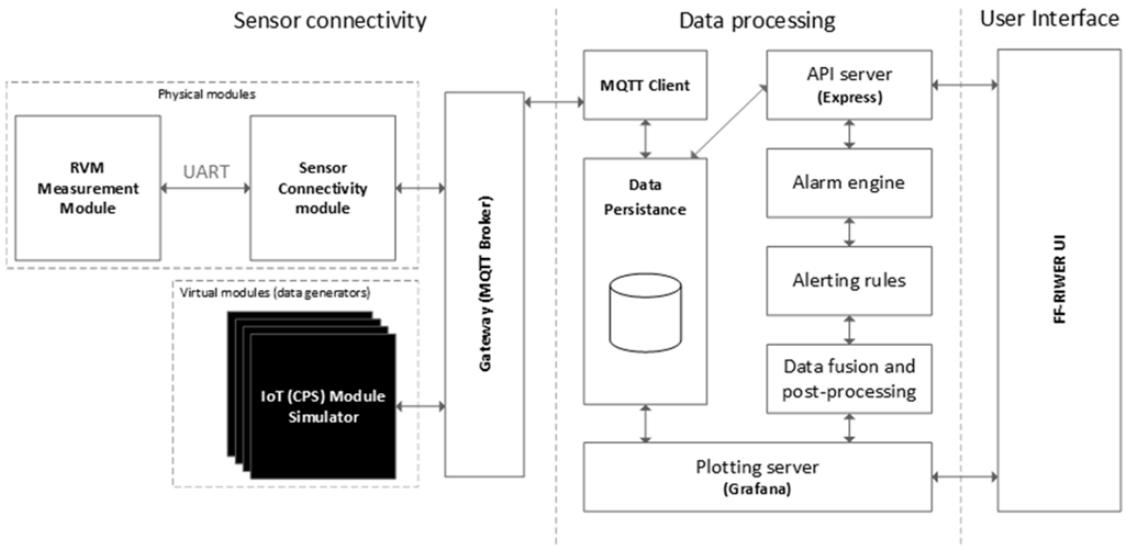

Figure 3: The detailed architecture for experiments [3]

RESULTS

After the finish, the FF-RIWER project was promoted as Success Story by HUBCAP EU Horizon project here https://www.hubcap.eu/success-stories/ff-riwer and on February 16th, 2023, it was included in a selection of 3 projects presented to the EU commission at the Final Review of HUBCAP (that ended in December 2022).
The technological results and their evaluations are concisely presented in the table of the Final Deliverable of the FF-RIWER Experiment dedicated to the final KPI's description and progress (see Table 2).

Table 2: Final KPI description and progress [3]

No.	Name	Description	Evaluated
1	**Miniaturization target for temperature sensor - length 1cm, diameter 3mm**	Length of excitation coil. Sensor diameter size, while it is placed through the eye of the sensing coil.	**100 %**
2	**Sensor resolution: 1°C**	Average measurement resolution defined as temperature measurement interval divided by number of measurement points obtained.	**100 %**
3	**Prototype platform response time of at most 15 sec**	The delay between the (simulated) reading of a sensor data, its delivery using the connectivity subsystem and receiving it inside the server data processing module	**100 %**
4	**Support at least 5 concurrent environmental alarms**	Number of IoT (CPS) instances that can send data to/from the FF-RIWER data processing module at the same time	**100 %**

DISCUSSION

Further Plans and Developments

As the next steps of this strategy, we will continue beyond the master thesis, by adding new contributions, such as the description of a new project proposal for a new Horizon 2020 competition, which represents:

- a development from the TRL4 / laboratory maturity level of the FF-RIWER pilot to a TRL6 / real production maturity level of the new proposal, and
- a pivoting from the Danube Delta to a Cardboard packaging company, where we want to do "Environmental Monitoring and adaptation for process and Energy consumption optimization in Cardboard packaging" (*EMapEcoCap*), which will include an advanced BI and AI/ML based system from a new partner in the project (beeno.it),

with the adding that after the completion of this new project we can pivot back to the *Delta ProEco* umbrella solution with the resulting TRL6. In Table 3 we presented the eMapEcoCap project responsibilities, planned activities and outputs.

Table 3: The *eMapEcoCap* project responsibilities, planned activities and outputs [3]

Start month	End month	Activities to be selected	Brief description of the activity to be performed	Main applicant	Applicant (2)	Industry Partner	Outputs
M1	M1	Prototyping	Analysis of the requirements provided by the Industry partner and project specifications for the hardware components. Analysis of the requirements provided by the Industry partner and project specifications for the remote monitoring cloud platform.	**x**			Release of project specifications for IoT devices and sensors. Release of Project Specifications for the cloud platform.
M2	M3	Prototyping	Cloud infrastructure design. Prototype development of IoT devices, according to the design specifications provided by the Industry partner, in collaboration with external technical expertise. First implementation of the monitoring platform in cloud, according to project specifications provided by the Industry partner. Equipment purchase.	**x**	**x**		Prototypes of Smart devices for temperature and humidity monitoring with support for Zigbee + WiFi + BLE Prototypes IoT gateway with support for Zigbee + WiFi + 4G LTE Release of first cloud platform version.
M4	M5	Testing, experimentation	Hardware installation at the Industry partner location and execution of trial tests for data gathering and transmission to the cloud platform.	**x**	**x**	**x**	Unit and component test. System Integration test. 1st Quality Control Document.
M6	M7	Demonstration and pilot	UI and E2E test at the industrial partner site.	**x**	**x**	**x**	Fixing issues and submitting for review. Final Quality Control Document.
M7	M8	Validation of the results	Execution of the final tests at the headquarters of the Industry.	**x**	**x**	**x**	Quality Assurance Document.
M8	M9	Training the industry partner using the solution	Coaching and training of Industry personnel on the use of the platform.	**x**	**x**	**x**	User Acceptance Testing.

CONCLUSIONS

The current paper presents the development of a platform that combines advanced monitoring technologies with targeted ecological actions to preserve and enhance the natural beauty of the Danube Delta, which addresses a range of issues, including the occurrence and control of floods, initiation and extinguishing of fires, detection, and control of poaching, monitoring of fish and bird populations and the stage of vegetation - with measures to help their development, monitoring and improving tourist activities, identifying pollution sources, and acting on them.

After presenting the context of the work, the "*Delta ProEco*" solution, which will in the future provide an integrated platform of solutions for monitoring solutions and eco actions in the Romanian Danube Delta, targeting floods, fires, poaching, fish and bird populations, vegetation, pollution sources, tourism, the paper presented the design and details of the experiments in the FF-RIWER pilot project, from the entrepreneurial strategy and technology design perspectives. The paper continues with results of FF-RIWER experiments and their evaluations, through the KPIs, a short discussion of the plans and further developments, from an entrepreneurial perspective.

Regarding the next steps, that we will continue by adding new contributions, such as the implementation of a new project proposal for a new Horizon 2020 competition, which represents:

- a development from the TRL4 / laboratory maturity level of the FF-RIWER pilot to a TRL6 / real production maturity level of the new proposal, and
- a pivoting from the Danube Delta to a Cardboard packaging company, where we want to do "Environmental Monitoring and adaptation for process and Energy consumption optimization in Cardboard packaging" (eMapEcoCap), which will include an advanced BI and AI/ML based system from a new partner in the project

with the adding that after the completion of this new project we can pivot back to the Delta ProEco umbrella solution with the resulting TRL6.

We also plan to better and larger disseminate these works and their results, to continuously scale up the entire development, both from entrepreneurial and technological points of view, to try to internationalize it from entrepreneurial point of view, to partner with more and more companies and state institutions, to do more connected projects based on pivoting the current solutions towards other industrial and environmental areas (like agriculture, green energy etc).

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