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Giuseppe Scanniello,
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CHALMERS | UNIVERSITY OF GOTHENBURG
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Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg

Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden

Telephone + 46 (0)31-772 1000

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Giuseppe Scanniello[1], Miroslaw Staron[2], Håkan Burden[2], and Rogardt Heldal[2]

[1] Dipartimento di Matematica, Informatica e Economia,
Università della Basilicata, Italy
giuseppe.scanniello@unibas.it
[2] Computer Science and Engineering
Chalmers University of Technology & University of Gothenburg, Sweden
miroslaw.staron@gu.se; {burden|heldal}@chalmers.se

Abstract. We carried out a controlled experiment and an external replication to investigate whether the use of requirement diagrams of the SysML (System Modeling Language) helps in the comprehensibility of requirements. The original experiment was conducted at the University of Basilicata in Italy with Bachelor students, while its replication was executed at the University of Gothenburg in Sweden with Bachelor and Master students. A total of 87 participants took part in the two experiments. The achieved results indicated that the comprehension of requirements is statistically higher when requirements specification documents include requirement diagrams without any impact on the time to accomplish comprehension tasks.

Keywords: Controlled Experiment, Replication, Software Models, SysML, UML

1 Introduction

A requirement specifies a capability or a condition that must (or should) be satisfied, a function that a system must implement, or a performance condition a system must achieve [20]. Sometimes requirements are provided directly by a customer (i.e., person or organization) paying for the system or are generated by the organization that is developing the system [9]. Ambiguous, incomplete, inconsistent, silent (unexpressed), unusable, over-specific, and verbose requirements (both functional and non-functional) may cause defects that will impact on overall quality of the system . For example, in the software engineering field, it is widely recognized that a substantial portion of software defects (up to 85%) originates in the requirements engineering process [38]. Issues in the specification of requirements may also introduce from communication problems among stakeholders [28].

In this context, modeling is very important and becomes even more relevant when computer based systems become larger, complex, and critical to human society. The System Modeling Language (SysML) is a general-purpose modeling language that provides a broad range of tools for engineering computer based systems. For example, the SysML provides multiple ways for capturing requirements and their relationships in both graphical and tabular notations [20]. Functional requirements can be modeled with use case diagrams and use case narratives. These notations are both in the UML (Unified Modeling Language) [30] and in the SysML. Requirements in the SysML can be depicted also on a requirement diagram (not in the UML). This kind of diagram is considered particularly useful in graphically depicting hierarchies of specifications or requirements [18].

Although there are a number of empirical investigations on the UML [10], only a few studies on the SysML have been conducted so far (e.g.,[29]). This lack is even more evident in the context of empirical investigations aimed to study the possible benefits deriving from the use of the SysML models in the requirements engineering process.

We present here the results of a controlled experiment conducted at the University of Basilicata in Italy with third year Bachelor Students in Computer Science. The goal of this experiment was to study the effect of including requirements analysis diagrams in requirements specification documents. The results indicated that the use of these diagrams improves the comprehension of specification documents without affecting the time to accomplish comprehension tasks. To show that these results were robust, an external replication was carried out at the department of Computer Science and Engineering (CSE[1]) in Gothenburg, Sweden, with Bachelor and Master Students. Varying the context or the environmental factors contribute some confidence that the effect is not limited to one particular setting and that the original results were not the result of the experimenter's bias [36]. That replication is also a differentiated replication because a variation in an essential aspect of the original experimental conditions was introduced, namely different kinds of participants were involved [4]. The results of the original experiment were confirmed in the replication. Both the experiments have been presented for the first time here.

2 The Experiements

We carried out two ABBA-type experiments [37] - the original experiment and its external replication. The original experiment (denoted E-UBAS) was carried out at the University of Basilicata in June 2012 with 24 third year students from the Bachelor's program in Computer Science. This experiment was replicated at CSE in December 2012. This latter experiment was denominated as R1-UGOT. The participants of R1-UGOT were 63 third year students from three Bachelor programs in IT, computer science and software engineering as well as first year students from the Master's program in software engineering.

The experiments were carried out by following the recommendations provided by Juristo and Moreno [22], Kitchenham et al. [26], and Wohlin et al. [37]. The

[1] This department is shared between Chalmers University of Technology and the University of Gothenburg, in Sweden.

experiments are reported according to the guidelines suggested by Jedlitschka et al. [21]. For replication purposes, the experiment material is available online[2].

2.1 Goal

Applying the Goal Question Metric (GQM) template [6], the goal of the experiments can be defined as:

– ***Analyse*** the use of requirement diagrams ***for the purpose*** of evaluating them ***with respect to*** the requirements specification documents ***from the point of view of*** requirements analyst and developer ***in the context of*** students in Computer Science/Software Engineering.

The use of GQM ensured that important aspects were defined before the planning and the execution took place [37].

2.2 Context Selection

We used two systems as the **objects in the experiments**:

Automobile. It is a mock-up of software for controlling car behavior with use cases about entering the car, anti-lock breaking or operating the climate control of a car. Figure 1 shows a requirement diagram of this system.

ESS (Enhanced Security System). The system is designed to detect potential intruders. When an intruder is detected, the operators of the central monitoring station contact the local police or security companies, warning them of the intrusion. The use cases include providing medical/intruder/fire emergency response or investigative data.

The requirements specification documents of these two systems were built on the samples provided in [18]. This book is used to prepare for SysML certification: the OMG Certified Systems Modeling Professional (OCSMP) [19]. The Automobile and ESS systems are used to introduce the basic feature set of the SysML to get the first two levels of the certification. The choice of domains to model was considered a good compromise of generality and industrial application. A more detailed, industrially relevant problem would be difficult to use at two geographically distinct universities with different profiles, the choice was also suitable for both notations thus minimizing the risk of biased objects of the experiment [2].

One of the authors reviewed all the documentation available in that book and then selected the diagrams and the chunks of the documentation that was of interest for our study. For example, use case narratives was added according to the template suggested by Bruegge and Dutoit [9]. For each experiment, the design choices above allowed reducing internal and external validity threats.

[2] `www.scienzemfn.unisa.it/scanniello/SysML/`.

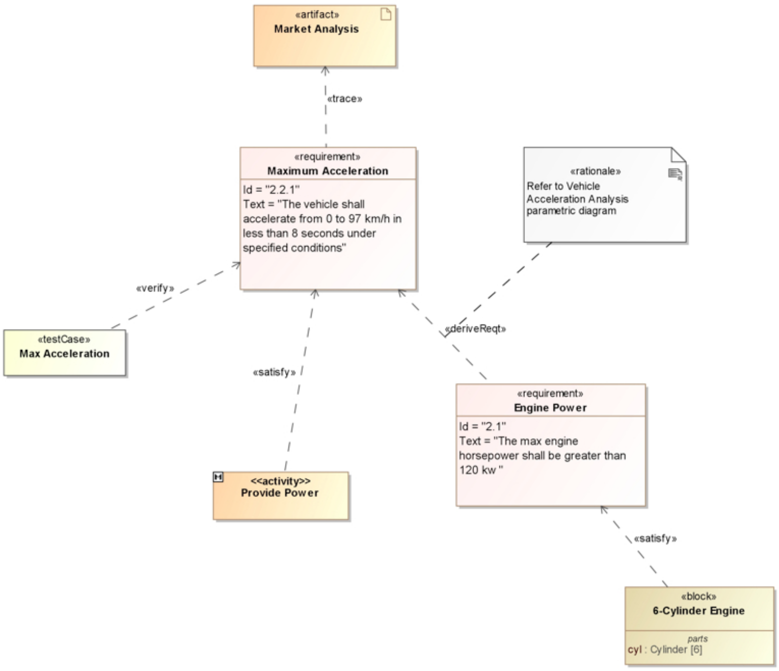


Fig. 1. A sample requirement diagram of the system Automobile

The documentation (including the diagrams) of both the selected systems was then translated into Italian (for the original experiment) to avoid that different levels of familiarity with English could bias the results. However, the replication was performed using the documentation in English. This difference in the experiments was introduced because the language of instruction at the Swedish university was English.

The materials available for the participants were: *(i)* a problem statement; *(ii)* the list of the non-functional requirements together with their unstructured textual descriptions; *(iii)* two requirement diagrams; *(iv)* a use case diagram and the narratives of its use cases; and *(v)* descriptions of the actors. The Automobile system was specified using 16 non-functional requirements, while ESS was specified using 14. The number of use cases of Automobile and ESS were 8 and 5, respectively. This slight difference in the size is because the requirements specification documents used in the experiments were based on the samples provided in [18]. The used specification documents are available online on the web page of our study.

2.3 Participants

We conducted the experiments under controlled conditions using *convenience sampling* from the population of junior software developers with *students as* *participants*. The participants had the following characteristics (the significant differences between these groups are in italics):

E-UBAS. The participants were students of *a software engineering course*. The participants had passed all the exams related to the following courses: Object Oriented Programming I and II and Databases. In these courses the participants studied and applied the UML [30] on university problems.

R1-UGOT. The participants were students of a *model-driven software development course*. These students attended one of four different programs - a Master program in software engineering or one of three Bachelor programs in IT, computer science or software engineering. All students had *successfully completed at least 120 ECTS credits*[3]. The course which was used for the experiment was aimed at in-depth learning of executable modelling [11]. The modeling experience of these participants was higher than those of E-UBAS.

Although the amount of training in modelling was different for both groups of participants, all participants studied the SysML for the first time as preparation for the experiments.

The students participated in the experiments on a voluntary basis: we did not force and we did not pay them for their participation. However, we awarded the students for their participation to the experiments with a bonus towards their final mark. They were clearly informed about these conditions. At R1-UGOT 70% of the students of the course attended the experiment and 80% of the students participated in E-UBAS. This shows that only the motivated participants attended the experiment.

2.4 Variable Selection

We considered the specification documents without requirement diagrams as the *Control Group* and the group with requirement diagrams as the *Treatment Group*. The independent variable in the experiment was *Method*. It is a nominal variable that can assume the following two values: RD (specification document with requirement diagrams) and NORD (specification document without requirement diagrams).

The direct dependent variables are:

Comprehension - the level of comprehension of the requirements.

Completion time - the time which the participant spent to accomplish the experiment task.

The variables were measured through questionnaires as **experiment instruments** - one questionnaire for each round. The questionnaire was composed of nine multiple-choice questions. Each question admitted one or more correct answers among a set of five. The comprehension questionnaire of each system was

[3] 120 ECTS is equivalent to 2 years of full studies. 1 year = 60 ECTS, European Credit Transfer System

7. The maximum acceleration of a car is strongly connected to (one or more answers may be correct)					
☐ Engine power					
☐ Car noise					
☐ The number of the cylinders of the engine					
☐ The space for the occupants inside the car					
☐ The maximum speed					
How much do you trust your answer?					
☐ Unsure	☐ Not sure enough		☐ Sure Enough	☐ Sure	☐ Very Sure
How do you assess the question?					
☐ Very difficult	☐ Difficult		☐ On average	☐ Simple	☐ Very Simple
What is the "main" source of information used to answer the question?					
☐ Previous Knowledge	☐ Requirements List	☐ Internet	☐ Use Cases	☐ Use Case Diagram	☐ Requirement Diagrams

Fig. 2. A question example from the comprehension questionnaire of Automobile

the same independently from the method experimented (RD and NORD). To quantify the quality of answers and the comprehension achieved, we used the approach proposed by Kamsties et al. [24]. In particular, we computed the number of correct responses divided by 9 (i.e., the number of questions in the comprehension questionnaire). We consider a response to a question to be correct if the participant selected all the correct alternatives and no incorrect alternatives were selected. The used measure assumes values in the interval $\in [0, 1]$. A value close to 1 means that a participant got a very good comprehension since he/she answered correctly to all the 9 questions of the questionnaire. Conversely, a value close to 0 means that a participant obtained a very low comprehension.

Figure 2 reports a sample question for Automobile. The correct expected answers are: *Engine power* and *The number of the cylinders of the engine*. These answers could be easily derived from both the list of the non-functional requirements and the requirements diagrams (see Figure 1). Each response that does not report only these two answers is considered incorrect. Although different approached have been proposed in the literature to estimate the comprehension achieved by the participants (e.g., [1], [32]), we opted here for the approach above because it is more suitable for multiple-choice questions and because we were interested in the correct and complete comprehension of requirements [24].

To calculate the second dependent variable - completion time - we used the time (expressed in minutes) to accomplish the task, which was directly recorded by each participant. Low values for the time mean that the participants were quicker in completing the experiment. Both variables complement each other - one describes the quality of the understanding and the other one the efficiency of the participant.

We also analyzed the effect of the other independent variables (also called co-factors, from here on):

System - denotes the system (i.e., Automobile or ESS) used as the experimental object. The effect of the System factor should not be confounded with the main factor. However, for the sake of consistency we analysed whether this assumption holds.

Trial - denotes in which experiment trial a particular participant was exposed to the requirement diagram. As the participants worked on two different experimental objects (Automobile and ESS) in two laboratory trials/runs. We analyzed whether the order might affect the results.

2.5 Hypotheses Formulation

The following two null hypotheses have been formulated and tested:

Hn0 : The mean value of the comprehension for the RD factor is the same as the mean value of the comprehension variable for the NORD factor.
Hn1 : The mean value of the time to complete the task for the RD factor is the same as for the NORD factor.

The alternative hypotheses are :

Ha0 : The mean value of the comprehension for the RD factor is **not** the same as the mean value of the comprehension variable for the NORD factor.
Ha1 : The mean value of the time to complete the task for the RD factor is **not** the same as for the NORD factor.

Hn0 and Hn1 are both two-tailed because we are interested in the effect of using requirement diagrams and do not expect a positive nor a negative effect. Even though it can be postulated that the participants in the treatment group were provided with additional information it could also be the case that the extra information required more time to understand. We can hypothesize that this additional information is more suitable to reduce ambiguities and to improve the comprehensibility of requirements, but impose additional burden on remembering extra information thus increasing risk for misunderstandings. Our postulation is supported by the used framework that is suggested by Aranda et al. [2]. This framework is based on both the underlying theory of the modeling language and on cognitive science.

2.6 Design of the experiments

We used the within-participants counterbalanced experimental design (see Table 1). This design ensures that each participant works on different experimental objects (Automobile or ESS) in two runs, using RD or NORD each time. We opted for that design because it is particularly suitable for mitigating possible carry-over effects[4]. As for E-UBAS, we used the participants ability as blocking factor: the groups are similar to each other with respect to the number of high and low ability participants[5]. This experiments is balanced with respect to the number of participants assigned to RD and NORD (each groups contained 6

[4] If a participant is tested first under the condition A and then under the condition B, he/she could potentially exhibit better or worse performances under the second condition.
[5] The students with average grades below 24/30 were classified as low ability participants, otherwise high, as proposed in [1].

Table 1. Experiment design

Trial	Group A	Group B	Group C	Group D
First	Automobile, RD	ESS, NORD	Automobile, NORD	ESS, RD
Second	ESS, NORD	Automobile, RD	ESS, RD	Automobile, NORD

students). The participants were randomly assigned to the four groups in R1-UGOT. The number of participants to the groups A, B, C, and D were 10, 17, 28, and 8, respectively. In both the experiments we gave a 15-minute break when passing from the first laboratory trial to the second one. The inequality of groups was caused by the fact that no blocking was used and the design was random.

2.7 Experimental Tasks

We asked the participants to perform the following tasks:

Comprehension task. The participants were asked to fill in a comprehension questionnaire for each system. We defined the questions to assess several aspects related to the comprehension of requirements. All the questions were formulated using a similar form/schema (see Figure 2). As suggested in [2], for each question in the comprehension questionnaires we also asked the participants to specify: *(i)* how much they trusted the answer given, *(ii)* the perceived level of difficulty, and *(iii)* the "main" source of information exploited to answer a question. The questions *(i)* and *(ii)* gave insights about the participant's judgment regarding the given answer and the ease to obtain information required to answer the question, respectively. Differently, the main source of information allowed us to get qualitative indications on how the participants used the models provided to deal with comprehension tasks. The analysis of these additional questions is available in the technical report.

Post-experiment task. We asked the participants to E-UBAS to fill in a post-experiment survey questionnaire. This questionnaire contained questions about: the availability of sufficient time to complete the tasks and the clarity of the experimental material and objects. The goal was to obtain feedback about the participants' perceptions of the experiment execution. The post-experiment survey questionnaire is shown in Table 2.

2.8 Experiment operation

The participants first attended an introductory lesson in which the supervisors presented detailed instructions on the experiment. The supervisors highlighted the goal of the experiment without providing details on the experimental hypotheses. The participants were informed that the data collected in the experiments were used for research purposes and treated confidentially.

After the introductory lecture, the participants were assigned to the groups A, B, C, and D (see Table 1). No interaction was permitted among the participants,

Table 2. Post-experiment survey questionnaire

Id	Question	Possible answers
Q1	I had enough time to perform the task	(1-5)
Q2	The objective of each task was perfectly clear to me	(1-5)
Q3	The questions of the comprehension questionnaire were perfectly clear to me	(1-5)
Q4	The answers to the questions of the comprehension questionnaire were perfectly clear to me	(1-5)
Q5	I found useful the experiments from the education perspective	(1-5)
Q6	I found useful the requirement diagrams	(1-5)
Q7	The requirement diagrams and the requirement list are more useful than the requirements list alone	(1-5)
Q8	How many time (in terms of a percentage) did you spend to analyze the requirement diagrams with respect to the total time to perform the comprehension task?	(A-E)
1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree		
A. $< 20\%$; B. $\geq 20\%$ and $< 40\%$; C. $\geq 40\%$ and $< 60\%$; D. $\geq 60\%$ and $< 80\%$; E. $\geq 80\%$		

both within each laboratory trial and while passing from the first trial to the second one. No time limit for performing each of the two trials was imposed.

To carry out the experiment, the participants first received the material for the first laboratory run, and when they had finished, the material for the second run was provided. After the completion of both the runs, the participants to E-UBAS were given the post-experiment questionnaire.

We asked the participants to use the following experimental procedure: *(i)* specifying name and start-time; *(ii)* answering the questionnaire; and *(iii)* marking the end-time. We did not suggest any approach to browse the requirement specification documents.

2.9 Analysis Procedure

To perform the data analysis, we carried out the following steps:

1. We calculated the descriptive statistics of the dependent variables.
2. We tested the null hypotheses using unpaired analyses because the comprehension tasks were accomplished on two different experimental objects (see Table 1). We have planned to use unpaired t-test when the data follow a normal distribution. The normality has been verified using the Shapiro-Wilk W test [35]. A p-value smaller than the α threshold allows us to reject the null hypothesis and to conclude that the distribution is not normal. If the data are not normally distributed, our non-parametric alternative to the unpaired t-test was the Wilcoxon rank-sum test (also known as the Mann Whitney test) [13]. The chosen statistical tests analyze the presence of a significant difference between independent groups, but they do not provide any information about that difference [23]. Therefore, in the context of the parametric analyses, we used Cohen's d [12] effect size to obtain the standardized difference between two groups. That difference can be considered:

negligible ($|d| < 0.2$), small ($0.2 \le |d| < 0.5$), medium ($0.5 \le |d| < 0.8$), and large ($|d| \ge 0.8$) [23]. Conversely, we used the point-biserial correlation r in case of non-parametric analyses. The magnitude of the effect size measured using the point-biserial correlation is: small ($0 < r \le 0.193$), medium ($0.193 < r \le 0.456$), and large ($0.456 < r \le 0.868$) [23].
We also analyzed the statistical power for each test performed. The statistical power is the probability that a test will reject a null hypothesis when it is actually false. The value 0.80 is considered as a standard for the adequacy [16]. The statistical power is computed as 1 minus the Type II error (i.e., β-value). Summarizing, we analyzed statistical power when a null hypothesis can be rejected, the β-value otherwise to understand how strong is the effect size of the null hypothesis.
3. To analyze the influence of the co-factors, we planned to use a two-way Analysis of Variance (ANOVA) [14] if the data was normally distributed and if their variance is constant. The normality and the variance of the data were tested using the tests of Shapiro and Levene [27], respectively. In case these assumptions are not verified, we would use a two-way permutation test [3], a non-parametric alternative to the two-way ANOVA.
4. To graphically show the answers of the post-experiment survey questionnaire, we adopted boxplots. These are widely employed since they provide a quick visual representation to summarize data.
5. The participants opinions of each question of the comprehension questionnaire (i.e., how much they trusted the answer given, the perceived level of difficulty, and the "main" source of information exploited) were analyzed by means of descriptive statistics illustrated by mosaic plots.

In all the statistical tests, we decided (as custom) to accept a probability of 5% of committing Type-I-error [37] (i.e., the α threshold is 0.05). The R environment[6] for statistical computing has been used in the data analyses.

2.10 Differences between the Experiments

We introduced some variations in R1-UGOT with respect to E-UBAS. Some of these variations were introduced because of the number of participants and time constraints:

- The participants of R1-UGOT were more experienced in software modeling than E-UBAS. This alteration was made to better analyze the effect of more highly experienced participants.
- A different group of experimenters conducted R1-UGOT. This variation was introduced to deal with external validity threats. However, consistency issues across the different experimenters could be possible. To administer these issues, we carefully managed communication among experimenters.

[6] www.r-project.org

Table 3. Descriptive statistics

Experiment	Completion time						Comprehension					
	RD			NORD			RD			NORD		
	Med.	Mean	Std. Dev.	Med.	Mean	Std. Dev.	Med.	Mean	Std. Dev.	Med.	Mean	Std. Dev.
E-UBAS	26	26.33	10.483	26	28.04	9.466	0.667	0.657	0.17	0.444	0.449	0.198
R1-UGOT	15	14.95	4.911	15	15.23	4.987	0.56	0.508	0.216	0.44	0.385	0.196

- To familiarize with the experimental procedure, the participants to E-UBAS accomplished in the training session an exercise similar to that which would appear in the experimental tasks. We used the specification document of an AudioPlayer system (details can be found in our experimental package). Since the participants at R1-UGOT were more experienced in modeling and because of time constraints, this exercise was skipped.
- In E-UBAS the participants filled in a pre- and a post-questionnaire. The results of the pre-questionnaire were used to get information about the participants' ability (the blocking factor). The post-questionnaire was defined to get feedback about the participants' perceptions of the experiment execution. Post-questionnaires was not used in R1-UGOT for time constraints and for the number of participants.
- To accomplish the comprehension task, we allowed the participants to E-UBAS to find information on the Web. This was not allowed in R1-UGOT due to the background of the students.

3 Results

We present the data analysis following the procedure presented above.

3.1 Descriptive statistics and exploratory analysis

Table 3 shows the descriptive statistics of completion time and comprehension, respectively (i.e., median, mean, and standard deviation), grouped by Method.

Comprehension. The comprehension values of the participants to E-UBAS was higher with RD. Similar results were achieved on R1-UGOT. In addition, we can observe that the participants to E-UBAS achieved better comprehension values than the participants to R1-UGOT on RD. For NORD, there was a slight tendency in favor on E-UBAS: the median values are mostly the same, while the mean value is lower for R1-UGOT. A plausible justification for that results is that the participants to E-UBAS were from a more homogenous group than the participants from R1-UGOT (i.e. one program compared to four programs at two different levels).

Completion time. On average the participants in both experiments spent less time for RD compared to NORD: 26.33 and 28.04 for E-UBAS and 14.95 and 15.23 for R1-UGOT. Within each experiment, the median values are the same independently from the method used (26 and 15 for E-UBAS and

R1-UGOT, respectively). We can also observe that the participants to R1-UGOT spent on average less time than those to E-UBAS to accomplish the tasks with both RD and NORD. This difference could be due to the fact that the participants to R1-UGOT had more experience with software modeling and therefore more familiar with UML based specification documents.

3.2 Influence of Method

Testing Hn0. For both the experiments, parametric statistical analyses could not be applied. As for E-UBAS, the Shapiro test returned 0.003 and 0.223 as the p-values for RD and NORD, respectively. The p-values on R1-UGOT were 0.086 for RD and 0.016 for NORD.

Table 4 shows the results for the analyses for Influence of Method. For both experiments, we can reject the null hypothesis Hn0. The p-values returned by the Mann-Whitney test were less than 0.01 in both the experiments, while the values of the statistical power were 0.949 for E-UBAS and 0.881 R1-UGOT - i.e. both above the 0.80 threshold.

Table 4. Results for Hn0 and Hn1

Experiment	Dependent Variable	#obs for RD	#obs for NORD	p-value	Statistical Power	β-value
E-UBAS	Comprehension	24	24	YES (< 0.001)	0.949	0.051
	Completion time	24	24	NO (0.556)	0.068	0.932
R1-UGOT	Comprehension	63	63	YES (< 0.001)	0.881	0.119
	Completion time	59	56	NO (0.805)	0.064	0.936

Testing Hn1. The data are normally distributed for E-UBAS (the p-values are 0.216 and 0.437 for RD and NORD, respectively). Therefore, the unpaired t-test could be used. This parametric statistical test could not be applied for R1-UGOT. In fact, the Shapiro test returned 0.028 and 0.154 as the p-values for RD and NORD, respectively.

The results shown in Table 4 indicate that Hn1 could not be rejected in both the experiments. The β-values are always high: 0.932 for E-UBAS and 0.936 for R1-UGOT. It is worth mentioning that the number of observations for R1-UGOT is less than 63 for both RD and NORD. In particular, we did not consider 11 observations (4 for RD and 7 for NORD) in this analysis because we did not obtain the finish time (the time was not provided in the questionnaires). At the end of each laboratory run, the experimenters were not able to check the start/stop time because many participants returned back simultaneously the experimental material they gave them for the experimentation.

3.3 Effect of co-factors

The results of the analysis of the co-factors is summarized in Table 5. For each experiment, this table reports whether or not a co-factor has any effect on each

Table 5. Analysis on the co-factors for comprehension

Exp_ID	System	Method vs. System	Trial	Method vs. Trial
E-UBAS	NO (0.373)	NO (0.941)	NO (1)	NO (0.623)
R1-UGOT	YES (< 0.001)	NO (0.596)	NO (0.366)	NO (1)

of the dependent variable. The results for completion time are not reported because the main factor did not have any effect on that variable. The obtained p-values are shown within brackets. We could apply a two-way ANOVA only for R1-UGOT on System. In all the other cases, we applied a two-way permutation test. In particular, the data were not normal in E-UBAS for RD on Automobile (p-value = 0.01) and for RD in the second laboratory trial (p-value = 0.039). As far as R1-UGOT is concerned, the data were non-normal for NORD in the first laboratory trial (p-value = 0.014). The results about the interaction between Method the co-factors System and Trial are shown as well.

System. The results show that the effect of System on comprehension was not statistically significant for E-UBAS (p-value = 0.373), while it was statistically significant for R1-UGOT (p-value < 0.001). Descriptive statistics suggested that the participants to R1-UGOT obtained better comprehension values when performing the task on Automobile. For that system, the median was 0.56 and the mean 0.542, while 0.33 and 0.352 were the the median and the mean for ESS, respectively. The effect of System could be due to the different levels of familiarity of the participants with the problem domain of the two systems. The difference could also be caused by the inequality of the groups at R1-UGOT. In this experiment and in E-UBAS the interaction between Method and System was not statistically significant. The p-values were 0.596 and 0.941, respectively.

Trial. The results show that its effect on comprehension was not statistically significant for both E-UBAS and R1-UGOT. The p-values were 1 and 0.596, respectively. In addition, the interaction between Method and Trial was not statistically significant for both the experiment: the p-values were 0.623 for E-UBAS and 1 for R1-UGOT. We can conclude that the data analysis did not reveal any carry-over effects (i.e., learning or fatigue).

3.4 Post-experiment survey results

Figure 3 graphically shows the answers of the post-experiment survey questionnaire. Indeed, the box-plots summarize the answers to the questions from Q1 to Q7 of the participants to E-UBAS. The participants of that experiment judged adequate the time to perform the comprehension task (Q1 - enough time). The median is equal to 1 (strongly agree). Regarding Q2 (objectives perfectly clear), the participants agreed on the fact that the objectives of the experiment were perfectly clear: the median is 2 (agree). For Q3 (questions clear) and Q4 (answers clear) the median are 2 (agree), namely the participants found clear both

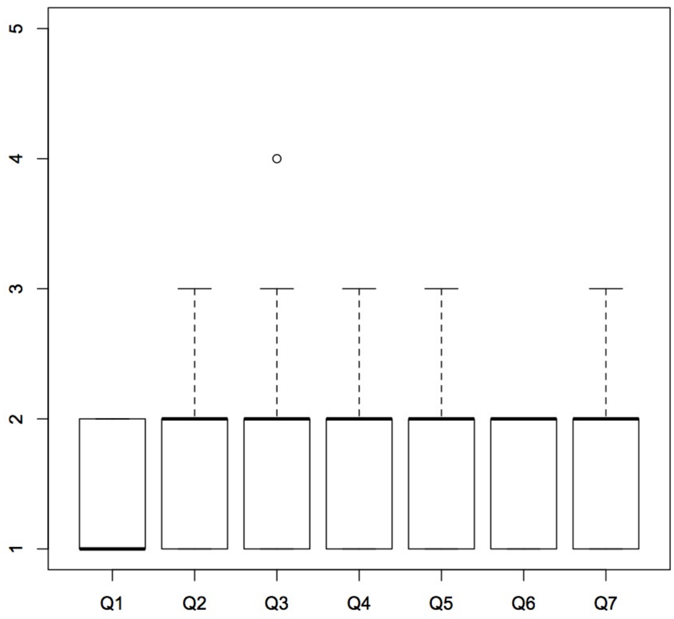


Fig. 3. Box-plot of the answers of the post-experiment survey questionnaire

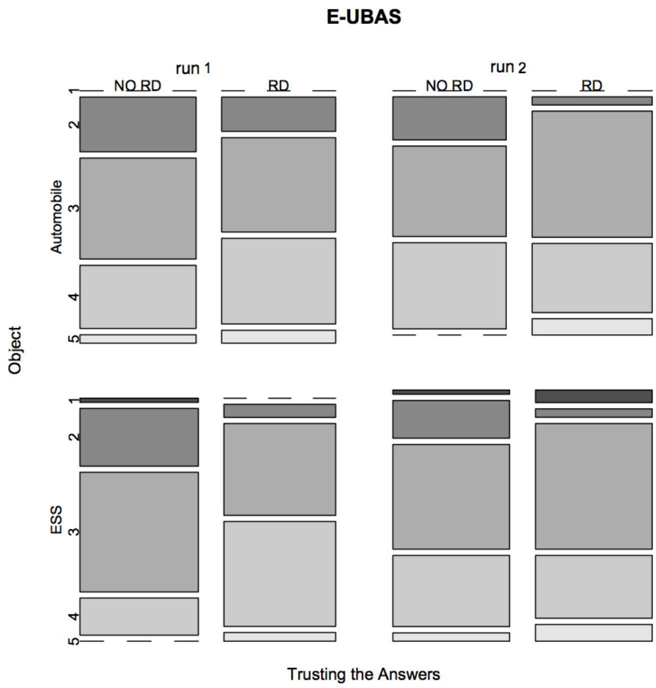
the questions and the answers of the comprehension questionnaires. The median for Q5 (education perspective) was 2 (agree). The participants found useful the experiment from the pedagogical perspective. The participants judged useful the requirements diagrams to comprehend requirements. The medians for Q6 (usefulness of requirements diagrams) and Q7 (requirements diagrams combined with a requirements list are useful) are 2 (agree).

With respect to Q8 (time spent to analyze requirement diagrams), the median is D. The participants declared to have spent from 60% to 80% of their time to read requirement diagrams, while performing a comprehension task.

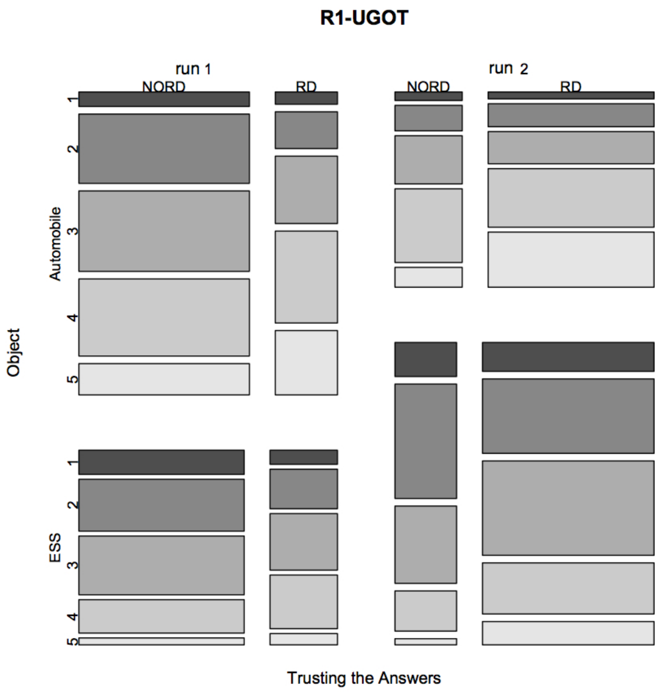
3.5 Further Analysis

In this section, we report the results of the analyses about the participants opinion for each question of the comprehension questionnaire: how much they trusted the answer given, the perceived level of difficulty, and the "main" source of information exploited.

Trusting the given answers. Figure 4.a depicts the mosaic plot about the trusting of the participants to E-UBAS in answering the comprehension questionnaires of Automobile and ESS. The analysis is performed grouping the data also for Trial and Method. The mosaic plot suggests that the trusting level increases when the participants are provided with requirement diagram. In fact,



(a)



(b)

Fig. 4. Mosaic plot about the trusting on the answers given by the participants to E-UBAS (a) and R1-UGOT (b)

whatever was the experimental object, the greater part of the participants answered "sure enough" (3), "sure" (4), or "very sure" (4). When the requirement diagrams were not provided, the participants were less confident of the answers given: the rectangle corresponding to "not sure enough" (2 - dark grey) for NORD is always larger than that for RD.

Figure 4.b depicts the mosaic plot about R1-UGOT. The pattern shown by this graphical representation is very similar to that observed for E-UBAS, namely the trusting level of the participants increases when they are provided with requirement diagram. It is worth mentioning that the mosaic plot in Figure 4.b presents some asymmetries because of the inequality of groups in Table 1.

Complexity of the questions. The participants to both the experiments overall found the comprehension tasks not so difficult both using or not requirement diagrams. Indeed, the tasks are mostly perceived less complex when the requirement diagrams are included in the requirement specification document (see the mosaic plots shown in Figures fig:complexity). As far as E-UBAS is concerned, in the second run the difference between NORD and RD is less clear.

Source of information. Figure 6 depicts the mosaic plots about the source of information used for answering the comprehension questionnaires in E-UBAS and R1-UGOT. These mosaic plots suggest that: requirement diagrams are the main source of information to accomplish the comprehension task. Regarding RD, the light grey rectangle (whose label is 6) is always the largest considering the trials and the experimental objects alone. The second source of information used is the requirement list (2), that becomes the first one when the participants accomplished the comprehension task with NORD. The personal knowledge is more relevant than UC and UCD in both the experiments.

4 Discussion

There are several ways in which representations (and also visual notations) can improve the reasoning and the comprehension [2, 7]. Based on the paper by Scaife and Rogers [33] and the results presented above, requirement diagrams does not affect offloading: they do not reduce cognitive effort. This kind of diagram makes reasoning and problem solving easier (i.e., re-representation) and due to its graphical notation allows spending cognitive power more effectively (i.e., graphical constraining). This could be possible because relations among requirements are made explicit when using that notation. Also, making explicit requirements derivations, and satisfy and verify relationships could improve the comprehension performances of the participants. Without requirement diagrams, all this information, that is present in the unstructured textual description of the requirements, has to be inferred, making reasoning more difficult and complex.

The achieved results also suggest that the benefit deriving from the use of requirement diagrams are independent from the UML modeling experience of

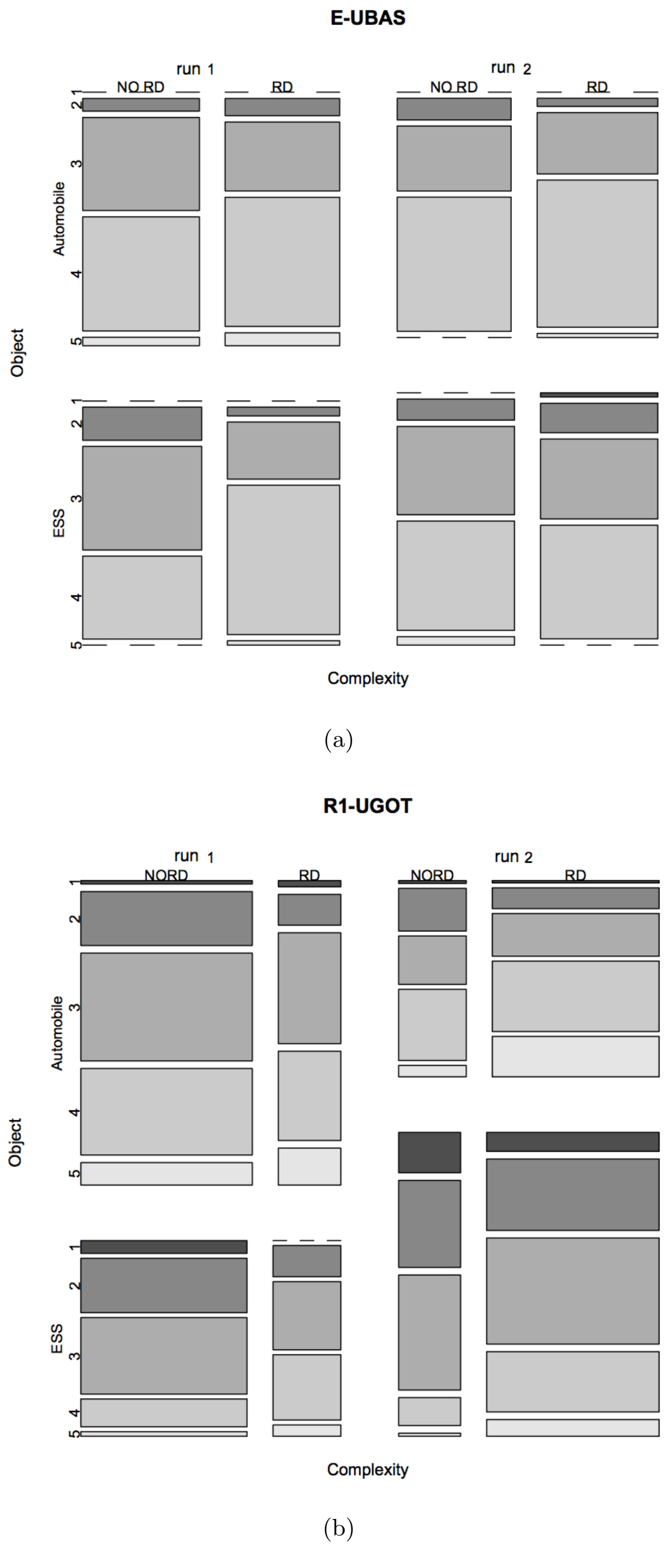
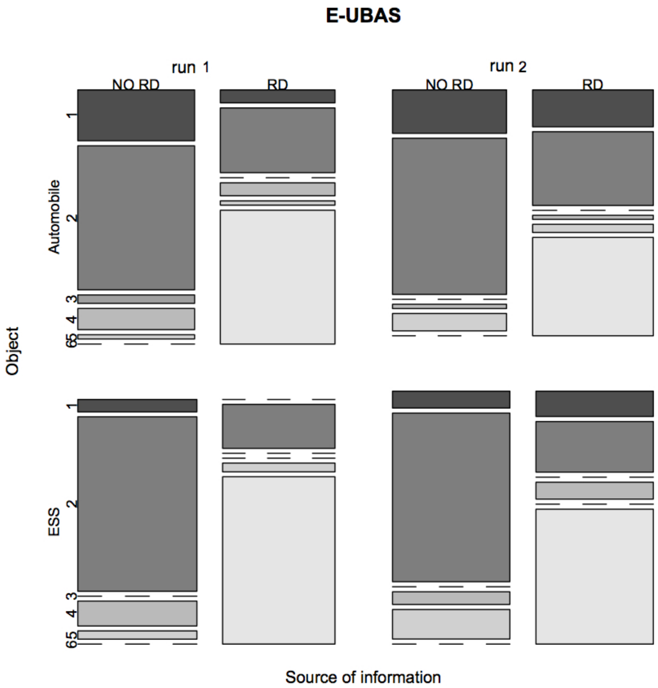
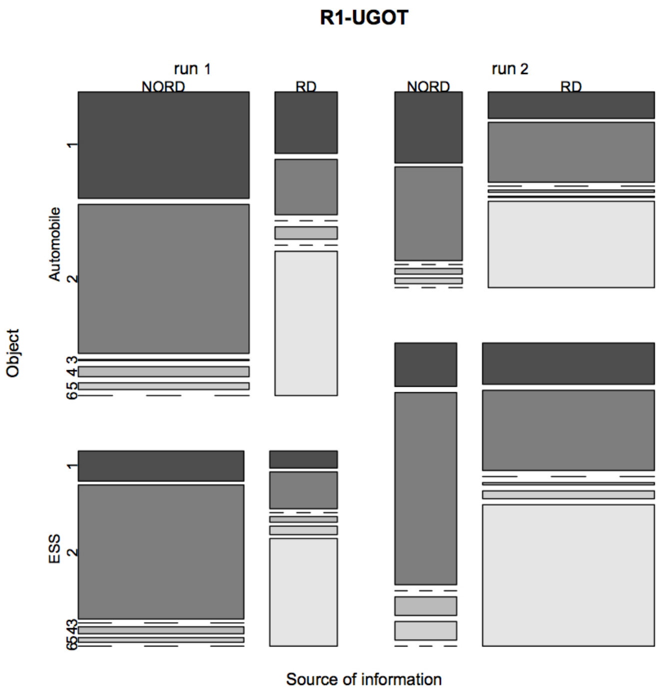


Fig. 5. Mosaic plot about the complexity perceived by the participants to E-UBAS (a) and R1-UGOT (b)



(a)



(b)

Fig. 6. Mosaic plots about the source of information the participants to E-UBAS (a) and R1-UGOT (b) used to accomplish the comprehension tasks

the participants to the experiments. In fact, for both the experiments the effect of Method was statistically significant on the comprehension of requirements. It seemed that modeling experience only affected the task completion time: more experienced participants spent less time (see Table 3).

Although we chose systems on which the participants were familiar with, we observed that for the replication performed in Sweden ESS seemed to be more difficult than Automobile in terms of comprehensibility. These results did not allow us to provide a definitive conclusion about the influence of the co-factor System (i.e., whether ESS was more difficult than Automobile) and could be justified by the participants' varying levels of familiarity with the problem domains of these systems. The effect of System and the fact that any statistically significant interaction between Method and System was observed suggest that the familiarity with the problem domain affected comprehensibility independently from the presence or the absence of requirement diagrams in the specification documents. This point deserves specially conceived future investigations.

4.1 Implications

We adopted a perspective-based approach [5] to judge the implications of our investigation. In particular, we based our discussion on the *practitioner/consultant* (simply *practitioner* in the following) and *researcher* perspectives [25]. The main practical implications can be summarized as follows:

- Independent of the experience of the participants, the use of SysML requirement diagrams is useful in the comprehension of requirements. This result is relevant from both the practitioner and the researcher perspectives. From the practitioner perspective, this result is relevant because requirement diagrams can be used as a communication mechanism among analysts, or as a validation tool between analysts and stakeholders. From the researcher perspective, it is interesting to investigate whether variations in the context (e.g., larger and more complex systems and more or less experienced stakeholders) lead to different results.
- The presence of requirement diagrams induces no additional time burden. The practitioner could be interested in that result because requirement diagrams allow stakeholders to get an improved comprehension of requirements without affecting the time to comprehend them. This result is also relevant for the researcher because it could be interesting to investigate in which cases the processing and the integration of the information in the requirement diagrams and in the specification document could increase or reduce task completion time.
- The study is focused on two kinds of systems. The researcher and the practitioner could be interested in answering the question: do the results observed hold for other kinds of systems developed?
- The requirements specification documents were realistic enough. Then, we believe that our findings could scale to real projects. To corroborate this assertion, we need further replications with different experimental objects as well as case studies in real software development projects.

– The requirement diagrams are less common in the software industry than the UML diagrams used in our specification documents (e.g., [15, 34]). The results of our study could then promote the adoption of requirement diagrams in the industry for both software and system modeling. Transferring a new technology, method, or tool to practitioners is easier when an empirical evaluation is performed and its results show that such a technology solves actual issues [31].

4.2 Threats to Validity.

We here present an overview of the possible threats that could affect the validity of our results.
Conclusion Validity. It concerns issues that affect the ability of drawing a correct conclusion. In our study, we used proper statistical tests. In particular, we used parametric test when the assumption were verified, non-parametric tests otherwise. Regarding R1-UGOT, the participants were from four different programs in computer science and software engineering.
Internal Validity. This threat has been mitigated thanks to the design of the experiment. Each group of participants worked on two tasks, with or without the requirement diagrams. Carry-over is another possible threat for internal validity. We statistically analyzed learning and fatigue effects. The results of the two-way ANOVA and permutation tests showed that the effect of Trial was not statistically significant in both the experiments. Another possible threat concerns the exchange of information among the participants. We prevented that monitoring the participants and asking back the material at the end of each run.
Construct Validity. It concerns the used metrics and social threats. The metrics are widely used with purposes similarly to ours (e.g., [24]). Regarding the second concern, we evaluated the participants on either the comprehension they achieved on the requirements nor the time they spent to accomplish the tasks.
External Validity. It concerns the generalization of the results. Possible threats are related to the complexity/simplicity of the comprehension task and the choice of the participants.

5 Conclusion

Although the SysML is becoming very popular as modeling language for engineering computer based systems, it has been the subject of very few empirical evaluations. For example, Nejati et al. [29] presented a framework to facilitate software design inspections conducted as part of the safety certification process. That framework is based on the SysML and includes a traceability information model, a methodology to establish traceability, and mechanisms to use traceability for extracting slices of models relevant to safety requirements. A supporting tool has also been developed [17]. The authors validated their proposal on one benchmark and one industrial case study. Differently, Briand et al. [8] presented the results of a controlled experiment, which has been conducted to assess an approach devised to establish traceability between requirements and SysML models. That approach was conceived to filter out irrelevant details, easing inspection and understanding. The results indicated a significant decrease in completion time and an increase in the correctness of the tasks performed.

Our study is different from those above because it pursues a different goal. In particular, the focus here is on the comprehensibility of requirements abstracted with SysML requirements diagrams. The achieved results indicated that the use of these diagrams significantly improves the comprehension without any effect on the time to perform the tasks. This result might be because the use of requirement diagrams better supported the processing and the integration of the information in the reader's mental model [2], so leading to higher levels of comprehension of requirements when these diagrams are present.

Possible future directions for our research will be focussed on the estimation of both the costs and savings the adoption of requirement diagrams might introduce when modeling a computer based system. Then, it would be worth analyzing whether the additional effort and cost to model requirements are adequately paid back by a more valuable improved comprehension. Future work could be also devoted to better understand the effect of the participants' ability and experience on the comprehension of requirements when they are abstracted with the notation considered in this study.

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Università degli Studi della Basilicata

Requirements Specification Document

RESIDENTIAL SECURITY SYSTEM

1. Problem Statement

The Security Systems Inc. is a company that for years has provided Residential Security Systems all over the country. Their systems are installed in private houses and in public places and are monitored by a central monitoring station (CMS). The system is designed to detect potential intruders.
When an intruder is detected, the operators of the CMS contact the local police or bodies in charge of safety, warning them of the intrusion.
The Security Systems Inc. has been successful for many years, but recently clients have preferred to close contracts with them, replacing their equipment with those of competing companies. Also, it was obvious that the systems of SS Inc. had become obsolete. At this point, the company decided to develop an advanced security system (ESS - Enhanced Security System) to recover their market share.

1.1. Definitions, acronyms and abbreviations

- **ESS:**
  Subject system (Acronym of: Enhanced Security System).
- **Occupant/ Investigator/ Intruder/ Physical Evironment:**
  The people will use ESS.

1.2. References

Part of this document has been found from the book:

- A pratical guide to SysML – Friedenthal, Moore, Steiner – Morgan Kaufmann

2. Requirements modeling: Requirement Diagram

2.1. Non-Functional Requirements

- **User Interface**
  Specifies the user interface of the ESS (application interface used by the CMS).
- **Emergency Services Interface**
  Specifies emergency services guaranteed by the ESS (detecting dangerous events).
- **Functional and Performance**
  ESS must ensure adequate performance regarding the detection of exceptional events.
- **Intruder Emergency Response**
  → *Intrusion Detection and False Alarm Rate:* ESS must provide intrusion detection and the frequency of false alarms. It must be ensured the detection of intrusions in the perimeter (Perimeter Detection), interior (Internal Detection) and entry-exit (Entry-Exit Detection) of the place where the system is present/installed.
- **Fire Detection and False Alarm Rate**
  ESS must ensure fire detection and must take note of the false alarms (frequency).
- **Medical Alert and False Alarm Rate**
  ESS must ensure the detection of health alarms and must trace the false ones (frequency).
- **Data Storage and Validation**
  ESS must allow secure storage of the collected data and their control by the responsible personals (Investigator).
- **Power Surge and Lightning Protection**
  ESS must protect the environment in which it is installed by: lightning and electricity overload.
- **System Vulnerability**
  ESS must minimize its vulnerability to malicious attacks, so guarantying the customers' security.

- **Availability**
  ESS must ensure high standards of availability, resulting from the defined security policies.
- **Fault Detection and Isolation**

ESS must enable the detection of faults and must to isolate them, so ensuring high standard of availability for the system.

- **Backup Power**

  ESS must allow the use of the emergency power, so ensuring high standard of availability for the system.

- **Installation Cost**

  The installation cost of ESS must be commensurate with the functional characteristics and availability of the system.

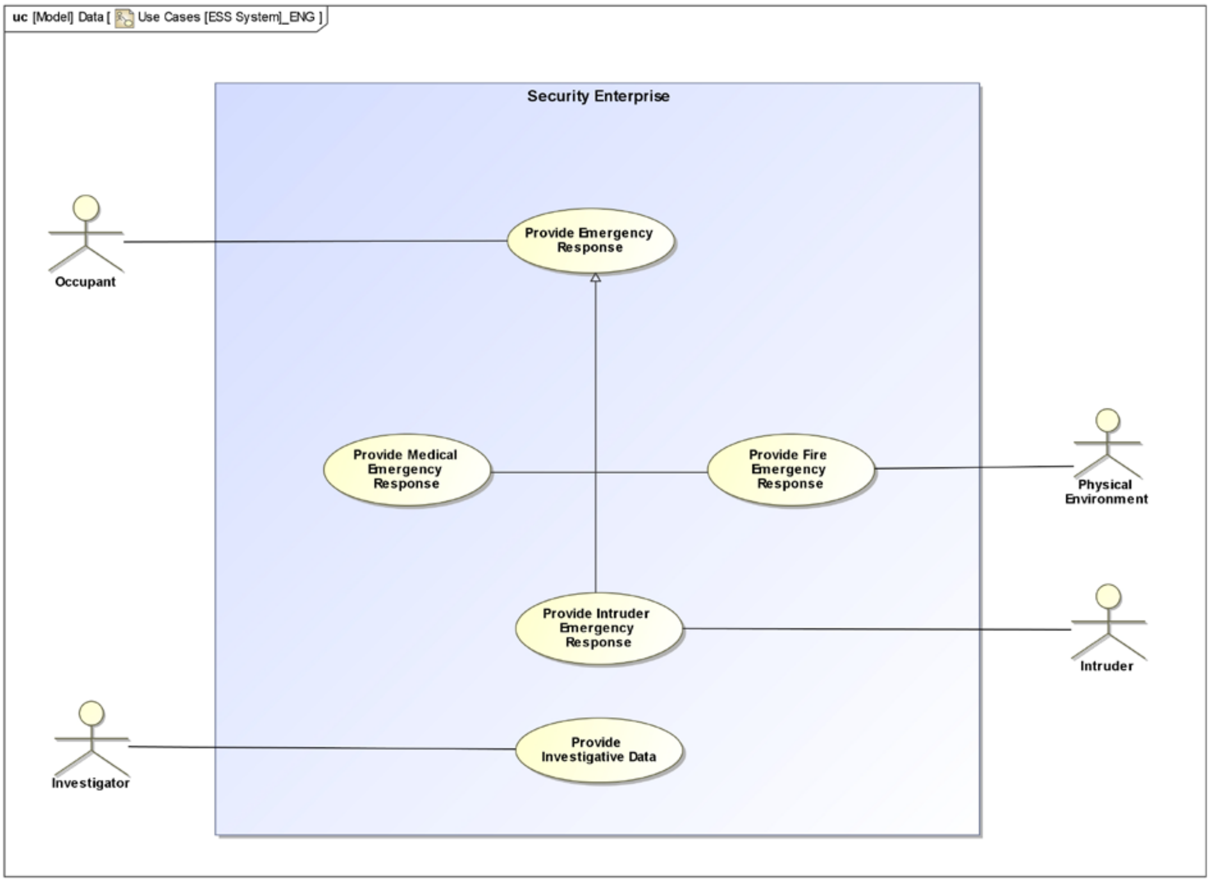
- **Recurring Cost**

  Recurring costs, such as updating and maintenance, must be commensurate with the characteristics of the system and its availability. The customer's specific needs have to be taken into account as well.

3. Use Cases Modeling

3.1. Use case diagram

High Level Use Case Diagram for a better comprehension of the major use cases and actors involved in them.



1. Use_Cases_Diagram_ESS_ENG

3.2. Actors

In this section we provide an exhaustive description of the actors, i.e., the external entities that interact with ESS. We group and specify the interactions allowed to each actor.

Actor	Version

Occupant	1.0
Description	
He/she is the person, who provides emergency responses to the system.	
Interactions	**Frequency**
1. Provide Emergency Response 2. Provide Medical Emergency Response	HIGH HIGH

Actor	**Version**
Investigator	1.0
Description	
The actor interested in the collected data.	
Interactions	**Frequency**
1. Provide Investigative Data	MEDIUM

Actor	**Version**
Physical Environment	1.0
Description	
The actor which represents the physical environment and providing emergency responses to the system.	
Interactions	**Frequency**
1. Provide Fire Emergency Response	HIGH

Actor	**Version**
Intruder	1.0
Description	
The actor who violates the environment is under video surveillance.	
Interactions	**Frequency**
1. Provide Intrude Emergency Response	HIGH

3.3. Use Cases

In the following, we present the use cases shown in Figure 2.

Name of Use Case	***Provide Emergency Response***
Actors	Occupant
Flow of Events	1. **Occupant** provides an emergency response 2. **ESS** detects the emergency signal sent it to the CMS
Precondition	An intrusion or dangerous events has been recognized.
Post-condition	The CMS notifies the appropriate responsible for safety to manage the event.
Quality Requirements	N/A

Name of Use Case	***Provide Medical Emergency Response***
Actors	Occupant
Flow of Events	1. **Occupant** provides emergency medical response (anyone feel bad physically) 2. **ESS** detects a medical emergency and sends it to CMS
Precondition	A dangerous event has been recognized.
Post-condition	The CMS notifies the responsible health emergency to manage the event.

Quality Requirements	N/A

Name of Use Case	***Provide Fire Emergency Response***
Actors	Physical Environment
Flow of Events	1. **Physical Environment** provides emergency medical response (anyone feel bad physically) 2. **ESS** detects a medical emergency and sends it to CMS
Precondition	A dangerous event has been recognized.
Post-condition	The CMS notifies the responsible to fire emergency to manage the event.
Quality Requirements	N/A

Name of Use Case	***Provide Intruder Emergency Response***
Actors	Intruder
Flow of Events	1. The presence of a **Intruder** is recognized 2. **ESS** detects a break-in, and sends a message to CMS
Precondition	It is happening a dangerous events.
Post-condition	The CMS notifies the appropriate responsible for safety to manage the intrusion.
Quality Requirements	N/A

Name of Use Case	***Provide Investigative Data***
Actors	Investigator
Flow of Events	1. **ESS** stores the data collected 2. **Investigator** requests the data relating to investigations 3. **ESS** returns the data requested by Investigator
Precondition	It occurrence of a dangerous event and the data were collected for its resolution.
Post-condition	
Quality Requirements	N/A

Name:_______________________________ **Start Time:** _________ **Finish Time:** _________

1. What are non-functional requirements that deal with the usability of user interfaces and the communication interfaces of the system and its subsystems? (one or more answers may be correct)

- O Availability
- O User Interface
- O Installation Cost
- O Emergency Services Interface
- O Internal Detection

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

2. What are non-functional requirements related to the requirement *Intrusion Detection and False Alarm Rate*? (one or more answers may be correct)

- O Availability
- O Perimeter Detection
- O Fault Detection and Isolation
- O Entry-Exit Detection
- O Internal Detection

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

3. What are non-functional requirements related to the requirement *Availability*? (one or more answers may be correct)

- O Fire Detection and False Alarm Rate
- O Fault Detection and Isolation
- O Installation Cost
- O User Interface
- O Backup Power

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

4. What are non-functional requirements related to the detection performance of exceptional events? (one or more answers may be correct)

- O Intrusion Detection and False Alarm Rate
- O Fire Detection and False Alarm Rate
- O Recurring Cost
- O Power Surge and Lightning Protection
- O Data Storage and Validation

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

5. What is the non-functional requirement that deals with the detection of intruders and false alarms? (one or more answers may be correct)

- O Fire Detection and False Alarm Rate
- O System Vulnerability
- O Intrusion Detection and False Alarm Rate
- O Perimeter Detection
- O Provide Investigative Data

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

6. The non-functional requirement *Intrusion Detection and False Alarm Rate* is derived from: (one or more answers may be correct)

- O Perimeter Detection
- O Internal Detection
- O User Interface
- O Intruder Emergency Response
- O Provide Emergency Response

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

7. The non-functional requirement Intruder Emergency Response is obtained from: (one or more answers may be correct)

- O The non-functional requirement Intrusion Detection and False Alarm Rate
- O The non-functional requirement Resolution
- O The Requirements Specification Document
- O The document of Security Policy Specification
- O The functional requirement Provide Intruder Emergency Response

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

8. The detection of intrusion is checked: (one or more answers may be correct)

- O Using a specific test entry
- O In dangerous conditions
- O From the Perimeter's Detection
- O Never
- O From the resolution of the camera installed

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

9. What are the functional requirements related to the requirement *Intruder Emergency Response*? (one or more answers may be correct)

- O Provide Fire Emergency Response
- O Perimeter Detection
- O Verify Entry Detection
- O Provide Intruder Emergency Response
- O None of this

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

Università degli Studi della Basilicata

Requirements Specification Document

RESIDENTIAL SECURITY SYSTEM

1. Problem Statement

The Security Systems Inc. is a company that for years has provided Residential Security Systems all over the country. Their systems are installed in private houses and in public places and are monitored by a central monitoring station (CMS). The system is designed to detect potential intruders.
When an intruder is detected, the operators of the CMS contact the local police or bodies in charge of safety, warning them of the intrusion.
The Security Systems Inc. has been successful for many years, but recently clients have preferred to close contracts with them, replacing their equipment with those of competing companies. Also, it was obvious that the systems of SS Inc. had become obsolete. At this point, the company decided to develop an advanced security system (ESS - Enhanced Security System) to recover their market share.

1.1. Definitions, acronyms and abbreviations

- **ESS:**
  Subject system (Acronym of: Enhanced Security System).
- **Occupant/ Investigator/ Intruder/ Physical Evironment:**
  The people will use ESS.

1.2. References

Part of this document has been found from the book:

- A pratical guide to SysML – Friedenthal, Moore, Steiner – Morgan Kaufmann

2. Requirements modeling: Requirement Diagram

2.1. Non-Functional Requirements

- **User Interface**
  Specifies the user interface of the ESS (application interface used by the CMS).
- **Emergency Services Interface**
  Specifies emergency services guaranteed by the ESS (detecting dangerous events).
- **Functional and Performance**
  ESS must ensure adequate performance regarding the detection of exceptional events.
- **Intruder Emergency Response**
  → *Intrusion Detection and False Alarm Rate:* ESS must provide intrusion detection and the frequency of false alarms. It must be ensured the detection of intrusions in the perimeter (Perimeter Detection), interior (Internal Detection) and entry-exit (Entry-Exit Detection) of the place where the system is present/installed.
- **Fire Detection and False Alarm Rate**
  ESS must ensure fire detection and must take note of the false alarms (frequency).
- **Medical Alert and False Alarm Rate**
  ESS must ensure the detection of health alarms and must trace the false ones (frequency).
- **Data Storage and Validation**
  ESS must allow secure storage of the collected data and their control by the responsible personals (Investigator).
- **Power Surge and Lightning Protection**
  ESS must protect the environment in which it is installed by: lightning and electricity overload.
- **System Vulnerability**
  ESS must minimize its vulnerability to malicious attacks, so guarantying the customers' security.

- **Availability**
  ESS must ensure high standards of availability, resulting from the defined security policies.
- **Fault Detection and Isolation**

ESS must enable the detection of faults and must to isolate them, so ensuring high standard of availability for the system.

- **Backup Power**

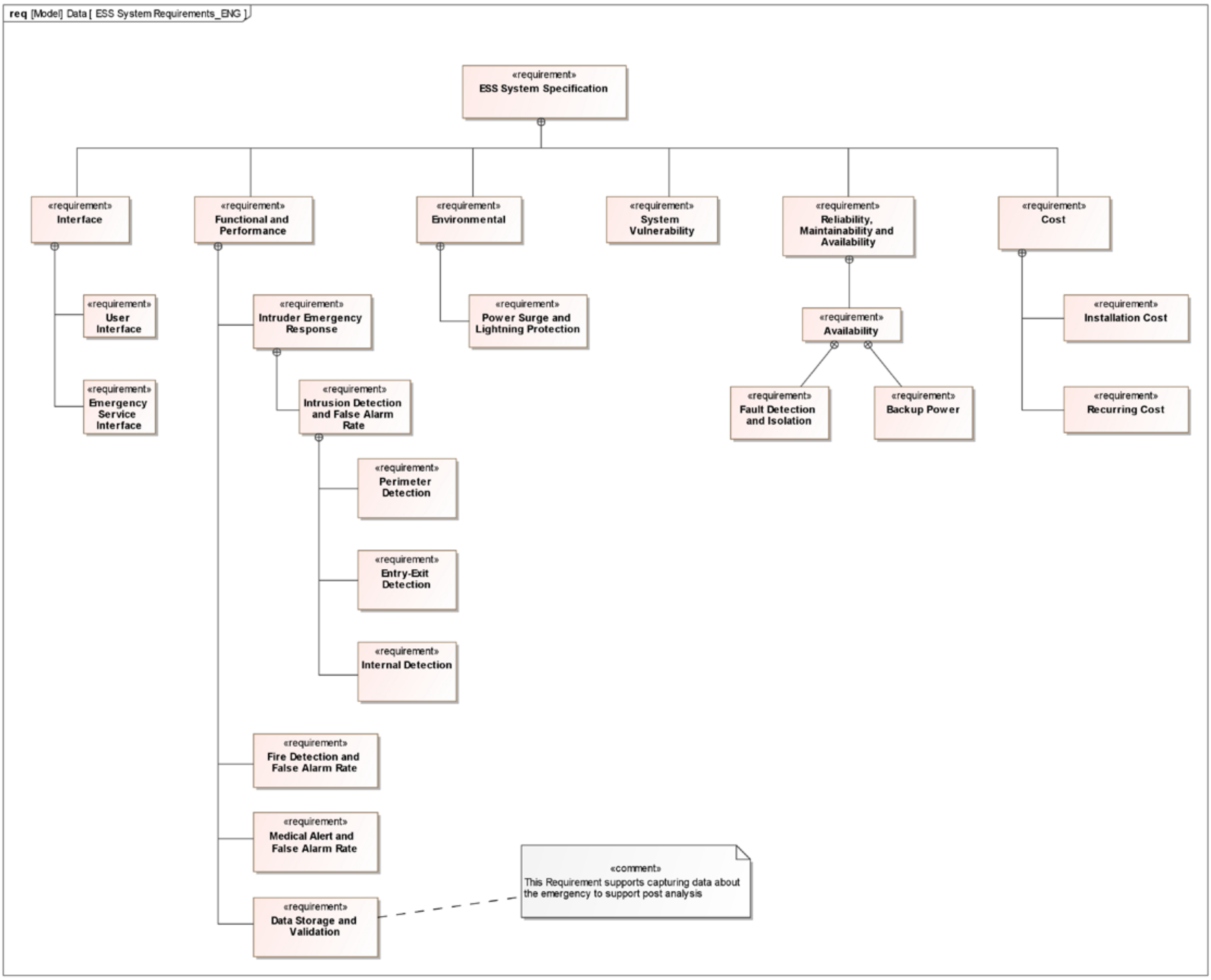
  ESS must allow the use of the emergency power, so ensuring high standard of availability for the system.

- **Installation Cost**

  The installation cost of ESS must be commensurate with the functional characteristics and availability of the system.

- **Recurring Cost**

  Recurring costs, such as updating and maintenance, must be commensurate with the characteristics of the system and its availability. The customer's specific needs have to be taken into account as well.

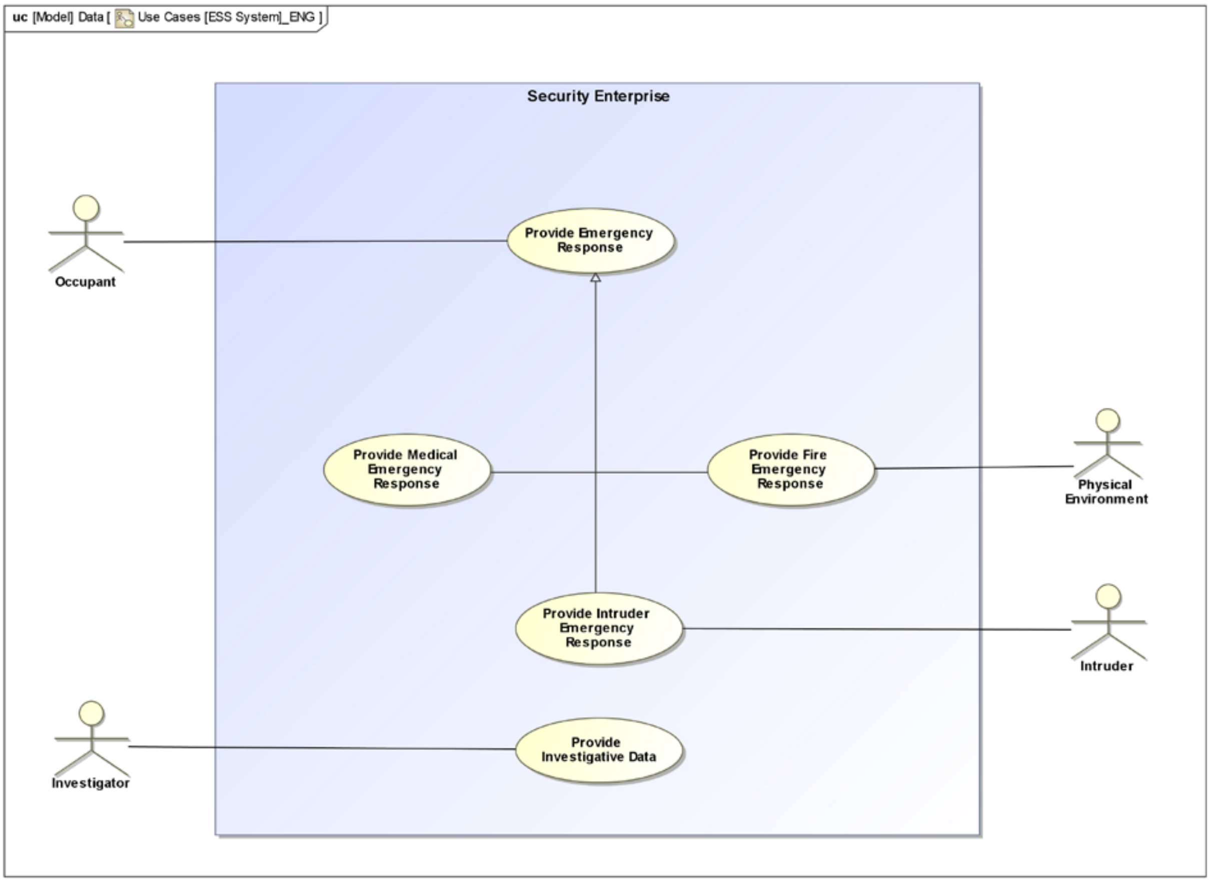


1. Requirement_Diagram_ESS_ENG

3. Use Cases Modeling

3.1. Use case diagram

High Level Use Case Diagram for a better comprehension of the major use cases and actors involved in them.



2. Use_Cases_Diagram_ESS_ENG

3.2. Actors

In this section we provide an exhaustive description of the actors, i.e., the external entities that interact with ESS. We group and specify the interactions allowed to each actor.

Actor	Version
Occupant	1.0
Description	
He/she is the person, who provides emergency responses to the system.	
Interactions	**Frequency**
1. Provide Emergency Response **2.** Provide Medical Emergency Response	HIGH HIGH

Actor	Version
Investigator	1.0
Description	
The actor interested in the collected data.	
Interactions	**Frequency**
1. Provide Investigative Data	MEDIUM

Actor	Version
Physical Environment	1.0
Description	

The actor which represents the physical environment and providing emergency responses to the system.	
Interactions	**Frequency**
1. Provide Fire Emergency Response	HIGH

Actor	**Version**
Intruder	1.0
Description	
The actor who violates the environment is under video surveillance.	
Interactions	**Frequency**
1. Provide Intrude Emergency Response	HIGH

3.3. Use Cases

In the following, we present the use cases shown in Figure 2.

Name of Use Case	***Provide Emergency Response***
Actors	Occupant
Flow of Events	**1.** **Occupant** provides an emergency response **2.** **ESS** detects the emergency signal sent it to the CMS
Precondition	An intrusion or dangerous events has been recognized.
Post-condition	The CMS notifies the appropriate responsible for safety to manage the event.
Quality Requirements	N/A

Name of Use Case	***Provide Medical Emergency Response***
Actors	Occupant
Flow of Events	**1.** **Occupant** provides emergency medical response (anyone feel bad physically) **2.** **ESS** detects a medical emergency and sends it to CMS
Precondition	A dangerous event has been recognized.
Post-condition	The CMS notifies the responsible health emergency to manage the event.
Quality Requirements	N/A

Name of Use Case	***Provide Fire Emergency Response***
Actors	Physical Environment
Flow of Events	**1.** **Physical Environment** provides emergency medical response (anyone feel bad physically) **2.** **ESS** detects a medical emergency and sends it to CMS
Precondition	A dangerous event has been recognized.
Post-condition	The CMS notifies the responsible to fire emergency to manage the event.
Quality Requirements	N/A

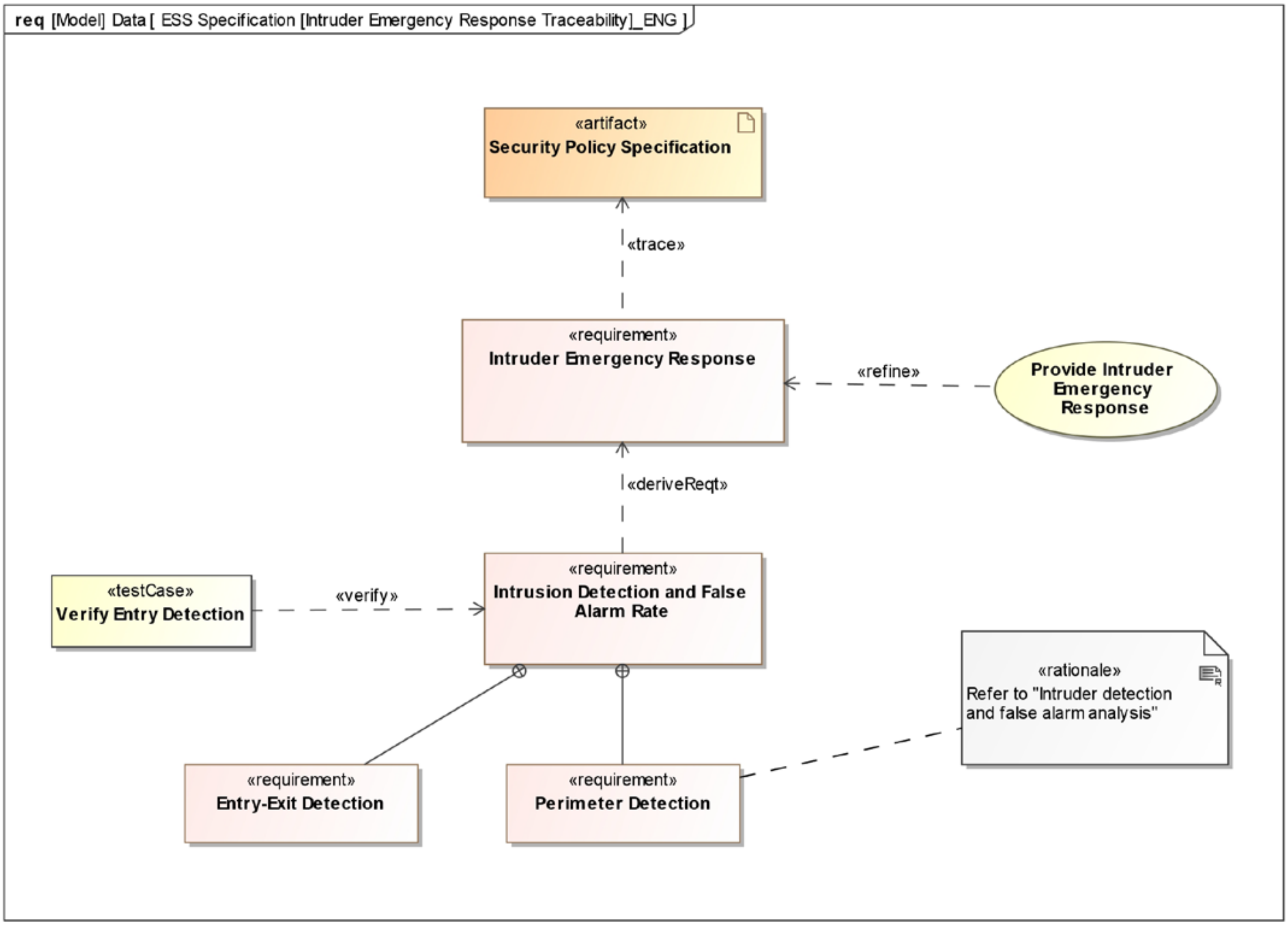
Name of Use Case	***Provide Intruder Emergency Response***
Actors	Intruder
Flow of Events	**1.** The presence of a **Intruder** is recognized **2.** **ESS** detects a break-in, and sends a message to CMS
Precondition	It is happening a dangerous events.

Post-condition	The CMS notifies the appropriate responsible for safety to manage the intrusion.
Quality Requirements	N/A

Name of Use Case	***Provide Investigative Data***
Actors	Investigator
Flow of Events	1. **ESS** stores the data collected 2. **Investigator** requests the data relating to investigations 3. **ESS** returns the data requested by Investigator
Precondition	It occurrence of a dangerous event and the data were collected for its resolution.
Post-condition	
Quality Requirements	N/A

4. Requirements Traceability

This figure shows the traceability of non-functional requirement "*Intruder Emergency Response*".



3. Requirement_Diagram_Traceability_ESS_ENG

Name:_______________________________ **Start Time:** _________ **Finish Time:** _________

1. What are non-functional requirements that deal with the usability of user interfaces and the communication interfaces of the system and its subsystems? (one or more answers may be correct)

- O Availability
- O User Interface
- O Installation Cost
- O Emergency Services Interface
- O Internal Detection

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram
+ Mark only one answer

2. What are non-functional requirements related to the requirement *Intrusion Detection and False Alarm Rate*? (one or more answers may be correct)

- O Availability
- O Perimeter Detection
- O Fault Detection and Isolation
- O Entry-Exit Detection
- O Internal Detection

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
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+ Mark only one answer

3. What are non-functional requirements related to the requirement *Availability*? (one or more answers may be correct)

- O Fire Detection and False Alarm Rate
- O Fault Detection and Isolation
- O Installation Cost
- O User Interface
- O Backup Power

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
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What is the source of information used to answer the question+?
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+ Mark only one answer

4. What are non-functional requirements related to the detection performance of exceptional events? (one or more answers may be correct)

- O Intrusion Detection and False Alarm Rate
- O Fire Detection and False Alarm Rate
- O Recurring Cost
- O Power Surge and Lightning Protection
- O Data Storage and Validation

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram
+ Mark only one answer

5. What is the non-functional requirement that deals with the detection of intruders and false alarms? (one or more answers may be correct)

- O Fire Detection and False Alarm Rate
- O System Vulnerability
- O Intrusion Detection and False Alarm Rate
- O Perimeter Detection
- O Provide Investigative Data

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram
+ Mark only one answer

6. The non-functional requirement *Intrusion Detection and False Alarm Rate* is derived from: (one or more answers may be correct)

- O Perimeter Detection
- O Internal Detection
- O User Interface
- O Intruder Emergency Response
- O Provide Emergency Response

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram
+ Mark only one answer

7. The non-functional requirement Intruder Emergency Response is obtained from: (one or more answers may be correct)

- O The non-functional requirement Intrusion Detection and False Alarm Rate
- O The non-functional requirement Resolution
- O The Requirements Specification Document
- O The document of Security Policy Specification
- O The functional requirement Provide Intruder Emergency Response

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

8. The detection of intrusion is checked: (one or more answers may be correct)

- O Using a specific test entry
- O In dangerous conditions
- O From the Perimeter's Detection
- O Never
- O From the resolution of the camera installed

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

9. What are the functional requirements related to the requirement *Intruder Emergency Response*? (one or more answers may be correct)

- O Provide Fire Emergency Response
- O Perimeter Detection
- O Verify Entry Detection
- O Provide Intruder Emergency Response
- O None of this

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

Università degli Studi della Basilicata

Requirements Specification Document

VEHICLE

1. Problem Statement

A car is a vehicle designed to let people move. Then, a relevant part of a car is composed of seats for the driver and other occupants. A car is able to autonomously move: to be a vehicle capable of moving independently using an engine.

A car should be easy to use, intuitive and user-friendly. In this example will be presented only the basic requirements, that each vehicle must have, i.e. the possibility to open the doors, to get in and get out, to drive it, and to manage the control of the accessories.

Note: in this document we use the generic term *Vehicle*.

1.1. Definitions, acronyms and abbreviations

- **Vehicle:** The subject system.
- **Vehicle Occupant:** It refers to the generic actor, who uses the vehicle. He/She can operate as Driver or Passenger.

1.2. References

Some of the material used in this document has been gotten from:

- A pratical guide to SysML – Friedenthal, Moore, Steiner – Morgan Kaufmann

2. Non-Functional Requirements

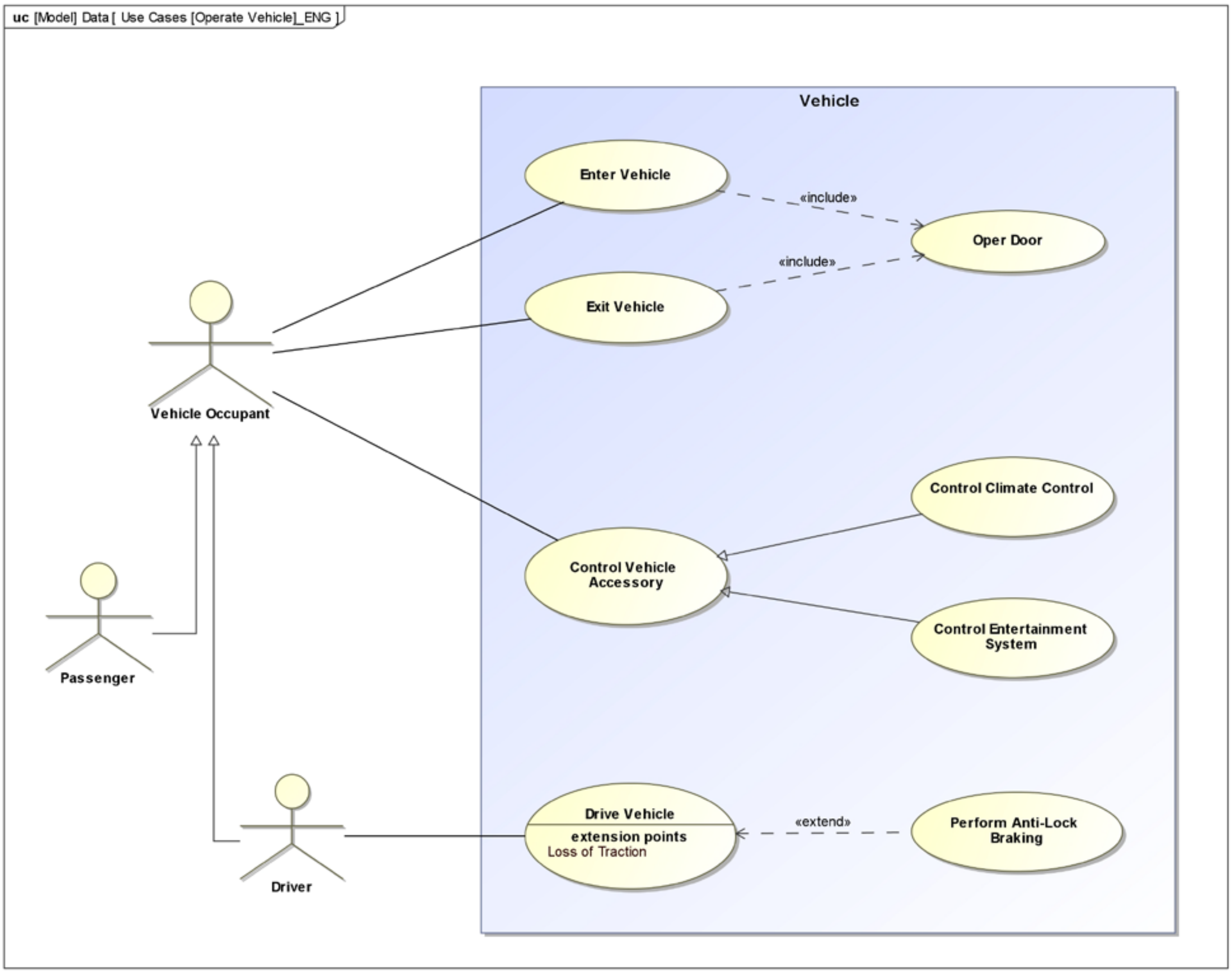
2.1. Non-Functional Requirements

- **Passenger Load**
  The vehicle must allow the entry and exit of passengers.
- **Baggage Load**
  The vehicle must allow the loading and unloading of baggage.
- **Vehicle Performance**
  The vehicle must ensure adequate performances defined staring from a market analysis. The performances will be verified by means of proper tests. Note that the performance requirements depend on the features of the vehicle engine.
- **Maximum Acceleration**
  The vehicle must provide an acceleration from 0 to 100 km/h in under 8 seconds under specified conditions.
- **Top Speed**
  The vehicle must provide a maximum speed of 230 km/h under specified conditions.
- **Braking Distance**
  The vehicle must provide a safe braking distance under specified conditions.
- **Turning Radius**
  The vehicle must provide a specific turning radius.
- **Emissions**
  The vehicle must ensure the low gas emissions to comply with the environmental regulations in force in our state (i.e., CO_2 emissions below 140 g/km).
- **Fuel Efficiency**
  The vehicle must ensure a minimum fuel consumption, in relation to the horsepower of the engine. Specifically, it must provide 20 km/l under certain driving conditions.
- **Riding Comfort**
  The vehicle must ensure high standards for the comfort of the occupants.
- **Space**
  The space spent to the occupants must be a minimum of 1000 m^3, so that ensure smooth transport and smooth guide.

- **Vibration**
  While moving, the vehicle vibrations should be minimal for guaranteeing a greater driving comfort.
- **Noise**
  The occupants must get a certain and fixed noise in all the operating conditions of the vehicle. This will ensure pleasing transport and driving.
- **Production Cost**
  The production cost of the vehicle must be proportional to the features and market's demands.
- **Reliability**
  The vehicle must ensure a specified level of reliability.
- **Occupant Safety**
  The vehicle must ensure the right safety for the occupants. To this end, the vehicle should be equipped with safety devices (e.g., air bag system and any additional safety devices).

3. Use Cases Modeling

3.1. Use case diagram



1. Use_Cases_Diagram_Vehicle_ENG

3.2. Actors

In this section we provide an exhaustive description of the actors, namely the external entities that interact with the subject system. We group and specify the interactions allowed to each actor.

Actor	**Version**
Vehicle Occupant	1.0
Description	
It refers to the actor who starts the various use cases.	
Interactions	**Frequency**
1. Enter Vehicle **2.** Exit Vehicle **3.** Control Vehicle Accessory	HIGH HIGH MEDIUM

Actor	**Version**
Driver	1.0
Description	
It refers to the actor who drives the vehicle.	
Interactions	**Frequency**
1. Drive Vehicle	HIGH

Actor	**Version**
Passenger	1.0
Description	
This actor is an occupant, who does not drive of the vehicle.	
Interactions	**Frequency**
1. Enter Vehicle **2.** Exit Vehicle **3.** Control Vehicle Accessory	HIGH HIGH MEDIUM

3.2.1. Use Cases

The use cases in Figure 2 are presented in the following.

Name of Use Case	***Open Door***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** inserts the key in the apposite space of the door or uses the remote control. **2.** The **System** recognizes the remote control signal or the insertion of the key into the space **3.** The **System** opens the doors
Precondition	The vehicle occupant has a key or a remote control for opening the vehicle.
Post-condition	The doors are open and the occupant can get in the vehicle.
Quality Requirements	N/A

Name of Use Case	***Enter Vehicle***
Actors	Vehicle Occupant
Flow of Events	**1.** ***Open Door*** **2.** The **Vehicle Occupant** opens the door to get into his vehicle **3.** The **System** detects the operation of door opening and triggers the small lock for opening the door itself **4.** The **Vehicle Occupant** enters the vehicle
Precondition	The vehicle occupant has previously opened the vehicle.
Post-condition	The occupant enters.
Quality Requirements	N/A

Name of Use Case	***Exit Vehicle***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** opens the door to exit the vehicle **2.** The **System** detects the operation of the internal opening of the door and triggering the small lock for opening the door itself **3.** The **Vehicle Occupant** may exit the vehicle
Precondition	The Vehicle Occupant was inside the vehicle.
Post-condition	The Vehicle Occupant is out of the vehicle.
Quality Requirements	N/A

Name of Use Case	***Control Entertainment System***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** presses on the button on/off of the entertainment system placed on the dashboard **2.** The **System** detects the user's choice and start/shut down the entertainment system
Precondition	The occupant is in the car (generalization of the use case: Control Vehicle Accessories).
Post-condition	The entertainment system is turned on or off.
Quality Requirements	N/A

Name of Use Case	***Control Climate Control***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** presses on the button on/off of the climate control system placed on the dashboard **2.** The **System** detects the user's choice and start/shut down the climate control system
Precondition	The occupant is in the car (generalization of the use case: Control Vehicle Accessories).
Post-condition	The climate control system is turned on or off.
Quality Requirements	N/A

Name of Use Case	***Drive Vehicle***
Actors	Driver
Flow of Events	**1.** The **Driver** is driving his vehicle **2.** The **Driver** slightly brakes/accelerates **3.** The **System** detects the pressure of the foot on the brake/accelerator and sends the appropriate signal to the system to manage the engine **4.** The **System** slows/accelerates
Precondition	The vehicle is running.
Post-condition	The vehicle slows/accelerates.
Quality Requirements	N/A

Name of Use Case	***Drive Vehicle with Perform Anti-Lock Braking***
Actors	Driver
Flow of Events	**1.** The **Driver** is driving his vehicle while raining **2.** The **System** the wheels begin to lose grip with the ground, so causing a loss of traction **3.** The **Driver** brakes suddenly **4.** The **System** detects the pressure on the brake pedal, and activates the anti-lock braking system (ABS) **5.** The **System** pushes the brake pedal upwards. It slows down smoothly avoiding the locking of the wheels
Precondition	The vehicle is running.
Post-condition	The vehicle decreases the speed.
Quality Requirements	N/A

Name:_______________________________ **Start Time:** _________ **Finish Time:** _________

1. What are the non-functional requirements related to *Vehicle Performance*? (one or more answers may be correct)

- O Maximum Acceleration
- O Top Speed
- O Vibration
- O Turning Radius
- O Braking Distance

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

2. What are the non-functional requirements related to *Riding Comfort*? (one or more answers may be correct)

- O Vibration
- O Braking Distance
- O Noise
- O Space
- O Fuel Efficiency

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
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+ Mark only one answer

3. What are the non-functional requirements related to *Passenger and Baggage Load*? (one or more answers may be correct)

- O Vibration
- O Passenger Load
- O Production Cost
- O Space
- O Baggage Load

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

4. What are the non-functional requirements related to *Green Usage*? (one or more answers may be correct)

- O Fuel Efficiency
- O Top Speed
- O Noise
- O Reliability
- O Emissions

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

5. The non-functional requirement *Noise* refers to: (one or more answers may be correct)

- O A car is in movement
- O A car does not move (the engine is switched off)
- O A car does not move (the engine is switched on)
- O Low fuel consumption
- O Low noise in the building process of a car

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

6. The non-functional requirements related to *Performance* are obtained from: (one or more answers may be correct)

- O Non functional requirement Maximum Acceleration
- O Non functional requirement Production Cost
- O Non functional requirement Reliability
- O Market Analysis document
- O Non functional requirement Space

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

7. The maximum acceleration of a car is strongly connected: (one or more answers may be correct)

- O Engine power
- O Car noise
- O The number of the cylinders that the engine contains
- O The space for the occupants inside the car
- O The maximum speed

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

8. The maximum speed of a car is checked: (one or more answers may be correct)

- O Using a specific test
- O In extreme conditions
- O Never
- O Uphill
- O Downhill

How much do you trust your answer+?
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How do you assess the question+?
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o Personal Knowledge o Requirements List o Internet o Use Case o Use Case Diagram

+ Mark only one answer

9. What are the functional requirements related to *Passenger and Baggage Load*? (one or more answers may be correct)

- O Enter Vehicle
- O Exit Vehicle
- O Drive Vehicle
- O Open Door
- O Perform Anti-Look Braking

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
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Università degli Studi della Basilicata

Requirements Specification Document

VEHICLE

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Note: in this paper we use the generic term *Vehicle*.

1.1. Definitions, acronyms and abbreviations

- **Vehicle:**
  Experimental system.
- **Vehicle Occupant:**
  It refers to the generic actor, who uses the vehicle. He/She can operate as Driver or Passenger.

1.2. References

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2. Requirements modeling: Requirement Diagram

2.1. Non-Functional Requirements

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- **Turning Radius**
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- **Emissions**
  The vehicle must ensure the low gas emissions to comply with the environmental regulations in force in our state (i.e., CO_2 emissions below 140 g/km).
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- **Vibration**

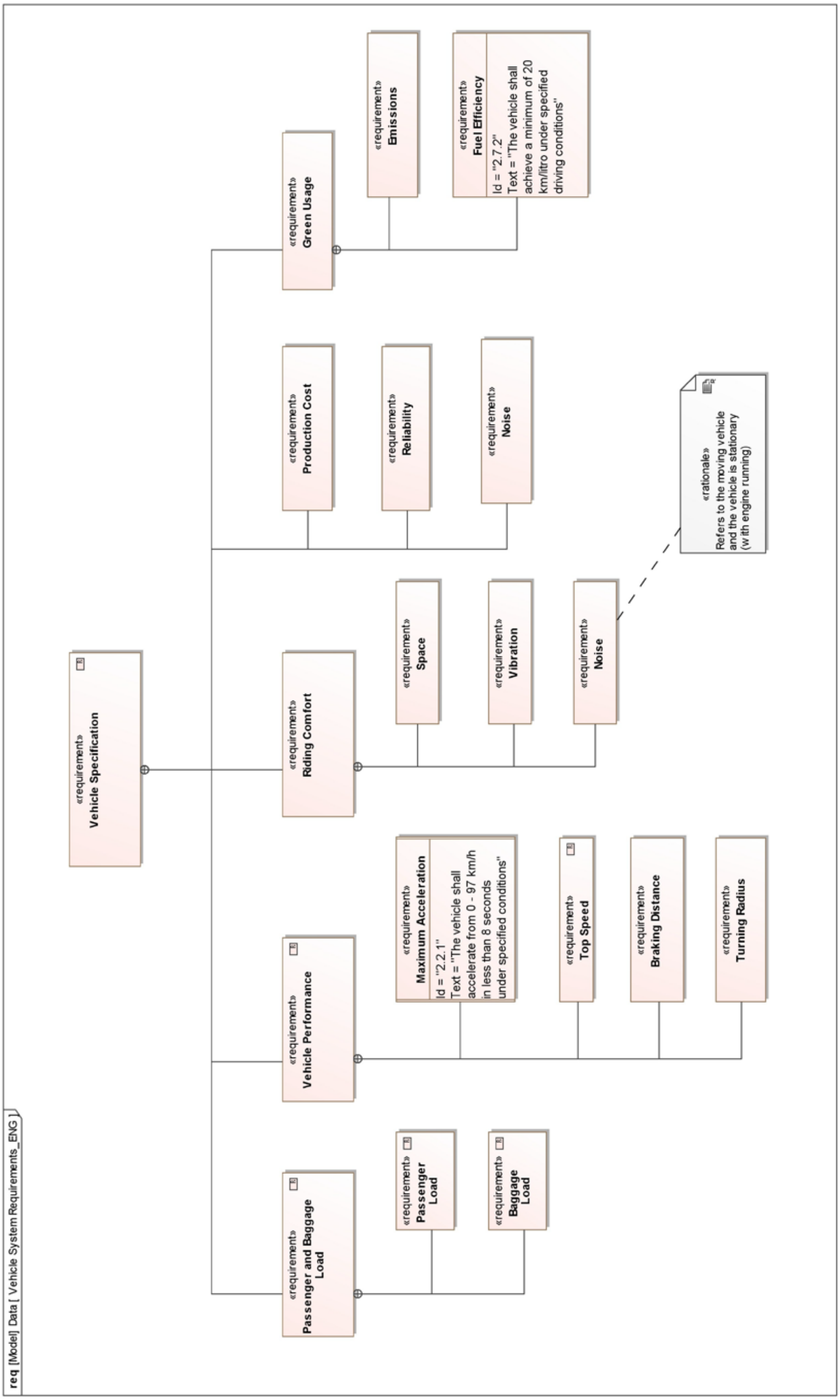
  While moving, the vehicle vibrations should be minimal for guaranteeing a greater driving comfort.
- **Noise**

  The occupants must get a certain and fixed noise in all the operating conditions of the vehicle. This will ensure pleasing transport and driving.
- **Production Cost**

  The production cost of the vehicle must be proportional to the features and market’s demands.
- **Reliability**

  The vehicle must ensure a specified level of reliability.
- **Occupant Safety**

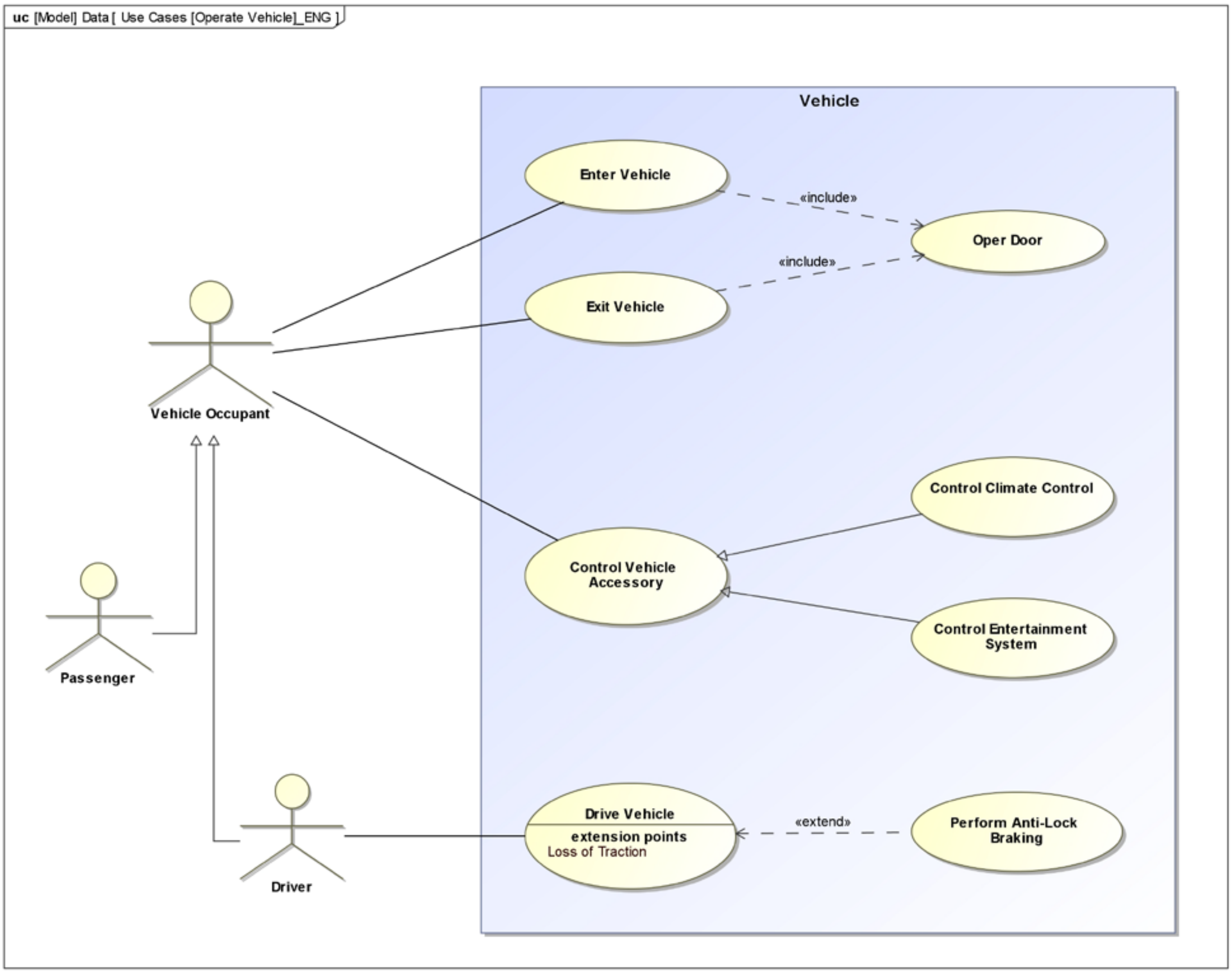
  The vehicle must ensure the right safety for the occupants. To this end, the vehicle should be equipped with safety devices (e.g., air bag system and any additional safety devices).



1. Requirement_Diagram_Vehicle_ENG

3. Use Cases Modeling

3.1. Use case diagram



2. Use_Cases_Diagram_Vehicle_ENG

3.2. Actors

In this section we provide an exhaustive description of the actors, namely the external entities that interact with the subject system. We group and specify the interactions allowed to each actor.

Actor	**Version**
Vehicle Occupant	1.0
Description	
It refers to the actor who starts the various use cases.	
Interactions	**Frequency**
1. Enter Vehicle **2.** Exit Vehicle **3.** Control Vehicle Accessory	HIGH HIGH MEDIUM

Actor	Version	
Driver	1.0	
Description		
It refers to the actor who drives the vehicle.		
Interactions		**Frequency**
1. Drive Vehicle		HIGH

Actor	Version	
Passenger	1.0	
Description		
This actor is an occupant, who does not drive of the vehicle.		
Interactions		**Frequency**
1. Enter Vehicle **2.** Exit Vehicle **3.** Control Vehicle Accessory		HIGH HIGH MEDIUM

3.2.1. Use Cases

The use cases in Figure 2 are presented in the following.

Name of Use Case	***Open Door***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** inserts the key in the apposite space of the door or uses the remote control. **2.** The **System** recognizes the remote control signal or the insertion of the key into the space **3.** The **System** opens the doors
Precondition	The vehicle occupant has a key or a remote control for opening the vehicle.
Post-condition	The doors are open and the occupant can get in the vehicle.
Quality Requirements	N/A

Name of Use Case	***Enter Vehicle***
Actors	Vehicle Occupant
Flow of Events	**1.** ***Open Door*** **2.** The **Vehicle Occupant** opens the door to get into his vehicle **3.** The **System** detects the operation of door opening and triggers the small lock for opening the door itself **4.** The **Vehicle Occupant** enters the vehicle
Precondition	The vehicle occupant has previously opened the vehicle.
Post-condition	The occupant enters.
Quality Requirements	N/A

Name of Use Case	***Exit Vehicle***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** opens the door to exit the vehicle **2.** The **System** detects the operation of the internal opening of the door and triggering the small lock for opening the door itself **3.** The **Vehicle Occupant** may exit the vehicle
Precondition	The Vehicle Occupant was inside the vehicle.
Post-condition	The Vehicle Occupant is out of the vehicle.
Quality Requirements	N/A

Name of Use Case	***Control Entertainment System***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** presses on the button on/off of the entertainment system placed on the dashboard **2.** The **System** detects the user's choice and start/shut down the entertainment system
Precondition	The occupant is in the car (generalization of the use case: Control Vehicle Accessories).
Post-condition	The entertainment system is turned on or off.
Quality Requirements	N/A

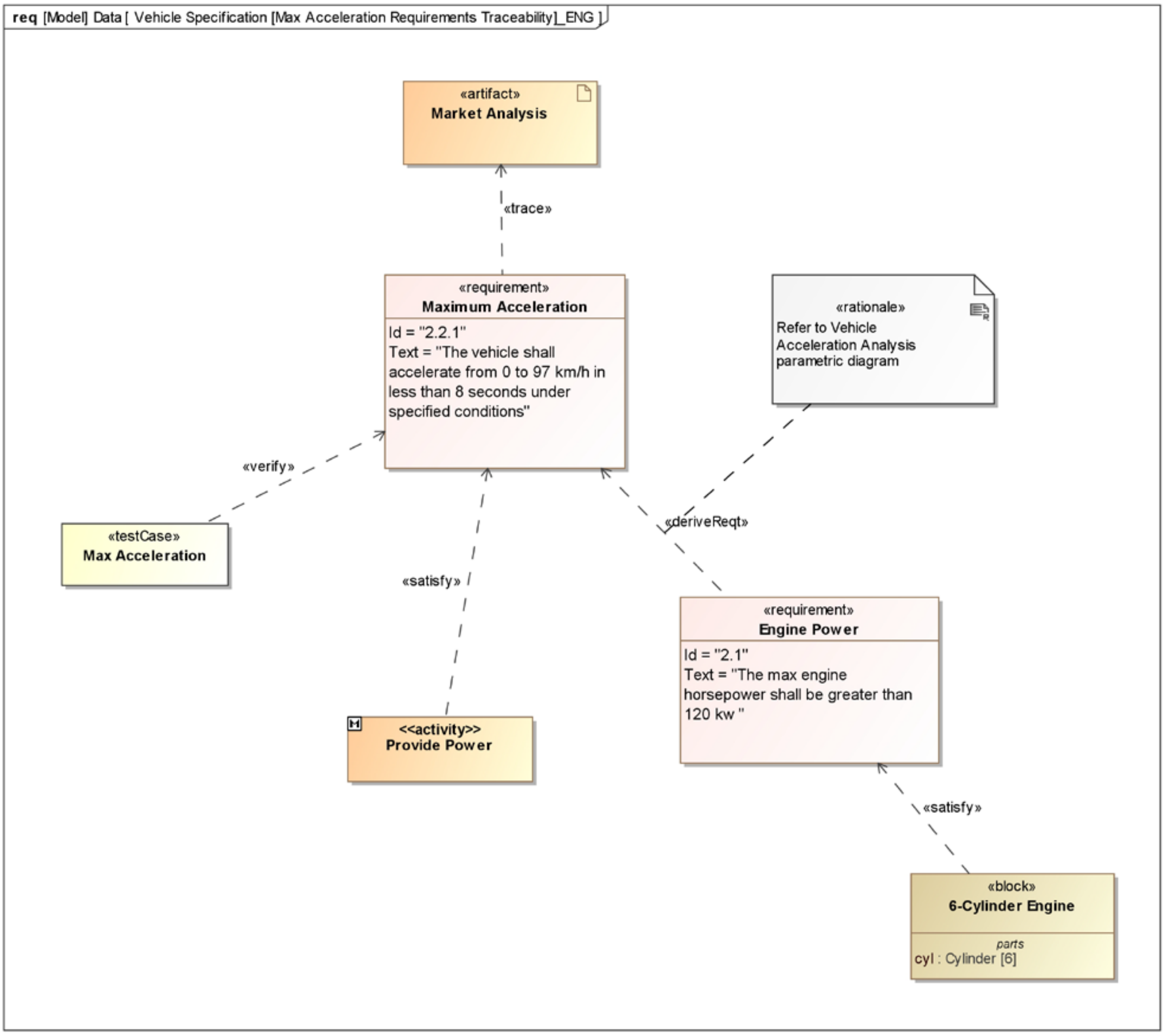
Name of Use Case	***Control Climate Control***
Actors	Vehicle Occupant
Flow of Events	**1.** The **Vehicle Occupant** presses on the button on/off of the climate control system placed on the dashboard **2.** The **System** detects the user's choice and start/shut down the climate control system
Precondition	The occupant is in the car (generalization of the use case: Control Vehicle Accessories).
Post-condition	The climate control system is turned on or off.
Quality Requirements	N/A

Name of Use Case	***Drive Vehicle***
Actors	Driver
Flow of Events	**1.** The **Driver** is driving his vehicle **2.** The **Driver** slightly brakes/accelerates **3.** The **System** detects the pressure of the foot on the brake/accelerator and sends the appropriate signal to the system to manage the engine **4.** The **System** slows/accelerates
Precondition	The vehicle is running.
Post-condition	The vehicle slows/accelerates.
Quality Requirements	N/A

Name of Use Case	***Drive Vehicle with Perform Anti-Lock Braking***
Actors	Driver
Flow of Events	**1.** The **Driver** is driving his vehicle while raining **2.** The **System** the wheels begin to lose grip with the ground, so causing a loss of traction **3.** The **Driver** brakes suddenly **4.** The **System** detects the pressure on the brake pedal, and activates the anti-lock braking system (ABS) **5.** The **System** pushes the brake pedal upwards. It slows down smoothly avoiding the locking of the wheels
Precondition	The vehicle is running.
Post-condition	The vehicle decreases the speed.
Quality Requirements	N/A

4. Requirements Traceability

This figure shows the traceability of the non-functional requirement "*Maximum Acceleration*".



3. Requirement_Diagram_Traceability_Vehicle_ENG

Name:_______________________________ **Start Time:** _________ **Finish Time:** _________

1. What are the non-functional requirements related to *Vehicle Performance*? (one or more answers may be correct)

- O Maximum Acceleration
- O Top Speed
- O Vibration
- O Turning Radius
- O Braking Distance

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

2. What are the non-functional requirements related to *Riding Comfort*? (one or more answers may be correct)

- O Vibration
- O Braking Distance
- O Noise
- O Space
- O Fuel Efficiency

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

3. What are the non-functional requirements related to *Passenger and Baggage Load*? (one or more answers may be correct)

- O Vibration
- O Passenger Load
- O Production Cost
- O Space
- O Baggage Load

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

4. What are the non-functional requirements related to *Green Usage*? (one or more answers may be correct)

- O Fuel Efficiency
- O Top Speed
- O Noise
- O Reliability
- O Emissions

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

5. The non-functional requirement *Noise* refers to: (one or more answers may be correct)

- O A car is in movement
- O A car does not move (the engine is switched off)
- O A car does not move (the engine is switched on)
- O Low fuel consumption
- O Low noise in the building process of a car

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

6. The non-functional requirements related to *Performance* are obtained from: (one or more answers may be correct)

- O Non functional requirement Maximum Acceleration
- O Non functional requirement Production Cost
- O Non functional requirement Reliability
- O Market Analysis document
- O Non functional requirement Space

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

7. The maximum acceleration of a car is strongly connected: (one or more answers maybe correct)

- O Engine power
- O Car noise
- O The number of the cylinders that the engine contains
- O The space for the occupants inside the car
- O The maximum speed

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

8. The maximum speed of a car is checked: (one or more answers may be correct)

- O Using a specific test
- O In extreme conditions
- O Never
- O Uphill
- O Downhill

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

9. What are the functional requirements related to *Passenger and Baggage Load*? (one or more answers may be correct)

- O Enter Vehicle
- O Exit Vehicle
- O Drive Vehicle
- O Open Door
- O Perform Anti-Look Braking

How much do you trust your answer+?
o Unsure o Not sure enough o Sure Enough o Sure o Very Sure

How do you assess the question+?
o Very difficult o Difficult o On average o Simple o Very Simple

What is the source of information used to answer the question+?
o Personal Knowledge o Requirements List o Internet o Requirement Diagram o Use Case o Use Case Diagram

+ Mark only one answer

Last name: **First name:**

1. **Bachelor program** O 1 O 2 O 3 O other
Master program O 1 O 2 O other
Where did you take the bachelor degree ____________________

2. List the university courses about design, programming, and maintenance, starting from the most recent ones:

	Course name	Attended	Passed	Grade
2.1	______________________	O	O	_____
2.2	______________________	O	O	_____
2.3	______________________	O	O	_____
2.4	______________________	O	O	_____

3. What is your GPA?: O [18-21) O [21-24) O [24-27) O [27-30]

4. Do you have professional experiences as a developer?
O NO, never
O YES, part-time: How many months? ___
O YES, full time: How many months? ___

5. Do you have professional experiences as an analyst?
O NO, never
O YES, part-time: How many months? ___
O YES, full time: How many months? ___

6. Do you have professional experiences as a maintainer?
O NO, never
O YES, part-time: How many months? ___
O YES, full time: How many months? ___

7. Define your experience as developer/analyst/maintainer with respect to your course mate.
O My experience is limited to the course exercise.
O I have limited experience.
O I have an experience on the average.
O My experience is greater than my course mate.
O I am an expert.

8. Judge your experience on

SysML	☐ **very low**	☐ **low**	☐ **average**	☐ **high**	☐ **very high**
Req. Diagrams	☐ **very low**	☐ **low**	☐ **average**	☐ **high**	☐ **very high**
Use Case Diagrams	☐ **very low**	☐ **low**	☐ **average**	☐ **high**	☐ **very high**
Use Cases	☐ **very low**	☐ **low**	☐ **average**	☐ **high**	☐ **very high**
UML in general	☐ **very low**	☐ **low**	☐ **average**	☐ **high**	☐ **very high**

Please indicate other modeling languages/notations:
____

9. Judge your experience in the maintenance of software models written by others (also in university laboratory activities)?

☐ **very low** ☐ **low** ☐ **average** ☐ **high** ☐ **very high**

Questionario Post

Lastname: **Name:**

0.1. Judge your experience on

SysML (in general)	o very low	o low	o average	o high	o very high
Requirements Diagrams	o very low	o low	o average	o high	o very high
Use Case Diagrams	o very low	o low	o average	o high	o very high
Use Cases	o very low	o low	o average	o high	o very high
UML (in general)	o very low	o low	o average	o high	o very high

0.2. Judge your experience in the maintenance of software models written by others (also in university laboratory activities)?

o very low o low o average o high o very high

Common questions

	Completely Agree	Agree	Neither agree nor disagree	Disagree	Completely disagree
1. I had enough time to answer the questionnaire	☐	☐	☐	☐	☐
2. The objectives of each task were clear	☐	☐	☐	☐	☐
3. The questions were clear .	☐	☐	☐	☐	☐
4. The answers were clear .	☐	☐	☐	☐	☐
5. I found useful the exercise	☐	☐	☐	☐	☐

Extra questions

Requirements Diagram

	Completely Agree	Agree	Neither agree nor disagree	Disagree	Completely disagree
6. I found useful the requirements diagram	☐	☐	☐	☐	☐
7. The requirements diagram and the list of non-functional requirements with respect to the list of non-functional requirements alone provides a better support in the comprehension of the non-functional requirements	☐	☐	☐	☐	☐

8. I spent on the requirements diagram with respect to the total time to accomplish the single task

☐ <20% ☐ >=20% and <40% ☐ >=40% and <60% ☐ >=60% and <80% ☐ >=80%