COST
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Brussels, 17 May 2024

COST

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action “Fatigue Benchmark Repository” (FABER) CA23109

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action Fatigue Benchmark Repository approved by the Committee of Senior Officials through written procedure on 17 May 2024.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA23109
FATIGUE BENCHMARK REPOSITORY (FABER)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to enhance the limited cooperation among stakeholders in the domain of computational fatigue analysis, to support the sharing, analysis and accessibility of research data among engineers, researchers and fatigue solver developers, which has been hindered due to various competitive issues. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

TECHNICAL ANNEX

OVERVIEW

Summary

Fatigue damage is the key factor in 80-90% of in-service failures of structural components. In any design, it is essential to be able to estimate the potential fatigue damage safely and expertly. Commercial fatigue solvers are program tools dedicated to allowing even a not very expert user to perform a straightforward fatigue life prediction. However, the fatigue damage process is very complex. It involves a large number and a large range of variables. The computation process is based mostly on empirical experience. Currently-used fatigue solvers are based on experimental evidence acquired during first two thirds of the 20th century. Although very many experiments have been conducted in the meantime, the computational basis has remained fixed, and little effort has been dedicated to a redefinition. The lack of interest of academia in the topic, the tendency of fatigue solver developers to implement computational strategies without understanding the problem adequately, the use by inexperienced and inexpert users, and final warranty denial for the results of fatigue solvers have led to a critical mass of problems, which can be marked as a loss of responsibility. Our project focuses on preparing a database of experimental fatigue data, which will be easily accessible for creating benchmark sets. Users from academia and from engineering sectors will be able to adopt the data quickly for testing various prediction hypotheses and various computational tools. An open-source fatigue software will be prepared. Only such joint action can restore a responsible attitude for the computational results presented by fatigue solvers.

Areas of Expertise Relevant for the Action	Keywords
● Mechanical engineering: Applied mechanics, thermodynamics ● Computer and Information Sciences: Machine learning algorithms ● Mechanical engineering: Databases, data mining, data curation, computational modelling ● Materials engineering: Structural properties of materials ● Computer and Information Sciences: Artificial intelligence, intelligent systems, multi agent systems	● Fatigue life estimation ● benchmark ● fatigue estimation software ● experimental fatigue data

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination

● Establishing the base for the large-scale cooperation by reviewing the current state of the art and developing common understanding of the issues the Action will face during development.
● Coordination of implementations:
a) The design, creation and promotion of a Fatigue Data Base Repository
b) Developing benchmark sets in categories of workgroup WG4
c) Open-source fatigue-prediction library able to process the benchmarks automatically
● Reaching solid and verified collection of experimental data by populating it by credible data. Establishing clear rules for data curation.
● Defining the output benchmark sets for individual treated categories in WG4 and supporting their use by case studies showing the optimum work within them and the potential time and financial gain.
● Making the benchmarking output understandable to users by reaching a broad consent on established criteria for measuring the output quality of the benchmarking process.
● Evaluating AI and Machine Learning approaches to enhance developed data sets, that can be validated by the fatigue testing community.
● Proposals of international standards for adding newly acquired data to further growth of data collection

based on newly measured experimental data.
● Achieving agreement on the scope of implementations of newly developed fatigue estimation methods into the fatigue solver, and on the responsibility for publishing its new validated releases.

Capacity Building
● Establishing the structure of the Action, which ensures the WGs are properly populated, led and the overall effort supervised.
● Ensuring the common agreement on data treatment by establishing the Data Committee to set rules for data processing routines and to encourage their use.
● Creating a system on data search for already existing experimental data items, securing and recording a link to them, allocating the teams for processing the data and collaborators for trailing and validating the final output.
● Managing the long-term sustainability of development by finding and supporting the responsible partners to deal with:
a) Creating/adopting and maintaining the data collection including the system for experimental data management
b) Creating/adopting and further implementation of a library of fatigue-prediction routines.
● Forming a network of experimental laboratories able to follow the defined routines and to support experimentation resulting from other works and research linked to the Action activities.
● Establishing the world-wide competition for the best fatigue prediction as a bi-annual competition with a defined content, scientific and executive board, and with connection to industry for defining the problems to be analysed and providing the testing material. Two volumes organized during the project.
● Securing the experimental data necessary for the competition by running chosen experiments in cooperating laboratories.
● Transition to a common use of built tools in all stakeholder groups, while inviting the stakeholders to a round table discussions with the special emphasis on fatigue solver developers.
● Ensuring the right data management and software tool management practice is maintained within the Action (staff training sessions, workshops to discuss the results, and STSM of key project members, while focusing on YRIs to change paradigms of a common proof in the domain of verifying fatigue methods and fatigue solvers).
● Growth of the Action through extensive dissemination to different stakeholders – and the transition to long-term horizon: Search for opportunities at national and international level to support the objectives of the Action. Supporting career development of YRIs and involvement of ITCs participants.

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TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. SOUNDNESS OF THE CHALLENGE

1.1.1. DESCRIPTION OF THE STATE OF THE ART

80-90% of all in-service mechanical failures are related to fatigue damaging [1]. A report on the economic effects of fracture in the United States [2] estimates the losses reached 4.2% of GDP within the year 1978. Fatigue damage is a complex process depending on a multitude of factors and can lead to costly repairs or in some situations, loss of life. Its prediction is mostly based on empirical relations, which in turn depend on extensive and costly experiments. Fatigue testing is significantly time expensive - a single experiment can take many months to complete for small and large structures. This means that, industry is motivated to evaluate for fatigue fitness in a virtual domain, such as a digital twin.

Computer-aided design (CAD) following the rapid development of computers impacted engineering. A description of the local stress and strain states, needed to evaluate fatigue fitness, can be generated using a finite element (FE) model of a component. The inclusion of FE-systems into the design reduced overall costs greatly. Their wide use has accelerated the development cycle in structural design. Today, companies assume that a bachelor graduate in engineering is capable to deliver this type of solution.

In the late 1980's, companies emerged to provide a computerised fatigue solution based on previous FE models. Fatigue solvers were intended as a support tool, aimed at reducing the cost and duration of the design period. When the early fatigue solvers were designed, the current state of the art in fatigue estimation know-how was implemented. Since then, development efforts have been focused mostly on increased computation speed, on establishing a seamless connection to previous analyses, or on implementing new domains. The core of the computations in fatigue solvers is as it was defined nearly 40 years ago. For designers, the goal is to integrate the virtual model development into one process, where the same person designs the component in the CAD-system, prepares an FE-model and solves it, and then conducts a fatigue analysis. Companies are facing this new reality with interest because fatigue solvers are seemingly much cheaper than fatigue analysts. In addition, fatigue solvers provide the promise of consistent output, and they can be operated from places where labour costs are low.

Advertisements made by companies selling fatigue software routinely present arguments like: “Q: Do I need to be a fatigue expert? A: No, you can leave that to us.” [3]. Company managers, who usually are not fatigue experts, are encouraged to make the decision to replace expensive fatigue analysts by a cheaper fatigue computational solver. However, they need not be aware of the commonly applied notice in the end-user agreement signed during the purchase, which states that the solver developer denies any warranty for the results obtained from the software. This kind of warranty denial is common today in many software domains. This lack of warranty is accompanied in the fatigue domain by the empirically based computation process, which need not be enough universal for every usage. The question is, how can the user test the correctness of the fatigue solver and have confidence in designed components?

Public evaluation of fatigue solvers could be relatively easily treated by processes common to other products. Users could check public benchmarks or any comparisons before they purchase the product. Fatigue solver developers often prevent that by an additional section of the end user licence agreement that denies the users the right to publish results of benchmarks that include their products without their consent. The status quo affects any development in new fatigue estimation methods, as there is no practical incentive in making the current solution better. Due to that, the companies are using the fatigue solver mostly for comparison of different design variants, and it is not believed any breakthrough in improving the quality of fatigue estimation could occur. This project aims to provide a complex and robust benchmark of fatigue data that can ultimately reduce component costs and save lives.

1.1.2. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The network involved in this COST project proposal is brought together by the lack of an existing, robust and affordable method to verify and validate highly complex fatigue methods and fatigue solvers in a context of technologically relevant applications. A cooperation within an interdisciplinary team from Mathematics, Physics, Engineering, Computer Science, Materials is required to solve this challenge.

During the early development of FE-analysis, NAFEMS (National Agency for Finite Element Methods and Standards) consortium was set up in the United Kingdom. "*By the late 1970's and early 1980's, as computing power became more widely available, increasingly industry was starting to solve practical engineering problems using finite element analysis techniques. There was however considerable concern that the accuracy of the methods, and software implementations, required to be verified in order to allow the results to be effectively used*" [4]. The same problems can be found today in the domain of fatigue solvers. The fatigue analysis is more complicated than FE-analysis. There are fewer experienced practicing fatigue analysts. The current trend to package whole virtual design into one computer-driven calculation process operated by a non-expert with a mere basic understanding of fatigue problems is driving us into even more unsafe waters. Not only verification of fatigue solvers, but also validation of fatigue models must be renegotiated among academia, software developers and industry.

There are various reasons for the current status quo:

- Company managers are forced to cut costs. Fatigue solvers promise to be the right tool for that.
- Affordable fatigue solvers reduced the funding of further research. Due to the necessity to publish or perish, researchers have tended to look for new research topics and have become less interested into checking what has been implemented into currently available software.
- Fatigue problems are very complex. Validation of the software only on specific in-house cases need not be sufficient for a universal use, because the calculation response cannot be generalized.
- Once the software has been bought, the dependency on it (and the dependency on its in-house benchmarking on real cases) makes its simple replacement impossible.
- The fatigue solver developers have little financial motivation for a better proof of quality.
- Fatigue research is very expensive. It requires a great deal of experimentation. It is not realistic to expect fatigue solver developers to perform extensive test campaigns to validate their software – it would increase their costs, and other more reckless competitors would quickly destroy them.
- None of the three parties (academia / industry / fatigue solver developers) can achieve a breakthrough alone which would rectify the current situation.

In academia, due to the lack of funding for further research in basic fatigue estimation, re-validation of used methods has become sparse and randomly driven. Many institutions do not have access to fatigue machines which are costly to run and maintain. Many large laboratories in the UK and EU are closing being replaced by cheaper software tools and virtual models. There are many more experimental data items than 30 years ago, but they are dispersed over too many sources. This increases the workload for a researcher to pursue verification, or to develop a new solution. The related extensive workload in turn decreases willingness of the researcher to complicate it by any data quality assessment. Misleading data sets could be used when the fatigue solver developers chose, which methods to implement.

Industry is not motivated enough to reinvest in primary research. In addition, large companies do their own research, but they keep the output private. They have built a solid base of experience with current fatigue solvers. This type of customer can be assumed to be satisfied with the status quo. However, any error in the serial production of such a company is extremely costly. Medium-sized companies do not have experience broad enough to carry out extensive benchmarking. They must rely on the quality of the fatigue solver, while public benchmarking of most such products is disallowed. Any customer looking for a sound information to facilitate the selection of the fatigue tool is prevented from finding it legally.

Fatigue solver developers have got caught in a trap that they built. They do not want to cooperate with other competitors to improve the situation. They cannot fund the necessary research by themselves. They can focus on large customers, which can use their own benchmark cases. If the target area is to be extended to medium- and small-sized companies, fatigue solver developers must claim "everything is fine and we can solve any problem that you may have", which is not true. The role of fatigue solver developers and their involvement within FABER was discussed with some of them. They find the fact that the user is the only responsible entity legitimate. They would appreciate the existence of the benchmark sets, but they do not want to cooperate, hoping they can reach to them through own customers.

The question of data analysis and of research data sharing became a major priority during recent years, and thus, e.g., Horizon 2020 and other European projects demands the produced data to be as open as possible. Though this new trend brings some positive aspects in the future for new data sets, it does not help with the described situation, unless a dedicated project on the multitude of fatigue scenarios is delivered. Any person willing to establish a benchmark set is sentenced to a tedious data processing to fit his/her private routine of data management. Indeed, the only improvement to the research outputs from the last century is the availability of the data items in an electronic format.

We are facing the loss of responsibility, where none of the stakeholders alone can find the way out:

1) **Fatigue solver developers** act in a competitive environment. Because of the desire to increase company profits, no single entity wants to be the first one to "come-out" stating: "Fatigue life estimate is more complicated than we have told you, and our tools may not be precise enough. These are its limits."
2) **Industry** is forced to use fatigue solvers to minimize the development time and costs. It has limited means to assure the tools provide the service in the quality they expect. It is afraid of revolutionary improvements because they do not expect the cost of the validation could be shared with other entities.
3) **Academia** lost funding and interest. The benchmarking of the fatigue basics is not highly active despite the often significant social and economic impacts of failure. It is extremely costly to prepare the high-quality sets, and there is little incentive in the practical outcome. It does not believe that any improvements could get projected into use in engineering domain, leading to a lack of perceived impact.

1.2. PROGRESS BEYOND THE STATE OF THE ART

1.2.1. APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE OF THE ART

The goal of the action presented in this project is to develop a global leading network of industry, academia and fatigue solver developers to build a fatigue benchmark repository that will allow all stakeholders to test the quality of fatigue prediction models and of their various implementations in either in-house software units or in purchased solvers. This would enhance EU competitivity, reduce research poverty and deliver safer components for citizens. The project will demonstrate that benchmarking is possible, and what level of result quality can be achieved. To quicken the development, validation and application process of new criteria, new fatigue software tool enabling large scale validation processes is to be developed.

Only the joint effort of partners gathered in this COST Action makes these challenging goals possible. We need Mechanical and Material Engineers for fatigue understanding, Civil Engineers, and other engineering domains to bring forth practical use cases, Data Analysts and Mathematicians for dealing with large data sets, Software Architects for the necessary implementations, Physics and Chemists to deal with the material aspects and a deeper insight into the material models.

Tests for individual benchmarks will be excerpted from a newly established collection of experimental fatigue data. The cooperation of research teams from European and worldwide countries will ensure the best-possible coverage of the developed experimental base thanks to the access to the local studies. The networking will enable the various teams to share their experience and to divide the workload into more research units. In addition, to the volume of the new database, the main target is data credibility and establishing stringent criteria for accepting experimental data to the benchmark set, meaning the development of recognised standards for experiments, archiving and background information will be crucial. Complete benchmarks will be available to all members on the project website and will be made available for over five years from the project end.

The existence of the benchmark sets is not sufficient to change the current situation. The software companies are active in preventing researchers from publishing any measurable quantities related to the estimation quality. We will engage with these companies to support transition to a new area of openness and improvement. Furthermore, the implementation of new research results are complicated. To improve the situation, and to make the validation process as open as possible, and to support the quick transfer of new solutions into the practical engineering analyses, the Action will focus on a second goal, the creation of a fatigue calculation program within the open-source scheme, continuous development of which could be shared openly over the world even after this COST project is finished.

All three stakeholders – academia, industry, and fatigue solver developers, plus the economy and society – will profit if the benchmark data sets for validating fatigue methods and the open-source fatigue program are made available.

- **Academia** will gain quick access to extensive and well-established data sets. Also Young Researchers and Innovators (YRIs), and members from Inclusive Target Countries (ITCs) will proceed quickly to real research, instead of spending months and years on gathering experimental data to test their theories. Members will gain the access to even recent implementation of various fatigue theories. They will not be forced to recreate them again from often limited description scattered over many papers.

- **Fatigue solver developers** will understand quickly which methods are worth implementing. They will be able to verify the implementation based on such sets. They can use the validation output to prove their customers how good their solution is. At last, they can use the open-source fatigue solver as the base for their further implementations.
- **Industry** will profit from the increased reliability of the predictions. Based on benchmark results, engineers will be able to evaluate the quality of the implemented solutions. They will be able to take reasonable actions to ensure their responsible use to provide safer products to society, reducing impacts such as pollution and loss of life.

1.2.2. OBJECTIVES

1.2.2.1. Research Coordination Objectives

The goal of the project is to provide to the community of fatigue analysts and researchers data sets that will shorten the time required for benchmarking fatigue models/implementations necessary for any verification and validation activities. Secondly, the newly built open-source software tool will make a clear sample of the output such benchmarks can provide. Accordingly, the development cycle of new fatigue prediction criteria will shorten, and the quality of in-house built or purchased fatigue prediction tools will increase. To reach this primary goal, the objectives underlying the research coordination are:

1) Establishing the base for the large-scale cooperation by reviewing the current state of the art and developing common understanding of the issues the Action will face during development.
2) Coordination of implementations:
   a) The design, creation and promotion of a Fatigue Data Base Repository
   b) Developing benchmark sets in categories of workgroup WG4
   c) Open-source fatigue-prediction library able to process the benchmarks automatically
3) Reaching solid and verified collection of experimental data by populating it by credible data. Establishing clear rules for data curation.
4) Defining the output benchmark sets for individual treated categories in WG4 and supporting their use by case studies showing the optimum work within them and the potential time and financial gain.
5) Making the benchmarking output understandable to users by reaching a broad consent on established criteria for measuring the output quality of the benchmarking process.
6) Evaluating AI and Machine Learning approaches to enhance developed data sets, that can be validated by the fatigue testing community.
7) Proposals of international standards for adding newly acquired data to further growth of data collection based on newly measured experimental data.
8) Achieving agreement on the scope of implementations of newly developed fatigue estimation methods into the fatigue solver, and on the responsibility for publishing its new validated releases.

1.2.2.2. Capacity-building Objectives

The group of submitters has already existed and cooperated for several years. Except for the newly created bilateral cooperations, the existing cooperation has given rise to the first on-going volume of experimental fatigue database for the subsequent fatigue estimation competition. Currently cooperation is a harmonised endeavour between 15 teams from ten countries. Within the Action, the cooperation of multiple teams will substantially increase the volume of developed papers and standards, data and evaluations and the scope and breadth of dissemination. The specific capacity-building objectives are:

1) Establishing the structure of the Action, which ensures the WGs are properly populated, led and the overall effort supervised.
2) Ensuring the common agreement on data treatment by establishing the Data Committee to set rules for data processing routines and to encourage their use.
3) Creating a system on data search for already existing experimental data items, securing and recording a link to them, allocating the teams for processing the data and collaborators for trailing and validating the final output.
4) Managing the long-term sustainability of development by finding and supporting the responsible partners to deal with:
   a) Creating/adopting and maintaining the data collection including the system for experimental data management
   b) Creating/adopting and further implementation of a library of fatigue-prediction routines.
5) Forming a network of experimental laboratories able to follow the defined routines and to support experimentation resulting from other works and research linked to the Action activities.
6) Establishing the world-wide competition for the best fatigue prediction as a bi-annual competition with a defined content, scientific and executive board, and with connection to industry for defining the problems to be analysed and providing the testing material. Two volumes organized during the project.
7) Securing the experimental data necessary for the competition by running chosen experiments in cooperating laboratories.
8) Transition to a common use of built tools in all stakeholder groups, while inviting the stakeholders to a round table discussions with the special emphasis on fatigue solver developers.
9) Ensuring the right data management and software tool management practice is maintained within the Action (staff training sessions, workshops to discuss the results, and STSM of key project members, while focusing on YRIs to change paradigms of a common proof in the domain of verifying fatigue methods and fatigue solvers).
10) Growth of the Action through extensive dissemination to different stakeholders– and the transition to long-term horizon: Search for opportunities at national and international level to support the objectives of the Action. Supporting career development of YRIs and involvement of ITCs participants.

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

The European Materials Modelling Council (EMMC) focuses on general material modelling and was supported within Horizon2020 project (2016-2019). This Action will complement the activities of EMMC and will be a focus point for recruiting new participants. The Action plans to interact with two working groups of EMMC:

- The Modelling and Validation Working Group focuses on finding gaps in existing models, multiscale modelling, and preparing a systematic workflow for checking various material models.
- The Repositories and Marketplaces Working Group - a hub for various repositories in Europe.

The ODIN (Online Data & Information Network) portal was hosted at the European Commission JRC. It includes the MatDB database, which contains also fatigue records. It claimed to be able to aggregate any fatigue experiments. This makes the database structure an option for adaptation for use within the FABER project since the access to the database including data feed or data retrieval is available. Similarly to EMMC, its focus differs from the goal of establishing data sets of high quality – the relation to FABER concerns only the data aggregation.

The NAFEMS consortium (National Agency for Finite Element Methods and Standards, www.nafems.org) does not focus on fatigue models, and when the topic of benchmarking in the fatigue domain was discussed with its representatives during one meeting in 2018, neither further response nor signs of interest followed. The clearly directed cooperative effort of its members makes FABER much stronger in data acquisition and in the subsequent use of the data than any national, company-based, or private activities. We are not aware of any other large-scale activity in preparing benchmark sets for predictive fatigue analysis.

As regards the open-source fatigue tools, there are multiple cases written as Python libraries (open-source software); however, none of these is an output of a larger collaborative effort. These items are usually driven forward by individuals within specific academic or engineering institution. As such, they are not comparable to the FABER's effort to make a joint tool that could be shared, maintained, and developed in a cooperation of multiple institutions and stakeholders.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS, EXPERTISE AND GEOGRAPHICAL BALANCE WITHIN THE COST MEMBERS AND BEYOND

If the fatigue prediction models are to be used in practical applications, they must be tested on as large a benchmark as possible, otherwise adequate quality of output cannot be guaranteed. A multi-national cooperation with the participation of multiple teams is the only solution to keep the workload invested by each participant sufficiently low to maintain the willingness to cooperate. Their involvement will be rewarded by providing a free access to the gathered data. To further decrease the workload, information about the Action will be disseminated to ensure that more entities and more information sources get involved.

The change of the status quo does not concern only research teams. To understand the problem, it is necessary to highlight it repeatedly, so that industrial managers understand the current threat. Industry interest is essential for further continuation of our effort, when our COST Action ends. The compound problems gathered in WG5 where multiple effects interact will not be finalised by benchmark sets in that moment. The interest of industry in FABER's output is necessary to increase their involvement in the Action.

The broader Action can influence more companies. The tools enabled within the COST Actions are useful for this goal: STSMs will allow us to cross-fertilize the ideas by allowing the specialists to visit other laboratories or companies, and to better understand the mutual needs. Virtual Mobility Grants will help us to fund the key persons above all in the implementation works to do key packets of work; ITC Conference grants will help to empower members from ITC countries to attend conferences important for their career growth but also for spreading further the Action objectives; Training Schools will support introduction of the right practice into the implementation and data management works.

This Action goes against the existing status quo – but the status quo is acceptable or even very fruitful and profitable in the short-term for many individuals and companies. This cooperation will give strength to the claims made by this project showing to other stakeholders that this understanding of the problem is not irrational, and that the problem really does exist.
The intention to increase the scope of the Action as much as possible and the need to process large scale of data items creates quite a demanding combination as regards the management of the cooperation, of data acquisition, of data processing processes, and of the implementation effort (database, fatigue tool). For this reason a Data Committee will be established. It will focus on tasks treated in WG1 to reach the optimum strategy based on a broad agreement of the Action members. To get the information on applied strategies to the Action members, and to ensure that the established policy is understood and complied to, three strategies will be followed:

1. A series of Training Schools will be prepared where the implementation will be explained.
2. A series of video tutorials explaining the data manipulation routines will be recorded.
3. For each task group of Action participants, one representative will be chosen to be more deeply educated in the data processing techniques. These Data Officers will take care of the allocated members. They will be preferably recruited from the YRIs, so that a longer continuity of their experience and higher ability to follow the winding roads of future data processing techniques will be ensured.

The Work Group Meetings will be organized preferably in ITC countries, which is a proactive step to support larger involvement from their members in the Action activities – the necessary travel costs are lower, and thus more members can join.

To increase the awareness of the significance of the joint effort and of the usefulness of benchmarking, several workshops will be organised, where the concept and the way the output of benchmarking can be analysed will be explained for new prospective adepts from research and engineering domains.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

The networking within this COST Action will provide a way to establish a broad base of members sharing the information and practices, and promoting their use and implementation. The activity of stakeholders will be rewarded by their immediate access to the available data. The data-oriented part of the project is more typical for members from academia above all, but the impact of the Action goes far beyond, and it should affect the industry (better understanding to limitations of used tools) and the fatigue solver developers (disruptive change in proving/monitoring quality of their products).

During the project run, the membership proportion from three stakeholder groups: academia, industry and fatigue solver developers, must change substantially. At this moment, most members come from academia while the fatigue solver developers are not willing to cooperate. However if a strong industry support is secured, the solvers will need to meet new requirements. Developing of the open-source fatigue tool is a further way to ensure such change. It will serve as a proof of concept that benchmarking is a viable approach. Thanks to that, securing the critical mass of the Action members will change the status quo at last. The issue of the loss of responsibility, and the availability of a solution to be used to heal it will be constantly reminded by all Action members.

Various actions pursued to increase the number of members to change the paradigm were mentioned in the previous subsections and in the project objectives. The primary targeted group will be engineers (Mechanical, Civil, Architectural), Physicists, Chemists and Computer Scientists (AI/Machine Learning) dealing with fatigue analyses in industry and large data sets. The broad member base will be motivated to spread the information on the Action goals and activities towards industrial partners. Industry should be one of the biggest beneficiaries of the project, as its resources to assembly the benchmark sets are limited, though engineers are in the position of the persons responsible for fatigue analyses performed.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAKTHROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

Scientific impact and breakthrough

The activities in the Action and its outcome will revive the interest in redefining and validating the key computation methods necessary for improving the status quo in the fatigue life estimation. It will help to understand the weak links in the whole computational process, on which the focus of cooperating researchers will be focused. These activities will clearly show that these basic concepts deemed for a long time as solved need a substantial revision, and the resulting publications will further incite the interest among researchers outside of the Action. Presence of the validated data sets for benchmarking new methods will help to quickly decide which concepts are reasonable for further extension.

The validated fatigue tool will enable to apply the current state of the art in the fatigue analysis. It will enhance further research and development because it will allow the researchers to skip the tedious reimplementations of competing criteria and methods. This set of services will allow to focus solely on the research of new ways, instead of losing so much time in preparatory activities, which is common today.

Technological impact and breakthrough

It is common today that the fatigue solvers are deemed to be suitable above all for comparing different design variants than to estimate the exact fatigue life. However, fatigue damaging is extremely complex problem with many degrees of freedom, which can modify the output fatigue life. The question can be posed: Will all these activities redefine the fatigue life calculation so substantially that the fatigue life estimation will really become reliable quantitatively and not just qualitatively? We do not have the answer ready. But we are sure that continuing in the current dispersed and chaotic activities in fatigue research while tying up the hands of engineers by luring them into using fatigue solvers, which are essentially not validated, will not result in improved output. In fact, the situation can only deteriorate, creating the space for unskilled people who operate the fatigue solvers, capabilities of which they do not understand, and validation of which was not checked until some catastrophic accidents happen.

The fatigue estimation competition will be organised twice during the Action's lifetime and will attract the interest both of practicing engineers and of researchers active in this area. It's results will show the readiness and quality of fatigue life estimations while using various current computational approaches. This will be a good starting point for highlighting the usefulness of future cooperation to improve the current state and to make the fatigue life predictions more stable in the estimation quality.

Benchmark sets will serve as the initial point for large-scale applications of big data analyses and machine learning algorithms. In fatigue analysis, there have already been multiple attempts on applying such solution types, however, large data sets are the basic condition for successful attempts. Too small data sets can lead to an overtrained mechanism, which is not valid anymore out of the training data. Though the transition to this solution type is envisaged in the last year of the project run, the databases will stay five years after the end of the COST Action. The Action will support a substantial breakthrough in fatigue life prediction based on AI solutions.

Socioeconomic impact and breakthrough

The initial analysis of the status quo showed that the way the fatigue analysis, in the domains of research and engineering applications, has arrived at a dead end. This COST Action can help to get to a round table all three stakeholder types (academia, industry, fatigue solver developers), and to facilitate finding a solution, which will redefine the mutual relations among them. Even fatigue solver developers who are reluctant to changing the status quo due to the fear they could lose customers, will benefit from the output thanks to the access to the benchmark sets and to the open-source code they can reimplement.

The output of the activities should lead to increasing the number of industrial companies which can deal with the fatigue analysis thanks to decreasing the cost of the entry step (validation of the acquired fatigue solver). This in turn should impact the quality of products they produce, durability in service of which should be better understood and enhanced. The losses caused to economics due to premature failures should be substantially reduced. Better understanding of damaging mechanisms should decrease the necessary safety coefficients to be applied, and to further reduce the costs related to experimental analysis of the complex technological units.

Finally, the simpler access both to experimental data ready for validation and to the open-source fatigue estimation tool can help to attract researchers from less developed countries to Europe, because it will simplify the path to reach measurable breakthrough with minimum invoked costs.

3.2. MEASURES TO MAXIMISE IMPACT

3.2.1. KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

The Action establishes work groups (WG) related to individual topics of fatigue analyses. Their members will be mostly YRIs located in various countries across the European continent, who are supervised by mentors taking care of their career growth, training, exchange of information, and research focus. The Action will try to ensure that YRIs, female participants and those from ITC countries lead certain key activities ensuring an effective balance in the Core Management Group. Each WG should meet online on a regular basis at least every two months so that their members could follow the development. Each six months, an online workshop based on the findings of each WG will be organised to increase the general awareness among the stakeholders.

It is expected these focused groups should help to breed new ideas, to help exchange of YRIs among various institutions, and to attract newcomers (focusing on female members to improve the current gender disbalance) to join the Action. It will bring together established researchers with a good overview of the studied subject, and a number of YRIs that could help disrupting the common conservatism related to the older generation and enhancing scientific dialogue. Training Schools will be preferably organized in ITC countries to encourage the participation from their researchers and related personal growth (and to decrease the invoked costs).

Opportunities arising from the STSMs are an important aspect of the project. The Working Group Meetings present an acceptable way to find consensus on some items (file formats, data processing, regression analyses, statistical evaluations of benchmark results). However, research cooperation on individual scientific topics will require more profound discussions so at least 2-3 STSMs for each WG per year are envisaged. These stays will substantially help the personal career development of the participants (above all YRIs), and they will also lead to better information exchange between institutions within Europe. The networking activities will have a profound impact also on mid-career members, who will get access to experience from other institutions over Europe and outside of it, and to cooperation in preparing joint grant projects across various cooperating institutions.

The objectives of the Action include goals that can be clearly documented by a published paper, or by a report. We will deal with deliverables, some of which mainly concern the Action, while others will be provided free-of-charge to the public (e.g. a description of the file format for gathering the experiments, or the open-source fatigue tool). The benchmark sets for each effect will be available to Action members, to enhance their involvement in the project goals, and also in order to provide room for further extension of the project after the Action ends. Establishing a license fee for external users of the tool is apossible mode of reaching future sustainability. The interested groups will be invited to join the Action, with the condition of active collaboration in the Action activities.

A major part of the team will focus on high-cycle fatigue issues typical, e.g., for the transportation industry. Complete timetable of related activities is presented in a Gantt diagram (4.1.4). One group of researchers will focus on low-cycle fatigue domain and related cyclic plasticity modelling. Sharing knowledge and developed codes in initial workshops will lead to a synergy for finding the procedures available for all Action members. Based on the discussions and further works, benchmarks in LCF domain will be prepared. On the other hand, due to a limited life of the project to 4 years some topics will not be considered, for instance, the crack growth phase.

The data aggregation process, which is a core element and one of the reasons for large-scale cooperation, will have to be carefully disseminated among the participants and stakeholders. A report on optimum practice will be published. A book highlighting the status quo in WG5 and case studies explaining how to use the benchmarks will be prepared. Some measures to ensure the right practice in the Action were described in Sec. 2.2.1, and they involve establishment of the Data Committee, and internal positions of Data Officers who should get an adequate training in data processing techniques to provide the community with enough expertise. YRIs and younger colleagues from industry will be the primary category of participants who will be actively encouraged for such positions, both because of their bigger absorption capacity of new techniques, and because their involvement in the research domain is expected to last longer. A motivation for them could be the final phase where the integration of the database and benchmarks with the big data processing is planned, and where a potential for a new research domain opens up.
The activity of Data Committee is of a tremendous importance. It should join experts on fatigue prediction, on fatigue experiments, and on data processing. It is therefore expected that senior and mid-career Action members will take part. The search for consensus on topics of WG1 can confront them with new domains, previously not explored by them, which can be further elaborated at their workplaces. The Data Committee should transfer the agreed consensus to Data Officers in a series of documents, and tutorials, which will be then further simplified for being used by all FABER members.

Several workshops will be organised, where the final format of the record of the experimental set will be discussed and finally defined. These workshops will be an important asset for the project, because the exchange of opinions and willingness to find consensus in a large group of researchers with vast experience is the only proper basis for the subsequent worldwide acceptance of the records of the data sets and of the file format prepared for their acquisition. The outcome will be discussed with external members e.g., from EMMC network, from NAFEMS or from ODIN repository, so that the consent is broad.

It is very likely that the data records will be created mainly by YRIs. To ensure that the data are acquired without induced errors, a series of Training Schools are planned from the second year of the project onwards. Workshops will be organized to explain the participants and interested audience the importance and the workflow of processing the benchmark sets, of recognizing patterns in their results, and how to apply the obtained information in practice.

3.2.2. PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The project website will be prepared at the start of the Action. This will include, or will link to the repository of the data sets and the sets of benchmarks. The planned completed contents will be designed, and further external funding will be sought, so that this work can be completed before the end of the project. The broader goal is not only to focus on fatigue benchmark, but also to join the whole community of fatigue researchers, and thus various tutorials, explanatory notes, etc., will be published and disseminated there. Establishment of a dedicated journal is under evaluation to provide quick description to interesting experimental data sets with tips of their usage in the verification practice, but also of its weaknesses.

The Action will attempt to introduce the project to all practicing researchers on fatigue prediction in Europe, to ensure the broadest-possible acceptance of the goals. The current participants will be encouraged to promote the action nationally and internationally, including non-European countries, to increase the project capacity. ITC Conference Grant holders will be supported to spread the Action goals and output at the conferences (International Conference on Fatigue, Fatigue Design, International Conference on Engineering Failure Analysis, International Conference on Multiaxial Fatigue & Fracture, etc.). The descriptions of the experiments will be discussed with the standardisation agencies (the applicants cooperate e.g., in Eurocode, IIW or on FKM-Guidelines), which will be invited to join the Action to increase the general acceptance of the final data format. The NAFEMS consortium will be invited to organise a joint workshop.

One of the most important items for communication with the audience is **the fatigue-estimation competition**, with two calls planned for the duration of the Action. The challenge will be advertised on social media, on the project website, on the website of various engineering and research organisations, and at various international workshops and conferences. The plan for tests manifesting the evaluated effect will be announced, and a call for the best prediction results will be opened. Once the call has been closed, the rest of the experiments will be performed, and the experimental and prediction results will be compared. The final challenge winners will be officially announced, and awards will be made during a relevant fatigue conference. Summaries of complete the challenge results (with the individual methods that have been used) will be published in impact journals.

The level of dissemination, within the Action and open to the public, is described in the deliverables in the next section. It is planned that at least four papers will be published within each research category of WG4 (i.e. more than 30 papers altogether), in high impact journals e.g., the International Journal of Fatigue, Fatigue, and Fracture of Engineering Materials and Structures. For each of the research categories the following 4 papers in impact journals (plus conference participations) are anticipated:

- A critical survey of existing prediction methods – state of the art.
- Acceptance criteria for benchmark sets (written standard), references to accepted and declined items.
- A summary of benchmark results (they can be delivered in more papers if more teams form).
- A description of the fatigue estimation competition, the related experimental data, and the results.

The fatigue solver developers will be invited to join the project activities. A meeting dedicated solely to this group will be organised to discuss the topic, in the attempt to demonstrate the positive impact that our project can have for stakeholders of this type. To increase the probability of change in their current approach, local resellers of fatigue solvers in individual participating countries will be contacted to explain them the consequences and gains they could get from FABER outputs.

National engineering societies (e.g., DVM, SF2M, Gruppo Frattura, SPFIE, ČSM, etc.) will be kept informed about developments, so that they can forward the information to their audience. We will attempt to promote the project at various fatigue conferences. A series of webinars/workshops on fatigue topics, as mentioned above, all for engineering audience will be organized by the Action at least twice a year. The goal is to attract the engineering domain to the project, and to explain the motivation for its establishing. In this way, webinars provide a very efficient solution how to reach audience without additional costs, and delays. Advertising the project goals and development on Action's social media (Facebook, LinkedIn, Twitter) is envisaged. This Action will be a starting point for other initiatives concerning the joint applications for national and trans-national projects, which could further advance the topics analysed.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

WG1 - DATA MANAGEMENT

WG1.1 - Parameters of the experimental fatigue analyses
Task: A structure of the data collection and of its tables necessary for aggregating data will be defined.
Activities: Various fatigue testing methods will be evaluated and parametrized. Existing database systems will be compared. Decision will be taken whether to use or extend any of them, or whether to prepare a new solution.

WG1.2 - Data test record
Task: The final data file format used for data entry, data processing and postprocessing will be defined.
Activities: Preparing a technical report describing the record will be published on the FABER website.

WG1.3 - Interface for data set recording
Task: Selection/implementation of the interface to access the gathered data and to process them.
Activities: Existing database systems will be surveyed and compared, and the best interface will be selected that allows a description of the experiments. Local or international grants will be sought to fund any changes (or to create the interface, if necessary).

WG1.4 - Data processing routines
Task: Running pilot activities in data processing and transforming the data into benchmarks.
Activities: Types of benchmark sets, and their suitability for describing various effects; focus on future ways in which the final benchmark results can be evaluated to highlight various properties; data mining; preparing for big data – requirements, potential methods of analysis, types of results; communicating with the subgroups of WG4 to select the optimum benchmark types.

WG2 - ANALYSIS OF FATIGUE DATA

WG2.1 – Deterministic vs probabilistic modelling
Task: Defining optimum way of regression analysis for deterministic and probabilistic models.
Activities: An analysis of existing regression models, evaluating their pros and cons, defining optimum parameters for deciding the closeness to the experimental data, analysing suitability of the data for various prediction goals, presenting outputs. Studying the possibility of transforming various deterministic solutions into probabilistic solutions.

WG2.2 – Treating the benchmarking output
Task: Standardization of the benchmarking.
Activities: Definition of processes and criteria useful for analysing the benchmark outputs.

WG2.3 – Artificial intelligence in fatigue estimation
Task: Applying AI on the generated data sets.
Activities: Finding the space where the AI could be useful in treating the data inputs and result either in an extended material description, or in a successful fatigue estimation.

WG3 – FATIGUE ESTIMATION COMPETITION
Task: Preparing two world-wide fatigue estimation competitions on best fatigue prediction.
Activities: Retrieving the data inputs from each sub-group of WG4, announcing, and advertising the competition to the international community. Negotiating with industrial partners on preparing specimens,

and with universities and research institutes on testing the individual experimental campaigns. Deciding the content, and the schedule. Gathering the submitted analyses, transmitting them to the WG4 sub-groups, supervising the final summary and announcing the winners.

WG4 –FATIGUE ESTIMATION CATEGORIES
Task: Assembling the benchmarks for each of hereafter mentioned 7 categories (sub-groups of this WG).
Activities: In each sub-group of WG4, the following phases are planned:

1. A review of existing models covering the partial effect prepared and submitted to a journal with a high impact factor.
2. These models will be categorized as regards the material parameters that they necessitate.
3. Relevant experimental data sought and delivered. The quality of the experimental set is assessed, and a decision taken whether the data set is worth aggregating and including in the benchmark set.
4. The data file record of the experimental set is prepared for the latter two groups. Another type of record will be created for test sets that are rejected, while stating reasons for the rejection.
5. The structure of the shortened record describing the individual test sets in the benchmark test will be defined, so that it covers all relevant aspects that could affect the final fatigue prediction.
6. A technical paper with the best practice recommendation will be issued to describe the optimum setup of the test campaign to adequately provide data inputs to test the analysed effect.
7. An impact paper will be submitted to describe the benchmark set and the rules to build it.
8. A definition of the fatigue estimation competition task in the given category.
9. Results of the challenge will be analysed and will be summarized into a high impact paper.

WG4.1 - Mean stress effect: The effect of the mean stress on fatigue life was recognized by the earliest fatigue researchers. Treatment of the mean stress today usually involves methods defined more than 120 years ago, which are deemed unreliable by some researchers.

WG4.2 - Critical volume effect: Several categories of effects are involved here – e.g., size effect, notch effect, load effect. An open question in fatigue failure prediction concerns how fatigue failure is affected by the stress distribution. There are various fatigue methods and fatigue solver solutions today, but there is a lack of comparisons between them.

WG4.3 - Load multiaxiality effect: The response of the research community to the problem is far from being finalized – the multitude of proposed criteria is hard to believe, though there are some criteria already implemented in fatigue solvers. The existence of all these proposed criteria at the same moment is possible only due to the lack of solid benchmark tests.

WG4.4 – Surface integrity: This sub-WG covers interrelated characteristics: topography (roughness, waviness, flaws...) and surface layer (plastic deformation, residual stress…). Most of technological operations result in a certain degree of roughness accompanied by residual stresses. Sometimes, compressive residual stresses are intentionally induced as they can reduce the probability of fatigue damage, while the treatment changes the surface topography as well (e.g., shot peening).

WG4.5 – Damage accumulation: In engineering, the simplest solution – the Palmgren-Miner linear hypothesis – is the only solution. More sophisticated models are too complicated, and input data demanding. The complexity of only small and large loading cycles mixed in uniaxial loading can be further enhanced by including more acting load channels, i.e., the outcome of WG4.3. Such cases bring the attention also to the problem of applying a cycle-counting (e.g., rain-flow method).

WG4.6 – Material anisotropy: Semi-products and final components have commonly different material properties in different directions due to the applied manufacturing processes. However, acceptance of this fact increases the already high complexity of the problems, and it increases the uncertainty about which part of the computational chain can be faulty. Often, the question of the (an)isotropy of the specimens used for the experimental campaign is not analysed at all.

WG4.7 – Low-cycle fatigue: The basic formula used for low-cycle fatigue, Manson-Coffin curve, relates the fatigue response to applied elastic and plastic strains and the records show dynamic changes in the elastic-plastic material response during the fatigue life. This question complicates significantly recording of the experimental data (and the fatigue estimation as well), because the number of observed parameters is enlarged. The subtask will thus focus on description of the low-cycle fatigue experiment including multiaxial input and the low-cycle fatigue estimations.

WG5 – COMPOUND PROBLEMS
Task: Preparing the base for future benchmarking in each of hereafter mentioned 4 subgroups. Due to the increased complexity, it is not expected that benchmark sets will be established here.

Activities: Transforming the experience gained in WG4.x to problems, where those effects interact in a more complex manner. The activities envisaged here will cover only items 1-4 of the WG4 list of actions. The other items in that list of activities will be dealt with in a project succeeding FABER.

WG5.1 - Additive manufacturing: In this technique, the non-homogeneous structure of the final solid material, including unintended pores of various shapes, and the residual stresses resulting from the production process are common. The complex shapes of the built structures call for the effects of size, notches, multiaxial loading, surface quality, etc., to be involved.

WG5.2 - Fatigue in contacts: Whenever two parts in a contact pair move mutually, a quicker fatigue damaging is observed. Contacts are common in many designs and joining technologies (rivets, bolts, lugs, etc.). Big stress gradients in the contact vicinity and multiaxial stress states are some of interacting partial effects to be discussed.

WG5.3 - Welded joints: Welding is one of the most widely used joining methods for producing permanent joints. In addition to various previous effects covered in WG4, the heat used to generate the joint causes high residual stresses to be induced in the so-called heat-affected zone.

WG5.4 - Riveted joints: Riveting is typical for the aeronautical industry, but self-piercing rivets are also used in the automotive industry. It was often applied in old steel structures (bridges, towers, etc.). The generated permanent joints are not easy to inspect, as the initiated cracks are often hidden below the rivet heads.

WG6 – OPEN-SOURCE FATIGUE LIBRARY
Task: Establishing a common base for all implementations of fatigue computation methods readied in WGs 4 and 5. Deriving the stable releases from the partial inputs.
Activities: Support of the implementation processes performed within WGs 4 and 5. Annual workshops for its users to highlight the current status and expected further development.

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

Table 1 presents the major deliverables planned within the project and date of their release (or submitted for publication). If the report is not explicitly described as internal, it will have a free access on the FABER website.

Table 1: Planned Deliverables

No.	WG	Item	Type	Month
1	1.1	Internal technical report describing database structure and description of the experimental data records for every topic of WG4	Tech. report	10
2	1.4	Technical report on various types of benchmarks, how their results can be processed, and understood	Tech. report	12
3	3	Technical report on all basic experiments supporting the fatigue estimation competition No. 1	Tech. report	12
4	4.x	At least 3 survey papers on the topics treated in WG4 submitted for publication	Impact papers	14
5	1.3	Technical report - A manual on transforming available experimental data into a data set readable by the FABER repository	Tech. report	17
6	2	A survey paper on regression curves for experimental data in stress-life space submitted for publication	Impact paper	18
7	2	A survey paper on application of probabilistic models in fatigue analysis submitted for publication	Impact paper	20
8	3	Public technical report on results of the key experiments for evaluating the prediction quality of submitted estimates within the fatigue estimation competition No. 1	Tech. report	22
9	4	Technical report on recommendations for optimum fatigue test campaigns for WG4 topics	Tech. report	23
10	3	Paper on the setup and results of the fatigue estimation competition No. 1 submitted for publication	Impact paper	26
11	3	The technical report on all basic experiments of the fatigue estimation competition No. 2	Tech. report	30
12	4	At least one survey paper on the content of experimental data available in the repository for WG4 submitted for publication	Impact paper	34

No.	WG	Item	Type	Month
13	3	Technical report stating the complete results from the experimental campaign related to the fatigue estimation competition No. 2	Tech. report	42
14	5	At least one survey paper gathering the content of experimental data from WG5 submitted for publication	Impact paper	43
15	4	At least 3 papers on benchmark results related to topics of WG4 submitted for publication	Impact papers	46
16	4	Paper on the setup and results of the fatigue estimation competition No. 2 submitted for publication	Impact paper	47

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

Limited interest from industry: Industry should benefit from the project results, but information about the project may spread too slowly. To increase interest from industry, following actions are planned: (1) contact through various engineering bodies (SF2M, DVM, CSM, SPFIE, ESIS); (2) encouraging current project members to contact potential members; (3) the FABER website, and it's promotion via social media (ResearchGate, iMechanica, LinkedIn); (4) the fatigue estimation competition; (5) a series of Training Schools for practicing engineers on fatigue topics; (6) Youtube videos from Training Schools.
Limited interest from fatigue solver developers: An initial meeting with their representatives is planned within the first six months of the Action. The customers and the network of local sales agents will also be contacted as they could benefit from the results of the project – the sales agents could finally show the customers what they are selling to them. At last, the development of the open-access tool within the Action will surely get them on board.

Lack of experimental machines and institutions to perform the experiments for the fatigue estimation competition: The current plan is to have two competitions for two different challenges. The preparatory works for the first challenge have already started. Industrial companies will be looked for to manufacture the specimens, and they will be rewarded twice: (1) by reaching experimental results they look for; (2) by seeing the optimum solution delivered by the participants. The search for an experimental facility that will agree to test the experimental set for free will be supported by other arguments – this facility will have the effective power to decide the way of presenting the results, including the final impact papers. A separate WG (WG3) has been set up in support of the competition.

International Relations: Relations between some nations in Europe and worldwide have become problematic. We actively try to reach as broad multi-national cooperation as possible to get the local experimental results accessible. Such data items are spread over very many countries, and even if some specific country closes its access, the damage to the Action project will not be decisive.

Recession in the (automotive) industry: Project is based on a broad cooperation of many joined individuals from different countries who are financed by various means. It should be thus less vulnerable to such effects. Cost-cutting and a transformation of existing relations and processes is demanding, but they also provide an opportunity to define a healthier future. When the recession happens, the traditional relations break, and the birth of a new concept ensuring high-quality results may find support.

COVID-19 or any other world-wide pandemics: COVID-19 pandemics affected means of networking previously common. If new similar issues emerge, we assume that also the scheme of networking will change. The meetings will get more virtualized. We still find the traditional face-to-face meeting as the best possible option of networking, so this mode will be preferred, whenever possible.

Only poor-quality data can be found for a given effect: It has already been commented that many experimental campaigns are organized in such a way that the output can be fuzzy, the test conditions unclear, etc. It may happen that only a few items among the existing data sets are found to be representative enough for a given effect in WG4.x. However, this kind of mishap does not invalidate the efforts that have been made. It will be certainly reported in the project reports.

Excessive complexity of the test records: Fatigue tests involve a big number of parameters, many of which are not currently monitored. A reasonable standard of data representation will be sought within WG1, while having in mind the even more complex problems are faced in WG5. Because of the increased complexity, solution of the WG5.x cases is not finalised by the benchmark sets since potential future developments are envisaged.

No funds available for preparing the interface for creating the test record: Primarily, existing software tools will be evaluated for this purpose. It may just involve a modification to an existing system, or an own tool may be created. In the worst scenario, the test records will be created manually. This would slow down the aggregation process, so further funding to improve this solution will be sought.

Disagreement for publishing benchmark results: At present, the end user licence agreements of fatigue solvers often contain a statement that no benchmark results may be presented without the consent of the developer. If the developer declines to join FABER or to present the benchmark results, their publication is not a matter for the FABER Action, but for its individual members or for other institutions to publish the findings. This problem can be mitigated by providing of benchmark inputs to interested institutions. Fatigue solver developers then face the situation when anybody can benchmark their solvers. However, other stakeholders are made aware when the solver developers attempt to prevent publications of the benchmark results. The negative impact of such an action is a bad advertisement for the fatigue solver, which the producer is unlikely to allow to happen.

4.1.4. GANTT DIAGRAM

		Year 1												Year 2											
		Q01			Q02			Q03			Q04			Q05			Q06			Q07			Q08		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.1	Parameters of experiments	various solution analysed									1	confronting with reality										WG5 interaction			
1.2	Data set record	possible formats analysed										interaction with WG1.1, 1.3													
1.3	Interface for data recording	various solution compared, optimum defined																5							
1.4	Benchmark analyses	establishing benchmarking rules											2	best benchmark setup for each WG4.x											
2	Data analyses	survey of models, comparative analysis																	6		7	implementations			
3	FABEST challenge	preparing 1st volume											3	submissions				experiments					8	summary	
4.x	Fatigue-influencing effects	survey of models, existing data													4	gathering data, optimum tests									9
5.x	Compound problems	survey of models, existing data											interaction with WG2								gathering data				
6	Open-source fatigue solver	reaching consent						implementation plan						basic setup of fatigue analysis											

		Year 3												Year 4											
		Q09			Q10			Q11			Q12			Q13			Q14			Q15			Q16		
		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1.1	Parameters of experiments	WG5 interaction											revision												
1.2	Data set record	rev.						rev.						rev.						rev.				rev.	
1.3	Interface for data recording	updates						updates						updates						updates					
1.4	Benchmark analyses	rules for benchmark results processing															WG5.x - big data, data mining								
2	Data analyses	implementation on WG4.x problems												AI and ML applications											
3	FABEST challenge		10	prep. Vol. 2			11	monitoring 2nd volume																16	
4.x	Fatigue-influencing effects	gathering data, BM def.									12	data management, benchmarking							13				15		
5.x	Compound problems	optimum tests													summary					14	updates				
6	Open-source fatigue solver	extensions for broad coverage of WG4												applications, verification, benchmark, AI implementations											

Explanation:	10	Number of the deliverable to be submitted at specified project month

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