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Risk Analysis of the Waste to Energy Pyrolysis Facility Designs for City of Konin, in Poland, Using SimLab® Toolpack

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1. Introduction

The term "*thermal treatment*" is used to describe a range of technologies that use heat to degrade the constitution of solid matter. These includes incineration and its variations, as well as advanced thermal conversion (ATC) technologies such as pyrolysis and gasification (Everard, 2004).

To ensure sustainable development in waste management, faster development and uptake of new technology is necessary. Landfills pollute the valuable underground water, incinerations emit dioxin and produce toxic ash. The solution is Integrated Waste Management, which uses all available resources for dealing with the waste problem. Novel processes utilizing pyrolysis and gasification have attracted publicity as a potential alternative to incineration. The main advantage that gasification has over incineration is its ability to conserve the chemical energy of the waste in the produced syngas rather than convert it to heat energy in hot flue gases. Therefore, gasification has greater flexibility in the recovery of energy and chemical value from waste stream (Klein et al., 2004). Gasification is by no means a novel process; in the 19th century so-called: "*town-gas*" was produced by gasification of coal and for example used for illumination purposes (Astrup & Bilitewski, 2010). Gasification (and combinations of pyrolysis plus gasification) processes are being developed in a number of countries. In Europe, there continues to be a strong desire to avoid incineration and reduce the amount of waste going to landfill in order to meet the EU landfill Directives. In the USA, low disposal costs and plenty of landfill availability in most regions have proved a significant barrier to the construction of any new thermal treatment facilities. Incinerations also increase the amount of CO2 in the carbon cycle because the have to burn fuel together with the wastes. The governments of most countries have signed a treaty to limit CO2 emissions at their 1999 levels. In Canada, a number of waste management projects are being planned based on the waste incineration technology. In Japan all leading thermal process companies now offer gasification solutions alongside incineration with financial support from the Japanese Government.

For many people, thermal treatment technologies for waste management represent an image of hell on Earth (Everard, 2004).

The main potential benefits and advantages of pyrolysis and gasification of waste with respect to incineration are (Juniper, 2001; Klein et al., 2002; Malkow, 2004 as cited in Astrup & Bilitewski, 2010):

- The possibility and flexibility to recover chemical energy in the waste as hydrogen and/or other chemicals feedstocks rather than converting this energy into flue gases.
- Potentially beter overall energy efficiency.
- Less trouble with corrosion.
- Potentially better option for CO_2 capture.
- Potentially lower emissions of dioxins.
- Improved quality of solid residues, particular for high-temperature processes.
- Gasifications units operating with a low fuel load, potentially facilitating small plants producing less than 1 MW.
- Potentially lower costs.

The main drawback of the current technology for pyrolysis and gasification are:

- Relatively homogeneous fuels are needed. Either specific material fractions can be fed to the gasifier, or mixed waste can be pretreated and homogenized.
- Although theoretically possible, the pyrolysis and gasification processes are complicated to control and troubles with slagging, tar production, and contaminants in the produced gas are not uncommon.
- Numerous waste related pyrolysis and gasification technologies exist, many of these only demonstrated in small scale and/or applicable to specific fuel types.. This requires careful review of the appropriateness of a specific technology for a particular waste mix, local conditions, etc.
- Overall energy conversion efficiencies of existing installations have been unable to compare with modern waste incinerators.

2. Market interest in gasification and pyrolysis

Gasification is a partial oxidation processes in which the majority of the carbon is converted into the gaseous form-called syngas-by partial combustion of a portion of fuel in the reactor with air, pure oxygen, oxygen-enriched air or by reaction with steam. Relatively high temperatures are employed: 900- 1100^{o}C with air and 1000-1400^{o}C with oxygen. Gasification as a technology underwent major development during the oil price crises of the 1970s and 1980s.

Pyrolysis is the thermal degradation of carbonaceous materials. It occurs at lower temperature than gasification (typically 400-800^{o}C), either in the complete absence of oxygen, or with such a limited supply that gasification. Pyrolysis has been promoted for biomass applications and in the treatment of scrap tyres, bur rarely as a stand-alone application for MSW.

Energy recovery is a secondary goal of waste incineration: thermal waste treatment and energy recovery are “married” within the waste-to energy plant (Pfeiffer, 2004). From an economic point of view, a waste–to- energy plant treating MSW is an enterprise using a special fuel.

Some technologies, including gasification and pyrolysis, offers flexibility in terms of energy production and material recycling, and is an attractive technology option for Integrated Waste Management.

The main advantage that gasification has over incineration is its ability to conserve the chemical energy of waste in the produced syngas rather than convert it to heat energy in hot flue gas. Another reason for interest in gasification is the view by political decision-makers (especially in the UK) that gasification is an alternative to incineration, because which would mean that incineration would no longer be necessary.

The United States Department of Energy (DOE) sponsored the 2004 World Gasification Survey in order to accurately describe the world gasification industry as it exists today, to identify planned capacity additions, and to keep the gasification community apprised of current data and trends (National Energy Technology Laboratory [NETL], (2005).

An additional 38 plants with 66 gasifiers have been announced and are forecast to become operational between 2005 and 2010, according to the 2004 survey. The additional capacity from these new plants is 25,282 MWth, an expected increase of 56%. Worldwide capacity by 2010 is projected at 70,283 MWth of syngas output from 155 plants and 451 gasifiers.

- Regional distribution: The Africa/Middle East region will lead the world's regional growth with 43% of planned capacity growth from 2005 to 2010, all from a single gas-to-liquids (GTL) project in Qatar that will produce liquid fuels from natural gas. The Asia/Australia region has planned projects that comprise 37% of the total planned growth, with China leading in this region. By contrast, plans for new gasification plants slowed in North America due to factors such as the economy and natural gas prices.

Feedstock distribution: Coal is the feedstock of choice for new gasification projects, identified for 29 of the 38 new plants (largely on the strength of the 24 chemical plants to be built in China). However, natural gas will be used in the largest single project from 2005 to 2010 at the nearly 11,000 MWth gas-to-liquid.

3. Description of case study

Solid waste management is developing into a complex task. New or modified treatment technologies are appearing. During the past two decades, thermal wastes management followed heavily disparate trends. In the 1980s, the focus was on new market players, and then in the 1990s on new technologies, especially pyrolysis and melting processes (Bieda & Tadeusiewicz, 2008).

Novel processes utilizing pyrolysis and gasification have attracted publicity as a potential alternative to incineration. Such systems offer some benefits in terms of recycling and public acceptance. However, because they are new, they are less proven in operation than conventional technologies-and may therefore be more risky. The main advantage that gasification has over incineration is its ability to conserve the chemical energy of the waste in the produced syngas rather than convert it to heat energy in hot flue gas (Klein et al, 2004).

The new Polish environmental strategy emphasizes the principle of sustainable development and it encourages the government of Konin to develop a waste management plan for their communities based on the use the technology for a gasification with waste to energy system. One scenario has been chosen: American Gasification System (design at 200 T/D). The Capital Budget – Project Costs of the American Scenario is given in Tables 1.

The revenues were based on the Proposal to Design, Develop and Construct a Waste-to-Energy Facility for the City of Konin. The revenues include:

- the tipping fees for landfill
- the revenues from energy sales
- other revenues.

The selling prices of the marketable material, and the tipping fee for each ton of waste that is delivered to the landfill are coming from the Waste Program Revenue from the city or others. The general operating parameters of the Konin's Waste-to-Energy Facility are as follows:

- operating weeks/year – 50 weeks
- receiving days/week – 5 days
- current tons managed – 63,000 Mg/year

Municipality has been entered into a contract to supply an average of 200/250 tons of municipal waste per day with options for increased volume as the demand increases.

Capital Budget – Project Costs (USD)		
1	**Etap 1**-Construction Management	600,731.00
2	**Etap 2-**Civil& Site Design/Site Work &Building Permitting, Gasifiers System	21,120,055.27
3	**Etap 3-**Continuous Emission Control, Monitoring Systems	999,599.10
5	**Etap 4-**Automatic Loading Systems	1,687,350.23
6	**Etap 5-**Office Furniture and Computers	4,25
7	**Etap 6-**Contingency Reserve	1,167,264.40
8	**Razem-Total Project Costs (USD**)	26,000,000.00

Table 1. Capital Budget – Project Costs of the proposed American Gasification System.

4. Monte Carlo simulation with SimLab®

The first task is to create a veritable deterministic model that represents the most likely scenario.

To use the SimLab® (SimLab, 2004), we must perform the following steps (Wajs et al., 2006):

- build model the relationships
- define assumption for probabilistic variables - manufacturing costs
- define the forecast cell, that is, the output variable - Total et the number of replication
- run the simulation
- simulate the model and analyze the outputs

- report results and make decisions.

In SimLab®, the assumptions or input range for each parameter was defined by choosing a probability distribution that describes the uncertainty of the data. Input distribution may be normal, uniform, triangular, skewed, or any shape that reflects the nature of the measurement being assessed.

At the start Simlab® displays the main panel (Figure 1); this panel is divided in three frames (Saltelli et al., 2004):

1. The *Statistical Pre Processor module*: generates a sample in the space of the input.
2. The *Model Execution module*: executes the model for each point in the sample of input factors.
3. The *Statistical Post Processor module*: performs the uncertainty and sensitivity analysis.

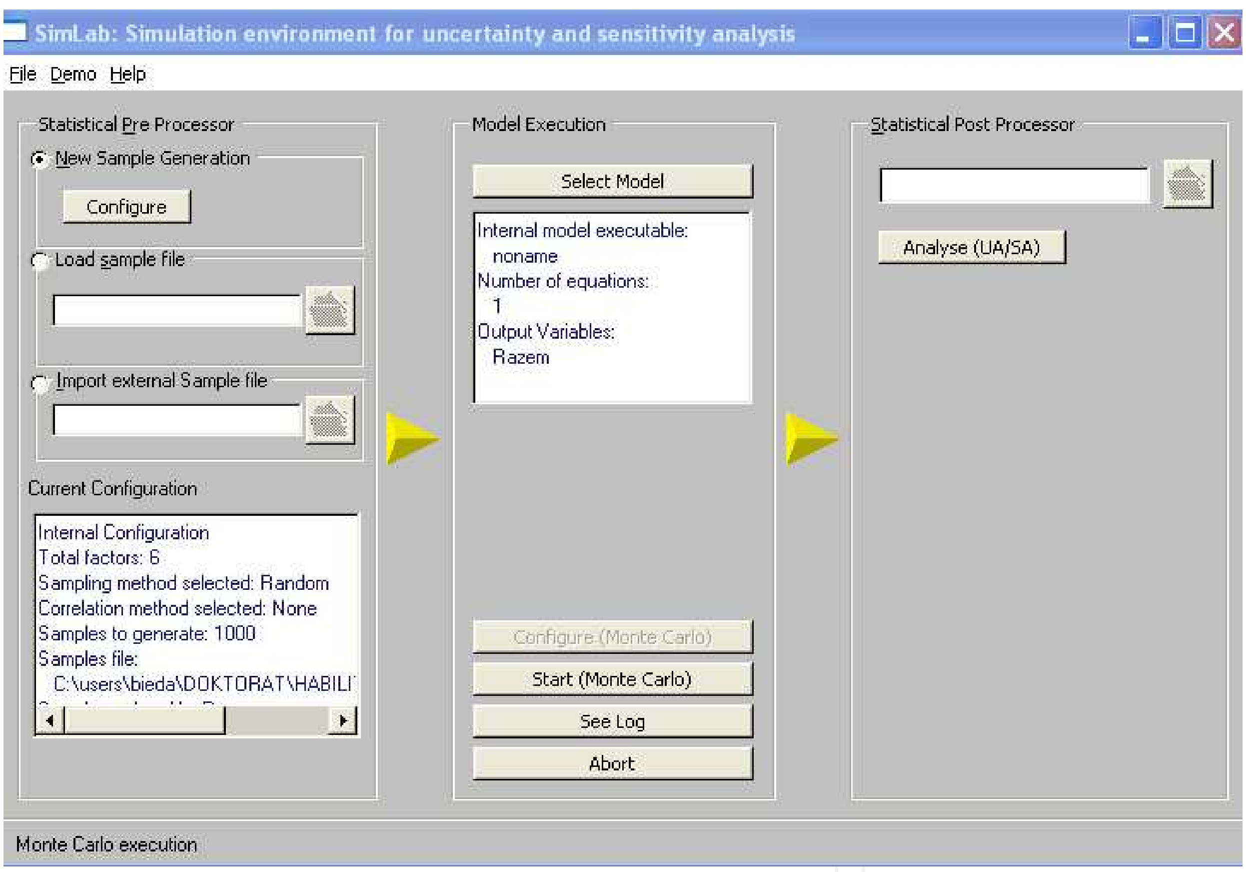

Fig. 1. Simlab® main panel.

5. Results and discussion

The deterministic project approach traditionally requires that the values for all input data be known exactly. But data in many real manufacturing projects cannot be precisely given. The stochastic approach is based on the replacement deterministic data with random variables. Important studies to stochastic variables incorporated in the data envelopment analysis can be found in (Sengupta, 1982, 1987, 1990, 1997, 1998, 2000, Cooper et al, 1998; Huang & Li, 1996; Morita & Seiford, 1999; Sueyoshi, 2000, as cited in Azadi & Saen, 2011).

Projects involve risk by nature (Zwikael & Ahn, 2011). Reducing the level of risk is extremely important in projects, and indeed results of this study suggest that project managers often use risk management planning practices, consistent with previous studies (Kerzner, 2009; Ahmed & Kayis, 2007; Voetsch, 2004; Zwikael, 2004, as cited in Zwikael & Ahn. 2011). The Project Management Body of Knowledge (PMBOK) defines risk management as one of nine project knowledge areas, alongside other topics such as scope, schedule, quality, and cost management (PMI Standards Committee [PMI], 2008). In some project contexts, risk management is perceived as a separate activity (Zwikael & Ahn, 2011).

- In countries with low levels of uncertainty avoidance, project managers place lower importance on risk management and hence do not always follow required processes.
- In industries with low levels of maturity, project managers do not frequently perform the risk management process.

When applying for European Union (EU) funding of projects, cost-benefit analysis (CBA) practitioners need to prepare comprehensive investment appraisals following the latest guidelines on CBA provided by the European Commission (2008). Since this Guide includes the need to conduct a proper risk analysis, partly through sensitivity analysis (Evans & Kula, 2011).

The purpose of sensitivity analysis is to determine the relationships between the uncertainty in the independent variables used in an analysis and the uncertainty in the resultant dependent variables. Sensitivity refers to the amount of uncertainty in a forecast that is caused by the uncertainty of an assumption as well as by the model itself. Sensitivity analysis can be used to find "*switch points*" -- critical parameter values at which estimated net benefits change sign or the low cost alternative switches (OMB, 2003). Sensitivity plots are not only fundamental to determining which are the prominent input variables, but can be invaluable indicators of whether a particular project should be pursued (Koller, 1999). In (Saltelli et al, 2004) sensitivity analysis have been presented as: "*those techniques will answer questions of the type 'which of the uncertain input factors is more important in determining the uncertainty in the output of interest?, or, if we could eliminate the uncertainty in one of the input factors, which factor should we choose to reduce the most the variance of the output?"*. Sensitivity analysis is considered by some as a prerequisite for model building in an any setting, be it diagnostic or prognostic, and in any field where models are used (Saltelli et al, 2004). Kolb quoted in (Rabitz 1989, as cited in Saltelli et al, 2004) noted that theoretical methods are sufficiently advanced, so that it is intellectually dishonest to perform modeling with sensitivity analysis. In Oreskes et al (1994) it has been shown that sensitivity analysis is not treated as a tool to build or improve a model, but it represents one of the possible licit uses that can be done of the model itself. Chapman & Ward (2004) have defined "*risk efficiency*" as the minimum risk level for a given level of expected performance.

The principal output reports provides by SimLab® are presented in Figure 2 through Figure 7 (probability distributions assigned to model input parameters), Figure 8 through Figure 13 (histograms of the output value-Razem (Total), Figure 14 (uncertainty analysis of the output value-Razem (Total), Figure 15 and Figure 16 (sensitivity analysis based on the *Standardised*

Regression Coefficients, SRC) and Figure 17 (sensitivity analysis - *Cobwebs plot* based on the *Standardised Regression Coefficients*, SRC) (Bieda, 2011). Based on the economic feasibility model presented in (Liberman, 2003), in this study used uniform distributions. Figure 15 and Figure 16 shown the results from the sensitivity analysis. The performance of the SRC is shown to be extremely satisfactory when the model output varies linearly or at least monotonically with each independent variable. MC analysis-simulation is the only acceptable approach for U.S. Environmental Protection Agency (EPA) risk assessments (Smith, 2006). Because all of the parameters of the economic model are independent, the using of the SRC is shown to be extremely satisfactory (Bieda, 2010).

SimLab® is didactical software designed for global uncertainty and sensitivity analysis, developed by the Joint Research Centre of the European Commission and downloadable for free at: http://simlab.jrc.ec.europa.eu (Simlab, 2004). The sampling techniques available in SimLab® are FAST, Extended FAST, Fixed sampling, Latin Hypercube, replicated Latin Hypercube, Morris, Quasi-random LpTau, Random and Sobol (Saltelli et al, 2004). SimLab® can also run models built in Microsoft Excel®. Using the SimLab® in order to determine the most relevant parameters sampling presented by sensitivity analysis, after selected the Monte Carlo (MC) simulation, sampling method, the optimal number of executions is considered at least 10,000 times.

There are available various commercial software packages in order to conduct the risk analysis using MC simulation. Among them, Risk® and Crystal Ball®, developed by Palisade Corporation and Decisioneering, respectively. Risk® was originally designed for business application and is easy to use without a need for extensive statistical knowledge and modeling capacity (Sonnemann et al, 2004). Crystal Ball® is a simulation program that helps analyze the uncertainties associated with Microsoft Excel® spreadsheet models by MC simulation (Sonnemann et al, 2004). Another function of the Crystal Ball® is the sensitivity analysis (Bieda, 2007).

According to Hullet (2004) the estimate of project cost risk can be made more accurate and better understood if the sources of risk are disaggregated into those that affect time and those that affect the burn tate per unit time. The schedule risk and cost risk analysis have been conducted in Microsoft Excel® and Crystal Ball®. In conclusion, Hullet (2004) muses that cost risk analysis that explicitly incorporates schedule risk analysis results, merging them with burn rate risk information in the estimates of cost risk that are more accurate than the typical approach. In the opinion of Leach (2005) anyone who is serious about realistically forecasting project schedules, in other words, truly managing projects, rather than just monitoring them, should be using MC simulation software to plan and analyze projects stochastically. Stochastic simulation (often called MC simulation) allows to capture and understand the uncertainty inherent in the project. Anderson (2005) in paper presented to the Denver Crystal Ball Conference in 2005 discusses the results of the using the MC simulation instead the analytic approach in the nuclear power plant steam generator repair/replacement cost/benefit analysis (before nuclear power plant steam generator replacement decisions have never included a MC simulation) and the strengths of the weaknesses of using Crystal Ball® and MC simulation. In conclusion, Anderson (2005) seems to think that MC approach was clearly appropriate to fully assess the impact of any decision on the ratepayer. Selection of data play a key role in application of risk analysis to project investments. In most industries the costs of raw materials and component parts constitute the major cost of a product – in some cases up to 70 per cent (Azadi & Saen, 2011). In this study the most likely Total Project Cost values are about 2.53563E+007 USD and 2.663226E+007 USD for the analyzed Scenario. Every manager has a different degree of aversion to risk In this study the most likely Total Project Cost values are about 2.53563E+007 USD and 2.663226E+007 USD for the analyzed Scenario. Every manager has a different degree of aversion to risk.

Positive coefficients indicate that an increase in assumption is associated with an increase in the forecast, negative coefficients imply the reverse (Evans & Olson, 1998). In the Sensitivity Charts (Figures 16 and 17) is presented that variables Etap2 is the most influential parameter (98.93%) in the Project Total Costs.

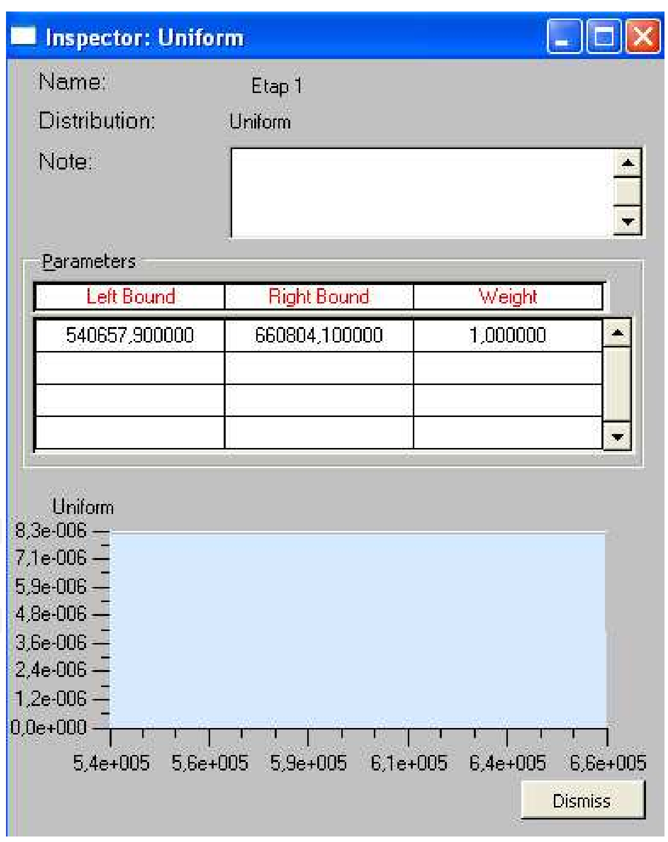

Fig. 2. Probability distributions assigned to input - Etap 1.

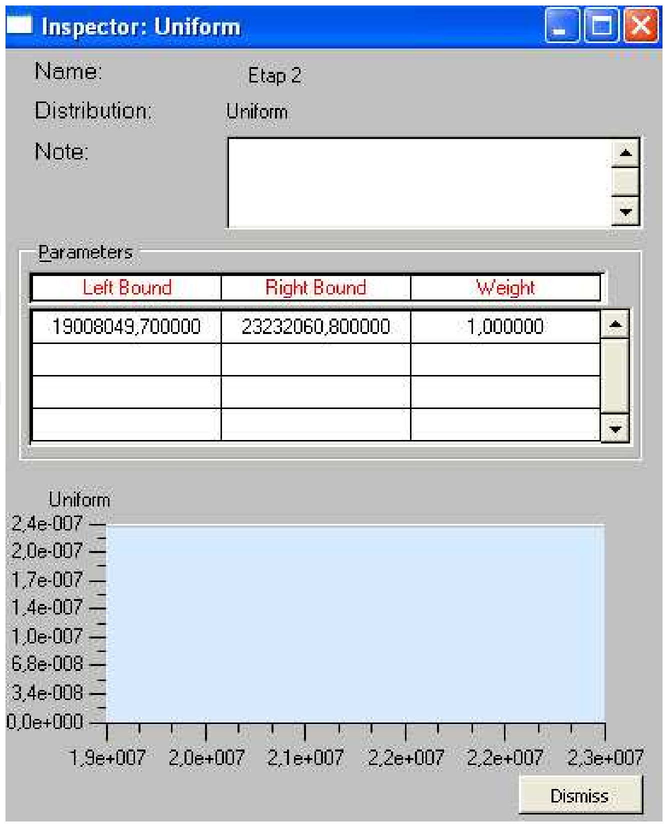

Fig. 3. Probability distributions assigned to input - Etap 2.

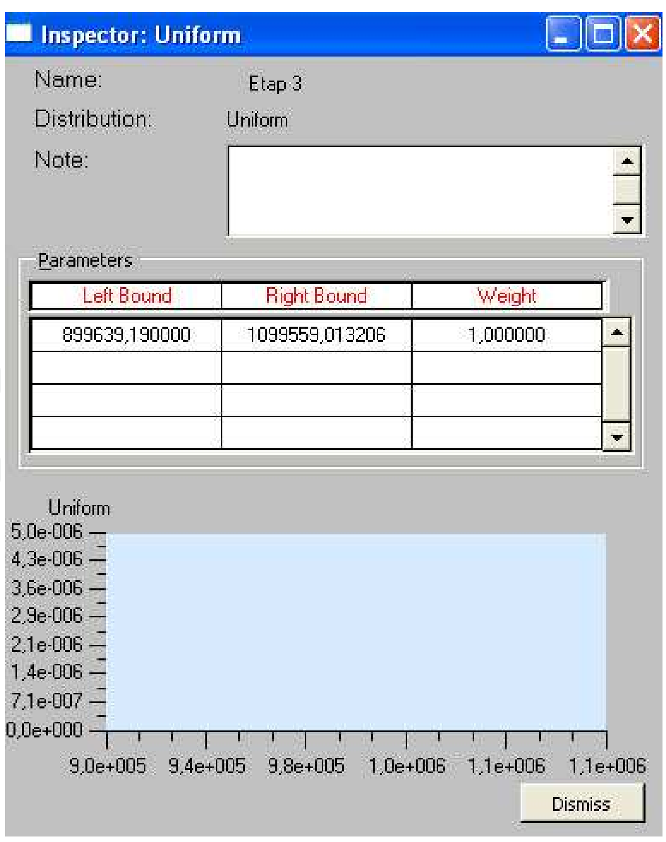

Fig. 4. Probability distributions assigned to input - Etap 3.

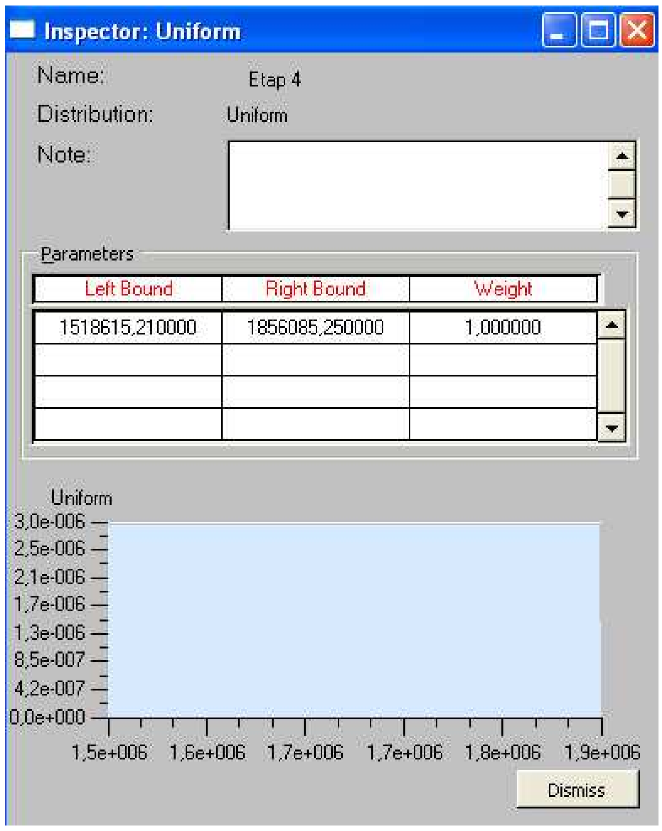

Fig. 5. Probability distributions assigned to input - Etap 4.

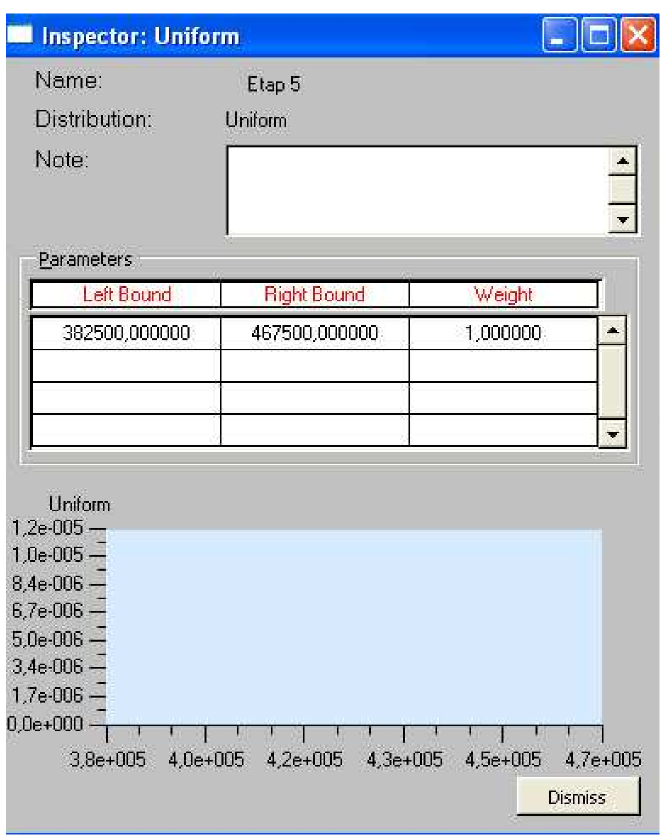

Fig. 6. Probability distributions assigned to input - Etap 5.

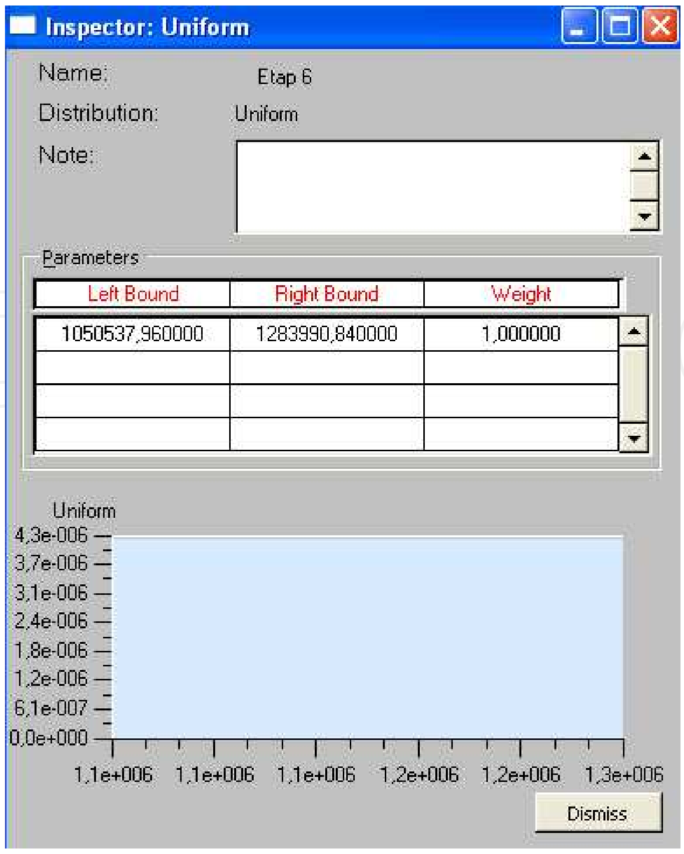

Fig. 7. Probability distributions assigned to input - Etap 6.

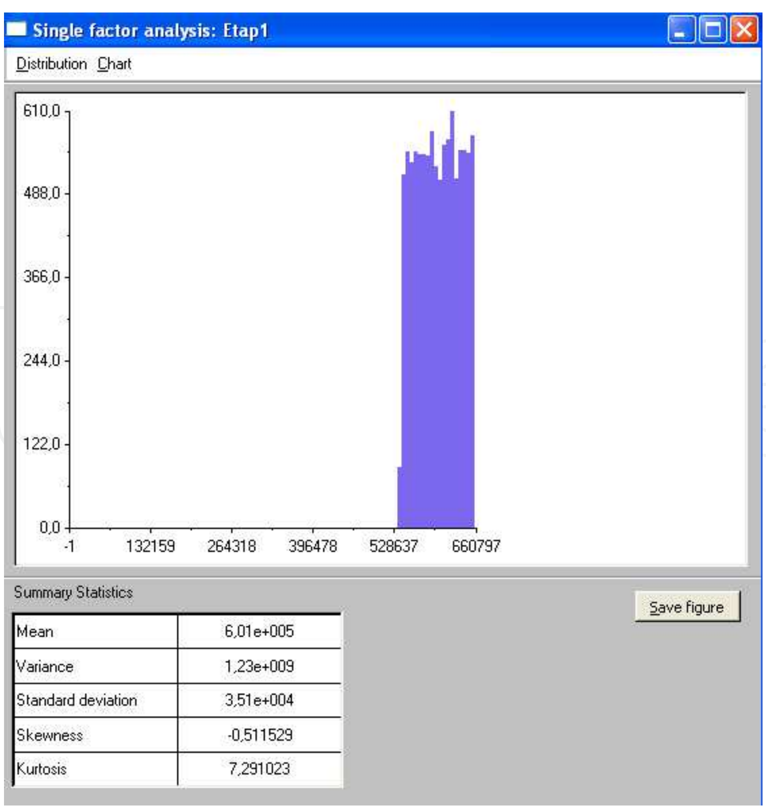

Fig. 8. Histogram results for Etap 1.

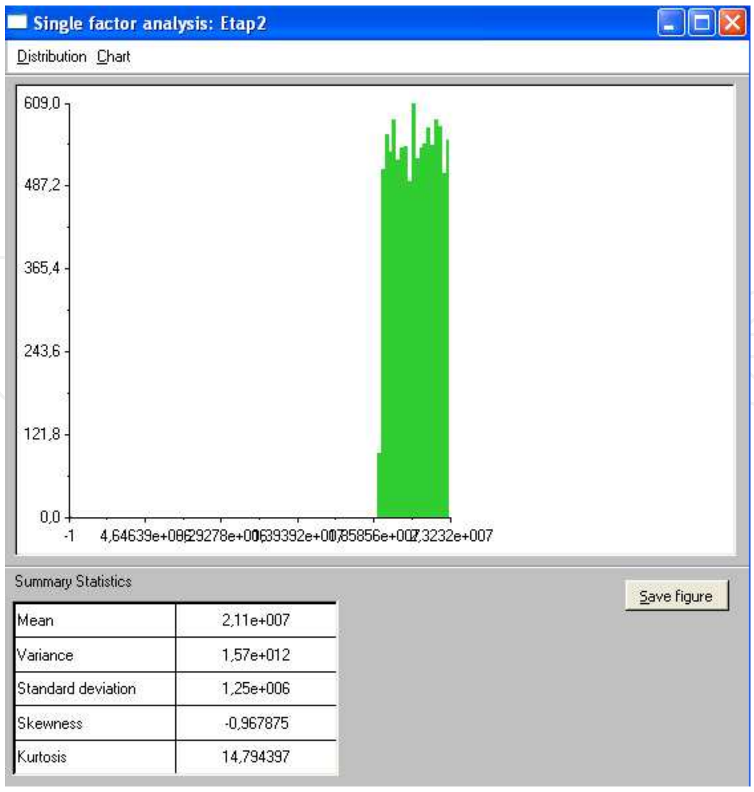

Fig. 9. Histogram results for Etap 2.

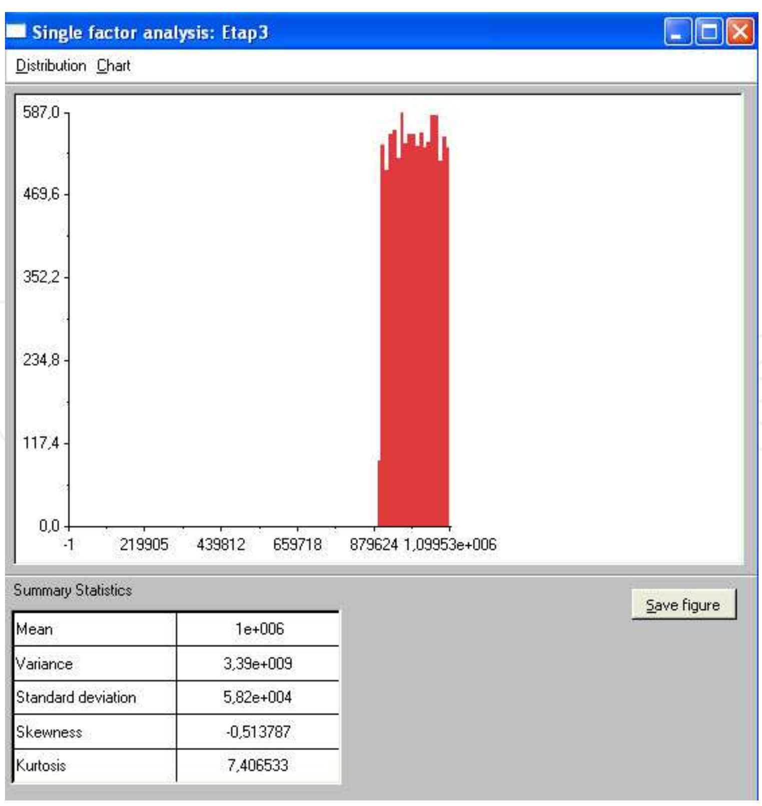

Fig. 10. Histogram results for Etap 3.

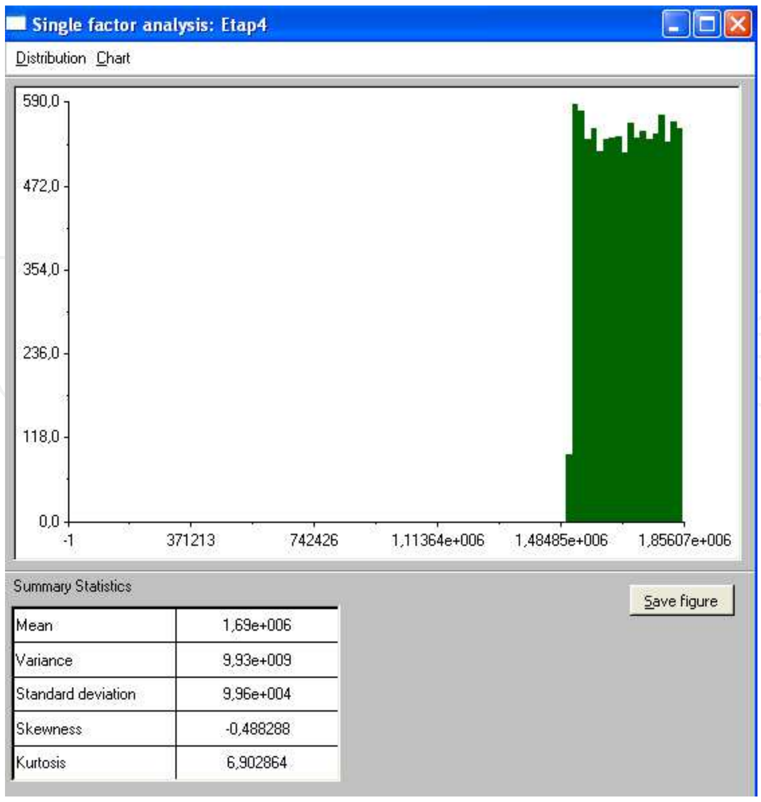

Fig. 11. Histogram results for Etap 4.

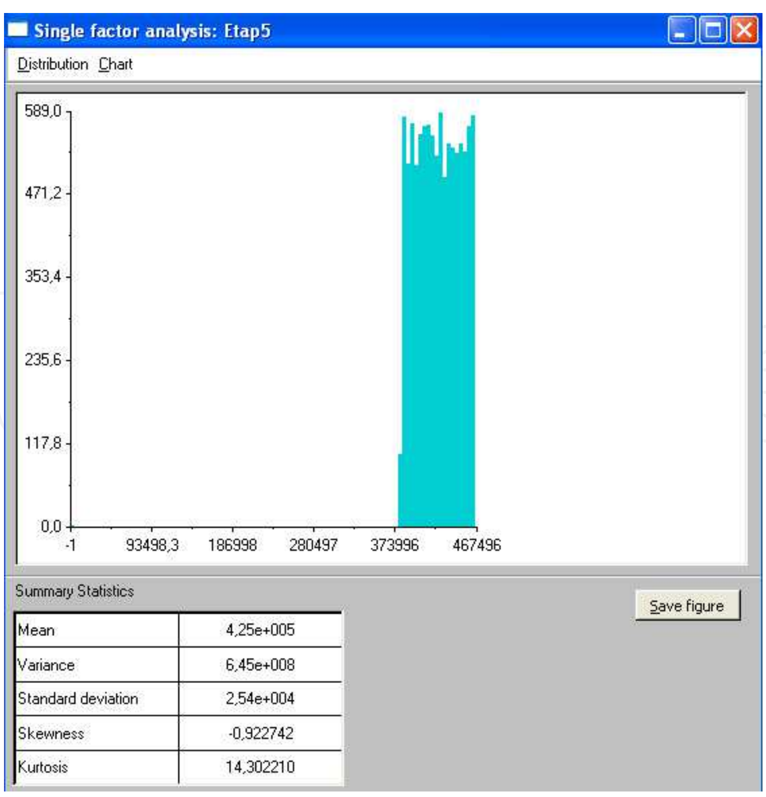

Fig. 12. Histogram results for Etap 5.

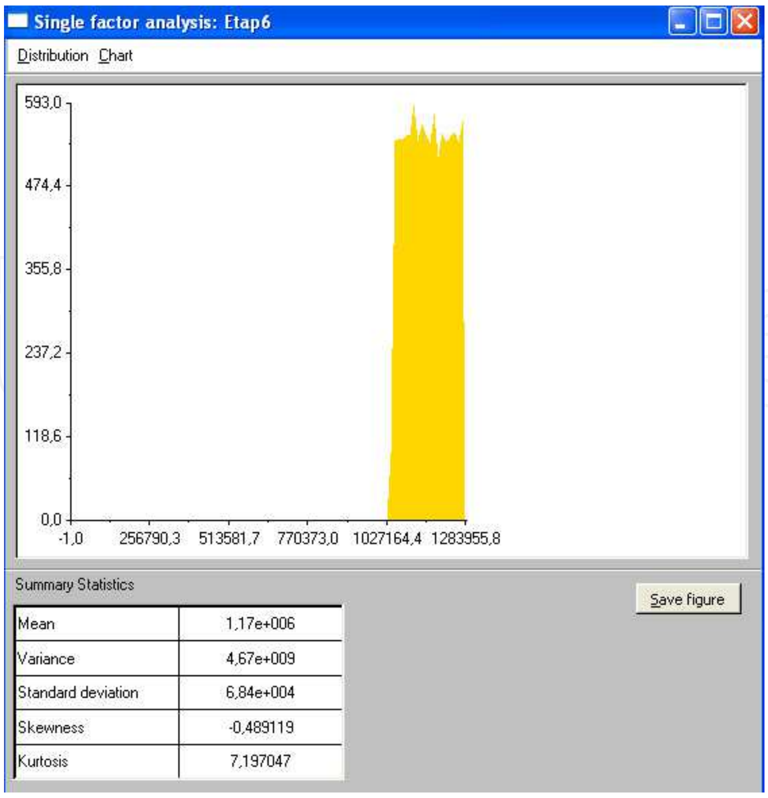

Fig. 13. Histograms results for Etap 6.

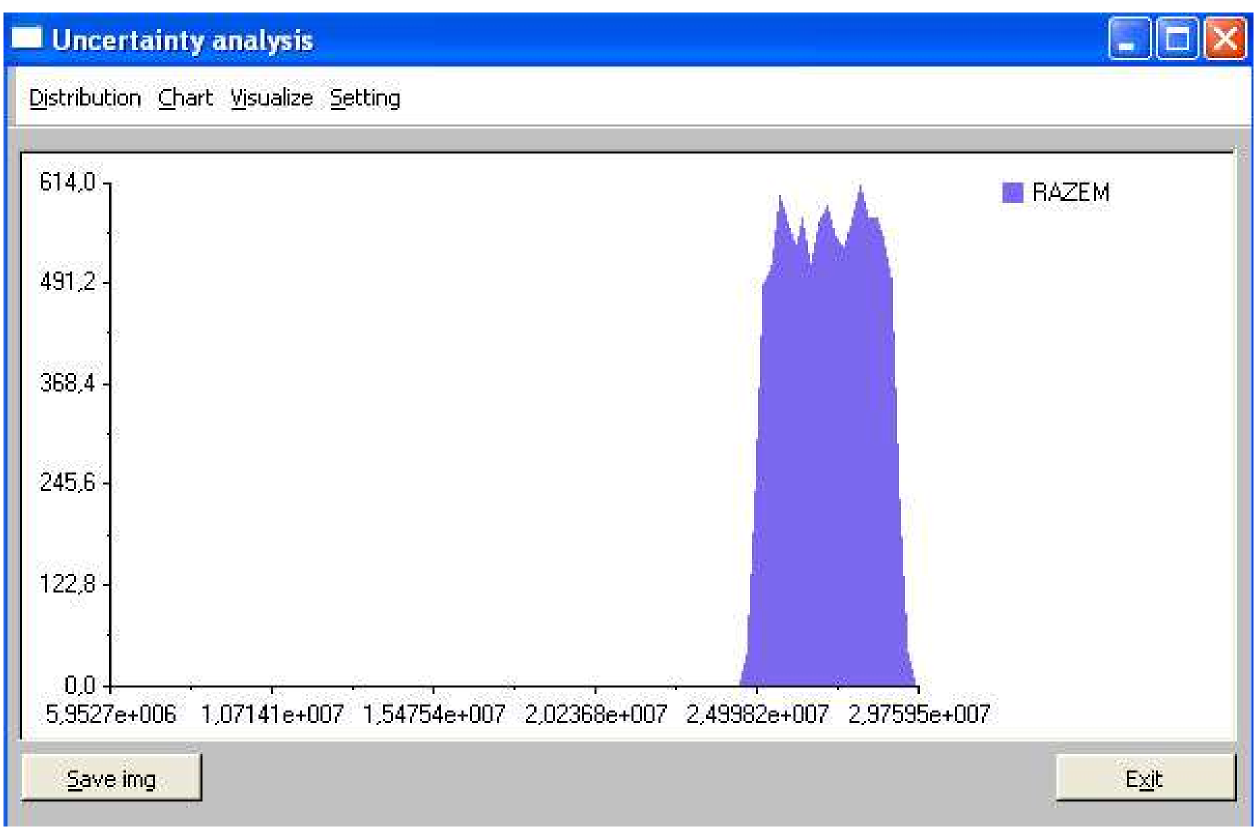

Fig. 14. SimLab® uncertainty analysis for RAZEM.

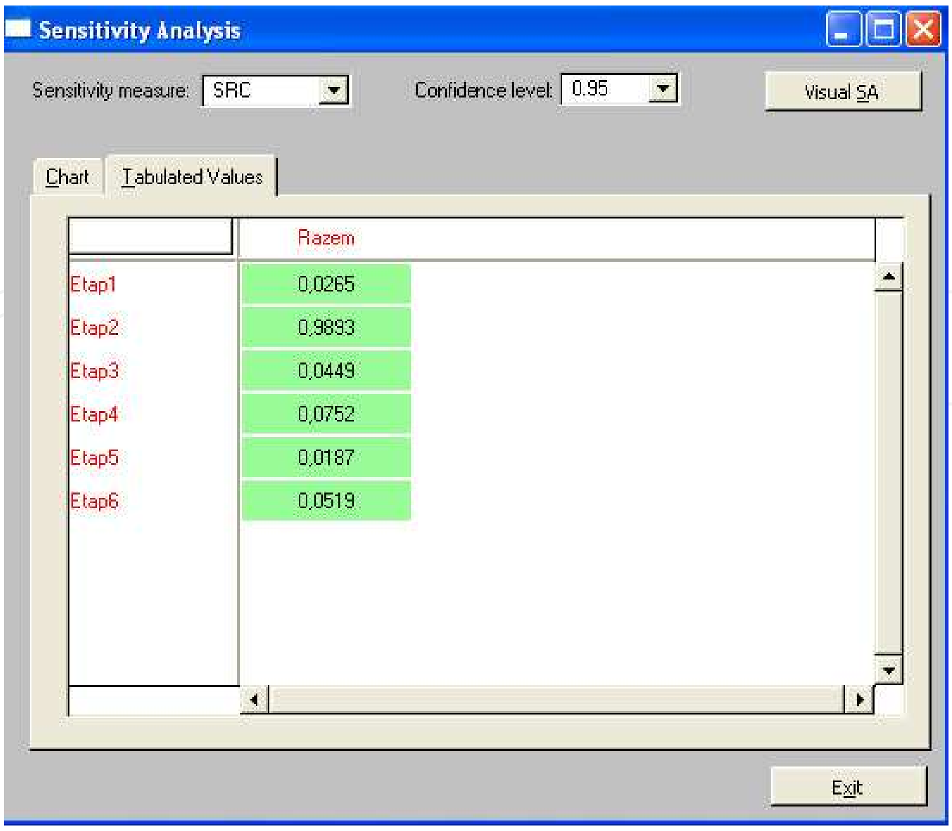

Fig. 15. Sensitivity analysis tabulated value (SRC) for the 95% confidential level.

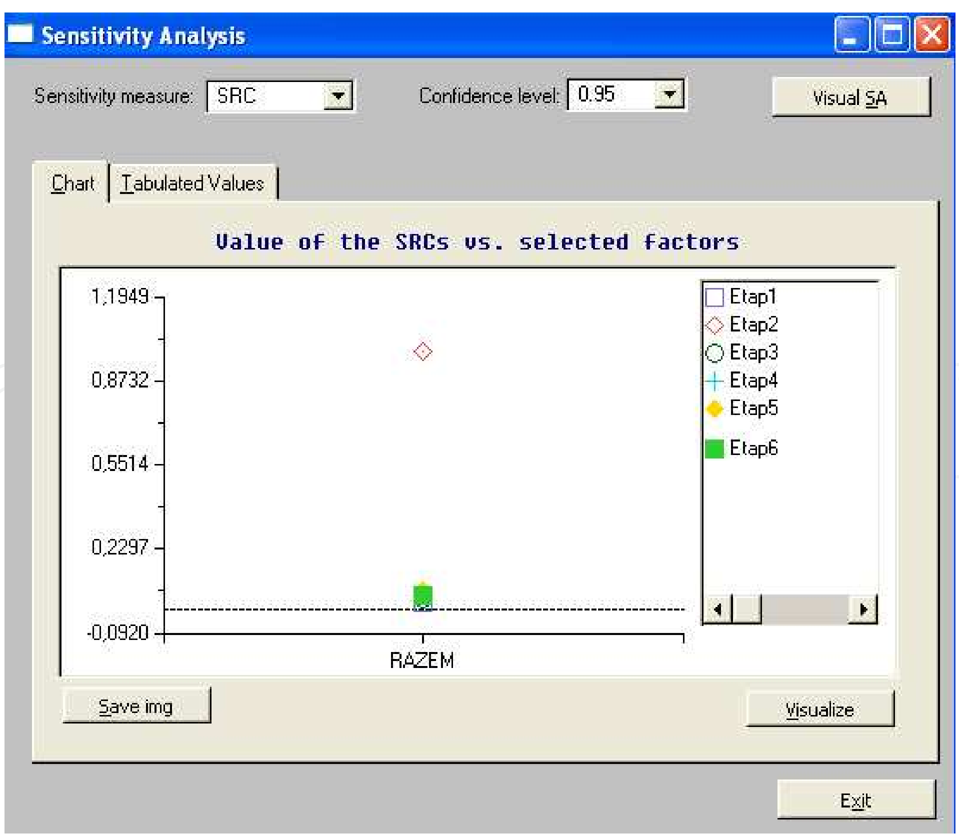

Fig. 16. Sensitivity analysis main Panel (SRC) for the 95% confidential level.

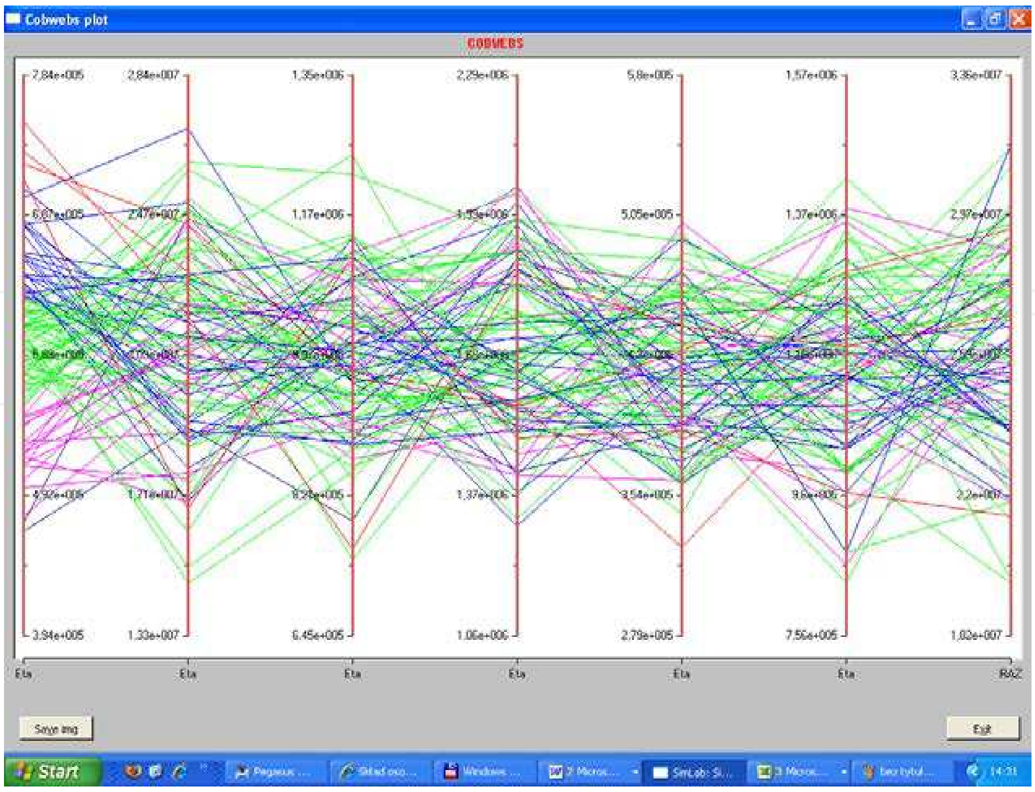

Fig. 17. Sensitivity analysis (*Cobwebs plot*) (SCR - *Spearman Rank Correlation*). (SRC) for the 95% confidential level.

When the 10,000 trials are completed, the histograms provide by SimLab®, given in Figure 9 through Figure 14, present *statistics summary.* The "*Mean*", "*Variance*", "*Standard deviation*", "*Skewness*" and "*Kurtosis*" values form the basis of starting points for the analysis.

6. Conclusions

This study found that the purpose of uncertainty analysis, and sensitivity analysis is to determine the potential directions for waste management decision support systems under uncertainty, because this technique accounts for uncertainties in the assumptions, and to introduce the sensitivity analysis

Because all of the parameters of the economic model are independent, the using of the SRC is shown to be extremely satisfactory.

Cost risk analysis can answer some questions that the traditional estimating method cannot. Included are:

- "*What is the most likely cost*?" The traditional method assumes that this is the baseline cost computed by summing the estimates of cost for the project elements, but this is not so.
- "*How likely is the baseline estimate to be overrun?*" Traditional methods do not address this problem.
- "*What is the cost risk exposure?*" This is also the answer to the question; "How much contingency do we need on this project?"
- "*Where is the risk in this project*?" This is the same as: "*Which cost elements cause the most need for the contingency*?" Risk analysis principles can be used to answer this question.

Uncertainty reduction in the project is performed during the planning phase of the project using the software package SimLab® for project risk management.

In summary, integrating risk analysis into waste to energy pyrolysis facility project management processes may be useful for the project managers. In this study the most likely Total Project Cost values are about 2.53563E+007 USD and 2.663226E+007 USD for the analyzed Scenario. Every manager has a different degree of aversion to risk.

7. Acknowledgments

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8. References

Anderson TS. (2005). Diablo Canyon Power Plant: Steam generator repair/replacement cost/benefit analysis. *Proceedings of the 2005 Crystal Ball User Conference,* Denver, Colorado, May 2005. Date of access 25 November 2011, Available from <http://www.anarisco.com.br/gerenciador/uploads/energia_a2.pdf>

Astrup T., Bilitewski B. (2010). Pyrolysis and Gasification, In*: Solid Waste Technology & Management, Chapter 8.8,* Christensen, pp. 502-512, John Wiley & Sons, Ltd, ISBN 978-1-405-17517-3, Chichester

Azadi M, Saen RF. (2011). Developing a WPF-CCR model for selecting suppliers in the presence of stochastic data*., Operational Research Society*, Vol. 24, Nr. 1, pp. 31-48, ISSN 0953-5543 (print)

Bieda B., Tadeusiewicz R. (2008). Decision support systems based on the Life Cycle Inventory (LCI) for Municipal Solid Waste (MSW) Management under Uncertainty. *International Transactions in Operational Research*. Vol. 15, Nr 1, January 2008, pp. 103-119

Bieda B. (2011). *Metoda Monte Carlo w Ocenie Niepewności w Stochastycznej Analizie Procesów Wytwórczych i Ekologii.* Wydawnictwo Naukowe AGH, ISBN 978-83-7464-344-3, Kraków, Poland (Polish)

Bieda B. (2010). Decision Support Systems Based on the Economic Feasibility Assessment for Municipal Solid Waste (MSW) Management Under Uncertainty Using Simlab® Toolpack. *Proceedings of the Sixth International Conference on Sensitivity Analysis of Model Output, SAMO*, ISSN 1877-0428, Mediolan, October 2010

Bieda B. (2007). Assessing the Economic Feasibility of the Waste to Energy Facility Using Crystal Ball. *Proceedings of the 2007 Crystal Ball User Conference*., May 2007, Denver, Colorado, USA. Date of Access 25 November 2011, Available from < http://www.anarisco.com.br/gerenciador/uploads/telecomunicacoes_1a.pdf>

Bieda B. (2005). The role of thermal treatment in an integrated waste management, In: *Waste Recycling*, Wzorek, Kulczycka, Fečko, Kušnierowa, pp. 104-113, ISBN 83-89174-83-9, Krakow

Chapman C, Ward S. (2004). Why risk efficiency is a key aspect of best practice projects. *International Journal of Project Management,* 22(8), pp. 619-631

European Commission (2008). *Guide to Cost-Benefits Analysis of Investment Projects*, Brussels, Directorate General Regional Policy

Evans DJ, Kula E. (2011). Social Discount Rates an Welfare Weight for Public Investment Decisions under Budgetary Restrictions: The Case of Cyprus. *Fiscal Studies*, vol. 32, no. 1, pp. 73-107, ISSN 0143-5671

Evans JR, Olson DL. (1998). *Introduction in Simulation and Risk Analysis*. Prentice Hall, New Jersey, USA.

Everard M. (2004). Hot stuff!-The role of thermal treatment in a sustainable society. *Waste Management World*, July-August, pp. 37-45

Hulett DT. (2004). Integrated Cost and Schedule Project Risk analysis. *Originally published as a part of 2004 PMI Global Congress Proceeding- Prague*. Date of access 25 November 2011, Available from <http://www.projectrisk.com/Welcome/White_Papers/Integrated_Cost_-_Schedule_Risk_Analysis.pdf>

Klein A, Whiting K, Archer E, Schwager J. (2004). Gasification and pyrolysis: what is the current situation for waste management?, *Waste Management World*, September-October, pp. 71-75

Koller G. (1999). Risk Assessment and Decision Making in Business and Industry - A Practical Guide. *CRC Press LLC*, Boca Raton, London, New York, Washington, D. C., USA

Leach P. (2005). Modeling uncertainty in project scheduling. *Proceedings of the 2005 Crystal Ball User Conference,* Denver, Colorado, May 2005. Date of access 25 November 2011, Available from <http://www.aertia.com/docs/crystalball/cbuc05-leach.pdf>

Liberman E. (2003). A Life Cycle Assessment and Economic Analysis of Wind Turbines Using Monte Carlo Simulation. *Master's thesis Air Force Institute of Technology*, Wright-Patterson Air Force Base, Ohio, AFIT/GEE/ENV/03-16

National Energy Technology Laboratory [NETL]. (2005). Gasification Robust Growth Forecast - World Survey Results. In*: A Current Perspective On the Gasification Industry - Robust Growth Forecast,* Date of access 8 November 2011, Available from: <http://www.netl.doe.gov/publications/brochures/pdfs/gasification_brochure.pdf>

Office of Management and Budget (OMB) - The Executive Office of the President. (2003). In: *Circular A-4, Regulatory Analysis.* Date of access 7 November 2011, Available from <http://www.whitehouse.gov/omb/circulars/a004/a-4.html>

Orekres N, Shrader-Frechette K, Belitz K. (1994). Verification, validation, and confirmation of nukerical models in the earth sciences. *Science,* 263, pp. 641-646

Pfeiffer E. (2004). Waste, or valuable product?. *Waste Management World*, September-October 2004, pp. 65-69

PMI Standards Committee. (2008). A guide to the Project Management Body of Knowledge, 4th ed. Newton Square, PA: Project Management Institute

Saltelli A, Tarantola S, Campolongo F, Ratto M. (2004). *Sensitivity Analysis in Practice. A Guide to Assessing Scientific Models.* John Wiley & Sons, Ltd

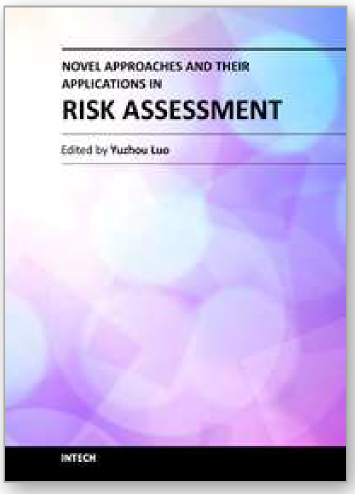
Simlab (2004). Software package for uncertainty and sensitivity analysis. Joint Research Centre of the European Commission

Smith, R. (2006). Use of Monte Carlo Simulation for Human Exposure Assessment at a Superfund Site. *Risk Analysis,* Vol. 14, Issue 4, pp. 433-439

Sonnemann G, Castells F, Schumacher M. (2004). *Integrated Life-Cycle and Risk Assessment for Industrial Processes*, Lewis publishers, CDD Press Company, Boca Raton, London, New York Washington, D.D

Wajs, W., Bieda, B., Tadeusiewicz, R. (2000). Project Cost Analysis for Niepolomice Municipal Solid Waste using the Monte Carlo Simulation. Int. Conference RISK ANALYSIS 2000, Bologna, Italy. In: *Wessex Institute of Technology Publishers,* pp. 225-234

Zwikael O, Ahn M. (2011). The Effectiveness of Risk Management: An Analysis of Project Risk Planning Across Industries and Countries. *Risk Analysis*, Vol. 31, No. 1, January 2011, pp. 25-37, ISSN 0272-4332



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Risk assessment is a critical component in the evaluation and protection of natural or anthropogenic systems. Conventionally, risk assessment is involved with some essential steps such as the identification of problem, risk evaluation, and assessment review. Other novel approaches are also discussed in the book chapters. This book is compiled to communicate the latest information on risk assessment approaches and their effectiveness. Presented materials cover subjects from environmental quality to human health protection.

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