THE 3ND INTERNATIONAL WORKSHOP ON SIMULATION FOR ENERGY, SUSTAINABLE DEVELOPMENT & ENVIRONMENT

SEPTEMBER 21-23 2015

BERGEGGI, ITALY

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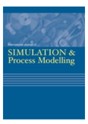

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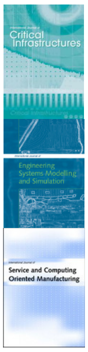

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CHAIRS' MESSAGE

It is our pleasure to welcome all back to Bergeggi (Italy) for the International Workshop on Simulation for Energy, Sustainable Development & Environment (SESDE 2015).

In the lovely framework provided by the Italian Riviera where the Workshop is held, Scientists and Subject Matter experts are going to meet and look at Modeling and Simulation applications related to Energy, Sustainability and Environmental Issues.

As well known the progress of Modeling and Simulation applications has been astounding to the extent that often it is the main approach to deal with complex issues (such as environmental concerns) in real complex systems.

Being centered on these aspects, SESDE has contributed to encouraging chapters in international communities, developing new ideas and promoting successful collaborative works. Thus SESDE promotes highly innovative approaches that are able to break the boundaries of Science and Technology enabling great strides toward the goals of the society.

The SESDE multidisciplinary and interdisciplinary nature makes it a unique and effective appointment attracting scientists from a variety of organizations and backgrounds and eliciting discussion and debate on new discoveries, technologies, and opportunities of progress.

We wish all the delegates a vibrant, highly productive, and strong event recalling that the close involvement and participation of scientists and leaders from academic and research organizations is highly appreciated.

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USING SIMULATION TO SUPPORT MANAGEMENT OF OFFSHORE RENEWABLE ENERGY FACILITIES

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ABSTRACT

International commitments to reduce carbon emissions and promote the adoption of renewable energy, has necessitated significant investment in developing wind energy capabilities. The installation, operation and maintenance of offshore turbines presents some unique logistical challenges and costs relative to their onshore versions. This is due to more complex foundations, additional infrastructure and installation requirements, and limited periods of accessibility due to wind and wave conditions. The cost of operations and maintenance (O&M) of offshore wind farms represents 30% of the total lifetime cost of a turbine and is approximately double the O&M cost for onshore turbines. We are developing a simulation-based decision-support tool for rapid modelling, analysing and optimizing the logistics and supply chain requirements for constructing offshore wind generation capabilities and performing the O&M tasks necessary to maintain their availability.

Keywords: energy, offshore wind, optimisation, decision support system

1. INTRODUCTION

Simulation can be of great benefit to the offshore wind industry in the coming years, assisting in the development of logistics for an emerging technology.

With international commitments to reduce carbon emissions and promote the adoption of renewable energy, wind energy usage is on the increase. The European Wind Energy Association (EWEA) forecasts that in 2030, there will be 400GW of wind power capacity installed in Europe, of which 150GW will be onshore and 250GW offshore, which could meet 28.5% of total EU demand (EWEA, 2011), which would see an increase from the 6.56GW installed capacity in Europe in 2013 (EWEA, 2013). The US has as yet no offshore installations, although projects are in development (Wind and Water Power Technologies Office, 2014). The International Energy Agency forecasts that by 2050 offshore wind turbines will account for one third of all wind energy generated (Philibert & Holttinen, 2013).

However, the installation, operation and maintenance of offshore turbines presents additional logistical challenges and expenses relative to their onshore versions, due to more complex foundations, additional infrastructure and installation requirements, and limited periods of accessibility due to wind and wave conditions (Hahn & Bloch, 2013).

The major components of an offshore wind turbine are considered to be the foundation, tower, nacelle (machine house), rotor hub and blades (Lange, Rinne, & Haasis, 2012).

The majority of current turbines use a monopile foundation, but with additional support needed with increasing depths and distance from shore, other structures such as jackets and tripods may be used, or even floating turbines such as Statoil's Hywind concept (Statoil, 2009). These structures are illustrated in Appendix A.

Various factors need to be taken into account when considering the supply chain requirements for offshore wind farms; location of manufacturers, transport to port, construction at port, port infrastructure readiness, type of assembly required, and cost and availability of vessels used for transport, assembly and maintenance of the turbines (Hahn & Bloch, 2013).

As the cost of chartering vessels for offshore wind farms can be extremely expensive, running into hundreds of thousands per day (Dalgic, Lazakis, & Turan, n.d.), it would therefore be prudent to plan installation and maintenance to minimise these costs, and to this end the use of simulation for decision support will play an important role.

This paper will give some background to the use of simulation and optimization in the area of offshore wind, and outline planned simulation tools to support management of this growing area.

2. BACKGROUND AND RELATED RESEARCH

While offshore wind is still a young technology, some work has already been carried out on the use of simulation and optimisation to support its logistics. Existing work in this field will be described below.

Hofmann's review (Hofmann, 2011) of decision support models concludes that here are numerous decision support models for all aspects of an offshore wind farm, but few covering the entire life cycle from construction to decommissioning. This review considered support structure, electrical infrastructure, transport, weather, wake, maintenance strategy and failures, and found that no model in the review considered all of these aspects.
Hagen (Hagen, Simonsen, Hofmann, & Muskulus, 2013) presents a multivariate Markov chain models for generating sea state time series for use in generating weather data for offshore wind farm simulations, considering significant wave height, wind speed, wave period, wind direction and wave direction.

2.1. Installation Phase

Lange (Lange et al., 2012) presents a simulation tool which models the supply chain for offshore wind turbines accounting for production and transport networks, land and sea resources, and weather. Various aspects are taken into consideration:

Assembly strategy – Several techniques are described. Star assembly involves the hub and rotor blades being assembled on land and transported horizontally to the wind farm. This requires large areas of space for storage and transportation. It uses a single but more complex lift for the blades, requiring longer conditions of favourable weather. Bunny assembly may be used for smaller installations. In this case, two rotor blades are connected to the hub on land and mounted on the plant before adding the third blade. This requires less width in the waterway for transportation, but is used only for installations less than 3MW. Single blade assembly is also mentioned as being under development, in which case the hub is first mounted, followed by each blade individually. This method allows blades to be transported above each other on racks, reducing footprint required in harbours and vessels.

Logistic strategies – the principal strategies used are pendular, in which installation vessel transports a number of components to the wind farm, carries out installation and returns to base port after the installation process, and feeder, in which the installation vessel is located at the wind farm site and components are brought to the wind farm from one or more ports by feeder vessels.

Consolidation vs accumulative transport – using the consolidation method components are produced in various sites and shipped to one base port; whereas with the accumulative strategy one installation vessel may stop at different ports to collect components en route to the wind farm.

Lange's simulation tool also considers resources such as lifting equipment, and transport vessel availability. Weather data from the proposed site may be included and used to simulate conditions using Markov chains; wind and significant wave height being of greatest relevance as these mainly determine whether vessels may leave port or perform installations. Processes disturbances are considered based on probabilities of failure.
Scholz-Reiter presents a mixed integer linear programming (MILP) tool for calculation of optimal scheduling for offshore wind farms (Scholz-Reiter, Heger, Lütjen, & Schweizer, 2010)(Scholz-Reiter & Lütjen, 2010), with the intention of minimising the total installation time. This model is limited to a single installation vessel, considering a loading set of how many substructures and top-structures may be loaded in each run, loading times and building times for each run, and considers weather in general periods of 1-3 days [in the example presented. These weather periods are randomly assigned, both with respect to length of weather period, and conditions, having an approximately equal probability of being good (top and substructure installation possible), medium (substructure only possible), or bad (no installation possible)]. This model is also presented as being suitable for short term planning using actual forecasts.
Ait Alla also proposes an MILP model for simulation of the installation of offshore wind farms, considering vessel utilisation, travel times and weather restrictions (Ait-Alla, Quandt, & Lütjen, 2013). This model also considers installation of cable to attach turbines to the grid, which is not accounted for in the previously mentioned models, and allows for multiple vessels. Stock of components is also taken into account (this is also considered in the Lange model, and noted but not taken into account by the Scholz-Reiter model). Weather is accounted for using means of historical data for each month of the year for the past 50 years.

2.2. Operations & Maintenance Phase

Dinwoodie (I. A. Dinwoodie & McMillan, 2014) describes four strategies for vessel procurement and considers the appropriate context for and cost implications of each. In increasing order of up-front costs these are:

1 - Fix on Fail – charter vessel when fault occurs; pay for duration of charted, but long mobilisation periods between failure and vessel readiness may affect turbine production availability.

2 - Batch repair – as above, but vessel charter is delayed until a number of failures have occurred; this involves less charters but greater possibility of revenue loss due to turbine down time.

3 - Annual charter (1-12 months) – failures outside the charter period are not addressed until the start of the next charter.

4 - Purchase of vessels – this has the highest up front cost, but may be an efficient use of funds if the failure rates of the turbines are high enough to ensure the frequent usage of the vessels.

The appropriate selection will depend on various factors, including number of turbines in the wind farm and frequencies of maintenance expected.
Vessel selection strategies are also discussed in (Dalgic, Dinwoodie, Mcmillan, & Revie, n.d.), while charter

rates estimation is discussed in (I. Dinwoodie, McMillan, Revie, Lazakis, & Dalgic, 2013).

Rademakers presents ECN's OMCE tool (Rademakers, Braam, & Obdam, 2008), (Rademakers, Braam, Obdam, & v.d. Pieterman, 2009) which may be used to estimate costs of calendar based preventative maintenance (1-2 visits per turbine per year, increasing after turbine is 3-4 years old to account for oil changes in gearboxes or major overhauls), unplanned corrective maintenance (required as a result of equipment failure)and condition based maintenance (in the case of unexpected wear of components, but failure has not yet occurred and downtime of turbine can be planned) over the following the next 1, 2 and 5 year periods, based on observed failure rates of components, degradation state of components, number of available days for repair and costs of labour, equipment and spare parts.
Garrad Hassan (now DNV GL) O2M tool for simulation is described in (Phillips, Morgan, & Jacquemin, n.d.), with particular focus on the effect of wave persistence (average duration of a particular sea state) in a given location.
The NOWIcob model (Hofmann & Sperstad, 2013) (Hofmann & Sperstad, 2014) covers activities in the operation phase of the offshore wind farm life cycle. It considers inputs such as vessel mix (number of vessels used, and buy/rent strategies), maintenance tasks (divided into time-based, corrective and condition based, as in (Rademakers et al., 2008), (Rademakers et al., 2009)), personnel shifts and maintenance base type (whether personnel are located onshore, offshore on motherships, or on vessels which remain offshore for more than one shift), and failure rates. Monte Carlo simulation techniques are used to model unpredictable factors such as weather and electricity prices. The model presents outputs in terms of turbine availability (both time-based [based on operative time and life cycle of turbine] and production based [based on real and theoretical possible energy production]), net present income based on of electricity generated, net present O&M cost, and net present profit.

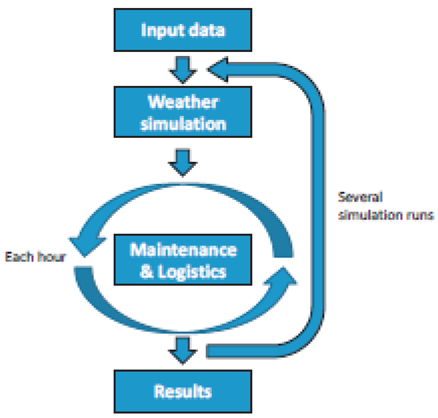

Figure 1: Simplified flow scheme of NOWICOB model

Dinwoodie's (I. Dinwoodie et al., 2013) combined operational and strategic decision support model uses a multivariate auto regressive climate model combined with a Markov Chain Monte Carlo failure and repair simulation to calculate costs (lifetime costs of vessels, revenue loss due to turbine failures etc.), which feed in to Bayesian Belief Networks and decision trees to illustrate the likely eventuality of various risks, and is suitable as a tool facilitate decisions on matters such as whether to purchase or rent vessels, and whether an operator should adopt an OEM manufacturer maintenance contract or carry out its own maintenance.
NOWIcob and the Dinwoodie et al. combined operational and strategic decision support model, along with two others (EDF's ECUME model and University of Stavanger offshore wind simulation model) are verified in (I. Dinwoodie, Endrerud, Hofmann, Martin, & Bakken, n.d.).
Karyotakis (Karyotakis, 2011) considers the effects of a number of parameters (including cost of energy, reliability and energy output), on the cost of energy, reliability and energy output of a wind farm using a planned intervention maintenance policy (equivalent to Rademakers' calendar based maintenance policy), by developing several models, and performing sensitivity analyses on the models for each of the inputs (including accessibility of wind farm, transport costs, decommissioning costs). These models are also validated by comparing them to three real-world wind farms.
Besnard identifies the following factors as critical to the maintenance support organisation of offshore wind farms: 1) location of maintenance accommodation; 2) number and type of crew transfer vessels; 3) use of helicopter; 4) work shift organization; 5) spare part stock management; 6) technical support; 7) purchase or contracting of a crane ship; and considers the first 4 in (Besnard, Fischer, & Tjernberg, 2013), optimising parameters for the maintenance support organisation based on difference between electricity income generated and costs of support teams.
Dewan (Dewan, 2013) proposes a logistic model for inventory management (for calculation of optimum number of spare parts required) and an O&M service model considering turbine reliability, crew and transport strategies, weather and scheduled maintenance. These are solely models, and no not feature optimisation techniques, other than simply feeding in a set of input parameters and inspecting results to determine the most suitable.

2.3. Optimising Operations & Maintenance

Besnard (Besnard, Patriksson, Strömberg, Fischer, & Bertling, 2011) presents a stochastic model for opportunistic maintenance planning of offshore wind farms, using rolling optimisation based upon a 7 day ensemble weather forecast; allowing for optimisation to be performed on a daily basis to update maintenance planning based on power production and weather forecasts. This stochastic optimisation model with one recourse stage is optimised using free MIP solver software and used to plan scheduling for maintenance tasks, given a list of the tasks required to be performed in the next 60 days, using the current 7 day forecast for the short term, combined with seasonal forecasts based on historical data for beyond the 7 day horizon. This model is intended to be used to take advantage of equipment failures and low production forecasts to perform service tasks at the most efficient times; however this model assumes a single maintenance team and requires daily updates from the maintenance planner.

The offshore wind industry is relatively young, and as such, work on optimisation for the supply chain is still in the early stages. The LEANWIND Industry Challenges Report - Supply Chain and Logistics [29] states that developing and maintain a cost-effective logistic system is essential to reduce the O&M costs of an offshore wind farm, and cost-effectiveness in the O&M phase is an important factor for the offshore wind industry to be competitive. The LEANWIND report also identifies developing improved models and tools for logistic concepts as an area which should be explored. It finds that there is a shortage of tools considering the logistic system for offshore wind farms, with [6] being an exception. As this particular tool does not contain an optimisation element, a similar tool incorporating optimisation, potentially with multiple objectives (e.g. time / cost) for installation may prove to be useful. An existing O&M model, e.g. [19] or similar, could also be incorporated, with the addition of multi objective optimisation, considering cost and availability. Current models tend to focus on one particular aspect, or optimisations are limited to a single objective (cost), and it may be advantageous for operators were able to plan to installations optimised based on both time and costs, allowing them to focus their resources more directly; and in the O&M phase to use optimisations based on cost and availability, as government incentives may be related to availability, while the operator would be seeking to maximise its revenue.

The primary focus in this research is on the use of simulation to address the particular logistical requirements of the offshore wind industry; while the use of multi-objective optimisation will be addressed in future work.

3. IMPLEMENTATION OF SIMULATION MODEL

It is proposed to model the supply chain for installation of offshore wind farms, into a simulation tool (which will be an extension of MYMIC's Scalable End-to-End Logistic Simulation [SEELS]) (Mathew, Mastaglio, & Lewis, 2012); and further to construct a tool for the multi-objective optimisation of the O&M phase of the offshore wind life cycle (e.g. cost vs availability of power output – it would desirable to maximise availability, while simultaneously minimising costs.) This optimization tool should also be designed to allow for integration into SEELS.

Initially the focus will be on the extension of SEELS to cover offshore wind farms and their associated transport vessels. The tool may be extended to other forms of offshore renewable energy, once the use case of offshore wind has been developed.

As SEELS is an established tool for logistics, it is proposed to develop architecture for offshore wind based upon the existing SEELS architecture, as partially represented in Appendix A (an extract from the SEELS simulation core architecture). Figure 2 below represents a method in which this structure may be built upon to similarly model offshore wind farms. It uses a class based upon the original Port structure to represent a wind farm Terminal is used as the basis for representation of both an individual turbine (or also an actual terminal in the case of a port with dedicated offshore wind facilities); with OperationalArea in the left branch of the diagram serving as the basis for components of an individual turbine (foundation, tower, nacelle, rotor hub, blades etc.) OperationalArea in the right branch of the diagram representing structures shared across by multiple turbines, or indeed the entire wind farm (offshore maintenance base, grid connections, etc.)

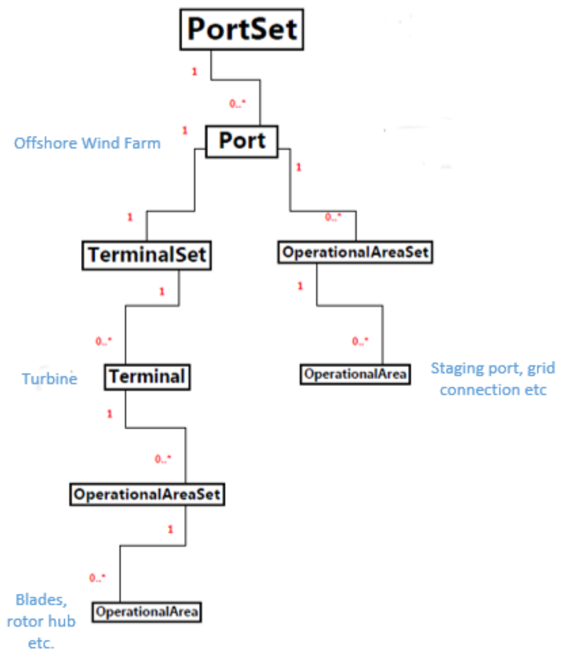

Figure 2: Proposed structure for SEELS extension.

As the components involved in offshore wind are quite large and are transported and assembled using different strategies, it will be necessary to add definitions to vessels and staging areas to define which components they may transport, store and operate on. It will therefore be required to add further

Each component of a turbine will also have parameters relating to particular failures which may occur, e.g. a

probability of each such failure occurring on that component within a given timeframe.
The simulation should allow for planned maintenance. Figure 3 below shows a potential process flow – in each time step in which the simulation is running, it will initially determine which turbines require maintenance in that window - those which fail in this window, plus those which on which maintenance was required in the previous window, but was not carried out. Each maintenance task will have a priority assigned to it, so that the tasks which are most urgently required are attended to first. The availability of equipment and components necessary to each task is checked. Weather will be used as an input to the model in some form, hence the accessibility of the turbines requiring maintenance will be determined by ensuring that wave height and wind speeds are not above the thresholds for safe access to the turbines. Finally, the maintenance tasks will be carried out as time allows in the window, starting with those of highest priority. All tasks which are not carried out will be carried over into the next window as still requiring action.

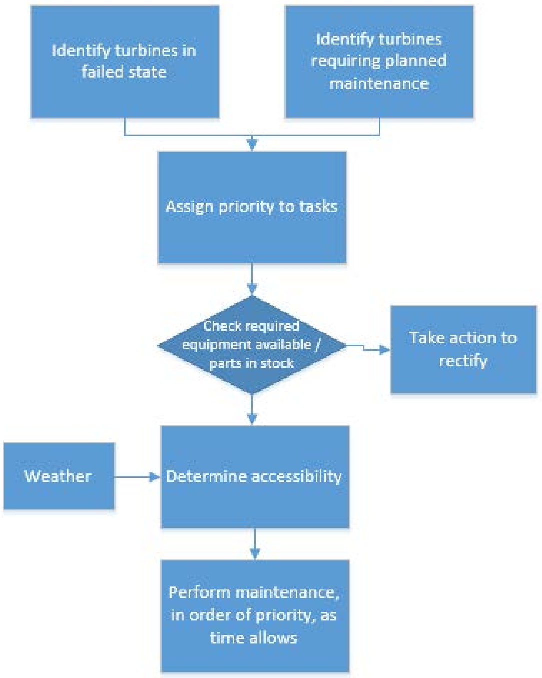

Figure 3 – Proposed process flow for simulation of O&M

4. CONCLUSION

The development of the offshore renewable energy sector in the coming years can be aided by the use of simulation. A proposed simulation tool for the case of offshore wind has been presented.

ACKNOWLEDGMENTS

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APPENDIX A – OFFSHORE WIND FOUNDATIONS / FLOATING STRUCTURES

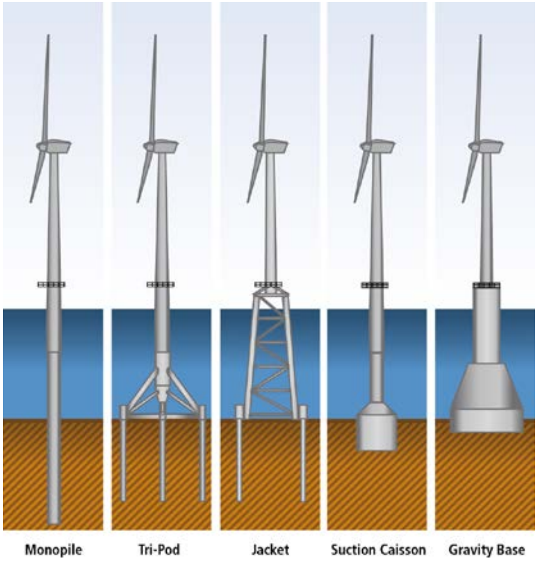


Figure A1 - Foundations

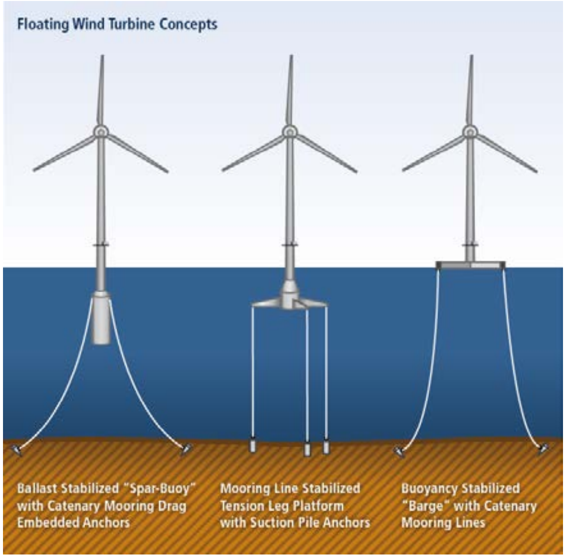
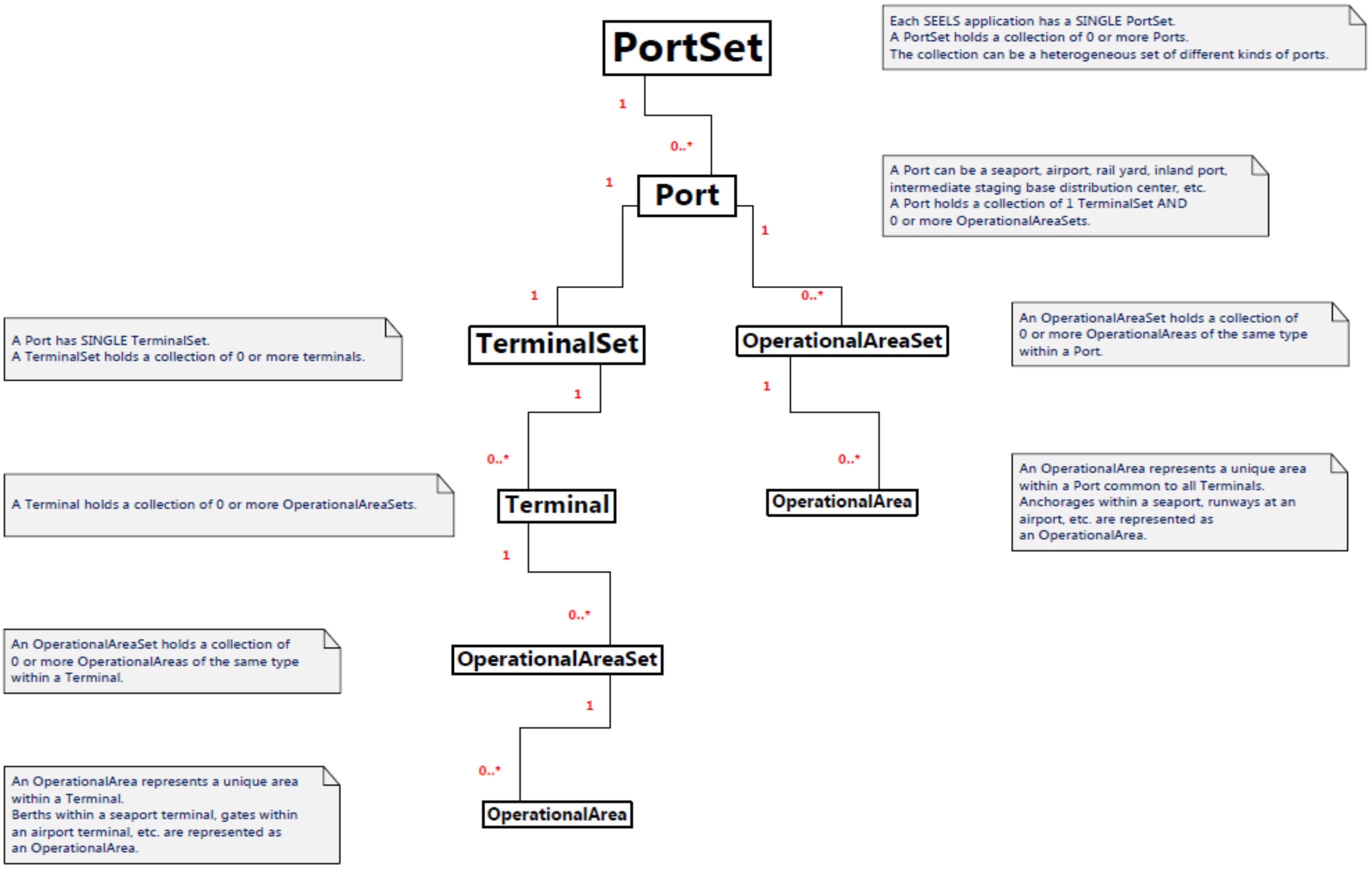


Figure A2 – Floating structures

APPENDIX B – EXTRACT FROM SEELS ARCHITECTURE



Architecture Organization from SEELS Simulation Core Architecture - UML Class Diagrams - Version 6

REFERENCES

Ait-Alla, A., Quandt, M., & Lütjen, M. (2013). Simulation-based aggregate Installation Planning of Offshore Wind Farms. *International Journal Of Energy*, *7*(2), 23–30. Retrieved from http://www.naun.org/main/NAUN/energy/b012001-201.pdf

Besnard, F., Fischer, K., & Tjernberg, L. B. (2013). A Model for the Optimization of the Maintenance Support Organization for Offshore Wind Farms. *IEEE Transactions on Sustainable Energy*, *4*(2), 443–450. http://doi.org/10.1109/TSTE.2012.2225454

Besnard, F., Patriksson, M., Strömberg, A., Fischer, K., & Bertling, L. (2011). A Stochastic Model for Opportunistic Maintenance Planning of Offshore Wind Farms, 1–8.

Dalgic, Y., Dinwoodie, I., Mcmillan, D., & Revie, M. (n.d.). Optimum CTV Fleet Selection for Offshore Wind Farm O & M Activities.

Dalgic, Y., Lazakis, I., & Turan, O. (n.d.). Vessel charter rate estimation for offshore wind O & M activities.

Dewan, A. (2013). *Logistic & Service Optimization for O&M of Offshore Wind Farms*.

Dinwoodie, I. A., & McMillan, D. (2014). Operational strategies for offshore wind turbines to mitigate failure rate uncertainty on operational costs and revenue. *IET Renewable Power Generation*, *8*(4), 359–366. http://doi.org/10.1049/iet-rpg.2013.0232

Dinwoodie, I., Endrerud, O. V, Hofmann, M., Martin, R., & Bakken, I. (n.d.). Reference Cases for Verification of Operation and Maintenance Simulation Models for Offshore Wind Farms. (Submitted for publication; draft version.), (7465), 1–14.

Dinwoodie, I., McMillan, D., Revie, M., Lazakis, I., & Dalgic, Y. (2013). Development of a Combined Operational and Strategic Decision Support Model for Offshore Wind. *Energy Procedia*, *35*, 157–166. http://doi.org/10.1016/j.egypro.2013.07.169

EWEA. (2011). *Pure Power - Wind energy targets for 2020 and 2030*. Retrieved from http://www.ewea.org/

EWEA. (2013). *The European offshore wind industry—key trends and statistics 2013*. *European Wind Energy Association*, *Brussels*. Retrieved from http://www.ewea.org/fileadmin/files/library/publications/statistics/European_offshore_statistics_2013.pdf

Hagen, B., Simonsen, I., Hofmann, M., & Muskulus, M. (2013). A multivariate Markov Weather Model for O&M Simulation of Offshore Wind Parks. *Energy Procedia*, *35*(1876), 137–147. http://doi.org/10.1016/j.egypro.2013.07.167

Hahn, M., & Bloch, C. (2013). U.S. Offshore Wind Manufacturing and Supply Chain Development.

Hofmann, M. (2011). A Review of Decision Support Models for Offshore Wind Farms with an Emphasis on Operation and Maintenance Strategies. *Wind Engineering*. http://doi.org/10.1260/0309-524X.35.1.1

Hofmann, M., & Sperstad, I. B. (2013). NOWIcob – A Tool for Reducing the Maintenance Costs of Offshore Wind Farms. *Energy Procedia*, *35*(1876), 177–186. http://doi.org/10.1016/j.egypro.2013.07.171

Hofmann, M., & Sperstad, I. B. (2014). Technical documentation of the NOWIcob tool (D5.1-53) 3.

Karyotakis, A. (2011). *On the optimisation of operation and maintenance strategies for offshore wind farms*. University College London. Retrieved from http://discovery.ucl.ac.uk/1302066/

Lange, K., Rinne, A., & Haasis, H. D. (2012). Planning maritime logistics concepts for offshore wind farms: A newly developed decision support system. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 7555 LNCS, pp. 142–158). http://doi.org/10.1007/978-3-642-33587-7_11

Mathew, R., Mastaglio, T. W., & Lewis, A. (2012). A simulation tool for high-fidelity modeling of complex logistical networks, (c), 6–14.

Philibert, C., & Holttinen, H. (2013). *IEA Technology Roadmap - Wind Energy*. Retrieved from http://www.iea.org/roadmaps/

Phillips, J. L., Morgan, C. A., & Jacquemin, J. (n.d.). Evaluating O & M strategies for offshore wind farms through simulation - the impact of wave climatology, *44*(0).

Rademakers, L., Braam, H., & Obdam, T. (2008). Tools for estimating operation and maintenance costs of offshore wind farms: State of the Art. *Proc. of EWEC*, *2008*. Retrieved from http://www.ecn.nl/docs/library/report/2008/m08026.pdf

Rademakers, L., Braam, H., Obdam, T. S., & v.d. Pieterman, R. P. (2009). Operation and maintenance cost estimator (OMCE) to estimate the future O&M costs of offshore wind farms. In *European Offshore Wind 2009 Conference*. Retrieved from http://proceedings.ewea.org/offshore2009/proceedings/statscounter.php?id=5&IDABSTRACT=116

Scholz-Reiter, B., Heger, J., Lütjen, M., & Schweizer, A. (2010). A MILP for installation scheduling of offshore wind farms. *International Journal Of Mathematical Models and Methods in Applied Sciences*, *5*(2), 371–378. Retrieved from http://www.naun.org/multimedia/NAUN/ijmmas/19-793.pdf

Scholz-Reiter, B., & Lütjen, M. (2010). Planning and control of logistics for offshore wind farms. In *Proceedings of the 12th WSEAS international conference on Mathematical and computational* *methods in science and engineering* (pp. 242–247). Retrieved from http://www.wseas.us/e-library/conferences/2010/Faro/MACMESE/MACMESE-39.pdf

Statoil. (2009). *Hywind Assembly and Installation Study*.Wind and Water Power Technologies Office. (2014). *Offshore Wind Projects 2006 - 2014*.

FUZZY INFERENCE ABOUT WIND RESOURCES IN URBAN ENVIRONMENT

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ABSTRACT
The advancement of renewable energy technology gave rise to the implementation of small wind towers in urban areas. A major problem in predicting the use of such facilities is the difficulty of measuring in micro-regions that suffer different influences of the surrounding environment. Thus a wind tower may be installed where it does not work properly. Fuzzy inference systems try to approach the thinking process of human language allowing for a more assertive decision process. For the development of a fuzzy inference system dealing with this issue it was necessary to determine the variables that most impact on the variation of the wind distribution in micro urban environment as well as using data from automatic weather stations which allow to estimate the wind regime for a macro region. These data are fed in a fuzzy inference system that outputs an adequacy rank for sitting a small wind tower.

Keywords: wind energy, artificial intelligence, renewables

1. INTRODUCTION

Wind energy extraction possibilities within cities are a challenging but promising research issue. It features opposite scenery to large wind farms. In the last quoted, the required great investment and the power extracted from the plant justify long-term measurement seasons, usually two or three years. In the urban environment with the prevalence of stand-alone, small turbines and custom installations for users a rather different approach is required. Shorter measurement sessions and faster investing / equipment installation decisions are necessary, notwithstanding being essential to take into account several factors.

Among these factors one can quote not only an obvious macroclimatic characterization of the wind regime but also a series of uncertain, fuzzy parameters hard to define accurately in an analytical way. Considering a single building where a wind turbine is supposed to be set up, the area surrounding it has many influencing factors: nearby buildings concentration or scattering, height and shape variation of the constructions, changing of wind directions, displacement heights, etc.

Considering the importance of knowing wind potential for urban planners, turbine manufactures, as well as for potential consumers, this research investigates a possible simpler approach for in site wind resource estimation. It resembles the 'measure-correlate-predict' approach described by Landberg et al (2003) but expects to replace the statistical correlation tools by a fuzzy inference one.

When traditional logical concepts are not able to assess adequately the desired parameters, fuzzy logic allows the use of vague concepts, expressing qualitative information form.

To address these differences in the environment of the uncertainties of the common mathematical models, the use of fuzzy logic proposed by Loft Zadeh in 1965, can be used to generate answers to several questions considering imprecise and contradictory data.

In recent studies in the United Kingdom Hopkins (2013) determined some parameters that influence the wind regime in the environment of large cities. This is done through the use of a complex data modeling with detailed geometric description of buildings and vegetation. Calculations of aerodynamic characteristics of wind regimes are performed and integrated to LIDAR system (light detection and ranging) that allowed to describe and predict the wind efficiency of the studied sites. In another study Caldas (2010) uses the WindPro and WaSP software for modeling the wind regime. In that study it is noticed the need of using input data as terrain models, roughness and constructs which may be fuzzyficated for possible use in fuzzy systems. The results of Hopkins studies (2013), it is suggested that the possible locations of wind turbines within a city can differ greatly

concerning suitability: "*The results suggest that there are viable sites distributed thought the city, including within the complex city centre, where at the most suitable locations above-roof Wind speeds may be comparable to those observed at well exposed rural sites. However, in residencial áreas, consisting of groups of buildings of similar Heights, it is likely that the majority of properties will be unsuitable turbine locations.*"(Hopkins, .2013).
For calibration of the fuzzy inference model using XFUZZY tool, it was necessary creating variables that could be transformed into linguistic variables, based on those that are most likely to influence the wind regime within the urban environment. The second part of this article describes the methodology for designing the system and its outputs. Using wind data from weather station of Arraial do Cabo (Rio de Janeiro / Brazil), one may determine that according to the statistical techniques region has an adequate potential for installing wind towers. By using a portable anemometer and measuring in a short period of time three different points compared with the automatic anemometer sought to demonstrate how the variables may have some influence on the suitability for installation of wind towers and subsequent calibration of the system. In the third part of the article the measurements are shown, as well as tables inserts and system outputs so in the subsequent section a pre-completion of studies done recently in the region can be given.

2. METHODOLOGY

The methodology relies on three cornerstones. At first, wind regime of a given region, obtained from large scale wind atlas is taken into account through the extraction of Weilbull distribution. A simpler and faster gathering of wind regime corresponding to data acquired from an anemometer inside urban area is also considered, producing its own Weibull distribution. At a second step, the anemometer installation site, which is also a candidate location for turbine placement, is described through fuzzy sets that express the location adequacy.
Finally rules relating macro and local wind distribution along with location adequacy are established for fuzzy inference purpose and processed by fuzzy inference toolkits.

2.1. Weilbul Distribution from Wind Dataset

In order to describe wind potential in a given region, a well-established procedure is the use of Weilbull probability distribution (Dal Monte et al, 2012). In this work the R package 'bReeze' (Graul and Poppinga, 2014) was used. Data were obtained from the automatic weather station Arraial do Cabo in the state of Rio de Janeiro, Brazil. Arraial Station-A606 OMM = 86892 (Figure 2) based on the year 2014 from January to December. The results are shown in Figure 1 below, extracted from the data series of case study region.

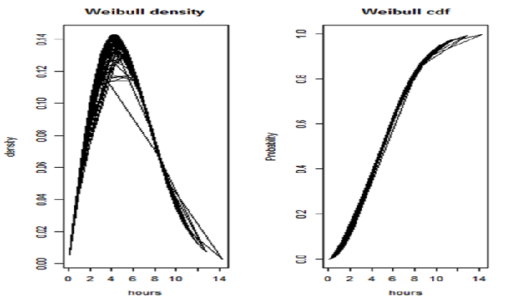


Figure 1: Weibull Distribution from study region dataset

Figure 2: Arraial do Cabo-A606 Code OMM: 86892 Latitude: -22.975468º Longitude: -42.021450º Height: 3 meters. Register: 23 UTC

2.2. Fuzzy Inference Rules

One of the major differences of using fuzzy inference systems is the possibility of using linguistic terms to demonstrate what one sees in reality. *"A linguistic variable u in the universe of discourse U is defined in a set of terms (or terminology), names or label, T (u), with each value being a fuzzy number set in U. For example, if u is speed, then its set of terms T (u) could be: T (speed) = {low, medium, fast} on the universe of discourse U = [0.100], where low, medium, fast, are terms or language of greatness variable speed"*. (Shaw, 2007).
To design the system for suitability for use vertical wind towers in urban areas was necessary to build sets of variables which the following. Based on Beaufort scale (LISKA et al, 2013) the variable *TVelocidadeVentos* (wind speed):

Table 1 Beaufort scale

Degree	Type	m/s	Ground effect
0	calm	<0,3	Smoke rises vertically
1	breeze	0,3 a 1,5	Smoke indicates wind direction
2	light breeze	1,6 a 3,3	The leaves move; mills start working
3	light breeze	3,4 a 5,4	Leaves flutter- and unfurl flags in the wind

4	moderate breeze	5,5 a 7,9	Dust and small raised roles; move the tree branches
5	strong breeze	8 a 10,7	Movement of large branches and small trees
6	fresh wind	10,8 a 13,8	Moving large trees; difficulty walking against the wind

Table 2 Fuzzy Variables based on the scale of Beaufort

Degree	Type	m/s	*Fuzzy variable*
0	calm	<0,3	mf0Calmo
1	breeze	0,3 a 1,5	mf1Aragem
2	light breeze	1,6 a 3,3	mf2BrisaLeve
3	light breeze	3,4 a 5,4	mf3BrisaFraca
4	moderate breeze	5,5 a 7,9	mf4BrisaModerada
5	strong breeze	8 a 10,7	mf5BrisaForte
6	fresh wind	10,8 a 13,8	mf6VentoFresco

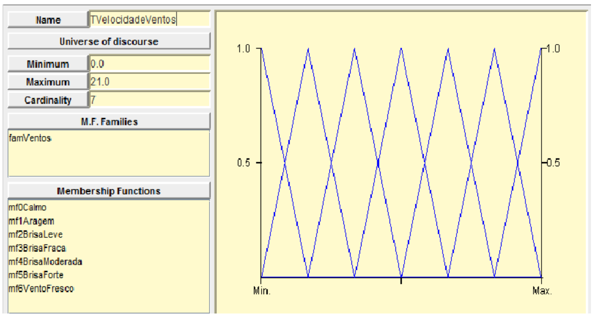


Figure 1. TVelocidadeVentos in XFUZZY

Roughness Land as *TRugosidade* based on *European Wind Atlas (1989)* roughness table that clusters terrain features in roughness classes.

Table 3 Scale Roughness Land Caldas (2010)

z0	Terrain features	Class roughness
1,00	city	3
0,80	forest	
0,50	outskirts	
0,40		
0,30	belts of trees	
0,20	trees and shrubs	2
0,10	farm with closed vegetation	
0,05	farm with open vegetation	
0,03	farm with few trees / buildings	1
0,02	areas of airports with buildings and trees	
0,01	areas of airport runways	
0,008	meadow	
0,005	plowed soil	
0,001	snow	
0,0003	sand	
0,0002		
0,0001	water (lakes, rivers, oceans)	0

Table 3 Fuzzy variable based on roughness degrees

Class roughness	fuzzy variable
3	mf3AltaCidadeFlorestaSuburbios
2	mf2MediaAreaComArvoresArbustos
1	mf1MediaPastoAeroportosFazenda
0	mf0BaixaAreiaNeveAgua

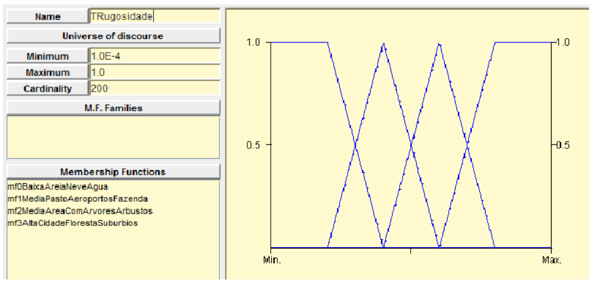


Figure 4 variable TRugosidade in XFUZZY

The orography is one of the most important elements in the characterization of the atmospheric flow, according to Caldas (2010). For this *TOrografia* type was created consisting of

- *mf0TerrenoPlano*
- *mf1ElevacoesDecliveSuave*
- *mf2TerrenoMontanhoso*

Also were created the variables:

1. *TProximidadeConstrucoes*: (proximity of buildings)
    - *mf0Distantes*
    - *mf1Proximas*

- *mf2MuitoProximas*

2. *TAlturaConstrucoes:* (height of buildings)

   - *mf0Baixa*
   - *mf1Media*
   - *mf2Altas*

3. *TAlturaLocalInstalacao* : (instalation height)

   - mf0Baixa
   - mf1Media
   - mf2Alta

4. *TAdequabilidade:* (suitability)

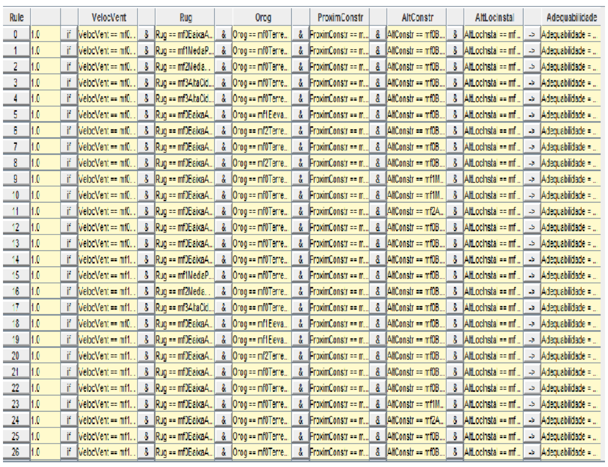
   - mf0Baixa
   - mf1Media
   - mf2Alta

Based on input variables the rules of fuzzy inference were created which do not require high computational demand as systems using symbolic computation (Shaw, 2007).

Expert systems that use progressive inference, also called "forward-chained inference" generally employ discrete variables or symbolic variables converted into discrete numbers. As a result, end up dealing with a huge number of rules, hundreds and often thousands are used in the knowledge base. This order of magnitude is much greater than the number of rules typically used in a fuzzy system (typically between 20 and 100).

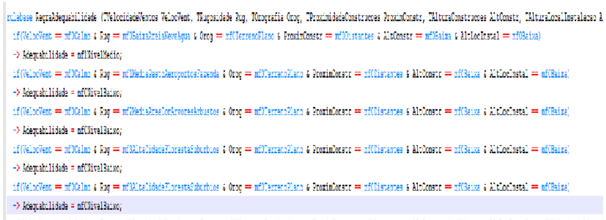
In addition, the expert system rules are triggered in series, not in parallel. Its true purpose is to conduct some kind of diagnosis, acting as a director or giving suggestions (Shaw, 2007).

A total of 86 inference rules were created for system tests, as shown in Figures 5 and 6.



Rule			VelocVent		Rug		Orog		ProximConstr		AltConstr		AltLocInstal		Adequabilidade
0	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
1	1.0	if	VelocVent == mf0..	&	Rug == mf1MediaP..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
2	1.0	if	VelocVent == mf0..	&	Rug == mf2Media..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
3	1.0	if	VelocVent == mf0..	&	Rug == mf3AltaCid..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
4	1.0	if	VelocVent == mf0..	&	Rug == mf3AltaCid..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
5	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf1Eleva..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
6	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf2Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
7	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
8	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf2Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
9	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf1M..	&	AltLocInstal == mf..	->	Adequabilidade = ..
10	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf1M..	&	AltLocInstal == mf..	->	Adequabilidade = ..
11	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf2A..	&	AltLocInstal == mf..	->	Adequabilidade = ..
12	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
13	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
14	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
15	1.0	if	VelocVent == mf1..	&	Rug == mf1MediaP..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
16	1.0	if	VelocVent == mf1..	&	Rug == mf2Media..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
17	1.0	if	VelocVent == mf1..	&	Rug == mf3AltaCid..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
18	1.0	if	VelocVent == mf0..	&	Rug == mf0BaixaA..	&	Orog == mf1Eleva..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
19	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf1Eleva..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
20	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf2Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
21	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
22	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
23	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf1M..	&	AltLocInstal == mf..	->	Adequabilidade = ..
24	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf2A..	&	AltLocInstal == mf..	->	Adequabilidade = ..
25	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..
26	1.0	if	VelocVent == mf1..	&	Rug == mf0BaixaA..	&	Orog == mf0Terre..	&	ProximConstr == m..	&	AltConstr == mf0B..	&	AltLocInstal == mf..	->	Adequabilidade = ..

Figure 5 Fuzzy Inference Rules created from XFUZZY



```
rulebase RegraAdequabilidade (TVelocidadeVentos VelocVent, TRugosidade Rug, TOrografia Orog, TProximidadeConstrucoes ProximConstr, TAlturaConstrucoes AltConstr, TAlturaLocalInstalacao A
 if(VelocVent == mf0Calmo & Rug == mf0BaixaAreiaNeveAgua & Orog == mf0TerrenoPlano & ProximConstr == mf0Distantes & AltConstr == mf0Baixa & AltLocInstal == mf0Baixa)
 -> Adequabilidade = mf1NivelMedio;
 if(VelocVent == mf0Calmo & Rug == mf1MediaPastoAeroportosFazenda & Orog == mf0TerrenoPlano & ProximConstr == mf0Distantes & AltConstr == mf0Baixa & AltLocInstal == mf0Baixa)
 -> Adequabilidade = mf0NivelBaixo;
 if(VelocVent == mf0Calmo & Rug == mf2MediaAreaComArvoresArbustos & Orog == mf0TerrenoPlano & ProximConstr == mf0Distantes & AltConstr == mf0Baixa & AltLocInstal == mf0Baixa)
 -> Adequabilidade = mf0NivelBaixo;
 if(VelocVent == mf0Calmo & Rug == mf3AltaCidadeFlorestaSuburbios & Orog == mf0TerrenoPlano & ProximConstr == mf0Distantes & AltConstr == mf0Baixa & AltLocInstal == mf0Baixa)
 -> Adequabilidade = mf0NivelBaixo;
 if(VelocVent == mf0Calmo & Rug == mf3AltaCidadeFlorestaSuburbios & Orog == mf0TerrenoPlano & ProximConstr == mf0Distantes & AltConstr == mf0Baixa & AltLocInstal == mf0Baixa)
 -> Adequabilidade = mf0NivelBaixo;
```

Figure 6 Code Created from XFUZZY

2.3. Set of fuzzy logic tools

This study used a free access code tool GNU XFUZZY XML-based (Moreno Velo, et al 2012). This is JAVA programming language based tool. This kind of software allows integration with other systems, which can be useful in designing a decision support system that is available to all, as well as Juzzy is also a free also available (Wagner, et al 2014).

2.4 Case Study

In order to test the developed procedure, studies have been developed in the central eastern part of the state of Rio de Janeiro, Brazil. It was made an investigation of the site by observing the wind atlas of the State of Rio de Janeiro, anemometer data collection to profile the wind regime of the region and site visit in 3 different points with different characteristics, but nearby enough to proof of urban interference with respect to surrounding constructions, height of buildings, terrain and local roughness measurement using a simple handheld anemometer, assuming the simplicity of logic characterized by uncertainties.

The study was done with 5 measurements on July 13, 2015, day with few clouds and big gusts of winds. A portable anemometer with coupled and adapted tripod to not interfere with the measurements was used, being placed at a low height of approximately 1.10 m.

- Point 1 is approximately 50m from the automatic weather station on the beach with no buildings around with low topography and low roughness of the terrain with good incidence of winds;

- Point 2 is 80m from the automatic weather station and in urban areas with buildings around with a rise of 4m in relation to sea level;

- Point 3 is approximately 300m from the automatic weather station at the foot of a hill and with plenty of buildings around, beyond the asphalt.

Figure 7 Angels Beach Arraial do Cabo - RJ measurement location, source: Google Earth

Figure 8 point 1 source: author

Figure 9 Point 2 source: author

Figure 10 Point 3 Source: author

3. RESULTS

To process the collected data it was used a fuzzy system created in XFUZZY in the Verification-Monitorization module.

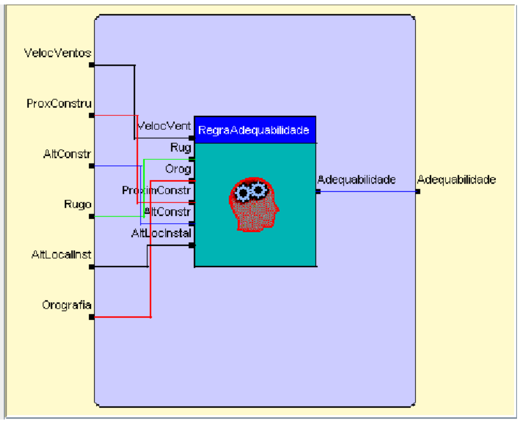


Figure 11 System Suitability Fuzzy created with the tool XFUZZY

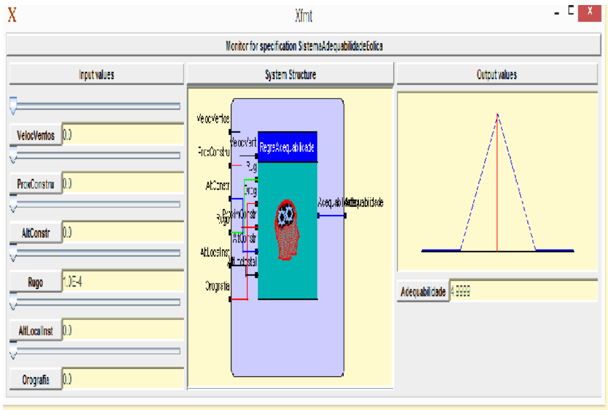


Figure 12 Monitoring with XFUZZY

Recorded measurements for the selected points:

- Point 1:

Table 5. Record of measured data in the site. source: author

Date	Time	Wind speed m/s	Temperature º C
11/07/2015	11h:45min	5.3	25
11/07/2015	12h:45min	5.5	25
11/07/2015	14h:00min	4.5	24
11/07/2015	15h:00min	2.8	28
11/07/2015	16h:00min	2.0	25

Table 6 Profile section 1

Roughness	sand - 0,003	mf1
Average winds speed	4.02 m/s – Weak breeze 3	mf3
High buildings	low	mf0
Buildings proximity	distant	mf0
Orography	0m	mf0
Local height installation	Low 1.10m	mf0
Weather station distance	50m	

Suitability (using fuzzy)	mean	

- Point 2:

Table 7 Record of measured data in the site source: author

Date	Time	Wind speed m/s	Temperature º C
11/07/2015	11h:50min	2.2	28
11/07/2015	12h:50min	2.3	28
11/07/2015	14h:10min	2.1	28
11/07/2015	15h:10min	2.1	28
11/07/2015	16h:10min	2.0	25.9

Table 8 Profile section 2

Roughness	City - 1	mf3
Average winds speed	2.14 m/s – weak breeze 2	mf2
High buildings	means	mf1
Buildings proximity	near	mf1
Orography	4m	mf1
Local height installation	Low 1.10m	mf0
Weather station distance	80m	
Suitability (using fuzzy)	High	

- Point 3:

Table 9 Record of measured data in the site. source: author

Date	Time	Wind speed m/s	Temperature º C
11/07/2015	12h:00min	1.3	28.1
11/07/2015	13h:00min	2.3	28
11/07/2015	14h:20min	1.2	29
11/07/2015	15h:20min	0.9	27
11/07/2015	16h:20min	1.0	24

Table 10 Profile section 3

Roughness	City - 1	mf3
Average winds speed	1.34 m/s – breeze 1	mf1
High buildings	means	mf1
Buildings proximity	Very close	mf3
Orography	6m	mf2
Local height installation	low 1.10m	mf0
Weather station distance	300m	
Suitability (using fuzzy)	low	

4. CONCLUSION

Preliminary tests suggest the feasibility of the proposed method. Further testing is required for verification of the method according to the proposed rules of inference. An initial observation the urban environment, in a place with lots of winds may seem suitable for installation of small wind towers, but some parameters must be considered as terrain and nearby buildings, as demonstrated in the case study where the installation in site 3 which is at the foot of a hill with lots of buildings around demonstrates not being a good place to install wind towers on top of houses.

REFERENCES

Dal Monte A., Castelli M.R., Benini E., 2012.Evaluation of the Wind Potential in the Province of Belluno (Italy). Proceedings IEEE Workshop on Environmental Energy and Structural Monitoring Systems (EESMS), 28-28 Sept., Perugia, Italy.

Graul C., Poppinga C., 2015. bReeze: Functions forWind Resource Assessment. Available from: http://cran.r-project.org/web/packages/bReeze/index.html [accessed 08 April 2015]

Landberg L., Myllerup L., Rathmann O., Petersen E. L., Jorgensen B. H., Badger J., Mortensen N. G., 2003. Wind Resource Estimation — An Overview. Wind Energy, 6, 261-271.

LISKA, G., et al. "Estimativas de velocidade máxima de vento em Piracicaba-SP via Séries Temporais e Teoria de Valores Extremos." Revista Brasileira de Biometria, São Paulo 31.2 (2013): 295-309.

Millward-Hopkins, J. T., et al. "Mapping the urban wind resource over UK cities using an analytical downscaling method." Proceedings of the EWEA Annual Conference. EWEA, 2012.

Millward-Hopkins J., 2013. Predicting the Wind Resource Available to Roof-Mounted Wind Turbines in Urban Areas. Thesis (PhD). The University of Leeds.

Moreno-Velo F.J., Barriga A., Sáncho-Solanez S., Baturone I., 2012. XFSML: An XML-based Modeling Language for Fuzzy Systems Proceedings IEEE International Conference on Fuzzy Systems, Jun. 10-15. Brisbane (Australia).

Rio de Janeiro State, Wind Atlas. Available from http://www.cresesb.cepel.br/publicacoes/download /atlas_eolico/AtlasEolicoRJ.pdf[Acessed 07 December 2014]

Simões, Marcelo Godoy, and Ian S. Shaw. "Controle e modelagem fuzzy."São Paulo. Blucher: Fapesp (2007).

Wagner C., Pierfitt M., McCulloch, .J., 2014. JuzzyOnline: An Online Toolkit for the Design, Implementation, Execution and Sharing of Type-1 and Type-2 Fuzzy Logic Systems. Proceedings of IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) July 6-11, Beijing, China

Zadeh L.A., Fuzzy Sets. 1965. Information and Control v8, 338-353.

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COAGULATION-ADSORPTION-FLOCCULATION PROCESS TO REGENERATE CIP SOLUTIONS. EFFECT ON THE PHYSICOCHEMICAL AND CLEANING PROPERTIES OF REGENERATED SOLUTIONS

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ABSTRACT
The regeneration of Cleaning In Place (CIP) solutions presents an increasing interest for chemical industries (food, cosmetic and textile sectors) and sewage treatment plants.
For the industrial sector, the regeneration of cleaning solutions allows to perform economies of water and chemical reactants. It is also involved indirectly in the improvement of the industrial productivity by reducing the downtime of the production equipment destined to the CIP operation.
On the other hand, the operation of regeneration allows to reduce global costs, in sewage treatment plants, of used solutions rejected by CIP units. Indeed, for the dairy industry, this volume can be up to 95% of the rejected volume to treatment plants. The present study exposes a new regeneration method of CIP solutions using sequences of adsorption-coagualtion-flocculation processes, coupled with a physical separation by decantation, flotation or membrane filtration

Keywords: Adsorption, Caustic soda, Cleaning-in-place Green chemistry, Regeneration

1. INTRODUCTION

Cleaning In Place (CIP) procedures are widely used, especially in the pharmaceutical and food industries, in order to ensure food hygiene and product safety as a whole (Gillham et al., 1999). The use of water and chemical reagents required for these cleaning operations have significant economical and environmental impacts. For the industrial sector, the regeneration of cleaning solutions allows to perform economies of water and chemical reactants by changing the cleaning sequences while maintaining constant the process efficiency. The improvement of the industrial productivity by reducing the downtime of the production equipment allowed to the CIP operation is also of concern. Besides, the operation of regeneration allows to reduce the process global costs, in sewage treatment plants, of used solutions rejected by CIP units. The volume of these effluents varies with the type of the process production and the nature of the treated products. Indeed, for dairy industries, processing 10^6 L of milk per day, up to 5 L of effluent per 1 L of processed milk are generated and 54 to 98 % of this volume comes straight from CIP units. In most cases the replacement of the CIP solutions is based on subjective criteria, such as color or odor and can be related to the characteristics of the equipment to be cleaned (Alvarez et al., 2007; Gésan-Guiziou et al., 2007). Different works have been carried out in order to investigate techniques used in the regeneration of cleaning solutions. Dresch (1998) studied sedimentation and centrifugation processes. Membrane filtration, such as microfiltration (Tragardh andJohansson, 1998), ultrafiltration (Dresch et al., 1999) and nanofiltration (Räsänen et al., 2002), have been tested. The present study highlights a new regeneration method of CIP solutions using sequences of adsorption-coagulation-flocculation processes and coupled with a physical separation by decantation. The chemical nature of effluents (strongly acidic or alkaline pH) and the extreme temperatures (70 °C to 75 °C) do not allow the application of reactants commonly used in water purification by physicochemical treatment, such as aluminium sulphate ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$) or ferrous sulfate ($FeSO_4$ $7H_2O$). Indeed, the coagulation of suspended solids in an aqueous solution is only possible within a defined pH range for each type of coagulant (pH values above 4 for ferric chloride and between 6 and 7 for aluminium sulphate). Studies led by Dif et al. (2013) based on a patent filed by Tastayre (2010) have made it possible to remedy this problem by using crude clay minerals as adsorbent/coagulant reagent. It has been demonstrated that clays such as montmorillonite, kaolinite and bentonite operate either by reducing electrostatic repulsion forces between the particles and thereby increasing the contribution of attractive van der Waals forces in the coagulation of suspended particles, or by adsorption and sequestration of suspended particles (Lagaly and Ziesmer, 2003). Assaad et al. (2007) showed the capacity of Smectite to coagulate at low concentrations in the solution. This effect is also advantageous in the recycling of CIP solutions due to the entrainment of pollutant particles by clay aggregates. Indeed,
Dif et al. (2013) demonstrated that the treatment effect of Smectite can operate over the whole pH range. It was shown that acidic pH causes destabilization and agglomeration of the adsorbent, which in turn induces the precipitation of the adsorbate and increases the

amount of organic matter removed from the CIP solution by carryover mechanisms in addition to the adsorption mechanism. At alkaline pH, the Smectite adsorbent still has a coagulative effect that contributes to global process efficiency by adsorption and carryover of the organic matter. Smectite thus emerges as a compound of choice for processing alkaline CIP solutions (Dif et al., 2013). Moreover, Delgado et al. (1986) and Kalra et al. (2003) have shown that characteristics (pH and ionic strength) inherent to polluted solutions significantly modify the physicochemical properties (average diameter and zeta potential) of complexes of clay-organic/inorganic pollutants and the electrostatic interactions governing adsorption at the clay surface. It would be productive to explore these parameters in order to increase treatment process efficiency.

To save on the water and chemical reagents needed to clean CIP solutions, the recycling operation should be performed several times to increase the profitability of the process. This requires that any residual organic and inorganic matters in the regenerated CIP solution do not contribute to equipment contamination. Indeed, cleaning efficiency is dependent on various parameters such as surface roughness, physicochemistry (Jullien et al., 2008) of the equipment, cleaning procedures and operating conditions. However, the physicochemical properties of the cleaning solution remain the most determinant parameter (Eide et al., 2003). Likewise, the disinfectant properties of CIP solutions remain crucial for qualifying cleaning procedures as hygienic. The aims of this work are multiple. First, the principle of a recycling process combining adsorption/coagulation and flocculation mechanismswas tested over several cycles on caustic soda and nitric acid CIP solutions soiled by whole milk. Physicochemical characteristics of regenerated solutions, such as total chemical oxygen demand (COD_T), total nitrogen content, surface tension and the loss of active material (acid or base) were tracked over time.

Based on these analyses, the efficiency of the recycling treatment process and its impact on CIP solutions was assessed. Second, the impact of multiple regenerations of caustic soda solutions on cleaning quality was investigated. Microbiological analyses were performed on stainless steel surfaces contaminated with bacteria and spores recognized as highly CIP-resistant. Finally, the solubilizing power of the regenerated CIP solutions on organic matter was tested by running the cleaning operation on soiled stainless steel surfaces fouled with sour cream.

2. MATERIALS AND METHODS

2.1. The adsorbate

The coagulation/adsorption tests were carried out, firstly on pure compounds of casein, lactose and triglycerides (vegetable fat). This product is often found, in significant amounts, in the dairy CIP solutions after cleaning process (Condat-ouillon; 1995). On the second time, analyzes were performed on whole milk in order to put forward potential cross-effects between the different compounds mentioned above on the treatment process.

2.2. The adsorbent

Analyses were performed with the Smectite (Elofloc 2-1, Elodys International, France) at the crude state. The sieving technique was carried out in order to select particle sizes between 40 and 80 μm, and thus to homogenize the clay suspensions used for adsorption tests. The flocculation step was performed using a cationic polymer with high molecular weight (D9645A, DESHENG, CHINA).

2.3. Regenerations of cleaning solutions

2.3.1. Treatment application on pure compounds

Regeneration cycles performed according to the reprocessing mechanism described by Dif et al. (2013) were investigated on a model of caustic soda (99% purity, VWR) and nitric acid (68% AnalaR NORMAPUR, VWR) CIP solutions presenting similar physicochemical properties to soiled those found in industry at the CIP unit outlet. In order to mimic cleaning conditions in the dairy industry, average concentrations of soda caustic and nitric acid solutions (i.e. 2% w/w or 0.53 M and 0.45 M M concentration, respectively) were used as reported by Räsänen et al. (2002) and Alvarez (2003).

Fig. 1 presents the setup for regeneration of CIP solutions. The reprocessing procedure consists in heating the acid or basic solutions to typical CIP station temperatures, i.e. 80 °C for sodium hydroxide solution and 60 °C for nitric acid solution (Ricketts, 2008).

Smectite and flocculant were used in optimal amounts as determined earlier. Regeneration experiments were carried out at 50 °C and the Smectite and flocculant were added after a 3 min time step. After the treatment steps, the suspended particles are separated from the liquid phase by sedimentation for 30 min.

Each regeneration cycle lasts 1 h 30 min, which corresponds to combined duration of heating, cooling and decantation. Added to this time is the 20 min duration of the centrifugation step used to process by-products. After each regeneration, the by-products recovered at the bottom of the decanter are centrifuged for 20 min at 15,000 g (10,000 rpm). This procedure recovers the supernatant, to be reintroduced into the initial solution, and the compact sludge, at 21% dry matter. Volume of treated solution is measured after each recycling cycle. This procedure tracks solution loss during processing and separation. Solution loss is estimated at 5% of the initial volume at each regeneration cycle, so this amount is added before each new recycling cycle in order to keep constant the treatment conditions. Reprocessing efficiency was monitored on regenerated solutions by measuring the

turbidity, COD_T (soluble and insoluble) and total nitrogen (TN) content of the treated solutions.
Photometric test kit method was applied for COD_T and TN measurements.

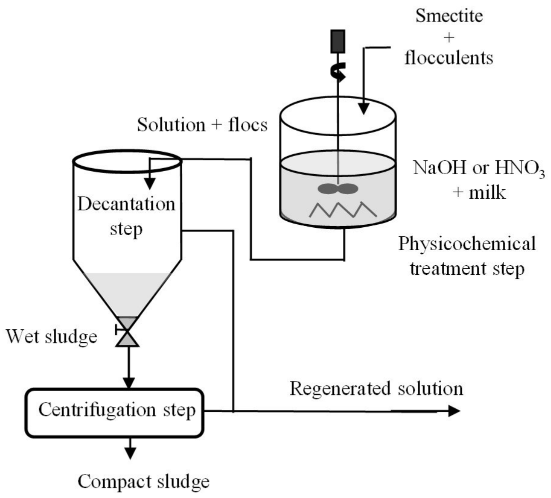


Figure 1 : Regeneration setup

2.3.2. Analysis of the cleaning capacity of the regenerated solutions

Analyses were led in order to study the cleaning and disinfection performance of regenerated solutions (R5, R10, R15, and R20). For each test, the solutions were compared against freshly prepared solutions (R0). First, efficiency of the regenerated solutions was checked by studying the cleaning kinetics of stainless steel tubes fouled with dairy cream. This was achieved by monitoring solution turbidity during the cleaning cycles to identify both rate of soiling detachment and ability of the solution to solubilize the fouling matter. Figure 2 depicts the setup used in this part.

2.3.3. Analysis of the effect of regeneration on fouled tube cleaning kinetics

The cleaning efficiency of regenerated solutions on organic and inorganic fouled matter was assessed using kinetics analysis on pipe walls (316 L stainless steel, polished inside to an average surface roughness Ra of ≤ 0.8 μm) cleaning. Turbidity measurements were used as parameter characterizing fouled dairy cream detachment and solubilization from the stainless steel surfaces, which was made possible due to the good solubility of fat matter in alkaline solutions. Triplicate experiments were performed on three separate tubes (L = 140 mm, inner Ø 23 mm) presenting very similar characteristics to tubes used in the food industry.
The fouling procedure consists of placing steel tubes, containing 13 g of dairy cream spread perfectly evenly throughout, in an oven at 130°C for 1 h 30. Each tube was turned every 15 min to evenly distribute the cream. The tubes were then reintroduced into a second oven at 100°C for 20 min. The fouled tubes were then fitted into the CIP installation at the test section designed as illustrated in Figure 2. This setup creates a modular system able to operate reduced volumes of cleaning solutions (10 L) using tank 3 (Figure 2). Experiments consisted in starting the cleaning step with tank 1 (30 L) and quickly switching the rig to tank 3 in order to concentrate the detached matter and thus assay solution turbidity during CIP cycles. Trials were performed with regenerated CIP solutions (R5, R10, R15 and R20) at 50-55°C for 30 min at 1500 L.h^{-1}. This time interval was set to be consistent with the fouled pipe preparation conditions and CIP procedure that enable good cleanability of pipe walls. Indeed, preliminary tests carried out with various solutions showed that surfaces are well cleaned after 10 min. Comparisons were made against freshly prepared solutions (R0) under the same conditions. Turbidity was measured at the outlet of tank 3 using a Hach 2100 turbidimeter (Hach Company, USA).

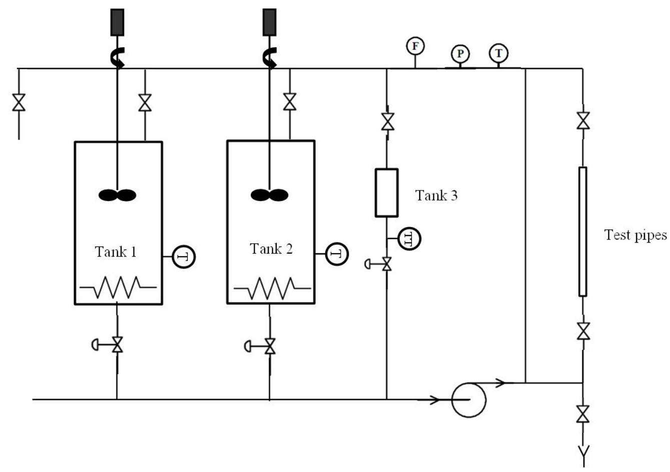


Figure 2: Diagram of the experimental setup

3. RESULTS AND DISCUSSIONS

3.1. Identification of optimal treatment reactant concentrations

Development of physicochemical regeneration of CIP solutions requires the identification of optimal treatment concentrations of Smectite and flocculant. Thus, the turbidity of regenerated solutions is chosen as a criterion of comparison between tests. This characterization method is considered as a reliable and easily implementable for reproducible process scale-up.
Figure 3 plots turbidity as a function of both Smectite (1.5 to 3 g.L^{-1}) and flocculant (1 to 25 mg.L^{-1}) concentrations applied to 2% (w/w) NaOH solutions soiled with 1% (v/v) whole milk.
Turbidity measurements on the supernatant, for each sample, were used to identify optimal cross-concentrations of Smectite and flocculant. At low flocculant concentration, turbidity decreased rapidly at

clay concentrations from 1.5 to 4 g.L^{-1} then increased or stabilized as higher concentrations (Fig. 3).

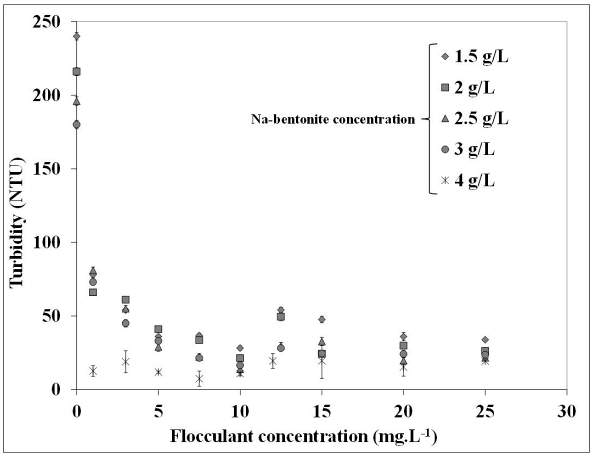


Figure 3: Effect of reactant concentrations on turbidity in NaOH regenerated solutions

The slight increase beyond the concentration of 10 g.L^{-1} is likely driven by the reactants and not contamination in the solution, as the water treatment literature reports that an overestimation of the flocculant and coagulant amount used in the physicochemical depollution induces an increase in turbidity of the medium caused by excess reactants remaining in suspension in the medium (Assaad et al., 2007). A clay concentration of 3 g.L^{-1} is considered sufficient to adsorb or carryover the pollution contained in the solution according to the mechanisms described by Dif et al. (2013). Beyond this concentration, small particles of clay that have not interacted with the pollutant matter remain in suspension in the solution. Thus, a Smectite concentration of 4 g.L^{-1} yields low turbidity values but increases experimental variability (see the larger standard deviations in Fig. 3) due to an excess of clay relative to the actual pollution content. The overestimation of the amount of flocculant able to facilitate and speed up the decantation of formed aggregates also induces an increase in turbidity of the NaOH solutions, highlighted by the significant standard deviation values observed at the flocculant concentration of 15 mg.L^{-1}. Thus, successive regenerations of NaOH solutions will be conducted using concentrations of 3 g.L^{-1} Smectite and 10 mg.L^{-1} flocculant (D9645C, DESHENG, CHINA).

The same approach was used to determine optimum concentrations for nitric acid reprocessing (results not shown in this work). The lowest turbidity was obtained for concentrations of 2.5 g.L^{-1} Smectite and 30 mg.L^{-1} flocculant (F9907A, DESHENG, CHINA). These concentrations will be used in further successive regenerations of nitric acid CIP solutions. The use of flocculant at high concentration, in comparison to the treatment of NaOH solutions, can be explained by the pH effect on the soluble fraction of the pollution. As described by Dif et al. (2013), the acidic pH induces soluble matter precipitation, in addition to the dispersion of particles present in the solution. Thus, the decantation of these particles needs the utilization of high flucculant concentration compared to the basic pH.

3.2. Successive regenerations of cleaning solutions

Successive recycling tests were performed using the same 2% (w/w) NaOH or nitric acid solutions several times in ageing and recycling cycles. The purpose of these trials was to systematically investigate the effect of the regeneration process on the composition and characteristics of cleaning solutions over successive ageing and recycling cycles. Since turbidity measurements alone are not sufficient to analyse the process efficiency, residual COD_T and TN measurements were applied on both acid and alkaline solutions.

3.2.1. Successive regenerations of soiled NaOH solutions

The COD_T present in NaOH solutions was monitored along the successive regeneration cycles before and after reprocessing to determine the COD_T reduction rate after each cycle and COD accumulation in successively regenerated solutions. Figure 4 shows initial and residual COD_T and total nitrogen (TN) at each regeneration cycle, where initial COD_T or TN corresponds to calculated values of pollution induced by the addition of 1% (v/v) whole milk.

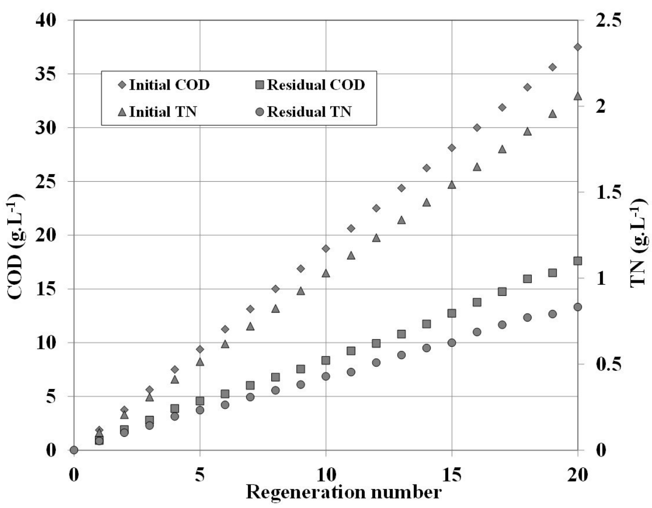


Figure 4: Initial and residual COD and TN of NaOH solutions over successive regeneration cycles.

Repeat addition of milk induces an increase in COD_T of 1.9 g.L^{-1} at each cycle. COD_T reduction rate, i.e. the ratio of removed COD_T to accumulated COD_T, was calculated after each regeneration cycle. The obtained values reveal that about half of the COD_T is removed at each cycle. The physicochemical regeneration reprocessing substantially eliminates all suspended and colloidal solids. Reduction in solution turbidity after recycling is better than 95% of the initial value. End-of-treatment turbidity values were between 5 and 20 NTU (Fig. 5). This result shows that the increase in COD_T values is due to the accumulation of a fraction of the soluble organic matters partially removed by the treatment process, and confirms the results obtained by Dif et al. (2013) on the adsorption of soluble casein molecules by the Smectite particles. Adsorption experiments performed by Dif et al. (2012) showed the physicochemical reprocessing with Smectite which removes the milk triglycerides and proteins fraction but not the lactose fraction. Indeed, the values of total carbon before and after treatment remain unaltered, which indicates that most of the COD_T accumulated in the regenerated solutions originates in lactose addition besides residual fat and proteins. This is supported by a study performed by Dresch (1998) on the regeneration of CIP solutions rejected by the dairy industry, which highlighted the contribution of fat matter to the increase in COD_T values in NaOH solutions since the skimmed milk/COD_T ratio was 1.8.

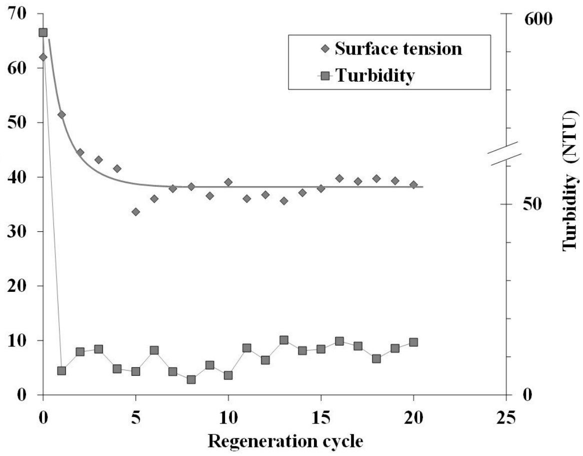


Figure 5: Surface tension (mN m^{-1}) and turbidity (NTU) of NaOH solutions (NTU) over successive regeneration cycles

The amount of nitrogenous matter contained in regenerated solutions is also evaluated using the photometric test kit method.

Preliminary tests of freshly prepared NaOH solutions (without milk), in which Na-bentonite and flocculant are added at the optimum concentrations, showed the absence of nitrogenous matter in the medium. Thus, the residual TN contained in regenerated solutions is due to the remaining proteinaceous matter after treatment and not to the excess of flocculant. Figure 4 shows the evolution of initial and residual total nitrogen contents for different regeneration cycles. These test results suggest that an accumulation of proteinaceous matter occurs through regeneration cycles even though about 60% of total nitrogenous matter is removed at each cycle (Figure 4). Dif et al. (2013) showed that Na-bentonite treatment of caustic soda solutions containing casein is incomplete, as 50% of soluble proteins initially introduced remains in the solutions subsequent to each regeneration cycle, which closely matches the results here observed. The reduction rate stabilizes at the 6^{th} regeneration. Under the imposed process conditions, this plateau (60%) is likely due to solution saturation with surfactants due to saponification of the fat matter and degradation of the protein matter. Figure 4 also shows that the amounts of COD_T and total nitrogen in regenerated solutions similarly evolve. However, Dif et al. (2012) found that the effectiveness of the physicochemical treatment is not the same for casein, lactose or triglyceride molecules. As molecules of lactose have a low molecular weight compared to proteins and TG, lactose molecules are less efficiently discarded by adsorption and coagulation processes. Accordingly, along successive regenerations a higher increase in COD_T content relative to TN is expected. This result shows that during treatment, aggregations of various compounds found in the solution may occur due to the action of the Na-bentonite and that matter removal is achieved by decantation and carryover regardless the nature of compound (Dif et al., 2013). This hypothesis is supported by Condat-Ouillon (1995) who showed that a fraction of proteins aggregates into larger particles, being associated to fat, will eventually sedimentate.

Modifications of the composition and physicochemical properties of regenerated solutions were observed by monitoring wetting properties based on surface tension measurements. Fig. 5 shows that surface tension decreases monotonously during the five first cycles of regeneration and then stabilizes at around 35 – 40 mN.m^{-1}. The initial value features the surface tension of freshly-prepared 2% (w/w) NaOH solution. The decrease of this value is due to the accumulation of surfactants formed by amino acid degradation products resulting from the saponification of lipids and other molecules that, under these pH and temperature conditions, are hydrolysed and form surfactant molecules (Condat-Ouillon, 1995).

These results confirm findings by Alvarez et al. (2007) showing a decrease in surface tension throughout regenerations of CIP solutions by membranes processes. The slow saponification of fat matters in alkaline medium allows the formation of glycerol and fatty acid salts (soap) which further contribute to this phenomenon.

According to Condat-Ouillon (1995), only 34% of fat matter is saponified after 8 h of reaction between fat matter (0.5 g L_1) and caustic soda (2% w/w) at 80 _C. The stabilization of surface tension at the 5th regeneration could be related to the critical micelle concentration (CMC) reached in the solution due to the accumulation of surfactants. Indeed, surfactant molecules have the ability to self-associate above a critical concentration called critical micelle concentration (Akisada et al., 2005) and thus form macromolecular aggregates of a few nanometers in diameter, called micelles.

Beyond this CMC, the chemical potential of the surfactant remains almost constant. Thus, any surfactant added beyond the CMC is associated to micelles. The surface tension at the CMC is therefore the lowest surface tension attainable.

To sum up, tests performed on soiled NaOH solutions showed that using Na-bentonite as a reagent in alkaline detergent treatments makes it possible to adsorb and trap substantially all of the particulate pollution and a large fraction of the soluble pollution (more than 60% of COD_T at each cycle). The active matter is preserved up to 97.5%. Surface tension measurements on regenerated caustic soda solutions showed stabilization at around 35 mN.m^{-1} from the 5th regeneration, corresponding to the CMC. The effect of decreasing surface tension on the cleaning properties of regenerated solutions was tested on stainless steel surfaces.

3.2.2. Successive regenerations of soiled HNO_3 solutions

The recycling protocol for nitric acid is substantially the same as that used to treat NaOH solutions, the only difference being the flocculation operation which uses a high-molecular-weight anionic polyacrylamide.

Measurements of HNO_3 concentration in regenerated acid solutions show a slight decrease in the molarity of nitric acid during the first two regenerations. For subsequent regenerations, the molarity loss can be considered as negligible due to the volume correction. Indeed, concentrations measured from the second regeneration were at 0.43 mol.L^{-1} as compared to an initial concentration of 0.45 mol.L^{-1}. The turbidity measurements showed near-zero values from the first regenerated solution, which reflects the total elimination of suspended solids.

Efficiency of the treatment process through regenerations was also studied by monitoring COD and TN evolutions. Figure 6 shows a reduction of total COD down to 80% for the last regenerations (13 to 20). TN elimination rate was also good, at 58% of initial accumulated amount (Figure 6).

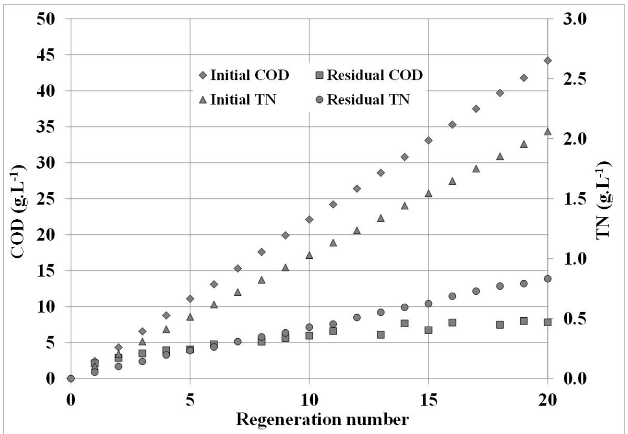


Figure 6: Initial and residual COD and TN of nitric acid solutions over successive regeneration cycles.

Compared to NaOH, nitric acid demonstrates a higher total COD reduction rate. This result can be explained by the elimination of most of the compounds present in the solution as a result of the acidic effect on matter precipitation. Dif et al. (2013) also found that during adsorption experiments on molecules of casein in acid medium, neutralization of the total protein charge at this pH directly impacts the solubility of the molecule, causing precipitation. This phenomenon is enhanced by the presence of clay particles.

3.3. Effect of successive regenerations on the cleaning and disinfection efficiencies of NaOH solutions

The recycling process combining adsorption-coagulation with flocculation allows cleaning solutions to acquire new physicochemical properties throughout the ageing process with an increase in total COD, by accumulation of the residual COD after treatment, and a decrease in surface tension. Here, is also investigated the effect of multiple regenerations on the detergent efficiency of NaOH solutions. Microbiological analyses were carried out on stainless steel pipes contaminated with bacteria and spores frequently isolated from dairy products and equipment surfaces.

3.3.1. Cleanability study on stainless steel pipes contaminated by *B. subtilis* spores under dynamic flow conditions

Trials under dynamic flow conditions were carried out on a CIP setup containing a hydraulic rig formed by 3 pipes previously contaminated with spores of *B. subtilis*. The cleaning step was operated using NaOH solutions freshly prepared or regenerated several times over.

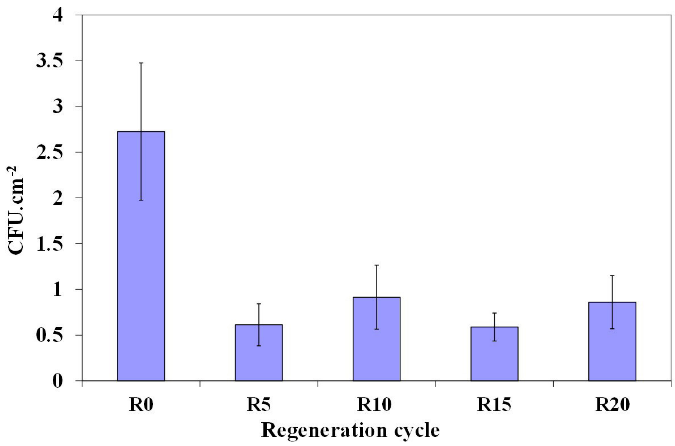


Figure 7: Residual contamination of stainless steel pipes after cleaning in dynamic flow conditions with freshly-prepared and regenerated NaOH solutions

This part of the study worked with moderate cleaning temperatures and flow rates in order to keep enough residual contamination after cleaning allowing comparison between disinfection properties of tested solutions. The aim was to quantify residual contamination after cleaning with fresh and regenerated NaOH solutions (Figure 7) and to compare the cleaning efficiencies of the solutions. Cleaning efficiency was evaluated by the ratio of residual contamination after cleaning to initial maximum contamination, which was fixed at 50 CFU.cm^{-2}. Results showed a high (> 95%) percentage of spores eliminated for all tested solutions, and that regenerated NaOH solutions maintained their efficiency against the sporulated form of *B. subtilis* as their bactericidal action was preserved through regenerations. Comparisons based on percentage of eliminated spores showed that regenerated solutions were actually more efficient than freshly-prepared solutions. Indeed, regenerated solutions posted cleaning efficiencies of between 97% and 99% whereas a freshly prepared NaOH posted spore removal rates of between 94% and 95%. This added efficiency could be due to regenerated solutions acquiring new physicochemical properties. Throughout the regenerations, residual organic matters remaining after regeneration induce a decrease in surface tension that allows better surface wettability and consequently faster cleaning than with fresh NaOH solutions. Finally, comparison between regenerations R5, R10, R15 and R20 does not allow us to draw firm conclusions on an increase in bactericidal effect of solutions with increasing in number of regenerations and, thereafter, accumulation of soluble matters. Analysis of the microbiological quality of regenerated solutions used in cleaning trials or inoculated with 10^5 CFU.mL^{-1} of *B. subtilis* spores showed that this strain can survive but in very low amounts compared to the amount initially introduced.

3.4. Study on fouled pipe CIP kinetics using freshly prepared and regenerated NaOH solutions

The detachment kinetics of matter (dairy cream) adhering to stainless steel pipe walls were investigated in response to regenerated solutions R5, R10, R15 and R20 and freshly-prepared solutions. Cleaning was performed using a reduced volume in order to concentrate the detached matter. Turbidity measurement was considered a good characterization parameter for both detachment and solubilization effects. Each regenerated solution was tested against a fresh solution in order to compare the results obtained under the same operating conditions.

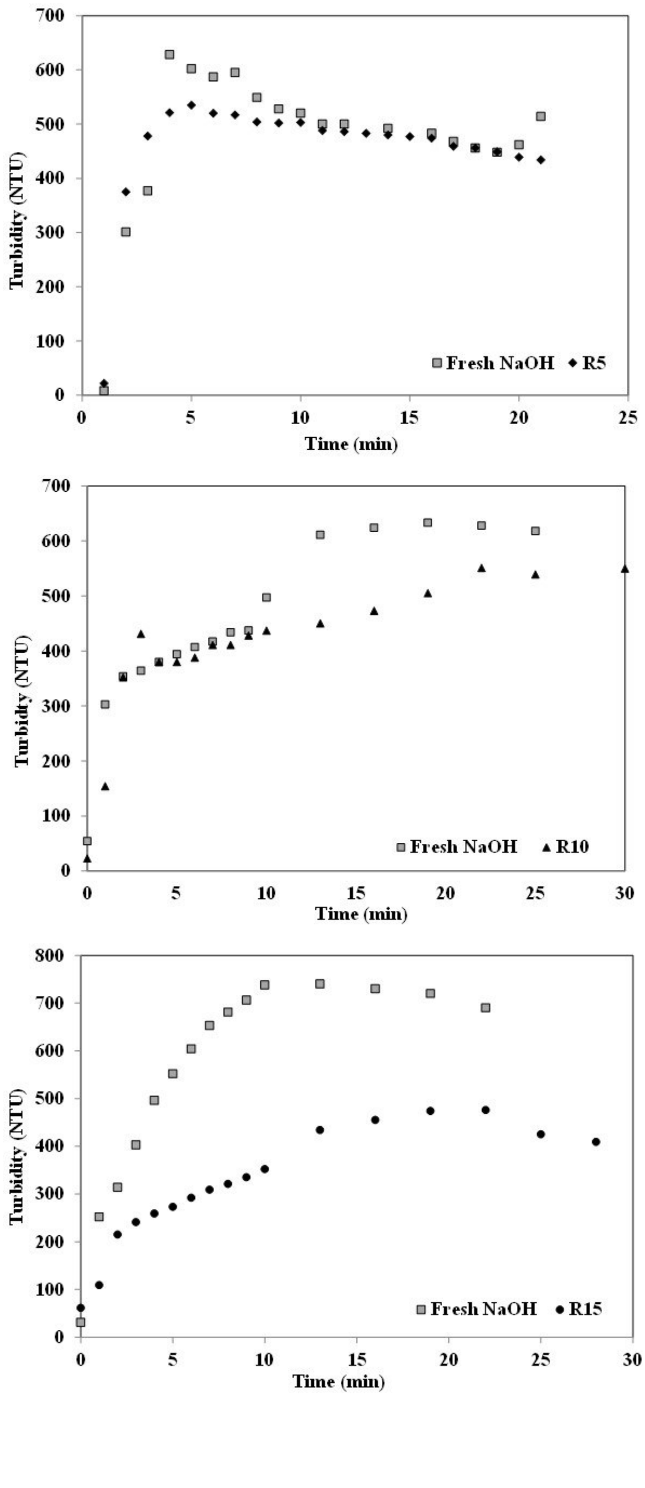
The different curves plotted (Figure 8) distinguish three phases in the cleaning kinetics:

- The first phase involves the detachment of weakly-adhered matter. During this phase (2 to 3 min), flow rate tends to stabilize, which explains the between-trial variation in turbidity,

- The second phase involves an increase in the turbidity in the different test solutions. This phase (lasting roughly 10 min) allows the detachment of all matters fouling the pipe walls,

- The third phase involves the solubilization of matters detached into the cleaning solutions. This solubilization occurs under the combined action of the agitation caused by solution circulating through the rig and the effect of thermal action of cleaning.

Figure 8 also shows that turbidity remains low in regenerated solutions compared to freshly-prepared solutions. Knowing that after 10 min of cleaning, all the matter adhering to the surface has detached, this result may be due to a larger solubilizing effect of regenerated solutions than freshly-prepared solutions.



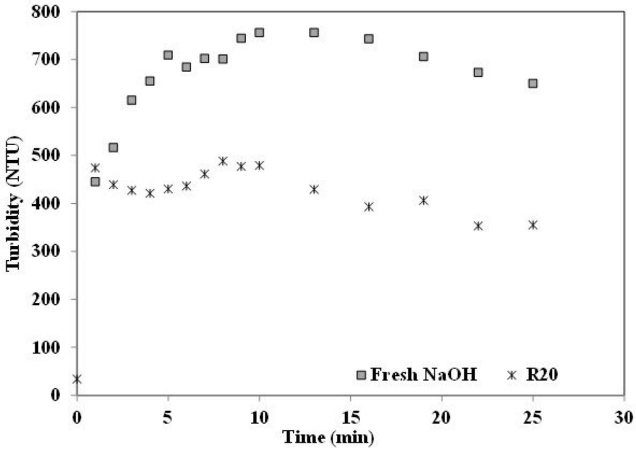


Figure 8: Study of fouled pipe cleaning kinetics using turbidity measurement. Fresh NaOH solutions compared against regenerated solutions (R5, R10, R15 and R20)

4. CONCLUSION

For food and cosmetic industries using CIP stations, excessive utilization of commercial detergents containing sequestering, surfactant, foaming and stabilizer agents creates heavy economic and environmental costs. A physicochemical recycling process combining adsorption–coagulation–flocculation operations enables CIP solutions to self-activate by producing surfactants from the organic matter removed from equipment surfaces. Here, different experiments demonstrated Na-bentonite to be an efficient CIP solution treatment reagent by adsorbing and sweeping of a portion of the contaminant load at the CIP station outlet. The purifying effect comes from its physicochemical properties and its ability to coagulate at extreme pHs, leading to the following efficiencies:

- NaOH solution regeneration with up to 97.5% of active matter, on top of eliminating over 60% total COD in each cycle,
- HNO_3 solution regeneration with over 95% of active matter, on top of eliminating over 80% of total COD in each cycle,
- Physicochemical reprocessing under extreme conditions of temperature (from 15 to 70°C) and pH (from 0 to 14).

Regenerated cleaning solutions can be directly reused for other cleaning cycles. During cleaning trials testing bactericidal effects found that, regenerated solutions outperformed fresh-prepared solutions and maintain their bactericidal activity for at least 20 regenerations. Analysis of cleanability kinetics on fouled pipes found that regeneration solutions have lower turbidity than freshly-prepared solutions, especially at the end of the cleaning cycle. This is due to an accumulation of soluble organic matter that, transformed over the regeneration process into surfactant compounds, leads to a decrease in surface tension and a subsequently solubilization of matter detached from pipe walls. The improved bactericidal and detergent properties of regenerated solutions can be exploited for cleaning equipment that conventional solutions struggle to clean. Thus, regenerated solutions could also be used as an additive to freshly-prepared solutions to improve their cleaning efficiency.

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REFERENCES

Akisada H., Kuwahara J., Noyori K., Kuba R., Shimooka T., Yamada A., 2005. Critical micelle concentrations and interaction parameters of aqueous binary surfactant: ionic surfactant mixtures. J. Colloid Interface Sci. 288, 238–246.

Alvarez N., 2003. Rationalisation du nettoyage en place en industrie laitière: durée, pertes de matière, effluents. PhD Thesis, Ecole Nationale Supérieure d’Agronomie de Rennes. France.

Alvarez N., Gésan-Guiziou G., Daufin G., 2007. The role of surface tension of re-used caustic soda on the cleaning efficiency in dairy plants. Int. Dairy J. 17, 403–411.

Assaad E., Azzouz A., Nistor D., Ursu A.V., Sajin T., Miron D.N., Monette F., Niquette P., Hausler R., 2007. Metal removal through synergic coagulation-flocculation using an optimized chitosan-montmorillonite system. Appl. Clay Sci. 37, 258–274.

Condat-Ouillon C., 1995. “Etude du comportement des constituants laitiers en milieu fortement sodique et de leurs interactions en filtration sur membrane: application à la régénération par filtration tangentielle des solutions alcalines de NEP de l’industrie laitière”. PhD. Thesis, INP Toulouse, France.

Delgado A., Gonzalez-Caballero F., Bruque J., 1986. On the zeta potential and surface charge density of montmorillonite in aqueous electrolyte solutions. J. Colloid Interface Sci. 113, 203–211.

Dresch M., Daufin G., Chaufer B., 2001. Integrated membrane regeneration process for dairy cleaning-in-place. Sep. Purif. Technol. 22-23, 181–191.

Dif M., Blel W., Tastayre G., Lendormi T., Sire O., 2013. Identification of transfer mechanisms involved in soiled CIP solutions regeneration at extreme pH and high temperature. J. Food Eng. 114, 477–485.

Dif M., 2013. Application d'un procédé d'adsorption-coagulation-floculation à la régénération de solutions acide et basique de Nettoyage En Place. Effet bénéfique du traitement sur les propriétés physicochimiques et nettoyantes des solutions régénérées. PhD thesis, University of Nantes, France.

Dif M., Blel W., Sire O., 2012. New physico-chemical regeneration process of CIP solutions. Chem. Eng. Trans. 29, 829–834.

Dresch M., 1998. Procèdes à membrane de régénération des solutions de nettoyage de l'industrie laitière PhD. Thesis, Ecole Nationale Supérieure d'Agronomie de Rennes. France.

Eide M.H., Homleid J.P., Mattsson B., 2003. Life cycle assessment (LCA) of cleaning-in-place processes in dairies. Lebensm. Wiss. Technol. 36, 303–314.

Faille C., Fontaine F., Bénézech T., 2001. Potential occurrence of adhering living Bacillus spores in milk product processing lines. J. Appl. Microbiol. 90, 892–900.

Fernández P., Riera F.A., Álvarez R., Álvarez S., 2010. Nanofiltration regeneration of contaminated single-phase detergents used in the dairy industry. J. Food Eng. 97, 319–328.

Gésan-Guiziou G., Alvarez N., Jacob D., Daufin G., 2007. Cleaning-in-place coupled with membrane regeneration for re-using caustic soda solutions. Sep. Purif. Technol. 54, 329–339.

Guglielmotti D.M., Mercanti D.J., Reinheimer J.A., Quiberoni A. del L., 2011. Efficiency of physical and chemical treatments on the inactivation of dairy bacteriophages. Front. Microbiol. 2, 1–11.

Husmark U, Benezech T., Faille C., Ronner U., 1999. Bacillus spores and moulding with TTC AGAR: a useful method for the assessment of food processing equipment cleanability. Biofouling 14, 15–24.

Judd S.J., Hillis P., 2001. Optimisation of combined coagulation and microfiltration for water treatment. Water Res. 35, 2895–2904.

Jullien C., Bénézech T., Le Gentil C., Boulangé-Petermann L., Dubois P., Tissier J., Traisnel M., Faille C., 2008. Physico-chemical and hygienic properties modifications of stainless steel surfaces induced by conditioning with food and detergent. Biofouling 24, 163–172.

Kalra S., Pant C.K., Pathak H.D., Mehata M.S., 2003. Studies on the adsorption of peptides of glycine/alanine on montmorillonite clay with or without co-ordinated divalent cations. Colloids Surf. A. Physicochem. Eng. Asp. 212, 43–50.

Lagaly G., Ziesmer S., 2003. Colloid chemistry of clay minerals: the coagulation of montmorillonite dispersions. Adv. Colloid Interface Sci. 100-102, 105–128.

Mo L., Huanga X., 2003. Fouling characteristics and cleaning strategies in a coagulation-microfiltration combination process for water purification. Desalination 159, 1–9.

Pan Y., Breidt Jr., F., Kathariou S., 2006. Resistance of Listeria monocytogenes biofilms to sanitizing agents in a simulated food processing environment. Appl. Environ. Microbiol. 72, 7711–7717.

Paugam L., Delaunay D., Diagne N.W., Rabiller-Baudry M., 2013. Cleaning of skim milk PES ultrafiltration membrane: On the real effect of nitric acid step. J. Memb. Sci. 428, 275–280.

Räsänen E., Nyström M., Sahlstein J., Tossavainen O., 2002. Purification and regeneration of diluted caustic and acidic washing solutions by membrane filtration. Desalination 149, 185–190.

Ricketts N., 2008. Cleaning-in-Place: Dairy, Food and Beverage Operations. A.Y. Tamime (Ed). Int. J. Dairy Technol. 61, 412–413.

Salle F., Douillard J.M., Bildstein O., Gaudin C., Prelot B., Zajac J., Van Damme H., 2013. Driving force for the hydration of the swelling clays: case of montmorillonites saturated with alkaline-earth cations. J. Colloid Interface Sci. 395, 269–76.

Suarez L., Diez M.A., Garcia R., Riera F.A., 2012. Membrane technology for the recovery of detergent compounds. J. Ind. Eng. Chem. 18, 1859–1873.

Tastayre G., 2010. “Method and device for the regeneration of polluted scrubbing solutions” WO2010063906. WIPO, France.

Tragardh G., Johansson D., 1998. Purification of alkaline cleaning solutions from the dairy industry using membrane separation technology. Desalination 119, 21–29.

SIMULATION OF HOME ACTIVITIES TO ANALYZE HOUSEHOLD ELECTRICITY COSUMPTION

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ABSTRACT
The aim of this paper is to propose a simulation model to study residential energy consumption. The model includes the inhabitant´s activities linked to their behavior and their habits.
Real data obtained from smart-meters placed in several households have been used to model the electrical consumption of the equipment.
The model is able to assess the influence in residential energy consumption electricity of behavior changes and to quantify the cost of good/bad good consumption habits and its environmental consequences.
We combine methods coming from statistical techniques and the engineering analysis.

Keywords: simulation, residential energy consumption electricity

1. INTRODUCTION

Nationally, energy consumption of the residential sector accounts for 16-50% of the amount consumed by all sectors and averages approximately 30% worldwide (Swan and Ugursal (2009)). Due to this importance many scientific research articles are devoted to model the energy consumption of the residential sector. A complete review can be found in Swan and Ugursal (2009), while specific models are described in Paatero and Lund (2006), Shimoda et al. (2004), Larsen and Nesbakken (2004), and Muratori et al (2013). The inhabitant behavior strongly influences energy consumption patterns and is an important factor that accounts for a big share of the observed variability in the household consumption (see, for example, Chiou (2009), Kashif et al. (2011) and Keirstead and Sivakumar (2012)).
The aim of this paper is to model the residential sector energy consumption by estimating the energy consumption of representative set of individual houses. We combine methods coming from statistical techniques and the engineering analysis.
Our interest is to understand the characteristics of the individual house consumption which present high variability, still not completely defined, mainly due to a great variety of households (individual houses/apartments, different sizes, building materials, sun orientation,…), differences in the occupant behavior and habits and differences in the amount and quality of the equipment.
In our model we consider all the consumptions coming from appliances and lighting. These consumptions are strongly dependent of the attitudes of the home inhabitants, while other consumptions, for example those related with the thermal control, are also highly influenced by other factors as the region climate, the building material characteristics and size, etc.
The construction of simulation model heavily relies on the input data available. We have detailed consumption data at minute frequency level obtained from metering devices placed in several households. These data allows us to determine the amount of energy consumed in each individual use of the appliance but also the consumption profile as a function of time. Lifestyle description combined with appliance consumption profile data is used to develop the simulation model.
The flexibility of the model allows discerning the effect of the occupants' behavior, by assessing the effect of changing their attitudes and habits, but also the effect of introducing new technologies.
This simulation model can be used as a bottom-top model to estimate the total energy consumption of a residential community if a set of representative dwellings (known as archetypes) is considered.

2. MODELING OF INHABITANT ACTIVITIES

Activities have been categorized into one of the following eight groups: Sleep, Breakfast, Eat, Dinner, Cook, Leisure, work and study staff at home, away from home.
The list of appliances and equipment included in the model are: Refrigerator, Freezer, Combo refrigerator, Oven, Kitchen glass-ceramic, Microwave, Dishwasher, Washing machine, Dryer, TV 32 " and 40 ", Computer, Lighting and Other equipment (radio, video game console…).
In addition, the house has been divided into four zones: kitchen, living room, bedroom and study and leisure room. The assignation of activities to each of these areas is as follows (see Table 1). When an individual is doing an activity, certain appliances are used according to his/her habits (see Table 2). Washing machine, dishwasher and dryer are not included in any activity because their way of use is limited to plug it in and let it

run by itself. However, the consumption of these appliances is also an important part of the model.

Table 1: Single Line Table Caption

	ACTIVITIES
Kitchen/dining room	Breakfast
	Eat
	Dinner
	Cook
Bedrooms	Sleep
Lounge	Leisure
Study and leisure room	Leisure
	Work and study staff
Outside of the House	Away from home

Table 2: Activities and appliances

ACTIVITY	RESOURCE
Sleep	None
Breakfast	Microwave
	TV 32 "
	Radio
	Lighting
Lunch	Microwave
	Lighting
	Radio
	TV 32 "
	Oven
	Ceramic hob
Dinner	Microwave
	Lighting
	Radio
	TV 32 "
	Ceramic hob
Cook	Lighting
	Radio
	Television
	Oven
	Ceramic hob
Leisure	Lighting
	TV 40 "
	Game console
	Computer
Work and study	Lighting
	Computer
Away from home	None

3. MODELING OF THE ELECTRICAL CONSUMPTION OF THE EQUIPMENT

To simulate the energy consumption of an appliance it is necessary to learn how is the consumption profile of energy against the time. For example, although the full cycle of a dishwasher washing can last 140 minutes, this does not mean that during that time interval the consumption of electricity is at the maximum power. The manufacturers of household appliances do not include in the user or technical specifications manual this type of consumption data. Usually, only the total energy consumed per cycle for those appliances that operate in a cyclic way, such as washing machines, dryers and dishwashers are provided. Or energy consumed per unit of time (hour, day, or year) in the case of refrigerators and freezers, which doesn't help much in determining these profiles (see Table 3).

There are two different ways for characterizing these profiles. On the one hand, there is the engineering way in which the consumption is inferred from the deep knowledge of the mechanical and electrical performance of each appliance. For example, in the case of a washing machine, times where it is heating water or centrifuging must be known as well as the instant consumption of energy at these time periods. Usually this information is not accessible.

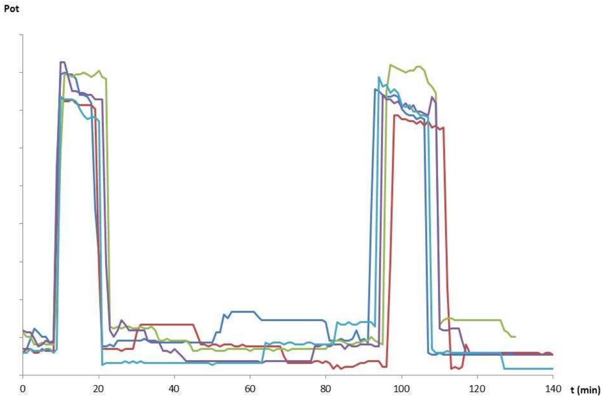
On the other hand, the data can be obtained by using metered devices. We carried out the monitoring of several appliances consumption. Figure 1 shows the resulting measurements for several operating cycles of a washing machine. A drawback is the large variety of models and marks for each type of equipment, and could be differences in the consumption pattern. Nevertheless, we assume a same shape and rescale according with the energy efficiency category of the unit. Following this methodology we have modeled the washer machine, dryer, dishwasher, refrigerator, freezer, oven, glass ceramic, etc. While the lighting is present in all the activities, the power of the above table refers to all the power installed in the housing.

Table 3: Power of certain appliances, energy consumed per cycle and cycle duration

	Energy consumed per cycle [kWh]			
	To^{+++} and^{++}	To^{+} and A	B, C and D	Life cycle
Washing machine	0.77	1.15	1.53	120 min
Dryer	1.4	2.1	2.8	120 min
Dishwasher	0.93	1.40	1.86	140 min
	Energy consumed in a year [kWh]			
	To^{+++} and^{++}	To^{+} and A	B, C and D	
Refrigerator	252,4	504,9	757,3	
Freezer	189,4	378,6	568,0	
Combi refrigerator	311,2	622,4	933,6	
	Energy per hour of use [kWh]			
	TO^{+}	TO		
Oven	0.8	1.12		
Ceramic hob	0.773			
	Power [W]		Stand-by [W]	

Microwave	1,500		4	
Computer	185		5	
Game console	200		4	
Radio	20			
	TO+	TO		
TV 32 "	43	86	3	
TV 40 "	65	130	3	
Oven			4	
	Low	Conv		
Lighting	250	1,000		

Figure 1: Consumption of energy associated to several uses of a washing machine

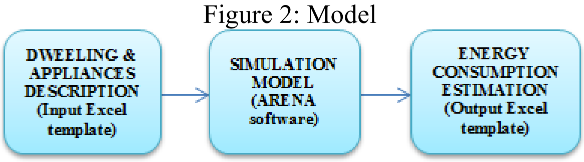


4. SIMULATION MODEL

4.1. Model construction

A discrete-event simulation model has been built to analyze household electricity consumption. The model is schematized in Figure 2.

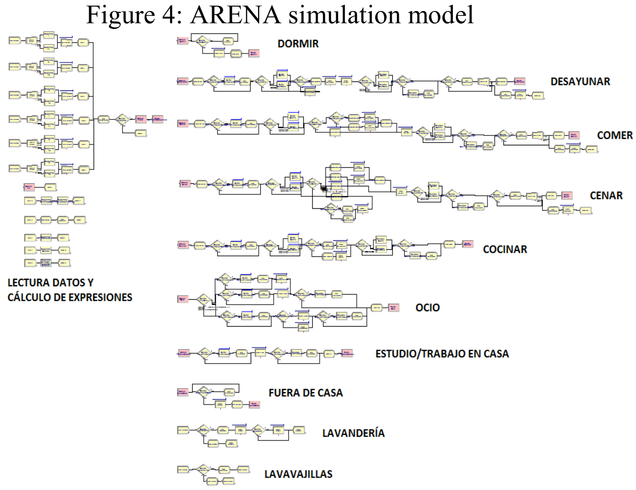
Figure 2: Model



A user-friendly Excel template has been built to facilitate the data input related with the schedule, the activities and the appliances used by each individual at home (see Figure 3). The simulation model was implemented in ARENA software. A screen capture of the model is shown in Figure 4. A 3D-animation of the model was included.

Figure 3: Excel template screen capture

Figure 4: ARENA simulation model



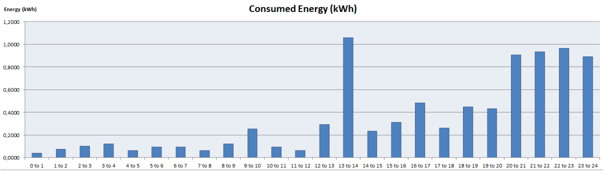
4.2. Experimental results

After verifying the model, a simulation with endpoint event was run. The number of replications was determined by sequential sampling to achieve prefixed half-width confidence intervals. A few seconds were needed to run each scenario. Generally one-minute time steps are used, but when some appliances (microwave, hob or oven) are working, the time step is reduced to one second, due to their consumption profiles.

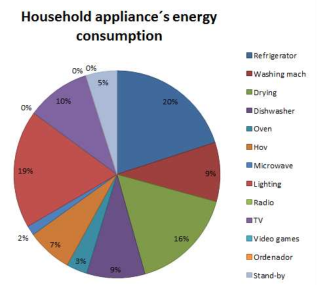
The energy consumed in each clock step interval (t, t +At) is calculated as the instantaneous power in t+At multiplied by At. The simulation results are captured in an Excel Template where a graphical and statistical analysis is provided. Performance measures are calculated in relation with energy consumption, household appliances consumptions, CO_2 emissions equivalent and costs for different tariffs. As an example,

Figure 5 shows some of these results for one scenario of a family of two adults.

Figure 5: Example of simulation results



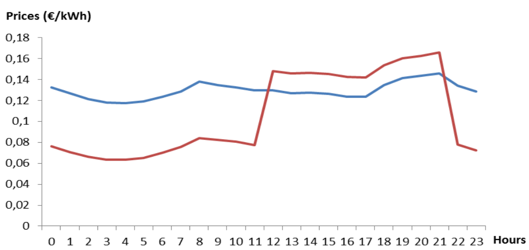
Expected energy (kWh)		
Refrigerator	1,6835	20,01%
Washing	0,7770	9,24%
Drying	1,3772	16,37%
Dishwasher	0,7675	9,13%
Oven	0,2756	3,28%
Hov	0,5966	7,09%
Microwave	0,1271	1,51%
Lighting	1,5500	18,43%
Radio	0,0000	0,00%
TV	0,8462	10,06%
Video games	0,0000	0,00%
Computer	0,0000	0,00%
Stand-by	0,4105	4,88%
TOTAL	8,4112	100,00%



Expected monthly consumption of energy	252,34 kWh
CO2 emissions equivalent	139,87 kg
Costs for general tariff	49,40 €
Costs for tariff with time restrictions	47,44 €

The simulation model allows to analyze and to compare different energy consumption profiles considering, among others, different types of families, specific consumptions patterns, the effect of good consumption habits, the effect of different levels of energy efficiency for domestic appliances and lighting equipment, the different seasons of the year, and different electricity price tariffs with (see for example red line in Figure 6) or with no time restrictions (see for example blue line in Figure 6).

Figure 6: Different electricity tariffs



5. CONCLUSSIONS

In this work we propose a simulation model to study residential energy consumption. The model includes the inhabitant´s activities linked to their behavior and their habits.

Real data obtained from smart-meters placed in several households have been used to model the electrical consumption of the equipment.

The model is able to assess the influence in residential energy consumption electricity of behavior changes and to quantify the cost of good/bad good consumption habits and its environmental consequences.

This assessment analysis can be used to smooth the residential energy consumption curve. Then, the simulation model can be extended to include renewable energy systems and used it to solve storage sizing problems (batteries or other energy storage devices) and the backup with other energy sources in island energy systems. This topic is one of our current work in progress.

The integration of this simulation model in an energy-oriented educational software constitutes another current author's research topics.

ACKNOWLEDGMENTS

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REFERENCES

Chiou Y.-S. 2009. Deriving U.S. household energy consumption profiles from american time use survey data – a bootstrap approach. Proceedings of the Eleventh International IBPSA Conference, 151-158.

Grandjean, A., Binet, G., Bieret, J., Adnot, J., Duplessis, B. 2011. A functional analysis of electrical load curve modelling for some households specific electricity end-uses. 6th International Conference on Energy Efficiency in Domestic Appliances and Lighting, 24p.

Kashif A., Le X.H.B., Dugdale J., Ploix, S. 2011. Agent based framework to simulate inhabitants' behaviour in domestic settings for energy management. Proceedings of the ICAART 2011, 190-199.

Keirstead J., Sivakumar A. 2012. Using activity-based modeling to simulate urban resource demands at high spatial and temporal resolutions, Journal of Industrial Ecology, 16, 889-900.

Larsen B.M., Nesbakken R. 2004. Household end –use consumption: results from econometric and engineering models. Energy economics, 26 (2), 179-200.

Muratori M., Roberts M.C., Sioshansi R., Marano V., Rizzoni G. 2013. A highly resolved modeling technique to simulate residential power demand. Applied energy, 107, 465-473.

Paatero J.V., Lund P.D. 2006. A model for generating household electricity load profiles. International Journal of Energy Research, 30 (5), 273-290.

Shimoda Y., Fujii T., Morikawa M., Mizuno M. 2004. Residential end-use energy simulation at city scale. Building and Environment, 39 (8), 959-67.

Swan L. G., Ugursal V.I. 2009. Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. Renewable and Sustainable Energy Reviews, 13, 1819-1835.

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MODELING ENERGY CONSUMPTION IN AUTOMOTIVE MANUFACTURING

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ABSTRACT
Developing a dynamic model of energy consumption for CNC machines in automotive industries helps to reduce the energy consumption by these machines. Since the last decade, a significant rise in energy usage has occurred due to the growth in the developing world. According to International Energy Outlook 2013, this trend will continue over the next three decades. As for CNC machines, there are various parameters in milling and turning operations that play a significant role in reducing energy consumption. In this study, parameters of machine tools are varied and the energy consumption is measured to identify the parameters that have the greatest impact on energy savings. Energy consumption models for milling and turning processes is developed by using system dynamics in order to comprehend the behavior of complex system and transform the static model of energy demand to the dynamic model.

Keywords: Energy optimization, machining process, turning and milling, cutting parameters

1. INTRODUCTION

One of the most important and useful processes in traditional manufacturing is metal cutting. Optimizing energy use in manufacturing processes is essential for reducing the amount of energy needed in machining new components and reducing the energy cost (Mativenga and Rajemi 2011). Given the controversy surrounding the environmental impact, reducing costs is not the only reason to improve energy efficiency; it is also important to reduce energy consumption to decrease the environmental burden of manufacturing (Narita et al., 2006). The largest share of emissions comes from industrial energy consumption in Asia. Because of high rate of usage in industrial sector and heavy use of coal in this region, Asian power sectors produce more than a third of total CO_2 emissions in the world (Mckane et al., 2007).

Machine tools that use enormous amounts of power but prove inefficient, with productivity below 20%, are discussed in (Draganescu et al., 2003). Thus, it is necessary to study machine tool efficiency, the relationship between cutting parameters, and specific consumed energy since the available information is not enough and the machine tool's efficiency has not been investigated by many researchers.

Cutting parameters are vital in machining processes since they are key factors in achieving the highest level of efficiency and output with the lowest cost (Montgomery, 1990). Advancement in the process efficiency can be achieved by experimenting with different cutting parameters, such as, for example, cutting velocity, depth of cut, and finding the most effective limits for each factors and thereby securing the desired output.

There are a number of studies about the performance modeling of milling that are focused more on tool wear, surface roughness, and cutting force. Shao et al. (2004) examined various cutting conditions. Average tool flank wear was considered in developing the cutting power model in face milling process. Next, Diaz et al. (2011) provided a strategy for energy and power reduction in milling operations and considered the specific energy as a function of material removal rate and demonstrated the specific energy model, which helped a product designer to evaluate the manufacturing energy consumption of their part's production.

Armarego et al., (1991) developed a model to show the relationship between specific power and cutting parameters, such as feed per tooth, depth of cut, and cutting speed in the face milling process. Likewise, the effects of cutting conditions on cutting force and cutting energy were investigated by (Polini and Turchetta 2004). Draganescu et al., (2003) proposed a statistical model of machine tool efficiency and specific energy consumption. The authors used the experimental data and response surface methodology to show the relationship between cutting parameters and specific energy consumption; however, there were some parameters, such as shear angle, which were not considered in this research.

Regarding turning operation, Camposeco-Negrete, (2013) proposed strategies to reduce energy consumption by optimizing cutting parameters in turning of AISI 1018 steel under constant material removal. Soni et al., (2014) presented a mathematical model to predict the surface roughness and material removal rate in turning process by considering cutting speed, feed rate, and depth of cut as process parameters. Malagi and Rajesh, (2012) developed software to estimate cutting forces in turning process. The work presented by Cica et al., (2013) likewise predicts the cutting parameters, namely the feed rate and depth of cut in turning operation.

However, significantly less research has been performed so far about the effects of various cutting parameters on the energy consumption in milling and turning operations. Hence, there is a need to build a comprehensive cutting process model that helps to analyze energy oriented processes in these processes.

2. OBJECTIVE

Energy demand has been increasing substantially in the manufacturing industries since the beginning of modern manufacturing era. Although selection of cutting conditions to reduce energy demand and its cost in manufacturing processes has been investigated in past research, there remains a need to analyze the machining system and energy flow to determine the most efficient methods. The aim of this research is to find the relationship between energy use and cutting parameters in milling and turning process of aluminum, in order to determine which parameters have the most significant impact on cutting energy consumption.

3. METHODOLOGY

Peng and Xu (2011) suggested that there are three levels to energy flow: the enterprise level, the shop floor level, and the process level. To reduce energy at the enterprise level, the energy monitoring methods were suggested (Kara 2011). At the shop floor level, energy consumption can be analyzed in the production department. The bottom level is process level in which it is shown that energy is distributed among four elements: machine tools, auxiliary equipment, cutting tools, and material supply. In this study, one of the critical aspects of energy savings is considered and can be used in the process level. This method is the energy efficiency in cutting processes, which is explored while evaluating the relevance in cutting parameters and the output in milling and turning operations. Moreover, it illustrates which cutting parameter has the most significant effect on the energy consumption.

According to Tang and Vijay (2001), System Dynamics (SD) is a useful technique for the analysis of complex systems, integrating the subsystems and parts into a whole, which can be simulated to improve insight into its dynamic behavior. Other advantage of using System Dynamics approach is that it is a computer-aided method that provides precise analysis and design.

System Dynamics tool can be utilized to demonstrate the dynamic behavior of machining processes (milling and turning). Results of simulation can illustrate the changes in the energy output according to the changes in the input parameters. Analysis of Variance (ANOVA) was also applied in this study to test and analyze the data obtained from Vensim simulation. The purpose of applying two-way ANOVA is to assess not only the main effect of cutting parameters on the energy consumption, but also investigate any interaction between them.

Then, sensitivity analysis is used to find which parameters have the most substantial effect on the energy consumption in milling and turning processes. Next, Response Surface Methodology is applied to form the best mathematical model for cutting parameters and energy demand in those processes.

3.1 Mathematical Model Used in Simulations

NOMENCLATURE	
P_0	Power consumed by machine modules without the machine cutting (kw)
t_1	Set up time (s)
D_{avg}	Average work piece diameter (mm)
L	Length of cut (mm)
f	Feed rate (mm/rev)
vc	Cutting speed (m/min)
k	specific energy requirement for particular material (Ws/mm3)
D_i	Initial diameter (mm)
D_o	Final diameter (mm)
t_2	Actual cutting time (s)
t_3	Tool change time (s)
T	Tool-life (s)
α	Cutting velocity exponent in tool life equation
β	Feed exponent
y_e	Energy footprint per tool cutting edge (kw/h)
A	non-symmetry of milling (mm)
F_c	Cutting force (N)
d	Tool diameter (mm)
K_c	specific cutting force in the shear zone
γ_o	Cutting rake angle (rad)
a_n	Approach angle (rad)

3.1.1. Turning process simulation model

The energy model in the turning process is introduced by Rajemi et al. (2010) in equation (1. The authors explain that total energy (E) consumption in turning can be estimated from the energy consumption of the machine during setup operation (E_1), energy for cutting operations(E_2), energy required for tool change (E_3) and energy to produce cutting action per cutting edge (E_4), produce work piece material (E_5). The final equation, which was adopted from (Rajemi et al. 2010), is utilized for the turning process simulation:

$$E = E_1 + E_2 + E_3 + E_4 \quad \textbf{(1)}$$

In Equation (1, energy (E_1) is the energy consumed by a machine during setup, and it is estimated by the power consumption of the machine and total time for set up tools and work piece. It is important to remember that during setup time the spindle speed is zero as the spindle has not yet been turned on (Rajemi et al., 2010).

The energy E_2 during machining is assessed based on the energy consumption of the machine modules and the energy for material removal as defined by (Gutowski et al., 2006) in equation **Error! Reference source not found.**.

The energy consumption in tool changing E_3 is estimated from a product of machine power and time for tool change. In turning operation, the tool is usually replaced when the spindle is turned off. Therefore, the power during tool change is equal to the power when the machine is in an idle state (Rajemi et al., 2010).

The parameter E_4 indicates the energy footprint of the cutting tool divided by the number of cutting edges. This is evaluated from the energy embodied in the cutting tool material, the energy consumption in tool manufacturing and the energy of any supplementary processes namely, coating. Moreover, E_4 is estimated from the product of the energy per cutting edge y_E multiplied by the number of the cutting edges needed to finish the machining pass. In equation (1, where t_1 is machine setup time (s), t_3 is tool change time (s) and T is the span of tool life (s) (Rajemi et al., 2010).

$$E_2 = (P_0 + K \times MRR)\, t_2 \quad (2)$$

$$E = P_0\, t_1 + (P_0 + K \times MRR)t_2 + P_0 t_3 \left(\frac{t_2}{T}\right) + y_E \left(\frac{t_2}{T}\right) \quad (3)$$

Equation (3 can be expanded to equation (4:

$$E = P_0 t_1 + P_0 \frac{\pi D_{avg} l}{f\, V_c} + K \frac{\pi l}{4}\left(D_i^{\,2} - D_o^{\,2}\right) + P_0 t_3 \frac{\pi D_{avg} l V_c^{\left(\frac{1}{\alpha}-1\right)} f^{\left(\frac{1}{\beta}-1\right)}}{A} + \frac{y_E \pi D_{avg} l V_c^{\left(\frac{1}{\alpha}-1\right)} f^{\left(\frac{1}{\beta}-1\right)}}{A} \quad (4)$$

3.1.2. Milling Process simulation model

Energy needed in milling operations is presented in equation (5, developed by (Polini and Turchetta, 2004). In order to find the consumed energy absorbed from the power network, it is necessary to divide the power of main spindle, which is a function of force and speed, by the material removal rate (Draganescu et al., 2003).

The specific energy consumption (E_{cs}) indicates how the cutting power can be used. The cutting energy (E_c) in equation **Error! Reference source not found.**(6 is a function of material removal rate (MRR) and specific cutting energy (E_{cs}). The higher feed speed, width of cut and depth of cut is in better use of energy in milling process.

Cutting force adopted from (Li and Kara, 2011) is defined as expressed in equation (7. The specific cutting force K_c is a function of the shear stress of the work piece material and the geometric properties of the cutting action.

$$Ecs = \frac{\mathrm{Fc{\times}Vc}}{(\text{feed speed}\times\text{width of cut}\times\text{depth of cut})\times 60000} \quad (5)$$

$$E_c = E_{cs} \times \mathrm{MRR} \quad (6)$$

$$Fc = K_c \times \mathrm{f} \times \mathrm{d} = \frac{(1-0.01\times\text{rake angle})\times\text{shear stress}\times\text{feed rate (c)}\times\text{depthof}}{(\text{feed rate (c)}\times\mathrm{SIN}(\text{approach angle}))^{mc}} \quad (7)$$

3.2. Response Surface Methodology

Response Surface methodology is used for turning and milling processes to build mathematical models of energy consumption and related cutting parameters (Montgomery, 1996).

Input parameters:

X_1=cutting speed (m/min)
X_2=feed rate (mm/rev)
X_3=depth of cut (mm)

Output parameter: energy consumption

In this experimental analysis of turning process parameters has been conducted from the industry at three levels -1, 0, 1 and represented in Table 1.

Table 1: RSM three-level table for 3 cutting parameters in milling process

Parameters	Level / Unit	-1	0	1
Cutting Speed	m/min	60	120	1800
Depth of Cut	mm	0.2	0.4	0.6
Feed Rate	mm/rev	0.2	0.3	0.4

4. RESULTS

4.1. Results for System Dynamics Simulation

Figures 1 and 2 present the SD model of turning and milling processes in Vensim, the simulation software. The inputs are cutting parameter values, selected according to work piece material (see 3.1.1 and 3.1.2 for details). The output is the amount of energy required by the machining process.

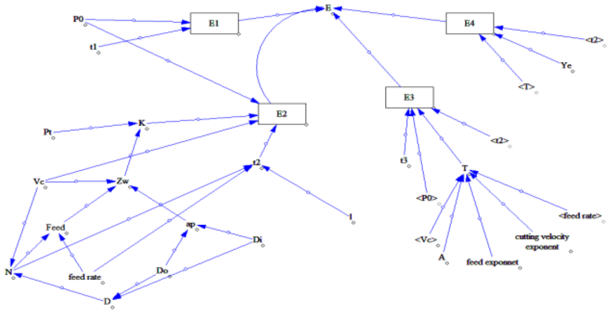

Figure 1: The Simulation Model Structure for Turning Process

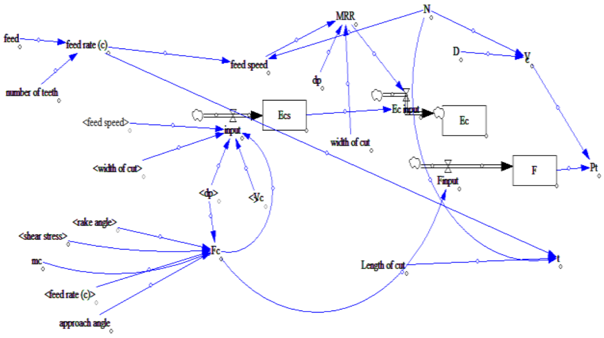

Figure 2: The Simulation Model Structure in Milling Process

4.2. Milling and Turning Processes: Case Studies (Procedure)

The cutting tool used is a face mill with diameter of 250 mm, initial cutting parameters: (K10/a_n = 6°, γo = 18°) and the work piece material is Aluminum. During each cutting test, one of the cutting parameters will be changed and its effect will be reflected in the energy output.

As Table 2 shows, cutting test is performed by varying the feed rate in simulation. As a result of increasing this parameter the specific energy consumption is decreasing.

Table 2: Feed Rate & Specific Energy Consumption in milling operation

Feed Rate (mm/rev)	Specific Energy Consumption (Kwh/cm^3)
0.2	1.0021
0.25	1.0016
0.3	1.0013
0.4	1.0009
0.5	1.0006
0.6	1.0004
0.7	1.0003

The same practice is followed to show the effects of feed rate on the energy consumption and material removal rate (MRR) in turning process.

Table 3: Feed Rate, MRR and Cutting Energy in Turning Process

Feed Rate (mm/rev)	E (kw/h)	MRR
0.10	0.0020	235.50
0.15	0.0018	353.25
0.20	0.0015	471.00
0.25	0.0014	588.75
0.30	0.0012	706.50

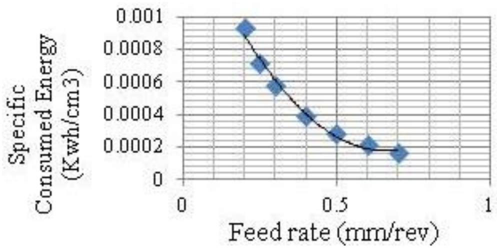

Figure 3: Effect of Feed Rate on Specific Energy Consumption in Milling Operation

The relationship between the specific energy consumption and feed rate in milling process is shown in Fig. 4. The polynomial equation 8 for feed rate and specific energy consumption is:

$$E_{cs} = 0.0034x^2 - 0.0045x + 0.0017 \quad (8)$$

According to **Error! Reference source not found.**, in turning operations while feed rate increases, the energy consumption is dropping. The polynomial equation 9 is:

$$E_{cs} = 0.0252x^2 - 0.0155x + 0.0037 \quad (9)$$

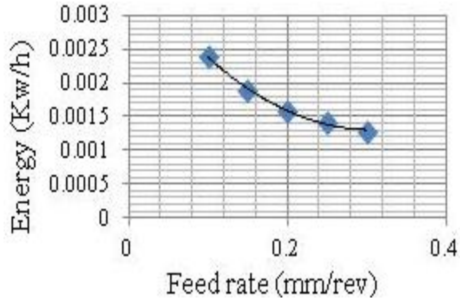

Figure 4: Energy Consumption and Feed Rate in Turning Process

After running simulation models in Vensim, the effects of cutting velocity, shear angle, depth of cut, edge contact length, and number of teeth were studied. The results showed that the growth in the cutting speed increases the specific energy consumption in both operations. However, the growth in other parameters such as depth of cut decreases specific energy consumption.

4.3. Results for Sensitivity Analysis

The main goal of the sensitivity analysis is to gain insight into which assumptions are critical and which assumptions affect choice. The process involves various ways of changing input values of the model (cutting parameters) to observe their effects on the output value (energy consumption).

Table 4 and Figure 5 illustrate which parameter has the significant influence on the energy demand.

Table 4: Sensitivity Analysis for Cutting Speed (V_c), Depth of Cut (d_p) and Energy Use in Milling

V_c(m/min) \ D_p(mm)	0.2	1.2	2.2	3.2	4.2	5.2	6.2	7.2
60	0.20	0.04	0.02	0.01	0.01	0.01	0.009	0.007
120	0.50	0.09	0.05	0.03	0.02	0.02	0.01	0.01
180	0.80	0.14	0.07	0.05	0.04	0.03	0.02	0.02
240	1.12	0.18	0.10	0.07	0.05	0.04	0.03	0.03
300	1.40	0.23	0.12	0.08	0.06	0.05	0.04	0.03
360	1.69	0.28	0.15	0.10	0.08	0.06	0.05	0.04

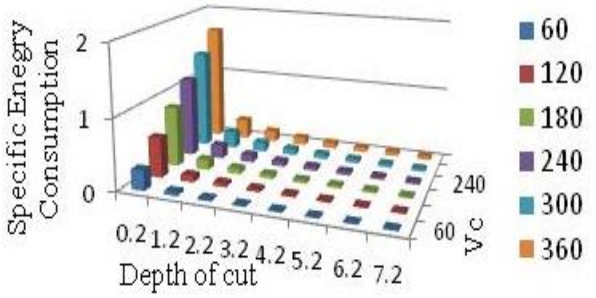

Figure 5: Sensitivity Analysis Table for Depth of Cut and Specific Cutting Energy in milling operation

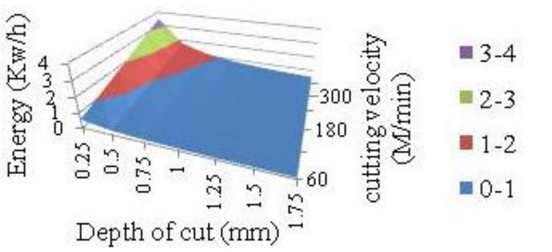

Figure 6: 3D Surface Plot for Depth of Cut, Cutting Speed and Energy Consumption in Turning

Table 5 (sensitivity analysis results) and Figure 6 demonstrate which parameter has the most significant effect on energy demand in turning process.

Table 4: Sensitivity Analysis for Depth of cut (mm), Cutting Speed (m/min) and Energy Consumption in Turning

Vc(m/min) \ D_p(mm)	0.25	0.50	0.75	1	1.25	1.50	1.75
60	0.57	0.28	0.19	0.14	0.11	0.11	0.09
120	1.15	0.57	0.38	0.28	0.23	0.19	0.16
180	1.73	0.86	0.57	0.43	0.34	0.28	0.24
240	2.31	1.15	0.77	0.57	0.46	0.38	0.33
300	2.89	1.44	0.96	0.72	0.57	0.48	0.41
360	3.47	1.73	1.15	0.86	0.69	0.57	0.49

The results of sensitivity analysis indicate that depth of cut has the biggest impact on the energy consumption in milling operation followed by feed rate; (D_P >Feed rate > V_C > Edge contact length> Rake angle> Number of teeth). However, it is resulted that feed rate has the most significant effect on the energy consumption in turning operation, followed by depth of cut; (Feed rate > D_p > Spindle speed > V_c).

4.4. Results for Response Surface Methodology

Table 6 presents the design table and data generated to demonstrate the relationship between rake angle, cutting speed and feed rate in turning process.

Table 6: RSM three-level design table for turning process

		Factor 1	Factor 2	Factor 3	Response 1
Std	Run	A:Feed rate	B:Vc	C:Dp	Energy
11	1	0.1	60	0.75	1.36001
4	2	0.3	60	0.75	4.07997
3	3	0.1	120	0.75	2.71998
19	4	0.3	120	0.75	8.15994
9	5	0.1	60	0.5	2.71998
14	6	0.3	60	0.5	8.15994
2	7	0.1	120	0.5	5.43996
12	8	0.3	120	0.5	16.3199
7	9	0.1	180	0.5	8.15994
15	10	0.3	180	0.5	24.4798
16	11	0.1	60	0.25	4.0799
10	12	0.368179	60	0.25	12.2399
8	13	0.1	120	0.25	8.1599
20	14	0.3	120	0.25	24.4798
18	15	0.1	180	0.25	12.23
1	16	0.3	180	0.25	36.71

The second order mathematical model was created using the data obtained from simulation to predict the energy consumption. Regression equations were formed using Design Expert 9.0 software for Energy consumption (Y) as follows:

$$y = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \sum\sum_{i<j=2}^{k} \beta_{ij} x_i x_j + \sum_{j=1}^{k} \beta_{ij} x_j^{2} + \varepsilon \quad (10)$$

$$E_{turning} = - 6.845 + 22.182 \times f + 0.077 \times V_c + 18.711 \times d_p + 0.593 \times f \times V_c - 75.104 \times f \times d_p - 0.205 \times V_c \times d_p \quad (11)$$

Combined effect of cutting parameters and energy consumption in the turning process is shown in Figure 7.

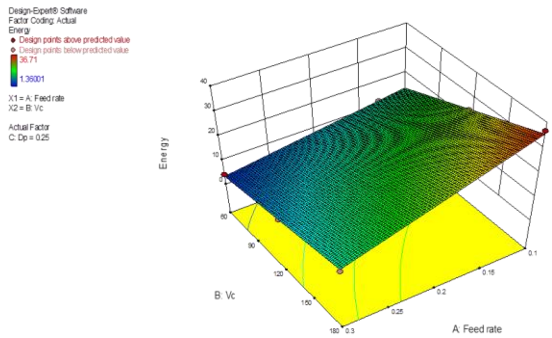

Figure7: Feed rate, cutting speed and energy in turning

4.5. RSM results for Milling Process

Factorial designs can be used for fitting quadratic models. A quadratic model can significantly improve the optimization process when a second-order model suffers lack of fit due to interaction between variables and surface curvature. The quadratic mathematical model is developed using the experimental values and responses to predict the energy consumption. A general quadratic model is defined as equation 10.

Equation 13 was formed using Design Expert 9.0 software for energy consumption in milling process (Y):

$$Y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4+\beta_{12}x_1x_2+\beta_{13}x_1x_3+\beta_{14}x_1x_4+\beta_{23}x_2x_3+\beta_{24}x_2x_4+\beta_{34}x_3x_4+\beta_{11}x_1^2+\beta_{22}x_2^2+\beta_{33}x_3^2+\beta_{44}x_4^2 \quad (12)$$

$$Log\_10(E_{milling})=1.039+2.7E\text{-}003\times V_c-0.067\times d_p-0.88\times f+0.013219\times\alpha_r+3.34E\text{-}003\times V_c\times d_p+6.058E\text{-}004\times V_c\times f+5.33E\text{-}005\times V_c\times\alpha_r-1.82\times d_p\times f-9.901E003\times d_p\times\alpha_r-0.029\times f\times\alpha_r-6.48E006\times V_c\text{^}2+0.032\times d_p\text{^}2+1.0006\times f\text{^}2+1.32E\text{-}006\times\alpha_r\text{ ^}2 \quad (13)$$

Table 7 shows the design table and data used to explore the relationship between milling process parameters.

Table 7: RSM three-level design table for milling process

		Factor 1	Factor 2	Factor 3	Factor 4	Response 1
Std	Run	A:cutting speed	B:depth of cut	C:feed rate	D:rake angle	energy
5	1	60	0.20	0.80	10	5.30
30	2	210	0.40	0.52	22.50	4.40
12	3	360	0.60	0.25	35	10.60
1	4	60	0.20	0.25	10	4.30
29	5	210	0.40	0.525	22.50	4.40
4	6	360	0.60	0.25	10	25.80
19	7	210	0.20	0.525	22.50	4.40
13	8	60	0.20	0.80	35	0.50
21	9	210	0.40	0.025	22.50	41.70
16	10	360	0.60	0.80	35	3.30
26	11	210	0.40	0.52	22.50	4.40
18	12	510	0.40	0.52	22.50	10.80
8	13	360	0.60	0.80	10	8
9	14	60	0.20	0.25	35	1.70
11	15	60	0.60	0.25	35	1.70
22	16	210	0.40	1.07	22.50	2.10
14	17	360	0.20	0.80	35	3.30
3	18	60	0.60	0.25	10	4.30
23	19	210	0.40	0.525	-2.50	13.60
6	20	360	0.20	0.80	10	8
15	21	60	0.60	0.80	35	0.05
27	22	210	0.40	0.50	22.50	4.40
28	23	210	0.40	0.52	22.50	4.40
10	24	360	0.20	0.25	35	10.60
2	25	360	0.20	0.25	10	25.80
17	26	90	0.40	0.52	22.50	1.90
7	27	60	0.60	0.80	10	1.30
25	28	210	0.40	0.52	22.50	4.40
20	29	210	0.80	0.52	22.50	4.40
24	30	210	0.40	0.52	47.50	1.90

Combined effect of cutting parameters and energy consumption in the milling process is shown in Figure 8.

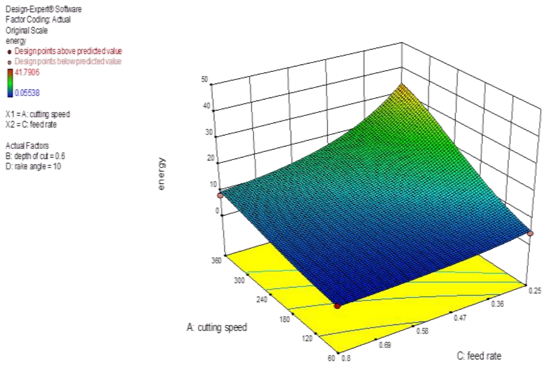

Figure 8: 3D plot of feed rate, cutting speed and energy in milling process

5. SUMMARY

- The purpose of this research is to build a comprehensive cutting process model which helps to analyze energy oriented processes in turning and milling operations.

- In order to understand the machining process at the process level, the effects of various cutting parameters on energy demand should be explored. To facilitate such effort, the System Dynamics tool was applied for both milling and turning processes on aluminum to build a dynamic model of machining operations.

- ANOVA and regression analysis were applied to the data obtained from the SD simulation to demonstrate the relationship between independent variables and dependent variables. Regression equations showed how much each variable contributed to the changes in energy consumption.

- Sensitivity analysis was utilized to demonstrate which parameters were most impactful on the energy consumption. The results of sensitivity analysis confirmed that feed rate is the most significant factor in reducing energy in turning process, while depth of cut has the highest impact on energy reduction in milling process followed by feed rate, spindle speed and cutting speed.

- Response surface methodology (RSM) helped to build a practical energy model (linear approximation) based on the data and cutting parameters for milling and turning processes (by careful design of experiments.) By using this method, the optimized model of the output variable which is influenced by various independent variables can be obtained. By applying the mathematical model, the manufacturers can find the actual and predicted energy consumption in milling and turning operations.

REFERENCES

Armarego, E.J.A and Smith, A.J.R and Karri, V., 1991. Mechanics of cutting model for simulated oblique rotary tool cutting processes. *Journal of Materials Processing Technology*, 28, pp.1–14.

Camposeco-Negrete, C., 2013. Optimization of cutting parameters using robust design for minimizing energy consumption in turning of AISI 1018 steel with constant material removal rate. *11th Global Conference on Sustainable Manufacturing*, Berlin, pp.149–152.

Cica, D., and Sredanovic, B., and Lakic-Globocki, G., and Kramar, D., 2013. Modeling of the Cutting Forces in Turning Process Using Various Methods of Cooling and Lubricating: An Artificial Intelligence Approach. *Advances in Mechanical Engineering*, Vol. 5, 798597.

Diaz, N., and Redelsheimer, E., and Dornfeld, D., 2011. Energy consumption characterization and reduction strategies for milling machine tool use. *Glocalized Solutions for Sustainability in Manufacturin, pp. 263-267. Springer, Berlin Heidelberg.*

Draganescu, F., and Gheorghe, M.,and Doicin, C.V., 2003. Models of machine tool efficiency and specific consumed energy. *Journal of Materials Processing Technology*, 141(1), pp.9–15.

Gutowski, T., Dahmus, J., and Thiriez, A., 2006. Electrical Energy Requirements for Manufacturing Processes. 13 th CIRP International Conference of Life Cycle Engineering, 31(Cvd), pp.1–5.

Kara, S., Bogdanski, G., and Li, W., 2011. Electricity metering and monitoring in manufacturing systems. In *Glocalized Solutions for Sustainability in manufacturing*, pp. 1-10. Springer, Berlin Heidelberg.

Li, W., and Kara, S., 2011. An empirical model for predicting energy consumption of manufacturing processes: a case of turning process. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 225(9), pp.1636–1646.

Malagi, R.R., and Rajesh, B.C., 2012. Factors Influencing Cutting Forces in Turning and Development of Software to Estimate Cutting Forces in Turning. *International Journal of Engineering and Innovative Technology (IJEIT)*, 2(1), pp.37–43.

Mativenga, P.T and Rajemi, M., 2011. Calculation of optimum cutting parameters based on minimum energy footprint. *CIRP Annals-Manufacturing Technology*, 60(1), pp.149–152.

Mckane, A., Price, L., and Berkeley, L., 2007. Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies.

Montgomery, D.C., 2007. *Introduction to Statistical Quality Control*, 2nd ed., John Wiley& Sons.

Myers, R. H., Montgomery, D. C., and Anderson-Cook, C. M., 2009. *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*. John Wiley & Sons.

Narita, H., Kawamura, H., Norihisa, T., Chen, L. Y., Fujimoto, H., and Hasebe, T. ,2006. Development of prediction system for environmental burden for machine tool operation. *JSME International Journal Series C, 49*(4), pp.1188-1195.

Peng, T., and Xu, X., 2011. A framework of an energy-informed machining system. In *Proceedings of the 7th International Conference on Digital Enterprise Technology, Athens, Greece*. pp. 160–169.

Polini, W., and Turchetta, S., 2004. Force and specific energy in stone cutting by diamond mill. *International Journal of Machine Tools and Manufacture*, 44(11), pp.1189–1196.

Rajemi, M.F., Mativenga, P.T., and Aramcharoen, A., 2010. Sustainable machining: Selection of optimum turning conditions based on minimum energy considerations. *Journal of Cleaner Production*, 18(10), pp.1059–1065.

Shao, H., and Wang, H. L., and Zhao, X. M., 2004. A cutting power model for tool wear monitoring in milling. *International Journal of Machine Tools and Manufacture*, *44*(14), pp.1503-1509.

Soni, V., and Mondal, S., and Singh, B., 2014. Process Parameters Optimization in Turning of Aluminum Using a New Hybrid Approach, 1(3), pp.418–423.

Tang, V., and Vijay, S.,2001. System Dynamics. In *Origins, Development, and Future Prospects of a Method. Massachusetts Institute of Technology, Cambridge, Mass. Research Seminar in Engineering Systems*.

EIA, U.,2013. Annual Energy Outlook 2013. *US Energy Information Administration, Washington, DC.*

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CHALLENGES AND OPPORTUNITIES IN IMPLEMENTING GREEN INITIATIVES FOR PORT TERMINALS

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ABSTRACT
The new Green Management Practices (GMP) paradigm has emerged as an effective management tool for firms to achieve superior performance and to deal with both economic and environmental aspects by applying ecological criteria. This is particularly true for port terminals where environmental issues are becoming critical due to the increase in freight volumes. Accordingly, this article proposes a flexible solution capable of recreating (after preliminary customization) a port terminal and while taking into consideration the main factors affecting sustainability of port operations. This approach provides the user with an advanced decision support system (DSS) for investigating managerial and policy implications in an eco-friendly framework. This work is positioned to culminate in the development of a software DSS whose aim is to support business decisions based on the environmental impact analysis of processes and activities performed in the course of the life-cycle of the port terminal, and to simulate and compare design alternatives in terms of both environmental impact and economic sustainability.

Keywords: Green Port, Sustainability, Modeling, Analysis and Simulation, Business Decision

1. INTRODUCTION

There is an increasing pressure in the transportation industry to devise and implement environmentally friendly strategies for global freight movement. Numerous approaches have been developed utilizing technological advances and innovative activities to reduce energy consumption and carbon emission in freight transportation. On one hand it has been argued that a firm can gain differentiation advantage not only by cooperating with supply chain partners, but also by implementing internal environmental operations and adopting environmental strategies throughout the supply chain (Longo 2012). This approach is known as *environmental product differentiation* and asserts that it is possible for firms to enhance their performance and simultaneously reduce the negative effects of their activities on the environment by implementing GMPs (Shrivastava, 1995). On the other hand, it has also been argued that firms perceive a paucity of evidence that the benefits derived from the implementation of Green Management Practices (GMPs) exceed the costs of pursuing these initiatives (Montabon et al. 2007).

Taking into account such conflicting considerations and given the importance of developing GMPs, the main goal of this paper is the definition and development of a framework capable of examining the linkage between the adoption of GMPs and the port's performance metrics - the application area of the framework proposed in this paper - which play the role of transportation intermediaries that facilitate trade flows across the global supply chain (Wong et al., 2009; Yang et al., 2009). Indeed, as far as sustainability in marine ports is concerned, several studies on a variety of ports worldwide have been carried out, e.g., Gupta et al. (2002), Saxe and Larsen (2004), Lucialli et al. (2007), Joseph et al. (2009), Mittal and Baveja (in press). Marine vessels, trucks, cranes, locomotives, and off-road equipment used for moving cargo were identified as the main sources of pollution (Bailey and Solomon, 2004).

Investigating this connection is a strategic issue for many companies (including those operating port terminals) due primarily to market pressures exerted by customers' and suppliers' increasing demand to minimize the negative environmental impact of operations (Karakosta et al., 2009, Golusin et al., 2011). Indeed, the concept of green port has been known since 1992 (Agenda 21), and subsequently, the quest for environmentally friendly measures has been on the rise.

As far as port terminals are concerned, the study of GMPs consists of identifying best practices that simultaneously reduce the negative impacts of port operations on the environment and improve terminal performance metrics. Unlike regulatory requirements, which originate externally, GMPs consist of operational processes that arise from within a firm. At the business planning level, GMPs are collections of internal efforts aiming to define business policies and processes that require the port terminal to assess its environmental impacts, determine environmental goals, and implement operations that establish environmental stewardship, monitor goal attainment, and undergo management review.

This paper reports the preliminary results of an ongoing research project, dubbed T-ESEDRAS (***T****erminals* ***E****nvironmental* ***S****ustainability* ***E****nhancement* *based On **D**ata **R**e-organization **A**nalysis and **S**imulation*). This project is a joint collaborative effort of the MSC-LES lab (University of Calabria), and Italian stakeholders operating in the Gioia Tauro Harbor area (e.g. ICO BLG Automobile Logistics Italia). The main goal is the development of DSS software that supports business decisions based on environmental impact analysis of processes and activities performed in the course of the life cycle of a port terminal. Using a simulation model, this work facilitates comparing alternatives in terms of both environmental impacts and technical and economic sustainability. By modeling sustainability and monitoring environmental impact (Bruzzone 2014), port terminal operations will be able to effect continuous improvement of their performance metrics. By using methodologies such as Life Cycle Assessment (LCA), the T-ESEDRAS simulation model aims to:

- Improve the economic efficiency and rationalize the use of resources in the early stages of the life cycle (often characterized by significant environmental impact);
- Improve and strengthen the firm's market position through the promotion of services designed to be eco-friendly;
- Improve risk management processes by strengthening and promoting collaboration among companies, suppliers, customers, local authorities, research universities and environmental groups.

To summarize, the T-ESEDRAS simulation model aims to test various configurations of green practices, and for each scenario, the model is designed to measure the performance of the tested solution.

The rest of this paper is organized as follows: Section 2 presents an overview of green initiatives in port terminals; Section 3 describes the simulation model architecture and conceptual models. Section 4 presents the T-ESEDRAS simulation model, its main features and functionality. Finally Section 5 summarizes the main findings and conclusions.

2. GREEN INITIATIVES IN PORT TERMINALS

In recent years, ports all around the world have been demonstrating an increasing commitment to environmental protection and sustainable operations through a variety of actions, mandates and initiatives. In order to maximize the benefits of sustainability-related operations, the concept of "*green port*" has been introduced. The idea underlying this concept is to render traffic and port operations eco-friendly. The attainment of "green port" status is one of the most important objectives of many marine ports worldwide; such a status can be reached through the pursuit of various approaches, such as energy efficiency, collecting and recycling rainwater and wastes on board, and "zero emissions" policies. Those marine ports that are located close to major cities must become integrated into their surroundings to ensure that a sustainable development takes place in harmony with the economy and social development of the port itself and of the host city.

In this study, a large number of major ports were considered in order to identify the interventions (GMPs) needed to move towards the green port status. Four different but interrelated aspects are considered:

- *Environmental impact assessment*, by monitoring air and water quality, optimizing the flow of standard and toxic wastes, reducing the noise pollution, etc.;
- *Energy and resource consumption*, in order to save energy and maximize energy efficiency. International seaport authorities are committed to support a more efficient and effective energy management in various ways, such as using renewable energy sources (e.g. sun, wind), installing biodiesel or biofuel systems and assessing available technologies. Such reduction in energy consumption is not necessarily associated with technical changes alone, since it can also result from a better organization and management or improved economic efficiency in the port area;
- *Infrastructures and services* provided by port handling facilities. Ways to maximize the impact of green initiatives in the port include planning and managing port terminals in a sustainable way, improving operations and rationalizing access to the port as well as creating and expanding telematic services based on new technology solutions ;
- *Costs and financial management* (such as "make or buy" analysis or new pricing policies) have to be considered in order to encourage sustainable and environmentally friendly practices.

An exhaustive list of "green initiatives" undertaken globally by top terminal operators has been prepared by using the extant literature, trade reports, news articles and terminal operator's websites; this list is presented in Table 1. Global initiatives can provide a useful benchmark and encourage the adoption/testing of these initiatives in other locations where they are not currently deployed. In order to have a clearer view of worldwide initiatives, these practices have been organized in terms of:

- *Action area*, which constitutes a broader category that includes a single green initiative;
- *Best practice,* intended as a single green management practice;
- *Expected impact*, which includes both direct and indirect consequences of adopting a specific initiative within the port area. In fact, by adopting a green management practice, a direct consequence could be the reduction of pollutant emissions within the port area, though it could entail an indirect power consumption that results in increased pollutant emission where power is generated.

Table 1: Green Practices in Port Terminals

Action Area	Best Practice	Impact
Reduction of energy consumption in exterior lighting of roads, yards and docks	Flow Reductions at nighttime at points of low traffic	Indirect emissions Electrical consumption
	Promoting the incorporation or replacement of high-efficiency equipment (LED lighting)	
	Replacement of existing bulbs with lamps using motion sensors in specific areas of the port with low traffic	
	Optimization of indoor lighting systems in buildings	
Reduction of fuel consumption by machinery	Automatic shutdown in case of stand-by (start & stop systems)	Direct emissions Fuel consumption
	Software for optimizing fuel consumption of port mobile cranes	
	Active Front End technology (AFE) for port cranes	
	RIS.GA system with electrical generators to reduce emissions in stand-by mode	
	Regenerative power	
Reduction of fuel consumption by vessels	Vessel speed reduction while entering the port area	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Onshore Power Supply (Cold Ironing)	
Replacement of equipment	Replacement of Rubber Tired Gantry (RTG) and Terminal Tractor (TT) by Automated Rail Mounted Gantry (ARMG) and Automated Guided Vehicles (AGV)	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Replacement of RTG/RMG by E-RTG or installation of eco-friendly systems	
Power management	Analysis of quarter hours, alarms overruns, load test	Indirect emissions Electrical consumption
	Establishment of consumption patterns	
	Verification of losses in electrical wiring for overloaded lines (reactive compensation)	
	Installation of voltage optimization units to control the equipment's voltage input	
Throughput Enhancing Methods	Traffic reduction and optimization	Direct emissions Fuel consumption
	Minimizing equipment idle time reallocating cranes	
Reduction of emissions by parked vehicles	Industrial hybrid vehicles	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Movement of employees on bikes and via an organized port e-bus network	
	Electric vehicles for movement of operators	
	Gate policies for incoming trucks	
Improvement in energy efficiency of buildings	Implementation of green roof projects	Direct emissions Fuel consumption Electrical consumption
	Usage of thermal inertia in industrial cooling facilities	
	Landscaping around buildings to reduce urban heat effects and provide cooling	
	Improvements in the consumption of air conditioners by energy classification change	
	Rainwater harvesting and sewage disposal	
Clean fuels usage	Recycling the hydrocarbon fraction of water in oil dumping of tankers to recover its fuel	Direct emissions Fuel consumption
	Using NH_3 for cooling systems instead of CFCs	
	Liquefied Natural Gas (LNG)	
	Ultra Low Sulfur Diesel (ULSD)	
	Biodiesel from algae	
	Green-diesel	
	Residual marine oil	
	Marine distillate oil	
	Blending biofuels	

Usage of renewable energies	Installation of wind energy in port facilities	Direct emissions Fuel consumption Electrical consumption
	Installation of photovoltaic energy for buildings	
	Installation of photovoltaic energy for equipment	
	Installation of solar thermal energy	
	Low-enthalpy geothermal energy (sea water heat pump)	
Port waste management	Conversion of waste into syngas or biogas	Direct emissions Fuel consumption Electrical consumption
Relationship-centric policies	Employee training	Direct emissions Fuel Consumption
	Relationships with stakeholders	
Electronic communication	Use of Integrated Information Systems	Direct emissions Fuel consumption Electrical consumption

Concerning the environmental impact of port operations, there is need not only to evaluate the environmental impact in terms of CO_2-equivalent emissions of all the equipment used in the port terminal (e.g. straddle carriers, trucks, tugboats, rail transtainers, ship arrivals and departures, etc.), but it is also required to investigate the environmental and economic consequences of a single or multiple green management practices over the terminal life cycle. Finally, according to Mittal et al. (in press), GMPs can be classified as follows:

- Technology-centric practices, such as cold ironing, replacement of traditional RTG, RMG or straddle carriers by container handling equipment powered by hybrid or fully electrical engines, and replacement of existing bulbs with high-efficiency equipment (LED lighting);
- Process-centric practices, such as gate policies in order to specify a time slot during which trucks are allowed to enter the port area;
- Relationship-centric practices, such as training operators with the goal of minimizing bad practices that can have a negative environmental impact.

3. SIMULATION MODEL ARCHITECTURE AND CONCEPTUAL PROCESS MODELS

Before conceptualizing container terminal operations, special attention should be paid to the general architecture of the simulation model being developed. Three activities need to be carried out in order to offer a rich experimental framework that enables the user to efficiently manage simulation runs, collect, and display and compare output results, and calibrate and optimize the model:

- A simple but sophisticated user-friendly animation view allows the user to observe system evolution in an interactive simulation environment. During model execution, the user can observe any object in action (e.g., a moving straddle carrier), so as to assure the correctness of proper operations flows;
- The model itself is run multiple times at various parameter settings. The user should be able to specify the range and step for parameter settings and let the simulation model runs all combinations. Alternatively, the user can programmatically control how parameter values affect a specific performance metric;
- After inputting model parameters and running the simulation, performance metrics need to be collected so as to compare simulation run outputs, the sensitivity of simulation results to changes in model parameters, and to tune parameters to improve performance metrics.

Conceptual models are used to understand the structure and dynamics of real-world complex systems like port terminals, (note that the T-ESEDRAS simulation model represents a container terminal model). The attendant diagrammatic representations, expressed in terms of mathematical and logical relationships, capture system structure and key aspects of the interaction among its components, thereby promoting deeper understanding of the system under study.

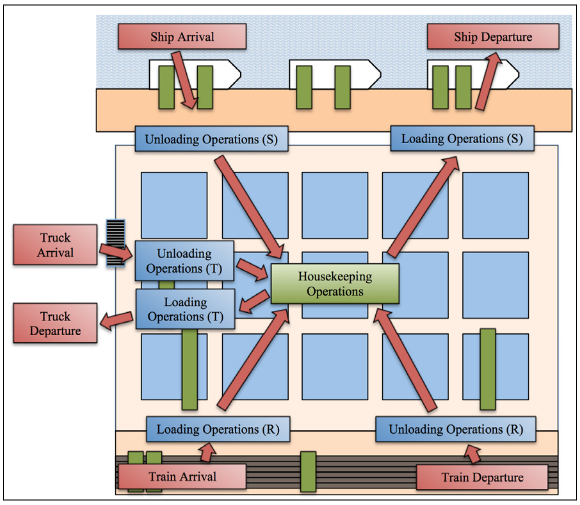

Figure 1: Schematic representation of a container terminal layout

To this end, flowcharts, being abstraction of model processes, are used as guidelines for simulation model development, in our case container terminal processes and activities (Banks, 1998). Figure 1 depicts a schematic representation of a container terminal lay-out. The layout is expressly designed to be as general as possible so as to encompass all key features of a container terminal, while being sufficiently flexible to allow the simulation model to capture multiple port terminal configurations. To this end, it has the following components:

- an approach/departure channel;
- a turning basin;
- a dock with three main berthing points;
- a yard where containers are stored;
- an entrance area connecting the port area with a highway, which is made up of 30 gates for incoming and outgoing trucks to be loaded and unloaded in the yard;
- a railway service with ten tracks.

Figure 2 depicts the flow chart used to abstract ship arrival and departure operations. Before entering the port area and approaching the assigned berth position, the ship is required to contact the port authority to check for berth availability and to require a maritime pilot to direct it to the port area. The ship may also require the assistance of a tugboat for performing maneuvers in the port area and completing entrance and mooring operations. Similar operations are then carried out when the ship leaves the port area. In a similar vein, Figure 3 depicts the flowchart conceptualizing container handling operations (container movements from berth to yard and vice versa) that are mainly performed by using Straddle Carriers (SC). More specifically, consider a container movement from quay to yard; after checking SC availability, if the container is already in the unloading zone (UZ) under the quay crane, the SC moves the container to the assigned slot in the yard area and performs housekeeping operations (if needed) and storage. Similar operations are carried out to move the container from its slot in the yard area to the loading zone (LZ, the buffer under the quay crane).

4. THE T-ESEDRAS SIMULATION MODEL

As mentioned in the Introduction section, this paper reports the preliminary results of an ongoing project named T-ESEDRAS (***T****erminals* ***E****nvironmental* ***S****ustainability* ***E****nhancement based* ***O****n* ***D****ata* ***R****e-organization* ***A****nalysis and* ***S****imulation*). The simulation model, presented in this section, takes the same name as the project.

In order to conform to the concept of Simulation as a Service (SaaS) the execution of a T-ESEDRAS simulation model can be invoked by a standard web browser.

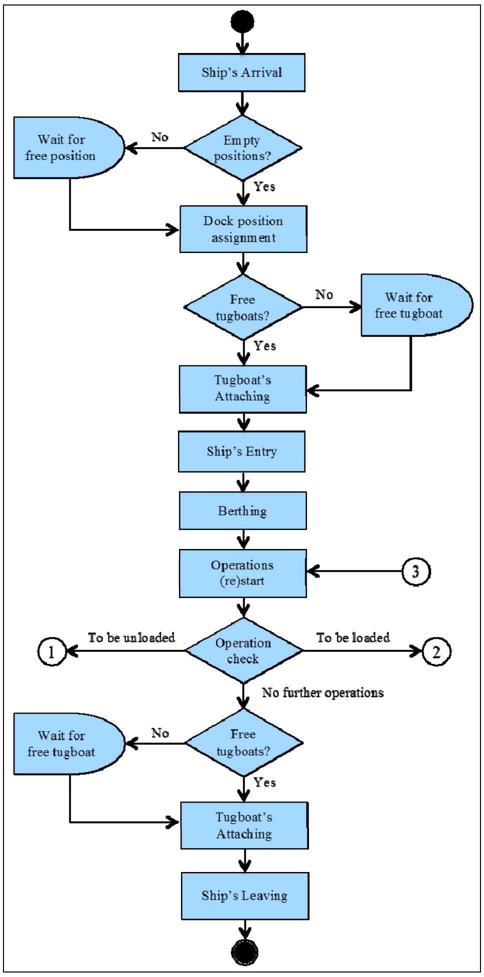

Figure 2: Flowchart for ship arrival and departure operations

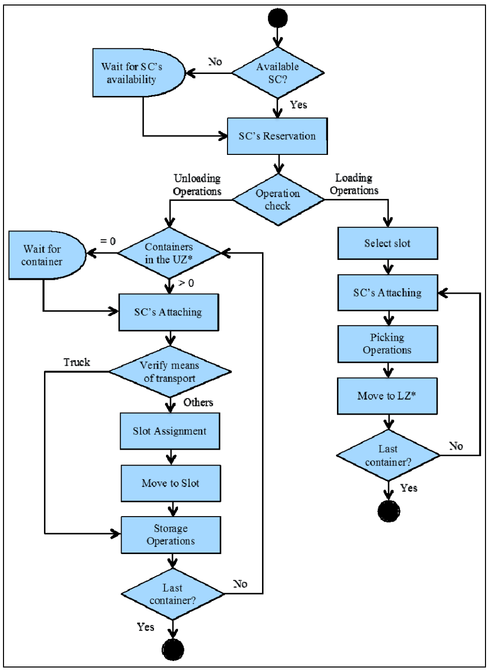

Figure 3: Flowchart conceptualizing container handling operations (container movements from berth to yard and vice versa)

This modeling and coding effort aims to allow users to overcome obstacles that are typical of non-service-oriented software, such as simulation models. Figure 4 displays the simulation model homepage, which allows the user to choose between two options:

- Immediately launch a simulation run with the system's default settings and no model customization;
- Modify the system's default settings and customize the model input parameters to fit the desired real-world system as close as possible by clicking on the *Simulation components* and/or the *Environmental parameters* links.

By clicking on the first customization option, *Simulation components*, a new view materializes where the user can set model parameters that control the behavior of agents in the simulated environment.

Figure 4: T-ESEDRAS simulation model homepage

In this section the user can modify a variety of model parameters, such as:

- The number of containers already stored in the yard. Port operations and activities (primarily unloading and loading operations) don't start as soon as the port is built because the yard is empty. A warm-up period is needed in order to initialize the simulation model with containers;
- The speed (in km/h) within the port area and the capacity (in TEUs) for each container ship, feeder ship, truck or train;
- Parameters related to the behavior of container handling systems (quay cranes, rail-mounted transtainers, straddle carriers, tugboats used to push or tow the vessels, etc.). These include speed, productivity, mean time to failure, etc.;
- The number of straddle carriers assigned to each berthing point, to a single transtainer and to straddle carriers dedicated to unloading and loading trucks in the yard.

By switching from the *Simulation components* view to the second customization option (or clicking on it directly in the homepage), the *Environmental parameters* view materializes. The goal of this view is twofold. Firstly, it gives the user the opportunity to select, through a checkbox, the green management initiatives to be assessed (in terms of environmental and financial impact) and the start-year for the practice. Secondly, it allows customizing all parameters related to the green management practices, including evaluation methodology, fuel and energy prices, emission conversion factors expressed both in terms of CDE and NO_x (to mention just two of the most dangerous pollutants), the type of fuel used by ships, trucks, trains, tugboats and container handling equipment as well as their fuel consumption rate.

Concerning the simulation model animation, a scaled representation of the container terminal and associated entities helps the user to visualize unfolding scenarios in the container terminal in terms of container flows (e.g., loading and unloading operations) and workflow (e.g., truck and train arrivals and departures).

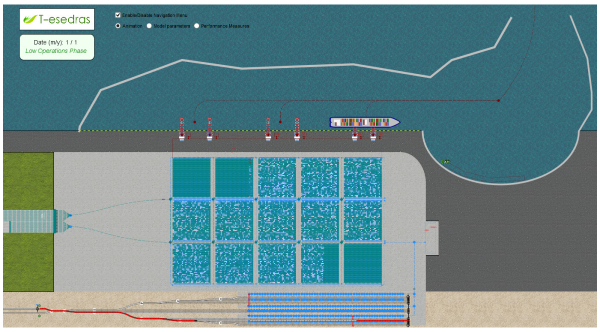

Figure 5: Animation view of a simulation model

The developed simulation model provides a set of performance metrics that measure both operational and financial aspects. All metrics have been selected with a view to assist port management in medium-term planning and control. Such metrics include performance measures related to container terminal operations, which are easy to calculate and simple to understand. While the operational performance of a container terminal is generally measured in terms of the time spent in it by containerships, a port manager would also be interested in the port's asset utilization and financial performance. To this end, Figure 6 shows a view of the operational metrics related to container terminal traffic. Metrics include yearly and monthly throughput in terms of TEUs, monthly totals of containership arrivals, monthly totals of feeder-ship arrivals, average waiting times for ships and trains, turn-around times, total TEUs handled, etc. The user may also change the view to observe container handling equipment utilization levels including those of straddle carriers, quay cranes, rail tracks, berth position, etc.

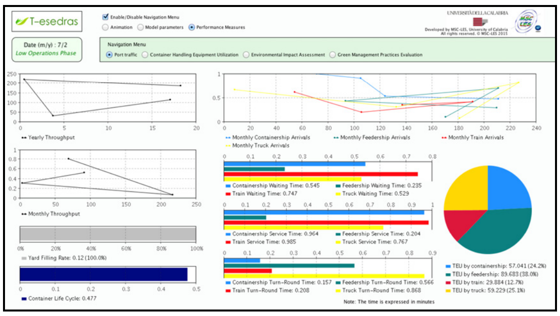

Figure 6: A view of operational metrics of a container terminal

However, the main objective of this study is to propose a set of sustainable environmental management metrics to be used by port authorities. All main activities performed within a container terminal are analyzed for potential environmental impacts and risks. Computed metrics should serve as “signals which allow data to become available for decision-making”.

The simulation model provides information about the environmental footprint of the container terminal activities, since studies show that carriers as well as container handling equipment have a major negative environmental impact both on the port area and its surrounding environment. To this end the T-ESEDRAS simulation model has two additional output sections that support the user in carrying out Environmental Impact Assessment and Green Management Practices Evaluation. Figure 7 displays a view of the metrics that support Environmental Impact Assessment. These include monthly fuel CO_2 and NO_x emissions for each container handling equipment.

Finally the T-ESEDRAS simulation model includes financial performance metrics including annual cash inflow/outflow, payback period, payback period diagram, net present value and net present value evolution diagram.

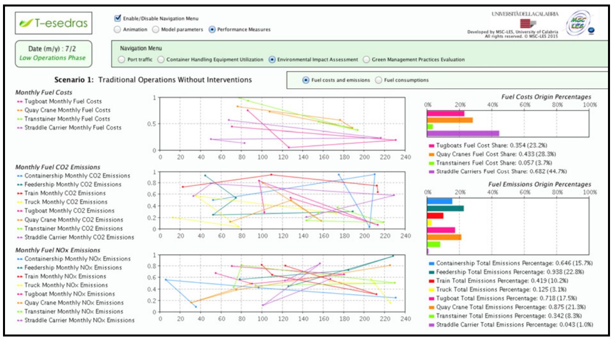

Figure 7: A view of environmental impact metrics

5. CONCLUSION

The continuing expansion of maritime transportation and the attendant environmental impacts provide powerful motivation for improving the sustainability of ports. As highlighted by Mittal and Baveja (in press), successful terminal operators with prior involvement in developing sustainability practices cannot rely on their past sustainability practices to remain market leaders. Instead they must innovate, deepen and deploy sustainability competencies as well as leverage new GMPs to ensure sustained success.

The strategic framework offered by the T-ESEDRAS simulation model can be useful in overcoming the abovementioned shortcomings, thereby improving the impact and extending the longevity of sustainability initiatives. Indeed, the T-ESEDRAS simulation model is proposed as a key tool to carry out environmental impact analyses of processes and activities performed in the course of the life cycle of port terminals. To this end, the simulation model can be used to simulate and compare alternative sustainability practices in terms of both environmental impact and technical and economic sustainability, thereby allowing terminal operators to work on continuous improvement of port economic efficiency and resource rationalization while maintaining an eco-friendly environment.

REFERENCES

Bailey, D, Solomon, G., 2004, Pollution prevention at ports: clearing the air, Environmental Impact Assessment Review, 24(7-8), 749-774.

Banks J., 1998. Handbook of Simulation. J. Wiley & Sons New York.

Bruzzone A.G., 2014. Special issue on modeling sustainability for the 3rd millennium. Simulation, Volume 90, Issue 2, pp. 131-132.

Golusin, M., Ivanovic, O., M., Teodorovic, N. 2011, The review of the achieved degree of sustainable development in South Eastern Europe—The use of linear regression method, *Renewable and Sustainable Energy Reviews*, 15(1), 766–772.

Gupta, A., K., Patil, R.S., Gupta, S., K., 2002, Emissions of gaseous and particulate pollutants in a port and port region in India, *Environmental Monitoring and Assessment*, 80(2), 187-205.

Joseph, J., Patil, R., S., Gupta, S., K., 2009, Estimation of air pollutant emission loads from construction and operational activities of a port and port in Mumbai, India, *Environmental Monitoring and Assessment*, 159(1-4), 85-98.

Karakosta, C., Doukas, H., Psarras, J., 2009, Directing clean development mechanism towards developing countries sustainable development priorities, *Energy for Sustainable Development*, 13(2), 77–84.

Longo, F., 2012. Sustainable supply chain design: An application example in local business retail. Simulation 88(12), 1484-1498

Lucialli, P., Ugolini, P., Pollini, E., 2007, Port of Ravenna: the contribution of port traffic to air quality, *Atmos Environ*, 41 (3), 6421–6431

Mittal, N, A. Baveja and R. Krishnan (in press). “Sustaining Sustainability in Marine Terminals: A Strategic Framework”, Journal of Transportation Research Forum (Forthcoming).

Montabon F., Sroufe R., Narasimhan R., 2007, An examination of corporate reporting, environmental management practices and firm performance, *Journal of Operations Management* 25 (2007), pp. 998–1014.

Saxe, H. , Larsen, T., 2004, Air pollution from ships in three Danish ports, *Atmos Environ*, 38 (24), 4057–4067.

Shrivastava, P., 1995, Environmental technologies and competitive advantage, *Strategic Management Journal,* 6(1), 183–200.

Wong C.W.Y., Lai K.H., Cheng T.C.E., Complementarities and alignment of information systems management and supply chain management, I*nternational Journal of Shipping and Transport Logistics* 2009, 1 (2), pp. 156–71.

Yang C.C., Marlow P.B., Lu C.S., Assessing resources, logistics service capabilities, innovation capabilities and performance of container shipping services in Taiwan, *International Journal of Production Economics* 2009; 122 (1), pp. 4–20.

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MUSHROOM CULTIVATION PROCESS, AGARICUS BISPORUS VARIETY: COMPARISON BETWEEN TRADITIONAL AND CLIMATE CONTROLLED CULTIVATION AND IDENTIFICATION OF ENVIRONMENTAL IMPACTS OF THE PRODUCTION PROCESSES

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ABSTRACT

Originally mushroom cultivation was carried out in caves that have gradually been replaced by climate controlled chambers, to control climatic conditions, requiring only energy consumption and cooling systems.

This paper presents a "cradle-to-gate" live cycle assessment (LCA) study of the process of mushrooms cultivation of the Agaricus bisporus variety. This study is based on real data gathered from a growing plant throughout a year, in order to provide accurate information of the environmental impact of various activities that is composed the production process. A comparison of two types of cultivation processes is performed: traditional cultivation and climate-controlled cultivation.

A general analysis of the main stages of the production process reveals a greater impact on the climate controlled cultivation process than in the traditional cultivation process.

Keywords: Environmental impact, Life Cycle Assessment, Mushroom cultivation, Agaricus Bisporus

1. INTRODUCTION

Agaricus bisporus, is a kind of fungus basidiomycete of the Agaricaceae family. Within the family of fungus, the Agaricus Bisporus is the most cultivated specie worldwide (Foulongne-Oriol et al., 2014; Tautorus, 1985; Saravanan et al., 2013) and is one of the most important vegetable crops worldwide. It is mostly used in cooking and is the most consumed food in the world (Foulongne-Oriol et al., 2014), because of its valuable nutritional properties (Wani et al., 2010).

2. METHODOLOGY

2.1. Life cycle assessment

The live cycle analysis or live cycle assessment (LCA) consist on a methodology that analyses and evaluates the environmental aspects and the potential impact of a material, product or service throughout the period of their life cycle (Leiva-Lázaro et al., 2014). LCA is an effective tool for decision-making (Azapagic et al., 1999) under the ISO standard 14040 (Martinez et al. 2009).

LCA helps in making decisions to choose the best alternative (Guinee, 1993), providing a basis to evaluate possible improvements in the environmental performance of a process or product (Azapagic et al., 1999). It is considered a powerful tool for sustainability.

The scope of the LCA methodology includes the extraction and processing of raw materials, manufacturing and assembly processes, product distribution, use of materials, maintenance, recycling and final disposal (Nash and Stoughton, 1994). It is an approach "cradle to grave" (Jiménez et al., 2014) that reviews the environmental effect of the processes, previously mentioned, in a holistic way (Barton, 1996).

LCA includes all loads and impacts on the life cycle of a product or a process, not focusing just only on emissions and waste generated during the process, unlike other systems of environmental impact (Leiva et al., 2015).

LCA can be used as a tool to identify critical points in the production process in order to identify possible solutions (Belussi et al., 2015). It is also a tool to review all the environmental aspects and potential impacts of a product, as it considers all aspects and phases of a product or process (Jiménez et al., 2014).

3. A CASE STUDY: CULTIVATION PROCESS (TRADITIONAL AND CLIMATE CONTROLLED PROCESS)

The cultivation process studied in this paper is divided into two methods currently used in the study area: Traditional cultivation and climate controlled cultivation.

The traditional cultivation process is carried out in cellars formerly used for wine production, which helps to maintain ideal temperature conditions for the mushroom cultivation. These wineries have only a ventilation system that renews the indoor air with fresh air, without control of temperature or humidity inside the room. The cellars are used rectangular 35 meters long, 4.5 meters wide and 2.4 meters high with a front door for input loading and unloading. The ventilation system is placed at the front and rear of the cellar, as a result the air flow inside the warehouse is adequate.

The climate controlled cultivation process takes place in rooms climatically controlled (relative humidity and temperature). These rooms have an air conditioning system and numerous air intakes for a homogeneous distribution in the room. The cellars are used rectangular 32 meters long, 7 meters wide and 4 meters high with a back door for loading and unloading packages of compost and casing material, and a front for staff access. All parameters are constantly controlled and monitored.

3.1. Modeling and analysis of the cultivation process

In the present study two types of cultivation processes are presented: traditional and climate controlled cultivation processes. The production process includes the following stages:

- Climatization.

The cultivation process conducted in climate controlled rooms, has a constant control of the temperature and a heating system supplied by biomass.

- Ventilation.

The growing process in ventilated chambers features just a ventilation system to keep clean air constantly recirculating through the interior of the chambers

- Preparation of the covering soil.

The first phase of the growing process is to prepare the soil used to cover the compost packages.

The process begins with the disinfection of the area where the covering soil is prepared, in order to prevent the appearance of diseases during the growing process. Peat is deposited in the disinfected area. This peat does not contain sufficient moisture, so water is added to bring the moisture content up to the level required for covering soil. Finally, fungicides are also added to prevent pests and diseases during the cultivation process.

- Preparation of the growing chambers.

The next phase of the process is the preparation of the growing chambers to place the compost packages. The process begins with the disinfection of the growing chambers to prevent the appearance of diseases during the cultivation process. Once disinfection is complete, the chambers are prepared by setting out the cages where the compost packages will be placed. The compost packages are then placed on the cages so that the cultivation process can begin

- Cultivation process.

The next phase is the cultivation process, which culminates with the harvesting of the end product. This process begins once all the compost packages have been placed on the cages in the chambers with the covering soil previously prepared. Then water is added to start the growing phase. Continual fumigation by adding fungicides and insecticides is required to prevent the appearance of pests during the process. During the cultivation process homogenisation (activation of the mycelium) and fruiting (development of the fruiting bodies) begin. When the fruiting process is completed the fruiting bodies are harvested.

- Waste management.

The final phase is the management of the waste produced during the process. The waste produced is placed in a separate container for collection and treatment at a specific plant.

4. SIMULATION RESULTS

Field measurements made during the study are presented. Concentration of CO2 measurements were performed inside the cultivation chambers, both in traditional and climate controlled cultivation. Measurements of temperature and relative humidity were also carried out.

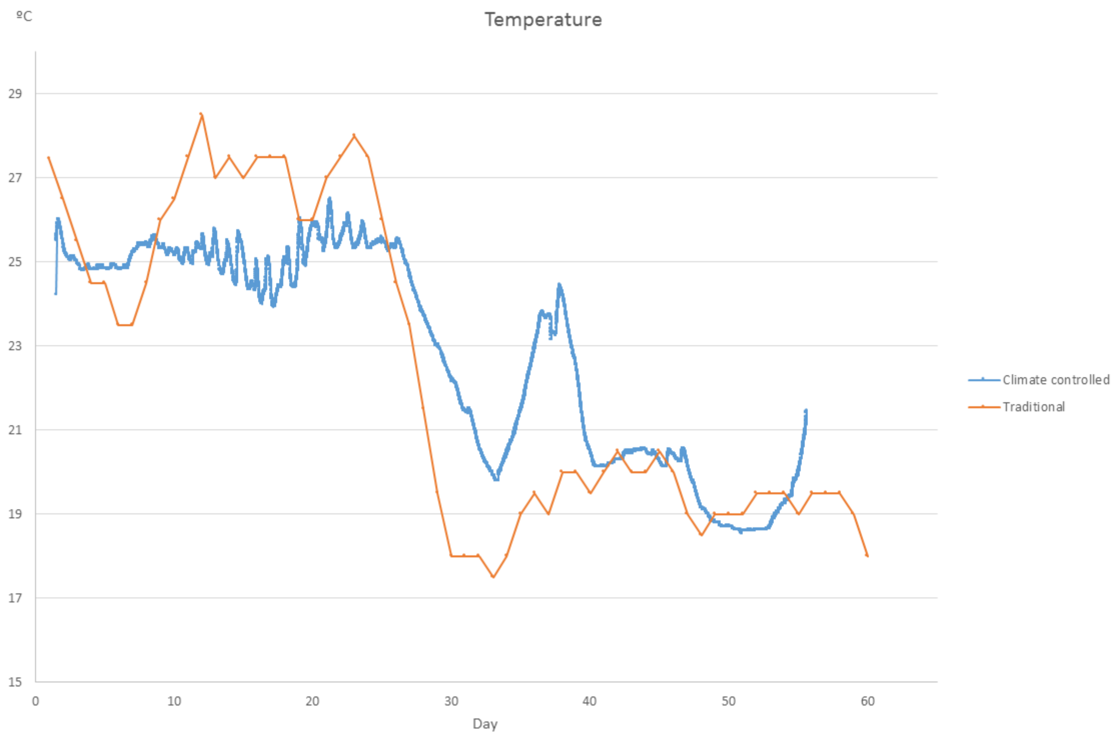

Figure 1: Temperature during the cultivation process

4.1. Temperature

Temperature is a very important parameter to control during the process. During the incubation phase it is critical to control the temperature to get a proper development of the mycelial activity. During the fruiting phase, it is important to maintain a suitable temperature for the proper development of fruiting bodies (Foulongne-Oriol et al., 2014; Largeteau et al., 2011)

The climate control system provides a high temperature control during the production process, especially during the incubation phase where the mycelial activity is considerable, rising high temperatures. The compost temperature remains constant during the incubation phase (Figure 1), effectively varying the temperature of the compost for the following stages according to the needs of the fungus.

The climate controlled cultivation allows greater control over the temperature. The temperature of both the compost and the culture room, is more stable in the heated chambers (Figure 1).

4.2. Relative humidity

Another parameter controlled during the cultivation process is the relative humidity in the cultivation chambers. It is especially relevant during the fruiting phase, as it will affect the development of the fruiting bodies. The relative humidity of the room is considerably reduced during the fruiting phase (Fig. 2).

The climate controlled process also allows greater control over the relative humidity of the chamber than in traditional process. Climate controlled cultivation chamber offers a more stable relative humidity is more stable with progressive changes than in traditional processes (Figure 2).

4.3. CO2 emissions

CO2 emissions are present throughout the process. Higher concentrations occur during the incubation phase where the mycelial activity is elevated (colonization of the substrate). As a result high CO2 emissions, above 10,000 ppm, can be found (Figure 3). A sudden drop in CO2 emissions occurs because the mycelial activity is reduced dramatically once the substrate is fully colonized.

After the incubation phase, CO2 emissions in the following phases are much lower because the mycelial activity is lower.

4.4. Impact categories

In this section the environmental impacts are quantified in the different categories studied using the CML method.

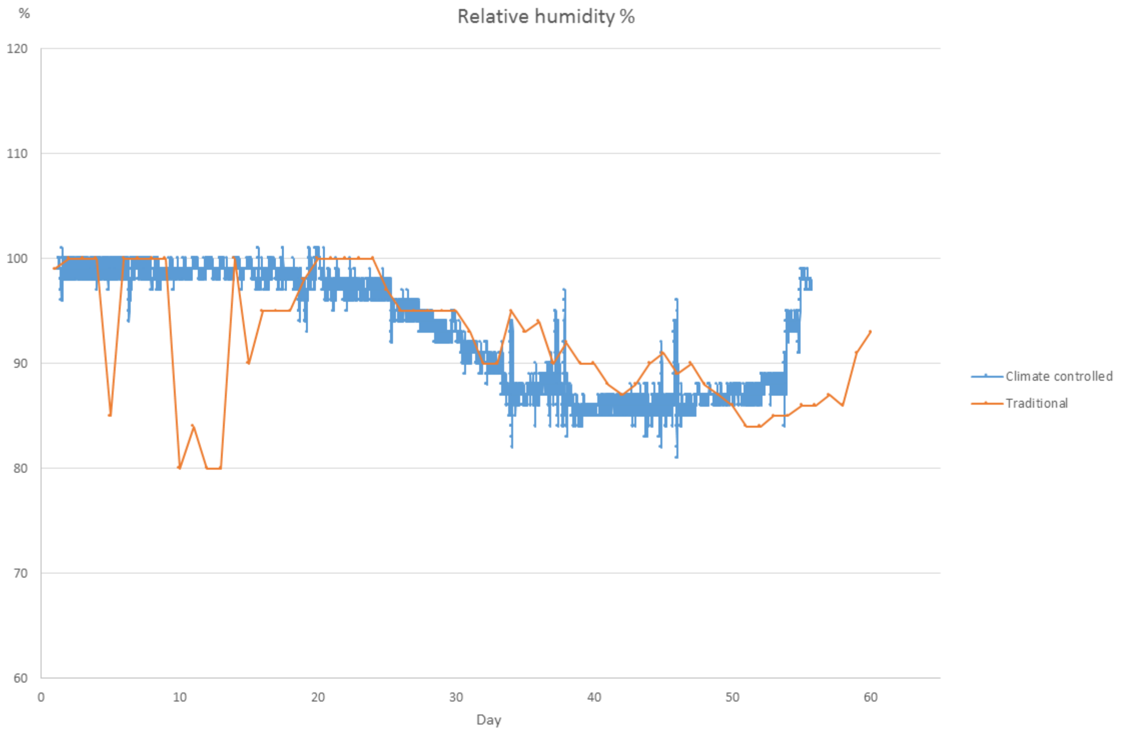

Figure 2: Relative humidity during the cultivation process

The climate controlled cultivation process has a greater impact in all categories due to a greater number of inputs consumed. The climate control system, with a higher energy demand than the ventilation system, has a higher percentage of impact on all impact categories studied.

5. CONCLUSIONS

The conducted study shows a greater impact, in all impact categories studied, in the climate controlled cultivation process than in the traditional cultivation process. The impact is higher because the energy demanded by the climate control system is much higher than the energy demanded by the ventilation system.

Although the impact is greater, the climate controlled cultivation process provides greater control of the temperature and relative humidity inside the cultivation chambers throughout the process. In addition, the time required for each chamber is considerably lower in the climate controlled process, average of 58 days per chamber, than in the traditional process, average of 63 days per chamber.

Although energy demand is greater, the climate controlled process allows carrying out the process at any time of year, because it does not depend on external conditions of temperature and humidity. By contrast, the traditional process is directly dependent on environmental conditions

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REFERENCES

Akinyele, J.B., Fakoya, S., Adetuyi, C.F., 2012. Anti-growth factors associated with Pleurotus ostreatus in a submerged liquid fermentation. Malaysian Journal of Microbiology 8, 135-140.

Azapagic, A. and R. Clift, Life cycle assessment and multiobjective optimisation. Journal of Cleaner Production, 1999. 7(2): p. 135-143.

Barton J.R. 1996. Life cycle assessment for waste management. Waste Management; 16:35-50.

Belussi, L., et al., LCA study and testing of a photovoltaic ceramic tile prototype. Renewable Energy, 2015. 74: p. 263-270.

Foulongne-Oriol, M., Navarro, P., Spataro, C., Ferrer, N., Savoie, J.M., 2014. Deciphering the ability of Agaricus bisporus var. burnettii to produce mushrooms at high temperature (25°C). Fungal Genetics and Biology 73, 1-11.

Guinee, J.B., et al., Quantitative life cycle assessment of products 2. classification, valuation and improvement analysis. Journal of Cleaner Production, 1993. 1(2): p. 81-91.

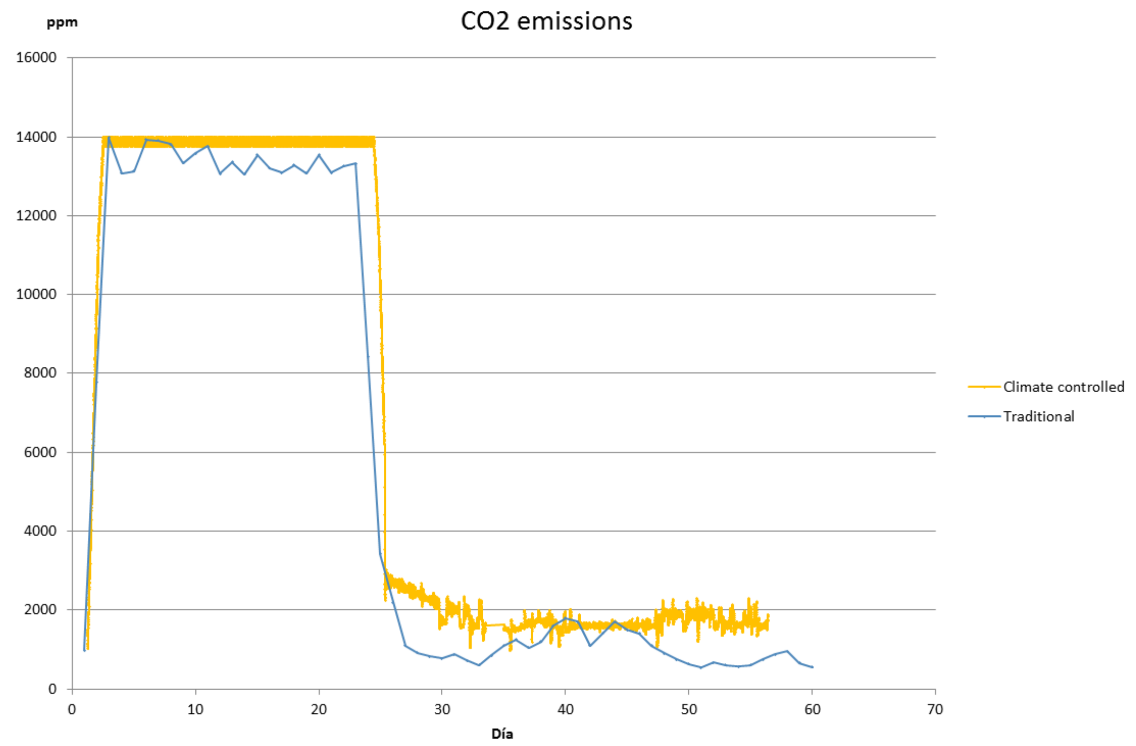

Figure 3: CO_2 emissions in the cultivation facilities

Jiménez, E., et al., Methodological approach towards sustainability by integration of environmental impact in production system models through life cycle analysis: Application to the Rioja wine sector. Simulation, 2014. 90(2): p. 143-161.

Kerrigan, R.W., M.P. Challen, and K.S. Burton, Agaricus bisporus genome sequence: A commentary. Fungal Genetics and Biology, 2013. 55: p. 2-5.

Largeteau, M.L., Callac, P., Navarro-Rodriguez, A.M., Savoie, J.M., 2011. Diversity in the ability of Agaricus bisporus wild isolates to fruit at high temperature (25 °C). Fungal Biology 115, 1186-1195.

Leiva-Lázaro, F.J., Blanco-Fernández, J., Martínez-Cámara, E., Jiménez-Macías, E., 2015. Environmental impact of agaricus bisporus mycelium production. Agricultural Systems 138 (2015) 38–45.

Leiva-Lázaro, F.J., et al. Production of compost for mushroom cultivation: A life cycle assessment study. in 26th European Modeling and Simulation Symposium, EMSS 2014. 2014.

Nash J., Stoughton M.D. 1994. Learning to live with life cycle assessment. Environmental Scienceand Technology 28: 236A-237A.

Saravanan, R., et al., Analysis of nutrients and minerals content in commercially purchased Agaricus bisporus. Research Journal of Pharmacy and Technology, 2013. 6(7): p. 765-768.

Tautorus, T.E., 1985. Mushroom fermentation. Advances in Biotechnological Processes 5, 227-273.

Wani, B.A., R.H. Bodha, and A.H. Wani, Nutritional and medicinal importance of mushrooms. Journal of Medicinal Plants Research, 2010. 4(24): p. 2598-2604.

A PROBABILISTIC *FR 13* SIMULATION OF STRATEGIES FOR COOLING OF AIR IN BUILDINGS WITH UNPLANNED TRAFFIC FLOW DURING SUMMER

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ABSTRACT
Many buildings with varying traffic flow (i.e. occupancy), such as public buildings and hotels, do not have a quantitative strategy to manage energy use. Although seasonal, energy use is difficult to predict. A problem is to know the risk of failure of a postulated energy strategy used for cooling of the building interior air to an *auto-set* value (customarily 22 ^{O}C). A new probabilistic assessment of the proposed *on-only* cooling strategy of Chu et al. (2015) has shown that some 12 unexpected, or *Fr 13*, failures can occur each summer, averaged over a prolonged period. Simulations highlight the cooling strategy is actually highly dependent on traffic flow (as occupancy) in the buildings, and not on ambient summer temperatures. Because all occupancy scenarios that could practically exist have been simulated the *Fr 13* risk assessment is an advance over more traditional assessments.

Keywords: cooling of large buildings; cooling strategy; varying traffic impact on cooling; probabilistic risk modelling; Friday 13th risk modelling

1. INTRODUCTION
Modern buildings, including commercial hotels and public structures, commonly have a massive concrete-and-steel frame to provide strength, together with a façade(s) of glass panes to provide internal light and vista during the day. These panes however permit heat transfer to the interior from ambient. As a consequence, during summer months, large air conditioning systems are installed to cool-down and maintain an *auto-set* room interior air temperature (customarily 22 ^{O}C).
In an attempt to limit operating costs, an energy strategy that is widely used, particularly in hotels, is that cooling to the room is switched on only when the room is occupied and switched off immediately when the room is unoccupied (this is the *on-off* strategy); this is especially true of hotels and government office buildings. An alternative however is to leave the cooling continuously on (the *on-only* strategy). Oddly, research has generally focused on the design and calibration and measurement of energy parameters, using discrete and deterministic assessments (Coakley et al., 2012; Eisenhower et al., 2012) and not on which of these strategies to adopt under given circumstances.
Recently, Chu et al. (2015) synthesised a cooling unit-operations model (Foust et al., 1980; Wankat, 2007) and established, using simulations for a range of room traffic flows (occupancy) and ambient temperatures, that the *on-only* strategy would be more energy efficient long-term than the *on-off* in the hot summer months in areas of South Eastern Australia. A major reason identified was that the thermal 'sink' (i.e. mass) that the building's concrete-and-steel affords, has to be cooled repeatedly with the *on-off* strategy; however with the *on-only* strategy however this heat is removed from the sink only once.
They concluded that the *on-only* strategy should be adopted.
A drawback with this formative study, however, is that occupancy and ambient temperature will be impacted by naturally occurring fluctuations about their likely (mode) value and will not be either fixed or evolve predictably as assumed by Chu et al. (2015).
A problem is to recognize these naturally occurring fluctuations in occupancy (traffic arrival and departure) and ambient temperature and to determine quantitatively whether these will have a significant impact on which strategy is better.
To quantify the impact of these naturally occurring fluctuations in key parameters in otherwise well-designed and well-operated systems, Davey and co-workers (Davey 2015; Abdul-Halim and Davey, 2015; Davey et al., 2015) have developed a new, quantitative probabilistic methodology. Their thesis is predicated on the fact that random change in values can sometimes accumulate unexpectedly in one direction and leverage significant change in process or product. They titled this underlying risk of vulnerability to surprise failure due to random affects as *Fr 13*. They have demonstrated this work with a number of case studies including surprise shifts from: sterile to non-sterile milk (Davey and Cerf, 2003); stable to unstable (washout) operation of a fermenter (Patil et al., 2005); removal of protein deposits in Clean-In-Place (CIP) processing to failure to clean (Davey et al., 2013; Davey et al., 2015); potable to non-potable water using ultraviolet (UV) irradiation (Abdul-Halim and Davey, 2015); efficient to inefficient

fuel-to-steam conversion in a coal fired boiler (Davey, 2015), and; failure of raw milk pasteurization (Chandrakash, et al.; 2015).
A major practical advantage claimed for *Fr 13* analyses is that all operational scenarios that could exist, including energy strategy failures, would be evaluated and quantified.

1.1. This research

Here we simulate for the first time the *on-off* and *on-only* cooling strategies using the emerging methodology of Davey and co-workers to investigate the impact of fluctuations in occupancy (traffic arrival and departure) and ambient temperature on the validity of the *on-only* cooling energy strategy advocated by Chu et al. (2015).
The approach is to extend the unit-operations cooling model of Chu et al. (2015) to incorporate realistic values for large-scale commercial parameters, and adapt the probabilistic method of Davey and co-workers in which a new dimensionless risk factor for the energy strategy (p) is defined. This risk factor is convenient as all $p > 0$ can be used to characterize the *on-only* energy strategy as a 'fail'.
The probabilistic simulations are based on a refined Monte Carlo (with Latin Hypercube) sampling (r-MC) of parameters (Vose, 2008). An advantage is that all practical scenarios that could exist operationally, including energy strategy failures, are evaluated and quantified.
Practical benefits and new insights gained through this probabilistic approach are discussed. It is envisaged that findings can be generalized.
The research will be of interest to operators and managers responsible for cooling of large public and commercial buildings.

2. MATERIALS AND METHODS

The model developed by Chu et al. (2015) is well-suited both in terms of its formative nature and underlying unit-operations mathematical synthesis. A single room is considered to have of width W, vertical length L, and interior depth D, Figure 1.
All symbols used are defined carefully in the Nomenclature.

2.1. Cooling model

A single glass pane (10 mm thick), comprised each of two external walls of the room was exposed to ambient. Because of the massive nature of materials of construction, the room ceiling and floor were assumed to be thermally insulated. The two opposing internal walls were assumed to be made from commercial clay bricks (110 mm thick), laid in a standard double-brick on-flat with an air gap. The air gap provided was, reasonably, assumed to provide a thermal barrier to ambient (or adjoining room in a multiple-room building).
It was assumed all heat transfer to and from the structure was by natural convection i.e. radiation and forced convection were ignored.

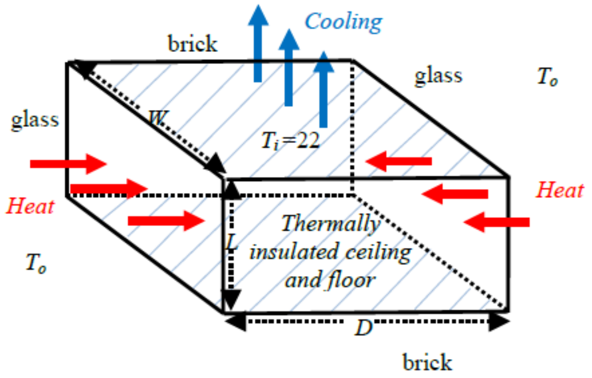

Figure 1: Simplified schematic of cooling unit-operations for a room during summer

Radiative heat transfer is ignored because it is widespread industry practice that curtains will be drawn closed, to mitigate radiative heat transfer.
The rate of heat energy transferred from ambient through both the glass and brick wall to the room interior, q, was given by (Holman, 2010; Perry and Green, 1997; Anon., 2013)

$$q = U_o A \Delta T \tag{1}$$

such that for the glass

$$q_{glass} = U_{o,glass} A_{glass} \Delta T \tag{2}$$

and for the brick

$$q_{brick} = U_{o,brick} A_{brick} \Delta T \tag{3}$$

The overall heat transfer coefficient (U_o) was given by (Holman, 2010; Perry and Green, 1997; Anon., 2013)

$$U_o = \frac{1}{\frac{1}{h_o} + \frac{d}{k} + \frac{1}{h_i}} \tag{4}$$

such that for the glass

$$U_{o,glass} = \frac{1}{\frac{1}{h_{o,glass}} + \frac{d_{glass}}{k_{glass}} + \frac{1}{h_{i,glass}}} \tag{5}$$

and for the brick

$$U_{o,brick} = \frac{1}{\frac{d_{brick}}{k_{brick}} + \frac{1}{h_{i,brick}}} \tag{6}$$

Because it was assumed that the wall had an air gap (cavity), there is no outside convective heat transfer coefficient shown in Eq. (6).
The total area for heat transfer for the glass panes was

$$A_{glass} = 2 \times L \times W \quad (7)$$

and, that for the brick walls was

$$A_{brick} = 2 \times L \times D \quad (8)$$

For cooling, T_o must be greater than T_i, and gave a temperature gradient such that

$$\Delta T = T_o - T_i \quad (9)$$

The temperature of the glass and air film on the glass was given by

$$T_{air,glass} = \frac{1}{2}(T_o + T_i) \quad (10)$$

The temperature of the air film on the brick wall was, similarly, given by

$$T_{air,brick} = \frac{1}{2}(T_{brick} + T_i) \quad (11)$$

in which T_{brick} = T_o i.e. it was assumed the temperature of the brick walls reached equilibrium with ambient in a short time once air cooling was switched off. Chu et al. (2015) argued this assumption was justified for example in hotels, where common practice is that this would occur mid-morning when the housekeeping staff finish cleaning and leave the room.
The correlation for Nusselt number was used to determine the convective heat transfer coefficient (Holman, 2010; Anon., 2013) for natural convection of air along the vertical glass wall (on either outside or inside) and the brick wall (inside only)

$$Nu = \frac{hL}{k} = \left(0.825 + \frac{0.387 Ra^{\frac{1}{6}}}{(1 + (\frac{0.492}{Pr})^{\frac{9}{16}})^{\frac{8}{27}}} \right)^2$$

for $10^{-1} < Ra < 10^{12}$ (12)

in which the Raleigh (Ra) number was (Holman, 2010)

$$Ra = Gr\, Pr \quad (13)$$

with

$$Gr = \frac{L^3 \rho^2 g \beta \delta T}{\mu^2} \quad (14)$$

and

$$Pr = \frac{c\mu}{k} \quad (15)$$

For the glass panes

$$\delta T_{o,glass} = (T_o - T_{air,glass}) \quad (16)$$

$$\delta T_{i,glass} = (T_{air,glass} - T_i) \quad (17)$$

For the brick

$$\delta T_{i,brick} = (T_{brick} - T_i) \quad (18)$$

Eqs. (1) through (18) were used to define the underlying unit-operations model for cooling of the room interior air to an *auto-set* temperature in summer.

2.2. *On-off* and *on-only* energy strategies

The model was applied to investigate two possible (and mutually exclusive) energy strategies.
In the *on-off* strategy, because the room cooling was turned off when unoccupied and turned on when occupied, the two brick walls that were assumed by Chu et al. (2015) to have reached equilibrium with ambient temperature would need to be cooled i.e.

$$q_{on-off} = (q_{glass} + q_{brick}) \quad (19)$$

This strategy they titled *on-off*.
However, the room was unlikely to be occupied every day. They defined traffic flow with an overall occupancy, η %. This meant that for the *on-off* strategy, energy use was a linear function of η, and Eq. (19) could be written as

$$q_{on-off} = \frac{\eta}{100}(q_{glass} + q_{brick}) \quad (20)$$

Chu et al. (2015) reported that the most likely occupancy, based on industry-wide (anecdotal) historical data for South Eastern Australia (Clarion Gateway, Choice Hotels International, Melbourne, *unpublished data*), was η = 75 %.
Their alternative strategy was to simply leave the room with cooling on continuously. This they titled *on-only*.
Because the room was continuously cooled, the interior walls of the room were assumed to be permanently at the room interior *auto-set* temperature T_i (= 22 ^{O}C).
Therefore only the energy transferred from ambient through the two glass panes would need to be removed in cooling. The overall energy demand for the *on-only* strategy was therefore

$$q_{on-only} = q_{glass} \quad (21)$$

2.3. Traditional deterministic single value assessment (SVA)

A traditional, deterministic and single value assessment (SVA) (Sinnott, 2005) of the unit-operations model of Chu et al. (2015) for cooling of the air is carried out as follows:

For the (commercial building silica type) glass pane wall, each of L = 2.5 m, W = 4.5 m and d = 0.01 m, $k_{glass,}$ = 0.78 W m^{-1} K^{-1} and k_{brick} = 0.69 W m^{-1} K^{-1} is specified; the mean thermal properties of air, ρ = 1.1774 kg m^{-3}, g = 9.81 m s^{-2}, μ = 1.862 x 10^{-5} kg m^{-1} s^{-1}, c = 1005.7 J kg^{-1} K^{-1}, k = 0.0262 W m^{-1} K^{-1} and β = 3.3333 x 10^{-3} K^{-1} are given at 300 K (Holman, 2010).

From Eq. (7) the area for heat transfer through the glass pane is A_{glass} = 22.5 m^2. For an assumed mean ambient work-day summer temperature (December through February, South East Australia) T_o = 35 ^{O}C, the value ΔT = (35 – 22) = 13 K, is obtained from Eq. (9). $T_{air,glass}$ = ½(35 + 22) = 28.5 ^{o}C (301.65 K) is computed from Eq. (10). From Eqs. (16) and (17) respectively, δT = 6.5 K for both the outside, $\delta T_{o,glass}$ and inside, $\delta T_{i,glass}$ of the glass wall.

Substituting values for each of L, ρ, g, μ, k, c, β and δT into Eqs. (14) and (15), the Grashof and Prandtl number are respectively $Gr = Gr_{glass}$ = 1.33 x 10^{10} and Pr = 0.71. From Eq. (13) the Raleigh number, $Ra = Ra_{glass}$ = 9.48 x 10^9. Since 10^{-1} < Ra < 10^{12} Eq. (12) applies for the air outside and inside, yielding the heat transfer coefficient, $h_{o,glass}$ = 2.61 W m^{-2} K^{-1} and $h_{i,glass}$ = 2.61 W m^{-2} K^{-1} respectively.

Substituting $h_{o,glass}$, $h_{i,glass}$, d_{glass} and k_{glass} into Eq. (5), yields the overall heat transfer coefficient, $U_{o,glass}$ = 1.28 W m^{-2} K^{-1}. Substituting $U_{o,glass}$, A_{glass} and ΔT into Eq. (2), the rate of heat energy transferred from the outside ambient to the interior of the room, q_{glass} = 374.75 W.

That is for the *on-only* strategy, following an initial start-up of cooling, given a uniform outside ambient summer temperature of 35 ^{O}C, 374.75 W will need to be removed to keep the room interior at 22 ^{O}C.

For the *on-off* strategy, the energy use is calculated as follows: From Eq. (18) $\delta T_{i,brick}$ = 13 K. Substituting $\delta T_{i,brick}$ together with values for each of L, ρ, g, μ, k, c, and β into Eqs. (14) and (15), the Grashof and Prandtl number are respectively $Gr = Gr_{brick}$ = 2.66 x 10^{10} and Pr = 0. 71. From Eq. (13) the Raleigh number, $Ra = Ra_{brick}$ = 1.90 x 10^{10}. Since 10^{-1} < Ra < 10^{12} Eq. (12) applies for the room interior air, yielding the heat transfer coefficient $h_{i,brick}$ = 3.24 W m^{-2} K^{-1}.

Substituting $h_{i,brick}$, d_{brick} and k_{brick} into Eq. (6), yields the overall heat transfer coefficient, $U_{o,brick}$ = 2.14 W m^{-2} K^{-1}. From Eq. (8) the area for heat transfer from the brick walls is A_{brick} = 25.0 m^2. Substituting $U_{o,brick}$, A_{brick} and ΔT into Eq. (3), the rate of heat energy transferred from the brick wall to the interior of the room, q_{brick} = 695.05 W.

That is, given a uniform outside ambient summer temperature of 35 ^{O}C, the energy transfer from Eq (19) is therefore $q_{on\text{-}off}$ = 374.75 + 695.05 = 1069.80 W.

The difference in energy use between the two energy strategies can be written as

$$q_{difference} = q_{on-only} - q_{on-off}$$
$$= q_{glass} - \frac{\eta}{100}(q_{glass} + q_{brick}) \qquad (22)$$

It is seen that a practical and convenient advantage of Eq. (22) is that for all $q_{difference}$ > 0, the *on-off* strategy should be applied and when $q_{difference}$ < 0, the *on-only* strategy is better. At $q_{difference}$ = 0 either strategy will be equally effective.

3. *FR 13* RISK MODEL

In contrast to the SVA, in the probabilistic *Fr 13* risk method of Davey and co-workers, the value of key input parameters is defined by a distribution, together with the probability (i.e. likelihood) of the value actually occurring in practical operation, and not by a single value.

The output is therefore a distribution of values of the probability of the particular outcome (Davey, 2015; Davey et al., 2015; Abdul-Halim and Davey, 2015) including unwanted outcomes i.e. failed strategies.

Additionally, a fundamental requirement of a rigorous application of this risk method is a practical and unambiguous definition of failure (Davey, 2011; Davey, 2015; Zou and Davey, 2015).

3.1. Defining failure

The amount of energy used in the two strategies can be used to define an energy strategy risk factor such that P = [q_{glass} (*1 – η/100*)]' – [q_{brick} (*η/100*)]*'* in which [q_{glass} (*1 – η/100*)]' and [q_{brick} (*η/100*)]' are particular (instantaneous) values (or more strictly, mathematically, one probabilistic simulation). However a computationally more convenient form of the energy strategy risk factor (Davey, 2015; Davey et al., 2015; Abdul-Halim and Davey, 2015) is

$$p = \left(\frac{[q_{glass}(1 - \frac{\eta}{100})]'}{[q_{brick}\frac{\eta}{100}]'} - 1 \right) \qquad (23)$$

Eq. (23) is computationally convenient because all p > 0 underscores a 'failed' adoption of the *on-only* strategy advocated by Chu et al. (2015).

3.2. *Fr 13* simulations

Eqs. (1) through (23) define the probabilistic *Fr 13* simulation for a failure in the *on-only* strategy for cooling of the room air.

The model is seen to be identical in form to the SVA because all mathematical operations that connect the parameters are the same. However, unlike the SVA where a single input and output value are computed, the inputs and outputs from the simulation are a distribution.

To emulate the naturally occurring fluctuations in value of the model input parameters with time the probability distributions need to be realistically defined. There are some 40 distribution types (Vose, 2008).

A refined Monte Carlo (with a Latin Hypercube) sampling (r-MC) is used to ensure values are sampled that cover the entire practical range of the probability distributions used to define the key parameters.

As pointed out by Abdul-Halim and Davey (2015) and others (e.g. Davey et al., 2015; Vose, 2008) sampling with 'pure' MC cannot be relied on to replicate the parameter distribution because it can both over- and under-sample from various parts of the distribution.

Table 1: Summary comparison of the traditional SVA with the new *Fr 13* simulation of applying the *on-only* cooling strategy

Cooling parameter	SVA*	*Fr 13* simulation†	
η (%)	75.0	21.66	**RiskTriang**(5,75,100)
T_o (^{O}C)	35.0	33.46	**RiskNormal**(35,5,**RiskTruncate**(25,45))
T_i (^{O}C)	22.0	22.0	Constant
L (m)	2.5	2.5	Constant
W (m)	4.5	4.5	Constant
d_{glass} (m)	0.01	0.01	Constant
k_{glass} (W m^{-1} K^{-1})	0.78	0.78	Constant
ρ (kg m^{-3})	1.1774	1.1774	Constant
g (m s^{-2})	9.81	9.81	Constant
μ (kg m^{-1} s^{-1})	0.00001862	0.00001862	Constant
c (J kg^{-1} K^{-1})	1005.7	1005.7	Constant
k (W m^{-1} K^{-1})	0.02624	0.02624	Constant
β (K^{-1})	0.0033333	0.0033333	Constant
L (m)	2.5	2.5	Constant
D (m)	5.0	5.0	Constant
d_{brick} *(m)*	0.11	0.11	Constant
k_{brick} (W m^{-1} K^{-1})	0.69	0.69	Constant
A_{glass} (m^2)	22.5	22.5	Eq. (7)
ΔT (K)	13.0	11.46	Eq. (9)
$T_{air,glass}$ (K)	28.5	27.73	Eq. (10)
$\delta T_{o,glass}$ (K)	6.5	5.73	Eq. (16)
$\delta T_{i,glass}$ (K)	6.5	5.73	Eq. (17)
Gr_{glass} (dimensionless)	13279136800	11706069825	Eq. (14)
Pr_{glass} (dimensionless)	0.713648	0.713648	Eq. (15)
Ra_{glass} (dimensionless)	9476634723	8354017994	Eq. (13)
$h_{o,glass}$ (W m^{-2} K^{-1})	2.61	2.503538258	Eq. (12)
$h_{i,glass}$ (W m^{-2} K^{-1})	2.61	2.503538258	Eq. (12)
$U_{o,glass}$ (W m^{-2} K^{-1})	1.28	1.231997634	Eq. (5)
q_{glass} (W)	374.75	317.6705899	Eq. (2)
A_{brick} (m^2)	25	25	Eq. (8)
ΔT (K)	13.0	11.5	Eq. (9)
$T_{air,brick}$ (K)	28.5	27.73	Eq. (11)
$\delta T_{i,brick}$ (K)	13.0	11.5	Eq. (18)
Gr_{brick} (dimensionless)	26558273600	23412139651	Eq. (14)
Pr_{brick} (dimensionless)	0.713648	0.713648	Eq. (15)
Ra_{brick} (dimensionless)	18953269446	16708035988	Eq. (13)
$h_{i,brick}$ (W m^{-2} K^{-1})	3.24	3.12	Eq. (12)
$U_{o,brick}$ (W m^{-2} K^{-1})	2.14	2.08	Eq. (6)
q_{brick} (W)	695.05	596.65	Eq. (3)
q_{on-off} (W)	802.35	198.04	Eq. (20)
$q_{on-only}$ (W)	374.75	317.67	Eq. (21)
p (dimensionless)		**92.55**	Eq. (23)

* Traditional, Single Value Assessment.
† One only of 5,000 scenarios.

When the number of samples is sufficiently large, the output mean will be normally distributed (Vose, 2008; Davey 2015). Davey and co-workers (e.g. Zou and Davey 2015; Abdul-Halim and Davey, 2015; Davey et al., 2015, 2013; Davey, 2011) have reported that this usually requires some 1,000 to 50,000 samples for a typical unit-operation simulation. This number can be readily established when a plot of number of failures, all

$p > 0$, versus number of r-MC samples has plateaued to a constant value. A random number generator is used (Vose, 2008). Importantly, with *Fr 13* simulations with a sufficiently large number of r-MC samples, all possible combinations of input parameter values and resulting output process scenarios that could occur in the energy strategy for room interior cooling will have been simulated, including failure.

4. RESULTS

Table 1 presents a comparative summary of results from the traditional SVA with those of the new *Fr 13* method.

Computations were carried out using Microsoft Excel™ with commercially available add-on *@Risk*™ (version 5.5, Palisade Corporation). The use of spread sheeting is advantageous as it has nearly universal use and the distributions defining naturally occurring fluctuations in parameters can be entered, viewed, copied, pasted and manipulated as Excel formulae.

The table permits the simulations to be read systematically down each of the columns. The parameters that define the unit-operation for cooling of the room interior air are given in column 1 of Table 1. The SVA computations are given in column 2. For example, inspection of column 2 shows the input data and resulting values for the intermediate calculations, and finally, for each of the two strategies, respectively, the value $q_{on\text{-}only}$ and $q_{on\text{-}off}$, (W).

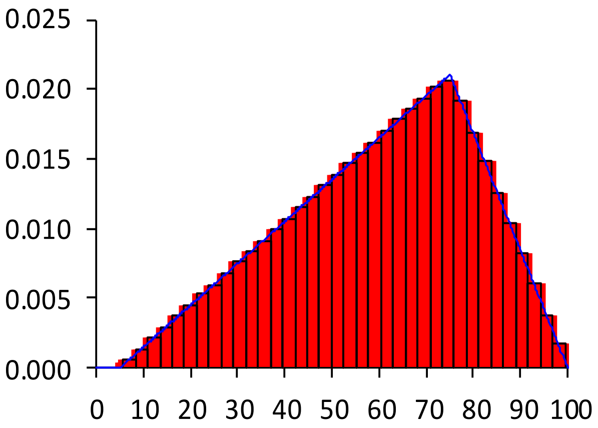

Figure 2. Distribution **RiskTriang** (5, 75, 100) for room traffic flow showing a minimum, most likely and maximum 5, 75, 100, % occupancy, η

The distributions used for the *Fr 13* simulations for each of traffic flow (as occupancy) (η %) and ambient temperature (T_o) are defined in column 4 of Table 1. For example, occupancy, (row 2 of Table 1) is defined by the distribution **RiskTriang** (5, 75, 100). This produces a triangle distribution with a minimum, most likely and maximum occupancy of 5, 75 and 100, % respectively. This triangle distribution is shown graphically as Figure 2.

However, to emulate fluctuations in the ambient temperature the distribution used is **RiskNormal** (35, 5, **RiskTruncate** (25, 45)). This produces a normal distribution with a mean of 35, standard deviation (stdev) of 5, and which is truncated to a minimum of 25, and a maximum of 45, ^{O}C. These truncations are used to restrict r-MC sampling to realistic temperatures that could actually occur.

5,000 simulations were found sufficient. Each can be regarded as a possible next-day scenario.

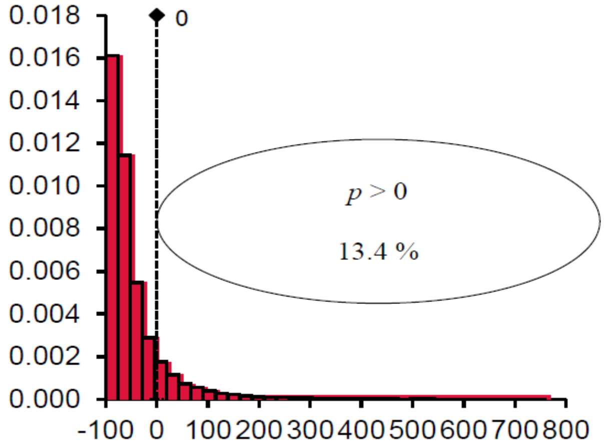

Figure 3. *Fr 13* simulation of *on-only* energy cooling strategy with 5,000 scenarios. The 670 failure scenarios (13.4 %) are shown to the right of the figure ($p > 0$)

A total of 670 (13.4 %) scenarios were identified with $p > 0$ in the 5,000 simulations, Figure 3. In this figure the *x*-axis is the value of the energy strategy risk factor, p, from Eq. (23) and because the *@Risk* output is a discrete histogram, the *y*-axis is the probability of p actually occurring (Vose, 2008). The failures are seen to the right of the figure ($p > 0$) and are therefore readily identified.

Ten (10) of these 670 failures which could occur as a result of adopting the *on-only* energy strategy are presented in Table 2.

It can be seen that in all cases the value $p > 0$, indicating a failure of the *on-only* energy strategy. The bold text in Table 2 (row 6, for failure scenario 4) is the particular scenario reported in Table 1.

Table 2: Ten (10) selected failures of the *on-only* strategy from 670 in 5,000 scenarios

Row	**η (%)**	**T_o (^{O}C)**	**p (dimensionless)**
1	5.67	30.16	757.77
2	15.02	40.08	215.84
3	18.80	34.38	131.67
4[&]	**21.66**	**33.46**	**92.55**
5	24.94	39.70	67.56
6	26.45	34.01	48.76
7	29.35	40.49	34.69
8	31.24	38.46	21.63
9	33.00	38.86	12.47
10	32.95	27.22	0.94

[&] Particular scenario of Table 1.

5. DISCUSSION

5.1. Model confirmation

An extensive test of model simulations showed them to be stable. Because predicted trends agreed closely with those of Chu et al. (2015) over a wide range of inputs it was concluded the simulations were free of programming and computational errors and that the *Fr 13* model was therefore suitable for the present purpose.

5.2. Failures of *on-only* strategy

The *Fr 13* findings, practically interpreted so that each simulation is thought of as a possible next operational day in any summer (assumed to be 90 days), show that adopting the *on-only* energy strategy could result in (670/5,000 x 90 =) 12 failures (13.4 % failure rate) each summer. However, these will occur randomly and therefore will not be spaced evenly in time.

This result however is based on the simplified model for cooling, but more particularly the distributions chosen to emulate the traffic flow and ambient temperature. The impact of varying these was therefore investigated.

It should not be implied by the reader that the numerical values given in Tables 1 and 2 would need to be measured to these exactly; these values are reproduced simply as the exact value sampled randomly in our r-MC simulations.

5.3. Establishing appropriate probability distributions

It appears reasonable that the ambient temperature would be normally distributed as has been assumed. The distribution is seen (Table 1) to be defined with a 2 x stdev about the mean to establish the minimum and maximum temperatures probable (25 and 45, ^{O}C). This ensures that 95.45 % of all r-MC samples will fall in this interval (Sullivan, 2004; Vose, 2008). Therefore the distribution of values sampled to emulate the naturally occurring fluctuations in temperature will cover a realistic range.

However, a potential problem is to accurately reflect the traffic flow (as occupancy).

Historical records are a very good guide to a long term mean and seasonal trend, but could not be relied upon to accurately predict a next-day event. This is because there will be irregular events such as transport strikes (rail, air or road), road and freeway closures due to accidents, or loss of electrical and other utilities to the building.

Unlike temperature, there could therefore be extremes with traffic flow; a very low value of η (possibly not zero), but also a large and finite value of η = 100 % (ideal for hoteliers and public building use). Given these two values and the industry wide knowledge that the most likely mean value is η = 75 % a triangle distribution was selected.

In the absence of unconditional data, a reasonable alternative however is pert (Vose, 2008). This distribution is also defined by a minimum, most likely and maximum. Repeat simulations of the *Fr 13* model with traffic flow as occupancy η defined by **RiskPert** (5, 75, 100) showed the failure rate could reduce to about 6 %. However, in the absence of more extensive trials, this is not seen at present as a meaningful change in the failure rate of the *on-only* energy strategy for cooling during summer.

The Spearman rank correlation coefficient (Snedecor and Cochran, 1989) readily available in *@Risk*, can be used to highlight the highly significant dependency of the cooling model on the distribution chosen for traffic flow, Table 3. The data of the table underscore a strong inverse correlation (coefficient - 1.00) between occupancy and the energy strategy risk factor, *p*. The impact of ambient temperature can be seen to be low (coefficient = 0.05).

Applied, this means that it is the change in traffic flow that will control the energy use and therefore should be used to adopt a particular energy strategy for cooling in this cooling model.

Table 3: Spearman rank correlation coefficient (Snedecor and Cochran, 1989) for the two input parameters to the *Fr 13* cooling model for traffic flow (as occupancy, η) and ambient temperature (T_o) on the energy strategy risk factor, *p*.

Input parameter	Coefficient
η	- 1.0
T_o	0.05

5.4. Results overview

A key insight is that the *on-only* energy strategy advocated by Chu et al. (2015) is predicted to fail in only about 10 % of all cases, averaged over the long term. This information is not currently available from alternate risk and hazard analyses.

A crucial reason is that these alternate methods do not take into account the possible impact of naturally occurring, random, and unpredictable fluctuations in the value of occupancy.

A major benefit with *Fr 13* model is that both the facts about the process and the effects of random change in parameters are separated (Abdul-Halim and Davey, 2015). This is highly advantages because it permits the effect of each parameter to be studied separately.

6. CONCLUSIONS

A new probabilistic *Fr 13* assessment of the proposed cooling strategy of *on-only* of Chu et al. (2015) for major structures such as public building and hotels, has predicted that it will fail in some 13.4 % of cases i.e. 12 unexpected, or *Fr 13*, failures each summer, averaged over a prolonged period.

Simulations highlight this cooling strategy is highly dependent on unplanned traffic flow (as occupancy).

Because all scenarios that could practically exist have been simulated, the *Fr 13* assessment is an advance over more traditional assessments.

Nomenclature

Numbers in parentheses after description refer to the equation in which the symbol is first used or defined.

A	area (m^2) (1)
A_{glass}	area of glass panes (m^2) (2)
A_{brick}	area of brick walls (m^2) (3)
c	specific heat at constant pressure = 1005.70 (J kg^{-1} K^{-1}) (15)
d	Thickness of medium surface (m) (4)
d_{glass}	thickness of glass pane = 0.01(m) (5)
d_{brick}	thickness of brick wall = 0.11 (m) (6)
D	depth of room = 5 (m) (8)
g	acceleration constant = 9.81 (m s^{-2}) (14)
Gr	Grashof number (dimensionless) (14)
h	heat transfer coefficient for air (W m^{-2} K^{-1}) (12)
h_o	heat transfer coefficient of outside air (W m^{-2} K^{-1}) (4)
$h_{o,glass}$	heat transfer coefficient of outside air adjacent glass pane (W m^{-2} K^{-1}) (5)
h_i	heat transfer coefficient of inside air (W m^{-2} K^{-1}) (4)
$h_{i,glass}$	heat transfer coefficient of inside air adjacent glass pane (W m^{-2} K^{-1}) (5)
$h_{i,brick}$	heat transfer coefficient of inside air adjacent brick wall (W m^{-2} K^{-1}) (6)
k	thermal conductivity of air = 0.026 (W m^{-1} K^{-1}) (4)
k_{glass}	thermal conductivity of glass (W m^{-1} K^{-1}) (5)
k_{brick}	thermal conductivity of glass (W m^{-1} K^{-1}) (6)
L	vertical length of room = 2.5 (m) (7)
Nu	Nusselt number (dimensionless) (12)
Pr	Prandtl number (dimensionless) (12)
p	energy strategy risk factor (dimensionless) (%) (23)
q	heat transfer (W) (1)
$q_{difference}$	heat difference between *on-only* and *on-off* (W) (22)
q_{glass}	heat transfer from glass (W) (2)
q_{brick}	heat transfer from brick (W) (3)
q_{on-off}	heat transfer for Strategy 1 (W) (19)
$q_{on-only}$	heat transfer for Strategy 2 (W) (21)
Ra	Raleigh number (dimensionless) (12)
ΔT	temperature (bulk) difference of air between outside and inside of room (K) (1)
$\delta T_{o,glass}$	temperature difference between glass wall and air film outside of room (K) (16)
$\delta T_{i,glass}$	temperature difference between glass wall and air film inside of room (K) (17)
$\delta T_{i,brick}$	temperature difference between brick wall and interior of room (K) (18)
$T_{air,glass}$	average film temperature air on glass (K) (10)
$T_{air,brick}$	average film temperature of air on brick (K) (11)
T_{brick}	equilibrium temperature of brick (^{O}C) (11)
T_i	*auto-set* (desired) bulk temperature of room interior air (K) (9)
T_o	mean daily bulk ambient temperature (outside air) (K) (9)
U_o	overall heat transfer coefficient (W m^{-2} K^{-1}) (1)
$U_{o,glass}$	overall heat transfer coefficient from glass (W m^{-2} K^{-1}) (2)
$U_{o,brick}$	overall heat transfer coefficient from brick (W m^{-2} K^{-1}) (3)
W	width of room = 4.5 (m) (7)
<u>Greek Symbols</u>	
β	volumetric coefficient of expansion of air = 3.3333 x10^{-3} (K^{-1}) (14)
ρ	density of air = 1.1774 (kg m^{-3}) (14)
μ	dynamic viscosity of air = 1.862 x 10^{-5} (N s m^{-2}) (14)
η	traffic flow (as occupancy) over the long term (%) (20)
<u>Subscripts</u>	
i	inside
o	outside
$'$	a particular r-MC scenario (23)

REFERENCES

Abdul-Halim, N., Davey, K.R., 2015. A Friday 13th risk assessment of failure of ultraviolet irradiation for potable water in turbulent flow. Food Control 50, 770-777. http://dx.doi.org/10.1016/j.foodcont.2014.10.036.

Anon., 2013. ASHRAE Handbook – Fundamentals. Atlanta, GA, US. ISBN: 9781936504466. (pp. Chpt. 4).

Chandrakash, S., Davey, K.R., O'Neill, B.K., 2015. An *Fr 13* risk analysis of failure in a global food process – illustration with milk processing. (Special theme invited research articles), Asia-Pacific Journal of Chemical Engineering – *in proof* (24 Mar 2015). http://dx.doi.org/10.1002/apj.1887.

Chu, J.Y.G., Davey, K. R., O'Neill, B.K., 2015. A preliminary simulation of strategies for cooling of air in buildings with unplanned traffic flow during summer. In: Proc. APCChE 2015 Congress (incorporating Chemeca), 27 Sept. – 01 Oct., Melbourne, Australia, Paper 313512 – *accepted 6 July.*.

Coakley D., Raftery P., Molloy P., 2012. Calibration of whole building energy simulation models: detailed case study of a naturally ventilated building using hourly measured data. In: Proc. First Building Simulation and Optimization Conference, Loughborough, UK, 10-11 Sept., BSO12, IBPSA, UK. (pp. 57-64).

Davey, K.R., 2010. A novel proposal to advance the discipline and to quantitatively safeguard important hygienic bio-processes. In: Proc. Australasian Chemical Engineering Conference (Engineering at The Edge)—CHEMECA, Sept. 26–29, Adelaide, Australia, Paper 0495. ISBN: 9780858259713.

Davey, K.R., 2011. Introduction to fundamentals and benefits of Friday 13th risk modelling technology for food manufacturers. Food Australia 63 (5), 192-197. ISSN: 1032598.

Davey, K.R., 2015. A novel Friday 13th risk assessment of fuel-to-stream efficiency of a coal-fired boiler. Chemical Engineering Science 127, 133-142. http://dx.doi.org/10.1010/j.ces.2015.01.031.

Davey, K.R., Chandrakash, S., O'Neill, B.K., 2015. A Friday 13th failure assessment of Clean-In-Place removal of whey protein deposits from metal surface with auto-set cleaning times. Chemical Engineering Science 126, 106-115. http://dx.doi.org/10.1016/j.ces.2014.12.013.

Eisenhower, B., O'Neill, Z., Narayanan, S., Fonoberov, V.A., Mezic, I., 2012. A methodology for meta-model based optimization of building energy models. Energy and Buildings 47, 292-301. http://dx.doi.org/10.1016/j.enbuild.2011.12.001.

Foust, A.S., Wenzel, L.A., Clump, C.W., Maus, L., Anderson, L.B., 1980. Principles of Unit Operations. 2nd edition John Wiley and Sons, NY, USA. ISBN: 0471268976.

Holman J.P., 2010. Heat Transfer. 10th edition McGraw-Hill, UK. ISBN: 978-0-07-352936-3. (pp. 2, 10, 27, 33, 45, 327 – 336 ff).

Patil, R.A., Davey, K.R., Daughtry, B.J., 2005. A new quantitative risk assessment of a fermenter for Friday 13th syndrome. In: Proc. 32nd Australasian Chemical Engineering Conference (Smart Solution-Doing More with Less) - CHEMECA. Sept. 25-29, Brisbane, Australia, Paper 79. ISBN: 9781604235142.

Perry, R.H., Green, D.W., 1997. Perry's Chemical Engineers' Handbook. 7th edition McGraw-Hill, US. ISBN: 0070498415. (pp. 5-13 ff).

Sinnott, R.K., 2005. Chemical Engineering Design. Elsevier Butterworth-Heinemann, UK. ISBN: 0750665386.

Snedecor, G.W., Cochran, W.G., 1989. Statistical Methods. 8th ed. Iowa State University Press, Iowa, USA, pp. 194. ISBN: 0750665386.

Sullivan, M., 2004. Statistics – Information Decision Making Using Data. Pearson Education, New Jersey, USA. ISBN: 0130618640.

Tom, S., 2008. Managing Energy and Comfort. ASHRAE Journal June 2008. (pp. 18-26).

Vose, D., 2008. Risk Analysis: A Quantitative Guide. 3rd edition John Wiley and Sons, UK. ISBN: 98780470512845.

Wankat, P.C., 2007. Separation Process Engineering. 2nd edition Prentice Hall, Boston, USA. ISBN: 0130847895.

Zou W., Davey, K.R., 2015. Fr 13 membrane fouling in combined ultrafiltration-osmotic distillation for concentrated fruit juice - demonstrated with pomegranate (*Punica granatum*). Chemical Engineering Science – *submitted* 30 April.

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ANALYSIS OF THERMAL AND ACOUSTIC PERFORMANCE IN RESIDENTIAL BUILDINGS WITH ONE WAY SLAB DEPENDING ON THE RIB WIDTH AND COMPRESSION LAYER

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ABSTRACT

Slabs are horizontal or inclined structural elements which directly receive and transmit loads to the columns, either directly as in bidirectional slabs, or through beams like in unidirectional slabs. They have great repercussion on sustainability, since they guarantee the optimal exploitation and utilization of resources, leading to lower costs and lower environmental repercussions. The Spanish Technical Building Code (CTE in Spanish), through the Basic Document of Noise Protection (DB-HR) covers two main areas: an acoustic overview of the building and the imposition of verification of in situ measures as a new method, and thermal conditioning, directly related to energy efficiency in present day. Energy consumption, and especially its waste or misuse, is one of the main environmental issues in Western societies. The consequence of this excessive consumption is the increased emissions of CO2 into the atmosphere; and reducing these emissions to "reasonable" levels is one of the main challenges for the continuation of life on Earth. Very often, it is considered that the industrial and transport sectors are solely responsible for the excessive energy consumption: however, in practice, in advanced societies energy consumption is divided approximately in even parts between the industry, transport and building sectors. This work analyzes and evaluates the impact on housing performances (acoustic and thermal) with unidirectional slabs. With that purpose, the variables rib width, compression layer, slab depth, and material used for the lightening element are modified. The graphical representation of the results reflects the performance of the different modeling processes. Remarkable is the need of incorporating metadata for the correct modeling, simulation, and selection of structural alternatives.

Keywords: thermal performance, acoustic performance, residential buildings, one-way slabs

1. INTRODUCTION

Slabs are horizontal or inclined structural elements which directly receive and transmit loads to the columns, either directly as in bidirectional slabs, or through beams like in unidirectional slabs.

The functions of the slabs can be divided into:

- Structural: They receive and transmit loads to beams and/or columns so that they do it in turn to the foundations and the ground. They provide transversal stiffness to the beams (monolithic). They link and brace the horizontal and vertical resistant elements of the building structure. Enough stiffness is necessary to prevent perceptible oscillations, and a limited deformation which is based on the type of load to bear. Structurally, the slab must have stability, resistance, stiffness and durability.
- Architectural: Their function is to support the divisions between floors. They support facilities, floors, ceilings and layouts for interiors and facades.
- Habitability: They provide thermal insulation, acoustic insulation, protection against fire, air tightness and water.
- Sustainability: They guarantee the optimal exploitation and utilization of resources; they also lead to lower costs and lower environmental repercussions.

This research focuses on the analysis of the variation in thermal and acoustic performances (Habitability) of unidirectional slabs.

Modern day society, in general, inhabits earth surrounded by sources of noise caused by human activities of all kind, be it leisure, industrial, facilities that make lives more pleasant and comfortable, transportation, etc. Some possible discomforts users feel, as buildings inhabitants are vibrations and incoming noises.

Researching the possible issues of soundproofing a building can lead us to draw conclusions, solutions not only a posteriori, but also many other preventive measures in the design and execution of a new construction work.

On the other hand, it is necessary to obtain a good acoustic design of buildings, with that purpose, the acoustic properties of walls, doors, windows… is studied, but inside the building.

It is therefore convenient to differentiate basic concepts in the field of architectural acoustics or building acoustics, such as soundproofing and acoustic conditioning. The objectives of each one, though related, are different but must be used together to unite and complement its potential.

The Technical Building Code (CTE in Spanish), through the Basic Document of Noise Protection (DB-HR) covers two main areas: an acoustic overview of the building and the imposition of verification of in situ measures as a new method.

The CTE considers the finished building as a product, considering the acoustic performances of the building as a whole, contrary to what was required so far by the NBE CA-88, which applied it to each of the construction elements. The DB-HR treats the elements, in a way that the soundproofing values are not solved by providing thicknesses to the materials, but by changing building systems.

The other important aspect for habitability is the thermal conditioning, directly related to energy efficiency in present day.

Energy consumption, and especially its waste or misuse, is one of the main environmental issues in Western societies.

The consequence of this excessive consumption is the increased emissions of CO2 into the atmosphere; and reducing these emissions to "reasonable" levels is one of the main challenges for the continuation of life on Earth.

Very often, it is considered that the industrial and transport sectors are solely responsible for the excessive energy consumption: however, in practice, in advanced societies energy consumption is divided approximately in even parts between the industry, transport and building sectors.

In the building sector, mainly determined by the volume of residential buildings (housing), power consumption is split between different points. See as an example the data presented in the EURIMA Congress in 2002:

- Buildings are responsible for a third of the total energy consumption.
- Within Europe, Spain is the second largest energy consumer in houses despite the alleged mild climate.
- Among European countries, Spain is the second largest source of CO2 emissions originated in housing.
- Spain is largest source of CO2 emissions per capita originated in housing.

This research analyzes and evaluates the impact on housing performances (acoustic and thermal) with unidirectional slabs. With that purpose, the variables rib width, compression layer, slab depth, and material used for the lightening element are modified. The graphical representation of the results reflects the performance of the different modeling processes. Remarkable is the need of incorporating metadata for the correct modeling, simulation and selection of structural alternatives.

2. METHODOLOGY

The methodology of this research focuses on the analysis of the acoustic and thermal performance for the case of unidirectional slabs.

The solutions are studied by varying the geometric arrangements of the slab depth and rib width. The study cases are shown in a summary in Table 1and Figure 2.

Table 1. Cases of slabs keeping lightening and cladding at fixed rates.

Lightening (cm)	Rib (cm)	HA (f_{ck})	Compres. Layer (cm)	Designation
15-20-25-30	12	25	5	15+5 - 20+5 25+5 - 30+5
			10	15+10 - 20+10 25+10 - 30+10
	14	25	5	15+5 - 20+5 25+5 - 30+5
			10	15+10 - 20+10 25+10 - 30+10
	16	25	5	15+5 - 20+5 25+5 - 30+5
			10	15+10 - 20+10 25+10 - 30+10

These 24 cases are modeled using two different lightening elements: vibro-compressed concrete and expanded polystyrene, Figure 1.

Figure 1. Modeled Materials for lightening elements.

For the correct identification of the modeled cases the following encoding is performed. A letter identifies the material used in the lightening element (H: vibro-compressed concrete, P: expanded polystyrene); below, two digits identify the structural depth of the lightening element and the thickness of the compression layer resulting from their addition the overall depth of the slab, ending with the letter "n" followed by a digit expressing rib width in centimeters. As an example, a case identified H20+10 n14, corresponds to a slab of total depth of 30 centimeters (20+10) in which a lightening element of vibro-compressed concrete with depth 20 is used, a compression layer 10 centimeters thick and resistant ribs 14 centimeters width.

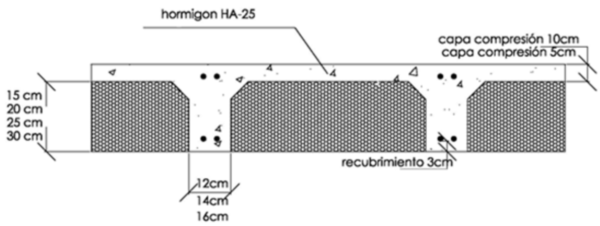

Figure 2 Sections of the floor.

The modeling of four discrete cases 4, 5, 6 and 7 meters of intercolumn with the usual loads in buildings and a beam width (primary structural element) of 60 centimeters is evaluated.

The next step was the thermal analysis of the different alternatives. The simulation is performed using the THERM software, developed at the Lawrence Berkeley National Laboratory. It is a software tool based on the finite element method for solving the two-dimensional equation of heat transmission.

This software tool has been properly tested by the examples of calculation proposed by different standard regulations such as ISO 10077- 2: 2003 "Thermal performance of windows, doors and shutters- Calculation of thermal transmittance" or UNE EN 1745: 2002 "Factory of masonry and factory components. Methods for determining the thermal values of a project. "

The calculation is performed by importing to THERM the corresponding section and creating over the template the model to be simulated using combinations of polygons. It is then necessary to define the properties of the materials involved and the outline conditions to be applied, Figure 3.

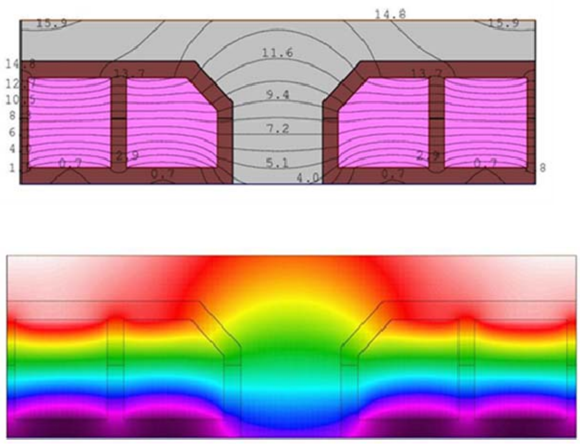

Figure 3 Modelling of the thermal analysis of the slab

With the above mentioned information, THERM executes the meshing for finite element analysis and the calculation of heat transfer in the simulated system.

To model the different slabs, the authors started from its sections, the different materials and properties and the implementation norms for calculating performances, based on the value of thermal transmittance U (W/m2K).

The assessment of the acoustic performance is complex. In the case of this study, the strategy is, given the technical and economic difficulties, to make trials in a laboratory to characterize the acoustic performances of the various slabs by the specific regulation of unidirectional slabs UNE-EN 15037-1 "Precast Concrete Products. Secondary beam and Vault Slab Systems."

The evaluation of acoustic performance is reflected by: the soundproofing against airborne noise Rw (dB) and the acoustic pressure transmitted by impact noise Ln,w (dB).

Once recorded the data of thermal transmittance, soundproofing to airborne noises and transmittance of acoustic pressure, the next step was to develop the graphical representations shown in the results section.

3. RESULTS

The presentation of the results is made by means of graphics. Each slab length presents a graph in which the X axis indicates the soundproofing of the proposed solution and in the Y-axis the information of the thermal performances of the analyzed proposal. To simplify the representations, the solution is characterized by the soundproofing.

The disappearance of cases with increased slab length is due to the fact that they are cases that are not technically feasible because of the excess of deformation.

In this case, the 48 alternatives studied are feasible. If expanded polystyrene (P) is used, better results are obtained by varying thermal transmittance between 1.44 and 2.16 W/m2K. Conversely, if vibro-compressed concrete (H) is used, the oscillation occurs in the range of 1.82 to 2.75 W/m2K.

In the acoustic performance, the soundproofing achieved by means of H solutions ranges from a 52.72 dB minimum and a 63.46 dB maximum, being the range lower for P solutions, ranging from 45.40 dB to 58, 39 dB.

In this case, 43 out of 48 alternatives studied are feasible. An increase of the lightened area occurs. In this way, the (P) solutions improve their thermal results varying transmittance between 1.36 and 2.07 W/m2K. In the (H) solutions there is a higher improvement due to a variation of the range of 1.76 to 2.54 W/m2K. This improvement comes from discarding the solutions with structural depth of 20 centimeters.

In the acoustic performance, the soundproofing achieved by means of H solutions ranges from a 54.28 dB minimum and a 62.97 dB maximum, being the range for the P solutions lower, ranging from 45.95 dB to 57, 64 dB.

This last increase of the lightened area narrows the feasible solutions to the ones with 20 and 25 centimeters of structural depth. In this way, the (P) solutions have a lower transmittance ranging between 1.31 and 1.73 W/m2K. The solutions (H) have a higher transmittance in the range of 1.72 to 2.22 W/m2K. The difference in the maximums of transmittance is of 29%.

In the sound performance, the soundproofing achieved by using the H solutions ranges between a 55.71 dB minimum and a 62.63 dB maximum, being the range lower for P solutions ranging from 47.66 dB to 57.13 dB. In this case, the worst acoustic solution in H is close to the best option in P.

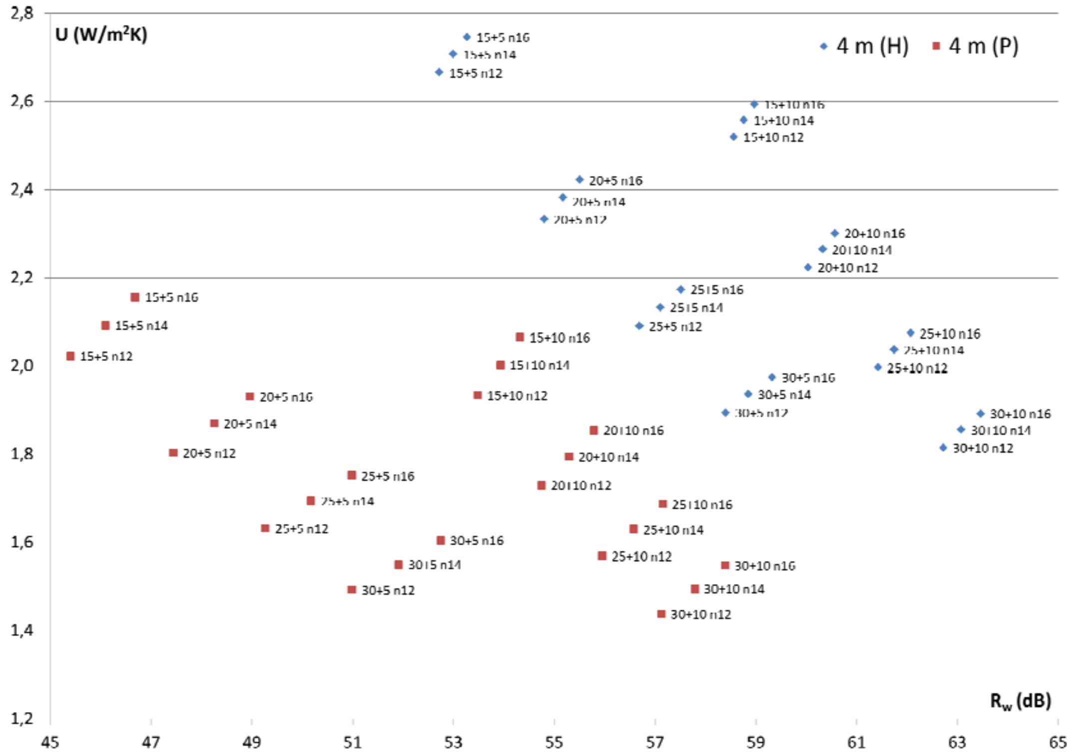

Figure 4. Acoustic/Thermal Results (Slab intercolumn 4 meters).

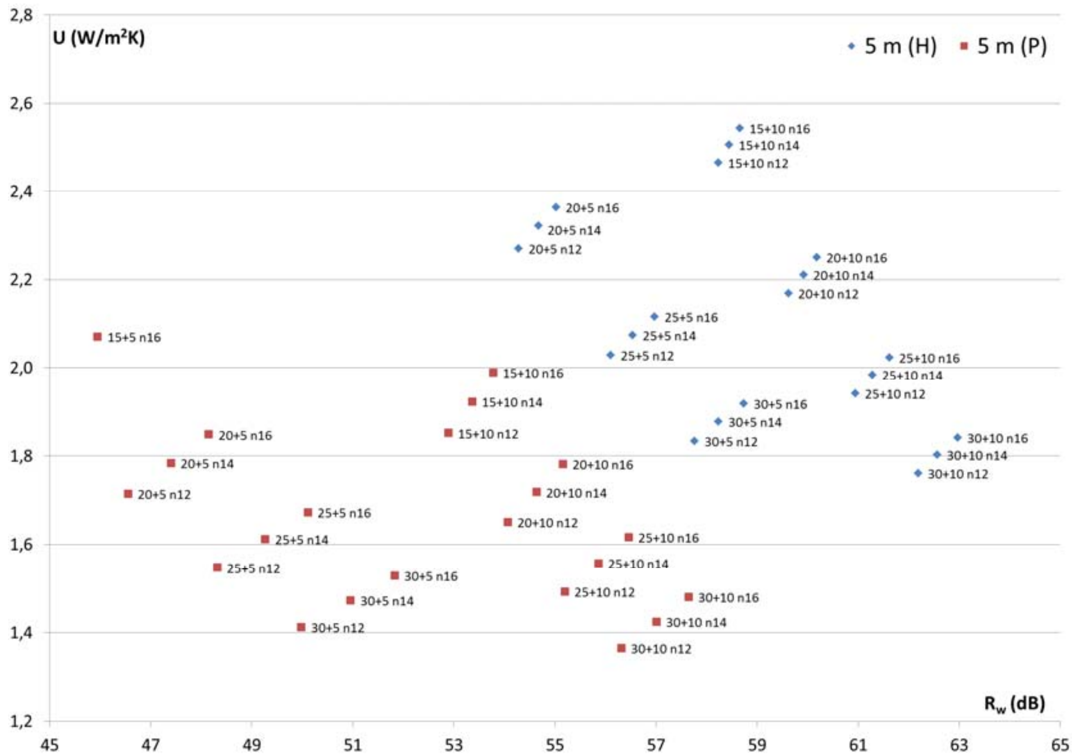

Figure 5. Acoustic/Thermal Results (Slab intercolumn 5 meters)

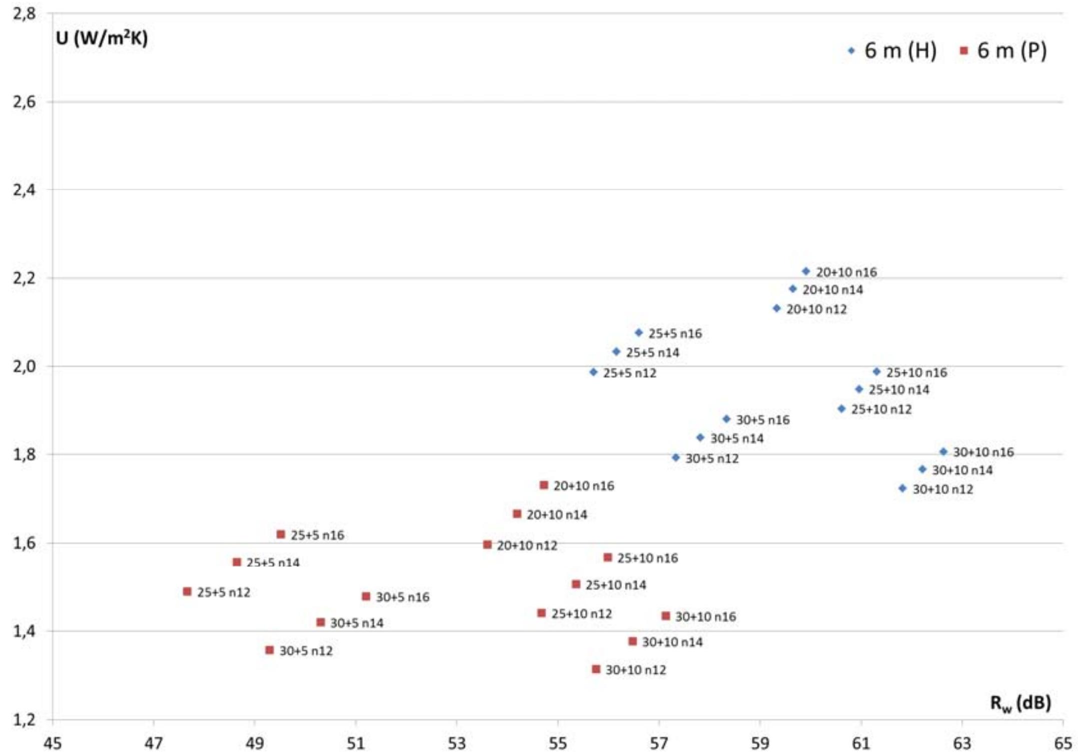

Figure 6. Acoustic/Thermal Results (Slab intercolumn 6 meters)

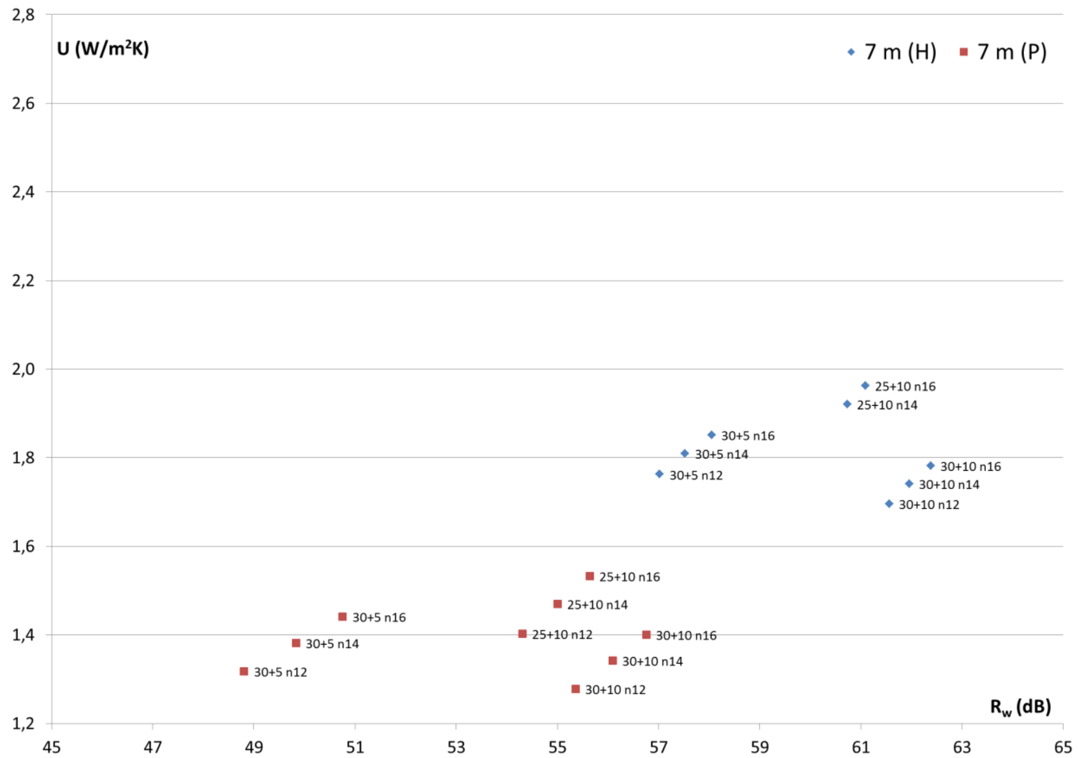

Figure 7. Results/Thermal Acoustic (Slab intercolumn 7 meters).

This last increase in the lightened area reduces the feasible solutions to the ones with a structural depth of 35 and 40 centimeters. In this way, the (P) solutions have a lower transmittance ranging between 1.28 and 1.53 W/m2K. The solutions (H) have a higher transmittance in the range of 1.70 to 1.96 W/m2K. The difference in the maximums of transmittance remains of 29% and the worst P solution has a lower transmittance than that of the best H solution.

In the sound performance, the soundproofing achieved by using H solutions ranges between a 57.02 dB minimum and a 62.38 dB maximum, being lower the range for P solutions ranging from 48.80 dB to 56.76 dB. In this case, the best acoustic solution comes from H cases, resulting in substantially lower soundproofing for the cases with the P option.

4. CONCLUSIONS

This research presents relevant information on in situ unidirectional slabs alternatives for concrete structures. It reflects and quantifies the impact on comfort and living conditions of the modification of geometric parameters of the slab.

The increase in rib width brings improvements for the acoustic performance assuming a loss in thermal performance. These variations are higher in P solutions than in H ones.

The increase in structural depth caused by the variation of the depth of the vault, slightly improves both acoustic and thermal performances, with higher impact in the thermal ones.

If the depth variation is caused by increasing the compression layer, then the acoustic performance is substantially improved and the thermal performance is worsened.

If the slab intercolumn is over six meters, and high structural depths are imposed, an important difference between the thermal performances of the P solutions occurs compared to the H ones. On the other hand, the acoustic performances of H solutions are substantially better than those of P solutions.

The evolution of national and European standards clearly leads to a tendency where the products incorporated to the construction should present a declaration of their performance. It is important that manufacturers inform the technicians about the properties of the products they commercialize, which should be supported by trials or tests that mark the corresponding harmonized standards.

REFERENCES

ALBATICI, R., PENASA, S., 2010. Building design and thermal inertia: When, why, where. International Journal for Housing Science and Its Applications, 34(4), pp. 221-231.

ANDERSON, B.R., 1991. Calculation of the steady-state heat transfer through a slab-on-ground floor. Building and Environment, 26(4), pp. 405-415.

BETTARELLO, F., FAUSTI, P., BACCAN, V. and CANIATO, M., 2010. Impact sound pressure level performances of basic beam floor structures. Building Acoustics, 17(4), pp. 305-316.

BRANCO, F.G., GODINHO, L., 2013. On the use of lightweight mortars for the minimization of impact sound transmission. Construction and Building Materials, 45, pp. 184-191.

CHO, T., 2013. Experimental and numerical analysis of floating floor resonance and its effect on impact sound transmission. Journal of Sound and Vibration, 332(25), pp. 6552-6561.

DI BENEDETTI, M., NANNI, A., 2014. Acoustic emission intensity analysis for in situ evaluation of reinforced concrete slabs. Journal of Materials in Civil Engineering, 26(1), pp. 6-13.

DIAZ SANCHIDRIÁN C., CABALLOL D., DÍAZ A. 2011. La protección frente al ruido de los forjados proyectados por Eduardo Torroja en la E.T.S. de Arquitectura de la Ciudad Universitaria de Madrid. Informes de la construcción, ISSN 0020-0883, Vol. 63, Nº. 524, págs. 59-64

FERNANDEZ-CENICEROS, J., FERNANDEZ-MARTINEZ, R., FRAILE-GARCIA, E., MARTINEZ-DE-PISON, F.J. 2013. Decision support model for one-way floor slab design: A sustainable approach Automation in Construction 35 PP. 460 – 470.

FRANCISCO JAVIER LEÓN VALLEJO F.J. 2000. Aislamiento acústico de forjados en edificios de viviendas. Montajes e instalaciones: Revista técnica sobre la construcción e ingeniería de las instalaciones, ISSN 0210-184X, Nº 337, págs. 125-136

GE, H., MCCLUNG, V.R., ZHANG, S., 2013. Impact of balcony thermal bridges on the overall thermal performance of multi-unit residential buildings: A case study. Energy and Buildings, 60, pp. 163-173.

GONZÁLEZ SUÁREZ J., MACHIMBARRENA GUTIÉRREZ M., LORENZANA LORENZANA M. T., GARCÍA VIDAURRÁZAGA M. D. 2003. Análisis comparativo del aislamiento acústico en medianeras y forjados: valores de los índices R' y R"w. Montajes e instalaciones: Revista técnica sobre la construcción e ingeniería de las instalaciones, ISSN 0210-184X, Año nº 33, Nº 378, págs. 42-48

HODA, A.S., 2006. Technical note: Controlling the impact sound insulation of concrete slab floors. Building Acoustics, 13(3), pp. 243-251.

OSIPOV, A., VERMEIR, G., 1996. Sound transmission in buildings with elastic layers at joints. Applied Acoustics, 49(2), pp. 141-162.

SIMÕES, N., SERRA, C., 2012. Ground contact heat losses: Simplified calculation method for residential buildings. Energy, 48(1), pp. 66-73.

STEWART, M.A., CRAIK, R.J.M., 2000. Impact sound transmission through a floating floor on a concrete slab. Applied Acoustics 59 (4), pp. 353-372

THOMAS, H.R.,REES, S.W., 1999. The thermal performance of ground floor slabs - A full scale in-situ experiment. Building and Environment, 34(2), pp. 139-164.

THOMAS, H.R., REES, S.W., LLOYD, R.M., 1996. Measured heat losses through a real ground floor slab. Building Research and Information, 24(1), pp. 15-26.

HUMAN BEHAVIOR SIMULATION FOR SMART DECISION MAKING IN EMERGENCY PREVENTION AND MITIGATION WITHIN URBAN AND INDUSTRIAL ENVIRONMENTS

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ABSTRACT

The paper proposes an innovative use of intelligent agents and computer simulation to support decision making in industrial and urban reorganization for preventing and mitigating disasters. The use of intelligent agents is used to reproduce the population and their perception of the situation and of the actions on the territory as well as their reaction. The authors are proposing the methodology to use these tools integrated with new big data available in towns to improve the quality of life and safety and to crowdsource best solutions in complex problems.

Keywords: *Modeling & Simulation, Smart Government, Emergency Management, Human Behavior Modeling, Intelligent Agents.*

INTRODUCTION

The world is in the throes of a sweeping population shift from the countryside to the city. The global urban population is growing by 65 million annually. For the first time in history, in 2001 more than one half of the world's population was living in towns and cities. (Dobbs et.al, 2001)

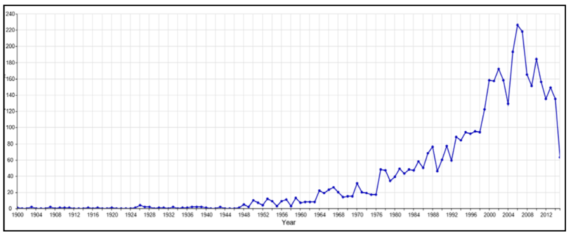

Figure 1: Number of Worldwide disasters due to floods (years 1900-2014) based on International Disaster Database

Since ancient times, people settled in strategic places, (i.e. on the coast, near rivers, in the at the foothills of mountains) first for defense reasons and later to develop trade.
This equilibrium between human and nature is always unstable; if fact in the past several cities were crippled

or even obliterated by natural disasters. (i.e. Pompei due to the volcanic eruption in 79 BCE, San Francisco in 1906 for Earthquake and Fire in 1906, and recently cities in Sumatra in 2004 for the earthquake and tsunami). Indeed the population growth, constructions, infrastructures and urbanization are overstressing the vulnerability of high density area as well as of the mega cities (Mtichell 1999; Brauch 2003; Hallegatte 2008).
Nowadays many experts agree on the fact that global warming and climate change are making natural disasters, like heavy rains, more frequent. It is essential to focus on disaster risk reduction in urban areas, as there is the highest density of population. (UN-Habitat, 2011); indeed the environment the climate change is expected to affect the statistics of natural disasters around the globe (Kahn 2005; Mills 2005; Van Aalst 2006).
Worldwide statistics reveal an increasing number of disasters and growing impacts of these events in the last three decades (Gencer E.A., 2013); whether the urbanization is going to be a driver of risk or mitigate risk levels in the future will also depend on decisions taken there (World Risk Report, 2014).
Public Administrators an constantly need to face strategic decisions that have a significant impact on the future of citizens and business.
In this context, the importance of good government is proved also by the number of studies. For example, Making Cities Resilient Report, 2012 defines some Risk reduction and Resilience factors:

- Institutional and Administrative Framework
- Financing
- Risk Assessment
- Infrastructure
- Schools and Hospitals
- Planning
- Training and Awareness
- Environment
- Preparedness
- Reconstruction

A critical element in reducing disaster impact in the future is the application of science and evidence of assessment of disaster risk, in order to anticipate and prepare for future hazards. (Government Office for Science, London, 2012).

1. MODELING & SIMULATION AND DISASTERS

So it is evident that the territory protection, respect disasters, results as a major issue becoming more and more important nowadays due to several reasons.
From this point of view it is evident the necessity to address the problem by activating preventive and mitigation projects on the territory (Burton 1997).
Modeling & Simulation (M&S) should be used as an effective support for decision makers for its capability to reproduce detailed elements and their complex interactions and to evaluate the different alternatives.
Due to these reason the authors propose the use of simulation for these needs, but by applying new paradigms that enable the integration with new available resources such as big data and mobile solutions; these aspects support the creation of a new generation of DSS (Decision Support Systems) that consider the population as an active part of the "problem", able to propose their own solutions, to validate proposals and obtain support on their implementation by achieving accreditation.
Indeed the simulator, proposed in this case, is based on stochastic discrete event simulation embedded within an interoperable simulation supporting the possibility to federate different models for covering the different aspects.
In facts, this simulator should be devoted to support strategic decision for decision makers reproducing urban context and industrial areas; these models should become a resource, available on the cloud, to generate quantitative analysis respect the impact of different alternative for prevention/mitigation of disasters; the simulation analysis over different possible scenarios could be used to spread the information among the citizens and to collect their feedback.
The idea is to create a quantitative computer simulation able to evaluate and quantify the effect of the different choices and related risks with benefits of new data available made available by open data and data farms respect urban environments (Kitchin 2014).
Indeed the simulator's interoperable architecture guarantees the possibility to integrate different systems within a dynamic distributed framework (Bruzzone, Massei 2010).
Obviously it is fundamental to consider the critical issues of developing models for this context (Amico et al.); traditionally major obstacles in developind DSS in this context include among others:

Data and Model are often not Available
Very often there are many tools already available, but they are not collated by the different offices and authorities that own them: it can be really hard to gather them to produce a single useable source.
Some data are available only in part, or other times in an aggregated format; privacy, data protection and security issues might affect many elements such as health or electoral data.
A large amount of data is important to predict a realistic future scenario and the so we have to see how

the European Union and national institutions will promote the concept of “Open Data”, and we will have to consider other big sources like social networks.

Missing Data Certification and Model VV&A
Verification, Validation an Accreditation of the Models as well as of the Data Certification are often partial or missed; sometime these issues are even addressed resulting in severe inconsistencies among database and unknown fidelity for existing models, leading to credibility losses toward decision makers

Obsolescence of Data and Models
The data available are often quite old and incomplete and it is difficult to use it as a trusted source. The urban and industrial data are subject to evolution and obsolescence and to use them it should be necessary to develop maintenance and updating procedures that often are not easy or possible to establish due to obsolete ICT infrastructure and limited resources.

Entry Barriers
Very often there are many tools available, in the different offices, but their use is limited because they require a license or because they need a skilled operator who may not be available.

Difficulty in understanding the Model
Many systems result extremely detailed and hard to understand; often they are equipped with difficult and non-intuitive interfaces, hard to use and not providing a clear picture of the whole model to the user.

Barriers against the publication of Results
The output of the complex simulation analysis doesn’t often give a clear map of the results; for instance data farming over large quantities of results proposed as static tables for the presentation of the outcomes result often as an obstacle for the use and acceptance of the model itself (Hofmann 2013).
Therefore, it is important to outline that recent developments in technologies and data resources are today mitigating these criticalities and that could support to overpass these criticalities; so new data sources and ICT infrastructures should be used in order to made available data and usability; in general this approach could improve the usability and impact of the proposed simulation including among the others: Internet of Things (IoT), Open Data, Data provided from Citizens, Social Networks as proposed in figure 2.

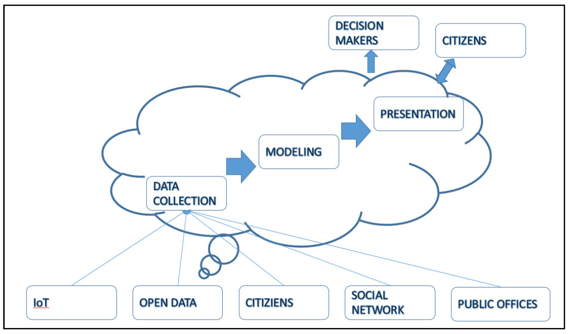

Figure 2: Combining Modeling and Simulation for Decision Makers and Citizen through Cloud Approach

2. POPULATION AS PROACTIVE ELEMENT IN PREVENTIVE AND MITIGATION ACTIONS THROUGH CROWDSOURCING

The authors propose to focus on a specific kind of disaster as starting point for the research corresponding to hydro-geological risk; so the simulator should support identification of best actions to be taken in order to prevent natural disasters (i.e. measure for consolidation, maintenance of rivers and sewers) by reducing risk of landslides, overflowing of rivers and flooding, reducing the risk of the creation of dangerous situation and consequent reduction in urban mobility.
Indeed the use of new simulation paradigms could allow population to understand the real risks and to perceive costs/benefits of Urban and Industrial reorganizations to deal with these kinds of disasters. By this approach it could be possible to achieve support and consensus; indeed due to the high degree of complexity, it is evident that people on the territory are usually a fundamental element to implement any solutions and crowdsourcing approach should provide interesting achievements as already investigated in urban context (Brabham 2009).
The authors already addressed the problem by proposing innovative MS2G (Modeling, interoperable Simulation and Serious Games) paradigm devoted to develop solutions combining game approach and interoperable simulation; these elements were applied to study the crowdsourcing applied to large town and Mega City (Bruzzone et al. 2014a).
In facts the recent experiences confirms that the dimension of the disasters could grow up to so large scale in terms of area and impact that it is fundamental to conduct actions to prevent and mitigate their effects; this fact is true both in case of man made and natural disasters (Xinhua 2010; Price 2013; Sudworth 2015).
The simulation provide the framework for crowdsourcing allowing the citizens to experience

interactively problems as well as potential solutions and to understand their costs/benefits; indeed crowdsourcing supported by MS2G supports population in:

- Understanding existing and potential threats as well as their risk and impact
- Estimating the costs/benefits of solution s proposed by authorities
- Understanding the sustainability of the possible alternatives
- Proposing their own solutions for being evaluated and compared with other ones
- Introducing additional critical issues to be addressed
- Increasing its level of collaboration with public authorities
- Receiving information and feedback about dangerous situations in the city
- Developing a mature political conscience and active participation in political decisions reinforcing positive consensus

In this context it is evident the challenge to identify and activate countermeasures through investments on the territory; the problem complexity, the financial resource required and the technological constraints make very difficult to implement effective solutions; by other point of view, most of these solutions could be very invasive of local population during their preparation (e.g. big constructions over intense populated areas, shortfalls in transportations) or when in place (e.g. additional taxes, relocation of productive and/or residential areas, loss of profit opportunities).
This context is really a complex system affected by emergent behaviors dealing with transportation, economics, politics etc.; so the use of crowdsourcing to extract solution extract solution is very promising (Bruzzone et al.2014b).
This approach could lead to develop a more mature and rational relationship between public authorities and population; so it could be developed a mutual trustiness based on understanding and *transparency* that could create capability to adopt courageous, but necessary decisions in this context.

3 M&S SUPPORTING STRATEGIC DECISION IN URBANIZATION AND INDUSTRIAL AREA

Among the different cases, it is evident that urbanized and industrialized areas are the main focus for this analysis; indeed the cities are getting more complex and much more urbanized along recent years creating very complex scenarios to apply preventive actions against disasters. In addition, the urbanization process leads to embedding large industrial areas and plants that affect the impact of the disasters and introduce additional constraints and challenges; all these elements could be addressed by applying M&S in analyzing the problem and supporting decisions (Bruzzone et al. 2011a; Bruzzone et al. 2014c).
Indeed, historically M&S has been largely used to support decision making in industry, even if the focus was strictly related to improve industry performances (e.g. Longo 2013; Del Rio Vilas et al. 2013; Bruzzone and Longo 2013). Instead, much more can be done in using M&S to support strategic decisions in preventing emergencies and disasters in urban and industrial areas.
Indeed, as anticipated, the natural disasters due to extreme meteorological events such as heavy rains happen more frequently due to climate change and global warming; this aspect is very significant in several areas and several Italian Urbanized areas are affected by this problem (Moromarco 2005)
Indeed the decision makers have limited resources: budget and time constraints, limited number of workers) and they need to keep maintain consensus among their citizens and guarantee safety in industrial town and industrial areas.
Indeed even if public administrators have a technical staff supporting them in the different tasks, they need to satisfy not only the complex technical aspects, but also the guarantee the quality of life of the population; this last element is usually strongly affected by their decisions; so consensus, quality of life and safety results result very strongly connected among themselves.
This is true obviously in relation to flooding phenomena, even if hydro-geological risk, obviously, is not the only challenge to be addressed: it is necessary to face many one day by day, e.g. crime, health, traffic, with different priorities; obviously the proposed approach, combined with other specific models, could be extended to the other areas.
In this context is necessary to simulate the effect of rational thinking respect each decision by quantitative models also taking into consideration the effects and reactions of the population.
Considering that simulation is the reproduction of reality by using computer models creating a Virtual Environment and running dynamic scenarios, it is evident the possibility to use it for analyzing and improving quality of life and safety (Mcleod 1999; Diaz et al. 2013); indeed traditionally M&S has been widely used in different applications both in military and in business domains. (Tremori et. al. 2015; Bruzzone et. Al. 2011a; Piera et. al 1996).
The authors propose here the use of Intelligent Agents (Bruzzone 2008) to allow the reproduction of complex behaviors among different entities affected by social relationships interacting with each other to consider the effect of population; indeed, it is proposed to reuse previous developed models focused on Country

Reconstruction, Urban Disorders, Civil Military Cooperation normally used for overseas scenario (Bruzzone et al. 2012).

Considering that all the actions needed to prevent flooding, often require a large amount of resources, both in terms of time and in term of money; so a virtuous administration should be able to schedule the activities for hydro-geological events according to the available resources in terms of time, money, and work; so these elements should be part of the model.

In general and as already outlined, an urbanized area is the result of the human presence in a natural environment; so it is evident that the model should address the different layers reproducing natural and urban systems summarized in table 1.

Natural systems reproduce the natural landscape of the city: the sky, the ground, the sea and the rivers; on the other side, the urbanized system reproduces all aspects connected with human activity.

System	Elements	Effect for the simulation
Natural System	Sky	Rain reproduction in the different zone of the city
	Ground	Simulating different ground permeability characteristics of the
	Sea	Simulating sea level fluctuation, and tsunamis
	rivers	Simulating the flooding due to high level of the water: Two different watercourses are considered: - Fluvial - Torrential
Urbanized system	Location of households	Simulating the more populated zones during the night
	Location of industries	Simulating the more populated zones during the day
	Mobility	Simulating the effect of natural events near the Hydrographic Basin of the river to roads, rail, and highways
	Location of points of interest	Schools, hospitals, stadiums are points of interest where there is a greater probability of high population density during certain hours of the day

Table 1: Different elements in the simulator

The interoperable approach allow to add to the simulation specific additional models based on the phenomena to be reproduced; for instance a model of rain could be developed by dividing the area into a grid, where each square has a given probability of showers. In this way it is possible to simulate heavy rains concentrating in certain part of the territory and town. The probability of rain could be estimated by the simulator, considering weather forecasts and historical data as well as update from the field. By this approach the simulated rain falls over the urban area surface and it is conveyed into the rivers and into the sewers increasing their flow based on terrain dbase. It is possible to consider different type of watercourse including fluvial and torrential ones. Torrential watercourses are usually more dangerous since they suddenly chance their behaviour, whilst fluvial ones change their behaviour gradually.

In this case the simulator could support decision makers in, evaluating respect different alternatives the impact of different preventive actions; all these estimations could be carried out virtually, before to undertake any specific decision and could be shared with population based on MS2G; in addition people could propose their solutions and evaluate the performance by same approach.

So this approach addresses the constant need to evaluate strategic decisions in order to prevent and mitigate the effect of potential natural disasters; indeed MS2G allows obtaining and sharing quantitative evaluations respect possible actions to be undertaken.

The authors propose as model for the urban and industrial areas including population reproduced by multilayer elements directed by Intelligent Agents (Bruzzone et al.2014d). By this approach it becomes possible to test different the scenario hypothesis facing not only budget, resources, and time constraints respect the impact of stochastic factors, but also reaction of people. Indeed Human Behavior Modeling & Simulation (HBM&S) is devoted to reproduce the people's actions within the simulation environment. In this simulator and according to the aim of this research, it is necessary to simulate different elements including emotions, psychology, rational thinking and social behavior. These different aspects characterize human behavior and generate often complex phenomena. Indeed, as anticipated different levels of complexity are defined: the first level is at the individual level, while the second one is at the population level, considering the different individual as a group.

There are several challenges in reproducing human behavior affecting these levels, indeed it is necessary to consider:

- **Rational Decision Making**
    - Intelligent Individual Behavior
    - Organization & Hierarchies
- **Emotion and Attributes**
    - Psychology, Culture, Social
    - Crowd Behavior
    - Social Networks

In the simulator proposed, the inhabitants of the city are simulated with single entities.

In this case the people objects represent human entities and are considered "intelligent" in applicative sense in terms of capacity to react to different stimuli as well as to their situation awareness.

In facts the HBM&S requires the capability to simulate the decision making process of the population even if in simplified way. (Gintis H. 2007)

In this case the use of Intelligent Agent is very important considering them as computer based entities with following characteristics (Wooldrige & Jennings, 1995):

- Autonomy: capability to operate without the direct action of humans, with some kind of control of their internal state.
- Social ability: capability to react with other agents (and possibly with humans) with a communication language
- Reactivity: ability to perceive their environment and respond to changes
- Proactiveness: capability to take the initiative

From this point of view, it is fundamental to focus the attention on modeling population behavior in terms of groups and individuals as well as respect their social networks; these elements allowed evaluating human factors over country reconstruction scenarios as well as on other and actions on the territory (Bruzzone, Massei 2010).
The proposed models reproduce humans as people objects, interest groups and entities. This multilayer approach uses people objects as element for representing individuals and/or small groups (e.g. a family), while interest groups correspond to aggregations of people objects (e.g. catholic people, rich people, farmers, inhabitants of a city quarter, teenagers, etc.). Obviously a people object belongs normally to multiple interest groups that are characterized by mutual relationships. Vice versa the entities are group of people that are aggregated or unites active on the terrain to carry out specific actions (e.g. a demonstration, a riot, a group of workers dealing with road reconstruction in some point of the map). The people objects are dynamically moving on the terrain based on their daily/weekly/yearly life cycle and on their characteristics; compatibility algorithms are used to define their aggregation and activities in consistency with their characteristics currently mapped by a set of parameters. People Objects are connected by social networks as well as interest groups by mutual relationships that dynamically evolve based on events and actions along simulation evolution (Bruzzone et al.2012).
Obviously the simulation should be tailored with specific data of the socio-cultural context to be studied; Intelligent Agents Computer Generated Forces (IA-CGF) have been developed as interoperable models, using IA and HLA (High Level Architecture), to simulate population behavior as well as its reactions to particular events that occur during the simulation (Bruzzone 2008). In facts Human Behavior modeling has been already applied both in military and in civil domain and examples on IA-CGF use are available for different cases including Haiti Earthquake (Bruzzone et.al 2010; Bruzzone et al. 2011b; Bruzzone et.al 2012) as proposed in figure 3.

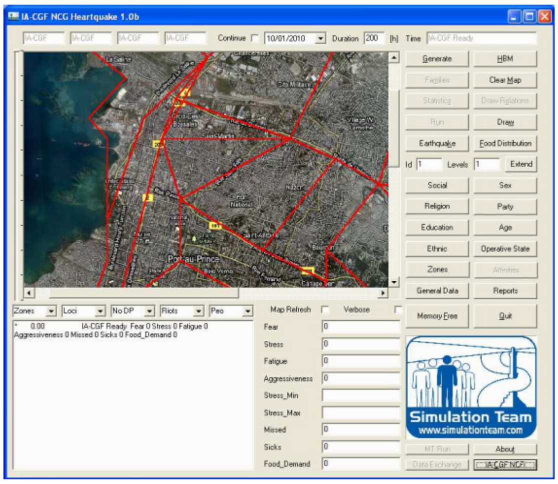

Fig 3: Example of Simulator interface applied to a large scale Disaster Relief Scenario

These previous researches represent the evolution on human behavior modeling in towns and regions to analyze urban unrest and emergency management along last 20 years (Bruzzone & Kerckhoff, 1996; Bruzzone et. al. 2014). Obviously the simulator should include the representation of urbanized area considering the location of households, and industry, in order to simulate the presence and the movement of the different individuals simulated by people objects and entities; in this representation the households and industries, together with other point of interest (like schools, stations, stadium, …) are attraction points for the people objects based on their characteristics.
In the proposed simulator, the setting of the scenario is based on the following scheme:

I) People Initialization:
In this phase people are created in the simulator, according with the number of inhabitants of the city

II) Setting local population characteristics
In this phase the local population characteristic are characterized in terms of statistical distribution, taking in account different parameters:

a. Gender
b. Health Condition
c. Age
d. Nationality
e. Marital status
f. Education level
g. Political Attitude
h. Residence District

Generation of the individual layer

In this phase the local population characteristics are generated randomly according with the available data and statistics of the local urban context.

III) Generation of the social Layer

After the generation of individual entities is possible to generate the social layer; this is generated by a stochastic aggregation of individual entities building families and social networks.

Simulating human modelling is critical from the point of view of verification and validation of the simulator, and the process of data collection and analysis is critical.

The emotional status of a single entity is simulated by taking in account different variables:

- level of stress
- level of fear
- level of trust
- level of political consensus

These parameters evolve thoughout the duration of the simulation and change both according to the internal relationship among the entities and the external actions set by the user.

CONCLUSION

The use of intelligent agents to reproduce population behavior in a large urban context provides a good research opportunity; the research underlines the conceptual framework of the simulator proposed.

Weather forecasting is possibly the most commonly accepted simulation as it is included in common decision making processes.

However, this approach, if properly applied, could allow developing a new generation of decision makers that consider simulation as an effective support for disaster prevention; this is not easy considering that in most of the case, current politicians prefer to spend 120 billions after a storm like Katrina than spend 20 to prevent the impact of the flooding.

Usually administrators are faced with openly hostile stakeholders that might even welcome a disaster. Including simulation in decision making systems relating to public safety takes vision, intelligence and political courage; the introducing of crowdsourcing and engagement of population could support the administration in developing such characteristics.

In facts there is also possibility to obtain additional support from insurance companies, major retailers and large industries interested in these issues

REFERENCES

- Brabham, D. C. (2009). Crowdsourcing the public participation process for planning projects. Planning Theory, 8(3), 242-262.
- Brauch, H. G. (2003). Urbanization and Natural Disasters in the Mediterranean: Population Growth and Climate Change in the 21st Century. Building Safer Cities, 149.
- Bruzzone A, Longo F (2013). An advanced modeling & simulation tool for investigating the behavior of a manufacturing system in the hazelnuts industry. International Journal of Food Engineering, vol. 9, p. 241-257, ISSN: 1556-3758, doi: 10.1515/ijfe-2013-0039.
- Bruzzone A.G. (2008) "Intelligent Agents for Computer Generated Forces", Invited Speech at Gesi User Workshop, Wien, Italy, October 16-17
- Bruzzone A.G., Massei M., (2010) “Intelligent Agents for Modeling Country Reconstruction Operation", Proceedings of Africa MS 2010, Gaborone, Botswana, September 6-8, 2010.
- Bruzzone A.G., Massei M., Longo F. Madeo F. (2011a). “Modeling and Simulation as Support for Decisions Makers in Petrochemical Logistics. In: Summer Computer Simulation Conference. The Hague, Netherlands, June 28-30, p. 200-203, SAN DIEGO:SCS
- Bruzzone, A. G., Tremori, A., & Massei, M. (2011b). Adding smart to the mix. Modeling Simulation & Training: The International Defense Training Journal, 3(3), 25-27.
- Bruzzone, A. G., Frydman, C., Madeo, F., Zacharewicz, G., Massei, M., Tremori, A., Messouci R. (2012) “Intelligent agents for simulation of civil military cooperation and psychological operations”, Proceedings of Summer Computer Simulation Conference, 44(10) 131-143
- Bruzzone A.G., Massei M., Agresta M., Poggi S., Camponeschi F., Camponeschi M. (2014a) "Addressing strategic challenges on mega cities through MS2G", Proceedings of MAS2014, Bordeaux, France, September
- Bruzzone A.G., Massei M., Tremori A., Longo F., Nicoletti L., Poggi S., Bartolucci C., Picco E., Poggio G.
 (2014b) "MS2G: simulation as a service for data mining and crowd sourcing in vulnerability reduction", Proc. of WAMS2014, Istanbul, Turkey
- Bruzzone A.G, M. Frascio, F. Longo, A. Chiurco, S. Zanoni, L. Zavanella, P. Fadda, G. Fancello, D. Falcone, F. De Felice, A. Petrillo, P. Carotenuto (2014c) "Disaster and emergency management

simulation in industrial plants" Proc. of the European Modeling and Simulation Symposium, 2014 Affenzeller, Bruzzone, Jiménez, Longo, Merkuryev, Zhang Eds., Semptember 10-12, Bordeaux, France, 978-88-97999-38-6

- Bruzzone A.G., M. Massei, F. Longo, S. Poggi, M. Agresta, C. Bartolucci , L. Nicoletti (2014d) "Human Behavior Simulation For Complex Scenarios Based On Intelligent Agents", In Proc. of SpringSim
- Burton, I. (1997). Vulnerability and adaptive response in the context of climate and climate change. Climatic Change, 36(1-2), 185-196.
- Calfee, S.H., Rowe, N.C., (2004) "Multi-agent simulation of human behavior in naval air defense," Naval Engineers Journal, published by American Society of Naval Engineers, Alexandria, Virginia, Vol.116, Iss.3, pp.53-64
- Diaz, R., Behr, J., Toba, A.L., (...), Longo, F., Nicoletti, L. (2013). Humanitarian/emergency logistics models: A state of the art overview. Simulation Series, 45 (11), pp. 261-268.
- Del Rio Vilas D, Longo F, Rego Monteil N (2013). A general framework for the manufacturing workstation design optimization: a combined ergonomic and operational approach. SIMULATION, vol. 89, p. 306-329, ISSN: 0037-5497, doi: 10.1177/0037549712462862
- Dobbs R., S.Smit, J. Remes, J. Manyika, C. Roxburgh, A. Restrepo, (2001) "Urban World: Mapping the economic power of cities", McKinsey Global Institute
- Gencer E.A., (2013) "Natural Disasters, Urban Vulnerability, and Risk Management: A Theoretical Overview "The Interplay between Urban Development, Vulnerability, and Risk Management Springer Briefs in Environment, Security, Development and Peace Volume 7, 2013, 7-43
- Gintis H. (2007) "A Framework for the Unification of The Behavioral Sciences", Behavioral and Brain Sciences 30,1–61
- GOL (2012) "Foresight Reducing Risks of Future Disasters: Priorities for Decision Makers" Final Project Report. The Government Office for Science, London.
- Hallegatte, S. (2008). An Adaptive Regional Input-Output Model and its Application to the Assessment of the Economic Cost of Katrina. Risk analysis, 28(3), 779-799.
- Hofmann, M. (2013). Simulation-based exploratory data generation and analysis (data farming): a critical reflection on its validity and methodology. The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, 10(4), 381-393.
- Kitchin, R. (2014). The real-time city? Big data and smart urbanism. GeoJournal, 79(1), 1-14.
- Kracke, R., Hauge, J.B., Duin, H., (2006). "Training of strategic decisions in collaborative networks through serious games," Network-Centric Collaboration and Supporting Frameworks Book Series, Springer publications, Berlin (Germany), International Federation for Information Processing, Vol.224, pp. 305-312.
- Kahn, M. E. (2005). The death toll from natural disasters: the role of income, geography, and institutions. Review of economics and statistics, 87(2), 271-284.
- Longo F (2013). On the short period production planning in industrial plants: a real case study. International Journal of Simulation & Process Modelling, vol. 8, p. 17-28, ISSN: 1740-2123, doi: 10.1504/IJSPM.2013.055189.
- McLeod, J. (1999). Simulation as a Possible Tool for Peace. Simulation, 72(5), 348-352.
- Mills, E. (2005). Insurance in a climate of change. Science, 309(5737), 1040-1044.
- Mitchell, J. K. (1999). Crucibles of hazard: mega-cities and disasters in transition, Tokyo: United Nations University Press.
- Moramarco, T., Melone, F., & Singh, V. P. (2005). Assessment of flooding in urbanized ungauged basins: a case study in the Upper Tiber area, Italy. Hydrological Processes, 19(10), 1909-1924. ISO 690
- Mustapha K., Mcheick H., Mellouli S.," Modeling and Simulation Agent-based of Natural Disaster Complex Systems", Proc. of Computer Science, Vol. 21, 2013, Pages 148-155, ISSN 1877-0509.
- Piera M.A., César de Prada (1996) "Modeling Tools in the Continuous Simulation Field" Simulation, SCS publications, Vista (CA), 66(3) pp. 179-189
- Price M. (2013) "Sardinia hit by deadly Cyclone Cleopatra and floods", BBC News, November 19, www.bbc.com/news/world-europe-24996292
- Strategia per la Crescita Digitale (2015) Presidenza del Consiglio dei Ministri 2014-2020", Rome, 3-5-2015
- Sudworth, J. (2015) "China explosions: What we know about what happened in Tianjin", BBC News, August 17, www.bbc.com/news/world-asia-china-33844084
- Tremori A. M. Agresta, A. Ferrando: (2015)" Simulation of Autonomous Systems in the Extended Marine domain International Journal of Simulation and Process Modeling
- UNISR (2012) "Making Cities Resilient Report"
- United Nations Human Settlements Program (UN-Habitat) (2011) "Global report on human

settlements: cities and climate change". Earthscan, London

- Van Aalst, M. K. (2006). The impacts of climate change on the risk of natural disasters. Disasters, 30(1), 5-18
- Wooldrige M., N.R. Jennings (1995)," Intelligent Agents: Theory and Practice
- World Risk Report (2014) United States University

1. Xinhua (2010) "Floods, landslides leave 3,185 dead in China this year", News, news.xinhuanet.com/english2010/china/2010-08/31/c_13471818.htm

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