Project-Based Learning in Industrial Maintenance - Implementation Guidelines and Case Studies

1. Introduction

This document presents an innovative educational approach developed under the SMTMC project: **the Project-Based Learning (PBL) method applied to industrial maintenance engineering**. Designed in collaboration with industrial partners, this methodology enables students to work on real-life industrial problems through structured teaching scenarios.

Each scenario is developed jointly by university and company supervisors, guiding students from problem analysis to solution design and implementation.

The case studies presented in this document showcase successful applications of this approach in four Tunisian universities, highlighting its educational, professional and industrial impact.

This result is transferable to any higher education institution aiming to strengthen university-industry cooperation, enhance students' technical and soft skills, and foster innovation in engineering education.

2. Objectives

TMC-Project Scenarios aim to :

- **Strengthen collaboration between universities and businesses**, by including professionals from the sector in the teaching process.
- **To offer students an applied learning experience**, by confronting them with real case studies and field assignments.
- **Develop the problem-solving and teamwork skills** that are essential in industrial maintenance.
- **Promoting innovation and technology transfer**, by encouraging students come up with solutions adapted to contemporary industrial challenges.

3. How TMC-Project Scenarios work

The TMC-Project Scenarios are based **on real case studies** identified in partner companies of the SMTMC project. Supervised by a **university tutor and a tutor**

The students are actively involved in analysing the problems, finding solutions and drawing up recommendations. Each scenario follows a multi-stage methodology developed by Plasmatrix, as shown in the diagram below (**Appendix** 1):

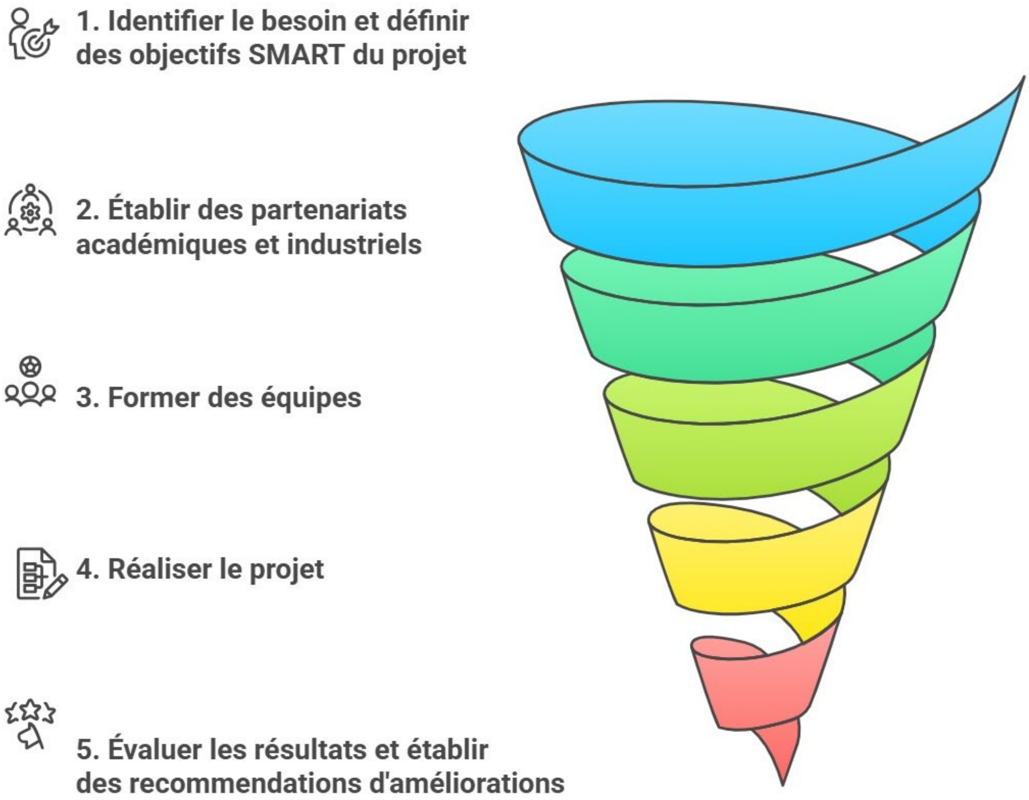

Figure : Guidelines WP2.3 - - Implementation of teaching scenarios

- Cooperation between universities and industry -

❖ ***Stage 1: Selecting the project theme***

The themes are defined according to the specific needs of companies and the skills targeted as part of the Maintenance Engineering training pathways and any related themes. Projects may cover a range of areas: **preventive maintenance, machine diagnostics, equipment management and optimisation (CMMS), integration of new technologies (IoT, Big Data, industrial automation, predictive maintenance, etc.), innovation,** etc**.**

❖ ***Stage 2: Setting up the teams***

Students are divided into **teams of 3 or 4 people**, depending on their technical skills and areas of interest. Each member is assigned **a specific role**, ensuring a balanced distribution of responsibilities and a collaborative approach to the project.

❖ ***Stage 3: Immersion in the company and analysis of the problem***

Teams students and, where appropriate, course leaders, visit the site to **observe and immerse themselves in the industrial environment.** They **interview maintenance managers**, collect data and analyse the **technical, organisational and economic constraints** of the problem identified.

❖ ***Stage 4: Writing case study***

A **detailed study of the problem** is drawn up by the students and the course leaders, including:

- Description of the industrial context,
- Identifying the issues and challenges,
- Analysis of available data and technical parameters,
- Defining project constraints and requirements.

❖ ***Stage 5: Search for solutions and project development***

The teams develop optimised maintenance scenarios based on :

❖ **Maintenance engineering** ,
❖ **Analysis of best industrial practice**,
❖ **The integration of innovative technological solutions** tailored to the company's needs.

❖ ***Stage 6: Implementing and validating the solution***

Wherever possible, the students test the proposed solutions directly in companies. **Interim reviews are** organised to assess the relevance of the approaches developed, adjust the recommendations and refine the methodology used.

❖ ***Stage 7: a report and presenting the results***

The students summarise the results obtained and formulate final recommendations. They then present their work to **a jury made up teachers, industrial tutors and company managers**. Structured feedback is collected to **improve the relevance of the proposed solutions and ensure educational continuity**.

4. Case studies by university

❖ University of Sfax (Annex 2)

Students from the University of Sfax worked on projects combining **technological innovation and industrial optimisation**, with a focus on reducing costs and improving performance.

1) **Design of a customised hand prosthesis**: This project has made it possible to design a customised prosthesis using **3D printing** and biocompatible materials, reducing production costs and lead times by **40%** compared with traditional methods.
2) **Design of a conveyor belt for a production line**: The students developed a **modular conveyor belt** designed to optimise the efficiency of a production line in the manufacturing industry. This solution enabled **30% reduction in**

   The result is **a significant reduction in production stoppages** and a significant increase in system flexibility.

❖ Carthage University (Annex 3)

Carthage University has focused on **operational excellence and equipment management** through innovative projects aimed at optimising industrial performance. Effective maintenance management requires **optimisation of production processes**, effective information management and rigorous planning to minimise downtime and maximise operational efficiency.

1) **Operational excellence through innovation and creativity**: This project, carried out in partnership with **Bontaz Tunisie**, aimed to improve the performance of the **production chain and equipment maintenance**. This was achieved applying **ideation and industrial problem-solving** techniques**, with the aim of integrating continuous improvement tools.** The students proposed strategies to optimise production management, reducing **unplanned machine downtime by 25%**.
2) **Development of a CMMS application for a medical analysis laboratory**: The students designed a **digital solution for managing equipment and stocks** to improve preventive maintenance management**.**

❖ University of Gabès (Appendix 4)

The University of Gabès has focused on the **preventive and corrective maintenance of industrial equipment**, in collaboration with specialist companies.

1) **Preventive maintenance for a fibre laser cutting machine**: Drawing up a **preventive maintenance plan** to avoid recurring breakdowns and improve equipment life.

2) **Preventive maintenance of a CNC wood router**: Development of a **systematic maintenance strategy** to guarantee the availability and efficiency of the equipment.
3) **Corrective maintenance on the FC2136 CNC machine**: In-depth diagnosis and implementation of a **targeted intervention plan** to reduce machine downtime and improve reliability.
4) **Optimisation of the maintenance plan for the fibre laser cutting machine**: Design of an **advanced maintenance programme** based on failure analysis and exploitation of operating data.

❖ University of Jendouba (Annex 5)

The University of Jendouba has focused on projects involving **technological innovation and the optimisation of energy and industrial resources**.

1) **Design and construction of a pyrolysis unit to treat petroleum products**: Development of a **system to convert petroleum waste** into high value-added products (gas, oil, carbon).
2) **Study and design of a 4-degree-of-freedom manipulator arm skid adapted "Seabot - 1"**: Design of an **underwater robotic device** for industrial interventions and offshore maintenance.
3) **Optimisation of solar panel parameters for wheat production in the northern regions of Tunisia**: Study and **optimisation of solar panel performance** to improve agricultural productivity and energy resource management.

4) **Development of stabiliser bars: combining analytical calculation and digital simulation FEM**: Design and testing of **innovative mechanical components** for industrial and automotive applications.

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5. Implementation of project scenarios

5.1 Selection of partner companies

The partner companies were selected according to **precise criteria**, taking into account their **sector of activity, their size, their technologies and their maturity in terms of maintenance**. These companies have demonstrated a **strong commitment supporting students**, by offering them access to industrial facilities and equipment to help them complete their projects.

5.2 Training industrial tutors

To ensure **effective supervision**, **specific training was given to the industrial tutors** involved in the projects. This training covered **the pedagogical, technical and logistical aspects** of the project scenarios, and also focused on **security protocols and confidentiality requirements** in industrial environments.

5.3 Project assessment

The projects were assessed on the basis of rigorous criteria defined in advance with the academic and industrial partners. The main areas of assessment included :

□ Relevance of the solutions proposed in response to the issues identified.

□ Quality of the case studies and final reports written by the students.

□ Level innovation and feasibility of solutions applied.

□ Student commitment and teamwork throughout the project.

□ Impact on the partner company, in terms improving processes and

In order to guarantee the effectiveness of the **TMC-Project Scenarios**, a rigorous evaluation has been put in place, incorporating the **monitoring recommendations** and **educational quality criteria defined by the Erasmus+ agency**. This evaluation measures **the impact of the scenarios on the acquisition of skills**, the employability of graduates and the added value for partner companies.

The evaluation is based on several strategic areas:

- **Quality of the solutions developed**: Relevance of proposed recommendations, technical feasibility and industrial applicability.
- **Impact on students**: Acquisition of technical and cross-disciplinary skills, progress in solving complex problems and satisfaction with the scheme.
- **Commitment and collaboration**: Students' ability to work as part of a team, interact with academic and industrial tutors and manage a project from start to finish.
- **Integration of new technologies**: Use of IoT, predictive maintenance and digital tools in the solutions developed.
- **Feedback from partner companies**: Assessment of the relevance of the proposed solutions, rate of adoption of the recommendations and impact on maintenance management within the company.

The valuation methods used include :

- **Detailed evaluation grids**, used during the final presentations to assess the quality of the solutions and recommendations.
- **Satisfaction questionnaires**, distributed to students and companies to measure the impact of the scheme and identify areas for improvement.
- **Review meetings with industrial and academic tutors**, to adjust the methodology and improve student support.
- **An analysis of the academic performance** of the students who took part in the scenarios, in order to measure the effect of this approach on their results and their integration into the world of work.

5.4 Distribution of results

The results of the project scenarios **were presented and circulated** to the various project stakeholders.

Presentations and publications: The results were shared at **academic seminars and conferences** organised with partner universities and companies.

involved.

Sharing with companies: Each partner company received a **detailed report**

on the studies carried out, enabling them to **capitalise on the solutions developed**.

6. Integration of the results of WP1 and the recommendations of deliverable D1.3

The TMC project scenarios were developed based on the conclusions of **Work Package 1 (WP1)** and the recommendations of deliverable **D1.3 - Analysis of maintenance skills requirements**.

The study carried out as part of WP1 identified **gaps in practical training**, highlighting the need for a **more immersive teaching approach** to better prepare students for the demands of the Tunisian job market.

In response to these findings, the TMC project scenarios have been **designed in close collaboration with partner companies and maintenance experts**, to ensure that they **reflect the realities on the ground**.

The **case studies developed** in the various universities enabled students to acquire :

- ☐ **Advanced analytical skills**, studying real-life problems and identifying the best maintenance strategies.
- ☐ **A command new technologies** (CMMS, IoT, Big Data) applied to industrial systems.
- ☐ **The ability to work in a team and manage complex projects**, thanks to the joint supervision of academics and industry professionals.
- ☐ **A valuable field experience**, facilitating their **professional integration** and reinforcing their attractiveness to industrial recruiters.

The results of the projects show that this methodology not only **bridges the gap between theory and practice**, but also encourages **innovation and the continuous improvement of maintenance processes** in the partner companies.

7. Impact assessment and sustainability

7.1 Impact assessment

The impact of the TMC project scenarios was measured through **qualitative and quantitative evaluation**, involving **students, industrial tutors and partner companies**.

Satisfaction surveys: A survey of students who had taken part in the projects revealed that **90% of them felt that they had enhanced their practical skills and their employability** thanks to to this approach. **Feedback from partner companies**: **80% of the companies involved felt that these case studies had provided real added value**, with solutions that could be applied to improving their their processes processes processes.

Review workshops with industrial partners: These meetings were an opportunity to identify the **strengths and areas for improvement in the project scenarios**, with a view to a possible **generalisation of the system to other technical sectors**.

Analysis of academic results: Students who took part in the project scenarios **obtained better academic results**, demonstrating a **better assimilation of technical concepts and greater confidence in their skills**. The conclusions of this evaluation confirm that the **TMC-Project Scenarios** are an effective pedagogical tool for developing key maintenance engineering skills, while offering an **immersive and professionalising experience**.

7.2 Sustainability

The partner universities in the SMTMC project have made **concrete commitments to ensure the continuity and sustainability of the project scenarios** beyond the duration of the project.

- **Institutionalisation of project scenarios**: Universities will include these case studies as **compulsory elements in their Masters in Maintenance Engineering**.
- **Creation of a database of scenarios**: A library of case studies will be created and regularly updated to provide **enriched teaching aids** for students and teachers.
- **Strengthening university-industry collaboration**: Agreements will be put in place to **expand the network of partner companies** and increase internship opportunities and and projects and industrial projects.

- **Introduction of a continuous assessment system**: A system for monitoring and improving the scenarios will be introduced, based on **feedback from students and companies** in order to guarantee guarantee **constant evolution educational content**.

□ **Dissemination of results**: The project scenarios will be **presented at academic and professional conferences** to encourage other universities and industries to adopt this approach.

Thanks to these initiatives, TMC project scenarios will become a **model for training. sustainable and evolving**, ensuring a permanent alignment between **the skills taught and the expectations of the job market**.

Monitoring and sustaining TMC-Project Scenarios

In order ensure the continuity and improvement of the TMC-Project Scenarios beyond the SMTMC project, a sustainability plan has been defined.

1. Institutionalisation of project scenarios

Gradual integration of TMC-Project Scenarios into Masters in Maintenance Engineering training programmes as a compulsory element.

Creation of a database of case studies, accessible to teachers and students and regularly updated to reflect new industrial issues.

Working with other schools to share best practice and extend this teaching approach to other technical courses.

2. Introduction of a continuous assessment system

Annual evaluation workshop with teachers, partner companies and students to adjust methodologies and improve the system.

Setting up a technology watch system to keep abreast of developments in the sector (new standards, emerging technologies, innovative maintenance practices).

Follow-up of graduates who have taken part in TMC-Project Scenarios in order to assess their professional integration and the impact of the scheme on their employability.

3. **Strengthening university-industry collaboration**

Formalise agreements with partner companies to ensure a continuous flow of industrial projects that can be used in teaching scenarios.

Organisation of seminars and workshops with industrial players to identify new project themes and adjust content in line with market developments.

□□ 8. Conclusion

TMC project scenarios have proven their **effectiveness as an innovative teaching tool, strengthening the link between universities and industry**.

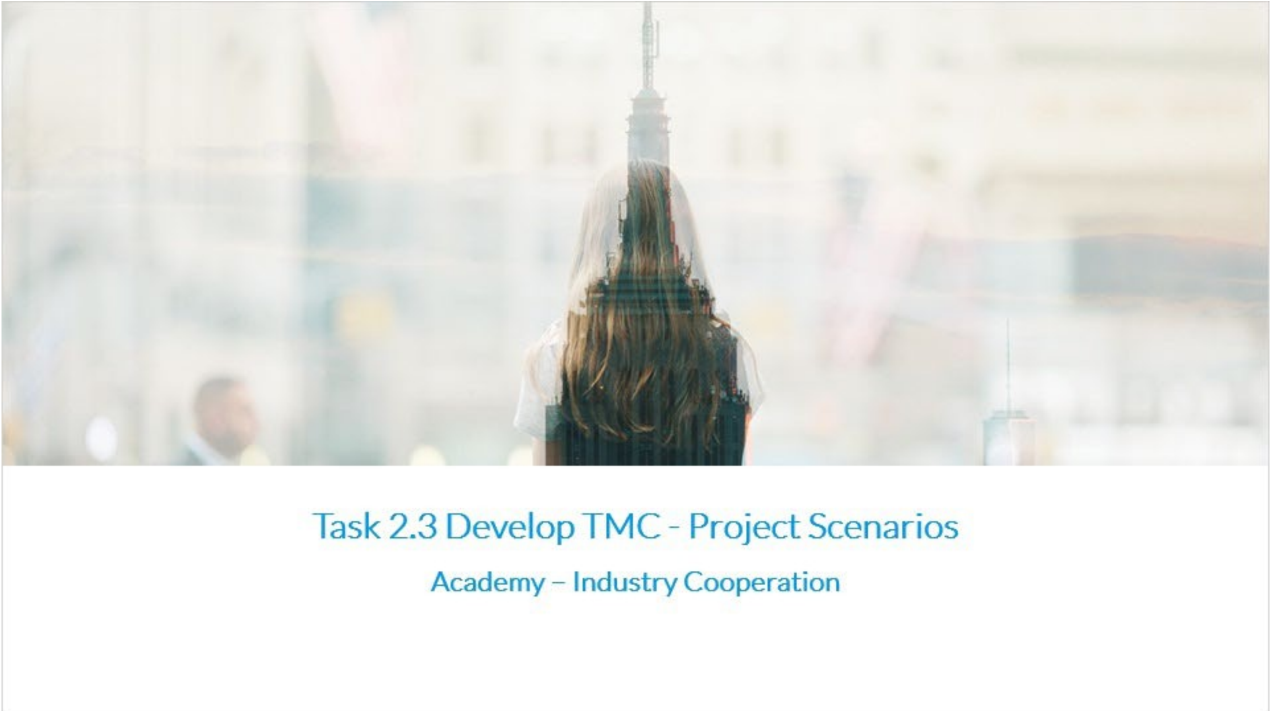
Thanks to this approach, students have been able to **apply their knowledge in concrete contexts**, develop their **ability to solve complex problems**, and gain **valuable experience in business**.

The positive evaluation of the projects by students and companies testifies to their significant impact on the **training and employability of graduates**.

The introduction of **strategies to** ensure **the long-term viability of the scheme**, with **the institutionalisation of project scenarios** in Masters degrees in maintenance engineering, and **ongoing collaboration with partner companies**.

Through these actions, the SMTMC project is making a major contribution to the **development of the maintenance sector in Tunisia**, by training a new generation of engineers capable of meeting **the technical and industrial challenges of tomorrow**.

Appendix 1



Objectives

Guidelines

For development of transversal skills of students, a practical project in an enterprise is introduced in the curricula. The project scenarios follow the Guidelines described below

1. Representatives from universities contact several manufacturing companies
2. Relevant companies are selected
3. Each selected enterprise proposes in discussions with supervisors from university a list with project regarding problems to be solved in the company.
4. A description template is formulated to be filled for each project
5. Teams of 3-4 students are formed
6. Each student team is assigned a supervisor from university and one from the company
7. The list of projects is published on the project web page, and each student team selects a project during a workshop organized by the university.
8. The students work together for solving the problem. Each team selects a leader. A project plan is drafted for each project and discussed with the supervisor.
9. A period of 10 days is dedicated for studying the state-of-the art for each project theme
10. The experimental part of the project can be performed at the laboratories in university, at the company or at both.
11. A common template for all reports is prepared by supervisors.
12. A final report is written followed by a presentation for colleagues, teachers and representatives from companies
13. The TMC Prize rewards the best project presentation.

The project duration is 6 - 8 weeks.

14. The project can be continued in the Master Thesis

Expected outcomes:

- Contributes to modernization of the Tunisian education system,
- Strengthen the cooperation between university and industry
- Improving practical and professional experience of graduates
- Creates the framework for the students to continue the projects at master thesis and further at PhD research level.
- Improves student employability rate
- Contacts with company managers given possibility for students to show their skills while companies to meet and select potential employees.
- For female students, it is a great opportunity to come in contact with company managers, engineers for finding jobs.

Set-up Steps :

• Phase 1: Student Teams

Phase 1: Students in the project course are distributed in teams of 3 – 4 students.

- Each group nominates a team leader
- It is preferable mixed groups of female and male students

Student teams

Working together with industry staff

• Phase 2

Phase 2: the course director nominates of the course administrator and the project supervisors

- one supervisor for each student team

Course administrator
Good contacts with the industry in the region

Project supervisors
Academic staff and PhD students

- Phase 3


Phase 3: Project administrator establish contacts with industrial association, chamber de commerce and companies in the region
▪ Visits companies and presents the course syllabus and the project goals, project duration (3 –4 months)
▪ Students or/and supervisor can propose companies for the project
▪ Short description of companies
industrial association
companies
chamber de commerce

- Phase 4

Phase 4: Relevant companies are selected by the course director and the supervisors

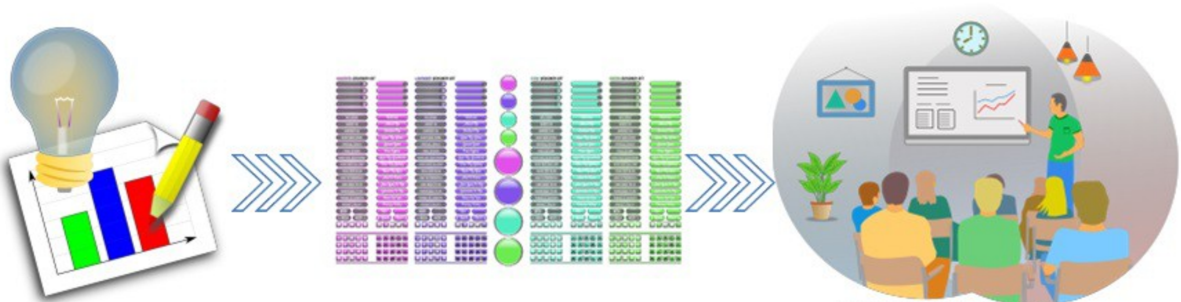
- A project description template is developed
- Each supervisor is assigned a company and a student team
- Supervisor visit the assign company, discuss relevant project proposals with the CEO, production manager, and others company representatives, and fill in the project description template.
- The company nominate a industry supervisor for the project, normally the production manager.

(a) university meeting for the company selection **(b) visits and discussion at companies** **(c) project description**

• Phase 5

Phase 5: The list of projects is published on the project web page, and each student team select a project during a workshop organized by the university

- The project description is refined by the supervisors from university and company
- The list of the projects are published on the course website.
- Workshop with students and supervisors for presentation of the projects.
- Student teams select projects.



refining project description **project list on the website** **workshop for project presentation and selection**

- Phase 6

Phase 6: The students work together for solving the problem.

- A project plan is drafted for each project and discussed with the supervisor
  - visit at companies (1-2 days) for discussion with industry supervisor about the project, problems and solutions, collection of existing documentation,
  - distribution of tasks between the members of the team,
  - study technical literature connected to the project subject (10 - 15 days),
  - experimental/computational work at the project, at the university or at the company,

(a) visit the companies

(b) studying technical literature

(c) experimental work/ testing

Phase 7

Phase 7 Project report, project presentation, price ceremony

- Project report template is prepared by the supervisors
- Final report drafted by the teams
- Project presentation for faculty members, representatives from industry and students
- Evaluation committee: 3 members form industry, academy and students
- TMC – Prize for best project and presentation for awarding the students

(a) final presentation

(b) award ceremony

Benefits

- Engaging in projects with industrial companies offers a multitude of benefits for both students and companies. Firstly, students are exposed to real-world problems, giving them practical experience and the opportunity to apply their theoretical knowledge in a real-world setting. This hands-on approach fosters the development of teamwork and collaboration skills as they work together to find solutions.
- In addition, collaboration with industry partners enhances the employability of students by equipping them with relevant skills and experience sought by employers. Companies, in turn, gain a better understanding of students' abilities through these projects, potentially opening up opportunities to recruit talented individuals.

- Moreover, the involvement of doctoral students in an industrial environment enriches their academic career by giving them exposure to the real challenges and practices of industry. It also bridges the gap between academia and industry, enabling mutual learning and knowledge exchange.

- Overall, these collaborations contribute to a more holistic educational experience that prepares students for a successful career after graduation.

Appendix 2: University of Sfax

Two case studies were developed and carried out by students at ISGI in Sfax, under the supervision of teachers who applied the case study method developed by Plasmatrix.

* Description of the case studies

Case study 1: Designing a customised hand prosthesis

- **Background:** Need identified during a visit to Hedi Chaker Hospital in Sfax for amputee patients.
- **Objective: To** reduce the time and cost of manufacturing customised prostheses.
- **Results :**
  - Use a 3D scan for modelling.
  - Biocompatible materials used.
  - Cost reduced by .
  - Prosthesis successfully tested on a patient.

Case study 2: Design a belt for a production line

- **Context:** EPI, a company specialising in the manufacture of automotive parts, was faced with modularity and maintenance problems.
- **Objective: To** improve the efficiency and lifespan of the system.
- **Results :**
  - Modelling in SolidWorks.
  - reduction production stoppages.
  - Modular design for easy future modifications.

Assessment phase

- Questionnaires for partners and students.
- Analysis of results: cost savings, reduction in downtime.

❖ Case Study 1: Design a Custom Prosthetic Hand

Teams of 4 students per project were formed with specific roles:

- Responsible for 3D modelling.
- Responsible for materials or mechanical constraints.
- Responsible for communication with the partner.
- In charge of documentation.

. Visit and Analysis

The team visited the hospital, interviewed doctors and patients, and analysed the current prosthesis manufacturing processes. They identified the following challenges:

- High cost of traditional prostheses.
- Long delivery times.
- Lack of customisation to adapt to patients' specific needs.

. Work on the Project

The team used the scanner and 3D printers acquired as part of the SMTMC project to design a personalised hand prosthesis. They :

- Modelled the prosthesis in 3D using scans of the patient's limb.
- Selected a biocompatible and durable material.
- Reduces production costs by 40% compared with traditional methods.

Proposed Solution

The case study was written up, detailing the design stages, the challenges encountered and the solutions found. The prosthesis was successfully tested on one patient, improving his quality of life.

5. Actual data obtained

Indicators	Hand prosthesis
Estimated initial cost	1,500 TND
Final cost	900 TND
Completion time	8 weeks
Reducing downtime	N/A
Partner satisfaction	95 %

. Public presentation

The team presented its work at a public session, receiving positive feedback from academic and hospital staff.

- **Case Study 2: Design and manufacture of a conveyor belt for a production line**

1. Theme selection

The theme was selected after a visit to a manufacturing company specialising in the production of automotive parts. The company needed a customised conveyor belt to optimise the routing of parts between the various production stages. The subject was chosen in collaboration between the university supervisor and the company manager.

2. Team training

A team of 4 students was formed:

- Student A: Responsible for 3D design with SolidWorks.
- Student B: Responsible for mechanical stress analysis.
- Student C: Responsible for communication with the company.
- Student D: Responsible for writing case study.

3. Visit and Analysis

The team visited the company, interviewed engineers and production operators, and analysed current processes. They identified the following challenges:

- The existing conveyor belts were too generic and could not be adapted to the specific requirements of the production line.
- Frequent maintenance problems led to production stoppages.
- A need for modularity to adapt to different types of room.

4. Work on the Project

The team used SolidWorks to design a customised treadmill. The key steps included :

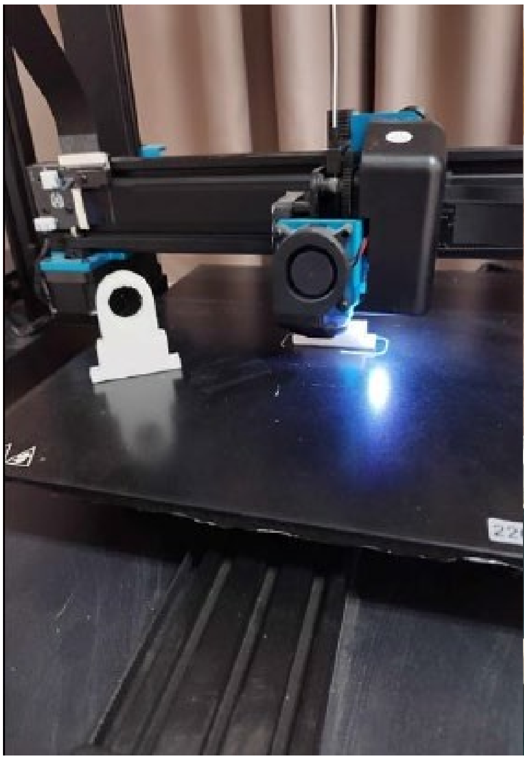
- 3D modelling of the conveyor belt, taking into account the specific dimensions of the production line.
- Simulation of mechanical stress to guarantee durability and reliability.

- Design of interchangeable modules to adapt to different types of parts.

Manufacture of Specific Parts :

Specific parts of the conveyor belt, such as modular supports and conveyor guides, were manufactured 3D printers acquired as part of the SMTMC project. This enabled:

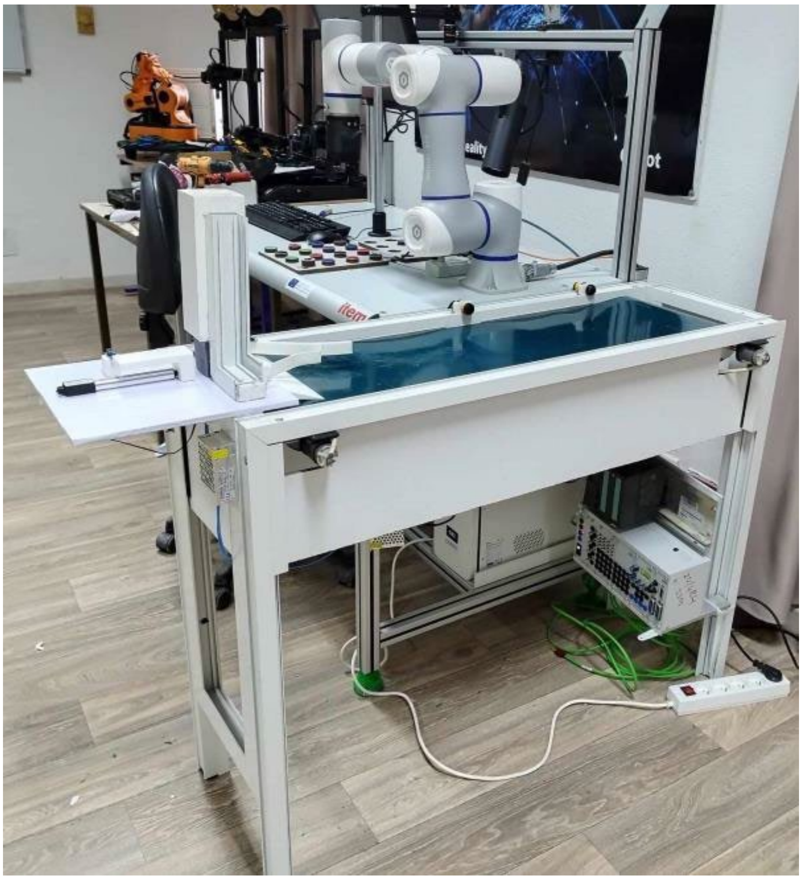
- Fast, cost-effective production of made-to-measure parts.
- Precise customisation to meet company's needs.
- Shorter lead times than traditional methods.




5. Proposed solution

The case study was written detailing the design stages, the challenges encountered and the solutions provided. The conveyor belt was manufactured and installed, reducing downtime by 30

% and production efficiency.



5. Actual data obtained

Indicators	Treadmills
Estimated initial cost	10,000 TND
Final cost	7,000 TND
Completion time	12 weeks
Reducing downtime	30 %
Partner satisfaction	90 %

6. Public presentation

The team presented its work at a public session, receiving positive feedback from company representatives and academic staff.

Appendix 3. Carthage University

The aim of Carthage University, through its engineering courses incorporating concepts related maintenance and the professional master's course in "maintenance engineering, is to strengthen the modern maintenance skills of graduates.

The implementation of practical workshops based on real industrial problems and using as far as possible the scientific equipment available at ENIB and also that acquired as part of the SMTMC project, is essential to enrich teaching practices and strategically align training with industrial needs.

We will present two case studies developed and carried out by students at the Bizerte National Engineering School (Carthage University), under the supervision of teachers who applied the case study approach proposed in the project.

✓ **Learning Scenario 1: Operational Excellence through Innovation and Creativity**

The "48 hours to innovate" workshop is a well-established tradition at ENIB for 3rd year engineering students. It aims to apply the tools and methods of ideation and creativity to solve an industrial problem in just 48 hours. This workshop is fully in line with the objectives of the TMC - EDU teaching scenarios proposed as part of the SMTMC project, which aims to develop students' cross-disciplinary skills through a practical project in a company.

For the start of the 2022-2023 academic year, with the start of the professional master's course, the master's students and 3rd year engineering students were confronted with an innovative industrial problem at Bontaz Tunisie.

Video link to event: https://www.facebook.com/Tunisierse/videos/937791897604521/

- **Background and objective :**

Bontaz Tunisie, a subsidiary of the Bontaz Group, develops and manufactures high-value-added automotive components (hydraulic systems, electric bicycle motors, braking systems, solenoid valves, etc.).). In the face of competition, Bontaz Tunisie is aiming for operational excellence improving efficiency of its production and maintenance chain.

- **Visit and Analysis**

Following a number of visits and discussions between Ms ***Olfa Mejri***, coordinator of the Industrial Engineering department at ENIB and head of the innovation module, and Mr ***Ghassen JEMLI***, production manager at Bontaz, it was agreed to hold a pilot workshop on 5 and 6 January 2023 on the company's premises in order to confront the students with the following challenges: proposing methods/tools to improve the performance of the production chain by reducing downtime, optimising machine maintenance and improving productivity.

- **Process and deliverables**

workshop run as follows:

- On the morning of 5 January 2023, the company presented an issue relating to "operational excellence".
- The students, divided into groups of 8 to 10, worked on developing concrete solutions, accompanied over the two days by academic and industrial supervisors.
- At the end of the second day, on 6 January 2023, they presented their work to a jury responsible for selecting the winning team.

Planning « 48 H pour Innover »

Heure	Jeudi 05 janvier 2023
9h00	Lancement des 48h pour innover (Introduction/planning +tirage au sort concernant l'affectation des sujets) *BONTAZ*
9h30-10h30	Présentation des **Sujets proposés par BONTAZ**
10h30	Pause-café
11h00-13h00	Analyse du défis (travail de production des idées en équipes sur la thématique entreprise)
13h00-14h00	*Pause déjeuner*
14h00-17h30	Créativité en groupe et rédaction des fiches idées (version papier et électronique)
17h30-19h00	Marché aux idées
Heure	**Vendredi 06 janvier 2023**
8h30-09h00	Bilan de la journée précédente
9h00-10h30	Tri des idées
10h30-11h00	Pause-café
11h00-13h00	Développement de l'idée retenue
13h00-14h00	*Pause déjeuner*
14h00-16h00	Préparation de la présentation (finalisation et maquettage, préparation des argumentaires..)
16h00-17h00	Présentation des idées devant le JURY: exposé « **6 minutes pour convaincre** », présentation des idées de toutes les équipes devant un jury et l'ensemble de participants au challenge.
17h00-17h30	**Délibération du JURY**
17h30-18h00	**Résultats et clôture** (une équipe gagnante par thématique)

Evaluation grid

Atelier "48h pour innover"
Fiche d'évaluation du jury

Equipe	Intérêt pour l'entreprise (note sur 5)	Créativité/ originalité concept (note sur 5)	Qualité/ créatitivté présentation (note sur 5)	Intérêt pour l'utilisateur (note sur 5)	Méthodologie de travail (note sur 5)	TOTAL
EQUIPE 1: SUJET 3 : Ordonnancement Atelier Mécanique						
EQUIPE 2: SUJET 1: KANBAN						
EQUIPE 3: SUJET 5: Ordonnancement Zone Lavage						
EQUIPE 4: SUJET 2: Chantier SMED						

Prize for the best proposed solution

✓ Teaching Scenario #2#: Developing a CMMS application

A second teaching scenario was developed at ENIB as part of the
"Industrial Maintenance" from the start of the 2021-2022 academic year, to strengthen students' cross-disciplinary and technical skills through a practical industrial project.

• Background and objective :

The project is being carried out in partnership with a recently medical analysis laboratory based in Tunis. The company's aim is to optimise the management of its equipment in order to ensure the safety and conformity of its services and thus improve its operational efficiency. The aim of the project is to develop a Computerised Maintenance Management System (CMMS). The aim of this application is to manage equipment, stocks and maintenance operations using the company's actual databases.

• Visit and Analysis

The project was initiated following discussions with the head of teaching, Med Amine Ben Hassena ENIB, and the laboratory team. Several meetings and a visit with the

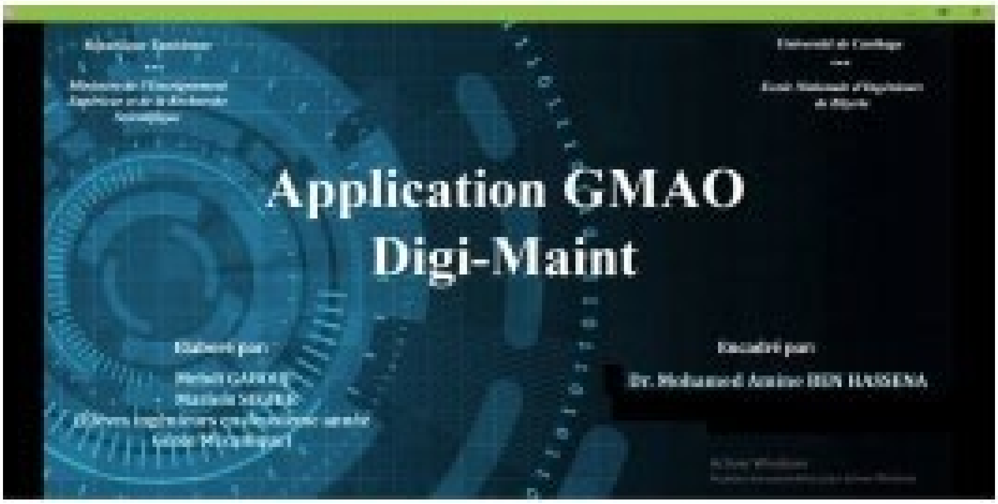
The students analysed the laboratory's specific needs and the challenges it faced, including equipment management, stock management and maintenance.

• **Process and deliverables**

The project will last 4 weeks, at the end of which a functional application will be delivered. At the same time, a video presenting the functionalities developed will be produced. The application will have to meet the laboratory's needs in terms of managing equipment, stocks and maintenance operations, while being fed by the company's actual databases.

<u>Examples of student presentations</u>

(all videos are available as supporting documents)

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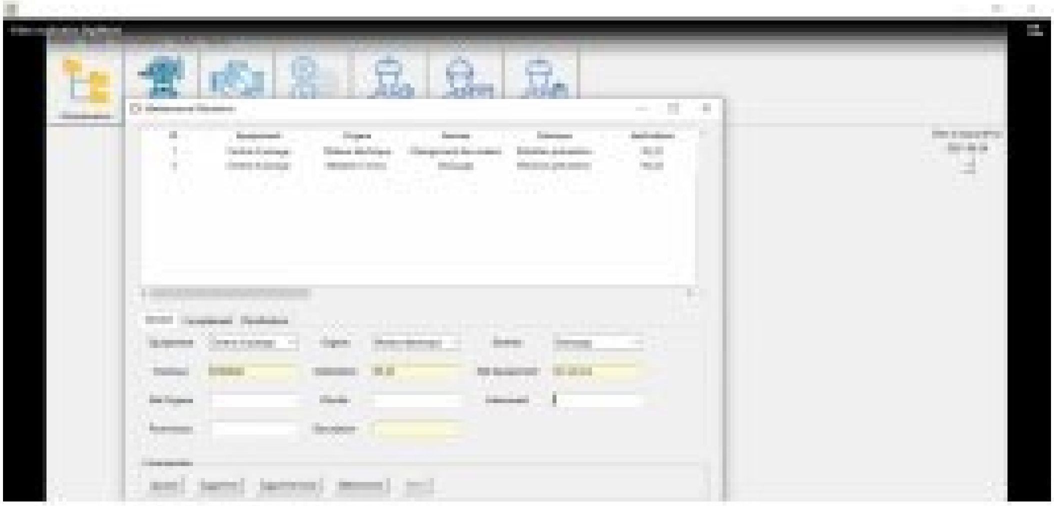

These projects and practical work, carried out in groups, have not only enabled students to exploit their technical and scientific knowledge, but also to develop cross-disciplinary skills such as teamwork, communication and creativity. What's more, the integration of the practical aspect with a concrete industrial aim is interesting and motivating for the students.

Appendix 4: University of Gabes

Background :

During this phase of the project, the main objective was to direct a group of students to a company specialising in the design and manufacture of special machines (the SOCOFAM company), to enable them to carry out in-depth studies on topics directly linked to industrial maintenance, ensuring that they offered opportunities to apply the students' theoretical knowledge to practical situations and thus present the company with a beneficial piece of work.

Objectives:

The ultimate aim of this initiative was to consolidate the students' theoretical knowledge by confronting them with practical problems in a real industrial environment. By carrying out practical case studies directly related to maintenance, the students were able to apply their knowledge and develop new problem-solving skills, which will enrich their academic and professional careers.

- 1st subject: Preventive maintenance constraints for fibre laser cutting machines

This work presents the study and maintenance of a fibre laser cutting machine, with particular attention paid to the constraints linked to the preventive maintenance of the machine's various components. The aim here is to focus on the specific maintenance constraints of the machine, with a presentation of the different types of maintenance, the associated objectives and the strategies used. In particular, a preventive maintenance plan has been drawn up for each major component of the machine, including the machine tool, laser, chiller and air compressor. This plan includes instructions for replacing the oil screen, the air filter, cleaning the radiator and general machine maintenance. Work sheets have been put in place to ensure optimum maintenance and guarantee the smooth operation of the equipment. This internship enabled us to develop a complete understanding of the technical and management constraints of preventive maintenance on fibre laser cutting machines.

❖ **2th topic: Preventive maintenance on a CNC wood router :**

The job involves studying and implementing a maintenance plan for a CNC Router machine used for machining wood.

The aim here was to work on the creation of a maintenance plan for the Router FC2136-16D CNC machine, which aims to highlight the objectives of maintenance, including reducing breakdowns, optimising productivity and reducing costs in the long term. The maintenance tasks to be carried out on the Router FC2136-16D CNC machine are determined, including the frequency of interventions and the steps required to keep the machine in good working order. Particular attention is paid to recording the maintenance carried out, to ensure rigorous monitoring and to identify any recurring problems.

The aim of this work is to highlight the importance of predictive maintenance for this CNC Router machine, emphasising the impact of good maintenance monitoring on equipment performance and durability. It also highlights the benefits of a well-structured maintenance plan, capable of reducing the risk of breakdown and optimising operating costs over the long term.

❖ **3(rd) topic: Corrective maintenance on the FC2136 CNC machine**

The course consisted of a detailed study and analysis of CNC machines (CNC Router FC2136). In terms of maintenance, the corrective maintenance of the CNC machine studied. A maintenance plan was drawn up, actions such as regular cleaning, checking oil levels, inspecting guides and rails, and updating the software. Operator safety was also a key focus, with particular attention paid to training, the use of personal protective equipment (PPE) and the creation of a safe working environment.

❖ **Topic 4: The maintenance plan for the fibre laser cutting machine**

The work involved studying the operation and maintenance of a laser cutting machine, in particular the RAYCUS laser source and its components. work involved analysing the overall operation of the machine, as well as setting up preventive maintenance procedures tailored to different parts of the equipment, such as the machine tools, coolers, laser system, air compressors and dust collectors. A detailed maintenance plan was drawn up, covering actions to be carried out daily, weekly, monthly, quarterly and annually. The aim was to keep the machine in good working order, optimise its performance and avoid breakdowns, by systematically monitoring maintenance.

Annex 5 University of Jendouba

❖ **Subject 1: Design and construction of a pycarolysis unit for treating petroleum products**

1. Context :

This process is increasingly used to recover oil waste, reduce environmental impact and produce energy resources or secondary raw materials (gas, oil, carbon).

In a global context of energy transition and sustainable resource management, the design of a pyrolysis unit to treat products of petroleum origin meets a dual challenge:

- Environmental: Reducing oil waste and limiting its impact on the environment.
- Economic: Making the most of petroleum residues by transforming them into useful products (synthesis gas, pyrolytic oils, activated carbon, etc.).

2. Objective:

The main objective of this project is to design and build a pyrolysis unit capable of efficiently treating products of petroleum origin. This unit will :

- Be adapted to the specific characteristics of petroleum waste (composition, viscosity, etc.).
- Maximising the conversion of waste into recoverable products (gas, oil, solid residues).
- Comply with environmental standards terms of emissions and by-product management.
- Be economically viable and scalable for industrial application.

3. Unit design :

- Sizing the pyrolysis reactor (temperature, residence time, etc.).
- Design of ancillary systems (feeding, cooling, product separation).

- Integration of control and safety systems.
- Production and installation :
- Manufacture of unit components.
- On-site assembly and installation.
- Setting up monitoring and control systems.

4. Testing and optimisation :

- Unit and pilot tests.
- Analysis of the products obtained (gases, oils, solid residues).
- Optimisation of operating parameters to maximise efficiency.

5. Validation and operation :

- Validation of the unit's performance.
- Operator training.
- Deployment on an industrial scale.

Topic 2: Study and design a 4-degree-of-freedom manipulator arm skid adapted to "Seabot - 1".

1. Background :

"Seabot - 1 is an underwater robot designed for operations in an aquatic environment, in particular for inspection, maintenance and intervention on underwater infrastructures (pipelines, offshore platforms, etc.). To enhance its operational capabilities, it needs a versatile and precise manipulator arm.

The manipulator arm must be mounted on a skid (modular structure) to facilitate its integration and deployment on "Seabot - 1". The skid must be designed to withstand the harsh conditions of underwater environments (pressure, corrosion, marine currents) while offering great flexibility and precision of movement.

2. Objective:

The main objective of this project is to design and produce a skid equipped a 4-DOF manipulator arm adapted to "Seabot - 1". This manipulator arm will
:

- Be compact and lightweight to adapt to constraints of underwater gear.
- Offer high precision and sufficient handling force for underwater tasks.
- Be resistant to extreme conditions (pressure, salinity, temperature).
- Be easy to install and maintain.

3. Unit design :

- The skid and manipulator arm will be designed several stages
- Design of the manipulator arm with 4 degrees of freedom (rotational and translational movements).
- Choice of materials resistant to corrosion and pressure (stainless steels, light alloys).
- Integration actuators (electric or hydraulic motors) and sensors (position, force).
- Design an intuitive user interface.

4. Testing and optimisation :

Once the skid and manipulator arm have been designed, tests will be carried out to validate their performance - **Laboratory tests :**

- Simulation of underwater conditions (test basin, pressure, salinity).
- Checking accuracy and arm strength.
- Durability and impact resistance tests.

5. Validation and operation :

The final phase of the project will consist of validating the system and deploying it:

- **Validation in real-life conditions :**

- Training operators to use the manipulator arm.
- Deployment of the skid on "Seabot - 1" for underwater missions.
- Maintenance and performance monitoring in the field.
- Optimisation of wage panel parameters for wheat production in northern Tunisia
- Development of bars bars: combination between the analytical calculation and FEM numerical simulation
- Study and design of the dust control system at the quarry by humidification

Topic 3: Optimisation of solar panel parameters for wheat production in the northern regions of Tunisia

1. Context :

Agriculture is a key sector in Tunisia, particularly in the northern regions where wheat production plays an essential role in the local economy and food security. However, this region facing challenges related water and energy management, particularly as a result of climate change and the scarcity of water resources.

The use of solar panels to power irrigation systems and agricultural equipment represents a promising solution for improving energy efficiency and reducing costs. However, the parameters for installing and operating solar panels (orientation, inclination, power, etc.) need to be optimised to suit the specific characteristics of wheat crops and local climatic conditions.

2. Objective:

The main objective of this project is to optimise the parameters of solar panels to maximise their efficiency in wheat production in the northern regions of Tunisia. Specific objectives include:

- Determine the best configurations for solar panels (orientation, inclination, power) based on the energy needs of farms.
- Assessing the impact of solar energy irrigation and wheat productivity.

- Propose economically viable and sustainable solutions for farmers.
- Contribute to reducing carbon footprint and improving climate resilience.

3. Unit design :

The design of the solar unit and its integration into farms will take place in several stages:

Solar panel design :

- Selection of appropriate solar panel technologies (photovoltaic, thermal, etc.).
- Determination of optimum parameters (orientation, inclination, surface area, power).
- Design of energy storage (batteries) and energy management systems.

2. **Integration with irrigation systems :**
    - Design of solar-powered irrigation .
    - Optimising systems to reduce water and energy .
    - Integration of sensors to monitor water and energy requirements.

Software design :

- Development a control and monitoring system for solar panels.
- Integration of weather data to adjust parameters in real time.
- Design a user interface for farmers.

4. Testing and optimisation :

Once the unit has been designed, tests will be carried out to validate and optimise its performance:

- Adjustment of solar panel parameters (orientation, inclination, etc.).
- Optimising irrigation systems to maximise water and energy efficiency.
- Improved control and monitoring algorithms.

5. Validation and operation :

The final phase of the project will involve validating the system and rolling it out on a larger scale.

1. **Validation in real-life conditions :**
   - Extensive testing on several farms to validate performance.
   - Assessment of the impact on wheat productivity and operating costs.
2. **Operation :**
   - Training farmers in the use of solar panels and irrigation systems.
   - Deployment of the solution in the northern regions of Tunisia.
   - Monitoring and maintenance of facilities to ensure their sustainability.

6. Expected results :

- An optimised solution for using solar panels in wheat production.
- Reduced energy costs and improved irrigation efficiency.
- An increase in wheat productivity and resilience.
- A contribution to environmental sustainability and food safety in Tunisia.

Topic 4: Development of stabiliser bars: combining analytical calculation and FEM numerical simulation

1. Background :

Stabiliser bars, also known as anti-roll bars, are essential components in vehicle suspension systems. They help to reduce the inclination of the vehicle when cornering, thereby improving stability, comfort and safety. However, the design of these bars requires precise optimisation meet specific requirements in terms of rigidity, strength and weight.

Today, traditional design methods are often based on simplified analytical calculations, which do not take into account all the complexities of real conditions of use. The integration of numerical simulation using the finite element method (FEM) enables the behaviour of stabiliser bars under different loads and stresses to be analysed in greater detail, while reducing development costs and times.

2. Objective:

The main objective of this project is to develop optimised stabiliser bars by combining analytical calculation and FEM numerical simulation. Specific objectives include:

- Improve the accuracy of stabiliser bar design by taking account of mechanical constraints and real-life conditions of use.
- Reduce the weight of the bars maintaining or improving their performance (rigidity, strength, durability).
- Minimise development and production costs through an efficient digital approach.
- Validate designs using physical tests to guarantee their reliability.

3. Unit design :

The stabiliser bars will be designed several stages:

1. **FEM numerical simulation :**
    - Creation of a 3D model of the stabiliser bars.

- Application of loads and stresses (forces, moments, vibrations).
- Analysis of results (deformations, stresses, safety factor).
- Optimisation of geometry and materials based on simulation results.

2. **Final design :**

- Integration analytical calculation and FEM simulation results.
- Definition of technical specifications for manufacturing.
- Design of brackets and fixings for integration into the vehicle.

4. Testing and optimisation :

Once the stabiliser bars have been designed, tests will be carried out to validate and optimise their performance:

- Simulation of complex scenarios (tight bends, rough roads).
- Verification of resistance to impact and fatigue.
- Optimisation of design parameters based on results.
- Manufacture of prototypes for laboratory testing.
- Measurement of rigidity, strength and durability.
- Comparison of physical results with numerical predictions.
- Adjustment of geometry and materials to improve performance.
- Reduced weight while maintaining strength and rigidity.
- Improved design to reduce production costs.

5. Validation and operation :

The final phase of the project will involve validating the stabiliser bars and deploying them:

1. **Validation in real-life conditions :**

- Installation of stabiliser bars on test vehicles.

- Road tests to assess stability, comfort and safety.
- Data collection to check compliance technical requirements.

2. **Operation :**

- Integration of stabiliser bars into series production.
- Training for production and maintenance teams.
- Monitoring performance in the field to ensure customer satisfaction.

6. Expected results :

- Optimised stabiliser bars, combining lightness, rigidity and strength.
- Reduced development costs through the use of FEM simulation.
- Improved stability and comfort for equipped vehicles.
- A design methodology that can be reproduced other automotive components.