SUSTAINABLE CAR INDUSTRY BASED ON GREEN LOGISTICS SIMULATION MODELS

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ABSTRACT

Sustainability is major issue, that emerged during recent crisis as an important aspect in designing industrial processes (Taplin 2001); in this paper it is presented a model to analyze the supply chain in term of cost efficiency and environmental impact (Daly and Cobb 1989); this analysis is based on simulation; in fact the paper GreenLog, a simulation model developed by the authors for studying these problems; the experimental analysis provide an opportunity for validating and verifying the simulator

Keywords: Sustainability, Environmental Impact

1. INTRODUCTION

The definition of sustainability as result of the application of methods of harvesting or of using resource so that the resource is not depleted or permanently damaged (Denton 1998); in fact today a strong emphasis is attributed to sustainability in social context corresponding to human activities and lifestyle involving the use of sustainable methods even in references to social and human resources (Hardin 1968).

The current crisis highlighted that target functions need to include environmental, social and economic sustainability in addition to time payback period and profit estimations for next four or height trimesters.

These issues have been extensively approached in the past (Daly et al. 1989); however it results that the time horizon represent a critical issue, that need to be consistent with user perceptions (Velasco 2008).

However recent event highlight the necessity to move from qualitative analysis and economic models considering generic and simplified hypotheses to quantitative models based on simulation to reproduce realistic scenarios (Amico Vince et al. 2000).

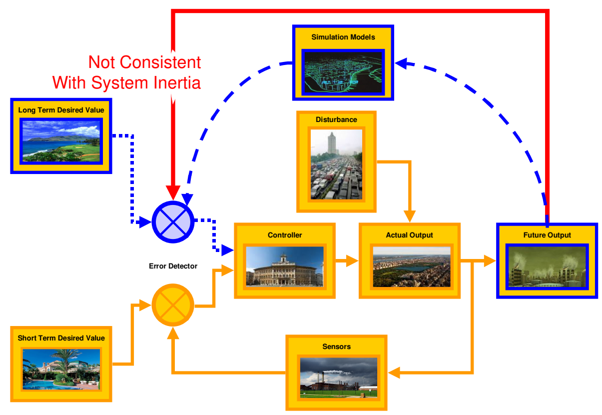

Figure 1 - Time Horizon and Sustainability

In fact a major problem, arising from the recent experience, corresponds to the short term horizon in decision making analysis; even large investments today are focusing on very short period pay back and usually long term considerations are depleted by contingency and short term targets.

In addition to analyze sustainability requires to consider additional factors that usually are regulated by pretty complex relations; so traditional quantitative techniques are often pretty inefficient in approaching these aspects and usually qualitative methods and/or expert feelings are the only approach taken in consideration.

Therefore the implications of our actions and their impact on the whole system, today are much stronger and complex than in the past, partially due to technology advances, partially due to population growth, without forgetting to take into consideration the "time horizon " issues (Miller 1998)

Due to these considerations, simulation (Spedding et al. 1999) represent an ideal approach for considering

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complex system, with many components interacting each other.

This paper propose a simulation model developed to investigate supply chain from point of view of environmental issues (Christensen 1999; Seamann 1992) in this case it is proposed a classical question, therefore the answer proposed is based on scientific models and quantitative hypotheses related to scenario configuration (Bruzzone et al. 2007). Obviously the result proposed are strongly related to the specific hypotheses and the specific configuration of the proposed case study (Melnyk and Handfield 1996), however the simulator allows to estimate the interactions and different factors; so while the results have just a local validity and the consideration can't be extended as general criteria due to the strongly not-linear nature of the problem, the model allows to test the sensitivity of the problem to different hypotheses and provides a methodological example in analyzing sustainability problems.

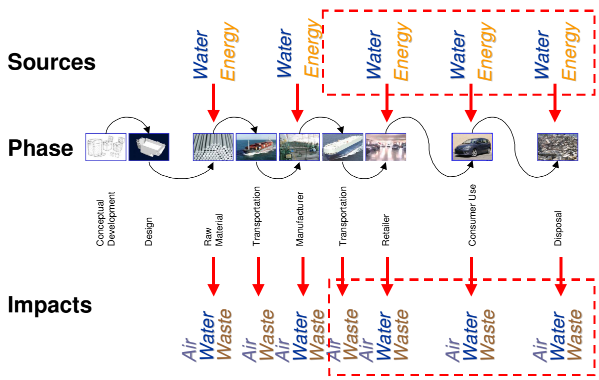

Figure 2 - Source and Impact of Car Supply Chain

2. SIMULATION FOR SUSTAINABILITY

It was already mentioned the critical issue in managing sustainability (Hibbert 1998) due to time horizon limitation; in fact it is interesting to analyze closed loop applied to this area as proposed in figure 1.

Therefore lets assume that the decision makers are driven by both short and long term goals (Ottman 1999); our real system react to the decisions taken by controllers in order to achieve the expected goals; usually short term target functions are emphasizing profit and social stability, while long term are paying more attention to quality of life and environmental issues (European Commission Dg Environment 2000).

From this point of view it is interesting to note that the long term target functions are often affected by significant inertia, so the time response results inconsistent respect the controller actions; due to this situation it becomes necessary to use simulation for estimating future state of the system by conducting experimental analysis on the models; this support the development of a predictive approach that is able to activate in time required actions for keeping the system under control.

In fact the long term impact of actual actions, due to the inertia of the real system, requires to adopt simulation as forecasting methodology in order to develop a predictive control.

Based on this approach it is critical to define performance indexes able to provide a guideline in guarantee sustainability in long term, without forgetting short term goals.

As always in analysis of complex systems it is critical to define target functions able to map completely the user expectations; usually in business activities it is important to include target functions covering at least: economic profits (Hick 2000), activities volumes, quality of the service provided; even in the case of complex system sustainability it is important to define KPI (key performance indexes) covering all the spectrum of short and long term (as well as medium) objectives (Stead and Stead 2000); this should include among the others:

- Profitability
- Value of Deliverables
- Quality of Deliverables
- Environmental Impact
- Social Stability

3. SUSTAINABILITY IN CAR INDUSTRY

Today an important aspect in manufacturing (Street 1986) and logistics is related to the sustainability and to the environmental impacts (Bruzzone 2004a). In fact traditional economic and financial aspects requires to be keep in consideration concurrently with social and environmental issues (Flachsbart 1999); therefore to proceed in development of interoperable models covering these aspects it is a big challenge, so the authors are proposing in this paper a specific case study as example to demonstrate these concepts and methodologies. It was decided to focus on car industry, currently very strongly affected by the financial crisis; however even in this sector an extensive analysis should result in complex scenarios affected by many uncertain variables (Quinn 2001) (i.e. market evolution, advertising effectiveness, factors affecting both value engineering and quality function deployment) (Bruzzone and Kerckhoffs 1996).

So the authors focused on a very specific case related to an on-going questions: "hybrid cars produced in far east and delivered in western countries are more sustainable than new generation traditional cars produced locally?" (Merkuryev et al. 2003; Sarkis 2006)

This context is still pretty large, and in order to be solved requires to define properly the scenario (type of car, production sites, recycling policies, mode of use, etc.).

Table I: Scenario Parameters				
	Value		Scenario	Phase
Road Car Carrier Cost	1.2	[Euro/km]	A	FE Factory-FE Port
Road Car Carrier Emission	0.00035	[tCO2/km]	A	FE Factory-FE Port
Road Car Carrier Capacity	9	[cars]	A	FE Factory-FE Port
Road Car Carrier Saturation	100%		A	FE Factory-FE Port
Impact on Road Car Carrier Transp.	100%		A	FE Factory-FE Port
Road Car Carrier Average Distance	12	[km]	A	FE Factory-FE Port
Road Car Carrier Empty Return	100%		A	FE Factory-FE Port
Ship Car Carrier Variable Cost	30,000	[Euro/day]	A	FE Port-SE Port
Ship Car Carrier Extra Cost (Suez)	200,000	[Euro/travel]	A	FE Port-SE Port
Ship Car Carrier Emission	0.1053	[tCO2/km]	A	FE Port-SE Port
Ship Car Carrier Capacity	6000	[cars]	A	FE Port-SE Port
Ship Car Carrier Saturation	9%		A	FE Port-SE Port
Impact on Ship Car Carrier Transp.	9%		A	FE Factory-FE Port
Ship Car Carrier Average Distance	19.21	[days]	A	FE Port-SE Port
Ship Car Carrier Average Distance	17,500.00	[km]	A	FE Port-SE Port
Ship Car Carrier Empty Return	0%		A	FE Port-SE Port
Road Car Carrier Cost	1.2	[Euro/km]	A	SE Port - SE Distributor
Road Car Carrier Emission	0.00035	[tCO2/km]	A	SE Port - SE Distributor
Road Car Carrier Capacity	9	cars	A	SE Port - SE Distributor
Road Car Carrier Saturation	100%		A	SE Port - SE Distributor
Impact on Road Car Carrier Transp.	100%		A	FE Factory-FE Port
Road Car Carrier Average Distance	200	[km]	A	SE Port - SE Distributor
Road Car Carrier Empty Return	100%		A	SE Port - SE Distributor
Hybrid Car Consumption	26.32	km/litre	A	Consumer Use
Hybrid Car Emission	104	[gCO2/km]	A	Consumer Use
Hybrid Car Acquistion Cost	28,000	[Euro/car]	A	Consumer Use
Hybrid Car Service Cost	750	[Euro/year]	A	Consumer Use
Hybrid Car Extra Disposal Cost (NiMH)	0.012	[Euro/car]	A	Dismissal
Hybrid Car Extra Emissions (NiMH)	480	[gCO2/car]	A	Dismissal
Road Car Carrier Cost	1.2	[Euro/km]	B	SE Factory-SE Distributor
Road Car Carrier Emission	0.00035	[tCO2/km]	B	SE Factory-SE Distributor
Road Car Carrier Capacity	9	[cars]	B	SE Factory-SE Distributor
Road Car Carrier Saturation	100%		B	SE Factory-SE Distributor
Impact on Road Car Carrier Transp.	100%		B	SE Factory-SE Distributor
Road Car Carrier Average Distance	800	[km]	B	SE Factory-SE Distributor
Conventional Car Consumption	16.39	km/litre	B	Consumer Use
Conventional Car Emission	155	[gCO2/km]	B	Consumer Use
Convential Car Acquistion Cost	14,000	[Euro/car]	A	Consumer Use
Convential Car Service Cost	500	[Euro/year]	A	Consumer Use
Notes: FE Far East / SE South Europe				

In addition the model reproducing these case is expected to be strongly not linear, so it is important to state that the obtained results are specific of the configuration of author's input and assumptions.

The case in fact focuses on comparing two different scenarios:

A] New Conventional Family Cars (unleaded gasoline) produced in South Europe and transferred within 1000 km to a regional distributor

B] New Hybrid Family Car (conventional combustion engine, electric engine and NiMH battery) produced in Far East and transferred in South Europe to a regional distributor

It is assumed that the cars are expected to be used for about 15'000 km/year and to have equivalent life cycle duration (i.e. a potential life cycle of 5 years); in table I it is proposed a synthesis of several parameters.

In figure 2 it is proposed a general scheme for analyzing the impact on environmental issues of car production (LockWood et al. 2007), in our case it was decided to consider equivalent the impact on environment and social aspect for manufacturing the car both in solution A and B; so the difference are computed just after the cars exit from production site parking; at the same time the consumer use profile is supposed to be equivalent on the both scenarios; service costs for the two cars have been hypothesized. The parameters adopted in these scenarios are fictional, even if they have been tunes on realistic values; any similarity to any car existing is merely coincidental. In figure 3 it is proposed the comparison among the different components of the A and B life cycle.

The sustainability it is measured respect CO_2 emission (Colvile et al. 2001) and total social cost; therefore the GreenLog simulator used for completing the analysis is even able to measure others factors such as different environmental impacts (i.e. tire disposal, oil waste), but in this case, due to the fact that it is supposed hybrid and conventional car have equivalent behavior it is not consider; the only difference evaluated it is related to service activities (additional electrical engine, controls and battery for case A) and extra disposal activities for batteries (in this case the hypotheses are focusing on NiMH batteries) (Krishnamurthi and Shanthi 2003).

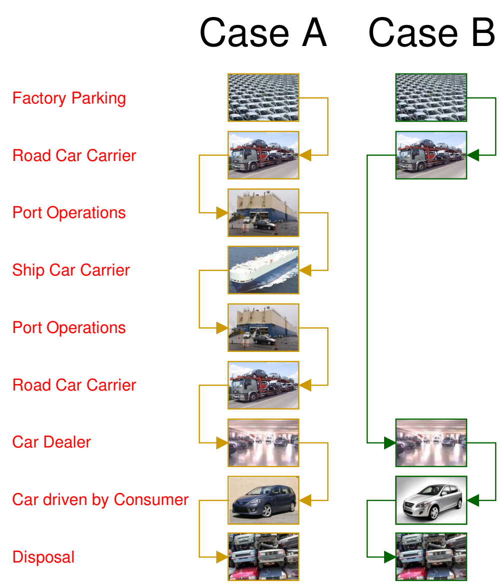

Figure 3 - Life Cycle of the two case studies

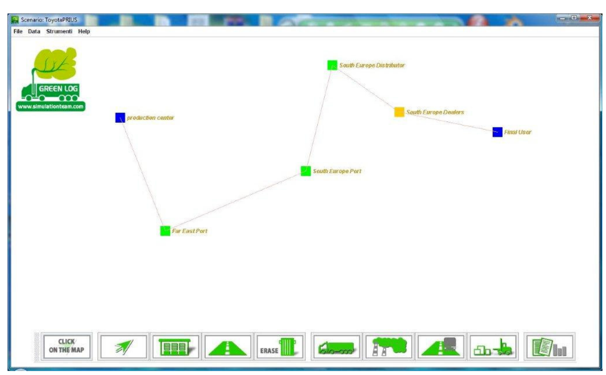

Figure 5 - Scenario A in Greenlog Simulator

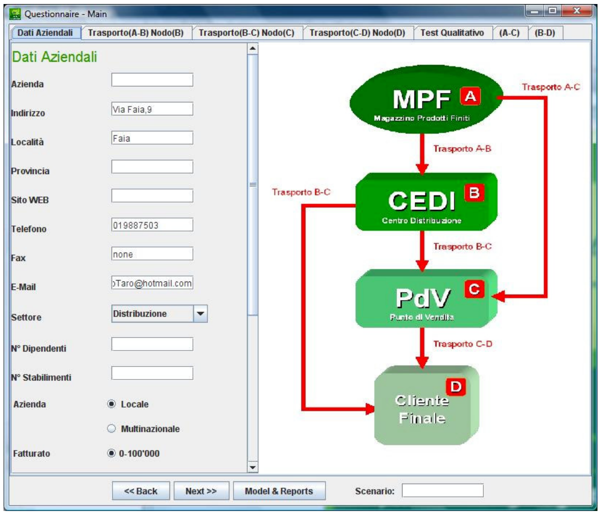

Figure 4 - Questionnaire for Company Self Evaluation

4. GREENLOG SIMULATOR

The authors developed an object oriented simulators for analyzing complex supply chain scenarios in term of overall efficiency and sustainability (Arnold 2006). This simulator it is named GreenLog (Green Logistics simulator) and it is based on web technologies for guaranteeing easy access and distributed use (Bruzzone et al. 1999) (Bruzzone et al. 2001) In fact GreenLog is part of a project for supporting environmental impact mitigation in Italian Logistics; this initiative involve Agencies (i.e. Assologistica Cultura e Formazione), Networks (i.e. Simulation Team), Institutions (i.e. MISS DIPTEM Genoa University) and Companies (i.e.Campari, CRAI, MARS, Sony, etc.); Green Logistics initiative (Gifford 1997) it is lead by MISS DIPTEM from technical point of view and it is based on a web portal (st.itim.unige.it/greenlogistics) where it is possible to access to several services:

- Company Qualitative and Quantitative Questionnaire (see figure 4)
- Self Measure of the Company Logistics Green Level based on automated configuration of the specific simulation model
- Supply Chain Simulation for measuring impacts and performances.

The model is based on the following main objects devoted to reproduce infrastructures, processes and performances; among the others it is possible to list the following objects:

- Logistics Node
- Logistics Link
- Vector
- Logistics Flows
- Environmental Impact

It could be interesting to dedicate just a special mention for the last object, the environmental impact (EI); EIs can be attributed to each of the other object and correspond to emissions, disposals, consumption etc. In fact each EI is related to a specific variable connected with the object where they are attributed, and by this relation it is possible to module the EI based on the dynamic evolution of the simulation (Bruzzone and Williams 2006) the relations are involving different variables including:

- Constant
- Distance
- Time
- Flow Volumes
- Flow Masses
- Costs
- Flow Types

Greenlog simulator is implemented in Java and the portal is currently active on Genoa University servers. Due to the user nature, the authors designed Greenlog in order to allow graphical construction of the conceptual model as proposed in figure 5 (Barros et al. 2005) The simulator provides easy GUI for all object creation and configuration (see figure 6) as well as automated reporting capabilities in figures (fig.7); another important feature it is the capability to present the results graphically issues directly over the logical network in order to identify critical component, for instance in figure 8, the Scenario A supply chain is related to the CO2 environmental impact (Bruzzone 2002a). It is important to note that when environmental impacts are evaluated often, just the impacts related to the "on going" state are taken into consideration; sometime this is wrong approach because it is necessary to consider the whole life cycle to avoid mistakes (Cox 1999). So it's very important to consider all the boundary conditions and relations in order to evaluate the logistical impacts.

The nature of these phenomena and the uncertainty on major aspects are strongly affecting the reliability of the results: i.e. comparing environmental impact of different compound emissions and estimation of their social costs. Due to these reasons it is critical to proceed since the beginning in Verification, Validation process with extensive test; this paper in fact represents exactly one good example of this procedure and the authors used this case for teaching in master classes and in decision makers executive course; based on the above mentioned consideration it should be emphasized the accreditation process to guarantee that stakeholders and decision makers will get benefits in term of sustainability from valuable simulators through their direct involvement in the VV&A (verification, validation and accreditation) activities.

5. EXPERIMENTAL CASE STUDIES

In fact the proposed example related to cars represents a good application of the proposed approach (Bruzzone et al. 2006a).

If a car is manufactured in Far East and sold in South Europe, it results characterized by a different life cycle respect another one directly manufactured and sold in South Europe.

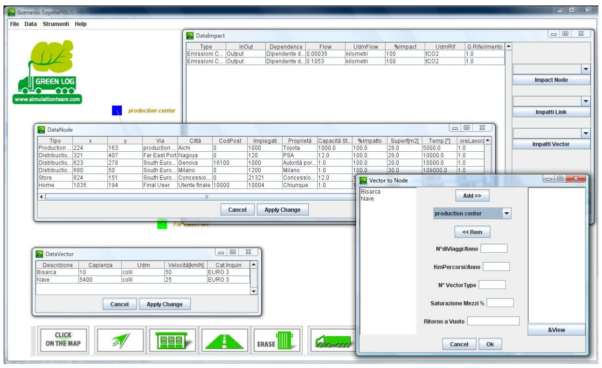

Figure 6 - Setting up the Object Parameters in GreenLog

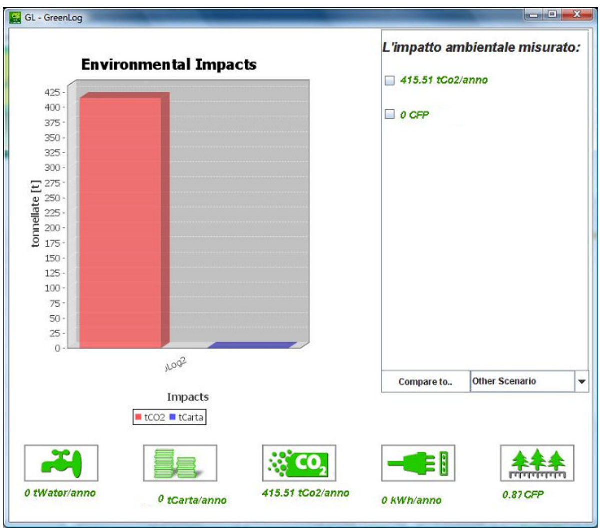

Figure 7 - Example of Greenlog Synthetic Output

Figure 8 - Greenlog highlight most critical element of the supply chain

It is interesting to evaluate the difference between the two life cycles considering to have different models as proposed in case A (Hybrid Car produced in Far East for South Europe) and B (Conventional Car locally produced and used).

This analysis is based on GreenLog Simulator adopting the setting above descripted proposed.

GreenLog simulator estimate the average emissions of CO2 for case A and B and based on their comparison respect car emissions it is possible to synthesize the results; for instance case B break even point in term of emission is obtained at 5'000 km, so the additional impact due to the long transportation by ship from Far East to South Europe is quickly balanced; viceversa based on current hypotheses on duty and insurance cost the B solution is more convenient in term of costs as proposed by figure 9.

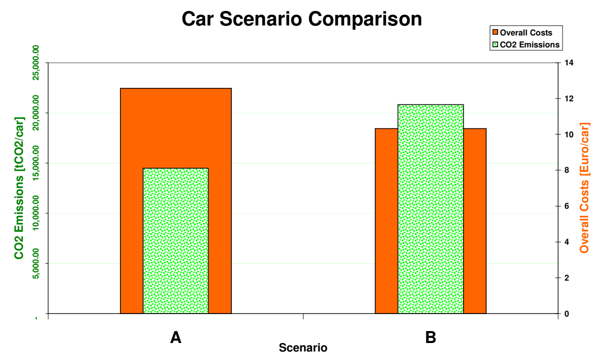

Figure 9 - Scenario A and B Comparison based on Greenlog Simulator Results

6. CONCLUSIONS

This paper present an application of Modeling and Simulation to sustainability issues (Bruzzone et al. 2004b) (Bruzzone et al. 2006b); the case used for the analysis represent a good example to highlight the complexity of this framework and the variety of variable and hypotheses required even to configure simple scenarios (Matthias 1999).

The approach for solving this problem it is based on the use of GreenLog simulator, developed by the authors to measure the performance of a supply chain for logistics and environmental point of view; to apply this model to the case study proposed resulted very easy and flexibile; in addition the authors used Greenlog, thanks to its web technology, as a support in classes and courses to involve student and decision makers on these subject with very good results (Bruzzone 2002b).

Currently the authors are working in developing new models to consider with major detail social aspects as well as long term effects; the development of scenarios on real case studies it is another important issue to diffuse knowledge on these methodologies for facing challenges related to sustainability and to complete validation, verification and accreditation on these models, working together with decision makers (Khoo et al. 2001; Shultz and Holbrook 1999

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