Table of Contents

Go Back

GROUP MODEL BUILDING AT A CHEMICAL COMPANY SYSTEM DYNAMICS FOR KNOWLEDGE ELICITATION AND SCENARIO TRAINING

Federico Barnabè
Department of Information Science
University of Bergen (Norway)
barnabe@unisi.it

Mathias Fischer
Department of Information Science
University of Bergen (Norway)
mathias.fischer@gmx.de

ABSTRACT

The paper presents the outcomes of a group model building project at a Norwegian chemical company that produces calcium carbide.

The project led to the creation of a system dynamics model describing the production process and of a computer-based interactive learning environment, a microworld, meant to reproduce most of the features of the operating and controlling software actually used in the company.

The process of organizational learning, the gaining of a better common understanding about the production process and the development of the different mental models of the plant operators are some of the main goals of the project.

Moreover, the method followed during the project can be considered as "general" and could be used in a variety of production processes, mainly in most of the manufacturing industrial firms, both for modeling production processes and for teaching and training the operators that manage those systems.

KEYWORDS: Group Model Building; Knowledge Elicitation; Chemical Production Process; System Dynamics, Common Understanding.

1. INTRODUCTION

This paper aims to present the outcomes of a group model building project related to a Norwegian chemical company[1]. The report will also consider the use of a System Dynamics model as basis for an enteractive learning environment[2].

The company produces calcium carbide using one of the world's largest closed furnaces and its production process is structured as a continuous production line.

The calcium carbide is produced using limestone and coal as raw materials. As raw materials arrive at the company, limestone is burned and coal is dried to remove the humidity in the materials. They are then filled into the furnace, where three electrodes

[1] The name of the company has been omitted for privacy reasons.

[2] The report will consider the use of System Dynamics models as developed for the first time by Jay Forrester (1961).

melt them to obtain the calcium carbide that will be used to produce sub-products or will be directly shipped worldwide.

The carbide production process in the furnace is characterized by a high level of complexity and by a large number of feedback loops that link all the different elements of the production process inside the furnace.

The consequence of the various feedback relationships is not only that the behaviour of the system is sometimes really hard to track and even to understand, but also that a certain level of instability can characterize the production processes. The furnace seems to be a sort of "black box" about which even managers and operators lack full knowledge and don't share a common agreement about how to handle it.

As a consequence, managers and operators need useful and powerful tools in order to handle the existing complexity and to find out feasible policies.

The model shown by the paper has been built thanks to several "group model building" sessions at the company. Using System Dynamics as a tool in order to boost a process of organizational learning, the paper will briefly summarize the methodology followed during the project and the principal results of the above-mentioned process of knowledge elicitation[3].

The principal expected outcomes of the project have been the following:

- the use of group model building sessions in order to develop a system dynamics model describing the production process;
- a better understanding of the whole production process, thanks to the above-mentioned process of knowledge elicitation from experienced operators;
- a general common agreement (of operators and managers) about the dynamics ruling the production process[4];
- the testing of feasible policies in critical situations thanks to the use of an ILE;
- a feedback about the perceived knowledge gained during all the process of group model building.

In particular, the use of System Dynamics not only to represent the dynamics of a complex technical production system but also as a relevant tool to be used to facilitate a process of organizational learning, are two fundamental elements the paper aims to stress.

The conceptual and the formal model will be discussed by the following paragraph.

The process of organizational learning, the gaining of a better common understanding about the production process and the development of the different mental models of the operators are some of the main outcomes of the project that this paper will deal with. The use of System Dynamics in the form of Group Model Building and the chance to experience the validation of the model thanks to an ILE, can be seen as the

[3] On the topic of knowledge elicitation and how to map this knowledge, see D. Ford, J. Sterman (1998: 309-340); J. Vennix, D. Andersen, G. P. Richardson, J. Rohrbaugh (2000: 29 and ss.); J. Vennix (1999).

[4] The gain of a better insight and not the building of a predictive tool is the fundamental aim of a system dynamics model. See J. W. Forrester (1961: 49). See also A. Ford (1999: 10) where he clarifies that "system dynamics models, whether they are used in business systems, ecological systems, or any other system, are designed for general understanding, not point prediction".

most important factors that boosted the process of knowledge elicitation during the project.

Moreover, the method followed during the project can be considered as "general" and could be used in order to model a variety of production processes, mainly in most of the manufacturing industrial firms, both for modeling production processes and for teaching and training the operators that manage those systems.

2. THE CHOICE OF THE GROUP MODEL BUILDING METHODOLOGY

Managers and operators usually take their decision upon some incomplete information: a relevant role is played by expectations, beliefs, perceived states of the system, perceived feedbacks, routines and rules followed, and so on[5].

As a consequence, the decision making process is generally far from being a process based on complete information and guided by full rational people[6]. If we also consider that the real world is often characterized by complexity, interrelation of many feedbacks, delays, policy resistance, it's possible to understand that managers and operators need a specific tool that could guide them through the above mentioned complexity, in order to achieve a better understanding of the always changing surrounding reality[7].

In the last past decades, modeling and simulation have been generally seen as technical tools, to be used to solve and get a better understanding about structured problems of prediction, optimization and financial planning.

Recently, however, models have reached a different consideration: they are seen as instruments to support strategic thinking, group discussion and learning in management teams[8].

Particularly used in the form of Group Model Building, System Dynamics is a powerful tool that can be used in order to stimulate a process of organizational learning and in order to elicit the existing knowledge of the most important actors: in this way, knowledge can be obtained more quickly and for conditions not observable in real life[9].

The final goal of this continuous process of learning is an evolution of the mental models of the relevant actors, considered as the results of their own beliefs and experiences[10]. Mental models represent the return point of each feedback and only

---

[5] J. D. Sterman (2000: 27 and 32).

[6] This concept was mainly stated by H. Simon (1957: 198). Referring to the bounded rationality of human agents, the Author stated that: "the capacity of the human mind for formulating and solving complex problem is very small compared with the size of the problem whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality".

[7] See J. Vennix (1996: 1): "Every organization regularly faces strategic problems. Choices have to be made which can have far reaching (often unanticipated) consequences, choices which may affect the whole organization. In the earlier days strategic decisions were frequently made by one person at the top of the organization. (…) Increasingly, teams become the critical building blocks upon which the performance of modern organizations depend".

[8] See Morecroft J. D. W. (2000: 3); Morecroft J.D. W. – Sterman J. (2000); Forrester (1961: 49).

[9] See J. Vennix (1996). The Author, p. 3, underlines that "system dynamics can be used as a method to systematically elicit and share mental models in teams. The process of building a model starts from the different perceptions of the participants. One underlining idea is that people's mental models are limited by human information processing capabilities. System dynamics can be helpful to elicit and integrate mental models into a more holistic view of the problem and to explore the dynamics of this holistic view".

[10] On the definition of *mental model* see Sterman J. (2000: 16); Senge P. (1992: 9); Ford A. (1999: 3); Vennix J. (1996: 21); Bianchi C. (2001: 51); Richardson G., Andersen D., Maxwell T., Stewart T. (1994: 182); Morecroft J. D. W. (2000: 7).

thanks to a change in them it would be possible to achieve new tactical and strategic goals, due to the creation of a common shared vision of reality within an organization.

Only changing the mental models of the actors is possible to realize a real process of learning and to complete the double-loop learning suggested by Argyris[11]: "to learn we must use the limited and imperfect information available to us to understand the effects of our own decisions, so we can adjust our decisions to align the state of the system with our goals (single-loop learning) and so we can revise our mental models and redesign the system itself (double-loop learning)"[12].

3. THE PROJECT

3.1. AN OVERVIEW OF THE PRODUCTION PROCESS

In order to produce the calcium carbide the company uses different kinds of raw materials, mainly lime and coal.

As the limestone arrives at the company, it's heated in a limekiln, essentially getting pure lime and carbon dioxide from that process. A percentage of unburned limestone persists in the raw materials. The following chemical equation describes this first phase:

$$CaCO_3 = CaO + CO_2$$

where:

- $CaCO_3$ = Limestone;
- CaO = Lime;
- CO_2 = Carbon dioxide.

The other principal component of raw materials is given by coal. Coal is added into the furnace coming from three different sources:

a) a great amount of coal is added directly from the top of the oven together with pure lime (coal comes from a previous stage of the process, the *dryer*, where it has been dried in order to reduce its percentage of humidity);
b) some dust of carbon ("fine coke") is added through a pipe in the center of each electrode, in addition to some dust of lime ("fine lime");
c) the electrode itself is made of carbon that is consumed during the production process.

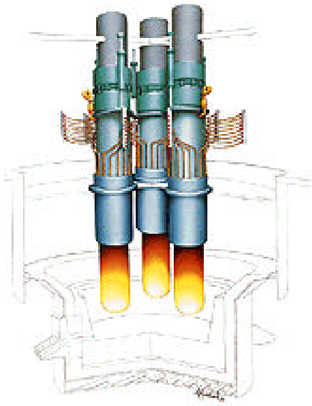
The gas carbon dioxide (CO_2) is taken away and later used in the following production stage called "Dicy Reaction Vessel" in order to produce an other chemical product called "dicyandiamide". From this point of the chemical process onwards the production of carbide in the furnace starts.

Once the raw materials are added into the furnace, the chemical reaction takes place and calcium carbide is produced.

---

[11] Argyris (1985).
[12] Sterman J. D. (2000: 25).

Figure no. 1 – The three electrodes



The furnace works thanks to three electrodes that produce electric arcs and melt lime and coal to produce calcium carbide.

The following equation describes the chemical process:

$$CaO + 3C = CaC_2 + CO$$

where:

- CaO = Lime;
- C = Carbon;
- CaC_2 = Calcium carbide;
- CO = Carbon Monoxide.

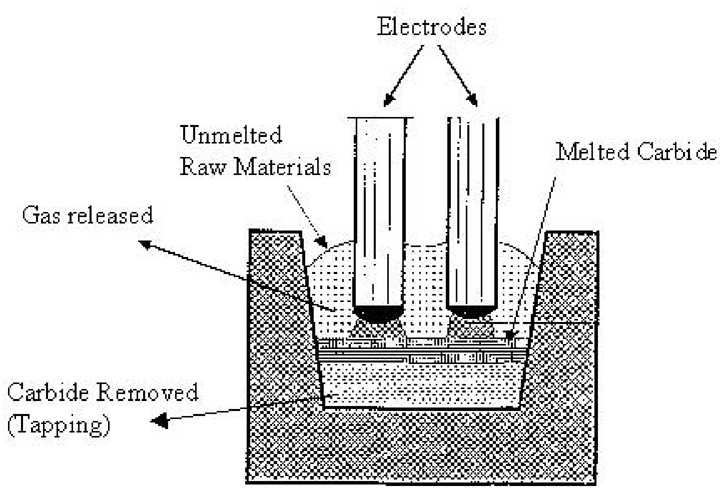
One part of lime needs three parts of carbon in order to produce one part of calcium carbide (CaC_2) and one part of carbon monoxide (CO). The gas carbon monoxide, CO, is then removed and used back in the limekiln in order to heat up and burn new raw limestone.

The final product, calcium carbide, creates a voluminous melted mass that needs to be removed in order to create some free space for the introduction of additional raw materials.

As a consequence, a procedure of tapping is done periodically to remove the final product from the bottom of the furnace, just leaving a minimum level of melted mass inside the oven.

The above-mentioned production features can be summarize by the following picture:

Figure no. 2 – A simplified interpretation of the furnace and of the production process



The principal uses of calcium carbide are the production of acetylene for welding and cutting, desulphurisation of iron and steel, and the manufacture of chemicals.

3.2. THE METHODOLOGY: The Group Model Building Sessions

An initial visit to the company allowed a first analysis of the production process. Afterwards many quantitative and qualitative data were collected and some first informal interviews with operators and managers were taken[13]. The modeling phase of the project then started.

Thanks to the presence of a *pilot system dynamics model*, this step of the project aimed to formulate dynamic hypotheses of the problem discussed, to build stocks and flows diagrams, to draw causal loop diagrams, to implement and further develop the existing model with new original model elements, to find out preliminary considerations about effects, reasons and possible policies related to the problem[14].

During the initial stages of the project a *questionnaire* was formulated. The questionnaire, formulated thanks to the information collected during the first stage of the project and to the help of a consultant of the company and of the control operator chief, has been delivered to the operators during the first group meeting of the project. The questionnaire was made by a large number of questions, both in the form of open questions and closed ones.

Some questions have been built with the use of graphs related to the behavior of many relevant variables.

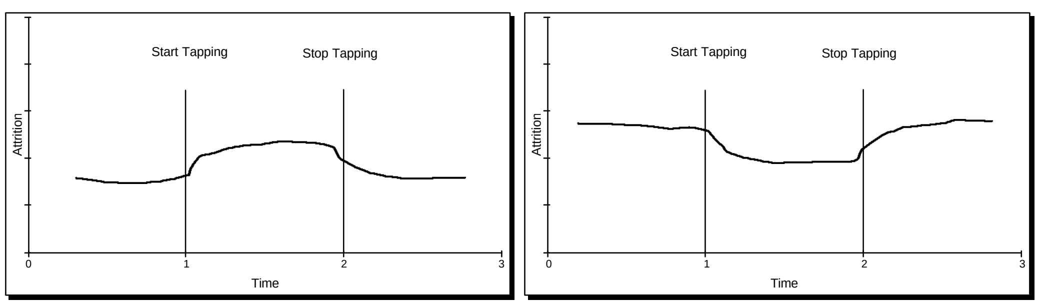
Each question included a small table asking about the perceived level of confidence about the given answer.

The questionnaire has been translated and delivered in Norwegian language for a better understanding[15].

As stated, the questionnaire was meant to represent the initial level of knowledge (about the system and its behavior) owned by the operators. The questionnaire was delivered to the operators again at the end of the ten scheduled sessions. The comparison between the answers given to the first questionnaire and those about the second one, led to a *measurement of the perceived level of learning* gained during the project.

Figure no. 3 – Example from the questionnaire

Q. How will the attrition of the electrode change when tapping is started?



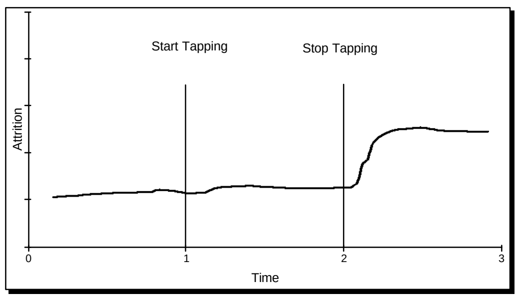
---

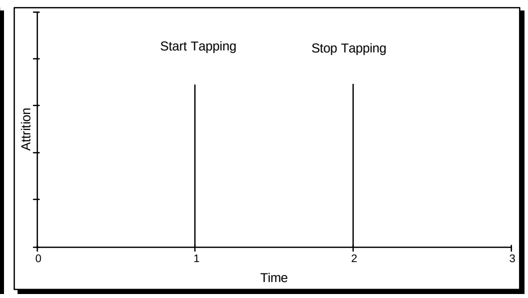
[13] The fonts that can be used in order to develop and implement a model can be made available from different sources. On this topic, see Forrester J. W. (1980: 555).

[14] On the different phases that should lead to the creation and to the use of a model, see Richardson G. P., Pugh A. (1981); Sterman J. D. (2000: 85-104); J. Vennix, D. Andersen, G. P. Richardson, J. Rohrbaugh (2000: 31).

[15] About the characteristics of questionnaires and the processes to follow in order to formulate and evaluate them, see F. Fowler (1993: 62: 104) and C. Frankfort-Nachmias, D. Nachmias (1996: 249-278).

1: O 2: O





3: O 4: O for your own drawing

Your comments:

2.5..3.5 Your confidence about the answers:

High confidence	*Low confidence*	*Very unsure*
O	O	O

Out of the ten meeting sessions with the operators, eight have been group model building sessions, organized on a basis of 1.5 hours each, during which the model has been built, validated, refined, discussed and simulated.

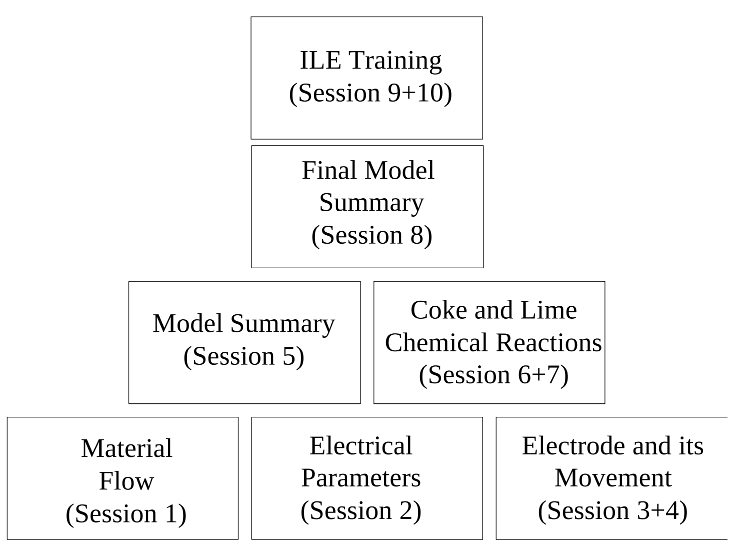
At the beginning of each meeting, the model representing the outcome of the previous session has been shown again and mainly reused.

Several simulations have been run to collect information and to make the discussion start.

After each session a synthetic summary of the meeting has been written and later delivered to the participants in order to give the opportunity of a free further thinking about the topics previously discussed. These handouts have been also useful to gather data, to stimulate new discussion topics and to improve the existing versions of the model.

The process can be represented as follows:

Figure no. 4 – The 10 group model building sessions



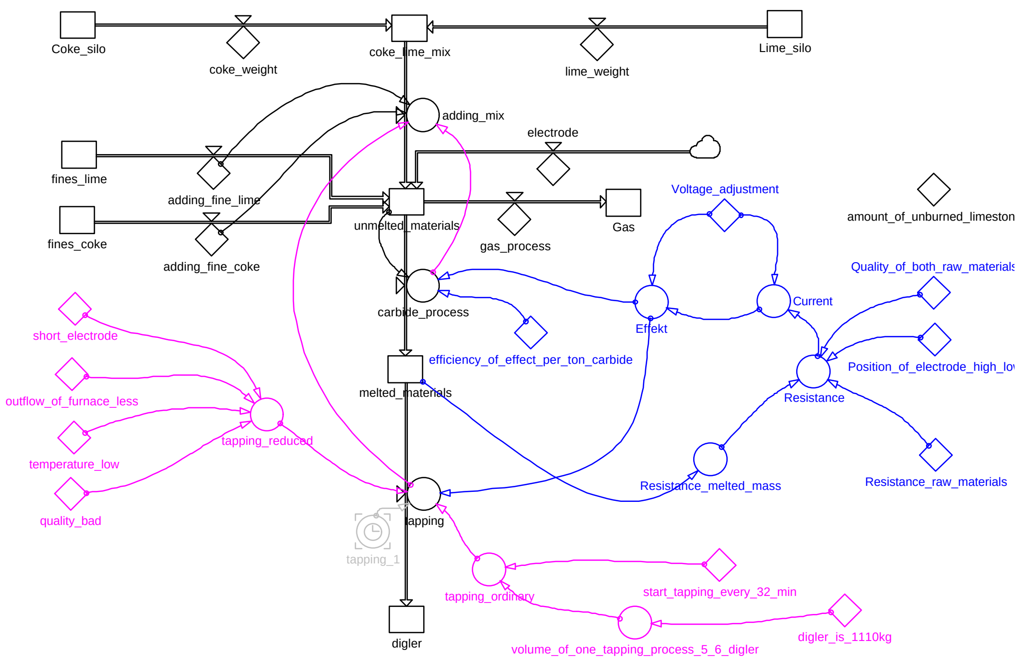
The topics discussed during each session have been the following:

- Session no. 1: *Material Flow*. The session dealt with the production process, mainly the physical structure of this production phase, from the mixture of the raw materials to the removal of carbide, tapped from the furnace.
- Session no. 2: *Material Flow and Electrical Parameters*. The modeling process went on about the production process, mainly focusing on the different parameters characterizing the features of the tapping procedure. The discussion was then centered on all the different electrical parameters inside the furnace, which change during the carbide production (resistance, voltage, current).
- Session no. 3: *Electrode and Electrode Movement*. The main topics have been the baking and the attrition of the electrode, and its movement by slipping or moving the complete "bakke" (clamp) system.
- Session no. 4: *Electrode and Electrode Movement*. The process continued on the electrode topic in detail. The attrition and the reasons for short electrode situations were particularly discussed.
- Session no. 5: *Summary of the Previous Meetings*. The session was meant to be a summary of meetings no. 1-4, combining together the single parts to one big picture. The behavior over time-graphs of the model was shown (time)step by (time)step to the operators to collect additional information and comments about the real behavior of the furnace compared to the simulated one.
- Session no. 6 and no. 7: *Quality and Chemical Reactions of Limestone and Coke*. The understanding of the chemical reactions between lime and coke required two full meetings. The discussion was mainly focused on the attrition of the electrode during the chemical reactions and on the necessity of a chemical balance among all the raw materials in the oven.
- Session no. 8: *Summary of the Previous Meetings*. A new summary was needed before the simulation sessions started. The aim was to check if the participants agreed with the model structure, having the feeling that the model was comprehensive and represented all the necessary relationships to explain causes and effects in the furnace behavior.
- Session no. 9: *Introduction to the ILE*. The session was the first of two simulation meetings. The operators were introduced to the features of the Interactive Learning Environment. Free practicing with tutorials, the challenge of a short electrode scenario and a plenary discussion (about feasible policies to adopt to solve the mentioned situation and about eventual improvements for the ILE) represented the characteristics of this meeting.
- Session no. 10: *Managing specific Short Electrode Scenarios with the ILE*. An other 5-hour session concluded the project. The operators handled different short-electrode scenarios. The discussion about feasible policies represented the main feature of the meeting. A questionnaire aimed to collect comments and to measure the perceived level of knowledge gained during the whole project was handed out.

It's worth mentioning that the model built during the meetings has been largely refined and developed in a second stage. The group model building sessions mainly aimed to facilitate the creation of a common shared picture about the production process, thanks to the elicitation of the mental models of the operators, and not to build a formal, complete system dynamics model.

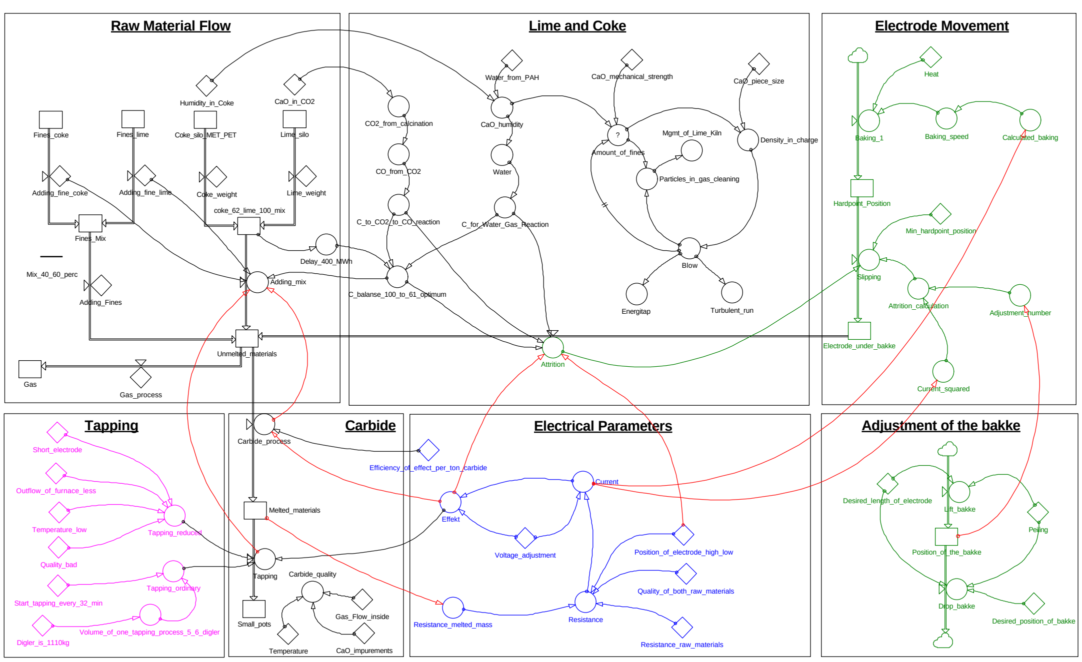
The following pictures show the model as sketched during sessions no. 2 and 8. It is clearly understandable that they represent just a simplification of the whole production process.

Figure no. 5 – Stock and Flow in session n. 2 – Material Flows and Electrical Parameters



The next picture shows the model after session no. 8.

Figure no. 6 – Stock and Flow in session n. 8 – Summary of previous meetings



As stated, the project led to the building of an *Interactive Learning Environment* that has been used in the last two meetings of the project (session no. 9 and 10). Those sessions, organized on a longer basis (5 hours), gave the operators the chance to experience by themselves their own beliefs, expectations and ideas, thus further boosting the process of learning and knowledge elicitation the whole project looked for.

3.3. THE MODEL: CLD AND STOCK AND FLOW DIAGRAMS

Continuous production lines are an important type of production systems. Their structures are characterized by a high level of complexity and by a large number of feedback loops that make it possible to link all the different steps of the production process in a continuous chain. Because of its vertical structure, each of the components in the system has a direct influence on the following component. Feedback relationships influence previous components.

This double influence between upstream and downstream components is the source of many relevant feedback loops. The interactions among the different loops constitute the complex structure of the system. The consequence of the above-mentioned relationships is not only that the behaviour of the system is really hard to track and even to understand, but also that a high level of instability often characterizes all the different production processes.

Several sectors have been defined and considered to build the model. The principal are the following ones: production line; electrical parameters; electrode movement; bakke movement; tapping structure; slipping (software calculation); lime; carbon; addition of fines; gas production.

The paper will mainly use CLD to describe the production process. Some simplified stock and flow diagrams will be also used. The complete model and the equations list can be found in the appendix to the paper.

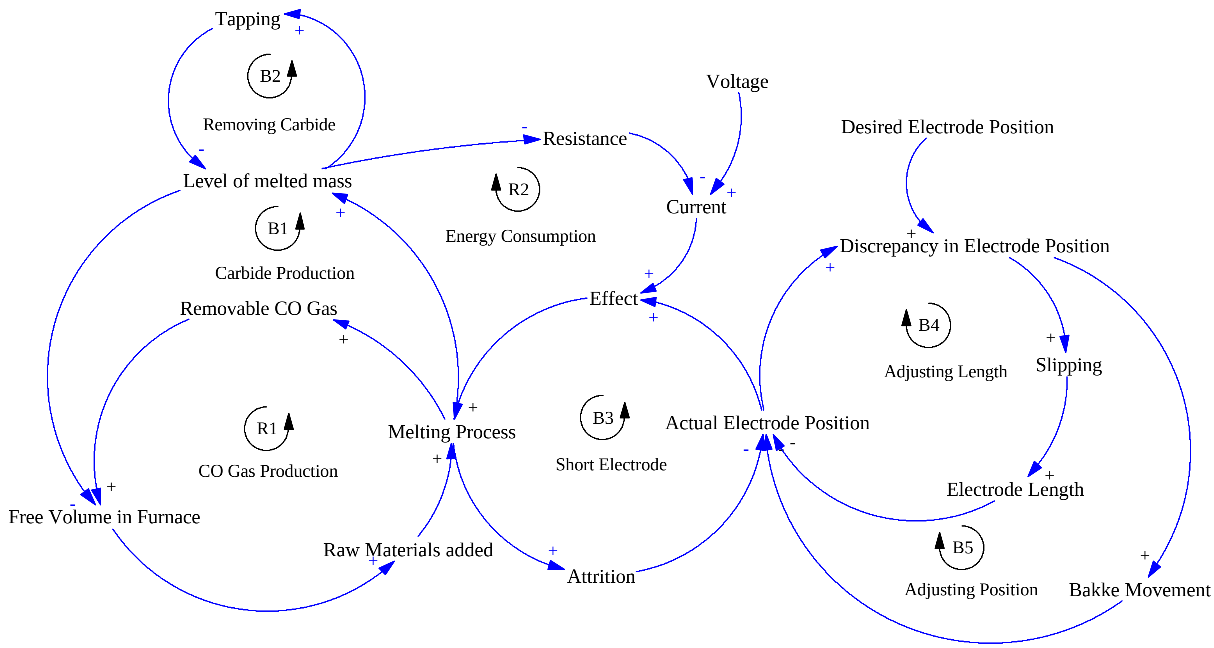
The time horizon selected for the simulations can be considered a short-time horizon. In fact, looking for stability and balance of the system, it's relevant to reproduce the working conditions daily experienced by the operators.

Since the company is on an on going production process 24 hours a day, the simulation runs mainly considered a time horizon of 72 hours or less.

The following picture summarizes the most relevant causal loops related to the production process inside the furnace[16].

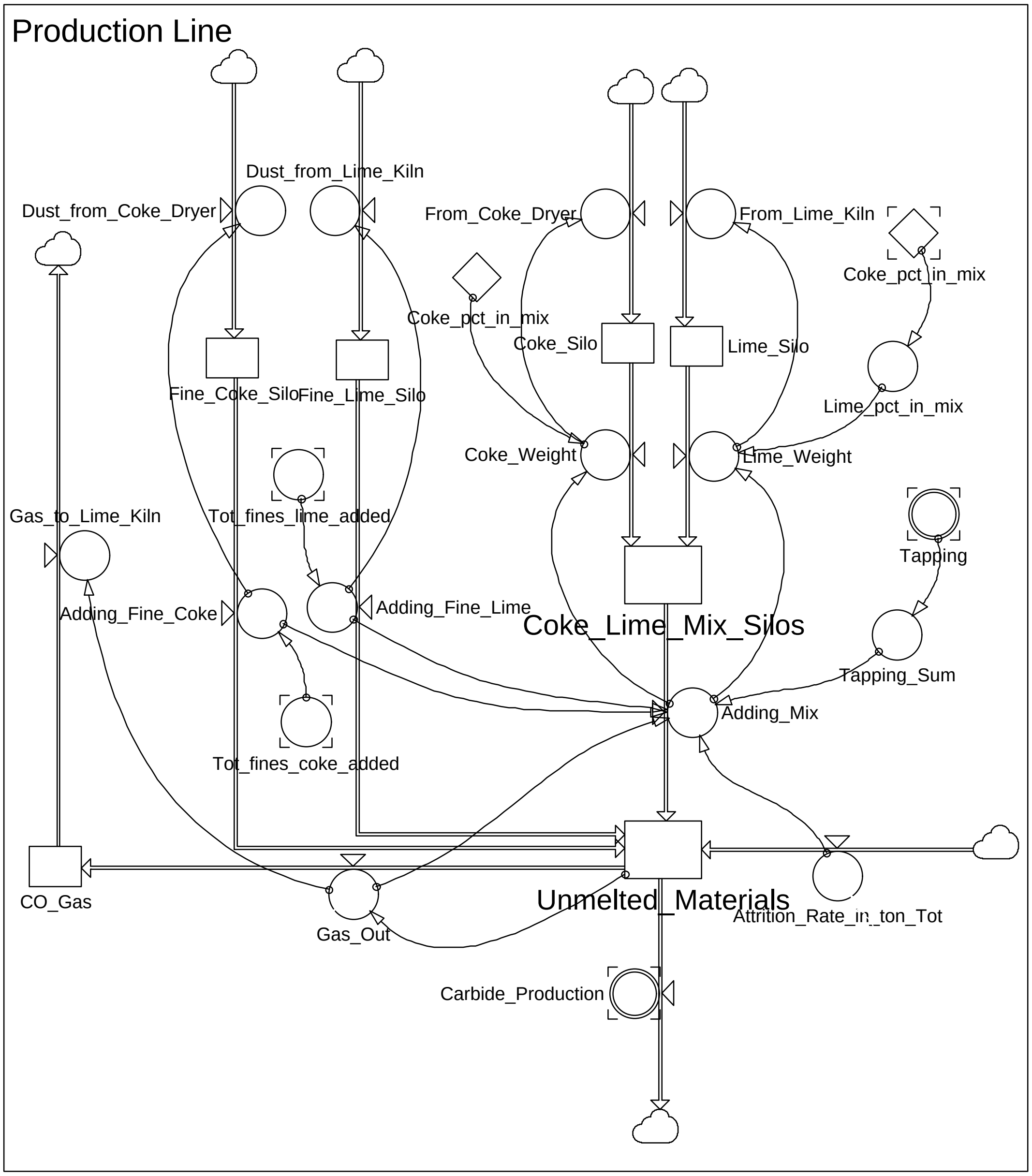
[16] On the use of causal loop diagrams A. Ford (1999: 82) underlines that "loop diagrams are used as a communication tool, not a simulation tool. They help us think about the structure of the system. They are used extensively in the system dynamics literature because there is a general consensus that understanding the underlying feedback loop structure of a system is a key to understanding the system's dynamics behavior".

Figure no. 7 – An overview of the production process



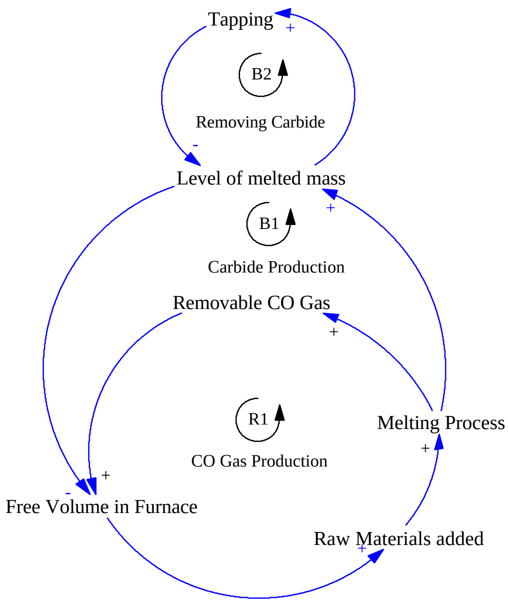
a) Production Line

Figure no. 8 – Stock and Flow diagram about the Production Line (simplified)



Once the raw materials are added into the furnace, the chemical reaction takes place and calcium carbide is produced. The following equation shows the production process:

Figure no. 9 – The Production Process



$CaO + 3C = CaC_2 + CO$

where:

- CaO = Lime;
- $3C$ = Carbon;
- CaC_2 = Calcium carbide;
- CO = Carbon Monoxide.

One part of lime needs three parts of carbon (coming directly from the top as coal, from the center of the electrode and from the consumption of the electrode itself) in order to produce one part of calcium carbide (CaC_2) and one part of carbon monoxide (CO).

The gas carbon monoxide, CO, is then removed and used back in the limekiln in order to heat up and burn new raw limestone. This removal creates free room in the furnace for the addition of new raw materials that will then become melted mass of calcium carbide (Reinforcing loop R1 *CO Gas Production*).

The amount of raw materials added into the furnace is depending on the amount of carbide which is removed by tapping and the gas produced by the melting process, less the fine materials added into the furnace and the carbon released by the electrode.

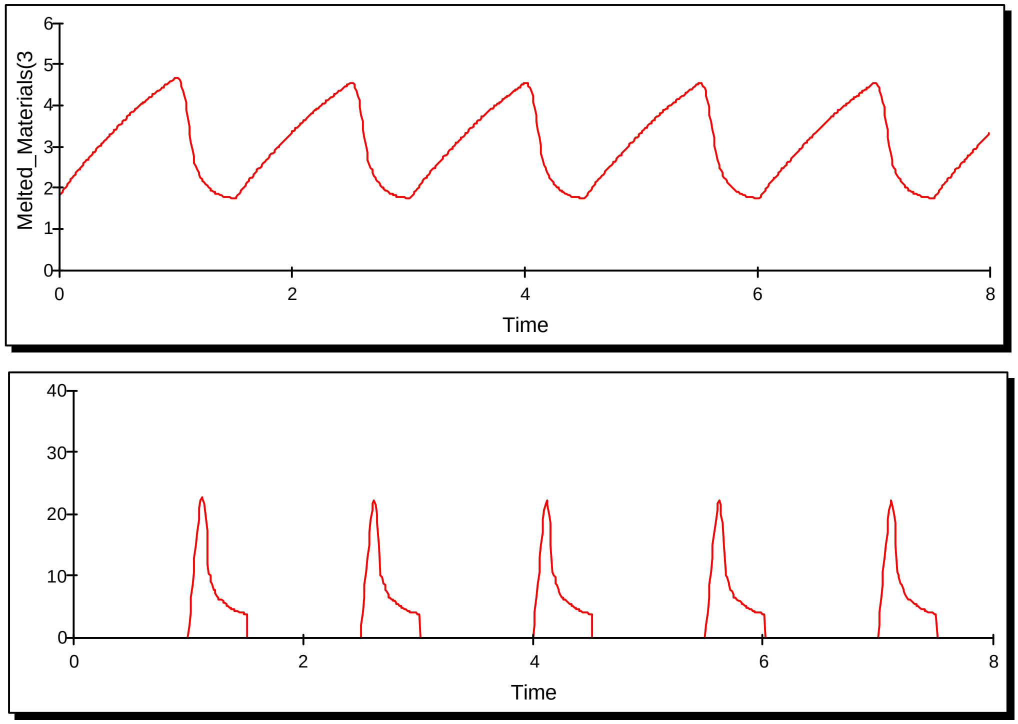
The final product, calcium carbide, creates a voluminous melted mass that needs to be removed in order to create some free space for the introduction of additional raw materials (Balancing loop B1 *Carbide Production*).

As a consequence, a procedure of tapping is done periodically to remove the final product from the furnace, just leaving a minimum level of melted mass in the oven (Balancing loop B2 *Removing Carbide*)[17].

The next graphs show the above-mentioned relationship.

[17] A minimum level of melted mass should always be present in the furnace in order to avoid a big change in the value of resistance, thus lowering the speed of the production process.

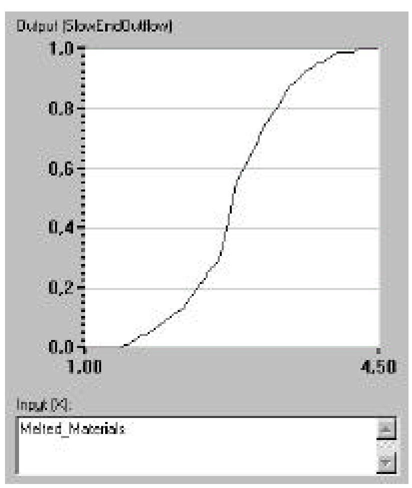
Figure no. 10 – The Tapping Procedure[18]



The tapping procedure is essentially done by opening a hole in the lower part of the furnace, removing the melted mass from the furnace and then closing the hole again. The outflow from the furnace is generally faster as soon as the hole is open, while it is slower when the level of the carbide in the oven decreases.

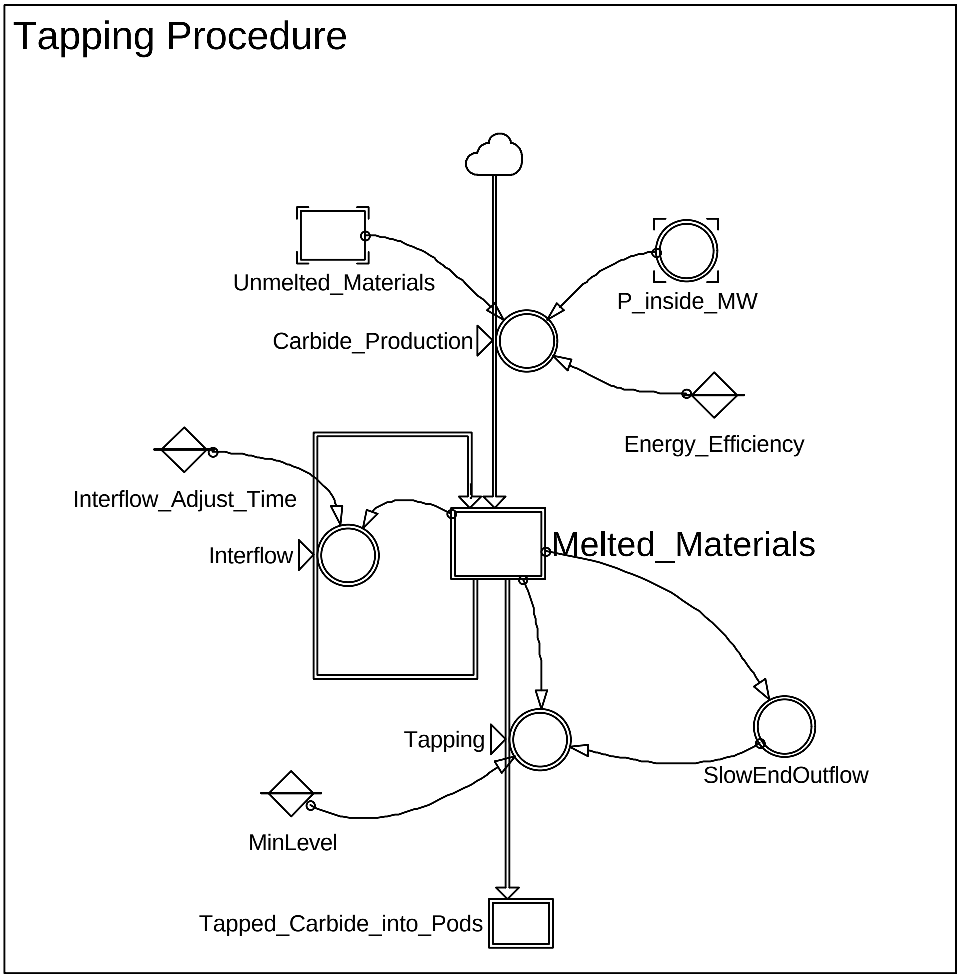
This nonlinear relationship can be represented as follows.

Figure no. 11 – Tapping Procedure Outflow



[18] The model considers the action of three different electrodes. However, for a bettere understanding, some of the graphs used in this article represent the behavior of just one of them.

Figure no. 12 – Stock and Flow Diagram about the Tapping Structure (simplified)



The model considers several different parameters that can be changed during this procedure: the tapping frequency, the initial time for the procedure itself, the length of the procedure, the normal volume tapped during each operation. All these different conditions regulate the tapping procedure.

Since the furnace works thanks to three different electrodes that create different melting zones below themselves, the model considers the possibility of an "interflow" of melted mass from zone to zone.

The equation is the following one:

(Melted_Materials(E)-Melted_Materials(E+1))/Interflow_Adjust_Time | E<3;

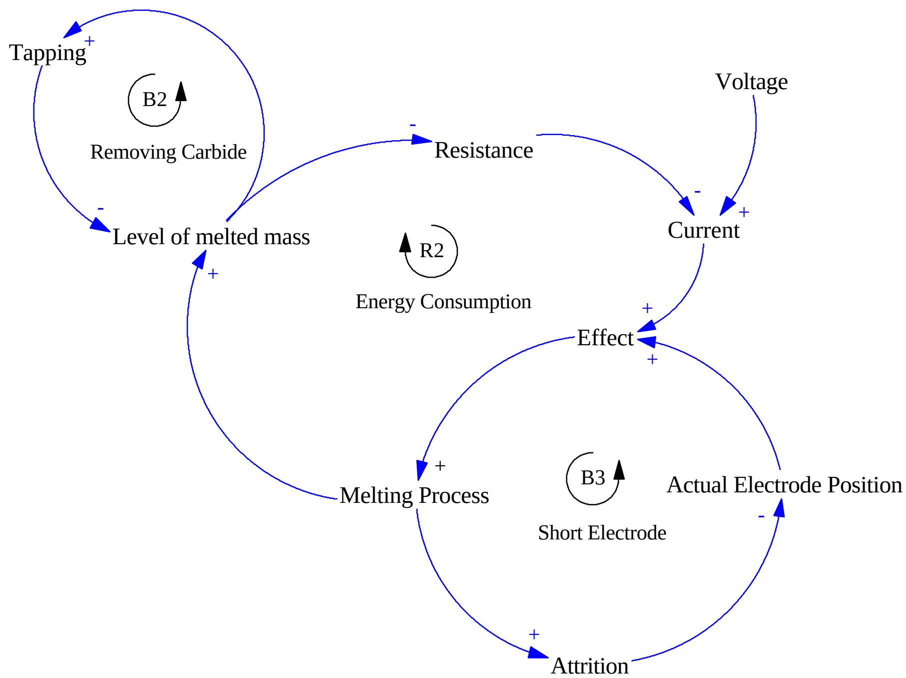
(Melted_Materials(3)-Melted_Materials(1))/Interflow_Adjust_Time

The interflow adjustment time can be changed depending on the different conditions of the furnace.

When tapped out, the calcium carbide is then transported to an other part of the factory. Part of it is packed and is sold as final product, while another part of it is transferred to the following production phase and used as raw material for the production of cyanamide.

b) Electrical parameters

Figure no. 13 – Energy Consumption and Short Electrode



The entire production process above described requires a great amount of electrical energy that is used in two different ways:

- at the top of the electrode, in order to bake electrode paste to produce new layers of carbon in the electrode itself;
- inside the furnace (the energy comes into the furnace through the electrode itself) in order to stimulate the chemical reaction.

Ideal working conditions would require to run the furnace at roughly 40 MegaWatt (MW), or at approximately 13 MW per single electrode.

The effect in the furnace is the result of the actions of many different parameters: voltage, resistance and current.

Briefly, the following equation shows the existing relationships:

$I = U/R$

$P = U*I$

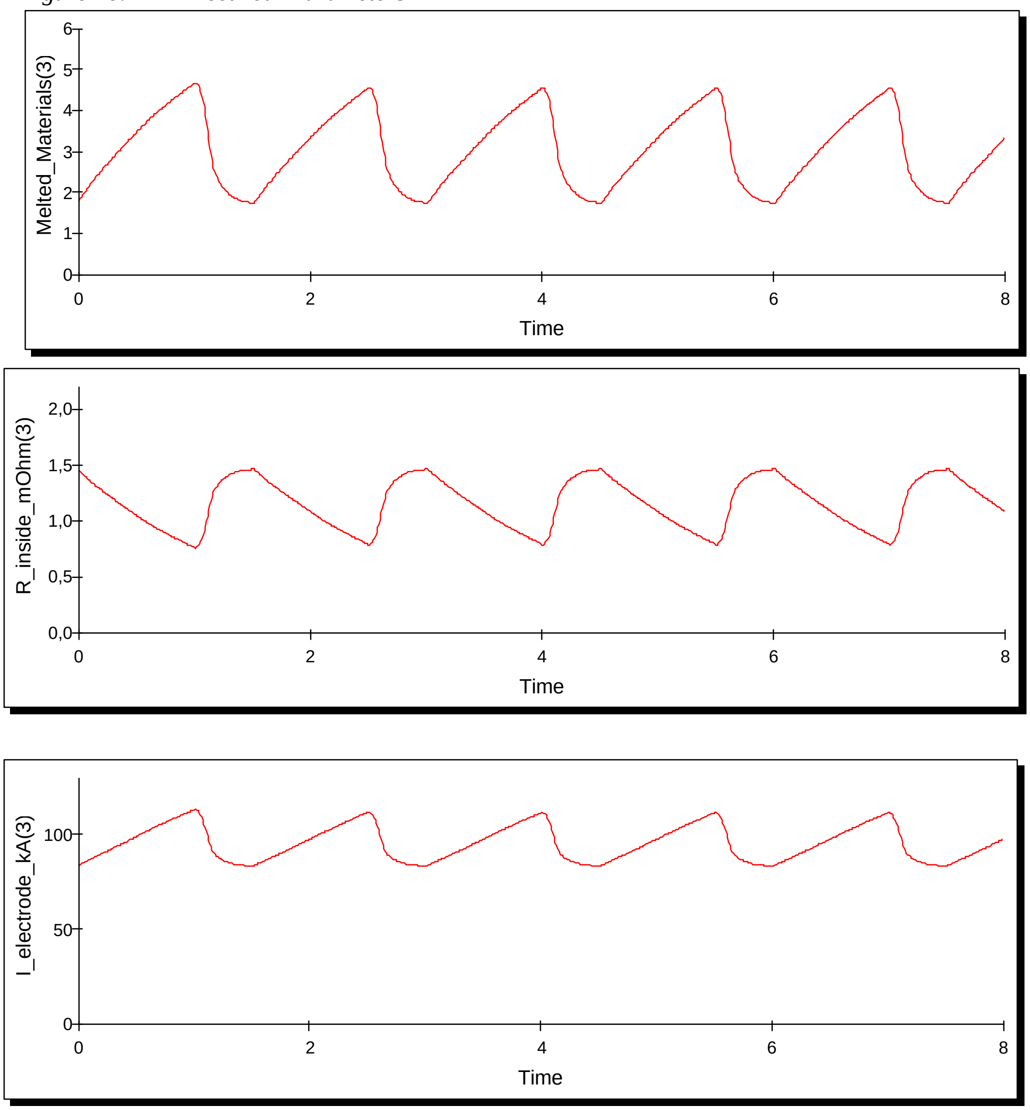
where:

- U = voltage;
- R = total resistance;
- I = current;
- P = effect.

Ohm's law I=U/R determines the current through the electrode by the applied voltage and the resistance of the melted and unmelted mass under the electrode.

As soon as the tapping procedure removes some tons of melted mass, a large space is set free inside the furnace and below the electrode. That space will be filled by the addition of new raw materials which will increase the resistance and will require a great amount of energy to be melted (Reinforcing loop R2 *Energy Consumption*). Only a high level of the effect can guarantee that the chemical reaction among all the different elements inside the furnace could happen. In fact, as a general rule, the lower is the resistance, the higher will be the current flowing through the raw materials and melting them to carbide.

Figure no. 14 – Electrical Parameters

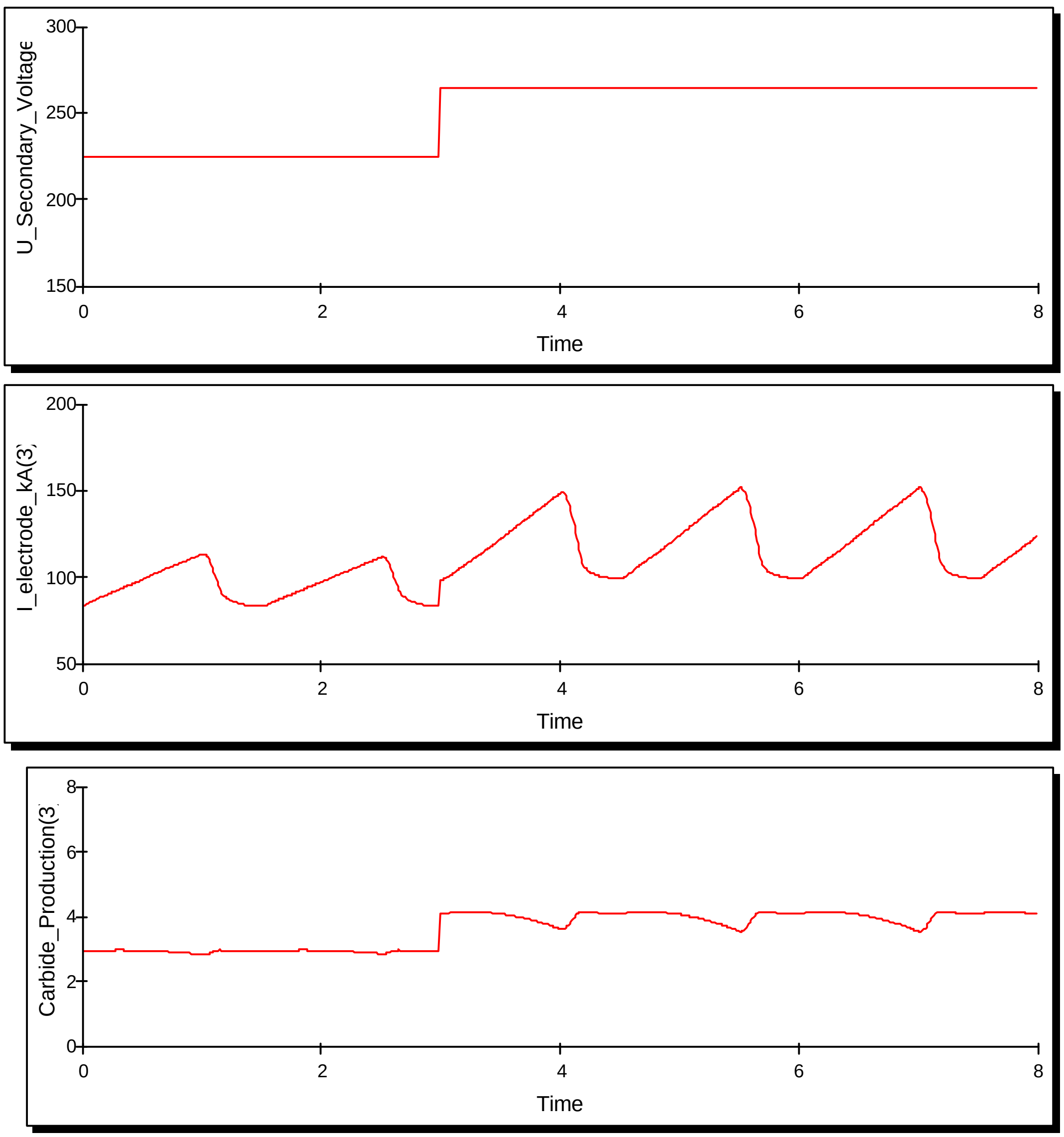


This high level of electrical energy can be obtained thanks to the adjustment in the level of the voltage that the operators control. In other words, whenever the production conditions require a change in order to keep a constant “desired” value of the effect in the furnace, the operators working in the control room can adjust the level of the voltage thanks to the use of a switch, as a policy to run the furnace.

This change will eventually increase (or decrease) the effect inside the oven and consequently the speed of the production process and the attrition of the electrodes themselves.

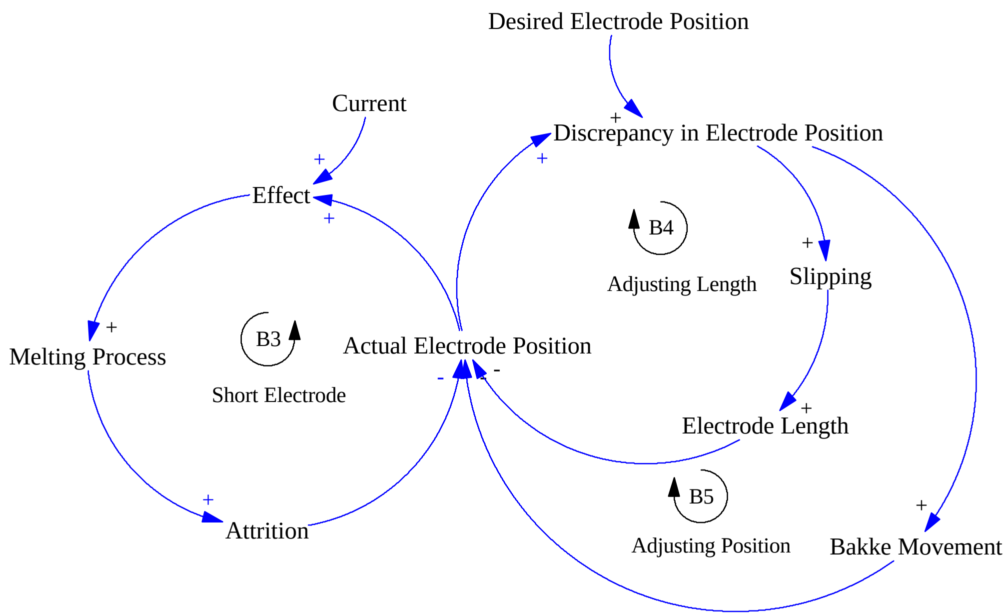
In particular, a high effect will create a high level of consumption of the electrode itself, which will eventually become shorter (Balancing loop B3 *Short Electrode)*. This situation will also lead to an increased value of the resistance and of the current, to a later decrease of the effect itself and of the speed of the carbide process.

Figure no. 15 – The influence of voltage on current and carbide production



c) Electrode Movement and Bakke Movement

Figure no. 16 –Electrode Movement and Bakke Movement



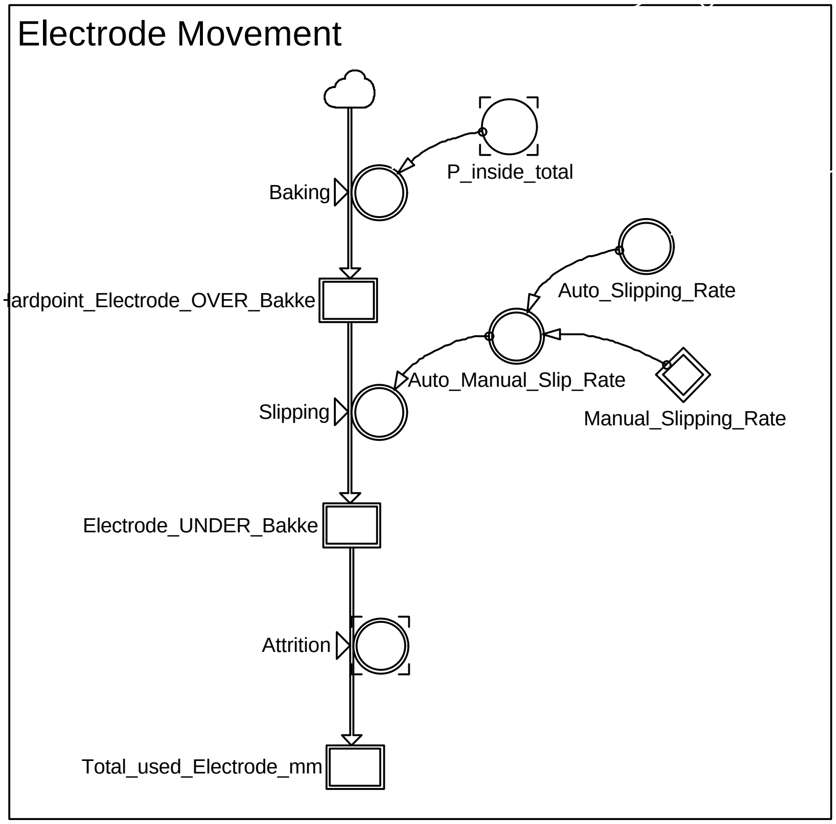
The furnace can operate in an ideal condition when the length of the electrodes is at a desired level and a large number of other parameters are at their normal values.

The problem to get a short electrode arises when the electrode is consumed inside the furnace due to attrition. Attrition is the release of carbon from the electrode and this happens due to the chemical reactions in the furnace.

To keep a constant position of the electrode inside the oven, compared to a desired position of the electrode, a continuous process of baking is done at the top of the electrode itself, thus creating new layers of carbon. At the same time, the electrode is slipped down inside the furnace. This operation will eventually guarantee to have an electrode long enough to keep a normal value of the effect (Balancing loop B4 *Adjusting Length*).

The normal movement of the electrode inside the furnace, so called "slipping", is controlled by software and mainly depends on the level of the effect and of the current. All the conditions and the relationships followed during these situations are represented by the section of the formal model called "Slipping".

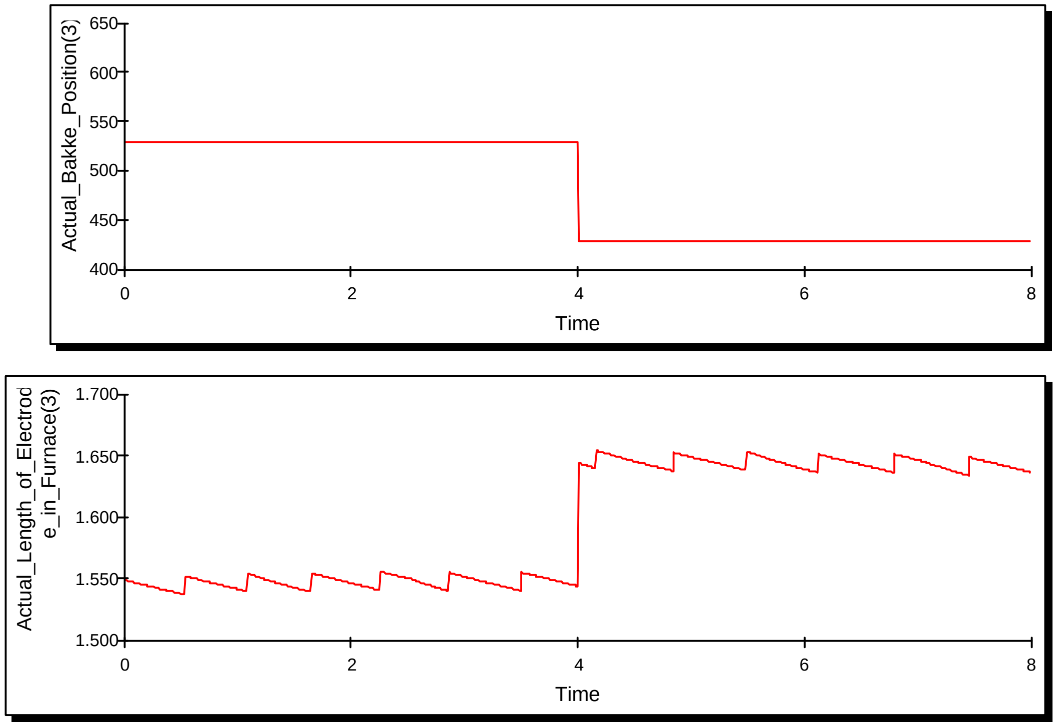
Figure no. 17 – Stock and Flow diagram about the Electrode Movement and Bakke Movement (simplified)



However, as stated, sometimes the attrition inside the furnace and the level of the effect could cause a situation of short electrode. That means that the position of the electrode is not proper in order to regularly stabilize the production process and the "normal" slipping procedure is insufficient in order to maintain the desired position of the electrode. In these cases the operators can change the position of the bakke (that means the entire electrode is moved) dropping or lifting it when necessary (Balancing loop B5 *Adjusting Position*).

In the following example the electrode no. 3 was shorter than its desired value. As a consequence, the operators changed the position of the bakke by lowering it to bring the electrode back to its desired position.

Figure no. 18 – Adjustment of the electrode length thanks to a bakke movement



3.4. THE INTERACTIVE LEARNING ENVIRONMENT

The whole group model building project led to the creation of an *Interactive Learning Environment*. The ILE has been then used in the last two meetings of the project (session no. 9 and 10), with the main goal to give the operators the chance to experience by themselves their own beliefs, expectations and ideas, and to better understand the behavior of the furnace.

In fact, the group model building process with the combination of the Interactive Learning Environment had two main purposes[19]:

- training and basis for discussion for experienced control room operators and tappers to handle short electrode scenarios;
- introduction into the complex furnace relationships for new employees in the operating and tapping area.

[19] The use of "microworlds" (Papert 1980), also called "virtual worlds" (Schön 1983), in particular, seems to be an important tool in order to boost the knowledge of operators and managers.
As John Sterman underlines (2000: 84), "managers seeking to enhance their organizational design skills, however, continue to design by trial and error, by anecdote, and by imitation of others, though the complexity of their organizations rivals that of an aircraft. Virtual worlds provide an important tool for managers in both the operation and especially the design of their organizations. There is clearly a role for models that help managers pilot their organizations better, and system dynamics is often useful for these purposes. But the real value of the process comes when models are used to support organizational redesign". On the topic of computer-based learning environment, see J. Vennix (1990: chapter 5). However, microworlds have their own limits, both conceptual and technical. See W. Isaacs and P. Senge (2000: 267) about how to overcome the limits to learning in computer-based learning environments. On the relevance of the process of simulation see J. W. Forrester (1974: par. 3-3).

The ILE contains several windows. Most of the windows are aimed to essentially reproduce the menus, the data reports and the graphs that the software used by the company produces and makes available for the operators.
Some other windows have been created with the goal to represent a tutorial section of the simulator, where the operators and new trainees can acquire further information about the production process and practice with the simulator and its features.

The next pictures will show some of the windows of the ILE. As stated, the ILE was used during the last two meetings of the project in order to manage some short electrode scenarios.

Figure no. 19 – One of the windows of the ILE (Electrode Details)

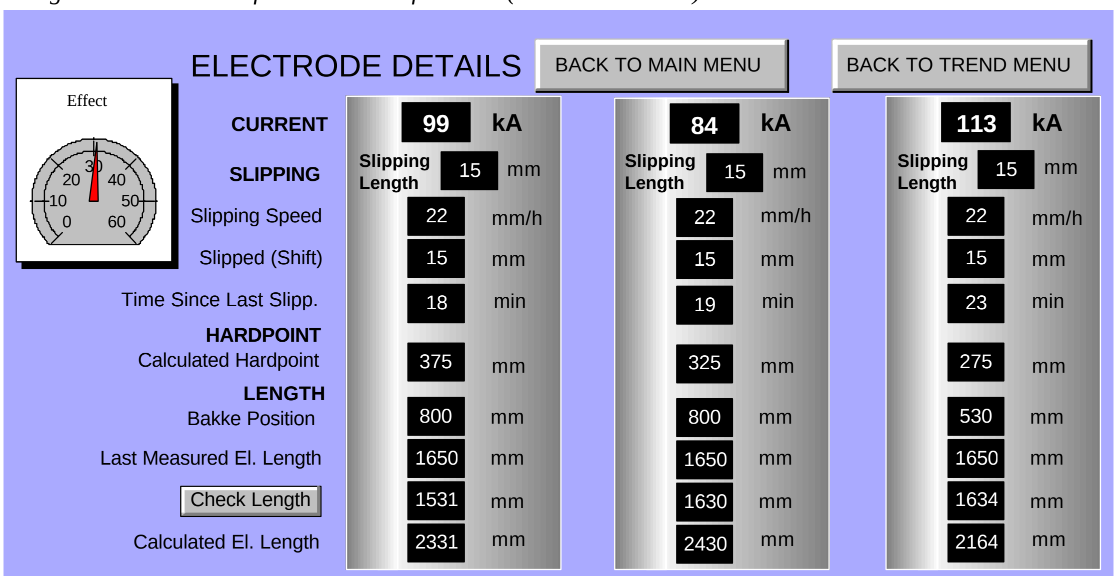


Figure no. 19 – The Control Panel of the ILE

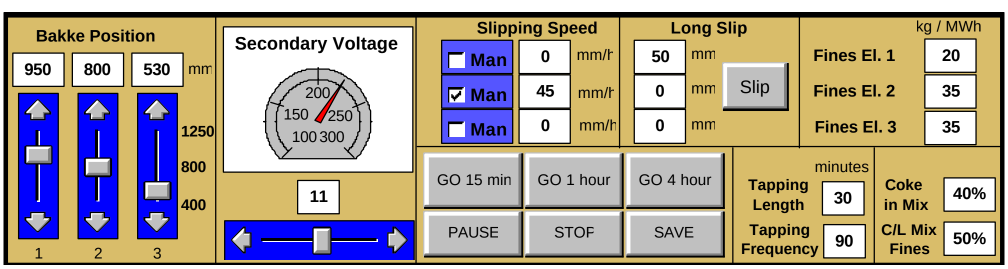
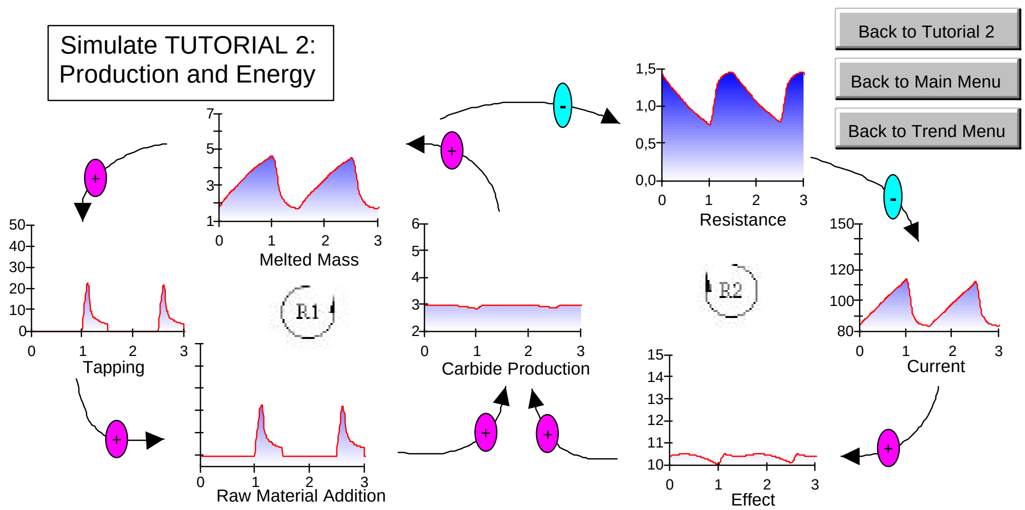


Figure no. 20 – One of the Tutorials of the ILE



3.5. THE LEVEL OF PERCEIVED KNOWLEDGE

After several weeks and ten meetings, the project eventually came to its end.

It is not an easy task to state if the process clearly led the operators to learn more about the production process. As a consequence, it's not easy to measure the level of knowledge gained during such a project.

In any case, it seems possible to state that the meetings allowed reaching some of the aimed goals. The use of System Dynamics in the form of group model building and the chance to experience the behavior of the systems and the effects of some applied policies thanks to the ILE, can be seen as the most relevant factors that allowed boosting the process of knowledge elicitation during the project.

However, in order to comment the outcomes and the success or failure of the project, the authors thought to directly quote some of the final comments of the chief-operator that took part to the meetings with the operators. Of course, this procedure doesn't allow having some completely objective comments, but it can be considered a proper way to gather some information about the level of perceived knowledge that the operators gained during the sessions.

As follows, one of the elements that has been most stressed, it is the capacity of the group model building sessions to communicate people a new way of thinking.

"The method makes it clear for everyone that a holistic view is necessary.

Building the system elements is necessary for the understanding, putting the elements together develops the understanding for the total system complexity. This is one of the strongest parts of the method, the ability to see both details and the whole at the same time".

"I'm really impressed by the final product from the work, both the model itself and the interface. The operators easily recognised the environment and felt comfortable by using the simulator".

“This method of learning about complex issues is unique, and should have a large potential when people with different experience, background and roles should learn to act together”.

4. CONCLUSIONS

The paper presented the methodology, the structure of a system dynamics model and the principal outcomes of a group model building process.

Although the described chemical production process can be considered a highly complex one, the model helped in creating a common shared picture among the participants and in getting a deeper insight on the system.

The process of organizational learning, the gaining of a better common understanding about the production process and the development of the different mental models of the operators are some of the main outcomes of the project.

As stated, the use of System Dynamics in the form of Group Model Building and the chance to experience the behavior of the model thanks to an ILE, can be seen as the most important factors that boosted the process of knowledge elicitation during the project.

The authors recognize as a success of the process that the operators accepted the behavior of the model and the features of the ILE as realistic ones. The reality of the microworld was never discussed, while only the different scenarios represented the focus of the discussion. A reason could also be that the operators participated in the modeling process, understanding and agreeing step by step with the underlying assumptions of the model itself.

The methodology followed showed to be successful in the above-mentioned industrial context. However, the described method could be considered as “general” and be consequently used in order to model a variety of production processes, mainly in most of the manufacturing industrial firms, both for modeling production processes and for teaching and training the operators that manage those systems.

The lesson we can learn from this project can be well expressed by the following words by John Sterman: “in practice, effective learning from models occurs best, and perhaps only, when the decision makers participate actively in the development of the model. Modeling here includes the elicitation of the participants’ existing mental models, including articulating the issues, selecting the model boundary and time horizon, and mapping the causal structure of the relevant system”[20].

---

[20] Sterman J. (2000: 36). See also P Senge (1992: 277) where he stresses the importance of group meetings in order to make everyone part of the discussion and of the dialogue.

LITERATURE REFERENCES

Argyris C. (1985), *Strategy, Change, and Defensive Routines*, Boston, Pitman.

Bianchi Carmine, *Processi di apprendimento nel governo dello sviluppo della piccola impresa. Una prospettiva basata sull'integrazione tra modelli contabili e di system dynamics attraverso i micromondi*, Giuffrè, Milano, 2001.

Ford A. (1999), *Modeling the Environment. An introduction to System Dynamics Modeling of Environmental Systems*, Island Press, Washington, DC, U.S.A.

Ford D., Sterman J. (1998), *Expert knowledge elicitation for improving mental and formal models,* System Dynamics Review 14(4).

Forrester W. J. (1961), *Industrial Dynamics*, The M.I.T. Press, Cambridge, Massachussets.

Forrester W. J. (1974), *Principi dei sistemi*, Etas Libri, Milano (original edition *Principles of Systems*, Whrigth-Allen Press, Inc., Cambridge, Massachussets, 1968).

Forrester W. J. (1980), *Information Sources for Modeling the National Economy*, Journal of the American Statistical Association, Volume 75, Issue 371, September.

Fowler F. J. Jr. (1993), *Survey Research Methods,* Applied Social Research Methods Series, Volume 1, SAGE Publications, Newbury Parks, California.

Frankfort-Nachmias C., Nachmias D. (1996), *Research Methods in the Social Sciences*, 5th ed, Arnold, London.

Isaacs W., Senge P. M. (2000), *Overcoming Limits to Learning in Computer-Based Learning Environments*, in Morecroft J. D. W., Sterman J. D., *Modeling for Learning Organizations*, 1st Paperback edition, from Productivity Press, Portland, Oregon (1994).

Morecroft J. D. W., Sterman J. D. (2000), *Modeling for Learning Organizations*, 1st Paperback edition, from Productivity Press, Portland, Oregon (1994).

Morecroft J. D. W. (2000), *Executive Knowledge, Models, and Learning*, in Morecroft J. D. W., Sterman J. D., *Modeling for Learning Organizations*, 1st Paperback edition, from Productivity Press, Portland, Oregon (1994).

Papert S. (1980), *Mindstorms*, Basic Books, New York.

Richardson G., Andersen D., Maxwell T., Stewart T. (1994), *Foundations of Mental Model Research*, in *Proceedings of the 1994 International System Dynamics Conference* Problem Solving Methodologies.

Schön D. (1983), *The Reflective Practitioner*, Basic Books, New York.

Senge P. M. (1992), *La quinta disciplina. L'arte e la pratica dell'apprendimento organizzativo*, Sperling & Kupfer Editori (original version *The Fifth Discipline*, 1990).

Simon H. (1957), *Administrative Behavior; a Study of Decision-Making Processes in Administrative Organizations*, 2nd ed, MacMillan, New York.

Sterman J. (2000), *Business Dynamics. Systems Thinking and Modeling for a Complex World*, Irwin McGraw-Hill.

Vennix A. M. J. (1990), *Mental Models and Computer Models*, PhD thesis, Nijmegen, The Netherlands.

Vennix A. M. J. (1996), *Group Model Building. Facilitating Team Learning Using System Dynamics*, John Wiley & Sons, Chichester.

Vennix A. M. J. (1999), *Group model-building: tackling messy problems*, System Dynamics Review 15(4).

Vennix A. M. J., Andersen D. F., Richardson G. P., Rohrbaugh J. (2000), *Model Building for Group Decision Support: Issues and Alternatives in Knowledge Elicitation*, in Morecroft J. D. W., Sterman J. D., *Modeling for Learning Organizations*, 1st Paperback edition, from Productivity Press, Portland, Oregon (1994).

Back to the Top