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A Software Prototype for Predicting Ground Test Costs on the A400M Aircraft

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INTRODUCTION

Airbus is the largest aeronautics and space company in Europe and a worldwide leader. Airbus Defence and Space (Airbus DS) [1] is a division of Airbus responsible for defense and aerospace products and services. Airbus generated net income of €3054 million in 2018 compared to €2873 million in 2017, which means an increase in the net income of 6.3%. It is important for the company to have an increasingly optimized policy for cost prediction and savings in order to improve its net income. Thus, this work is focused on prediction and cost improvement in relation to ground tests performed on aircraft. The work presented was carried out as part of the project "FSP20: Futuro Sistema de Pruebas, Visión 2020," funded by Centre for Industrial Technological Development (CDTI) under the FEDER-INNTERCONECTA program. The FSP20 project was a collaboration project among Airbus DS and various companies and research organizations. Another work [2] has been already published by the authors in the context of this project. This work was focused on the failure prediction and correction in the ground test process of an aircraft.

In ground testing, all parts of the aircraft, as well as the systems, must be meticulously checked, and the testing involves a large number of company staff and resources. Each of the ground tests on the aircraft is known as ground test instructions (GTI). In order to execute the GTIs necessary to test the aircraft, Airbus DS uses a test system consisting of a software application linked to a hardware system for interconnection and communication.

One or more executions can be required to complete the set of systems tested in a GTI. This is because there are very long GTIs and it is possible for the company's operators to carry out the execution of one part of the GTI in a shift. In addition, if any type of error occurs during the execution of the GTI, it is necessary to correct it and repeat the test (or part of it) again. Thus, this set of executions carried out to perform the entire GTIs of an aircraft implies, logically, a set of costs for the company. If there are extra costs, then the ground testing process of the aircraft is extended over time (sometimes much longer than necessary). The costs can vary for each test and for each aircraft depending, for example, on how much the source code of the test has been polished over time or the skills that the ground test personnel of Airbus DS have acquired to perform it optimally. Over time it is logical for a GTI to have a negative (or at least flat) cost trend, though this does not always happen.

Within the costs associated with a test, Airbus DS proposed to the authors the development of a software prototype for the prediction of the main three types of costs in GTIs:

1) The number of incidences generated during the execution of the GTIs on an aircraft. Test failures are known in the terminology of the Airbus DS as "incidences." Thus, these incidences in the test process cause delays in the deliveries of the aircraft. Since those tests that generate incidences must be totally or partially repeated, the time required for performing the tests is increased.

2) The number of total executions necessary to complete a GTI on an aircraft. A GTI may need one or more executions to finish. It depends on various factors such as the number and types of the incidences generated, source code failures to be corrected, shift changes of the operators performing the test, etc.

3) The total time invested to complete a GTI on an aircraft. This time would be calculated by adding the time spent in the different executions needed in that GTI.

In addition, the software prototype could predict the total cost of ground tests of the aircraft by adding the set of costs of all its GTIs.

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Given these issues, test cost prediction is a critical top to aircraft production and cost optimization. However, there is no work published on this aspect in the literature. The works that can be found on cost prediction in aeronautics are focused on other aspects such as the maintenance of an aircraft [3]–[5], its design and development [6], [7] or even the cost implied in the delays of a commercial aircraft [8], [9]. Thus, the present work is a novel contribution in the state of the art about cost prediction applied to aeronautics.

The work presented focuses on the development of a prototype, which allows to predict the abovementioned three types of costs in GTIs as well as predicting the costs for the ground testing of aircraft.

For the development of the prediction models, the work has focused on the A400M aircraft of the Airbus DS Company, carrying out a data mining process from the company database for this aircraft. The A400M is the most technologically advanced long-range military transport aircraft developed by Airbus DS, and its process of testing and assembly is carried out in Seville (see Figure 1).

In order to evaluate the prediction models, a software prototype was implemented. This, in addition to making predictions, provides a user-friendly environment to show the results.

The article is organized as follows. The section "Generation of Predictive Models" describes the phases followed for the preprocessing of the data sources and generation of the different predictive models. "Environment" shows the environment of the prototype as well as an example of its use. We then present the "Results" obtained by the prototype for real tests of GTIs carried out by Airbus DS Company. The "Conclusion," closes with a brief summary and conclusions. (Note that data in some some tables and

Figure 1.
A400M ground testing and assembly process.

figures (such as the code for the GTIs) have been hidden due to a confidentiality agreement between Airbus DS and the University of Seville.)

GENERATION OF PREDICTIVE MODELS

For the generation of the different models, the following phases were carried out:

1) *The extraction of data sources:* In this first phase, the extraction of the information available for GTIs was carried out. For this purpose, a dump of the aircraft simulation database and the extraction of the files of the folder tree of this simulation environment were used as data sources. The simulation data condense all the information registered prior to the real test of the aircraft. Specifically, the data used for the folder tree include both the information of the test results and the source codes executed for those tests. The extraction of the sample was dated May 2017.

2) *The generation of the input data table:* The automatic generation of a base table was programmed, which would be used to study each of the suitable parameters for predicting GTI costs. This phase will be described in detail in the section ‘‘Generation of Input Data Table.”

3) The study of the influence of the parameters on the different costs: It was necessary to study and validate mathematically which parameters, of all the available and potentially suitable ones, are necessary for the realization and training of the prediction models. In this way, from the totality of possible parameters, an analysis of its correlation with the output variables in the prediction was made, and the necessary ones were selected to generate the predictions. This phase will be described in the section “Study of the Influence of the Parameters on the Different Costs.”

4) *The training of predictive models for costs:* Once the previous steps were completed, the models for the prediction of costs and times in GTIs were trained, generated, and validated. Finally, this phase will be described in detail in the section “Training of Predictive Models for Costs.”

Figure 2 shows a flowchart of the phases involved in the design of the different predictive models.

GENERATION OF INPUT DATA TABLE

In this step, the extraction and generation of a table that condensed and registered all the necessary parameters for the different predictions was programmed. For the generation of the table, it was necessary to process the dump of the aircraft simulation database as well as the extraction of the files of the folder tree of the test system.

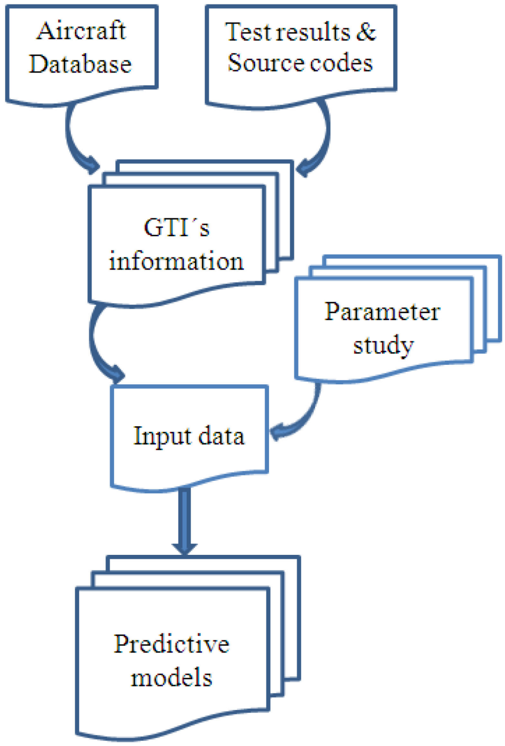


Figure 2.
Phases in design process.

Among these parameters of the table would be both the inputs (used to carry out the predictions) and the targets (values to be predicted). The processing and generation of the input data table, as well as later the generation of the prediction models, were programmed with the IBM Modeler 18 tool [10], which is one of the most used and powerful tools for database processing as well as performing a data mining process.

Initially, the generated table included, for each of the GTIs performed to date, the set of parameters shown in Table 1. These parameters were chosen according to the information provided by Airbus DS about the main factors influencing the GTI costs, and they were all potentially suitable for the cost predictions. The parameters with the RES_ prefix are relative to resources used to complete a GTI. Together, they provide a pattern of the complexity of that GTI. On the other hand, the parameters with prefix COS_ are corresponding to costs generated in the completion of the GTI.

As it is possible to see in the table, the incidences were distinguished (COS_INCSA and COS_INCSW) according to their two types [2]: Abortive incidences (incidences due to serious failures during the course of the testing process, which cause high extra costs to the company) and

Table 1.

Parameters Used for the Cost Prediction	
Parameter	**Description**
GTI	Code that identifies each GTI.
MSN	Code of the aircraft on which the GTI was executed.
VERSION	Code of the GTI version
RES_EXES	Parameter that refers to the number of total executions that were necessary to complete said GTI in the corresponding aircraft.
RES_OPERS	Parameter that registers the number of operators that have been necessary to complete the GTI in the corresponding aircraft.
RES_WSTATS	Parameter that stores the number of execution stations (or computers that the operators used in the test process) that were necessary to complete the GTI in the corresponding aircraft.
RES_TSTATS	Parameter that registers how many test stations (or stations where the aircraft moved in the test process) the corresponding GTI needed on said aircraft before it is successfully completed.
RES_USERS	Parameter that registers the number of different users in the test system that have been necessary to complete the GTI on the aircraft on which it has been performed.
RES_VERS	Parameter that contains the number of different versions (times that the source code of the GTI has been modified) that have been registered for that GTI.
COS_INCSA	Parameter that contains the cost in number of abortive incidences which the GTI has had for the corresponding aircraft.
COS_INCSW	Parameter that contains the cost in number of non-abortive incidences which the GTI has registered in its executions for the corresponding aircraft.
COS_TIME	Parameter that counts the cost in total number of hours invested for all executions of said GTI for the corresponding aircraft.

nonabortive incidences (incidences do not imply the mandatory ending of the test and the extra costs are lower than in the abortive ones).

Regarding the extracted table, the total number of executions registered in the table was 4678 as of May 2017. These executions were those registered for a total of 580 GTIs completed on 15 aircraft (from MSN7 to MSN21). The execution results of aircraft up to the MSN6 were not extracted because Airbus DS did not consider these data meaningful to be used in predictions (see Table 2).

STUDY OF THE INFLUENCE OF THE PARAMETERS ON THE DIFFERENT COSTS

The features described in Table 1 were suspected by Airbus DS experts to be the independent variables responsible for a large percentage of cost variance. Accordingly, these variables were analyzed using feature selection algorithm to determine the contribution for predicting the target variables related to costs.

The objective of the study was framed within a prediction in a time series. The reason is that the costs of a GTI usually present a downward trend through the different aircraft in which it has been performed. Thus, for example, a given GTI performed on a second aircraft is expected to have lower costs than the first aircraft because of correction of certain occurrences observed on the first. That is, it is assumed that the costs of a GTI have a negative (or at least flat) trend over time.

Three parameters were added to Table 1 in order to carry out the time series analysis. These three parameters were the following:

1) RES_EXES_MSNNEXT: This parameter contains the number of executions that were necessary to complete the GTI on the aircraft immediately following the one on this record.

2) COS_INCSA_MSNNEXT: This parameter contains the cost in number of abortive incidences that were necessary to complete the GTI on the aircraft following the one on this record.

3) COS_TIME_MSNNEXT: This time parameter contains the number of hours spent for the total number

Table 2.

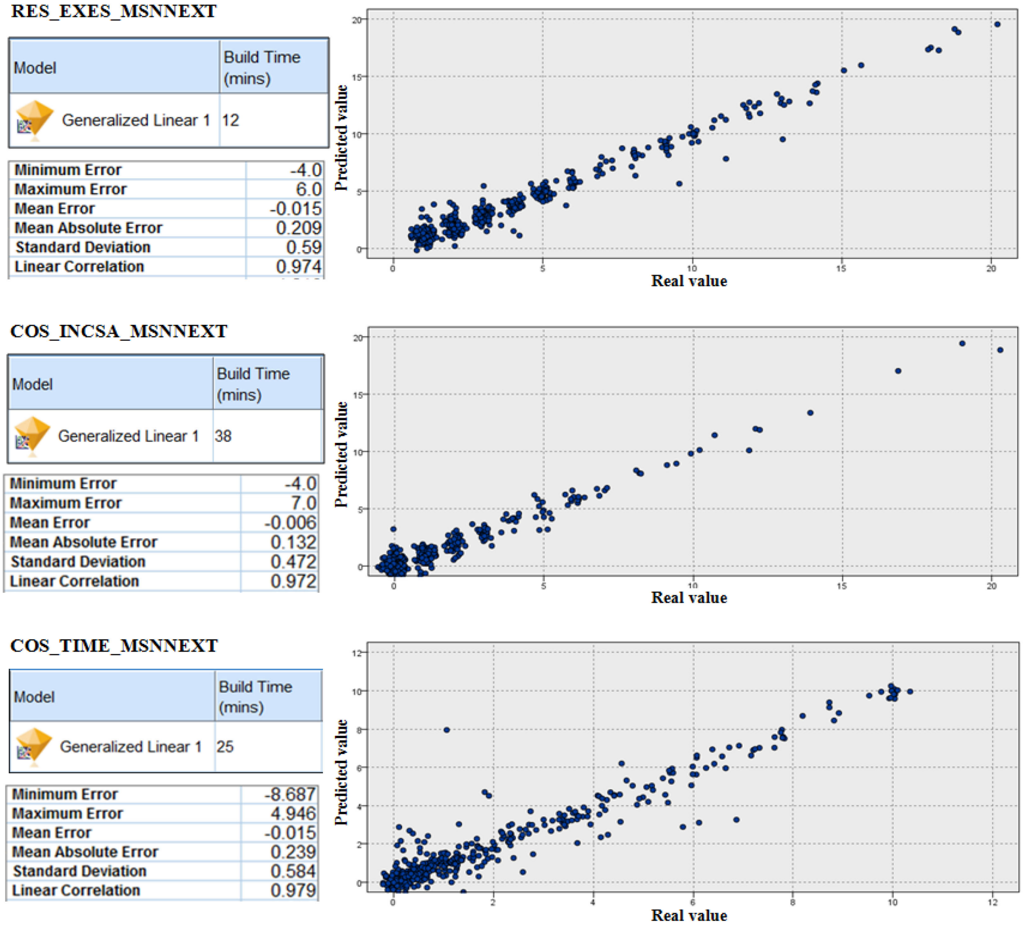
Excerpt From the Table Used for the Cost Prediction (Simulated Data)

GTI	MSN	RES_EXES	RES_RTIS	RES_OPERS	RES_WSTATS	RES_TSTATS	RES_USERS	RES_VERS	COS_INCSA	COS_INCSW	COS_TIME
[illegible]	[illegible]	6	4	12	1	1	1	0	5	0	2.316
[illegible]	[illegible]	8	1	16	1	1	4	0	7	0	2.279
[illegible]	[illegible]	1	1	2	1	1	1	1	0	0	0.517
[illegible]	[illegible]	1	0	2	1	1	1	2	0	0	0.229
[illegible]	[illegible]	1	0	2	1	1	1	2	0	0	0.469
[illegible]	[illegible]	2	0	4	1	1	1	2	1	0	1.429
[illegible]	[illegible]	1	0	2	1	1	1	3	0	0	0.559
[illegible]	[illegible]	1	0	2	1	1	1	4	0	0	0.022
[illegible]	[illegible]	1	0	2	1	1	1	4	0	0	1.968
[illegible]	[illegible]	1	0	2	1	1	1	5	0	2	0.156
[illegible]	[illegible]	1	0	2	1	1	1	5	0	0	0.053
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.023
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.057
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.046
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.754
[illegible]	[illegible]	1	1	2	1	1	1	0	1	0	0.085
[illegible]	[illegible]	1	1	2	1	1	1	0	0	0	0.244
[illegible]	[illegible]	1	1	2	1	1	1	1	0	0	0.070
[illegible]	[illegible]	1	0	2	1	1	1	2	0	0	0.223
[illegible]	[illegible]	1	0	2	1	1	1	2	0	0	0.286
[illegible]	[illegible]	1	0	2	1	1	1	2	0	0	0.216
[illegible]	[illegible]	1	0	2	1	1	1	3	0	0	0.772
[illegible]	[illegible]	1	0	2	1	1	1	4	0	0	0.136
[illegible]	[illegible]	1	0	2	1	1	1	4	0	0	0.243
[illegible]	[illegible]	1	0	2	1	1	1	5	0	2	0.024
[illegible]	[illegible]	1	0	2	1	1	1	5	0	0	0.095
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.031
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.020
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.023
[illegible]	[illegible]	1	0	2	1	1	1	6	0	0	0.465

of executions necessary to complete the GTI on the aircraft following the one on this record.

For the last aircraft on which that GTI was executed, a value of -1 was stored in the above parameters (later those records would be filtered for the training of the models).

Once the above parameters were added to Table 1, the records corresponding to the last aircraft of each GTI were filtered out. Subsequently, the analysis of the influence of the different parameters in relation to the variables to be predicted (RES_EXES_MSNNEXT, COS_INCSA_MSNNEXT and COS_TIME_MSNNEXT) was performed. The



RES_EXES_MSNNEXT

Model	Build Time (mins)
Generalized Linear 1	12

Minimum Error	-4.0
Maximum Error	6.0
Mean Error	-0.015
Mean Absolute Error	0.209
Standard Deviation	0.59
Linear Correlation	0.974

COS_INCSA_MSNNEXT

Model	Build Time (mins)
Generalized Linear 1	38

Minimum Error	-4.0
Maximum Error	7.0
Mean Error	-0.006
Mean Absolute Error	0.132
Standard Deviation	0.472
Linear Correlation	0.972

COS_TIME_MSNNEXT

Model	Build Time (mins)
Generalized Linear 1	25

Minimum Error	-8.687
Maximum Error	4.946
Mean Error	-0.015
Mean Absolute Error	0.239
Standard Deviation	0.584
Linear Correlation	0.979

Figure 3.
Training results of prediction models.

Feature Selection algorithm within IBM Modeler was used in order to perform this analysis. This algorithm [11] allows one to perform a deep mathematical analysis on the degree of influence of a certain parameter in relation to another.

In this way, once the algorithm was applied for each of the target parameters of the predictive models (RES_EXES_MSNNEXT, COS_INCSA_MSNNEXT and COS_TIME_MSNNEXT), it was verified that all the input variables were relevant in order to carry out the predictions.

All the input variables were marked as important by the feature selection algorithm in order to predict the variable COS_INCSA_MSNNEXT. After applying the feature selection algorithm for the other two target variables, the same results in terms of influence were obtained. All input variables were marked as important for prediction.

TRAINING OF PREDICTIVE MODELS FOR COSTS

Once the feature selection was made, three predictive models were generated in order to predict each of the target variables. For this, a set of aircraft was used to train and generate the models, and a second set was used for the validation of the models generated with the previous group.

For the extraction of the database dated May 2017, there were a total of 580 different GTIs. Aircraft from the MSN7 to the MSN18 were used for learning (training set) and the rest (Aircraft from the MSN19 to the MSN21) were included in the validation set. In this way, a standard distribution of 80% of data for training and 20% for validation was used.

Although some tests were done with other modeling algorithms within IBM Modeler (such as artificial neural networks), a generalized linear model was finally the chosen one to get the best results. This algorithm [11] is a flexible generalization of ordinary linear regression, which breaks down the variability observed in a response variable based on two components (systematic and random) linked to each other by a function (link function). A generalized linear model is a way of unifying several statistical models, including linear regression, logistic regression, and Poisson

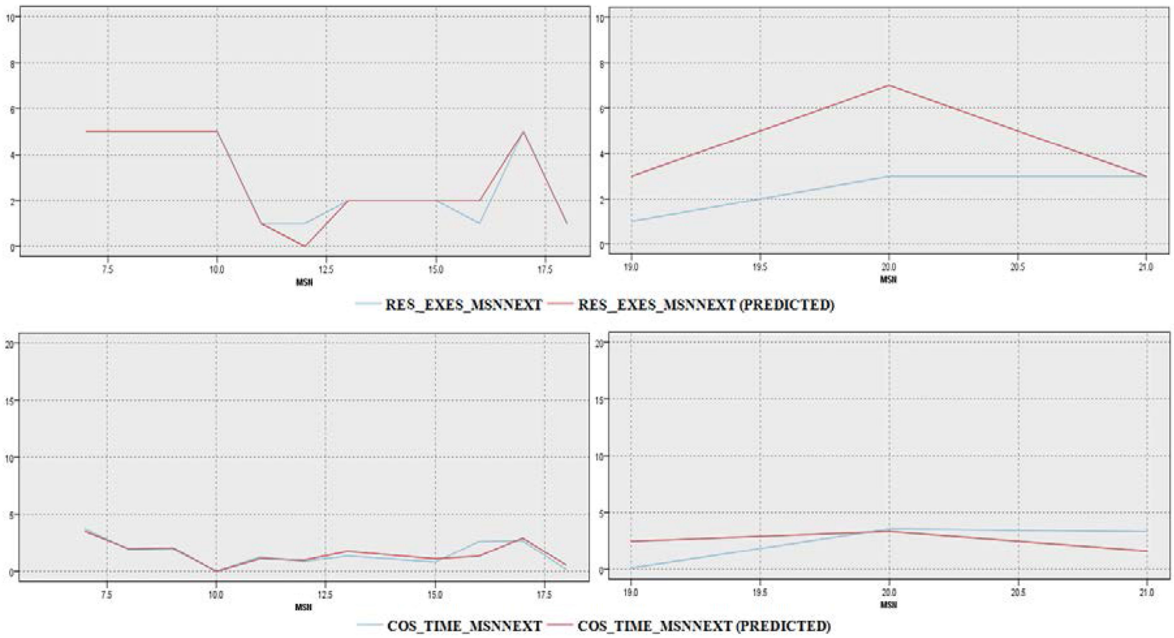


Figure 4.
Examples of cost predictions for two GTIs.

regression, under a single framework. In addition, this model allows for the dependent variable to have a non-normal distribution. This algorithm has already been used in other published works for the estimation of costs [12]–[14]. Although the algorithm has not been used in avionics manufacturing processes, it has given good results in estimating costs (main objective of the prototype presented).

Once the algorithm was chosen, the next step was to obtain the models for cost prediction based on the complexity pattern of a GTI. These ones were generated for the set of GTIs completed in the training set aircraft (MSN7-18), and subsequently validated in the validation set aircraft (MSN19-21).

After training, the results obtained in the three models were those shown in Figure 3. The results are good in the three target variables, since in all cases the average error is below 2 and the standard deviation has a low value (which can be checked graphically comparing the set of real values and that of predicted values). This means a good fit, especially knowing the limitations in the models and the variability in the number of incidences for the different tests.

In Figure 4, as an example, it is possible to observe the predictions relative to two GTIs. For the first one, the number of executions necessary to complete the first GTI is predicted, and for the second GTI, the total time (in hours) spent to complete said GTI is predicted. The training graphs (MSN7-18) are shown on the left, and the validation graphs (MSN 19-21) are shown on the right. As it is possible to observe, the difference between the real results (in blue color) and those predicted by the model (in red color) is quite small, correctly predicting the cost trend as well as an approximate value in the aircraft used to validate the models.

ENVIRONMENT

An environment for the prototype was designed for the integration of the prediction models into the Airbus production system. This was developed in the C++ language using the C ++ Builder XE (from Embarcadero RAD Studio XE). In this way, the models generated with IBM Modeler were subsequently programmed in the C++ language and integrated into the prototype.

Once the prototype is executed, the user is shown the main window. This window is shown in the following captured image (see Figure 5).

Thus, the main window of the prototype has the following sections:

1) In the upper left there are two tabs: GTIs and MSNs. These tabs allow the user to select the subsequent predictions to be made: either by GTIs or by MSNs. In the first case, the predictions will be made for a GTI, while in the second case the predictions will be associated with the sum of all the GTIs associated with an aircraft.

2) In the upper right, with the label LAST FINISHED MSN, the user is informed about the most recent aircraft whose ground testing process has been completed.

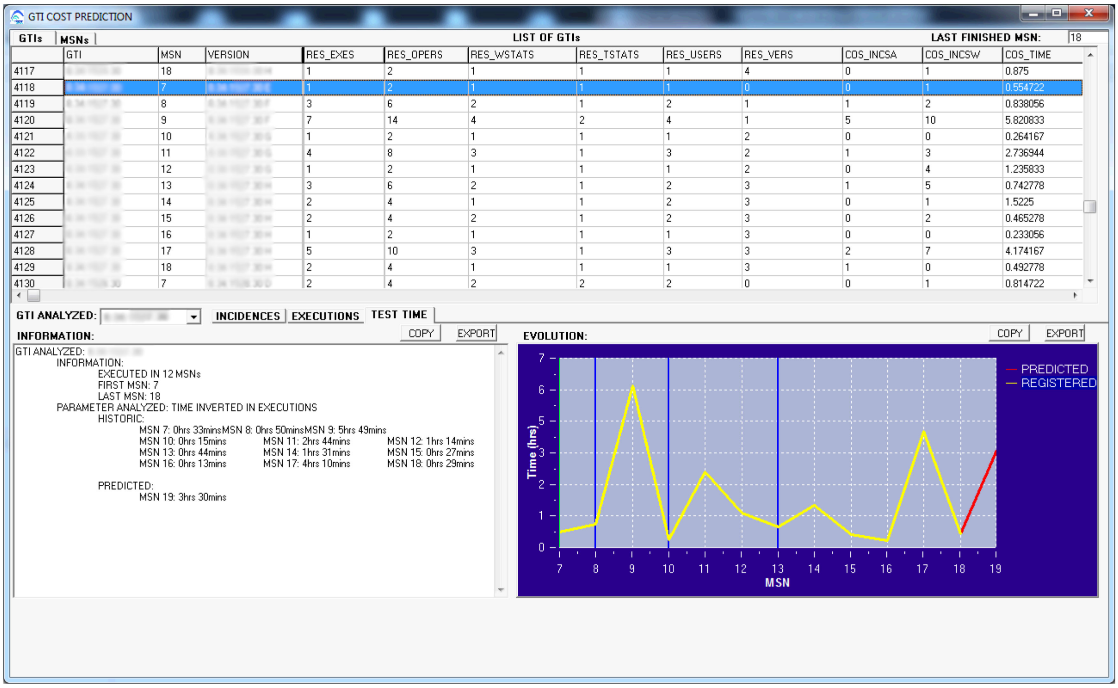


Figure 5.

Environment of the prediction software.

3) The data table labeled LIST OF GTIs contains the list of different GTIs executed in the past in the test system ordered by aircraft. This list, in addition to the GTI code and the corresponding MSN, contains the parameters corresponding to the different executions of that GTI.

4) The three tabs (INCIDENCES, EXECUTIONS, TEST TIME) shown below the previous table allow the user to specify the specific parameter on which the analysis will be carried out (prediction of incidences, number of necessary executions, or total time invested in the completion of the corresponding GTI or MSN, depending on the selection). The drop-down list shows the identification code of the GTI or MSN selected for the corresponding prediction.

5) Below the previous tabs, the result of the prediction is shown in two ways: one textual and one graphic. The report contains information associated with GTI or MSN, depending on the selected tab. Thus, the graphical part of the window (labeled EVOLUTION) shows a graph showing the evolution of the selected parameter along the successive MSNs sorted in time. The information recorded in the past is shown with a yellow line, while that related to a prediction is shown with a red line. In addition, a vertical blue line in a given MSN indicates the different version changes (modifications) of the GTI over time.

An example of GTI prediction is presented in Figure 5. Thus, it can be seen how the user selected a GTI and a prediction related to time (by selecting the tab TEST TIME). In the text box, the user is informed of both the general data of the selected GTI (such as the first and last aircraft number on which it was executed), as well as the specific data corresponding to its execution history (specifically, the time it took to complete the GTI in each of the 12 aircraft in which it was executed). Additionally, the prediction results are shown for the next aircraft, where it has not yet been performed (in the example it would be the MSN19, with a prediction of 3 h and 30 min needed to complete the GTI for that aircraft).

If the MSNs tab at the top of the window has been selected, the different predictions are focused on the aircraft as a whole, and the top table of GTIs no longer applies. In Figure 6, it is possible to observe a prediction of the number of executions regarding an aircraft.

The prediction software shows the following information: corresponding aircraft number (MSN), number of GTIs already completed in that aircraft (GTI FINISHED), number of GTIs to be completed in said aircraft (GTI TO PERFORM), as well as the value of the selected prediction parameter (INCIDENCES, EXECUTIONS, TEST TIME). If the aircraft has not been finalized yet, the information is headed with the text PREDICTED. If the aircraft has completed its ground tests, the calculation is performed as the total of the sum of the prediction parameters for all of its GTI tests. On the other hand, if

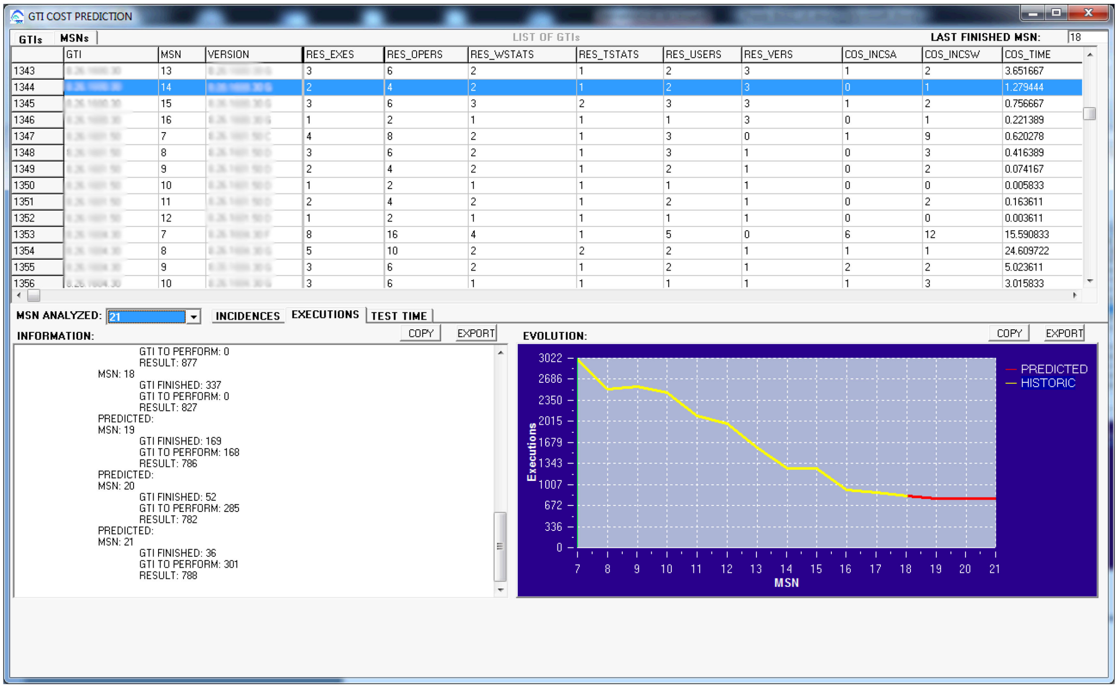


Figure 6.
Example of execution prediction for an aircraft.

the aircraft is still in the testing phase, the result of the parameter for the GTIs already performed on the aircraft is added, and the prediction value is added for the rest. Regarding the graphic part (labeled EVOLUTION), the prediction parameter is shown along the different MSNs of the interval (from MSN7 to the selected MSN). Thus, the evolution of the value in those aircraft that have already been completed is shown in yellow, while those MSN aircraft that still have GTIs to be completed are shown in red.

RESULTS

In order to evaluate the reliability of the prediction system, the cost predictions of the prototype were tested with real cases (not simulated) of GTIs performed by the Airbus DS Company. Specifically, the results of these predictions were obtained after the realization of a test battery, and they are described in this section.

The procedure used to obtain the results of these tests had the following steps:

Table 3.

Prediction Results for Aircraft

	Prediction			Actually			%Success		
Aircraft (MSN)	Incidences	Executions	Time	Incidences	Executions	Time	Incidences	Executions	Time
[illegible]	672	1717	1583	682	1737	1710	98.53	98.84	92.57
[illegible]	585	1513	1319	657	1620	1725	89.04	93.39	76.46
[illegible]	694	1619	1705	742	1725	1762	93.53	93.85	96.76
[illegible]	530	1418	1432	604	1553	1739	87.74	91.30	82.34
[illegible]	532	1405	1657	556	1451	1730	95.68	96.82	95.78
[illegible]	507	1399	1546	566	1470	1684	89.57	95.17	91.80
[illegible]	525	1362	1625	662	1582	1736	79.30	86.09	93.60
	RELIABILITY						**90.48**	**93.64**	**89.90**

Table 4.

Prediction Results by GTI

		Prediction			Actually		
GTI Analyzed	Aircraft (MSN)	Incidences	Executions	Time (hrs)	Incidences	Executions	Time (hrs)
[illegible]	[illegible]	0	1	1.3	1	4	2.3
[illegible]	[illegible]	0	1	0.1	0	1	0.08
[illegible]	[illegible]	0	1	0.9	0	1	1.01
[illegible]	[illegible]	0	1	0.09	0	1	0.04
[illegible]	[illegible]	0	1	0.01	0	1	0.02
[illegible]	[illegible]	0	1	0.06	0	1	0.2
[illegible]	[illegible]	0	2	2.14	0	1	1.6
[illegible]	[illegible]	0	1	0.1	0	3	0.8
[illegible]	[illegible]	4	7	4.07	1	2	0.92
[illegible]	[illegible]	13	15	15	8	10	21.2
[illegible]	[illegible]	0	1	0.1	3	11	8.23
[illegible]	[illegible]	7	1	13.49	3	7	6.01
[illegible]	[illegible]	0	1	0.7	1	3	0.9
[illegible]	[illegible]	0	1	0.7	1	2	0.9
[illegible]	[illegible]	3	7	15	7	11	12
[illegible]	[illegible]	1	2	1.61	0	1	1.2
[illegible]	[illegible]	0	1	1.02	3	4	2.06
[illegible]	[illegible]	0	1	0.01	0	1	0.02
[illegible]	[illegible]	0	1	1.04	0	2	1.57
[illegible]	[illegible]	1	4	7.23	4	7	6.23
[illegible]	[illegible]	0	1	0.92	0	1	1.21
[illegible]	[illegible]	0	2	1.06	1	4	1.72
[illegible]	[illegible]		1	0.1	0	2	0.31
[illegible]	[illegible]	0	1	267	4	7	8.12
[illegible]	[illegible]	1	2	0.3	0	2	0.2

1) Making predictions of a set of MSNs and specific GTIs chosen by Airbus DS, using the extraction of the database dated May 2017.
2) Obtaining results registered as of May 2018 in the MSNs and GTIs used in the predictions.
3) Comparison of actual and predicted results.
4) Evaluation of the prediction results and generation of a reliability rate (validated by Airbus DS) for cost models.

In this way, the test battery was divided into two types:

1) Prediction by MSN (comparison of the sum of costs related to all the GTIs of the aircraft).
2) Prediction by GTI for a battery of tests (specifically, 25 GTIs).

Between these two types of tests, the results of the first one were more easily quantifiable and could provide a more global and accurate view of the prediction results (by covering all the GTIs of the aircraft).

PREDICTION BY MSN

Table 3 shows the prediction results for each of the three predicted parameters (number of incidences, executions, and time spent for the GTI) on a set of aircraft (MSN) completed on the date that the battery of tests was performed (May 2018), and which were still being tested as of the data extraction date of May 2017. Thus, to obtain the results, a comparison of the predictions of the prototype was made with what was registered in the database.

Given that this table shows real and sensitive data related to tests, the MSN code is hidden due to a confidentiality agreement between Airbus DS and the University of Seville.

The reliability of the predictions of the prototype in terms of complete aircraft had: an average of 90.48% in terms of number of incidences in GTIs, an average of 93.64% in terms of executions, and around 90% in relation to prediction of time spent in the realization of the GTIs.

These results of over 90% in the three target parameters were considered satisfactory and better taking into account the nature and complexity of the problem.

PREDICTION BY GTI

For this analysis, Airbus DS randomly selected a sample of 25 important GTIs from approximately 600 registered in the last dump of the database for all the aircraft. Subsequently, the predictions of the three prediction parameters for each of the selected tests were carried out. Finally, these results were compared with the real ones, already registered in the database. The results are shown in Table 4.

Those prediction values that, according to Airbus DS company personnel, were considered too far from the actual values subsequently recorded in the database have been marked in yellow and red. The remaining values can be considered to represent a successful prediction. Thus, the prediction results were considered satisfactory for 58 predictions (75 predictions in total, 17 in yellow). These results imply 77.3% of success in predictions of target parameters of GTIs.

CONCLUSION

The performance of the entire GTIs of an aircraft implies a set of costs for the company. Besides, if there are extra costs, due to an error during the execution of the test, then the ground testing process of the aircraft is extended over time much longer than necessary. The research group of the authors belonging to the Electronic Technology Department (Spain) worked with the Airbus DS Company and developed a software prototype for cost prediction in the executions of GTIs. Specifically, the prototype is designed for predicting the three types of costs involved in a GTI: number of incidences generated, number of executions required, and total time necessary to complete the GTI. In this way, with the help of the prediction software, Airbus DS can pay special attention to certain GTIs, trying to correct errors in them or optimize their implementation. The prediction models were generated through a data mining process with the simulated data registered by the company on its ground testing process in the past. Thus, the software prototype has been designed as an application for Microsoft Windows, which integrates the different prediction models and provides a graphical environment to the user.

The prototype has been tested with real tests to obtain reliability results that would allow Airbus DS to use the prediction values with a predictive reliability of at least 75%. After performing these tests, the cost prediction models achieved satisfactory results, enough to validate its use. Thus, for the prediction of costs related to the totality of GTIs in the aircraft, the percentage of success was over 90%. On the other hand, regarding costs detailed by GTI, the success rate was 77.3%, which can be considered a good result taking into account the Airbus DS requirements as well as the difficulties and complexity of such fine predictions.

The developed prototype is an important contribution that complements the work [2] previously published. Thus, while [2] allows Airbus DS to predict the occurrence of incidences in order to improve the performance of certain GTIs, the prototype presented in this article allows it to predict the different type of costs in order to have a forecast of resources (both at GTI and aircraft level).

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