MODELLING AND SIMULATION AS INNOVATIVE FRAMEWORK FOR EVALUATION PROCEDURES IN EDUCATION AND RECRUITMENT

AGOSTINO G. BRUZZONE
MISS - DIPTEM –
University of Genova
Via Opera Pia 15
16145 Genoa, Italy
www.simulationscience.org

ENRICO BOCCA
Centro Italiano di Eccellenza in Logistica Integrata
Via Balbi 5
16100 Genova, Italy
st.itim.unige.it/cieli_lss

MARINA MASSEI,
MATTEO BRANDOLINI
Liophant Simulation
Via Molinero 1
17100 Savona, Italy
www.liophant.org

Abstract: Presently, there are numerous techniques and systems that can be developed to make a rational evaluation of knowledge and skills, thus simplifying the work of researchers. In this paper, the main goal is to present an innovative means of evaluating the performances and capabilities of candidates and students based on advanced use of modelling and simulation. By the proposed approach simulation becomes an enabling technology to innovate the recruitment and education processes by allowing a quick, quantitative and objective evaluation of the "candidate's" solutions/decisions over dynamically evolving challenging problems. The paper presents different models in use for this purpose that have been experimented in selection and recruitment for R&D (Research and Development) positions; the examples present clearly the benefits of using "virtual problems" for evaluating effective understanding and problem solving capabilities. Statistical results of this approach over a sample of international students with different backgrounds interacting with industrial logistics simulators are included in the paper as validation for the effectiveness of proposed approach.

INTRODUCTION

It is important to recognise the potential of quantitative computer models and simulators to provide significant support for the evaluation and recruitment of young, well-prepared resources in the engineering field.
Today's standard human resource evaluation/recruitment procedures are based on analysing and solving a few case studies, working alone or in a team, and carefully evaluating the candidates' problem-solving skills and teamwork capabilities. However, thanks to the new approach proposed by the authors based on the use of simulation models, it is also possible to evaluate interactions, results, problem-solving actions and reasoning skills, even if it might become difficult to evaluate the effectiveness of different solutions.
In fact, one of the main problems for young post-graduates is that their problem-solving capabilities are significantly reduced by the qualitative approach applied in recruitment policies. Computers are a useful tool that could be implemented to simplify complex calculating operations and to deal with the different scenarios that may arise.
During the recruitment process the candidates usually analyse the test case and provide a reasonable solution, identifying criticalities, bottlenecks and economic analysis, especially in terms of costs or revenues. However, almost all these parameters are qualitative; hence it is very difficult for the researcher to obtain important detailed feedback on the proposed solution.

For these reasons the authors have introduced computer models to provide measurable output: thus, it is possible to evaluate, in real-time, the impact of the solutions proposed by the candidate in terms of overall performance. Quantitative computer models represent the new frontier in the recruitment process: many new techniques become available, such as the use of web technologies designed to spread the selection base to a large worldwide community and to provide the candidates with a self-assessment procedure. But that's not all. By using a computer it also becomes possible, during the final selection stage, to evaluate the interaction without obfuscating the originality of the individual solutions. The authors will present some applications of this methodology along with the results generated through this experimental campaign.

THREADS RELATED TO THE USE OF SIMULATION IN EDUCATION

The first field analyzed in this paper refers to the evaluation procedures in the education and training sectors: these two areas are strictly related and for a long time these sectors have benefited from the use of new techniques. For this reason it is interesting to evaluate the impact relative to the use of simulators and computer models. It is also of interest to evaluate the solutions provided by students in the simulator, thus allowing the students to interact with each other and to deal with a "Virtual World".

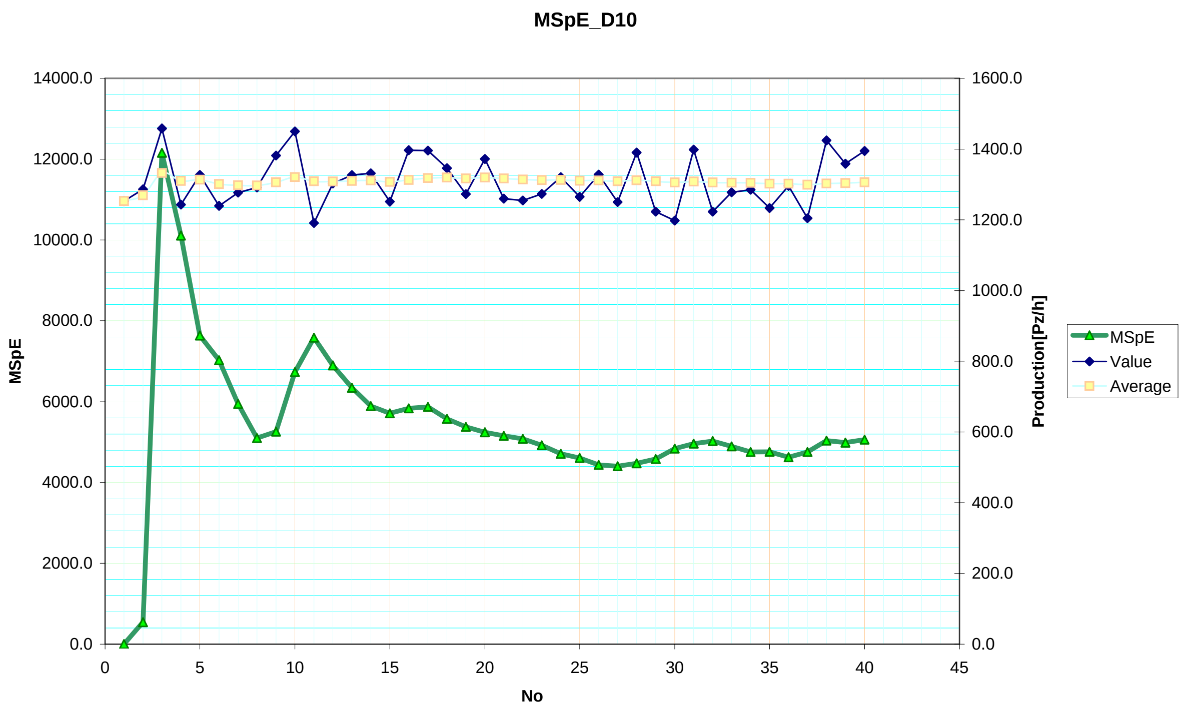

Figure 1: Example of Validation Report requested to Candidates based on DOE on a Simulator Scenario

These tools can be used to implement models designed to support real learning processes based on "Direct Experience", even though the changes are involved are not very simple. The candidates must meet some preliminary requirements: they must have good fundamental skills (i.e. statistics), extensive knowledge of DOE (Design of Experiments) and similar methodologies, be fully aware of all model constraints and limits, and so on (see figure 1).

One of the main potential concerns about using this method is that students, when interacting directly with the models, might end up wasting their time by not discovering anything useful or become disoriented as a result of misunderstanding goals due to the complexity of the systems.[2]

In effect, all the proposed models contain approximations and this represents an additional potential source of errors. That's because by operating under improper conditions the approximations might lead students to infer the wrong relationships from the simulation. Therefore, usually it is very difficult to discover those potential errors and correct them, also because complex logical operations inside simulators are decorated with very good-looking and attractive animation or computer graphics that make them look extremely realistic.

Even considering these aspects and risks, the authors' experience shows that the main limit in using such techniques in education is the lack of tools in this specific field; thus, there is extensive potential for developing tools in this area.[14]

SCIENTIFIC SKILL EVALUATION USING M&S

Simulation applied in the field of scientific capability evaluation and research selection is considered a logical step as a result of sector evolution: today's selection procedures are often based on the results of candidates' approach to simulated scenarios.[30] In this case, the term "simulated" is not linked to computer simulation. In a certain sense it is easier to understand how computer M&S techniques could help to define those scenarios in a realistic and challenging way that is not possible with other approaches.

With this in mind, it is possible to see a parallel with the evolution of the simulation for training, especially in the military field, where the first steps were taken in the middle of the 20th century, evolving to distributed operations in the '90s and continuously developing in present times towards automatic evaluation systems. [12][23]

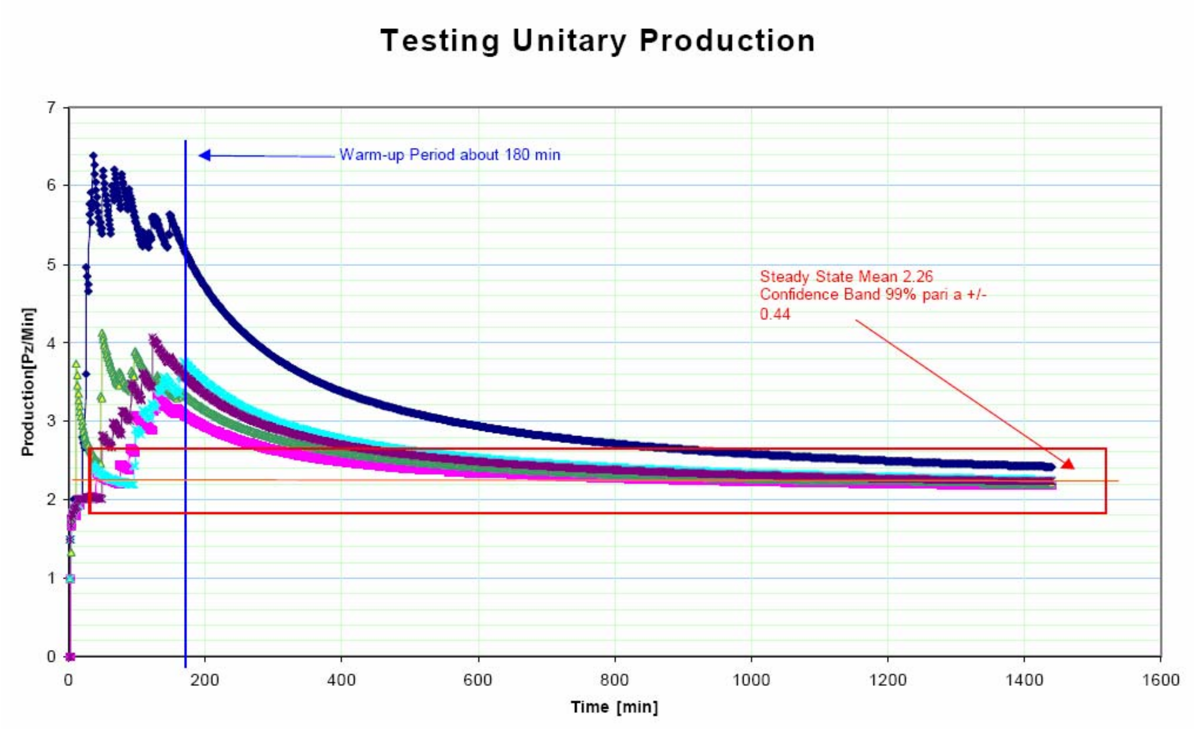

Figure 2: Evaluation Criteria applied to the reports provided by different candidates

In any case, it is an innovative approach to define new models for personnel selection activities, such as:

- Fast screening to evaluate large numbers of candidates operating on small but challenging systems interconnected through the web while interacting with simulation systems and communicating the results;[11] [26]
- Complex problem remote analysis that can be submitted to the remote instructor by a group of trainees whose operational timeframe while remotely connected can be extended. [15]

Fast screening can increase the number of candidates, making it possible to concentrate traditional screening, which is more time consuming and expensive, on a smaller and pre-selected number of candidates. In this way the final selection procedure can be redesigned while focusing on additional issues.[29] The second type of selection could be applied instead to quantitative comparisons of experts, thus limiting the use of internal resources and procedure times.[25] Using these approaches and other new ones in the researcher selection process can improve the evaluation approach as well as a comparative and quantitative performance analysis.

The authors propose a set of preliminary applications in which to implement such concepts based on the experiments carried out and their successful results.

FIRST CASE STUDY AND APPLICATIVE EXAMPLE FOR RECRUITMENT

The first example involving the use of computer simulation for screening researchers was carried out in the academic personnel evaluation field. It is very difficult indeed to bound research in a simulation model, but there are some specific situations in which research must be extensively integrated with such particular expertise. The application was made in the engineering field, and the industrial engineering sector in particular, that requires scientific testing capability of problems affected by variables to be measured, data to be analyzed and compared, and conceptual liaisons to be estimated. In this case the capacity of the candidate to analyze, evaluate and solve realistic problems using computer tools can be identified using simulations models. In particular, even if this is a very limited application of such concepts, it is important to note how quantitative results based on computer simulation can be used to measure such skills.

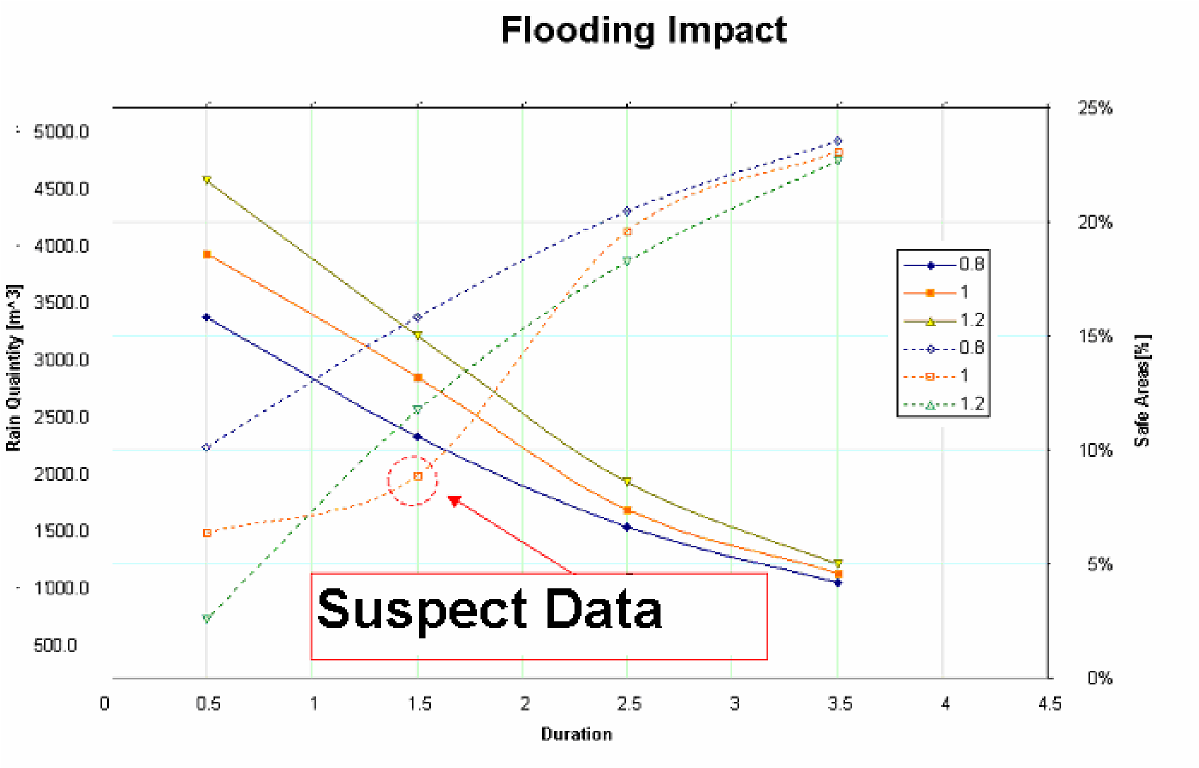

Figure 3: Creating a Challenge with regard to Data provided in a Scenario for Researcher Selection

Obviously, these results must be integrated with other evaluation procedures to effectively support the overall selection process.[19]
The authors introduced a set of computer simulation packages designed to evaluate post-graduates for positions in academic environments. Among others, some of the packages developed for industrial engineering candidates referred to different kinds of simulators: environmental management, mechanical department, manufacturing facility, engineering tenders, etc.[4] For instance, in the manufacturing case, it was requested to estimate and identify the real system warm-up period and the time baseline in order to obtain results to compare with real system data (see figure 2).[10] In addition, the authors developed three other different simulators tools to apply in this sector to evaluate the candidates while focusing more on technical releases in experimental techniques such as those related to complex systems: missile launching procedure, micro particle interactions, and weather impact on flooding phenomena over a geographic region.[13][16][17]
For instance, in order to select different technical/scientific thematic areas the candidate has to identify some correlations and, in particular, to compare the results obtained by using a simulation with real data (see figure 3). In this case, involving the selection of different technical/scientific thematic areas, the candidates were requested to identify, using the simulator, some correlations also by comparing the results with real data [6].

One important part is when candidates are requested to determine correlations among different factors and/or to identify the incorrect data using the validated model.[1]

Figure 4: Example of a Simple VB Candidate Evaluation Simulator

The tools as anticipated was adapted for guarantee easy use from candidates (see figure 4) and were extensively used in researcher evaluation processes involving industrial engineering personnel, leading to a rapid motivated quantitative selection over a set of 45 candidates.[27] The candidates who passed the computer simulation were interviewed for a final evaluation.

A CASE STUDY IN EDUCATION: IEPAL

Is it possible to use globalization more effectively to improve logistics knowledge and skills and to solve real problems in other continents?

IEPAL is an international project involving the construction of numerous logistics and supply chain management experiences based on the use of advanced techniques to increase knowledge and skills in the field of advanced logistics by exchanging know-how between Europe and the USA.[24]

The author's objective was to promote an exchange of simulation knowledge, also through grants allowing young people able to acquire experience around the world.[21] They organized such a series of modules that became the pilot experiment for a wider range of activities. It was very critical within the framework of IEPAL to define the proper learning process due to the fact that as a program co-funded by the European Community and the USA Department of Education, there were also many constraints involving budget aspects and completion time. Therefore, the need arose to create ad hoc experiences.[18] The timeframe for developing such an experience was rather limited due to various problems: first, the fixed grant was used to maximize the number of students that would be able to travel, but this implied that the organization had to make rather short modules in order to respect the budget. Another constraint was the need to respect normal course attendance for the students. This meant that the experience had to take place during the summer, when courses end. The first point was to correctly dimension the module duration and structure to provide benefits both for trainees and companies that had a problem to be solved (see figure 5).[22]

The most effective solution was to create three-week modules, with two/three persons attending each one, coordinated by an internal tutor and supervised by one of the Liophant Members[17]. In this way, the companies could benefit from an average of 30 man days (5 working days per week for 3 weeks for 2 persons), a timeframe which is sufficient for the students to understand the context of the company and the various aspects of the problem, to collect data and to find a feasible solution.[20] The internal tutor acts as a reference, pointing students in the right direction to find data and information about the constraint, and as a liaison between the students and company management. Instead, the Liophant coordinator's role was to guide the teams in applying the right approach

IEPAL MODULES

The most important test to verify the reliability of the IEPAL results was to make the teams work on real problems in real companies. For the first series of experiences, the authors selected a set of companies within the framework proposed by the IEPAL project member industrial consortium.

to solve the problem, without wasting any time or resources and finding the most useful techniques to tackle and solve the problem.

TEAM CONSTRUCTION: SCIENTIFIC APPROACH

The background work to set up IEPAL modules was structured so as to maximize the benefits that could be obtained from such experiences.[7] This implied the need for planning to select the companies and the tasks to be assigned, to find internal and external tutorships and to create work teams.[8] Teams were made by creating a convenient mix of students from Europe and the USA, trying to balance competencies in terms of educational background (computer science vs. industrial engineering) and degree level (bachelor students, master students, etc.) [3]. 9 students from Europe and 8 from the USA, with different backgrounds, passed the IEPAL experience selection phase. The students' skills can be summarized as follows:

	Computer Science	**Industrial Engineering**
Bachelor's degree	*4*	*8*
Master's degree	*3*	*2*

Table 1: Students Background

The solution implemented was designed to maximize the benefits of team work and to increase students' knowledge and experience, helping them to efficiently solve the assigned task while providing benefits to the trainees and to the hosting company at the same.[3] Another aspect was to create teams according to personal skills and interests, based on a detailed analysis of each student's curriculum.

Taking all these parameters into account, the final scheduling for the modules can be summarized as follow:

Module A: 1 USA, CS Bachelor + 1 EU, CS Master
Module B: 1 USA, CS Bachelor + 1 EU, IE Bachelor
Module C: 1 USA, CS Bachelor + 1 EU, IE Bachelor
Module D: 1 USA, CS Bachelor + 1 EU, IE Bachelor +1 EU IE Master
Module E: 1 USA, IE Bachelor + 1 EU, CS Master
Mod.F-Task 1: 1 USA, IE Bachelor+1 EU, IE Bachelor
Mod.F-Task 2: 1 USA, IE Bachelor+1 EU, IE Bachelor
Mod.F-Task 3: 1 USA, IE Bachelor+1 EU, CS Master

The results of this selection created a set of entities representing various interesting logistics aspects: from aircraft and special crane services to retail companies and port authorities and from container terminals to special treatments for refrigerated goods. The following is a short description of the companies involved in IEPAL project.

Sector	***Container Terminal***
Stage Title	*Statistical Analysis on Reefer Container Storage and Movement*
Target	*Strategic Analysis to Improve the Logistic Structure of Frozen Goods Movements*
Input Data	*1)Container Movements inside VTE over the last 4 years* *2)Reefer Container Movements inside VTE over the last 4 years* *3)Frozen Food Movements inside VTE over the last 3 years* *4)Frozen Food Consumption in Italy over the last 3 years* *5)Overview of the Italian Logistic Market for the transportation of Frozen Goods*
Output & Deliverables	*1)Analysis of the Italian Logistic Market for Frozen Goods from the Factory to the Final User* *2)Analysis of the Maintenance Costs for Frozen Goods during the Transportation* *3)Analysis of the Cost of Building and Maintenance of other Logistic Structures* *4)Analysis of the Frozen Food Market trend in Italy* *5)Analysis of the Reefer Movement trend.*

Sector	***Aerospace Industry***
Stage Title	*MRP Analysis and Revision of the Logistic Process of the Inner Supply Chain*
Target	*To highlight and increase service effectiveness*
Input Data	*Current flow; data fleet; history of failures and MTBF, past orders and requirements registration*
Output & Deliverables	*1)Statement of a computer tool (i.e. MS Excel or other) to plan the requirement provisioning* *2) formulation of a logistic curve resulting from an algorithm:* ***CUSTOMER SERVICE RATING= f(warehouse level)*** *3)OPTIONAL: Study of a relational database (i.e. MS Access or other) for spare parts management* *A critical unit TEST CASE will be used in this program*

Sector	***Constructions***
Stage Title	*Feasibility Analysis of Company Reorganization*
Target	*To highlight positive and negative aspects of company centralization in order to support strategic decisions*
Input Data	*1)Current flow and organization; data on working people, operational means and infrastructures* *2) data about the small companies recently acquired by Vernazza and about geographical distribution*
Output & Deliverables	*1)balance of benefits and problems regarding the decision to centralize or decentralize company structures* *2) organization and planning of personnel and operational means in case of centralization and decentralization* *3)conclusions and personal support in decision making on this subject*

Sector	***Shipping & Port Activities***
Stage Title	*Analysis of goods arrival time and methods at maritime terminals*
Target	*To identify driver costs on policy management, estimate stopping time and rotation coefficient in the terminal area*
Input Data	*Ship arrival timetables, goods shipping data*
Output & Deliverables	*1)Analysis of terminal logistic organization based on available data: gaps and possible improvements* *2)Synthetic analysis of multimodal transportation status quo into the terminal: gaps and possible improvements* *3)Performance analysis (rotation index, etc.) in relation to ship arrivals*

Sector	***Retail***
Stage Title	*Ramp-Up for White Meat Platform and Warehouse*
Target	*To evaluate supplier performances in order to test the benefits of the new automated platform/warehouse*
Input Data	*Measurement of the quality and quantity of goods delivered and check on compliance with due date*
Output & Deliverables	*Statistical analysis of new system and supplier performance, evaluation of satisfaction*

Sector	***Port Authority***
Stage Title	*Feasibility plan, economic evaluation, logistics and design of a new distribution center*
Target	*To redesign the distribution system in Venice, by analyzing the logistics and costs of truck to ship transshipment operations resulting in a strategic and efficient distribution service.* *To highlight the critical aspects of goods logistics to support the new center in the Venice area*
Input Data	*Requests from final customers, features of transportation means, constraints and bonds, costs, traffic flow data*
Output & Deliverables	*A feasibility analysis completed with design, cost analysis, means of transport and evaluation of the proposed solution* *Goods Strategic Flow Analysis* *Requirements for supporting a new supply chain for the Venice area*

Table 2: IEPAL industrial partners

CRITICAL ASPECTS & TEST PHASE RESULTS

One of the most important results achieved in this logistic experience was feedback from students (about lessons learned) and from companies (about the reusability of the analysis performed). It could be said that almost in every case the experience created a very positive synergy between company and students. For the case involving the Container Terminal, for instance, the students found that the staff was willing every day to help find information or other input data.[9] They met with their internal tutor and sometimes also with the Main Director twice per week. It was an interesting way for students to improve their knowledge of the logistic system and the international rules for container navigation. A very stimulating aspect for both participants in that team was to make a comparison with another student, from another country and with a different culture, age and background. For this reason the analysis of this case study utilized more then one approach. In fact, even if the workload was not very light, in the end, the results were completely satisfactory. For the case involving the Aerospace Industry experience, the students' work was so highly appreciated and the results so interesting that they were asked to come back at the end of their experience to present the results to Company top management during a meeting organized for that specific purpose.

The Shipping Company Experience was constantly monitored by the internal tutor who held a daily brainstorming session with the students about the intermediate results and information needed to develop further steps.

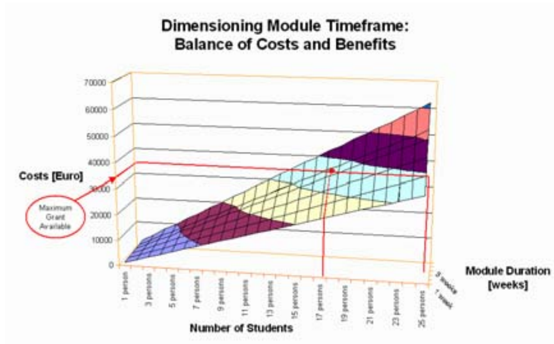

Figure 5: Team Working Experience Design

The final work was presented to the company owner to the overall satisfaction of all those involved.

Another experience involved Construction services; this experience focused on a company reorganization based on the acquisition of some new smaller and geographically distributed companies with their own resources and potential market. In this case, the Liophant coordinators had to re-orient the work to a certain extent, because the topic was very complex in terms of the aspects to be evaluated. However, the company greatly appreciated the work that was done, and could be used as an interesting basis for more in-depth analyses.

The experience involving Retail Business area, focused on some more critical aspects: it was a small part of a study being conducted for this company by DIPTEM-University of Genoa. The data collection phase was rather difficult since the suppliers' arrival timetable was concentrated mainly during the night, and the workload was unusual for students without any previous work experience (it was their first real job). But the organization tried to solve the contingent problem by reorganizing the timetables for the students (i.e. additional free time after a night data collection session and so on). In the end, the data collected by the students and their first-level statistical analysis was used to perform additional in-depth studies by DIPTEM- University of Genoa.

The last experience of this first set was performed in the Venice area, while all the others took place in the environs of Genoa. This created more complex situations that had to be dealt with and resolved. First, the organization had to ask a local member of the enterprise consortium to establish contacts with companies in the Venice area. However, due to contingencies and that the experience was taking place in the summer (reduced timetables/holidays for many workers), the 3 modules to be carried out in that location became one big problem-solving case with many different tasks commissioned by the Port Authority.

Therefore, the organization decided to create a six-member team by gathering together the three teams that were previously scheduled. This huge and complex problem was divided into sub-tasks and the team into smaller sub-groups, each working on one topic and then putting results together. The case study was to plan and design a new distribution center for food goods in the Venice area that could store and dispatch material to all final customers, i.e. both big or small companies.

Data collection was particularly difficult due to the fact that a wide variety of information had to be collected about means of transportation, traffic and its constraints (Venice has no large streets but a complex network of canals), customers' requirements as well as terrain and structure costs. Data were collected not only at the Port Authority, but even at the municipal administration, the Venice police and traffic management departments, and at the companies that built means of transportation. Then each sub-team focused on a particular aspect: warehouse layout and location, internal and external means of transportation, timetables, routing and dispatching costs. At the end of this work, the Port Authority organized an effective presentation of this study to the local Authorities.

The test phase of this first series of modules was performed using a set of questionnaires to evaluate overall performance. Obviously, the questions were different from the ones used to select the candidates, from the group of students and from companies, in the preliminary phase. Different series of questions were used and evaluated first separately and then together to obtain an overall performance parameter. Results from the Genoa area were kept separate from the ones from the Venice area.

The results of the overall evaluation of the Genoa and Venice experiences are shown in the following figures. Scores ranged from 0 to 10, so 6 is an average value: below such a value the evaluation is insufficient, while more than 6 represents a good evaluation.

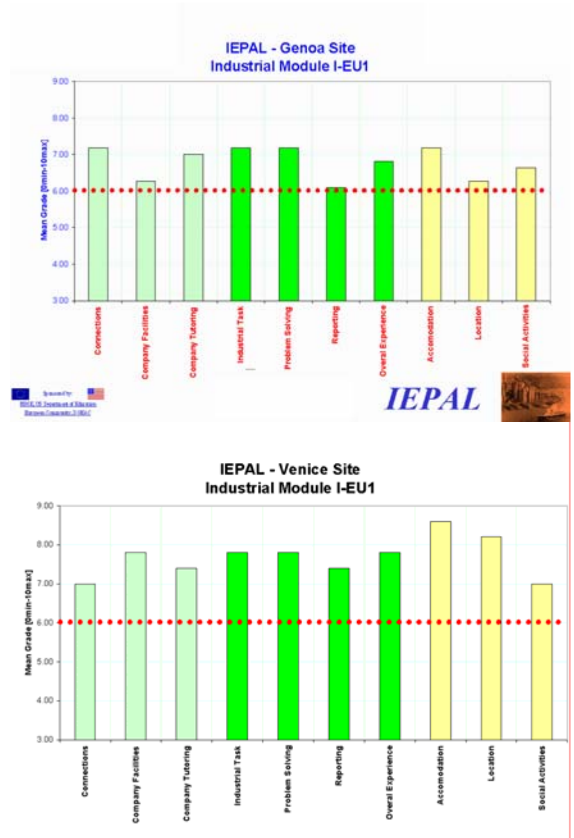

Figure 6: Quality Assessment in Industrial Modules

In this case, the evaluated performance levels referred to all the different topics considered in the individual questionnaires. A first series of 3 parameters, the first 3 bars in the figures, represent an overall judgment within the company framework:

- Connections
- Facilities
- Tutoring

The second series, with four indicators, refers to problem solving and the module itself:

- Evaluation of the task given
- Evaluation about their Problem Solving capability
- Evaluation about reporting to tutors
- Evaluation of the overall experience

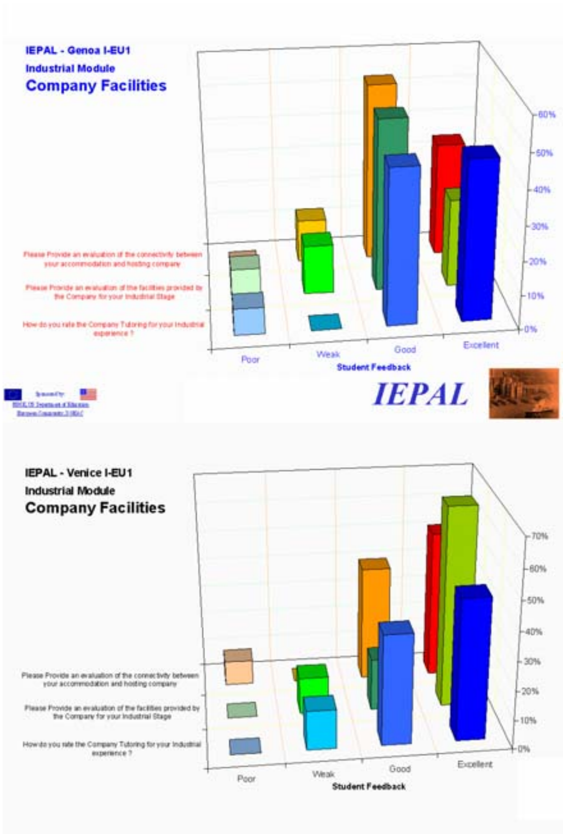

Figure 7: Company Facility Evaluation

The last series of three indicators represents the judgment about accommodations, also provided by the Module Organization Committee, and the parameters refer to accommodations, location and social activities.

An analysis of the results of the first two series of questionnaires shows how the students evaluated the module and the company that hosted them as summarized in figure 7. The possible judgments to be given were poor, weak, good, excellent. There were three questions about the company itself:

- About the connection between accommodations and workplace
- About the facilities given to students by the company
- About internal tutoring provided by the company

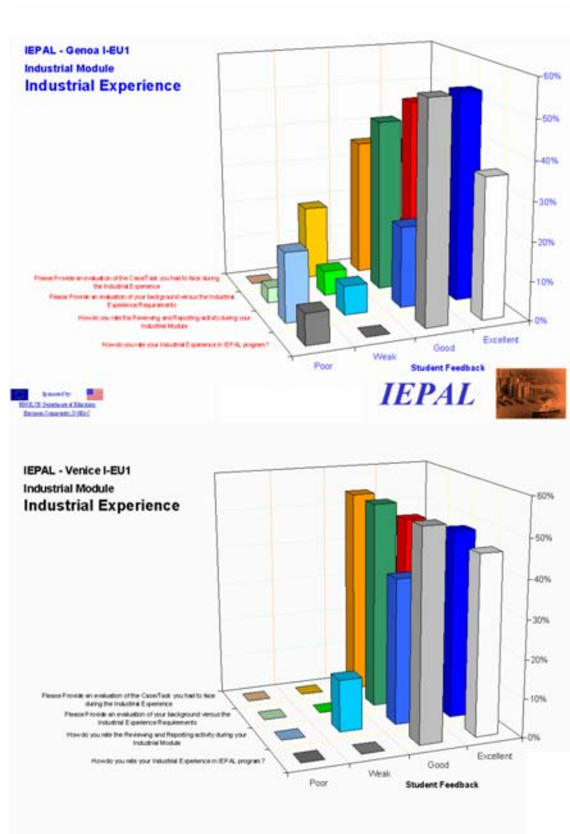

Figure 8: Experience Acquired in Industrial Modules

The second series of question focused on the experience. Using the same evaluation parameters, the students had to evaluate:

- the case study to be analyzed
- their background versus the industrial case requirements
- the reviewing and reporting phase to coordinators
- the overall experience in terms of lessons learned

Also in this case a summary of the experimental results is proposed in figure 8.

Company feedback was used instead to evaluate the team make-up and problem-solving capabilities. The parameter was the reusability of the studies carried out by each team as judged by the hosting company. The independent variables were the percentage of students with a different background: computer science or industrial engineering skills as is presented in figure 9 where this target function is represented versus the Computer Science (CS) and Industrial Engineering (IE) capabilities available within each team.

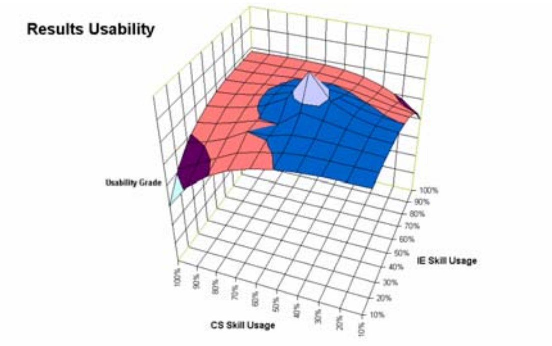

Figure 9: Result Usability based on Team Composition

The results of this analysis show that to obtain the best performance in logistics problem solving (in terms of the reusability of the results for the company), Computer Science and Industrial Engineering skills must be mixed in equal proportions.

SYNTHESIS OF THE RESULTS

The main critical aspect about this first set of experiences was the very short timeframe within which to achieve all the goals. However, as previously mentioned, this gave more students the opportunity of having such an experience, acquiring logistics knowledge from real cases and learning how to tackle and solve real problems by co-operating with foreign students with different backgrounds and who speak different languages: Italian, German, French and English. Since they communicated mainly in English, the language and culture differences did not seem to represent a major obstacle for the majority of the students involved. In fact, for the most reactive of those students, it also provided the necessary stimulation.[28] The reporting and coordination phase had just one critical aspect that must be taken into account: it took place mainly outside of working hours (i.e. in the evening or on Saturdays) since students had to work in companies from Monday to Friday. In any case, the overall results from the evaluation phase show that the first session of the IEPAL experiences was structured correctly, and that for the successive series of modules it was only necessary to adjust some details based on the lessons learned from the testing phase feedback.

CONCLUSIONS

This proposed approach related to the use of M&S in the critical sectors of Education, Selection and Recruitment demonstrated to be innovative and useful. Based on the results of these preliminary experiences, such techniques could be implemented to provide solid and reliable performance measurement baselines while focusing on other aspects thanks to the use of traditional techniques.
Increasing the number of candidates applying distributed procedures for screening can add more opportunities to evaluate researcher and to improve their training. In the meantime, this approach can be applied to carry out a quantitative evaluation that could also provide candidates with feedback to improve their skills, identifying any errors with precision.

ACKNOWLEDGEMENTS

The authors would like to thank the DIPTEM Director, Prof.Roberto Mosca and also to extend their gratitude to Dr.Salvatore Capasso, Director of CFLI – Intermodal Logistics Consortium, who offered the group of companies in which the modules took place, and also each enterprise involved in the experience and their internal managers: Garassino, Mairo, D'Angelo Messina, Vernazza, Cannito Travi, Neglia, Salmoiraghi, Bruzzone, Albertazzi, Milazzo and the entire staff of the Venice Port Authority.
Many thanks as well to all the IEPAL Partners and student participants from Universitè de Aix - Marseilles III (FRA), University of Magdeburg (GER), Boston College (MA, USA), Stevens Institute of Technology (NY, USA), University of Central Florida (FL, USA), National Center for Simulation and Kennedy Space Center (FL, USA). Last but not least the authors would also like to extend their gratitude to DGEAC - European Community and FIPSE – USA, for cofunding this international project.

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