VV&A of Complex Modeling and Simulation Systems: Methodologies and Case Studies

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Abstract: - During the conceptual modeling, the design and the development of Modeling and Simulation Systems, the Verification and Validation phases should be taken into account because they are fundamental for clearly understanding if the simulated system is corresponding to real one.

In this work the authors proposed a short overview of methodologies, procedures and techniques used for the Verification and Validation (V&V) phases in three different cases corresponding to three simulation models.

The first case involves a simulation model developed for the maintenance management (both corrective and preventive) of motorways typical sets of items (TVCC, smoke detectors, variable message panels, etc…) subjected to failures and that needs to be planned at regular intervals. The second case is about a simulation model that identifies the probability of a ship to be detected by a submarine dynamically into a specific naval scenario. The third and last case focuses on a human behavior simulation model developed in order to evaluate alternative emergency management policies for in tunnels.

For each case, a different set of validation and verification methodologies, procedures and techniques has been applied depending on Verification (conceptual model, design and implementation) and Validation (structural and results) processes.

Keywords: - Verification and Validation, Simulation, Design of Experiments, MSpE

I INTRODUCTION

The VV&A (Verification, Validation & Accreditation) phase is very important while developing a simulation model ; this phase in fact involves all the whole process of the model life cycle, starting from the conceptual model, then passing to the design and implementation phase and, at last, focusing on the validation of the structure and the results.

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In the following lines let's have a look on what VV&A is, considering also the reference normatives, redacted by DMSO (Defense Modeling and Simulation Organization) of the United States DoD (Department of Defense), such as 5000.61 and others.

II AN OVERLOOK TO VV&T

VV&T is an acronym that indicates three different phases of the simulation study:

Model Verification

Model Validation

Model Testing

The first phase of model verification is devoted to build correctly the simulation model, starting from the problem formulation to the final implementation, through the flow chart development; the validation phase is useful, indeed, to verify if the model, inside its applicability dominion, behaves in a coherent way according to the study main targets; the testing phase, finally, is devoted to subject the model to a test series in order to evaluate its behavior and its accuracy: if the test is not passed, the model has failed.

As seen on introduction, every phase of the model life cycle, is subjected to a corresponding VV&T phase: if that one is not passed, it is necessary to go back to the previous phase.

The first step of the model life cycle is no doubt the formulation problem: inside this phase an accurate study is needed in order to formulate correctly the real problem, considering all the internal and external variables, which are often stochastic, interdependencies, not intuitive behavior and so on.

When the problem has been correctly formulated, a conceptual model needs to be developed: starting from the input data, using appropriated techniques such as best-fit analysis, it is possible to determine the probability distribution that best fits on the data collected.

After that, inputs must by analyzed and modeled using self-driven (random) or trace-driven (user defined) input sequences.

In the next phase model needs to be represented in a communicative way, in order to be clearly understood, judged and compared with real system and the project goals, using tolls like flow charts, diagrams, graphs, technical specifications and so on.

The following phase aims to translate this communicative model to an executable one (not including the experimental implementation), using ad hoc software (i.e. PowerSim©), or programming languages (i.e. C++, etc…).

For the experimental campaign the Design of Experiment (DOE) technique is no do doubt one of the most used.

DOE consists in the development of a schema devoted to collect all the desired information and to allow the final user making conclusions; there are different DOE techniques that can be applied to a model: for instance ANOVA (Analysis of Variance), RSM (Response Surface Methodology), CCD (Central Composite Design).

Finally, analyzing the results, applying the VV&T principles, it is possible to evaluate the model and then if the problem needs to be reformulated modifying some criteria or aspects.

The US DoD (Department of Defense) DMSO (Defense Modeling and Simulation Organization) has also redacted some normative about the VV&A processes for their simulation models, the most important of whom is surely 5000.61

o A - The 5000.61 Normative

The 5000.61 normative is specifically devoted to VV&A of simulation models and it clearly explains some aspect of these phases.

The 5000.61 normative first individuates the actors of the VV&A process making differences between them:

The V&V Agent, which is the bridge between the M&S Developer and the M&S Sponsor, and is responsible of the Verification and the Validation phases.

The M&S Developer, which implements the model, subjected to V&V phase by the V&V Agent

The M&S Sponsor, which has the problem to be solved and specifies the goals and the requirements that the model has to meet.

The Accreditation Agent, which focuses his works on the model accreditation making the final tests and then preparing the relative documentation.

All these subjects, involved in VV&A process, have to perform the activities established in the VV&A RAM (Responsibility Assignment Matrix).

5000.61 normative provide also a series of definitions related to the VV&A matter, defining also VV&A scope and applicability and the responsibilities.

It contains also policy statements and a series of procedures to attain on order to correctly complete the VV&A process.

These procedures refer to the scope of the policies and procedures, the plan requirements, the documentation requirements, the accreditation documentation requirements, the responsibilities in simulator's maintenance and upgrading, the overall requirements and the special cases.

Following all the procedures contained in 5000.61 normative it is possible to complete successfully the VV&A phase of a simulation model; in the following paragraphs are presented three different models, which has been successfully verified, validated and tested.

III Three Different V&V Applications with Three Different Models

In this research three different models are presented:, different both for the situation simulated and for the VV&A techniques.

The first model, called SIGMA (Sistema Integrato di Gestione della Manutenzione) refers to the maintenance for a motorway set of items like TVCC, Variable Message Panels, Smoke Detectors, etc…

The V&V techniques are applied in the whole simulation project using best-fit analysis, integration with database and experts judgments, as represented in detail in the next sub paragraph.

o A - The SIGMA Model

SIGMA is a simulation model in PowerSim™, which is devoted to determine the correct level of preventive maintenance, thanks also to optimization manager, and to forecast the failure intervals of the different items.

The SIGMA model test case is significant because it has been tested on a mountain motorway located in Piedmont, north-west of Italy, which has a significant level of traffic (it links Italy with France and it passes through the 2006 Winter Olympic Games Locations) and an high amount of bridges, tunnels, and so, items.

Once formulated the problem, a series of failure incidents has been collected, referring to the years 2006 and 2007, divided by type of item in failure and location, and then calculated the average value of MTBF (Mean Time Between Failures) and MTTR (Mean Time to Repair), using a best-fit analysis using a specific tool inside the ARENA ™ suite, choosing among different probability distributions like Uniform, Exponential, Triangular, Weibull, etc…

The authors found 13 different types of items whose have almost one failure in 2006-2007 periods; for each item a probability distribution has been determined:

Item	**Distrib**
Trasmission Ring	Exponential
Ice Panel	Exponential
Radio	Triangular
Variable Message Panel	Exponential
Smoke Detectors	Exponential
SOS	Uniform
Phones	Weibull
TVCC	Weibull
UCS (Traffic Light	Weibull

Systems)	
Video Wall	Weibull
Broad Band	Average
Rain Panel	Average
UPS	Average

Table 1 – items and distributions

In order to simplify the modeling phase, reducing the number of variables involved, beta distribution has not been taken into account; for three kinds of items, which had only one failure each, (Broad Band, UPS and Rain Panel), the raw average value has been considered.

SIGMA results, thanks to the model integration with Database and ERP Systems, has been compared with the historical values inside the failure dossier of the Sistemica Database, and no significant differences were found, so the model passed successfully the V&V phase.

SIGMA model has also an optimization module devoted to set the PA (Preventive Actions) correct level, in order to reduce both the number of the working yards on the motorway segments and the maintenance costs, in order to save men and money resources and to minimize users' discomfort.

This module has been subjected to a V&V phase devoted to find the best number of replications in order to have a significant population for the GA (Genetic Algorithm) optimization: in order to do this a MSpE (Mean Square Pure Error) analysis has been provided.

The MSpE is a typical technique devoted to find the optimal simulation run duration or the optimal number of replications. The MSpE curve, in fact, after an initial phase of instability, decreases going under a certain threshold value : when the curve has an asymptotic trend the optimal value has reached.

In SIGMA optimizer the MSpE found an optimal value of 20 replications and the results of the analysis is a 17% reduction of the number of work yards and a 4.1% reduction on the global maintenance costs, as shown in fig. 1.

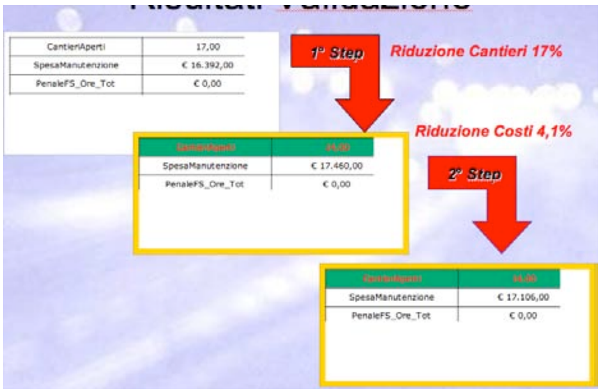


Fig. 1 – Validation Results of the SIGMA optimizer

The second model analyzed in this work is one devoted to determine the detection probability of an HVU (High Value Unit) ship, protected by a ASW patrol unit, by a hostile submarine.

o *B - The ASW Model*

The model considers an HVU (High Value Unit) ship, which starts simulation from its coordinates' origin. The ship's motion can be reproduced using an ordinary derivate differential equations system of the first order that could be easily solved using the Runge-Kutta integration method.

The aim of the V&V phase is to demonstrate that the model provides the same results of the mathematical theory of the Non Sprint and Drift Detection Probability, where:

$$(1) \quad p = \frac{PSR}{\left(\vec{U} + \vec{V}\right)L} E(U,V,W)$$

and:

$$(2) \quad \tilde{E}(U,V,W) = \frac{1}{N+1}\sum_{i=0}^{N}\sqrt{U^2 + W^2 + 2U \cdot V \cos\left\{-\theta + \frac{2(\theta)}{N} i\right\}}$$

with:
U = HVU speed
V = Patrol Unit Speed
W = Submarine Speed
PSR = Patrol Sensor's Range
L = Screen's Range

$$\theta = \arcsin\left(\frac{U}{V}\right)$$

In the Monte Carlo simulation will be simultaneously varied both the submarine's angular position (attack angle) and the time attack, in order to compare the results obtained with the formulas contained in the theory

Simulation will terminate if at least one of this two condition verifies:

- The submarine reaches the HVU unit at a distance which is less than TDZ (Torpedo Danger Zone) (attack successful) before the patrol unit intercepts it
- The patrol unit reaches the submarine (attack failed) before it reaches the HVU, at a distance which is less or equal than PSR (Performance of the patrolling Unit Sensors)

MOE (Submarine's Detection Probability in an attack distance of the HVU) will be a fraction of 1000 replications in which the patrol unit will neutralize the threatening: the value will be compared with the theoretical value determined. An example of this is provided with the following data:

- u = 8 knots
- v = 18 knots
- R = 1 mile
- PSR = 10 miles
- w = 24 knots
- θ = arcsin(u/v) = 26°

and the following probability distributions:

- T with uniform distribution between 12 e 18 hours;
- θ_0 with uniform distribution between $-(\pi/2 + \theta)$ e $(\pi/2 + \theta)$;

The model has been implemented using Powersim™ and, after that, an experimental campaign devoted to determine MOE has been led. Comparing this value with the calculated MOE, it has been possible to validate the proposed approach.
In particular, replacing in the formulas dertermined the values above, the p value is about 0,1334 (a detection probability of 13,34%), while the 1000 replications results of the simulation provides a p value of about 0,14, coherently with the theory.
In the next figures are represented two trajectory examples extracted from the experimental campaign and the speed graphs (absolute speeds and w spped module).

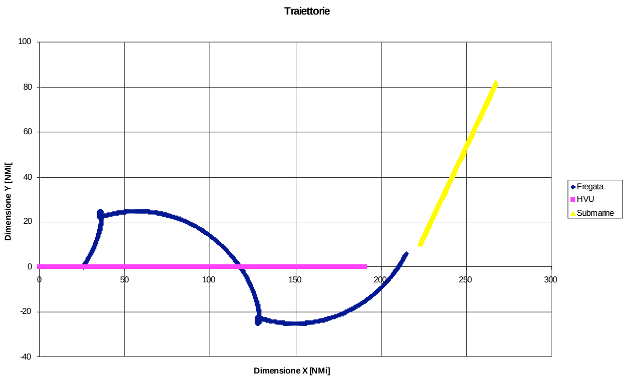


Fig. 2 – Submarine Detected by the Patrol Unit

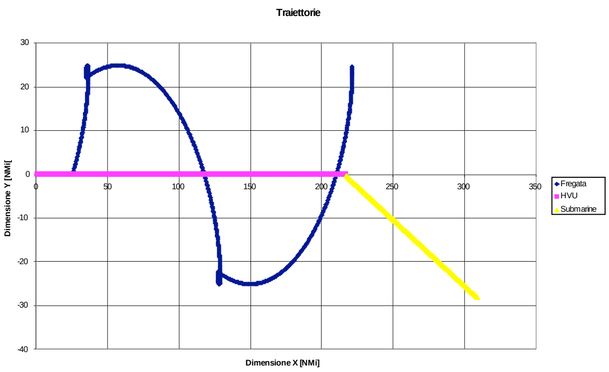


Fig. 3 – Submarine reaches HVU inside its TDZ

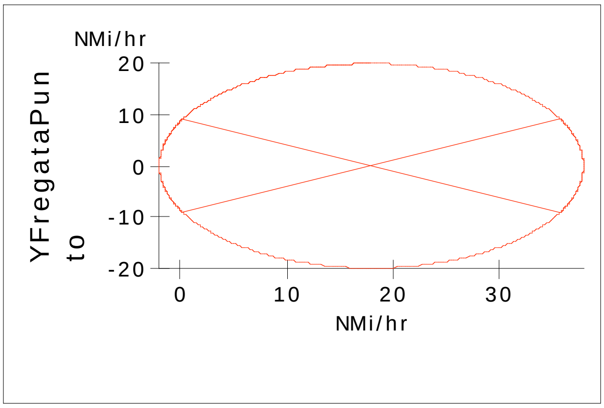


Fig. 4 – Absolute Speeds Trend Graph

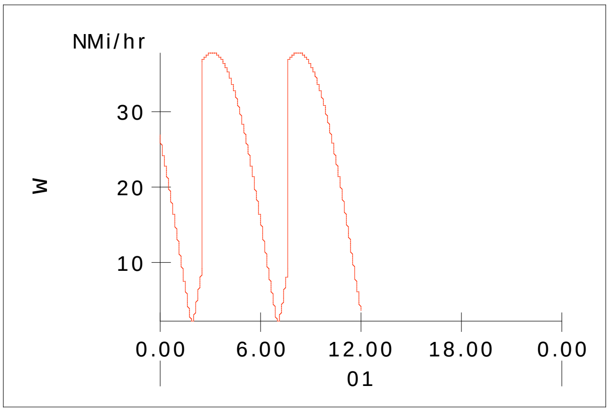


Fig. 5 – Patrol Unit w Speed module trend Graph

The last complex system analyzed proposes an innovative technique to validate a human behavior simulation model during a motorway tunnel evacuation.

o *C - The Tunnel Evacuation Model*

The last model analyzed proposes a simulation model capable to understand human behavior in an emergency situation such as a motorway tunnel evacuation is.
The evaluation technique proposed is the Multi Criteria Decision Analysis, in particular Thomas Saaty's AHP (Analytic Hierarchic Process).
In this case a Super Decisions™ model has been implemented, taking into account all the factors that affects the final objective function: avoid the dangerous situation.
In the model a network has been developed considering physical, emotional, cognitive and social factors as high-level criteria, each one divided into sub-criteria, which are the state variables of the problem.
AHP's theory has been used in order to verify and validate this model, so it will be briefly described: the first step is to make the pair comparison using Saaty's judgment metrics, obtaining n2 coefficients: only n(n-1)/2 of them have to be directly established by the decision maker or by the expert, because aii=1 and aji= 1/aij for every i and j. All these coefficients define a square, simmetric matrix (A) called «Pair Comparison Matrix».

$$\mathbf{A} = \begin{vmatrix} a_{11} & a_{12} \dots & a_{1n} \\ a_{21} & a_{22} \dots & a_{2n} \\ \dots & & \\ a_{n1} & a_{n2} \dots & a_{nn} \end{vmatrix}$$

Fig. 6 – Pair Comparison Matrix

The second step is to determine the local weights, which measure the relative importance of the elements.

Directly calculating the vector elements as a product on th row coefficients, it is possible to determine the priority dividing the vector element by the sum of them.

(3) v1 = a11 * a12....* a1n

(4) v2 = a21*a22....*a2n

(5) p1 = v1/Σvk with k=1 to n

...

Multiplying then the priority for each corresponding coefficient and summing them, it is possible to determine the weights, which are normalized dividing them be the sum of all the weights.

(6) W1 = (p1*a11)+(p2*a12)....+(pn*a1n)

(7) W1norm= W1/Σwk with k= 1 to n

These formulas have been applied for every criteria and sub criteria and compared to SuperDecisionsTM model results.

For the panic high level criterion, divided into three subcriteria (Negative Events Occurring, Lack of Info and Closing Exit) the theory result provided a 66,67 % importance for the first factor, a 6,66 % for the second one and a 26,67% for the third (fig. 6), such as happens in SuperDecisionsTM

	Exit Closing	Lack Info	Negative Event	Vector	Priority	Weight	Weight Norm
Exit Closing	1	4	0,4	1,6	0,060094	0,43943662	0,266666667
Lack Info	0,25	1	0,1	0,025	0,000939	0,109859155	0,066666667
Negative Event	2,5	10	1	25	0,938967	1,098591549	0,666666667
				26,625		1,647887324	
				Eigenvector			

Fig. 7 – Panic Sub Criteria matrix calculation

A further example could be provided by the impact of the four high-level criteria on the main objective function. Figure 7 shows the results, where Car Saving criterion has a 17% importance, Health Preserving a 67%, Panic and Others' Behaviour a 8% importance each. The model Provided a 16,67% for the first criterion, a 66,67% for the second and a 8,33% each for the last two.

	Car Saving	Health	Panic	Others	V	P	W	W NORM
Car Saving	1	0,25	2	2	1,00	0,00	0,25	0,17
Health	4	1	8	8	256,00	1,00	1,02	0,67
Panic	0,5	0,125	1	1	0,06	0,00	0,13	0,08
Others	0,5	0,125	1	1	0,06	0,00	0,13	0,08
					257,13		1,52	
					Eigenvector			

Fig. 8 –Impact of High Value Criteria on Goal matrix Calculation

• IV Other Examples of VV&A in Complex Simulation Models

The Authors have matured in the last 12 years, a vast experience on VV&A of complex simulation models, both in industrial and military field, realizing how different projects require different techniques to be verified and validated. One of the most appreciated techniques to determine the sensibility of model outputs to different input variables is anyway the sensitivity analysis. In the following are given some examples of research projects in which sensitivity analysis has given some interesting results, in some cases unexpected.

Among all the research projects in which Authors were involved and in which VV&A was applied to complex simulation models (models for the Airplane Production Logistic Supply Chain based on HLA, Oil spill modeling for emergency reactions, target tracking and recognition of military targets etc.) here are presented both cases for industrial applications, both for military, and this will allow to put in evidence also the main differences among the approaches to VV&A and simulation adopted by different kind of sponsors (military and civil subjects).

o *A - FED: a fleet and plant management simulation model*

The FED model was a particular case of research in which the Authors were involved. In this case the research was committed by a very famous energy company to a very well known Italian Certification Company, in order to define the parameters to govern loading and unloading operations of a fleet of ships in a port with a specific plant able to manage carbon, ashes, gypsum, limestone.

The Authors were involved as experts, by the Italian Certification Company, in order to perform the VV&A of the simulator that they realized to reach the research goals.

The complexity of the model was due to the fact that there were defined at least 46 different variables in input to the problem, considering variable percentages of materials to be loaded/unloaded, economical factors, waiting times, different ships with different capacities and so on.

The Authors, after performing various other techniques included in Design Of Experiments, made some sensitivity analysis considering 4, 5 6 and 8 factors chosen by Subject Matter Experts in order to determine the total cost per year of the plant and fleet management. Various simulations were run with different input of sensitivity factors and not only, just to test the robustness of the defined solutions.

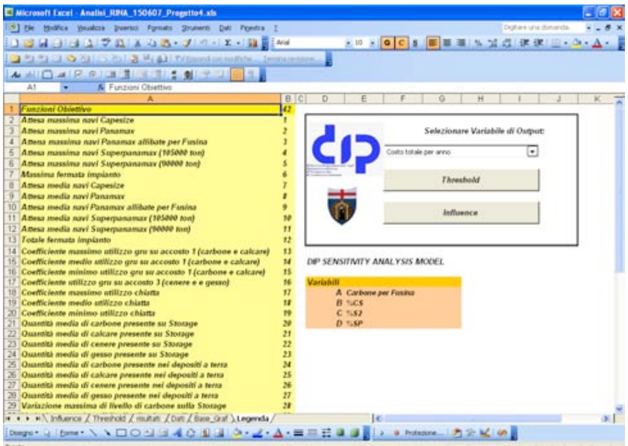
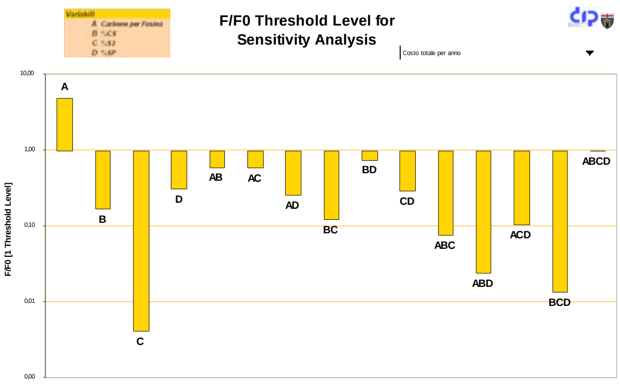
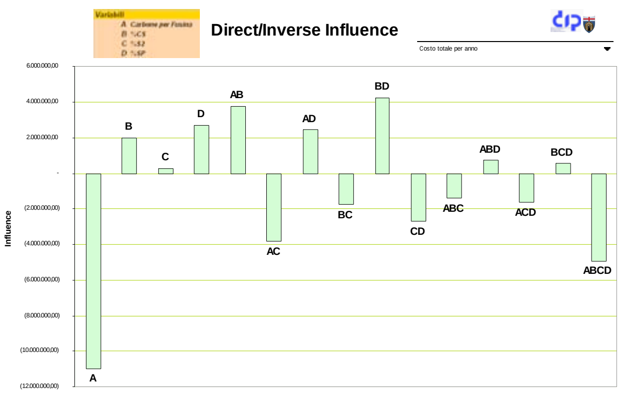


Fig. 9 – “SAFED” Sensitivity Analysis Model for FED Simulator

The analysis performed considered two kind of outputs: whether the final result is affected by one or more factors (or by the combination of some of them) and whether the influence of those factors is direct or inverse to the result. The model created for Sensitivity Analysis (SAFED) had the flexibility of determining the chosen target function among a set of defined ones (by the choice of SMEs) and recalculate numerically and graphically the effects of the factors.





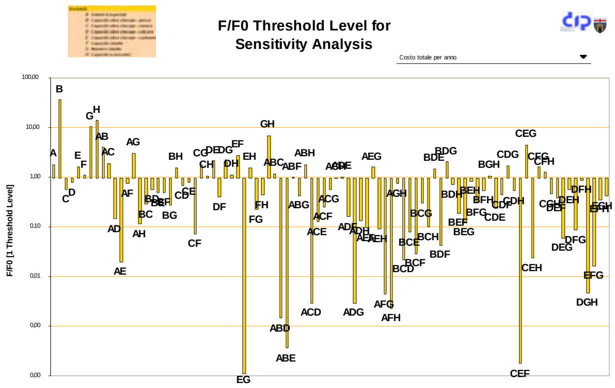


Fig. 10 a, b, c, – some outputs of sensitivity analysis using different variables as input for total cost

The results were interesting: one of the most evident effects was an inverse influence of the carbon percentage in the plant, while the capacity of the ships involved in the operations was significant just for the ones transporting gypsum. This is probably due to the results of combustion and chemical reactions in the plant.
Interaction of effects was in almost every case not influencing the system behavior.

o *B - The RIOT model Sensitivity Analysis*

A second case that Authors will mention is the RIOT model sensitivity Analysis. RIOT model was a research in the military field that should be used as pre-test for a wider project on anti-terrorism simulation models able to interact dynamically with war-gaming systems used by all the NATO Armies. The RIOT model was in this sense propaedeutic to define the factors to be considered in the full simulator scope.
For this specific study several procedural steps have been made:
First, the equations for each function have been extracted, taking in account some precise factors. There are two models describing the behavior of the two functions: violence and repression, in a contest of demonstration. A first model, more simplified, has been used to define CAAM (Contingency Action Analysis Model: modeling the configuration with riots and disorders on short time framework such as 24h), and then a second model, called MTAM (Medium Term Analysis Model), more complete and consequently more complex in its development, has been used to model companies and long term disorders.
Once the functions to be developed have been determined, the research has the aim of putting in evidence what are the factors that mainly influence the behavior of such functions, this is made through a deterministic sensitivity analysis.
The first model is the simplest. The two variation functions are linear equations.
Though this model is simple, is the one that gives the first useful information analyzing output of these functions. It

can be said that it is the basis for a more complex study that has been made for MTAM.

A sensitivity analysis with parameters intended as factors has been made. The first step is to define the three target functions:

Duration: Time value when Real Violence approaches zero

Maximum: Maximum value of Real Violence function.

Medium: Average value of Real Violence function.

The goal of this analysis is to determine which are the parameters mainly affecting output values of the three target functions.

Once made the sensitivity analysis the aim is to evidence graphically parameters mainly affecting targets. Obviously, the studied factors are the five parameters originally considered.

In this specific study reiterations on treatments are not present and being a deterministic analysis it is not necessary to study error effect.

To analyze results for each target, a graphical output makes all easier.

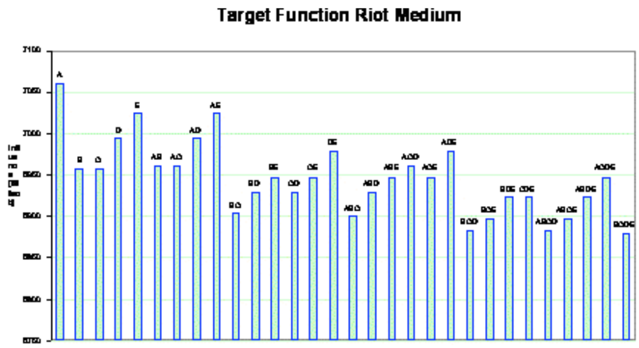


Fig. 11 - Graph of effects with target function medium

It is easy to notice that effects more influencing target medium are respectively parameter referred to Riot Type (A), Parameters of Impact in degree of Observed Violence (E) and their interaction. This analysis could be repeated for each target.

The same procedure is repeated for the target duration

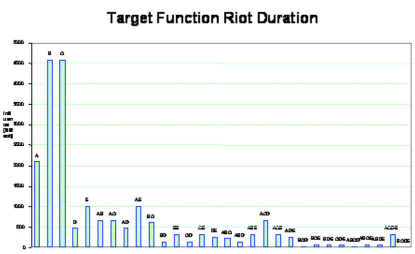


Fig. 12 - Graph of effects, target Duration

It can be noticed how minimum variations of Repression (B) and Rioters (C) for the model can produce significant variations of analyzed outputs.

Taking in account target duration, factors mostly influencing this function are Repression (B), parameter regarding way of acting repression, and Agent Repression (P), parameter linked to preparation of forces actuating repression.

Another way of representing values could make better understand the obtained results.

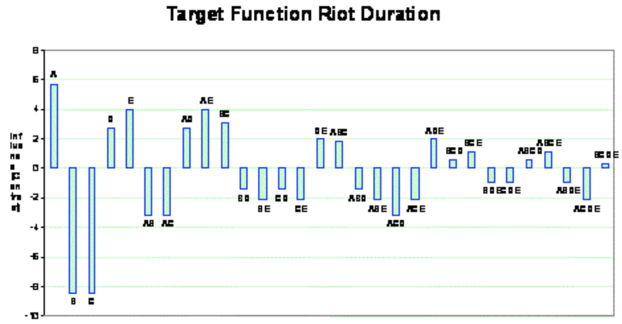


Fig. 13 - Graph of effects with target Duration (different scale)

It has been made the analysis also for the last target: Maximum.

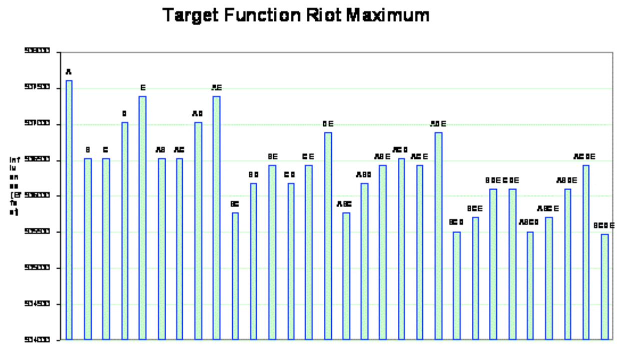


Fig. 14 - Graph of effects with target Maximum

Also in this case it can be noticed that the factors mostly significant in functions behavior are:

A = Riot Type

E = Degree of Observed Violence

And their second order interaction.

Outputs are the same as in the case of target Medium. This puts in evidence that maximum degree of violence in a demonstration does not depend mostly on who and how makes repression, but from the kind of demonstration in act and from the perception of violence by the specific environment.

It is interesting to notice that both in Riot Medium both in Riot duration the most significant factors are to be considered kind of riot, impact of observed violence and their interaction.

Model MTAM (Riots and Disorders on medium term timing involving companies) scenario observes longer term disorders, this makes the analysis more complex and more complete.

The number of factors in comparison to CAAM is higher and thus the complexity increases.
The research is based on more complex functions, factors to be considered now are 16 (towards the 5 in the CAAM).
After building the sensitivity table, in this case we will have a total of 65.536 runs.

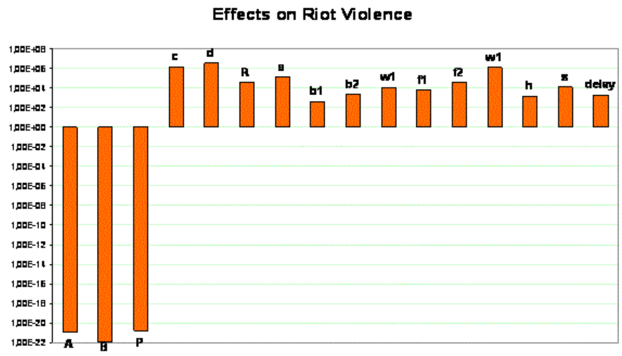


Fig. 15 - Graph of effects of Riot Violence in MTAM

Taking in account 16 factors is easy to understand what are the ones influencing mainly the function.

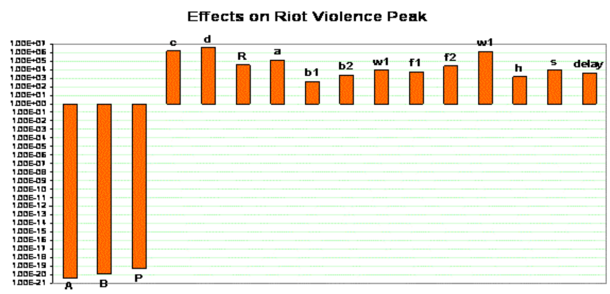


Fig. 16 - Graph of effects of Riot Violence Peak

From both graphs is easy to understand that the 3 factors of major influence are:
A = Riot Type
B = Repression
P = Agent Repression
It is interesting to notice how in this scenario the analysis results are different from Scenario CAAM
In this context it is understandable how it is particularly delicate to define a model, its parameters and their variation in function of outputs.
Obviously the results of the sensitivity analysis on riot violence an peaks for the MTAM scenario, show that the factors having more influence on the target functions are different from the ones in the CAAM Scenario.

o *C - An Application on Target Recognition Simulation*

In this research, the aim was to develop a demonstrator (FLODAF) on the potentialities of Simulation and Artificial Intelligence Techniques (in particular Fuzzy Logic) for the target recognition process on military vessels, using signals coming from different sensors, combined with usual techniques such as Bayes or Dempster/Shafer method.
In this case the experiment for Sensitivity Analysis was based on a set of functions offered by the demonstrator: the settings were such to enable or not certain algorithms or process or not specific information; to resume the factors used in the experimental campaign is given the following table:

Factor	Id	Low State	High State
ESM	a	Not used in the Fusion	Used in the Fusion
IR/EO	b	Not used in the Fusion	Used in the Fusion
Fuzzy Logic	c	Not used in the Fusion	Used in the Fusion
Bayes/ Dempster-Shafer	d	Use of the Bayes algorithm	Use of the Dempster-Shafer algorithm

Table 2 – factors for sensitivity analysis

The target functions used in such application were three, and in particular:
Segmentation Index: ratio between the number of targets generated and the real number of targets within the scenario being analyzed.
Unreliability Index: ratio between the number of targets not recognized and the number of targets within the scenario being analyzed.
Robustness Index: the lowest probability assigned to a target correctly recognized within the scenario being analyzed.
In the scenario, the Garibaldi, admiral ship of Italian Navy was the observer, sailing 30 knots NE with slight veer to starboard and speed increase to 32 knots; deck radar active. The Authors put in the scenario also three vessels for the recognition: one friend, one foe, one neutral. Here are given the details of each:
Allied ship (O.H. Perry Class - USA), 32 knots NE with slight veer to port, at 8 a.m. about 3 miles away; radar active and detected by IR/EO, ESM, Radar
Enemy ship (Kara Class), 30 knots NW veering to starboard, at 3 a.m. about 6 miles away; radar active and detected by IR/EO, ESM, Radar
A Neutral Cargo Carrier (Hamana Class), at 1 a.m. about 8 miles away with a NW route at 18 knots; navigating radar active, detected by IR/EO, ESM, Radar
To test also the 3rd dimension potentialities of the demonstrator, another entity was included in the scenario: an Enemy Helicopter (KA-32), at 5 a.m. about 5 miles away on a reconnaissance flight from NW-NE at about 130 knots with radar activated and detected by IR/EO, ESM and Radar.
Disturbances were also included in the scenario in order to test effect in worse conditions of weather.
Also in this case the values obtained were put in graphs in order to have a more easy glimpse of the effects. The ordinates indicate the influence based on a measurement of experimental contrasts where the positive values indicate direct proportionality and the negative ones

indicate inverse proportionality between the effect and the specific target function.
Thanks to the graphs it is possible to notice immediately the influence of the independent variables in linear terms (i.e. a, b, c, d) as well as their higher-order combinations (i.e. abc). In this case, all the factors considered have a significant effect on the target function "Segmentation", especially the ESM sensor, and the use of Fuzzy Logic leads to a more efficient generation of targets.
The most interesting thing is any case how the interaction of all the 4 factors creates the most important source of segmentation.

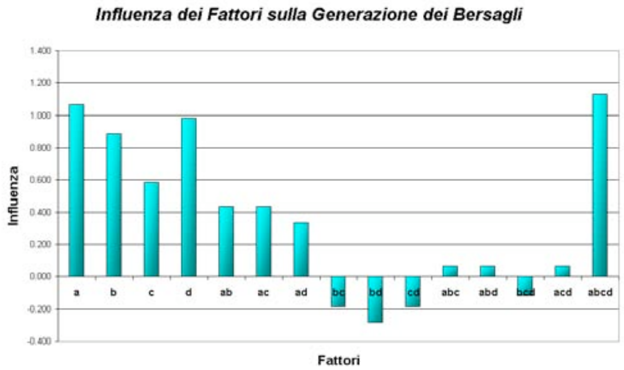


Fig. 17 – influence of factors on Segmentation function

The second target function is system unreliability. In this case, the most significant factor is the sensor IR/EO. However, it is also important to notice how IR/EO, by its interaction with ESM and with the Dempster-Shafer algorithm, is one of the combinations determining reliability factors of the system.

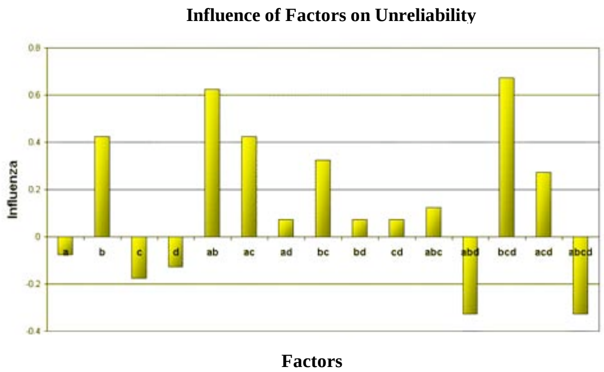


Fig. 18 – influence of factors on unreliability function

It is important to notice how use of Fuzzy Logic has the greatest impact on reliability, importance exceeded only by the interaction of all the four factors. This was an important result for the research, proving the accuracy of the basic Data Fusion concepts, for instance that the proper fusion of data coming from various sensors creates greater benefits with respect to the generalized use of information combining from the single sensor.

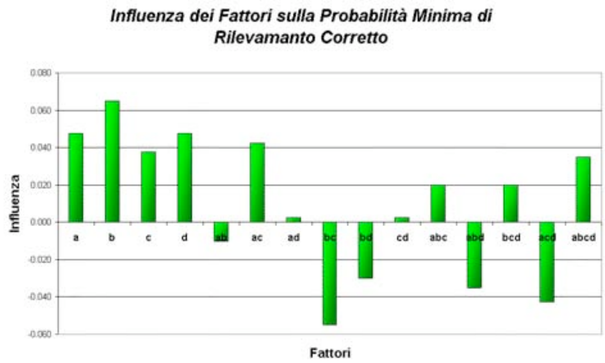


Fig.19 - influence of factors on the Robustness Function

Similar considerations can be determined from the results of the influence on the minimum probability of correct detection. The factor determining the lowest probabilities is again IR/EO; but is to be noticed that respect to the results generated during the previous test, the use of IR/EO allows significant benefits in combination with the use of Fuzzy Logic, with the Dempster-Shafer algorithm and with ESM.

V CONCLUSIONS

This research has the aim to show the importance of the V&V phase during all the life cycle of a simulation model. This work has also underlined the existence of different techniques to verify and validate models that are all powerful tools for facing and solving complex problem.
The authors moreover validated and verified also other complex simulation systems, implemented using HLA (High Level Architecture), taking into account all the procedures contained in the 5000.61 normative, in order to successfully implement very complex simulation models.
It is also important to underline how the application field determines normally a different approach to VV&A. The Authors have in fact experienced both applications in the military field and in the industrial field, and put in evidence some main differences:
in the industrial field, people sponsoring the research normally do not pay much attention to VV&A phase, unless it is required for a specific purpose. They are interested in the result of the simulation and, unfortunately, in most cases they do not care about the simulation model itself, making more and more difficult the accreditation phase. The question is that they have a problem and they want it to be solved, regardless of the applied technique. Very often even the subject matter experts do not know very well the rules or the mathematical models to be put inside the simulator, and it's very hard to find historical data for the tests. In many cases, moreover, sponsors do not care about learning to use the simulation model: they just use it for a specific purpose and ask the developers and researchers to run the model and extract the results, presenting the result themselves in a very simple and quick briefing putting in evidence economical aspects and benefits (i.e. gain or saving). Even if the simulation model

is the most useful, fast and affordable ever made, it will be difficult, in the industrial field, that the sponsors will reuse it after the first time, unless it's mandatory.

In the military field the situation is quite opposite: People from the commissioning institution will participate in all the phases of the model construction, taking care on the algorithms and formulas to be put inside, on the parameters to be regulated, on the historical data to be used. Mostly in the military field even the language or simulation tool to be used for model creation is determined by the commissioning entity.

In many cases it is identified a key-user and many subject matter experts, that participate actively in the model definition and building. Often they have also specific knowledge on information systems and also in simulation, and this could be very helpful in the research. Military pay much attention to VV&A techniques used during each phase, and like to have very exhaustive documentation about that, explaining not only the results but also the input, assumptions made, techniques applied and so on. Often they ask the developers and researchers to conclude their work giving to a classroom of persons interested in the research, a tutorial on the use of the model and a series of exercises in order to expertise and test the model themselves. It will be very likely that a simulator made for a military scope, will be reused more and more by the sponsors and key-users.

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