A quality assurance process of the Model-Based Design assets of the HUBCAP platform

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Abstract: Digital Innovation Hubs (DIHs) are innovation ecosystems playing a boundary role in supporting Small and Medium Enterprises (SMEs) along digital transition. Recently, several pan-European networks of DIHs have been arising. Each of them is characterized by a specific set of assets (services, skills, competences, technologies, etc.) and is able to provide one or a combination of the four typical DIH functions (support to find investments, skills and training, test before investing, innovation ecosystem and networking). To effectively provide these assets, DIHs are developing digital platforms to showcase, sell or deliver their assets, adopting a dedicated business model. The HUBCAP ecosystem (composed of DIHs, technology/tool providers and users, and academic partners/RTOs) has recently developed a digital platform offering Model-based Design (MBD) assets (models and tools) to be employed for Cyber-Physical Systems (CPS) development. The platform is enriched with a sandbox enabling virtual collaboration among potential users of the new technologies to be developed. The sandbox represents a key means to defuse the mistrust around MBD, traditionally needing strong technical and specialized skills and competences to be used and applied. However, to foster an effective and successful provision of MBD assets and to ensure the quality of the content related to the MBD assets offered in the HUBCAP platform, a dedicated process, to be integrated into a wider governance mechanism of the platform, is needed. Therefore, this paper, grounded on the network requirements previously defined by the HUBCAP stakeholders, proposes the assurance process for the quality check of the MBD assets offered by HUBCAP and shows its application to its portfolio. The process turned out to be effective to evaluate the assets offered, triggering an iterative continuous improvement process of their related content and allowing to assign a quality badge to each of the assets complying with the established quality threshold.

Keywords: Digital Innovation Hub, quality assurance, cyber-physical systems, model-based design, digital platform.

I. Introduction

Digital Innovation Hubs (DIHs) are innovation ecosystems able to play a boundary role [1] in supporting Small and Medium Enterprises (SMEs) along their digital transitions [2]. Recently, several pan-European networks of DIHs have been arising. Each of them is characterized by a specific set of assets (services, skills, competences, technologies, etc.) [3] and is able to provide one or a combination of the four typical DIH functions (support to find investments, skills and training, test before investing, innovation ecosystem and networking) [4], [5] to reach sustainability [6]. To effectively provide these assets, DIHs are developing digital platforms [7] where they can showcase, sell or deliver their assets, adopting a dedicated business model. The HUBCAP ecosystem (composed of DIHs, technology/tool providers and users, and academic partners/RTOs) has recently developed a digital platform offering Model-based Design (MBD) assets (models and tools) to be employed for Cyber-Physical Systems (CPS) development (HUBCAP project, 2020). The platform is enriched with a sandbox enabling virtual collaboration among potential users of the new technologies to be developed. The sandbox represents a key means to defuse the mistrust around MBD, traditionally needing strong technical and specialized skills and competences to be used and applied. However, to foster an effective and successful provision of MBD assets to the users and to ensure the quality of the content related to the MBD assets offered in the HUBCAP platform, a dedicated process, to be integrated in a wider governance mechanism of the platform, is needed. Therefore, this paper, grounded on the network requirements previously defined by the HUBCAP stakeholders, proposes the Quality Assurance (QA) process of the MBD assets offered by HUBCAP and shows its application to its portfolio. The process turned out to be effective to evaluate the assets offered, triggering an iterative continuous improvement process of their related content and allowing to assign a quality badge to each of the assets compliant with the established quality threshold. The paper is structured as follows. Section 2 introduces the research context. Section 3 describes the research methodology. Section 4 presents the results and Section 5 discusses them. Section 6 concludes the paper and opens rooms for further research.

II. RESEARCH CONTEXT

A. *HUBCAP project and the digital platform*

The HUBCAP ecosystem provides MBD assets (models and tools) to support the development and adoption of CPS technologies [9], [10]. The network is composed of DIHs, technology/tool providers and users, and academic partners/RTOs and has recently developed a digital platform to offer to its users its MBD assets through the support of a sandbox, enabling the virtual collaboration among users along the development process of CPS. A sandbox is a testing tool that is used in different fields of technological innovation, and its function is to provide a secure and controlled environment to test and examine new technological solutions before being launched into the market. These controlled and regulated environments are also called regulatory sandboxes. In the HUBCAP project, the sandbox can be described as a tool present in the HUBCAP platform, that enables users to try MBD tools and models directly from an internet browser without having to install anything locally. The sandbox capability of the platform helps potential users' trial new CPS design technology before investment, which reinforces the test before invest function, one of the main purposes of a DIH, and one of the most difficult to offer, since it requires complex architectures and high costs. HUBCAP has implemented an intelligent solution that avoids its stakeholders both the complexity and the cost of testing new technological solutions of the CPS domain.

B. *MBD assets: models and tools*

The HUBCAP platform divides its assets into catalogues, one for Models and one for Tools. Each one provides general information about the different assets and their providers, information that is furnished according to specific templates present in the catalogues.

The models catalogue holds 93 models. Models consist in mathematical representations used to design, analyse, verify, and validate dynamic systems, and applied to CPS represent the coupling of its environment, physical processes, and embedded computations [11]. The tools catalogue for its part, holds around 53 tools, intended as applications developed basing on MBD techniques that can be run in the platform to test solutions in a multiplicity of domains. An example of each type of asset is provided hereafter to better explain the difference between them.

The first example is the "Energy model for fuel tank truck", a model taken from the HUBCAP models catalogue presented in the Fig. 1. In most cases, models are presented with their description and diagram.

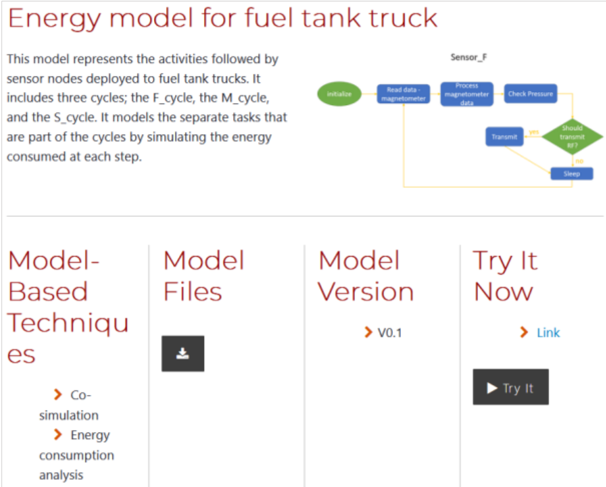

Fig. 1. Example of the Energy model for fuel tank truck model

"CHESS" tool is presented in Fig. 2. In it, one or more of the different MBD techniques on which the tool is based are shown as well as the different domains in which itncan be applied.

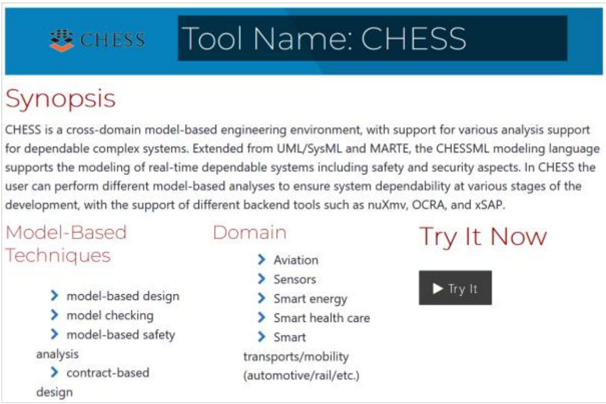

Fig. 2. Example of the CHESS tool

These contents have been continuously updated, also contributed by the SMEs winners of the open call. The number of models in the platform is indeed contributing to the KPIs of the HUBCAP project.

The tool and the model catalogues are now also connected to the sandbox environment. It is also possible to launch the sandbox directly from the model catalogue with the "Try It" feature. The models cover various application domains including control engineering, electrical engineering, automotive, and avionics. Almost all of the 93 models currently in the catalogue have been connected to the sandbox environment (Fig. 3). As well, most of the 53 tools currently present in the tool catalogue, have been connected to the sandbox environment (Fig. 4). The sandbox can be launched directly from the tools catalogue with the "Try It Now" feature. These tools are provided by the HUBCAP partners, SMEs partners, and they are uploaded, installed, and tested inside the HUBCAP Collaborative Platform sandbox to constitute the contents of the catalogue of tools.

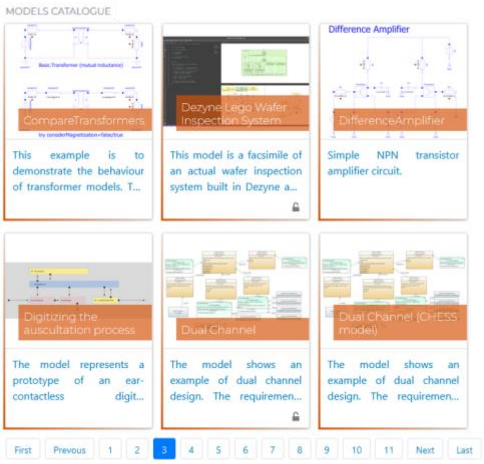

Fig. 3. The HUBCAP Models Catalogue

To ease the access of information, the main wiki page will be enriched with a navigation tree (Appendix A). In this context, the navigation tree is an interactive visualization that connects the key entities of the HUBCAP platform that are the tools, the models, the techniques, and the application domains. The entities are structured as a tree. The levels (from left to right) that compose the tree are:

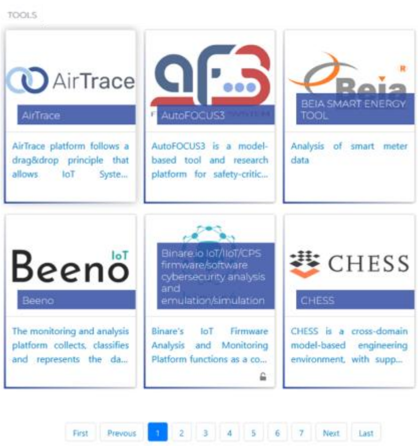

Fig. 4. The HUBCAP Tools Catalogue

- Level 0: root node. The model-based design domain,
- Level 1: families of techniques (e.g., Model Checking),
- Level 2: specific techniques (e.g., Deadlock Checking),
- Level 3: model-based design tools (e.g., COMPASS),
- Level 4: models (e.g., SmartGrid).

III. RESEARCH METHODOLOGY

The QA process proposed in this paper has been developed based on an analysis of both the literature and technical material related to quality assurance of assets on digital platforms, and the project requirements previously defined by the HUBCAP stakeholders. The literature review was mainly focused on the research of standards for quality assurance utilized in similar contexts, and on methods to support quality assurance processes. That’s how the ISO/IEC 25010:2011: norms for systems and software and Quality Requirements and Evaluation (SQuaRE) were considered and analysed along with different methodologies based on the principles of continuous improvement. At the beginning, as a part of the literature analysis conducted, it was discussed about generating and setting the QA process for catalogues based on external methods, guidelines and techniques related with the reinforcement of quality. However, after the analysis, the methods and standards selected were discarded because they didn’t fit well with the requirements to be addressed in this particular QA process. Thus, it was decided to create a tailored solution, according to the main characteristics and peculiarities of the platform and of its catalogues. Indeed, the HUBCAP platform entails many particularities, and the method utilized for uploading and hosting information requires a customized QA process.

Therefore, the process was simplified and limited to the review of the contents provided for each asset without considering an extant methodology for periodic reviews. Thus, an internal method was generated to perform the QA process. In detail, the main input to build the checklist to be used in the QA process has been the list of requirements of the models and tools developed during the HUBCAP project. These functional requirements are divided into several categories, but the QA process centered only in the “Asset Catalogue Item definition” with a focus on the information loaded into the platform. For both models and tools, the functional requirements are of two types: (a) Security requirements (dedicated to provide the guidelines for the login, user management and functions for the roles present in the platform (Administrator, provider, end user)) and (b) Asset Catalogue Requirements (divided into two sections, an asset catalogue items definition and an extensive list and description of all the possible actions that can be done inside the catalogues). The first section of (b) gathers all the fields needed to describe an asset in the platform (35 items for tools, and 31 for models). Some items requested for the models were for example the modelling languages or model types (ordinary differential equation, differential algebraic equations, finite elements method, etc.) utilised, and the provision of a step-by-step guide (file or URL). Likewise, some items requested for the tools were for example the MBD analysis technique implemented (simulation, model checking, safety analysis, etc.), the technology readiness level (TRL), the TRL explanation. In a second step, all these items were considered to configure the checklists that were later provided to the reviewers to conduct the QA process. Then, in the second section of (b), further technical details are specified focusing on the different functions in the catalogues such as add, update, search, and remove assets. However, these weren’t considered into the QA process being not its focus.

Then, a series of five workshops (lasting 1 hour each) with the MBD academic experts and MBD tool providers belonging to the HUBCAP project have been conducted to select the useful requirements and refine the QA process. The development and improvement of the QA process was conducted in an iterative way. Indeed, at the beginning, the process was composed only of three phases. Finally, based on the input received during the workshops, a fourth phase (QA implementation: HUBCAP partners revise tools and models) was added to guarantee the updated value of the content available on the platform related to the assets.

A. The application to the HUBCAP project

At the time of the analysis conducted, in the HUBCAP platform, the asset catalogue counted around 72 models and 28 tools. The tools and models were divided equally between the 8 DIHs composing the HUBCAP network, assigning the same number of models and tools to be checked for each one as shown in Table 1.

TABLE 1
MODEL AND TOOL ASSIGNMENT FOR EACH PARTNER

Partner	Number of Models	Number of tools
AU	9	3
UNEW	9	3
FOR	9	3
VV	9	3
ULBS	9	3
RISE	9	3
FBK	9	5
POLIMI	9	5

Nine models and three tools were assigned to each partner (aside from FBK and Polimi who received five tools each). The task leader sent the checklists and the instructions to be completed according to the assigned assets. Then, the task partners had one month to complete the QA process, and once completed the answers were updated to the HUBCAP platform.

B. Preliminary analysis

The main approaches selected in the literature analysis were three.

The first alternative (the ISO/IEC 25010: 2011 - Systems and software Quality Requirements and Evaluation (SQuaRE) [12]) was considered to base the QA process for catalogues on the ISO standards that are established for system and software products quality. This approach was considered interesting since it allowed to evaluate in a broad way the catalogue feature and its functioning. This approach considered 8 main characteristics (Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, Portability) and 31 subcategories, providing standards for each of the subcategories. However, this alternative was discarded since it was decided that the main focus of the QA had to be centered on the contents and information provided by each asset provider and uploaded to the platform and not on the functioning of the platform itself.

A second alternative considered was to adopt a method to foster periodic reviews of both the platform and its assets under the principle of continuous improvement. To that end, the PDCA Cycle ISO9001 was analysed [13]. In this case, the QA process had to follow the PDCA Cycle through the following main actions: (1) Getting the inputs for the method, in the form of relevant information (for example: through surveys to identify quality requirements from the platform manager perspective; mural; brainstorming; among others). (2) Checking external and internal issues. (3) Implementing continuous improvement and (4) generating mechanisms to measure results. However, this approach was also discarded since it required more complex inputs and it wasn't really efficient according to the objectives of the QA process desired. This method would have implied extra effort as it considers the functioning of the platform and it is not focused on the quality of its content.

A third alternative analysed and discarded for the same reason of the previous one is the Kaizen Methodology [14], also focused on the principle of continuous improvement.

However, the main concepts on which these three approaches are grounded were applied to develop a sound QA process of the assets listed in the HUBCAP platform.

IV. RESULTS

4.1 The proposed Quality Assurance Process

To ensure a standard level of quality for the information of the assets present in the HUBCAP platform, a QA process for both catalogues has been proposed, developed, and implemented. The QA process is divided in four main steps: Identification of Model and Tool requirements, Generation of a quality checklist based on the requirements, Generation of a short manual on how to perform the quality check of the catalogues by a reviewer, and Execution of the QA revision. The process is summarized in the workflow diagram in Appendix B.

The first step consists in the identification of the items that are needed to be checked for each asset. The main input to build the checklist to be used in the QA process has been the list of requirements for the models and tools previously defined during the HUBCAP project to develop the digital platform. The requirements indicate the information needed, and requested as items to be filled during the upload process of a new asset to the platform. These established the minimum information considered necessary to adequately describe an asset in the platform.

The second step of the process is the development of the models and tools checklists, both structured on the items retrieved from the requirements. Model and tool QA checklists contain all the items identified in the first step as needed to be checked. Initially, the QA process was intended to be conducted by the role of an "asset reviewer", who was supposed to be a HUBCAP DIH partner and specialized in MBD. As explained in section 3.1, finally it was decided to divide the effort between all the eight DIHs of the network, assigning an equal number of assets to be reviewed by each of them.

The third step of the process consists in the preparation of a brief manual with the instructions to use the checklists correctly, sent to each asset reviewer via email, with the aim of guiding the QA process through all its steps.

Finally, once the checklists and the instructions on how to use them were well established, the asset reviewers are able to start the implementation of the QA, identified as the step four of the process.

4.2 The application of the Quality Assurance Process to HUBCAP platform

The checklist to conduct the process manually was proposed. It consists of an excel file structured in five columns: Item, Description, Instructions, Answers, and Comments as indicated in Appendix C. The exact same format was used for the Tool checklist.

Broadly defined, the instructions given to the asset reviewers were to check in the platform the correctness or absence of the information for each item and to report it in the checklist choosing the adequate option in the fourth column of Appendix C. Then, the reviewer had to write in the last column all the possible comments regarding anomalous items. The only possible options in the fourth column were "yes" highlighted in green, and "no" highlighted in red, making it easier to identify the items that must be corrected for the provider.

One of the last actions inside the implementation of the QA process (step four), is the establishment of a contact with each asset provider to ask for modifications of the items that are needed to be corrected or in which it is needed to provide further information. Initially, it was proposed that each asset reviewer had to be in charge of contacting the providers of the specific asset. However, later it was decided to concentrate the communications on a task leader to offer a seamless communication with the tools and models providers. Lastly, it was also proposed to initially address the correction of critical items. To this end, the conduction of a priority analysis on the current data was suggested. The final goal of this step is to identify which of the items require to be addressed first, and which of them can be corrected over time.

V. DISCUSSION

With the final goal to structure the QA process and to create a path to the improvement of the platform's quality, the items considered relevant to guarantee assets' quality were identified through an analysis of the complete set of data gathered from the platform. First, the items were ranked for both the types of digital assets (i.e., tools and models) by considering per each asset and per each item the number of times in which the content has been inserted in an incomplete/wrong way, as shown in Appendixes D and E. In this way, the assets that have the highest amount of missing or incorrect information in the platform have been detected. The aim of this activity is to impel the asset providers to complete first the items needing higher effort and that have low percentage of completion.

In addition, due to time restriction reasons, it was decided to conduct the QA process manually. Nevertheless, a proposal of automation of the process was made and evaluated, deducing that it would require the platform developer with a big amount of time and effort for its implementation. Therefore, a trade-off analysis between this effort and that required to perform manually the periodic control of the assets along the time should be performed.

VI. CONCLUSIONS

This paper proposed the QA process developed for the MBD assets provided in the HUBCAP platform. The development of the process has been presented, together with its main phases and its application in the HUBCAP project. The process turns out to be effective to both control the content related to the MBD models and tools added to the platform by the single providers and trigger its continuous improvement along the time. However, the process proposed is not free from limitation. It needs a high effort from both a governance and an operational/maintenance perspective. For its improvement, there is the need to set and implement a notification system able to automate the process to assign reviewers to the assets and to ask to the asset providers an update of the assets' content. To support this, the development and implementation of a new "revision mode" in the HUBCAP platform is being discussed. Its aim should be on one hand to add the feature of notifying directly to the asset provider when an information is missing or wrong, and on the other hand to automate the process of QA, developing a new interface (embedding the QA checklist on the platform) available for the reviewer that will permit him/her to conduct the process in a simpler, faster, and more efficient way and to centralize the communication dynamics of reviewers with both the platform governance and the asset providers. However, the HUBCAP platform developer highlighted the complexity of the development and implementation of this alternative, requiring a big amount of time and effort. For this reason, the decision about how to continue to perform in the future the check of the new entries of models and tools added to the platform has still to be taken. Finally, based on the analysis performed to define the average level of complete/correct content of the items describing the assets uploaded to the platform (Figures 8 and 9), a quality labelling will be built to assign badges to the assets characterized by a satisfying level of quality of the related content and to indicate to the platform users the assets described in a more complete way, giving them the opportunity to choose those characterized by a higher quality level of the related content.

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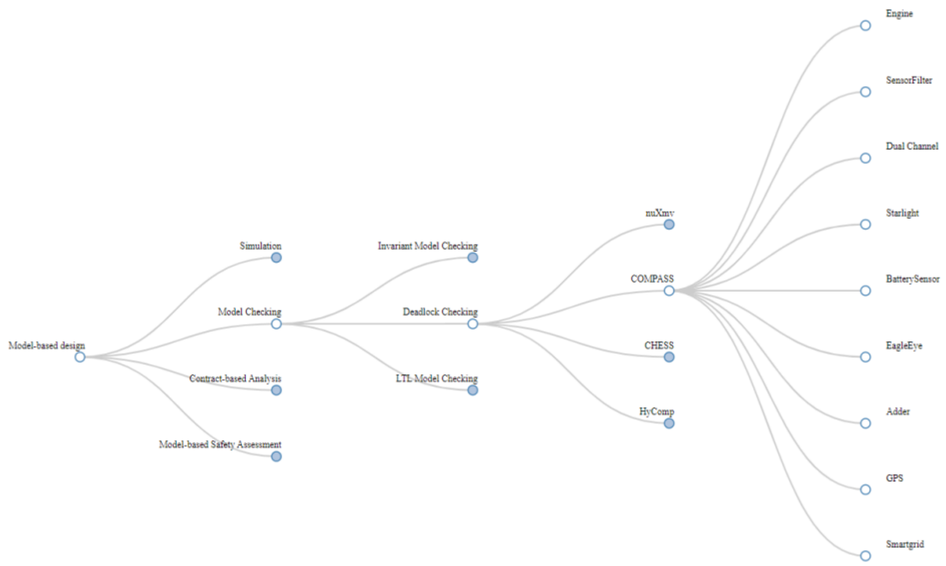
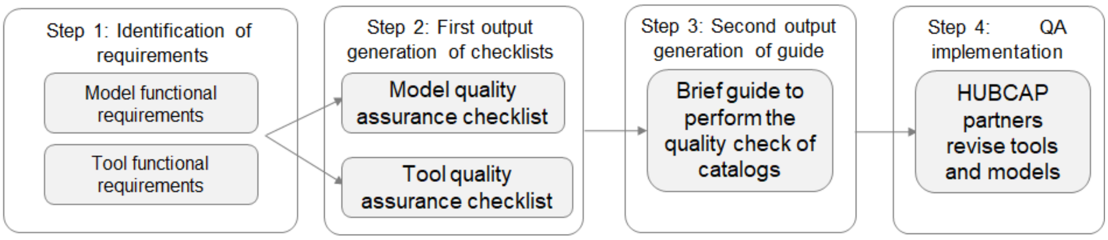
Appendix A. NAVIGATION TREE: FROM TECHNIQUES TO MODELS



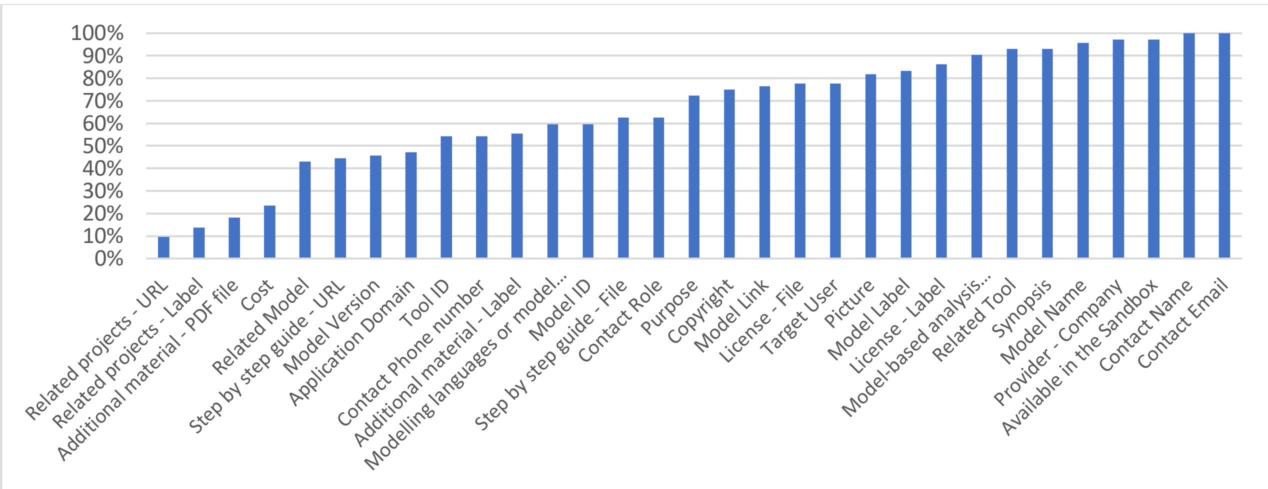
Appendix B. WORKFLOW DIAGRAM OF THE QUALITY ASSURANCE (QA) PROCESS



Appendix C. MODEL CHECKLIST FORMAT

Model Name:	(Write model's name in this cell)			
Item	**Description**	**Instructions**	**Answer**	**Comments**
Model Name	Is the name correctly indicated?	If it is correct, indicate it in the "Answer" column. If not, please indicate it and make a comment on the issue	Yes	
Modelling languages or model types (ODE, DAE, FEM, etc.) utilized	Is any Modelling language or type indicated?	If it is correct, indicate it in the "Answer" column. If not, and it's required, please indicate it and make a comment on the issue.	No	
Model-based analysis technique implemented (simulation, model checking, safety analysis, etc.).	Is any Model-Based Technique indicated?	If it is correct, indicate it in the "Answer" column. If not, and it's required, please indicate it and make a comment on the issue		
Model Version	Is the model version provided?	If it is correct, indicate it in the "Answer" column. If not, please indicate it and make a comment on the issue		
Model ID	Is the model ID provided?	If it is correct, indicate it in the "Answer" column. If not, please indicate it and make a comment on the issue		
Tool ID	Is the tool ID provided?	If it is correct, indicate it in the "Answer" column. If not, please indicate it and make a comment on the issue		

Appendix D. % OF MODELS WITH ACCURATE INFORMATION BY ITEMS OF THE PLATFORM



Appendix E. % OF TOOLS WITH ACCURATE INFORMATION BY ITEMS OF THE PLATFORM