THE ROLE OF INNOVATION IN INDUSTRIAL DEVELOPMENT SYSTEM. A SIMULATION APPROACH FOR SUSTAINABILITY OF GLOBAL SUPPLY CHAIN NETWORK

Liberatina Santillo [(a)], Giuseppe Converso [(b)], Luigi De Vito [(c)]

[(a)]DICMAPI University of Naples Federico II Naples, p.le Tecchio 80, ITALY
[(b)]DICMAPI University of Naples Federico II Naples, p.le Tecchio 80, ITALY
[(c)] CNR – IMCB Naples, ITALY

[(a)] santillo@unina.it, [(b)] giuseppe.converso@unina.it, [(c)] ludevito@unina.it

ABSTRACT
This paper shows the relationship between Supply Chain Management and sustainability at global level. As we shall see, it will be shown that relationship using a Causal Loop Diagram then we will move on a Stock and Flow Diagram, developing an ad hoc model in System Dynamics. The model will show how the whole system will crash in total absence of Innovation, then we will figures two scenarios, each with different Innovation levels, and see how the Innovation will compensate the depletion of all primary resources. We will also consider financial sustainability as endless, leaving financial matters to the economists.

Keywords: Innovation, Global Supply Chain Network

1. INTRODUCTION

Innovation has a double impact on the environment. While it contributes to impoverish the environmental resources of the planet, it has the ability to compensate that decrease. Since natural and primary resources are the first link of any supply chain, especially at the global level, it is therefore legitimate to deal with Sustainable Supply Chain Management (SSCM).
SSCM is a set of managerial behaviors that include a low negative or (even positive) environmental impact, also through a multidisciplinary approach of such practices at all levels of the production cycle.
It is assumed that such behavior, arising from the normal process of business decision-making, rather than an imposition by the government.

In this paper we will demonstrate the fundamental role of Innovation in balancing the massive depletion of primary resources, using a System Dynamics simulation model.

System Dynamics is an approach used to model the behavior of complex systems in a certain time range. Developed at MIT back in 1950, by J.W. Forrester first and then by P. Sange, SD is mostly used to describe enterprises behaviors, even if we maintain SD perfectly describes strategic situations.

SD make use of two main tools: Causal Loop Diagram and Stock and Flow Diagram. The first one consist graphic maps showing relationships between all the single elements of the system. It has two pros: it's a first graphic approach to the problem, then it shows all the feedbacks between each quantity. The cons instead are that it is only a qualitative approach, since there's any quantitative information. That limit is overcome with the Stock and Flow Diagram. Its basic elements are: stock variables, shown as boxes that describes the state of the system, flow variables shown as valves that fill or decrease the levels, links that transport the information from levels to flows, the functions that rule the way levels are used to let the flow work.

2. STATE OF THE ART

The SSCM brag a significant literature, developed massively since the mid-90s onwards. It examines the various environmental implications of several business activities such as product design, production cycle,inventory management. Early research on SSCM concerns the management, from collection to rework the returned products.

In 1995, Greenberg highlights the importance of mathematical models for environmental control. Fleischmann analyzes the quantitative models, dividing his work into three areas: distribution planning, production planning and inventory control.

Kleindorfer et al. (2005) use the term sustainability in a diffuse manner, referring to the environmental management,talking about the Closed Loop Supply Chain, integrating profit, people and planet in the corporate culture.

Toktay and Ferguson (2006) have developed models to support a manufacturer's recovery strategy in the face of a competitive threat in the market of the product manufacturing.

Atasuand van Wassenhove (2008) examine the environment rework from the perspective of marketing, focusing on important aspects of remanufactured products, such as low cost, parts reuseand constraints on the supply chain.

Ketzenberg, Van der Laan, and Teunter (2006) treat the value of information (VOI), when a company faces the uncertainty of demand, product returns and repairs. The objective is to evaluate the VOI by reducing the factors of uncertainty one by one, thus evaluating the economic savings.

Therelationshipsamong the actors of a supply chain network, cover every aspect of business, for example through the sub-contracting (outsourcing of activities mainly related to the production, taking advantage of the expertise of the supplier), outsourcing (of one or more activities of the value chain. Involvement greater than the sub-supply involves the expenditure of energy and resources in mate selection and implementation of specific investments to manage the relationship with the latter), licensing (a contract by which a company licensor grants to the licensee company economic exploitation of a patented intellectual property, trademarks and patents and not, or know-how, maintaining the property. licensee agrees to pay royalties relate to the economic results), franchising, venture capital and private equity (respectively forms of participation in the venture capital firm emerging or already).

We may thus apply the concepts of SSCM on a global scale, if we think that the relationship between companies tend not to have more geographical limits.

2.1. Subheadings

Initial Caps, bold, flush left. Use Times New Roman Font and 10 points in size. Start the text on the next line. Please use the "Heading 2**"** style.

2.1.1. Secondary Subheadings

Initial Caps, bold, indented of 0.7 cm. Use Times New Roman Font and 10 points in size. Start the text on the next time. Please use the "Heading 3" style.

3. INNOVATION AND SUSTAINABLE SCMC

From the macroeconomic point of view, research and innovation in particular will have a positive impact on the availability of raw materials, the first ring of each supply chain. The need to model the process of innovation is illustrated by the fact that in addition to the obvious advantages already mentioned, the use of technology may have a negative impact on the environment. The relationship between technology and environment is twofold and moves along two paradoxically opposite. On the one hand the intensive use of technology involves a high consumption of raw materials, with consequent environmental stress, on the other hand the use of technology, in terms of research and innovation, can lead to a better and more efficient use of raw materials , with consequent environmental stress less. In other words, we talk about sustainable technological development.

In any macroeconomic model, a production cycle of goods and services on the one hand has a positive influence on job opportunities, and inevitably the supply of goods and services, on the other hand has a strong negative impact on the availability of raw materials, seen both as materials needed for the production and as energy resources (for example, fuel oil, natural gas and fossil). At the same time, the increase in labor income and therefore inevitably generates consumption, which together with the offer and as a result of solid macroeconomic laws, tends to bring the market back into balance.

One of the tasks of the Supply Chain Risk Management (SCRM) is the analysis and the treatment of all possible threats to the chain. The overall objective of SCRM is to ensure that the chain will continue to operate as expected, with a constant flow and continuous materials from suppliers to end customers. This is possible by increasing their ability to withstand adverse events. If you know the seriousness of the risk, then you know how to deal with it. The response varies depending on the type of risk and consequences associated with it.
We see this behavior in terms of Causal Loop Diagram (CLD, cfr. Fig. 1):

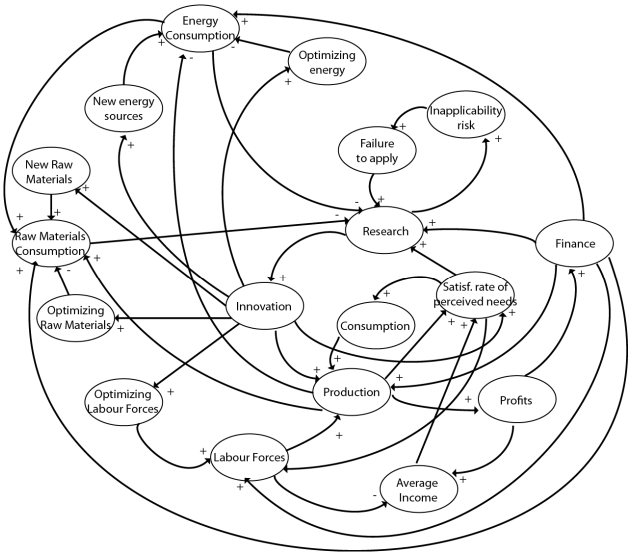

Figure n. 1: Causal Loop Diagram

Let's then suppose the financial sustainability as infinite, and let's take the assumption that, since 20% of the population consumes an average of 80% of the available resources of the planet, what can happen if the remaining 80% of the population increase its own life standards up to or comparable to the 20% mentioned.

In this case, the global supply chain will crash, because when the number of employees increases, and then exceeds the threshold of poverty and access to consumption, increase their disposable income, and therefore will increase the demand first and then consumption. This increase will reverberate positively on industrial production, stimulated to meet the perceived needs of the population and then in turn it will increase as well. In the CLD we already considered implicitly the processes of recycling of raw materials and energy. Of course, an increase in production is given by an increase in labor resources involved, but also of the energy and raw materials, the increase in production will lead to increased profits, they'll be back in a circle fueling monetary reserves, generating hence welfare. We know that the majority of raw materials and non-renewable resources are limited, so naturally tend to run out, for example, despite the continuing search for new sources of raw materials. The impact can therefore be increasing the number of people accessing the consumption does not only accelerate the process suddenly runs out of resources.

A course like this is naturally parasitic and inevitably requires a strong balancing process, or at least of a slowdown in the process of exhaustion, with the ultimate goal of improving the availability of energy resources and raw materials, optimizing consumption (process innovation) but also discovering new (product innovation). The centerpiece of this cycle is precisely balancing innovation and research. Clearly, not everything that is produced by research becomes innovation, In other words, when a research ends, it is not said that the result can be directly implemented, so it is easy to incur the risk of inapplicability which leads to the failure innovation. Such non-innovation in compensation can still be a source of stimulus for subsequent research, in order to successfully transform them into new innovation. Innovation can then act on an optimized consumption of raw materials and / or energy sources or even produce new ones, in any case going to increase their availability, and then to counteract the deleterious effects of massif exploitation. In a nutshell innovation in this case is very strong weapon in defense of the technological sustainability of the global supply chain.

3.1. The Stock and Flow diagram

Based on the process outlined in the causal loop diagram, in the compilation of the model the following quantities have been identified and classified (cfr. Fig. 2):

Level variables:
- Recycled Energy Consumed
- Recycled Energy
- Energy Scrapped
- Energy Used
- MP consumed recycled
- MP dropped
- MP extracted
- MP recycled
- New energy
- Newmaterials
- Production consumed
- Production dropped
- Total production
- Reserve consumed
- Reserve available:
- Reserve power
- Reserve MP

Auxiliary variables:
- Innovation:
- Percentage increase in population
- Population
- Productivity energy
- Productivity matter
- Research
- Expenses for the purchase of materials and energy

Constants:
- Cx Innovation
- Energy Price
- Price MP
- New energy production Price
- Price new production MP

Flow variables:
- Consumption
- New energy added
- New MP added
- Recycling Energy
- Recycling Energy consumed
- Recycling MP consumed
- Recycling MP
- Recycling MP input
- Recycling Energy cons
- Recycling energy input
- Recycling MP cons.
- Scrap energy
- Scrap MP
- Scrap production
- Consumption Rate
- Extraction Rate MP
- New energy Rate
- New MP Rate
- Production rate
- Energy use Rate
- Gains

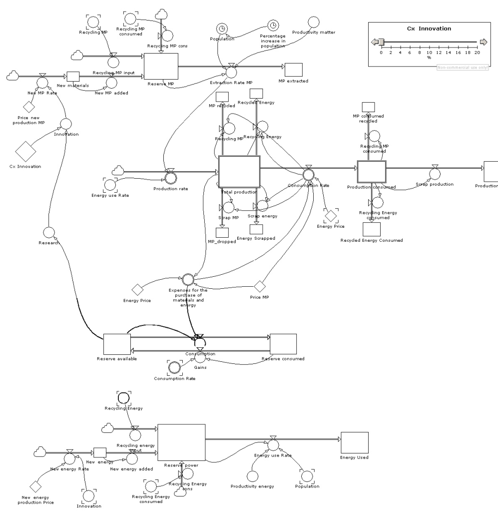

Figure 2: Stock and Flow Diagram

3.2. Validating the model

In our model, a slider was applied on the Coefficient of Innovation (Fig. 2), that allows us to vary at will, its value within a range defined by us between 0-10%.

To validate the model, we started the simulation by resetting the innovation level on the slider. The result, shown in Fig. 3, is in line with those who say, as the Italian ASPO (Association for the Study of Peak Oil) and the maximum of Hubbert, i.e. the peak extraction of raw material for single nation after which the available reserves tend to decrease in a rather sudden, is more or less reached, and then in little more than fifty years the availability of oil tend to run out. The plastic instead will end with a slight delay due to the recycling process. Both raw materials and renewable energy will be depleted since the steady increase in population leads to increasing in consumption.

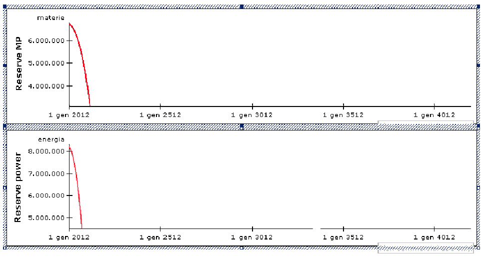

Figure n. 3: Innovation = 0

3.3. First scenario

Therefore we hypothesized a first scenario, introducing a 1% innovation value in the slider. In this case we found a similar pattern for both monitored processes, but with a slower decay, which showed that a low rate of innovation does not solve the problem of scarcity and lack of materials, but move only away the time which all the materials run out and then the system crashes.

The signal given by the model should however be taken positively, either because the innovation, while not completely solving the problem, provides further autonomy, cfr Fig. 4, and encourages us to try new simulations with higher values of innovation, as well as in the second scenario.

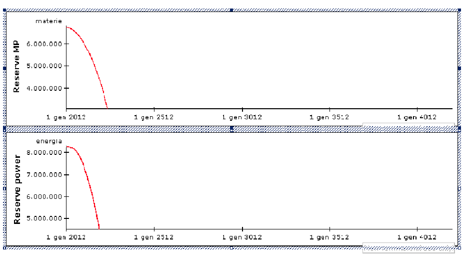

Figure n. 4.: First Scenario , Innovation =1

3.4. Second scenario

In a second scenario, we increased the innovation level on the slider up to 6%. The results here are completely subverted, as shown in Fig. 5; while in the first scenario, the system crash occurs more slowly, materials and energy resources won't deplete, and the system will not crash. In this scenario the innovation plays an important role, both in the optimization of resources and materials, both in the identification of substitute products that are likely to be even more easily recyclable, increasing each own stock.

The trend, as you can imagine, and as you can see from the graphics, is growing.

As already mentioned, one of the key points of this model is the financial sustainability endless. This simulation includes a gold reserve generator, for which at the time when the population increases, a fraction of its richness in the process returns, is able to re-feed the respective initial reservations.

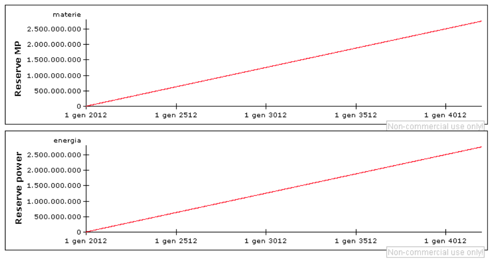

Figure n. 5: Second Scenario Innovation = 6

3.5. Future developments

This particular model, although still in prototype stage, has a strong significant potential. Infact, with a more accurate and complete data collection, it can be vectorialized, creating arrays of simulations, one for each most important raw material, such as steel and cast iron, clay, silver, plastic, and the main sources of energy, such as oil, coal , wood, etc.. In this way it is possible to better understand the dynamics and interrelationships of the exploitation of primary resources, understand the trends and see which resource crashes first, to evaluate the Hubbert peak, possible influences of the limiting factors.

The aim of this work is also laying the groundwork for the creation of a team and the scheduling of work for the implementation and programming of such a model..

ACKNOWLEDGMENTS

If the paper requires an acknowledgements section it can be placed after the main body of the text.

REFERENCES

Greenberg, H. J. (1995), Mathematical programming models for environmental quality control. *Operations Research*, 43(4), pp. 578-622,

Fleischmann, M., Runwaard, J. B. M., Dekker, R., Laan, E., Nnunen, J. A. E. E., & van Wassenhove,

L. (1997), Quantitative models for reverse logistics: a review. *European Journal of Operational Research*, 103(1), pp. 1-17,

Kleindorfer, P. R., Singhal, K., & van Wassenhove, L. N. (2005). Sustainable operations management.*Production and Operation Management*, 14(4), pp. 482-492

Ferguson, M. E., &Toktay, L. B. (2006). The effect of competition on recovery strategies.*Production and Operation Management*, 15(3), pp. 351-368

Atasu, A., Van Wassenhove, L. N. (2008). Remanufacturing as a marketing strategy. *Management Science*, 54(10), pp. 1731-1746.

Ketzenberg, M. E., van der Laan, E., &Teunter, R. H. (2006). Value of information in closed loop supply chain. *Production and Operation Management*, 15(3), pp. 393-406.

Gallo M., Murino T., Santillo L. C. *A lean redesign for a manufacturing process through computer simulation* (2012) Advances in Computer Science, pp 416-422

Bessant J., Lamming R. (2003). Putting supply chain lerning into practice.http://eprints.uk/79/1

Harland R., Zheng J., Johnsen T., Lamming. R. (2004). *A Conceptual Model for Researching the Creation and Operation of Supply Networks*. British Journal of Management, Vol. 15, pp. 1–21

Gallo M., Aveta P., Converso G., Santillo L. C. *Planning of supply chain risks in a make to order context through a System Dynamics approach*.. NEW TRENDS IN SOFTWARE METHOLOGIES, TOOLS AND TECHNIQUES. p. 475-496, IOS Press, ISBN: 9781614991243

Guizzi, G., Chiocca, D., Romano, E., *System dynamics approach to model a hybrid manufacturing system* (2012) Frontiers in Artificial Intelligence and Applications, 246, pp. 499-517

Chiocca, D., Guizzi, G., Murino, T., Revetria, R., Romano, E., *A methodology for supporting lean healthcare* (2012) Studies in Computational Intelligence, 431, pp. 93-99.

Murino, T., De Carlini, R., Naviglio, G., *An economic order policy assessment model based on a customized ahp* (2012) Frontiers in Artificial Intelligence and Applications 246 , pp. 445-456

Guizzi, G., Murino, T., Romano, E., *An innovative approach to environmental issues: The growth of a green market modeled by system dynamics* (2012) Frontiers in Artificial Intelligence and Applications 246 , pp. 538-557

Murino, T., Romano, E., Santillo, L.C., *Supply chain performance sustainability through resilience function* (2012) Proceedings - Winter Simulation Conference , art. no. 6147877 , pp. 1600-1611

Gallo, M., Grisi, R.M., Guizzi, G., *A vendor rating model resulting from AHP and the linear model* (2010) International conference on System Science and Simulation in Engineering - Proceedings, pp. 370-377.

Gallo, M., Guerra, L., Guizzi, G., *Some considerations on inventory-based capacity scalability policies in RMSs* (2010) International conference on System Science and Simulation in Engineering - Proceedings, pp. 342-347.

Di Franco, R., Gallo, M., Guizzi, G., Zoppoli, P., *Project risk management: A quantitative approach through simulation tecniques* (2009) Proceedings of the 8th WSEAS International Conference on System Science and Simulation in Engineering, ICOSSSE '09, pp. 326-333.

AUTHORS BIOGRAPHY

LIBERATINA C. SANTILLO is a Full Professor - at the Department DICMAPI - University of Naples - Federico II -. At the same University Department (Degree in Mechanical Engineering, Industrial Engineering, Materials Engineering) she teaches “Goods and Services Production System” and “Work Safety”. She is Professor of Industrial Plants at Neptune Consortium University. Her research interests cover both the management of the industrial production of goods and services, and the safety procedures of work activities. She is President of a major training institution and a member of several Italian clubs with scientific, social and charity purposes. Her email address is santillo@unina.it.

GIUSEPPE CONVERSO received his Ph.D. in Technology and Production Systems from Department of Materials and Production Engineering - University of Naples - Federico II - Faculty of Engineering - in 2006 and has since collaborated with the DICMAPI - University of Naples - Federico II -. His research interests include optimization via simulation, process reengineering, simulation output analysis, and applications of simulation methods to plant design system. His e-mail and is giuseppe.converso@unina.it.

LUIGI DE VITO holds PhD in Production System Tehnology at University of Naples Federico II, and work for C.N.R., National Research Council. His email address is ludevito@unina.it.