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Functional analysis of a process line aimed at supporting the risk analysis with the ALBA methodology: the use case of MAPEI

Relatore: Chiar.mo Prof. Simone Colombo

Tesi di Laurea Magistrale di:
Fabio Frassini
Matr. Nr. 725641

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I would like to dedicate my thesis
to the ones that have never gave up
to realize their goals.

Chapter Summary

Figure Summary vi

Table Summary ix

Abstract Italian x

Abstract English xi

Italian resume of the project developped xii

1 Introduction 1

2 Extensive Abstract 3

2.1 Functional definition 3

2.2 Work organization 5

2.3 New representation 7

2.4 Unique instrument of evaluation 10

2.5 Definition of the binary code 12

2.6 Evaluations of consequences. 13

2.7 Variable for the work load. 13

3 Nowadays used techniques 15

3.1 Inductive and deductive methods 15

3.1.1 Fault tree Analysis 15

3.1.2 Hazard Operability 16

3.1.3 Failure Mode Effect Analysis/Failure Mode Effect Criticality Analysis 18

3.2 Predictive Methods 19

3.2.1 Montecarlo 19

3.2.2 I.D.D.A. Integrated Dynamic Decisional Analysis 20

4 System analysis: 22

4.1 S.A.F.E.T.Y. 22

4.2 Background of analysis 23

4.3 Safety as integration of different levels 25

4.4 Caracteristics of the levels 29

4.5 The importance of the hierarchy 30

4.6 Functional Hierarchy 34

4.7 Specifications 38

4.8 Functional analysis 41

4.9 Logic Sequence 44

4.10 The Semantics of the Process 46

4.11 The F.A.S.T. (Functional Analysis System Techniques) 49

4.12 Cognitive analysis 50

5 Which Instruments are necessary to create the Tool Box: Diagrams. 52

5.1 P&IDs diagram: Where? 52

5.2 H.T.I. Human Technology Interfaces: How? 54

5.3 D.A.D Decision Action Diagram (hierarchical scale): Who? 56

5.3.1 Competences and control 58

6 Software A.L.B.A.(Algoritm Logic Bayesian Analysis) 60

6.1 DETA program 62

6.1.1 Syntax of input files 62

6.1.2 Logical Contrains 63

6.1.3 Probabilistic devices 64

6.2 Integration with Gantt and with the functional tree 65

6.3 How to connect the questions? 66

7 Work development 67

7.1 Task analysis 67

7.2 Gantt Development 68

7.2.1 First vision 68

7.2.2 The second diagram: Where? When? 68

7.2.3 The Third Diagram: Who? 70

7.2.4 The final version 71

7.2.5 Standard used in the Gantt 73

7.3 The interface between the Gantt diagram and the A.L.B.A. software 73

7.4 Excel Develpment 75

7.4.1 First input files 75

7.4.2 Second input files 79

7.4.3 The third version 82

7.4.4 The fourth version 87

7.5 A.LB.A. (Algoritm Logic Bayesian Analysis) 89

7.5.1 First A.LB.A. Input File (Mapei2) 89

7.5.2 Mapei 9 91

7.5.3 Mapei 10 92

7.5.4 Mapei 11 93

7.5.5 Mapei 12-13 94

7.5.6 Mapei 14 96

7.5.7 Mapei 15 99

7.5.8 Mapei 17 (after meeting with Mapei) 100

7.5.9 Mapei 18 105

7.5.10 Mapei 19 105

7.5.11 Mapei 20 108

7.5.12 Mapei 21 108

7.5.13 Mapei 22 109

7.5.14 Mapei 23 110

7.5.15 Mapei 26 112

8 Future development of the Functional activity 113

9 Final Results Discussion 115

9.1 Critical Components 118

10 Bibbliography 124

11 Thanks giving 129

Figure Summary

Figure 2.1 Pasta example function division 5
Figure 3.1 FTA basic example (Ann Marie Flynn, 2002) 16
Figure 3.2 HazOP Table Example 17
Figure 3.3 Example of possible parameter to evaluate for each node 17
Figure 3.4 FMECA Example Table 19
Figure 3.5 MonteCarlo Method Possible outcome 20
Figure 3.6 Montecarlo Method counter of accidents 20
Figure 4.1 Causes of losses in the largest hydrocarbon-chemical plant accidents in % (Daniel Crowl, 2002) 23
Figure 4.2 Macro – Meso – Micro Model (Vaughan, 1996) 27
Figure 4.3 Integration of the 6 levels in order of deepness of analysis (Coze, 2013) 28
Figure 4.4 Example of a decomposition of the levels 30
Figure 4.5 Example of specific action decomposed between different levels. (Jae Han Yoon, An Integrated Process Model for the Systems Development Requiring Simultaneous, April 7-10, 2008) 30
Figure 4.6 Information contained in the levels (Manuel Lambert, (1999)) 33
Figure 4.7 Every level have his goals and actions to satisfy (Manuel Lambert, (1999)) 34
Figure 4.8 Functional Hierarchy structure (Mohammad Modarresa, (1999)) 35
Figure 4.9 Integration in one graph of the single perceptions (Mohammad Modarresa, (1999)) 36
Figure 4.10 Example of possible description of the phrases defining the actions with a multidisciplinary approach (Mohammad Modarresa, (1999)) 37
Figure 4.11 Example of trasformation from the P&Id's to a graph in this case a Goal Tree (Mohammad Modarresa, (1999)) 38
Figure 4.12 Database schema for integrated process (Jae Han Yoon, An Integrated Process Model for the Systems Development Requiring Simultaneous Consideration of the SE Process and Safety Requirements, SysCon 2008 -) 40
Figure 4.13 Input and Output for the functional analysis 43
Figure 4.14 Structure of the Functional Analysis 43
Figure 4.15 Pre-commisioning questions (King, 1998) 48
Figure 4.16 F.A.S.T. description 49
Figure 4.17 S.O.R. model 50

Figure 4.18 Step Ladder Model and R-S-K based model 51
Figure 4.19 Activity type, CoCom resources and generic failure bound 51
Figure 5.1 Example of a Process and Identification diagram (also called P&Ids), property of Mapei 54
Figure 5.2 Cognitive architecture associated to a mental workload (Daiana Martins Vitório, 2012). 55
Figure 5.3 Example of a Human Machine Interaction, peroperty of Mapei..... 56
Figure 5.4 Example of D.A.D. for the operator 57
Figure 5.5 Hierarchical description of the Human Operators, property of Mapei. 58
Figure 6.1 Logic And..... 66
Figure 6.2 If, Than, Else Configuration 66
Figure 7.1 First raw vision of the model and its function, not grouped. 68
Figure 7.2 How the different Phases are connceted with each other, property of Mapei 69
Figure 7.3 Brief description of the single elements and their sub-systems File Gantt 2012.11.29 .. 70
Figure 7.4 Expansion of one element in its sub-procedures 70
Figure 7.5 Maximum expansion of the level until its basics funtions..... 71
Figure 7.6 Immage of the last Gantt Diagram Explosed and extract of the first functions 72
Figure 7.7 List of the possible question to be asked in the model. 77
Figure 7.8 First screening of the questions and development of the model 78
Figure 7.9 List of the 125 possible questions and their connections. 80
Figure 7.10 Detail of the first and last fourteen questions..... 81
Figure 7.11 Quick overview of the deepness of the system. 83
Figure 7.12 Quick overview of the model focused on the machine 2 86
Figure 7.13 Final model developped for the machine 2 88
Figure 7.14 File Input IDDA Mapei 2 90
Figure 7.15 Example of a “story”, output of the Idda Software 92
Figure 7.16 Perfect Example of a loop generated by a wrong connection in the recalls of the model 93
Figure 7.17 Output file Xmapei135 S.667.000 97
Figure 7.18 Example of a story that would generate a loop but for to not eliminate it we manage it in a different way highlighting before the modification in the next file. 98

Figure 7.19 Consequences structure file with the value attribuited from the mapei safety service 112
Figure 9.1 Shape of output file and probability and entropy evaluaition 115
Figure 9.2 Structure of the beans 116
Figure 9.3 Histograms of the beans 117
Figure 9.4 Cumulative Complementary of the Risk 117
Figure 9.5 First Priority Element 118
Figure 9.6 Second Priority Element 118
Figure 9.7 The operator is opening the valve of resin L(red tube) and the valve for the resin C is closed (blue tube) 119
Figure 9.8 Third Priority Element 119
Figure 9.9 Fourth Priority Element 119
Figure 9.10 Fifth Priority Element 120
Figure 9.11 Characteristic of one of the raw material and its security phrases 120
Figure 9.12 Sixth Priority Element 120
Figure 9.13 Twenty third Priority Element 121
Figure 9.14 Maximum Risk History 121
Figure 9.15 Higher consequences history 122
Figure 9.16 General evaluation of the input story 122

Table Summary

Table 2.1 Division into Levels 7
Table 3.1 Example of possible use of key word of the HazOP 18
Table 4.1 Example of Functional Tree 44
Table 6.1 Typical A.L.B.A. Input chain 62
Table 6.2 Typical A.L.B.A. Input chain and constrain 63
Table 6.3 Typical A.L.B.A. Input chain and double constrain 64
Table 6.4 Example of input and different constrains 64
Table 7.1 Symbols Used 73
Table 7.2 Questions and level division 82
Table 7.3 First level of question in the excel File 84
Table 7.4 Second level of Functions 85
Table 7.5 Third level of functions 86
Table 7.6 Functions division into levels 87
Table 7.7 Mapei 10 modification 92
Table 7.8 Mapei file 11 main modification 93
Table 7.9 File input Mapei 12 96
Table 7.10 Main modification of the input file 14 96
Table 7.11 Input file change after meeting with mapei/1 100
Table 7.12 Input file change after meeting with mapei/2 100
Table 7.13 Input file change after meeting with mapei/3 101
Table 7.14 File Inputt ALBA Mapei 17 after the modification with the HSEQ responsible 104
Table 7.15 Modification for the raw matherial 106
Table 7.16 File Inputt Mapei 19 107
Table 7.17 Modification in Mapei 20 108
Table 7.18 Some modification of the file 21 109
Table 7.19 Pneumatic system and electrical energy 109
Table 7.20 Modification of file 22 109
Table 8.1 Cognitive resources 113
Table 8.2 C.R.E.A.M. division of cognitive resources and probability bounds 114

Abstract Italian

La tesi in oggetto è stata svolta con lo scopo ultimo di permettere a qualsiasi analista di rendere riproducibile e sistematica l'analisi funzionale attraverso l'identificazione di quei passaggi reputati fondamentali per la buona riuscita dell'analisi di un processo.

Passaggi o momenti fondamentali della nostra analisi sono stati: l'identificazione del materiale necessario alla base del nostro percorso, l'estrapolazione delle informazioni dai dati fornitici dall'azienda insieme cui è stato sviluppato il progetto, la resa sistematica della scelta dei dati, il trattamento dei dati stessi e infine lo sviluppo dell'analisi finale relativa alle possibili problematiche di uno dei macchinari oggetto di analisi.

L'analisi funzionale al centro del nostro progetto è stata identificata come la valutazione di tutte quelle azioni che permettono al processo di "passare di livello" senza perdere dati fondamentali ed eliminando inutili passaggi tramite l'utilizzo della logica che governa il processo stesso.

I dati analizzati sono stati valutati ed inseriti nel software A.L.B.A. (Artificial Logic Bayesian Algorithm) a partire dalle variabili stabilite nella suddivisione tra i suoi elementi primari selezionati per la nostra valutazione.

Il software permette di estrarre dati da un input di struttura binaria ed è in grado di identificare i cammini critici presenti, restituendo inoltre tutte le combinazioni possibili e gli eventi più interessanti per la valutazione del decisore in relazione all'importanza della manutenzione degli interventi da eseguire.

La nostra analisi è stata fatta partendo dalla produzione di un collante a base alcolica per l'edilizia, identificando elementi di criticità anche sotto il profilo della sicurezza degli operatori, possibili altri sviluppi possono essere ampliati al re-design del processo o a qualsiasi altro processo con il solo cambiamento delle variabili di riferimento.

Abstract English

The thesis I'm proposing has been developed with the idea to provide to any analyst the opportunity to have a reproducible and systematic approach to the functional analysis thanks to an efficient identification of all that passages that must be fundamental for the correct analysis of the project.

The fundamental passages of the analysis have been: the identification of the necessary graphs and diagrams, the extrapolation of the information from the data given us by the company with whom we worked together, let the approach becoming systematic, the treatment of the data and the development of the final analysis concerning the possible problems of one of the equipment of the line under analysis.

The heart of this thesis has been represented by the functional analysis, intended as evaluation of all of the actions that permit the process to go further without losing any fundamental data and deleting useless passages, just using the governing logic of the process.

The data analyzed has been valued and thanks to the A.L.B.A. Software (Artificial Logic Bayesian Algorithm) we insert the inputs and the variables defined by the division of the process in its primary elements selected for the evaluation.

The software provides the possibility to extract from a binary input the critical path in the input, giving also the possible combinations and the identification of the most interesting events for the evaluation of the person that is determining, for example, the priority in the maintenance of the process.

The analysis has been done starting from the production of an alcoholic base adhesive used in the construction sector. We then identify the criticality of the production and of the operators' security, some other possible development can be extended in the redesign or to any other process with just the changing of the reference variables.

Italian resume of the project developped

La tesi sviluppata è stata suddivisa in nove capitoli suddivisi come segue:

Capitolo 1: il primo capitolo riguarda il perchè è stato scelto il processo studiato e ne introduce il suo studio

Capitolo 2: questo capitolo in qualche modo rappresenta il possibile articolo scientifico da poter pubblicare qual'ora se ne verifichi la necessità, introduce in modo pratico tutti i temi trattati nella tesi da me proposta per la resa struturale di un approccio di scomposizione funzionale di un processo, rendendolo binario ed identificantone le azioni o le apparecchiature su cui risulta prioritario intervenire

Capitolo 3: in queso capitolo sono brevemente introdotte le tecnche maggiormente utilizzate al giorno d'oggi per la valutazione e previsione di eventi incidentali, spesse volte sono tecniche giudate dalla conoscenza degli analisti relativamente ai processi in esame.

Le tecniche visionate sono molto spesso settoriali, ossia prendono in esame solo alcuni parametri alla volta per predire le possibili interconnessioni tra eventi.

Capitolo 4: questo capitolo, rappresenta il vero cuore scientifico del progetto che ho sviluppato, vengono identificati i passaggi salienti della integrazione effettuata a partire da differenti strumenti utilizzabili da un analista in fase di studio di un processo di produzione industriale.

Il passaggio fondamentale è stato il capire come integrare aspetti di un processo completamente diversi come il lato technologico e quello umano in un unico approccio di rappresentazione e di valutazione.

Si sono anche valutate differenti aspetti caratterizzanti i possibili incidenti per riunirli in un unico approccio logico paragonando quanto da noi proposto con quanto ad oggi in utilizzo. Si è anche brevemente accennato a quello che significa l'approccio cognitivo in un processo industriale.

Capitolo 5: il capitolo esprime quella che è stata la base pratica da cui si è partiti con lo sviluppo del modello finale di rappresentazione del caso pratico in oggetto della proposta di tesi

Capitolo 6: questo capitolo è stato ideato come manuale di istruzioni per l'utilizzo del software da noi utilizzato, sono inoltre presenti spunti per l'implementazione del software con altri applicativi utilizzati per la rappresentazione finale del modello in esame. La peculiarità di questo software è

che ti permette di visualizzare le possibili strade intraprese dal sistema a valle di una assegnazione di eventi o variabili elettive su cui basare il modello di analisi. Le strade sono così viste come la successione storica degli eventi espressi alla base dell'analisi, creando così la storia del processo.

Capitolo 7: questo capitolo rappresenta il cuore del lavoro svolto sotto l'aspetto più pratico, sono presenti i tre strumenti utilizzati per lo sviluppo del progetto in sé: i diagrammi di gantt (utilizzando Microsoft Project) per identificare quali potessero essere gli sviluppi temporali delle diverse azioni, successivamente si è utilizzato un foglio di calcolo (utilizzando Microsoft Excel) per identificare quali potessero essere i collegamenti tra le differenti azioni e funzioni da ottemperare per la corretta realizzazione del prodotto da produrre. Infine si è utilizzato il software A.L.B.A. per poter raggiungere un risultato a partire da una espressione combinatoria di singoli eventi binari combinati tra loro. L'affinamento del file di input è passato attraverso svariati passaggi poiché la minima variazione logica ha implicato un notevole dispendio di interconnessione tra gli eventi.

Capitolo 8: questo capitolo rappresenta i possibili futuri sviluppi ed approcci a questo modello di analisi, volutamente posizionato prima delle conclusioni sta a rappresentare la multidisciplinarietà dal approccio poiché grazie ad una analisi cognitiva più diffusa e puntuale questo strumento può essere utilizzato anche in fase di ridisegno di processi e pratiche produttive a tutto campo aumentando la consapevolezza delle possibili manchevolezze da parte degli operatori di campo.

Capitolo 9: nel ultimo capitolo sono esposti i risultati della nostra analisi reale l'identificazione degli eventi più significativi le possibili modifiche da implementare nella fase organizzativa, tecnologica e produttiva per una migliore e più sicura produzione della linea da noi analizzata.

1 Introduction

Nowadays, thanks to the increasing knowledge in the field of safety it becomes necessary to understand all the different connections and interactions that humans can have with the machines.

Today we're having access to a lot of different information, from many different models, sometimes this environment is getting complex, and that's why we thought that could be interesting to define how different diagrams can be integrated in a unique solution.

In the industry those kind of complex problem can be really difficult to solve, basically, because the structure of the workplaces are not made to be flexible as other sectors of the economy.

Why are we comparing the process industry with other sectors?
Because they're more dynamic and are used some Best Practices that can be helpful for us, for this reason we keep in our mind a hot phrase that we always have to look for: "Learn from Success!".

At this moment, the problems of lack of "real" communication, the relations between human and machines and the necessity of feeling safe in your own house are always demanded to the extended use of technology.

The people who lives in the surrounding of any industrial plants, to feel safe in ther own houses, usually cares only about the technological upgrades in the plant their living close by and are not interested in other important modification, for example in the organization of the workforce inside factory.

Even more, an analyst normally is trying to understand a process just sitting at his desk, watching graphs. This is happening without a complete understanding of the field; for this reason it becomes necessary to have a single tool that will support the decisions and that is comprehensive of all the necessary infos to perform an analysis

Starting from those basics ideas we thought that we could take as a challenge to introduce something that can help in review of the Safety Report, mandatory by the Seveso Directive.

The European "Seveso" Directive is requiring the communication to the citizens of any modification of the Safety Report, for this reason we got in contact with the Mapei Industry Plant located in Robbiano di Mediglia, east side of the city of Milan near the Linate Airport and in this

factory, subject to this European Directive, we started our investigation on an old production line of glue for fitted carpet and linoleum.

In the work, the needs expressed by the plant HSE manager were to have under control the movements of alcoholic products, and its combinations, in order to prevent hazard in general and possible events of fires and explosions.

2 Extensive Abstract

2.1 Functional definition

The project developed has been inspired by a concept already known in the software and automation engineering, the functional analysis.

The functional analysis we are presenting is focused on the definition and highlighting of the fundamental elements of the production process.
A necessary requirement of the analysis is that it must be easy to be approached and reproduced, isolating and showing the most important details for the specified focus.
To identify these elements we thought and implemented an approach that will satisfy the analyst's needs such as: the process must be complete, the process is represented in an easy understandable structure, the information necessary to satisfy the goal should define a perimeter of intervention and all the input and output functions must be clear.

The analyst should define each single action, or event of the process, in order to let the model highlight possible critical aspects or critical sides of the process itself.

For this reason, after the process definition and after the description of the action involved in the process, the analyst will need to select the most important tasks thanks to the "functional aspect" that will be assigned to each of them.

Each task has a functional aspect, its composed by the link between the actions and by the sequence of them, their performance and after a correct logical disposal is possible to reduce the total amount of them without compromising the necessary data for the analysis.

The functional aspects must be ranked according to their relevance for the process, this implicit rank is defined as Functional Value.

The concept of Functional Value is represented through some questions, relevant to the process' logics, which will define the important steps. In our case, the questions to be submitted might be as follows:

-What is the operator, or the machine, performing?

-Why is the operator performing the action?

-When is the operator performing this action?

-Which is the behavior of the operator while the action is ongoing?

These questions permit to clearly identify the action under analysis.
To link all these different information and create a new approach to the study of the plant's safety we had to split and investigate many different aspects.

The logic of the process is intrinsically connected with the physics and with the possible events that can be generated by the conjunctions of different actions of the process.

The synthesis of the elements and actions performed in the process plant creates a sort of skeleton that allows keeping up the process without unnecessary data. The moments defined with the functional analysis are then becoming the functions of the process.

As above said, the process is thus divided in several functions. However, the different functions do not share the same complexity. To better express the overall system the functions are categorized according to their complexity in a pyramidal structure. Thus, a process is defined by few complex functions (main functions), which are themselves divided in sub-functions up to the least articulated ones.

The above described functional analysis can be applied also to everyday life.

Example: I need to eat and I want to have pasta.

The first step the analyst should do is to understand which kind of process is under investigation, define its limits and focus on the requirement asked to reach the goal defined by its commitment. First off I have to check if I have pasta, if I have a pot, if the water is available, if I have a sauce and if I have a source of energy.

These five checks of raw materials are part of the process necessary to fulfill the requirement: eat a dish of pasta.
Unfortunately, those five elements are not necessary to describe the process because the process to prepare pasta is represented by the actions necessary to complete the process: heat the water, cook the pasta, prepare the sauce, prepare the pasta (duly dressed) and serve it.
Those four steps are done by several tasks that must be achieved in a specific order before reaching the next goal.

For example to heat the water I need the pot, I need the water and I need energy.

An example of sub-functions is the heating of the water:

1- put the pot under the tap

2- open the valve of water

3- fill the pot (till a certain level is reached)

4- put the pot on the burner

5- heat the water until it boils

In each step expressed above there are sub-steps not written that are implicit, not made explicit because not relevant to our analysis.

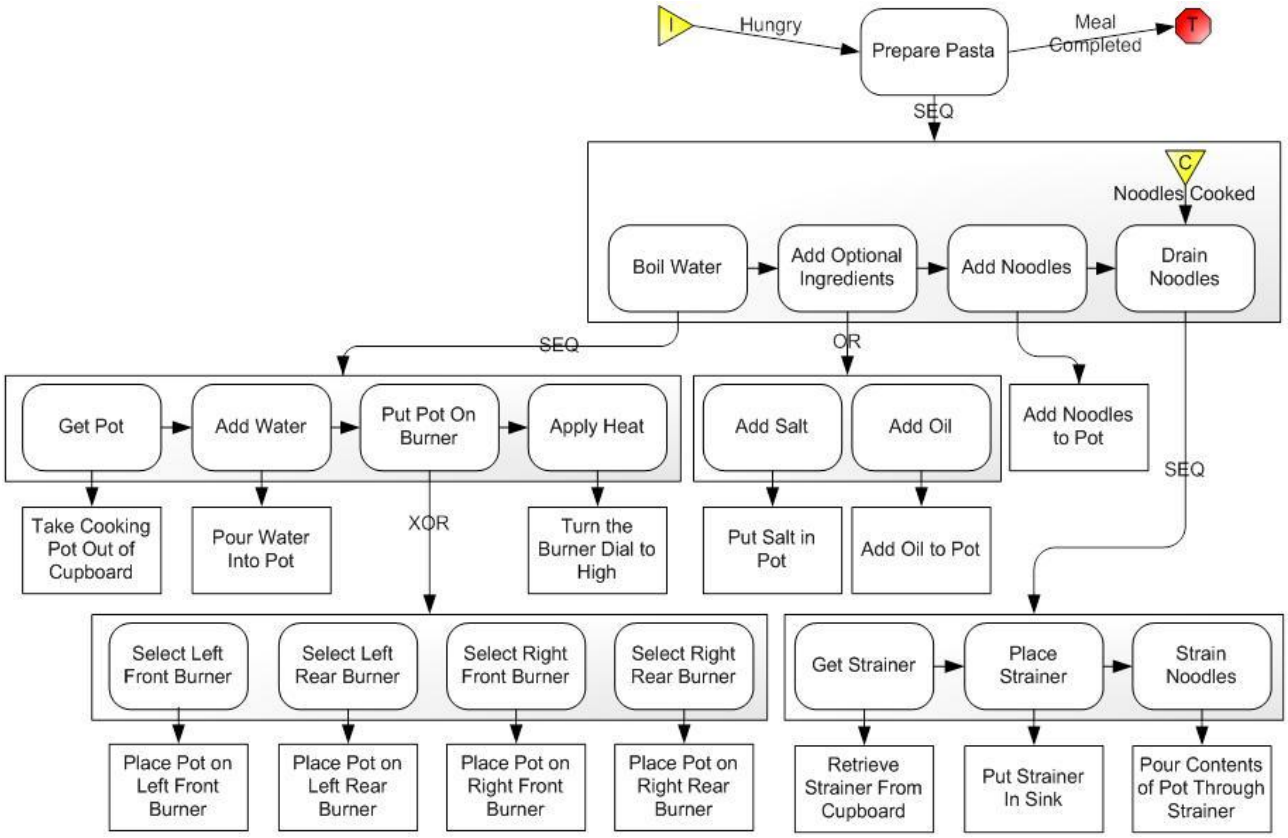


Figure 2.1 Pasta example function division

2.2 Work organization

The analysis and definition of the functions have been categorized according to their characteristics to proceed with the operations.

The first decision has been to define which one could be the starting point. For this reason we collected and / or built three main graphs necessary to represent different aspects of the work

breakdown structure. These three different pre-analysis covered our necessity to fulfill some requirement before start working

- Analyze the scheme of our plant. Thanks to schemes like the P&IDs or the PFD we understood which machines and flow lines are involved in the production. This part concerned the hardware of the plant. In our “pasta” example this part has been expressed by the pot, the scheme of water and the scheme of the source of energy.

- Analyze how the humans are interfacing with the plant. We had to build the HTI (Human Technology Interaction) to recreate which ones were the human–machine interactions to share the information. The information flows were going from the machine to the human with the technology outputs or from the humans to the machine thanks to the technology inputs, thus providing a translation-flow between the two communication languages. In the “pasta” example this part is concerning the opening of the water valve and the movement of the pot.

- Analyze the Human decisions. To evaluate this we built the DAD (Decision Action Diagram) necessary to highlight the roles of the humans in the production process and, thanks to the C3 (Command-Control-Communication) scheme, we were able to understand which were the decisional flow of the information.

Once the three main diagrams were built, we started to work on a common language to allow for these three graphs to “communicate”, with the ultimate goal of recreating one representation “embedding” the information contained in the three schemes. To that aim, we decided to divide them into different layers or sub-functions.

Each layer has been characterized by a specific attribute. This way the analyst can isolate each layer from the others because it has an uniques caractheristics.

In this double dimensions connections the analyst have the opportunity to move in two different sides, horizontally and vertically. The horizontal dimension is providing the possibility to see the functions of the same level conntected together while the vertical disposition is allwing the analyst to investigate on the caractheristic of the task divided for the specific attributes.

The layers, if defined in a homogeneous and correct way, give the opportunity to decide the desired level of analysis without compromising the final quality of the work. This is possible because each layer is carrying specific information. In the “pasta” example the actions to heat the

water are sub-functions of the higher process.
The actions in the layers become more specific and precise with the increasing level of the layers.

For a further creation of the input file, dedicated to the risk analysis, and for to better understand which actions are performed at a specific level, we transformed the action from a pure description to its related possible question, this permits to underline which is the variable that is leading the event.

Each layer of questions, defined by the levels, was designed to follow the timeline of the production. Thanks to the layers' structure we can go, in an extended analysis, from a gross set of information into a more specific and small option of outputs.
As it is possible to see below in the example relevant to the process we're investigating:

-Phase C: Mixing	Level 1
-C.1: Machine 2027	Level 2
-C.1.a.: Start-up Checklist	Level 3
-C.1.a.1: Daily Production Plan	Level 4
-C.1.a.1.1: Formula's control	Level 5

Table 2.1 Division into Levels

The funtions are therefore seen as a fundamental bricks that must be defined in order to define the fundamental passages necessary to reach our final product.

In our idea the function are representing the base to than identificate the variables governing the event necessary to describe, the functions are also evaluating the importance of the action related to them in the process description

Once defined the function, and than the desired aspect to underline, is easy to highlight in the input file the most usefull variable, cause the specific logic that is leading the connections can help the analyst to delete unnecessary informations.

Functions are representing the reason why we perform a specific action or set of actions at a specific time and not earlier or later.

2.3 New representation

The means we used to represent the Functional Analysis is a widely known tool called Gantt Diagram.

This tool, intensively used by Project Managers, allows, following a timeline, to link and split the different activity of a project and for us it represented a concrete help to connect the different layers of the projects in macro areas, areas, phases, sub-phases, action and sub-actions.

Each line of the diagram, also called task, has been characterized by its execution time or by the sum of its subtasks' duration, the link between previous and following task and the resources that are assigned for its achievement.

For a better understanding, we're trying to represent in the most precise way possible what is done according to the phenomenological timeline of the process, defining homogeneous characteristic in the different levels.
To define the connections between the different functions and between the levels we have been guided also by the HSE manager to define wich one could be for example the possibility of connection or mistake for some task we have identificated.

The layers' level has been characterized by its specification, like:

- Level 1 is characterized by one of the four phases of the process;
- Level 2 defines the area/space of where we are performing the specific set of actions;
- Level 3 is the macro group of actions that define the time status of the machine (startup, shutdown, etc.);
- Level 4 is the real action performed in that specific moment and it can be a simple action or a more complex that still needs to be divided in more simple ones;
- Level 5 is defining the sub-actions or the actions that are necessary to perform a control of what was done before.

This hierarchic division is providing a high number of tasks to evaluate if compared with a conventional analysis. Some of the task are not defined by a specific time duration (because could last just a few seconds) and there are also some of them thatcan be recursive in different moments of the process, like the quality control of the product.

The tasks' abundance in our process has been represented by more than 250 different rows in the Gantt diagram.

This abboundance is due, to the fact, that while a system functional analysis is ongoing, the actions needs to be evaluated whether or not they has been accomplished by the human or by the machine.

The definition of action is concerning also the description and division of them into its basics components such as: detection (for example from a detector), logic of understanding of the situation and actuation of an answer out of the knowledge of the actuator.

Once decided that one of the characteristic of the action is satisfy by the humans, for example, it become instrinsecally necessary to understand which is the most important cognitive resource to assign to understand which are the requirement that the subjects needs to fulfill, in this way also the human cognition than needs to be modelized.

Once the actions were ranked, we assumed to assign to each task one or more cognitive resources that can characterize it. Four types of cognitive resources have been identified: observation, interpretation, planning and execution (according to the Contextual Control Model - Co.Co.M.). The analysis can attribute the various cognitive resources among the actions, and thanks to this he can clarfy the level of mental workload necessary to perform the specific assignment and its cognitive demand profile.

This four cognitive resources have been identificated after several studies and, in this project they have been distributed comparing each action with a dataset of possible actions token in studies find the bibliography research

In a general overview of the level compared with the cognitive resource attribuited is possible to denote that the levels were caring together a “somehow typicall”, of the level, cognitive resource.

- Level 1 is not represented by any cognitive resource. in our project we have been focused on the manufacturing side of process, aspect not included in this level. This level is, in fact, typically involving design aspects;
- Level 2 as for the level 1 the cognitive resources are not applied to this level;
- Level 3 normally this level is characterized by a cognitive resource of planning or interpretation. These figures are the highest ranks in the manufacturing process’ hierarchy;
- Level 4 normally the attributed cognitive resources are execution or observation;
- Level 5 typically is represented by a cognitive resource that generally was execution or observation

The interpretation of these functions can permit the analyst to evaluate possible situations where the cognitive load of the operator is overloaded, so the demand of workload demanded can't be satisfy, is necessary than to redefine the workload of the operator while a specific important tasks needs to be performed.

2.4 Unique instrument of evaluation

In this structured situations, where different side of the plant are communicating on a specific multidisciplinary instrument, such as the one we are trying to modelize with our work, it becomes possible to evaluate the most critical situations and where possible deviations, from the standard conditions, that can damage the system.

Possible non-compliant situations can be determined by mistakes, lack of controls, not directly controlled areas and so on.
To understand and define possible problems it becomes necessary to analyze separately the most important actions and considered the most effectivedeviations from the standard conditions.

Usually the actions defined as most important were carrying specific attributes: they can be the last of the group, considered as a bottleneck, the ones that represent a physical block, the ones where it is possible the mismatching in the decisions or where security barriers could fail.

Some examples can be:

- C.1.a.6 Print the Receipt; it is considered a Bottleneck because if no receipt has been printed the system is not allowed to continue in the production;
- C.1.b.5 Operation for Control and Quality; this task is considered the last of the Conduction (C.1.b) before proceeding to the next phase;
- D.1.a.6 Definition of the packaging of the production; it is considered a physical block to continue with the discharge of the product;
- A possible mismatch in the decision can be to keep the wrong valve open, like the valve for the Resin C open instead of the one for the Resin L;
- Safety barriers can fail if the compressed air is not working, thus keeping the intake valves in the wrong position.

The above explained examples are the typical one that can explain the ratio behind the election of the possible task, and not other, to monitor to keep the system safe.

It can also be possible to modify the final goal of our analysis, just modifying the question related to the functions, if for example the final goal is going from safety to quality, is possible to shape differently the perspective of the question changing than what we are going to underline.

In the future input file is also possible shape depending on the logic of the connections, or modify the evaluation of each task where is becoming necessary changing the values that are assigned to the questions variables. Some of the deviations, in our analysis, are providing the same output because the barriers of the system might be the same for several problems or should manage the same variable.

For the opposite reasons, one specific task answered in an earlier or later "position" would not provide any, or the same, deviations, thus underlining the importance of the logic behind the link of the tasks.The definitions of the connections are made for area of competences instead of for time shift.

The variables that are managing the different functions can be seen as a set of four subjects inherently connected: Behavior, Event, Goal, and Structure.

- The behavior underlines the side of the function that represents the way of how we accomplish it.
- The event gives the overview of the consequences for the loss of the function.
- The goal represents the conditions or the objective to attain.
- The structure shows the part that physically performs the function.

The possible mix of these four subjects might be all valuable but, in our opinion, the hierarchical order can be:

- Goal, Structure, Behavior, Event.

Obviously the inside ranking of the level is governed by the appearance order of the action.

- Goal can be characterized by the mission of the group of task or action that will take place, example: C. Mixing of the product (Symbol: Capital Letter);
- Structure is defined by the spatial areas of where the goal will be arranged, example: C.1 Machine 2 (Symbol: Number),
- Behavior is intended as which are the passages necessary to complete in the structure, example: C.1.b. Operations (Symbol: Letter);

- Event is the real action or task to be completed for the right execution of the process, example: C.1.a.8 Balance Calibration (Symbol: Number).

Our model can be approximately view as a F.A.S.T. (Functional Analysis System Techniques) Analysis because the tool we used can be read bi-dimensionally, horizontally and vertically.

The horizontal view is characterized by the definition of "What" you do (reading the graph from right to left) and "How" you do in the opposite way.

The vertical view is, instead, characterizing the order of implementation of the tasks.

This scheme is pretty easy to understand and is not taking too long before a correct use, the only difference we are introducing is the evaluation of the cognitive functions, that is creating a third dimension for the correct analysis, becoming somehow a "Cognitive and Functional Analysis System Techniques".

2.5 Definition of the binary code

Starting from the basic function, we created a checklist of all the necessary actions, expressed as questions requiring a binary answer.
The use of the code is possible thanks to the Alba Software (Artificial Logic Bayesian Algorithm).
This software gives the opportunity to introduce and develop possible logical constrains and manage the development of algorithm thought a specific logic of connections.

The definition of a binary outcome and constrains is giving us the chance to define the elective variable that is ruling that moment, always starting from facts that happens or not.

The creation of this binary code gives also us the opportunity to drastically reduce the possible outcomes of the model. This optimization is possible because the algorithm is giving the opportunity to constrain the outcomes connections out of the questions, where logically possible.

This approach is useful if the questions are accurate. If so, the possible deviations are not so probable and the environment of the possible outcomes is somehow predictable and limited by the not verified checklist.

Each question needs to be clear and satisfactory of the reality of the process, if the question doesn't satisfy completely the function is necessary to investigate more in the detail the outcome

multiplying the amount of data to interrogate in order to understand where the intervention is useful.

In our model we started to interrogate our system with more than 90 questions, and those will represent the parameters of our model. After a cutting and revaluation of the necessary function we reached a final value of 25/30 that still means more than 90.000 possible outcomes combinations of functional events.

This 90.000 possible outcomes in the end are representing possible stories of events that can happen in the process plant, this because each parameter of the model is a happening of the shift of production.

2.6 Evaluations of consequences.

The attributions of the "Plant value" for each task of the checklist are evaluated together with the responsible of the plant.

This Value is a mix of the typical equation R=P*M and the possible reputational damages due to the loss of control of the specific function.

This objectification of value is a new standard for the industry of these days because it also evaluates what is the future performance of the product to sell, a sort of geo-localization for the industry plants.

Where the public opinion gives attentions to the possible deviation from the standard condition a loss of function is drastically more important than just a loss of productions.

For example in the case we have studied, a lot of importance has been given by the possible not compliant product but the maximum scale value has been given to the events where there will be a loss of safety controls.

2.7 Variable for the work load.

After the evaluation of the consequences it becomes fundamentals to study and, possibly, redesign the plant with the assigned values of safety to respect.

The reconstruction of the system starting from the consequences becomes easy thanks to the reproducible work done for the decomposition of the process itself.

The high value given by the analysis done is that, differently from the other methods of safety analysis, the functional hierarchy ideas permits to read the system in both directions zooming in and zooming out depending on the necessity of intervention.

The coded approach to the decompositions allows a future analyst to evaluate the operation of the workers and of the machines without a contamination due to the experience on field.

If the decomposition is done without losing of information the recreation will be not too complex and the intervention will be surgical.

In our case the level for a precise intervention will be done on a 4^{th} level of deepness, where the actions are already uncoupled but sufficiently accurate to identify the action.

This level of approximations is enough to understand if, for example, the workers are overloaded of work or if they can pay enough attentions to their tasks, otherwise it can be necessary to insert a double barriers or a modification to the design of the process.

3 Nowadays used techniques

3.1 Inductive and deductive methods

3.1.1 Fault tree Analysis

The fault trees is a deductive failure analysis in which an undesired event, or state of the system, is analyzed decomposing the system failure in its elementary components and using Boolean logic and operations to evaluate the final system failure probability.

The Fault trees analysis, also called FTA in literature, can be used to identify the logic of events that can lead to an undesired state, can be used as a tool to identify possible mistakes and to redesign manuals of intervention.

The procedure steps are: definition of the top event, decomposition of the top event in sub events until the decomposition of the primary events that can cause it and where data are available.

Basically the logic operations for the FTA analysis can considered to be two and are expressed by: And gates to connect events that must occurs simultaneously, Or gates to connect events that occurs if one of the two connected events occurs.

There are also other operations such as the or Inhibit gates, priority gate, the Exclusive Or gate or the M out of N gates that can be part of the analysis in specific cases.

After the graphical definition is also possible to ad joint a qualitative analysis where each event can be valued 1 if the event is true or 0 if the event is false and then set a possible equation for each tree to discover the possible cut sets and minimal cut sets.

Is also possible a quantitative analysis if is possible to evaluate each single event that is composing our three.

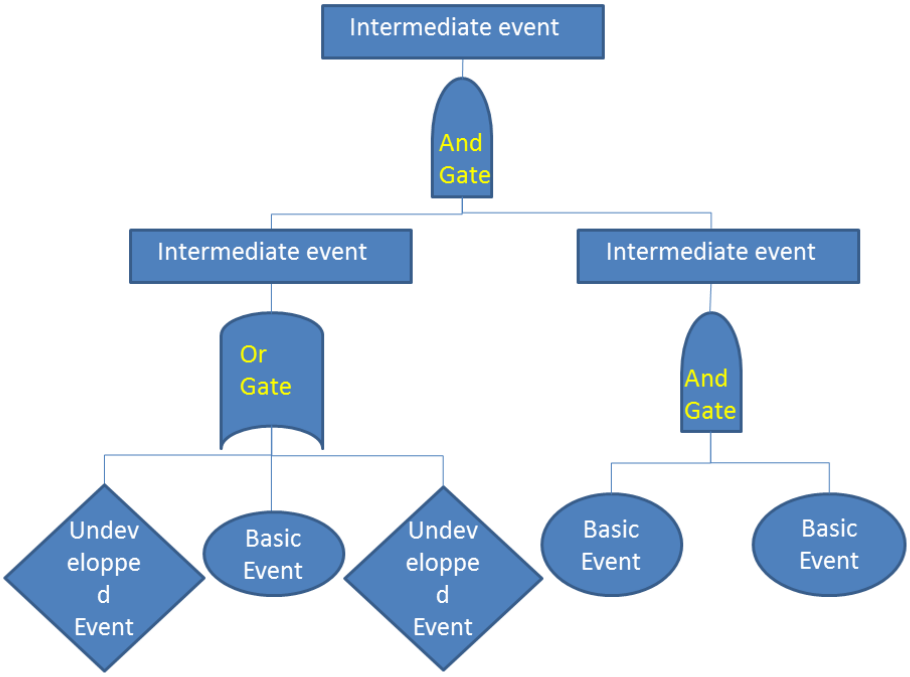


Figure 3.1 FTA basic example (Ann Marie Flynn, 2002)

The power of this method is that can be easy to be shaped, it is giving a clear representation and the minimal cut set can be a synthetic result of the system criticality.
The weakness of the process is that is possible to concentrate to only one top event at the time and that the connections between the components are identified by the knowledge of analyst.

3.1.2 Hazard Operability

The hazard operability, or commonly called HazOp, Is one of the most used analysis to identify possible problems in the system

This analysis is deductive and also inductive, because it helps to search for the causes of accidents and it induces to evaluate the consequences of the problems.

Is an extremely systematic analysis and is based on the possible deviations from the standard conditions of the process.

This analysis is guided by specific keywords that are managing the deviations from the standard conditions in a specific equipment or line after the identification of the selected parameter.

After the selection of the “node”, the part of the equipment or the line, the operation mode and the definition of the parameter to modify is used a key word to analyze the cause and

consequences of the deviation and define the protections necessary to reduce the impact of the wrong event.

This analysis is usually conducted by expert of different sectors that can evaluate each passage, all the comment must be signed and becomes important for each deviation evaluated.

Hazop can be also useful for the development of the operator procedures, the verification of the project, to request extra alarms or blocks and something more.

Study title:							Page: of		
Drawing no.:		Rev no.:					Date:		
Hazop Team:							Meeting date:		
Part considered:									
Design intent:		Material: Source: Destination:							Activity:
No.	Guide word	Element	Deviation	Possible cause	Consequences	Safeguards	Comments	Actions required	Actions assigned to
Assign each entry an unique tracking number	Insert deviation guide word used	Describe the guide word pertains to (material, process step, etc.)	Describe the deviation	Describe how the deviation cause may occour	Describe what may happen id the deviation occours	List control (preventive or reactive) that reduce the deviation likelihood severity	Capture key relevant rationate, assumptions, data, etc.	Identify any hazard mitigation or control actions required	Record who is responsible for actions

Figure 3.2 HazOP Table Example

Flow	Composition	Ph
Pressure	Addition	Sequence
Temperature	Separation	Signal
Mixing time	Start/Stop	Stirring Phase
Operate	Transfer	Speed
Level	Maintain	Particle Size
Communication	Reaction	Control
Services	Viscosity	Measure

Figure 3.3 Example of possible parameter to evaluate for each node

Guide words	Meaning	Example
No (not, none)	None of the design intent is achieved	No flow when production is expected
More (more of, higher)	Quantitative increase in parameter	Higher temperature than designed
Less (less of, lower)	Quantitative decrease in a parameter	Lower pressure than assigned
As well as (more than)	An addictional activity occours	Other valve close at the same time (other fault or human error)
Part of	Only some of the design intention is achieved	Only part of the system is shut down
Reverse	Logically opposite of the design intention occours	Back flow when system shuts down
Other than	Complete substitution, another activity take place	Liquid in the gas piping
Early later	The timing is different from the intention	

Table 3.1 Example of possible use of key word of the HazOP

3.1.3 Failure Mode Effect Analysis/Failure Mode Effect Criticality Analysis

FMECA is a multidisciplinary techniques widely known used for the decision making process.

FMECA is based on few fundamental steps, such as: the decomposition of the process in its components, the definition of the mission phase, definition of the inputs and outputs function and requirement and finally the reconstruction of blocks diagrams to relate the items between each other's.

The FMECA can be different depending on the focus of the analysis, for example Design or Process.

For each evaluation (probability, criticality and severity) is necessary a definition of the possible level of acceptance divided in a scale of values, the final risk evaluation is possible with a multiplication between this three values.

Component	Failure mode	Effects on other components	Effects on subsystem	Effects on the plant	Probability	Severity	Criticality	Detection methods	Protections and mitigations
description	Failure modes relevant for the operational mode indicated	Effects of the failure mode on adjacent components and surrounding environment	Effects on the functionality of the subsystem	Effects on the functionality and availability of the entire plant	Probability of failure occourrence (sometimes quaitative)	Worst potential consequences (qualitative)	Criticality rank of the failure mode on the basis of its effects and probability (qualitative estimation of the risk)	Methods of detection of the occourrence of the failure event	Protections and measures to avoid the failure occurrence

Figure 3.4 FMECA Example Table

As is possible to see in the

Figure 3.4 are shown “how” and “what” is necessary to write in the analysis to evaluate in the correct way each of the passages.

3.2 Predictive Methods

3.2.1 Montecarlo

The Montecarlo Method is a computational algorithm that permits the analyst to evaluate possible consequences.

Is an extremely multidisciplinary method, in facts its possible applications are spread in many different sectors.

Its applications in the safety world are defined by the possibility to replicate the possible failure of the system after the definition of the status of the process, the ratio of transport and the interaction that all the equipment can have with each other’s.

For the right application of this method is necessary to define: the plant, the components of the plant, the state of the plant, the possible transitions and the plant life.

Extremely important is also define the transition between transitions state of the component and transition state of time for component.

This method, in the end, is powerful to produce the possible path of the plant and deduce the possible accidents to prevent the maintenance.

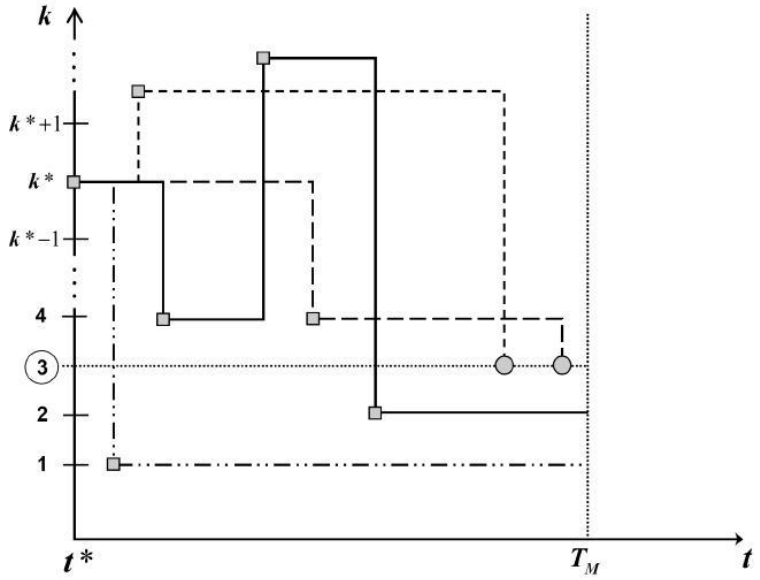


Figure 3.5 MonteCarlo Method Possible outcome

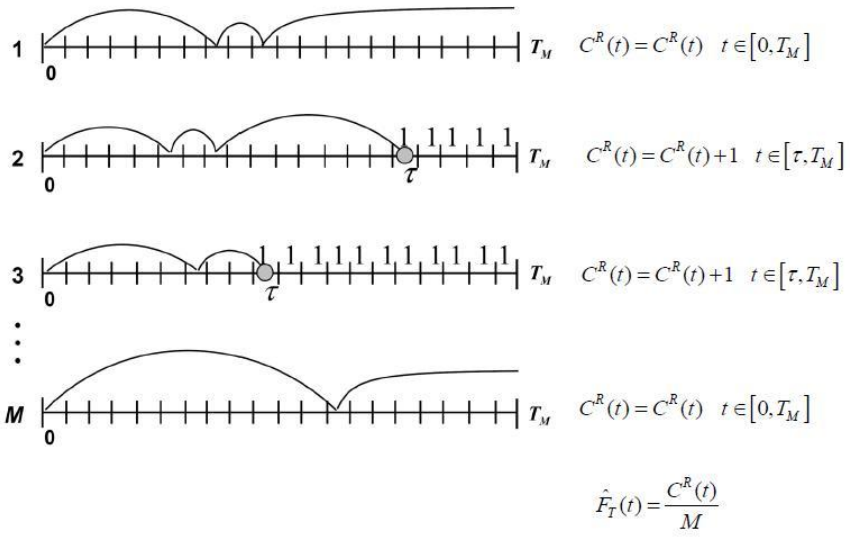


Figure 3.6 Montecarlo Method counter of accidents

3.2.2 I.D.D.A. Integrated Dynamic Decisional Analysis

IDDA is tool able to model the logic of a complex system: it provides a representation of all the possible alternative states into which the system could evolve, as real logical and temporal sequence of events. Each branch can follow several paths, with probabilities conditioned by the evolution of the events preceding the branch itself.

The system description has the form a binary chart, where the real logical and chronological sequence of the events is described; the direction of each branch is characterized by a probability

of occurrence that can be modified by the boundary conditions, and in particular by the same development of the events themselves (probabilities conditioned by the events dynamic).

In other words, starting from the analyst's description of the system (using an appropriate syntax), IDDA develops an enhanced form of "dynamic" event tree, representing all the sequences of events compatible with the description received from the perspective of both the "logical" construction and the "probabilistic" coherence.

In short, IDDA is concerned with system logic, i.e. the logical-probabilistic connections within a given universe, treated dynamically and in which the logical model is fully integrated with its physical and phenomenological model.

One of IDDA's main advantages is that it offers all the tools that are needed in order to overcome the issue of the binary proliferation of alternatives, limiting the problem to a manageable field.

IDDA is thus capable of providing a model of the system in question, which can be used to support documented, substantiated and well-founded decisions on the basis of an analytical presentation of the possible alternatives and of the "risk" (in terms of probability and consequence) that each entails.

4 System analysis:

4.1 S.A.F.E.T.Y.

Reading some books regarding Safety Management once I found an acronym that in my point of view is representing the 5th essence of the safety meaning:

System,

Attitude,

Fundamentals,

Experience,

Time,

You.

I found this synthesis really representative because in my opinion it is a great integration of the several different approaches I've been finding in my bibliographic research.

Actually, this intuition to integrate different aspects of safety in a new set of possibilities defining a specific new environment can help us to understand which ones are the specifications that can bring the systems into a wrong nominal form with just one look.

One example is proved by the petrochemical industries where the 12% of the causes of losses is still unknown and where approximately the 25% of the hardware losses is unknown too, as shown in the **Errore. L'origine riferimento non è stata trovata.**.

Interesting to highlight in an in-depth analysis are the "Typical engineer's questions", those questions are necessary to isolate the specifications of the subject and are focused to 4 different aspects of the causes of losses:

- the identification,
- the location,
- the timing and
- the magnitude.

Related to these aspects are joint the questions which are:

- What is the problem? (Identification)
- Where is the problem? (Location)
- When the problem occurs? (Timing)
- When it was first observed? (Timing)
- How far does the problem extend? (Magnitude)
- How many units are affected? (Magnitude)
- How much of any unit is affected? (Magnitude)

To solve these problems we decided to create a method that could be comprehensive of all those aspects that are necessary for the work of the analyst.

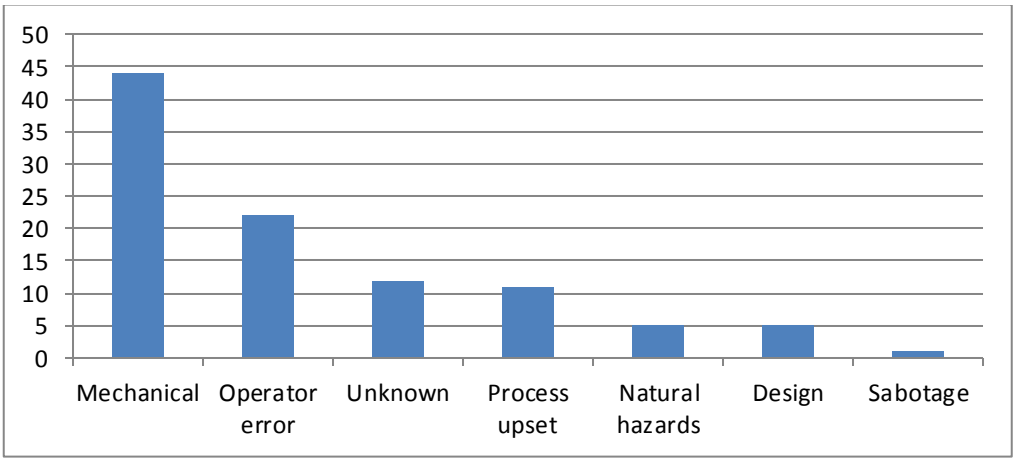


Figure 4.1 Causes of losses in the largest hydrocarbon-chemical plant accidents in % (Daniel Crowl, 2002)

4.2 Background of analysis

System analysis is allowing the analyst to understand which ones are the systems and the sub-systems involved, is also providing the opportunity to highlight some specific procedures more than others.

In an interesting articles from Erik Hollnagel that is still on press (Hollnagel E. , Is safety a subject for science?, 2013) we found some interesting definitions and a new approach to the Safety sciences:

"*Safety science is therefore taken to refer what we know about safety and the ways we have built and continue to build this knowledge. In other words is how we study the subject that matter, and now, our subject is safety*"

But also, safety does not represent an agreement that should be studied, or can it be said to exist in any concrete or material sense, or to be real (Westenhoff, 2011) this actually is the preface to a new definition of safety.

Through the ages the feeling of safety has always been developed practically in an indirect way, starting from the definitions of a risk, a hazard, a near miss, an incident, or an accident. (Heinrich, 1929)

Going through the main distinctions between accidents and injury, where one is the result of the other, the development of its definitions become the one we used nowadays, the main concept to express is that safety is when nothing goes wrong or even if something goes wrong it has to be behind an acceptable level.

Definitions, like the one, by The International Civil Aviation Organization or U.S. Agency for Healthcare Research and Quality that respectively define safety as "*the state in which harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management*" and "*freedom from accidental injury*" so, standing from this point, is clear the inverse relations between safety and risk.

The inverse relations between risk and safety put the analyst in a position of not personal direct control, to fulfill the expressed needs of keeping safe a system, to direct manage the process is than necessary an in between passage.

This indirect passage can create a lot of problems, the indirect there can create some shadows in the perception and the errors can be multiplied for each translation you should pass by.

What we are trying to explain is that we speak about safety while we are only watching to the unsafety of the system identifying different variables to manage.

Until the accident of Three Miles Island the main focus defined for the prevention always has been centered in the passive technologies without a high consideration of the human factor roles. After 1979 these factors becomes structural and they have been included in every industrial step of the industry: operational side, design, constructions and maintenance (Swain, 1983) until human factors reached the organization model in a later time..

This way of iterations and work can basically provide benefit just as a feedback, so once the situation has become real and not before, the main problem is represented by the not prediction of a future accident.

Other studies release the definition "*safety is a dynamic-non-event*" that spreading around it becomes "*safety is a dynamic success*" (Weick, 2001).

To explain the previous phrase we can say that is easier to keep and manage simple operations in a safe dynamic, with specific variables, than manage all the operation at the same time with variables that can perceived wrong because are not directly measured..

Detailing more the last definition we can almost define safety as the ability to succeed when expected and unexpected events are revealed, that can also be translated into the knowledge of why things goes right as the complete understanding of every day action's which easily can be summarized in how you work safely?

4.3 Safety as integration of different levels

One of the most difficult challenges of our work is representing by how an analyst should integrate all the pieces of information about a system into one specific tool useful for the analysis of the system.

For this reason we have to integrate many specifications as the locations, the equipment, how the work has been organized, understanding which are the variables ruling the safety of the system.

This challenge can be briefly seen as methodological and also theoretical.

Before the proposal of integration between the different aspects of the plant we need to have a good knowledge of the process itself and also we have to understand how the system is dominated in terms of "*what is necessary to perform*?", and "*why is necessary*?" and "*how you do it?*".

These questions are actually generating the point of view of the system and are also evaluating which one is the limit of investigation and understanding.

Something not trivial is the ability to understand the most important functions to manage safety, and this is proportional with the experience of analyst.

What we are searching is a plain and understandable way of representing our system to easily know where and how to intervene before and after the design of the plant.

In our work we decided to use as a link between the actions using a Gantt diagram, this diagram is allowing the user to create a timeline of the work, with the same block approach, but is also permitting to assign different resources to every single function defined, integrating its cognitive functions if necessary.

A big success for us will be to be able to create a powerful tool that will give the possibility to the analyst to have under control a large amount of data such as technology, operators, managers and executors together in the same environment of analysis.

To link together this kind of different “items” we used the same approach as the one developed from the NASA (National Aeronautics and Space Administration of the U.S.A.).After the accidents of the Challenger aresearcher called Vaughan, in 1996, she started to investigate on the possible causes of the explosion of the American Shuttle, in this cited research she divided the contribution for the decision of the launch decisions and she could be able to evaluate the contribution of each level involved in the decisions that brought to the accident.

She ends her analysis investigating in three different levels, the macro-level (represented by the environmental or external causes), the meso-level (represented by the organization itself) and the micro-level (represented by the cognitions of the individuals) making an extreme exemplification of the pattern represented by the failure of the system under her analysis.

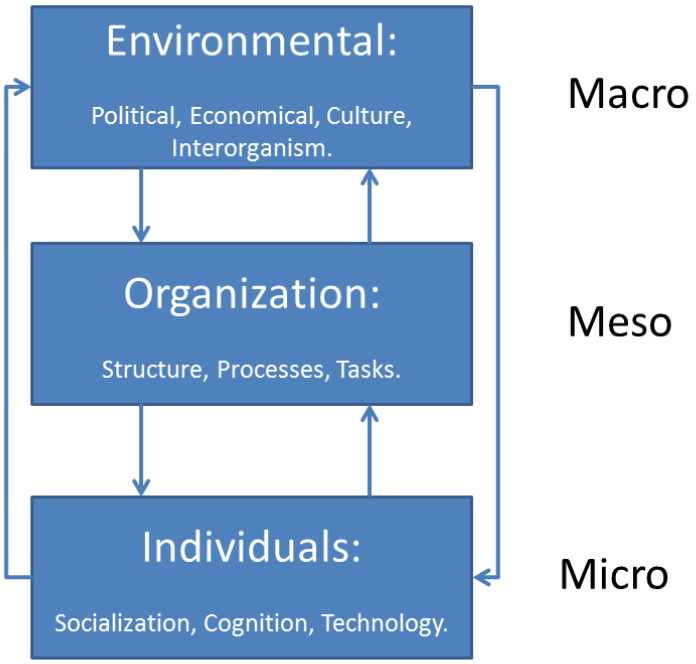


Figure 4.2 Macro – Meso – Micro Model (Vaughan, 1996)

La Coze, instead, is proposing a mix between the two models just explained where he's proposing a new scheme composed by six different areas:

1) strategic adaptation
2) technological or organizational changes
3) design and implementations of safety barriers
4) ability to treat the signals for specific safety problems
5) a good safety department able to challenge the organization
6) safety reviews that can create redundancy

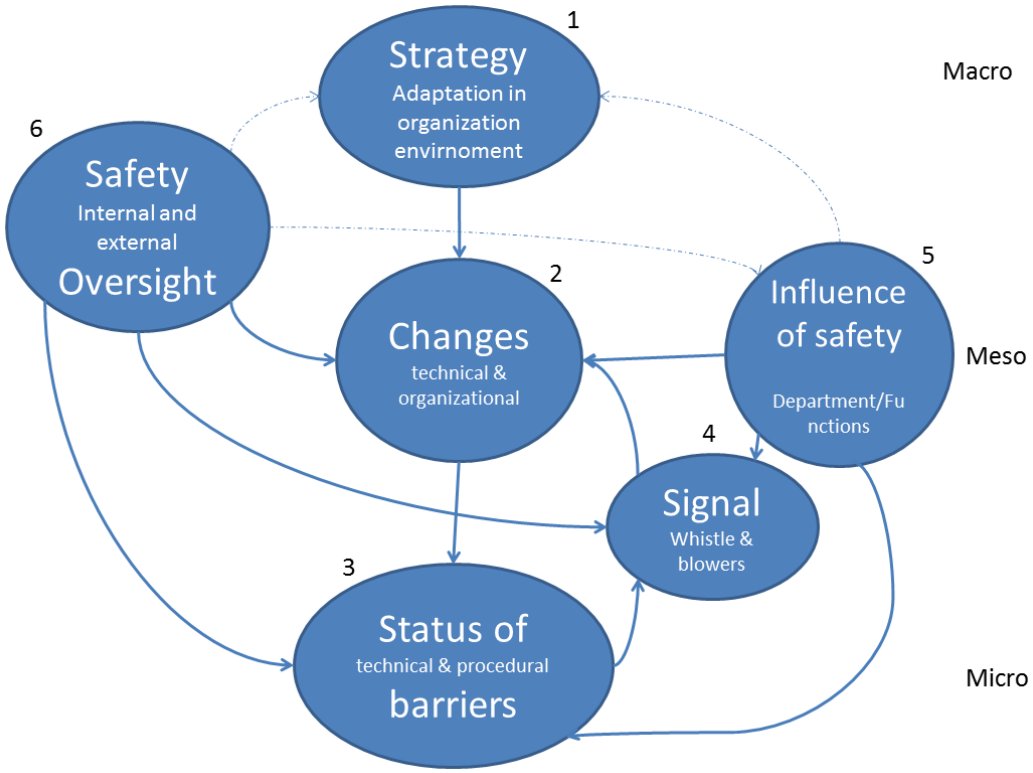


Figure 4.3 Integration of the 6 levels in order of deepness of analysis (Coze, 2013)

This scheme is actually introduced to better integrate in the safety assessment a more dynamical and systemic approach to safety. The technological point of view is integrating in this way a descriptive method. The study we cited is "Outlines of a sensitising model for industrial safety assessment" (Coze, 2013)

Comparing our work with the bibliography just cited in our work we used to split the levels a scale from the macro to the micro with these specifications used in order of appearance: location or space, time and operations.

Interesting to evaluate,going from micro to macro, is that the micro level is involiving the status of the bareers and the evaluations of the signals out of the sensors of the machines as a not dividible elements to evaluate. Then in the meso level are fitted the changes in the procedures in the technical side, such as any organizational procedures, and are also placed the definition of the departments funtions, one example can be the priority attribuition to one process line instead of another one. Finally in the higher level we consider the strategy of the organization, for example the planning of specific products, and the general overview of the company that can consider for example the quality of the production more important than the quantity.

In the end we can compare this proposals as the archaic one and its last review more detailed.

4.4 Caracteristics of the levels

In many studies we find a real interest in the correct division between different levels into blocks and sub-blocks until being able to reach the actions or functions that are not breakable anymore.

We decided to follow somehow our study as follows.

The first decision we took was to be able to divide as much as possible all the different functions of the analysis in order to be as clear and detailed as possible, this becomes possible creating layers that could go into deepness in the process structure. Second of all we divided the system in order to characterize each level with a particular attribute and we wanted that this attribute could be satisfied by the caractheristic of the level or by the sum of the levels below, each below level can be seen as a check list to be complete in order to complete the upper function. With a structure like this is becoming clear that we are designing a sustainable tree that can be read in two directions from up to down (discovering new details and from down to up discovering the upper goal of the analysis).
Is becoming also really intuitive to, later on, discover the possible mistakes and isolate them from the rest, this because all the components are exploited in its fundamental elements.

The most important side of our project was to try to keep specific information at the same level of deepness. This is extremely difficult because the functions with similar characteristic are mixed and are usually non easy to visualize.

For example in Figure 4.4 are represented systems and systems elements, the system elements can be seen as the final action to perform on the machine while the system can be view as the sum of different actions. Is possible to see that the “systems” are spread in the diagram even if, for each level, is necessary to fulfill a specific requirement in order to be placed at the specific level. In this order, defined by requirement to fulfill, there is also the possibility that for different branches the requirement can be satisfy by just a “system element”, this because is already fully described for the specific necessity, something that is possible even at high levels.

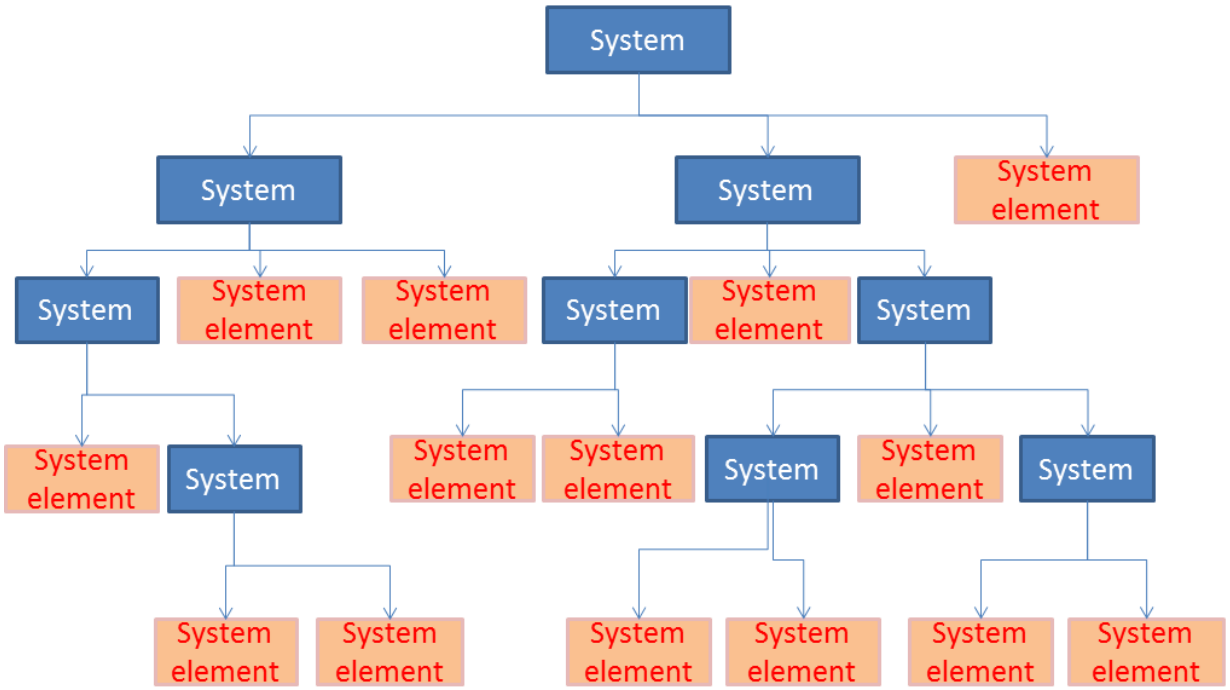


Figure 4.4 Example of a decomposition of the levels

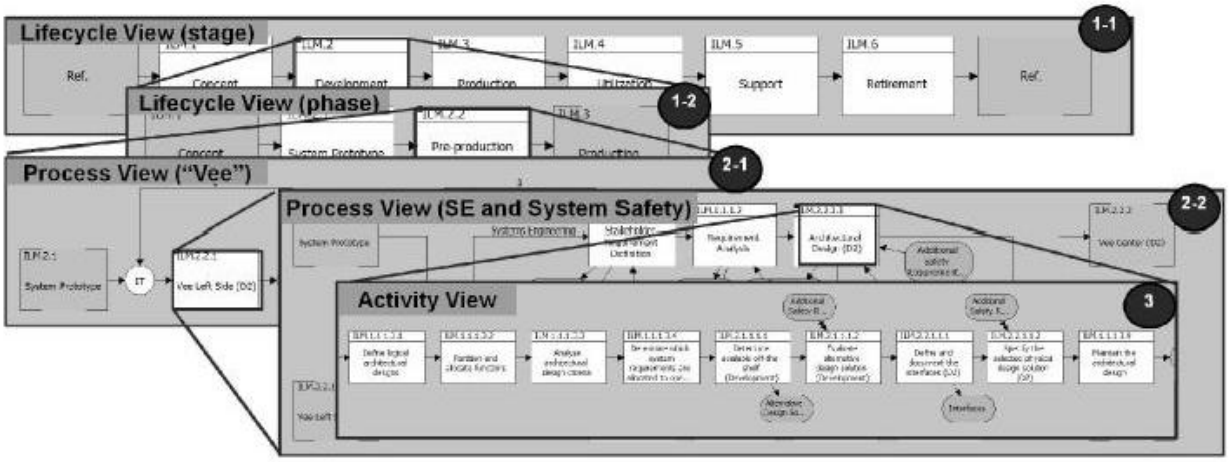


Figure 4.5 Example of specific action decomposed between different levels. (Jae Han Yoon, An Integrated Process Model for the Systems Development Requiring Simultaneous, April 7-10, 2008)

4.5 The importance of the hierarchy

While we were creating our model, we have seen that an important side of our work should be spent on being able to create a good communication approach between the different levels of our plant. This would permit us simplify the passage of knowledge and it will let tend our plant to be more manageable. In the last years the challenge of the supervision of the systems is becoming

more and more important, due to the high complexity of the systems, the needs is to involve always more variables to take under control, this permits to have the plant more controlled by sometimes less manageable.

Complex systems are often related to hierarchical system because the single independent, or nearly independent, function from which the system itself is composed can be structured as a sum of easier functions.

The links between the different actions of different grades is always difficult and can be seen as the real added value while evaluating the logic behind the structure of the plant, or the operations in the plant itself. The difficult part is the brake down the system with a consistend approach and keep the functions at the center of this division.

Depending on the hierarchy, and the focus that can be really variable, the idea is to try to keep the system easy to trace and, at the same time, a scheme where is clearly shown which are the fundamentals with what is necessary to complete system. Important, to have under control at the same time, are three criterios such as the production, the safety and the cheapness of the all system.
For this reason a good hierarchy and structure would be the one where you create a big added value while the system is safe and cheap.

To satisfy what just expressed is necessary to have clear which functions and actions need to be communicated and how this infos must be supplied to the operator on field. To describe a good hierarchy is necessary to clarify who have to decide, what and how to trace the communications between the different levels. This will permit the analyst to clearly understand where to intervene in the managing decisions.

In our analysis we ranked the functions for geographical disposition of the element that must supply it, than the physical connections between the functions and the cognitive resources necessary to understand the activity to do.

For cognitive resource, in this moment, we mean the mental workload necessary to carry on the action to perform. The information necessary to describe every single action can be summarized in three main chapters:

- What kind of information is necessary to complete the task?
- How this action has to be performed?
- When the function has to be accomplished?

Normally, we have seen that the task that require a lower level of cognitive resources are regarding the monitoring of some action to be performed, this can be due to the simple necessity to react with reflex to something that is happening. This cognitive requirments are becoming more clear when you have to diagnose something, for this ations is required a higher level of knowledge. Here the task can become more subjective, and more suitable, depending on the human operator beacause, depending by the operator that is carring on the actions, the task can be influenced by the way of reasoning and by the competences of the operator it self.

If the system is hierarchically clear and hierarchically structured, this is allowing to put the analyst in an less complicated position to intervene. For example, during emergnecies responde to the alarms without any dubt. In Figure 4.6 is possible to see that the main focus is dividing between monitoring task and diagnosis ones. A normal comparison where the actions on the plant are ofter overviewed by someone with a higher knowledges than the one which is monitoring what is happening. The picture can be seen as an example of any level of how the plant is composed. Each level is characterized by actions to perform just on the base of the reflex, actions achieved proceding instructions or actions done based on the knowledge of the process (axis Y), each task also can be described, with numbers, analogically, symbols or hierarchically depending on the grade of complexity as seen following the X axis.

In the study proposed by (Manuel Lambert, (1999)) the evaluation of the X,Y plan can be seen as the relation between the operator and his supervisor where some of the actions are absorbed, depending on them codification, into more complex one while supervised.

This permits to reproduce for each level of the pyramid of the system the same approach and later on is allowing to extract the necessary infos to describe the system in its entire complexity

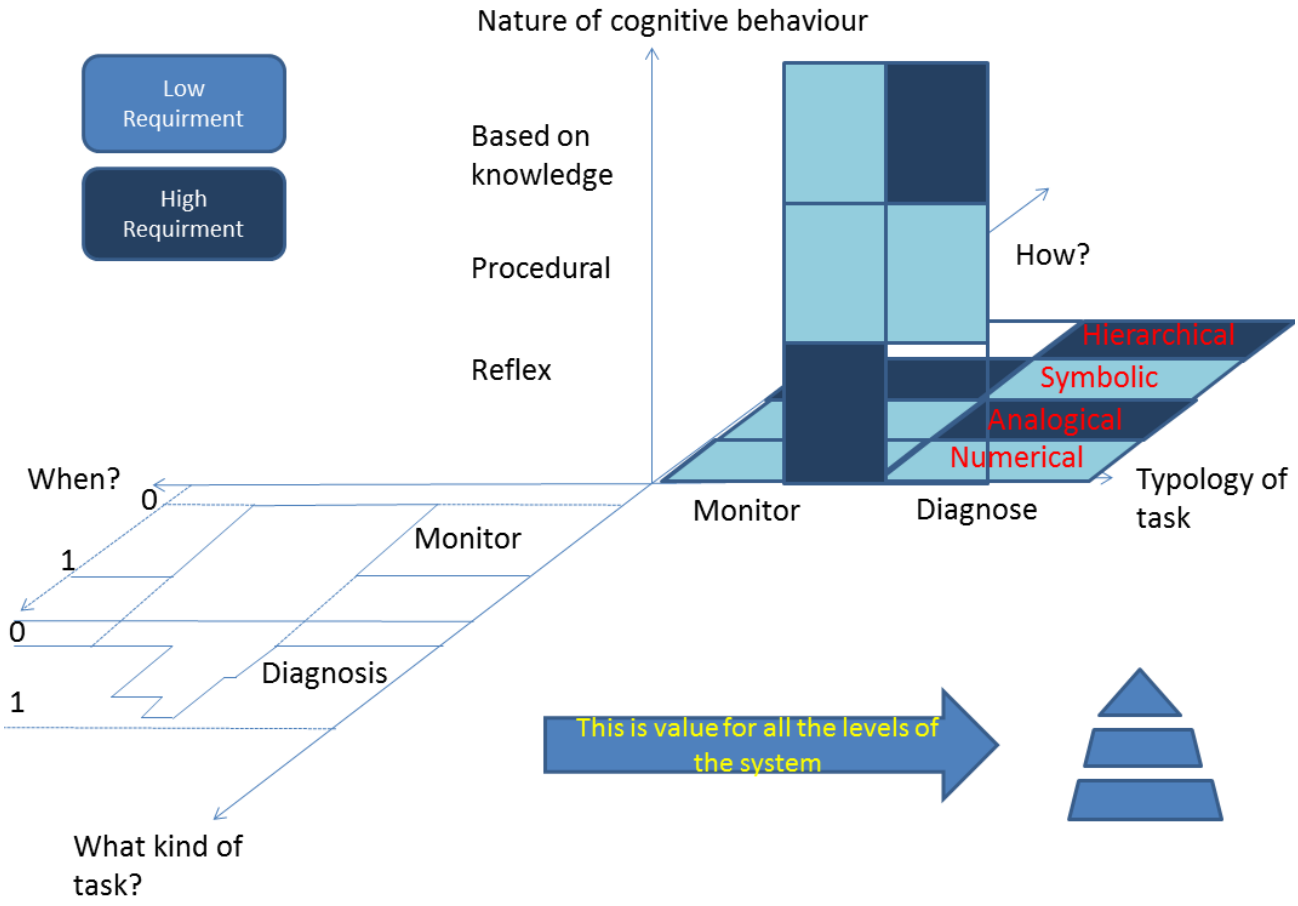


Figure 4.6 Information contained in the levels (Manuel Lambert, (1999))

Helpful to underline is that is always the analyst, or the request made to the analyst, are focused in defining the level of deepness that should be followed, basically the needs is always to have focused and connected three elements where to base the analysis:

- Structural (to describe the physics elements),
- Functional (to describe the mission of the elements) and
- Behavioral (to describe the way to perform the actions).

These three specifications can be seen as blocks with their functional specification as the heart of the analysis, this elements must be linked together witha double arrow that permits them to communicate each one with the two other specifications.

The function analysis, also called FA, can have a double virtue, internal and external: external to produce material for the value analysis necessary to satisfy clients' requirement and internal to describe the characteristics of the process.

Obvious to remark is that going from the top of the pyramid to the bottom the functions to measure are becoming always more specific to diagnose.

One of our goals is the to propose an analysis approach that would not be subjective but more objective as possible especially in the definition of a consistent hierarchical structure especially for the human supervised functions.

In Figure 4.7 is possible to see a tipicall structure of supply chain where, with the division between structural, functional and behavioral is possible locate different branches in different levels that are mutually connected. Here, the outputs and inputs are strictly related to each other while passing between different functions of any levele of the pyramid, this structure is also typical of the continued control mode.

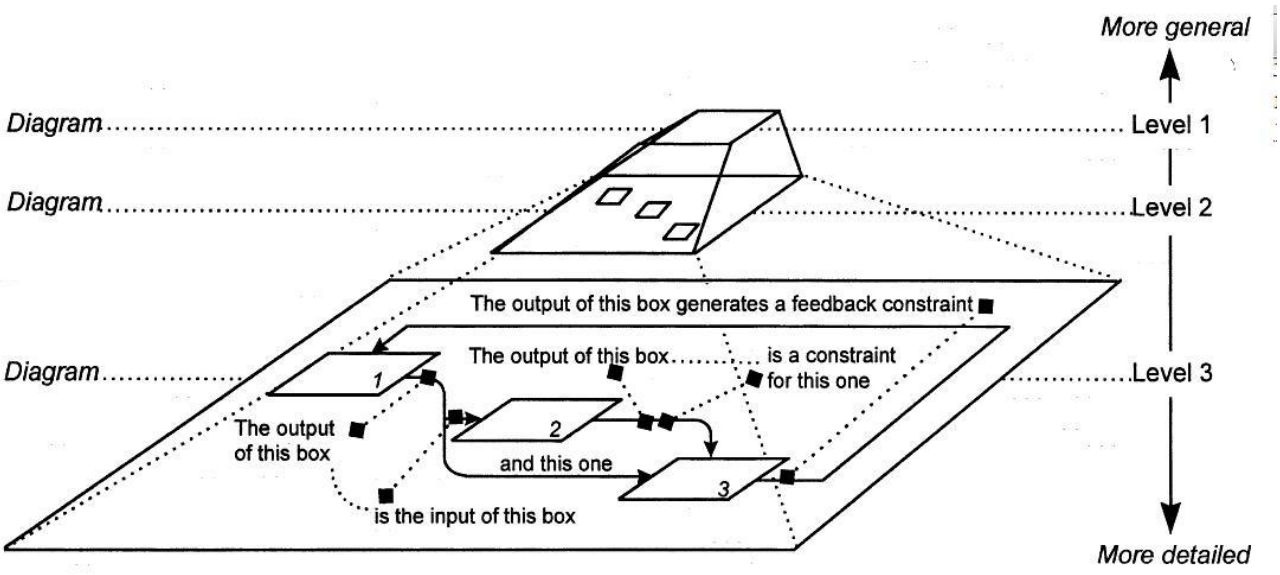


Figure 4.7 Every level have his goals and actions to satisfy (Manuel Lambert, (1999))

4.6 Functional Hierarchy

To fulfill the needs of the analyst, in the conceptualization of the system, we studied several modes to represent with the most pertinent approach the system, in the final resume we assumed as a main variable the Functional mode as the more representative approach usable.

In the paper of (Mohammad Modarresa, (1999)) we have discovered an approach that includes many of the requirement we are trying to satisfy with our proposal. The paper is trying to find an unique translator for several different lenguages approach. The functional hierarchy proposed is permitting us to evaluate the relevance of the actions in terms of process importance, if is certainly achieved or not, even more is extremly multidisciplinary.

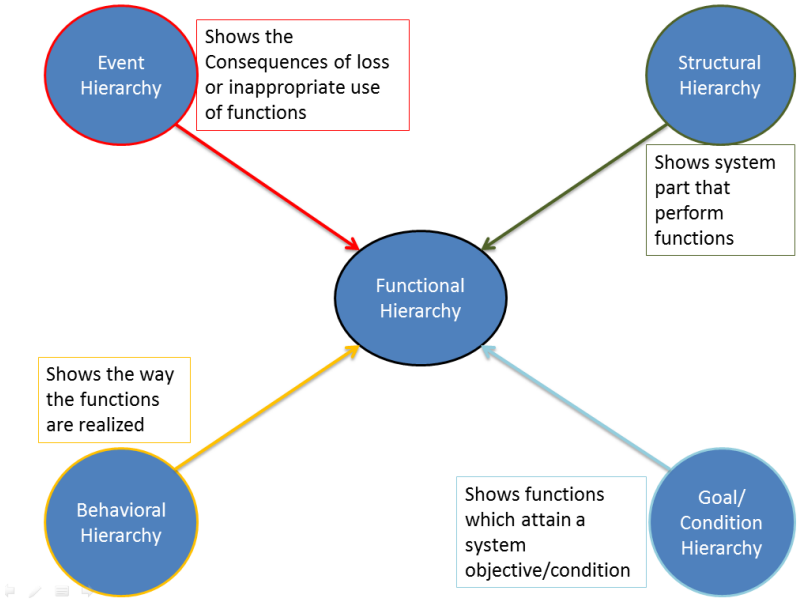


Figure 4.8 Functional Hierarchy structure (Mohammad Modarresa, (1999))

The several information we're obtaining analyzing the system by different approaches gives the opportunity to create different slices in the same layer of observation, integrating information from four different aspects of the system interconnected with each other's.

The four hierarchical contribute are:

- Behavioral: is expressing how the action is performed describing a set of state transitions and can express the difference between expected and observed behavior
- Goal/condition: permits to describe the internal environmental conditions describing the state of the system due to the actions performed or the one still waiting to be performed
- Event: are the expressions of the milestones happening in the system, the situation that are happening or occurring with certainty.
- Structural: permit to define the importance of the actions dividing in grade of importance for the defined goal.

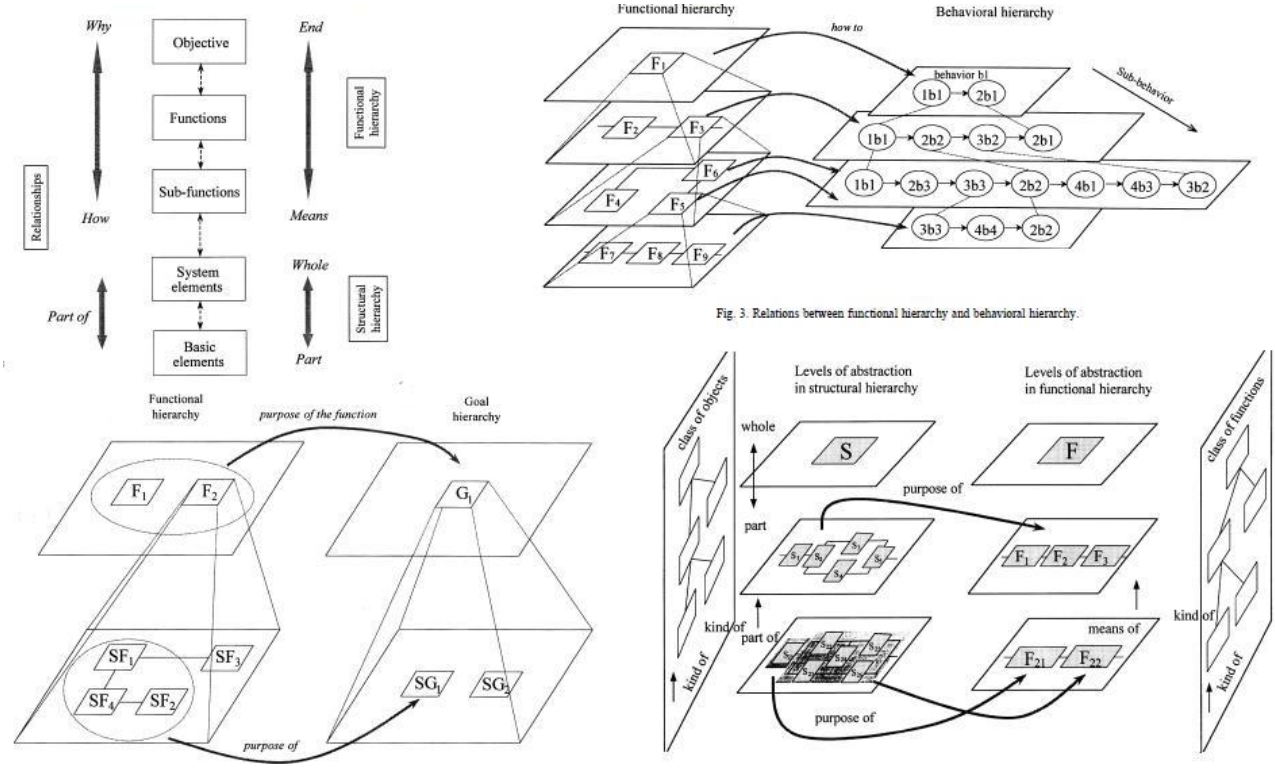


Figure 4.9 Integration in one graph of the single perceptions (Mohammad Modarresa, (1999))

In a brief explanation, the Figure 4.9 is representing the connections that the different elements are having with the functional requirement and any, of the four just expressed, contributes are having its direct translation into a functional variable that can be analysed individually. The definition of the layer is becoming than intuitive, iterative and descriptive of the all process this because the functionality is becoming the common language to define the different aspects of the system.

The relations between the nodes in the functional hierarchy can be logical or physical. The usually logical connections are used to be binary, while physical's links are used to be not binary.

In this way is also possible to define it primitive functions, a concept developed also in the same paper to describe the basic functions that are representing the variables from the database which each action can be made of.

The four aspect from how is composed this database are:

- The Functional promitives: which is describing, in an allegoric possible phrase, the verb or the action that must be done by the function.

- The physical variables: can actually being translated as the subject of the phrase to have under control.
- The objects: is generally the items that is necessary to keep tracked.
- The context: is actually represented by the surrounding on where the phrase is fitted.

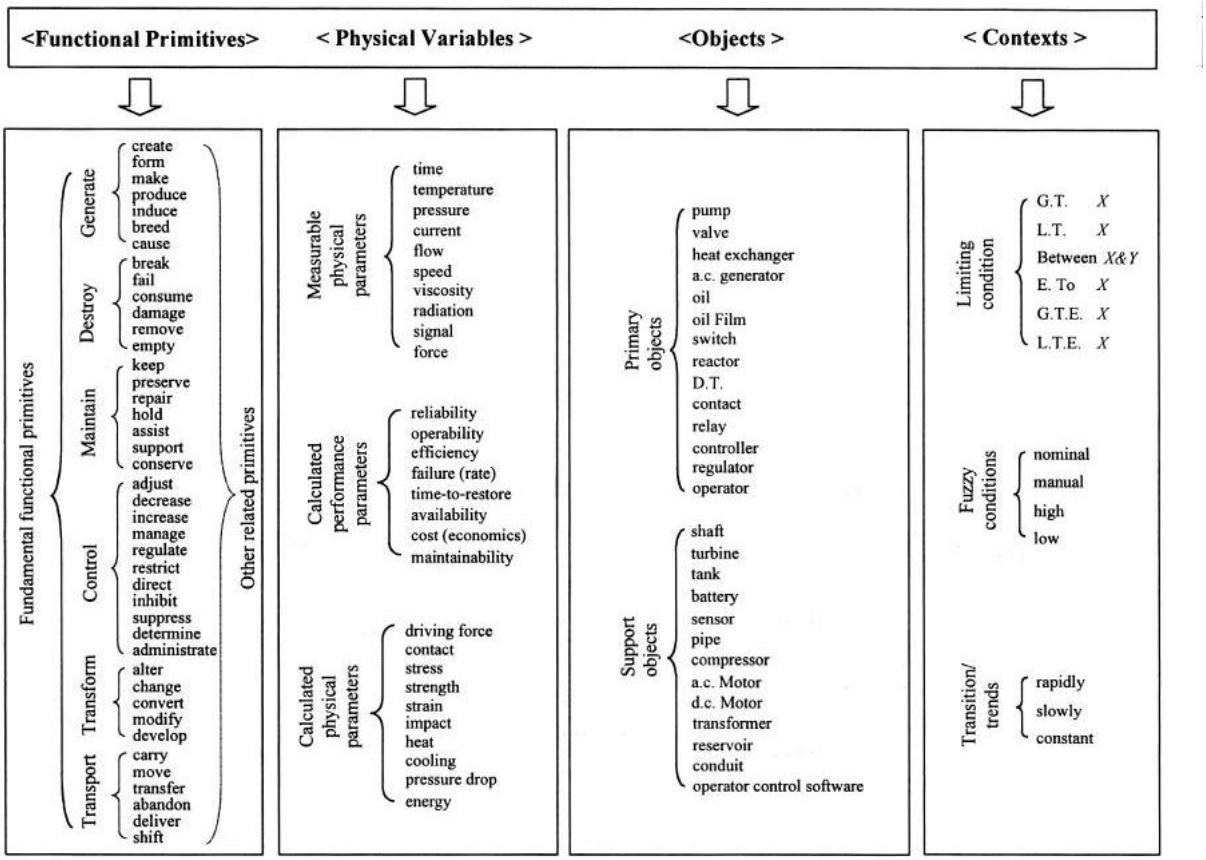


Figure 4.10 Example of possible description of the phrases defining the actions with a multidisciplinary approach (Mohammad Modarresa, (1999))

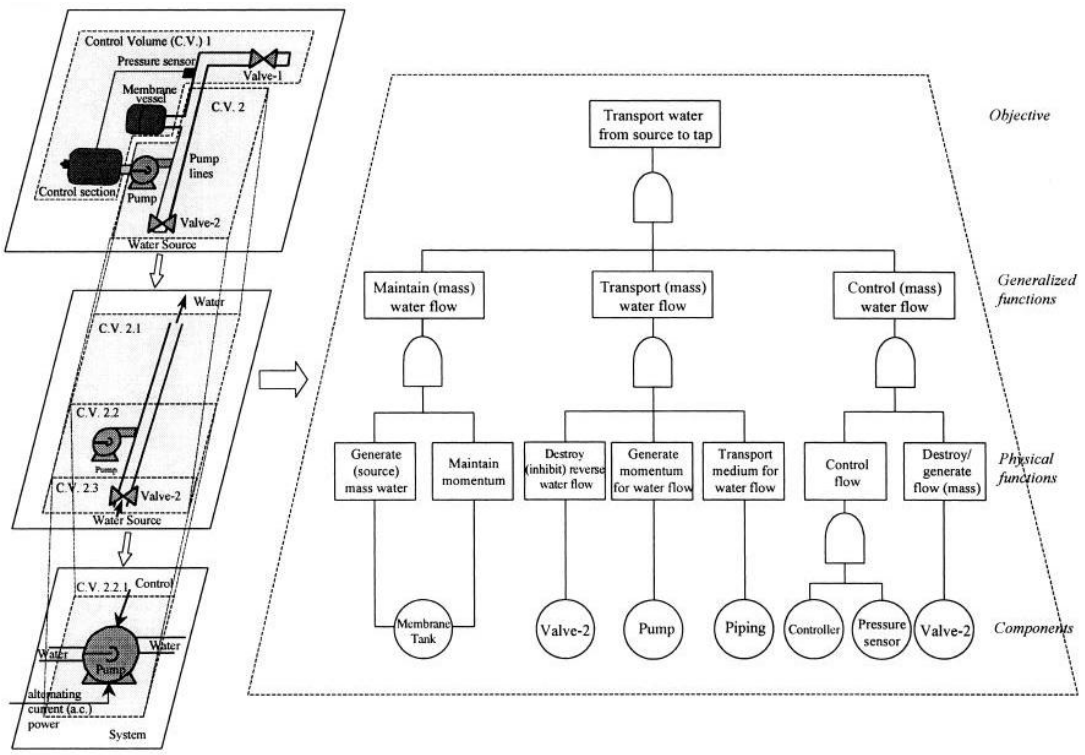


Figure 4.11 Example of trasformation from the P&Id's to a graph in this case a Goal Tree (Mohammad Modarresa, (1999))

4.7 Specifications

For all the reasons expressed above, to support this analysis, we have to know several information like:

- Which is the state of the unit under investigation?
- Which machines are on the line?
- How the organization of the unit is organized?
- Whate are the guidelines or the best practices to work with?
- How humans can effectively work on their workplace?

How to collect then all these necessary data?

Some data have been given by Mapei, some others we had to be able to rebuild it by our self, as extra controls or procedures that has recently been updated.

Some of the data given by Mapei has been the P&ID's diagrams, while the Decision and Action Diagram, also called D.A.D, and the Human and Technology Interactions, H.T.I we had to rebuild it starting from the manual of cunductions.

These data are useful for us because we have to assemble a database that could fit with the idea expressed in the Figure 4.12

The scheme expressed in Figure 4.12 can be evaluated as the base for the creation of a database, in these scheme we can see what are all the informations that is necessary to extrapolate to create a complete analysis of the elements part of the plant.

The main components of the system are:

- Components: the components represent the physical part of the system, it can be build from other component, it involves hazard, in the component is allocated one or more function and is constraints by constraint
- Constraint: is the block that is not permitting to go deeper or is vinculating the outputs of the components for example, is constrained by other constraints is traced by requirments and can trace from hazard
- Function: are the hearth of the scheme and are involving the operation of the system its requirement involving the hazard and having the item as output, are allocated in the components and can be part of another function or can be decomposed in other subfunctions.
- Hazard: is the subject to minimize it is involved in the requirement of the system, in the functions necessary for the process, is also involved in the components and is part of the item to produce and can only be minimized by constrains
- Item: is the final goal of the process, is the outcome of the functions and intrisecally involves hazards to minimize
- Requirment: can be seen as the starting point of the system, intrinsically incorporates other requirments, is traced by functions and constraint but it involves hazards that must be resolved by the constraint it selfs.

These scheme involves actually all the informations that must be fulfilled to have under control the all process. In our project we had to satisfy some requirement passing accros the structural decomposition of the functions allocates in components and logically or physically constraints minimizing the hazard while having item as an outcomes.

When we are able to satisfy all this six detailed passages, reading the documents given us, only than is possible to describe a correct analysis of an integrated process, to satisfy and

connect all this different informations together, we had to work on the timeline and integrating the infos with the Gantt diagram.

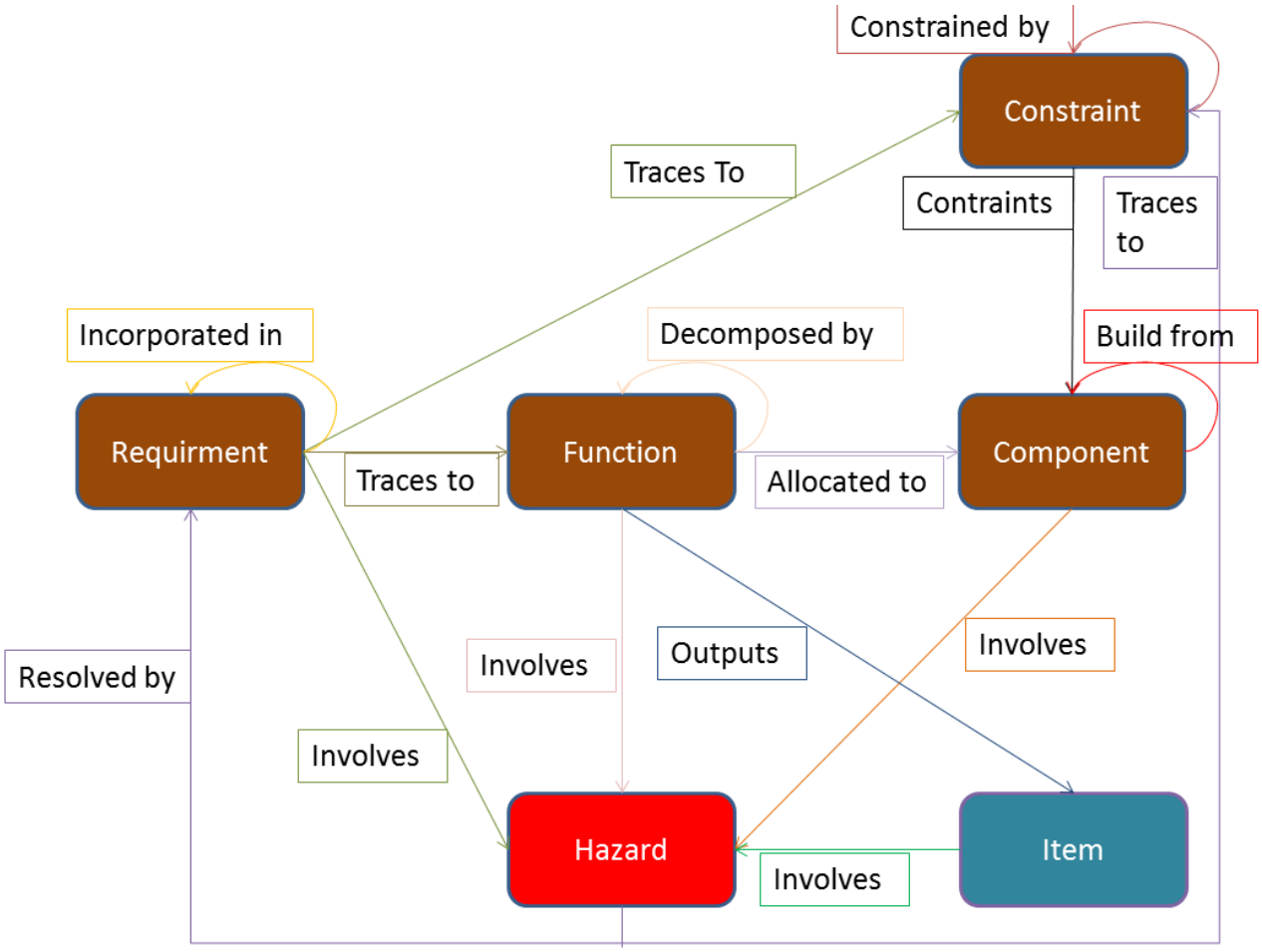


Figure 4.12 Database schema for integrated process (Jae Han Yoon, An Integrated Process Model for the Systems Development Requiring Simultaneous Consideration of the SE Process and Safety Requirements, SysCon 2008 -)

The Gantt diagram is providing the possibility to link together different information, recreating a timeline of intervention, this is possible thanks to the discretization of the process. Even more with this diagramm is possible to attribute to each task a resource that will conduct that specific operation, something that can help us in the further "task analysis"

In the Gantt diagram we had to work on the "Task Analysis" and also on the "Functional Analysis" represented by the action presented in our diagram (the reason why to highlight one action in respect to the others for example), which actually means investigate and understand why we perform that action and to what that specific action is necessary for.

The Task Analysis is mandatory because it gives us the opportunity to define the procedure and design the checklist and is also e first example of structured analysis that integrates several aspects of the complete industrial environment comprehensive of humans behavior and machine analysis.

Good TA you have to follow the following 6 steps:

- Define the task under investigation and identify the purpose of the task analysis. The analyst should have some further evaluation methods in mind for which the TA will be useful and should have reason for needing this type of analysis to be performed.
- Data collection - In order to carry out the TA it is necessary to obtain data about the task is performed. This could be collected via observation of the task in question or from a detailed specification of the device under analysis. Alternatively, interviews or questionnaires with people that have first-hand experience of performing that task could be conducted to gather the necessary detail.
- Define the overall task goal, which will be presented as the top level in the TA. An example might be "increase average speedby two steps". This describes what has been achieved by performing the task; however, at this stage there is no indication of how the task will be performed.
- Determine the next level of sub-goals by breaking down the overall goal. This provides more information about how to accomplish the task; however, it can still be broken down into smaller units, which will describe the individual operations (performed via the visual, manual or cognitive modes) that need to be performed.
- Continue breaking down the sub-goals until all operations are identified.
- Define plans to describe how to perform the operations in each sub-goal level of the hierarchy. In the fan speed example, the two operations will have to be performed in series, one after the other. The plan will instruct the user to "perform 1, then 2". Operations can also be performed in parallel, and in this case the plan would instruct the user to "perform 1 and 2 together". Numbers should be assigned to the different levels in the hierarchy.

4.8 Functional analysis

The definition of the functional analysis is to intend the effects of a system, subsystem to its product or part of the system itself.

Every single function has a single and definite purpose in order to say “what” and “why” has to be done before than “how”.

Functional analysis is aimed by the idea, in order to design, develop and prove complex engineering system, that the main requirements of the system is intended to fulfill must be clearly established.

Functional analysis is also carrying on the concept of breaking down the main system functions thought-out many different design levels (for examples system, subsystem, units) to better define all the layers we need to know the number of levels involved, the idea is the one that, may be in a second time, the analyst can structurally decompose the function in a n+1 levels to better explain the action needed.

The main objectives of the functional analysis are:

- Allow complex engineering system to be well understood and realized
- Ensure that the functions are partitioned in an appropriate manner
- Control the coherence of the project and the link between the actions needed to reach our goal
- Identify functional requirements of a system and the interfaces between actions.

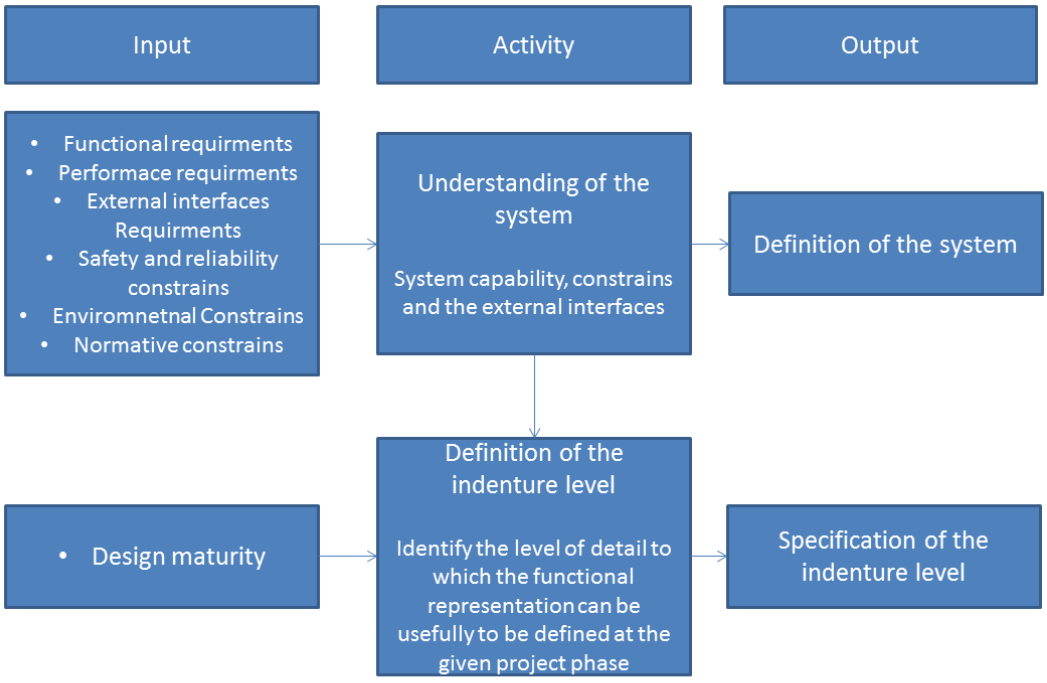


Figure 4.13 Input and Output for the functional analysis

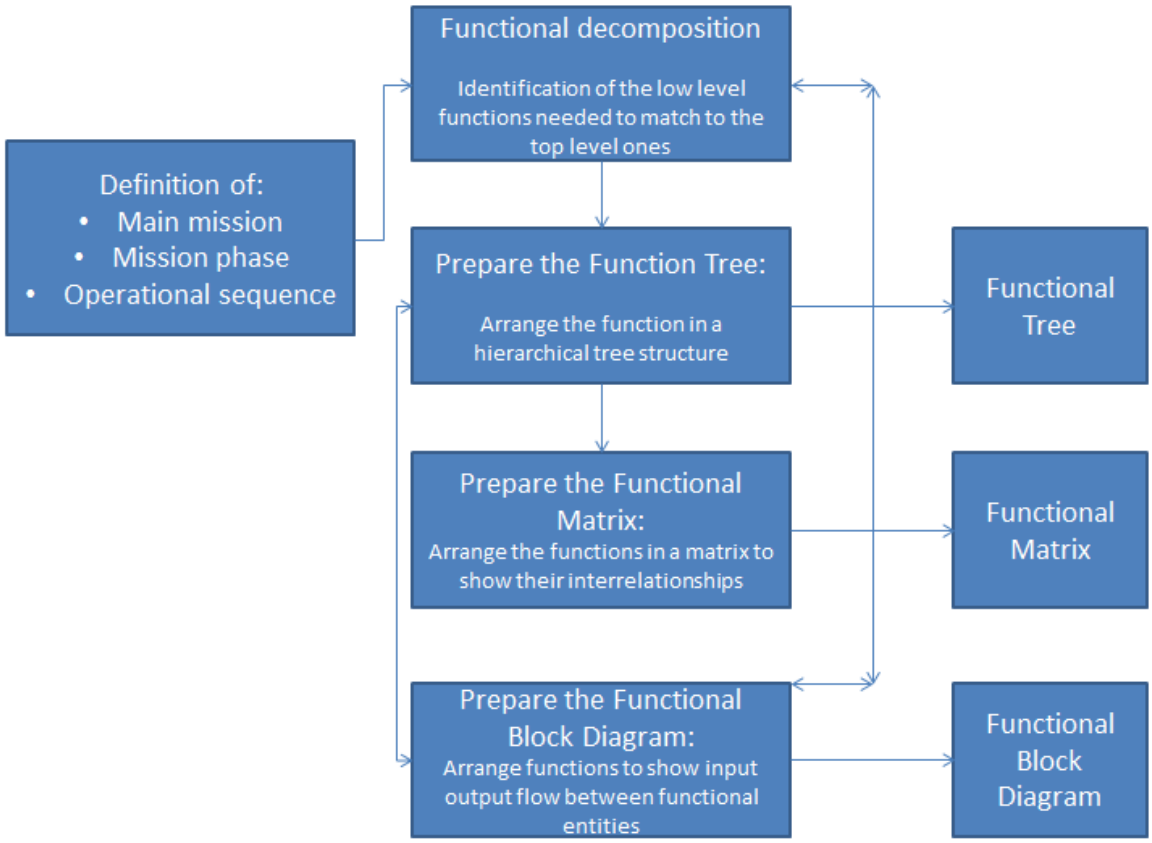


Figure 4.14 Structure of the Functional Analysis

Subdividing among the levels of importance of the involved areas the different sub-sequences we are able to create a sort of a tree also called “function tree” that provide a clear visibility of a large amount of functional elements showing up the complexity of the system.

The function trees are also allowing to enable errors, omissions, inconsistencies and duplications to identify more easily through the branches exploited of the areas involved, even more is allowing the user to easily verify that the lower level functions are consistent with the top level functions (is also true that a lower level functions can be required by a number of main functions and therefore it can also appear more than just once in the subdivision).

Function	Description
1	Pre management
A	Process
1.1	Preliminary analysis
1.2	Building of disposal areas
1.2.1	Building of the dump for the waste disposal
1.2.2	Excavation and fillings to build the storage area to be water proofed

Table 4.1 Example of Functional Tree

The functional analysis, can also be used to schematize the process under investigation through milestones; these milestones are the minimum one that can reproduce the actions necessary to represent the reality of our process.

Behind the necessity of the identification of the function from which is made our process, it must be clear that is required a good knowledge of the process to understand why we use an action instead of another one, everything in order to reduce the complete amount of functions involved in the re-generation of the system to simulate.

Functional Analysis is therefore necessary to understand and rightly evaluate the passage and steps that must be achieved describing why you perform an action, or task giving, an explanation of the reasons, situation extremely important in the safety world.

Thanks to a right evaluation of the functions is possible to reduce and redesign, where necessary, the task. Evaluating each task directly and without other steps is not shifting our evaluation into a wrong one.

4.9 Logic Sequence

After the identification of the basic function involved in the analysis, an important and fundamental step is the creation of the connections between each single function that characterize our process.

A quite complex work has been the creation of the structure from where to start the analysis, different variables has been evaluated like:

- Time dependent, with the problem that than we would have to deal with sub-action that were working at the same time;

- Space dependent, also in this case we could deal with action performed in the same space at different time

At the end we decided to identify as a main variable the “Functional-Priority” rather than any other, the variable Priority is actually regarding what you should do first to be able to accomplish than your next goal but also would mean that it should be used in deepness because to build the Macro-System starting from the Micro-System that is managed with the same approach, this for not lose the specific reason that guided us in the previous choice.

The logic behind this decision of variables is the fact that you must achieve a specific input in order to allow the action defined to be performed using the resources typical of the “black box” defined.

The functionality instead represent the necessity that the action needs to be functional for any reason to the specification, is the input that is the most effective on the output of the action and at the same time it represent in the best way the action.

The definitions of the connections are made for area of competences instead of for time shift.

The variables that are managing the different functions can be seen as a set of four subjects inherently connected: Behavior, Event, Goal, and Structure.

- The behavior underlines the side of the function that represents the way of how we accomplish it.
- The event gives the overview of the consequences for the loss of the function.
- The goal represents the conditions or the objective to attain.
- The structure shows the part that physically performs the function.

The possible mix of these four subjects might be all valuable but, in our opinion, the hierarchical order can be:

Goal, Structure, Behavior, Event.
Obviously the inside ranking of the level is governed by the appearance order of the action.

- Goal can be characterized by the mission of the group of task or action that will take place,
- Structure is defined by the spatial areas of where the goal will be arranged, example

- Behavior is intended as which are the passages necessary to complete in the structure,
- Event is the real action or task to be completed for the right execution of the process.

4.10 The Semantics of the Process

As seen in the previous Figure 4.10 is important to define an approach that can be implementable also for further evaluation, this approach must be multidisciplinary also for further implementation in other sectors but still related to the safety side.

Something we discover during the work, is an issue typical of every process and every manual, the analyst needs to understand perfectly what has been written on the manuals for this reason is than extremely necessary to translate words from paper to reality. Sometimes what has been written is not exactly the same as what is happening on practice or is difficult to understand if the background is a bit different.

Translating from what is written in the manuals to the reality can be hard, this because there are some action that are written. More than once, we have seen that actions that should be done at a specific time has been postponed because must be done more than once as a double check for the action performed before.

Due to the high repetitiveness of the actions, over and over again, sometimes the operators are also actuating shortcuts not written and this can generate misleading process-stories. This reasons brought us to have a comparison after the first sketch of the process designed between the analyst who designed the logic of the process and the plant operators that are daily working on the plant.

Understanding the semantics of the process should also mean understand exactly which actions are necessary to implement, without any doubt or possible misunderstanding by the reader, because the user who read the paper has to be in the position to not actuate in the wrong way.

A perfect understanding of the process is allowing also the analyst to investigate the plant operator in the right way, reducing the possibility of reproducing errors in his analysis.

Concerning our work, the right understanding of the process means, being able to reduce the total amount of the possible fail option into the only one necessary to describe the plant, our goal is to understand which is the only action necessary to describe a specific passage in the most detailed

way, this must be done in order to not have a second option and variable that could influence the interrogation of the system.

Interesting, to investigate by the analyst, is the identification of the goal of the analysis regarding the effectiveness of the question that can be made to understand the system. Depending by the requirement of the contractor of the analysis, starting from the input given by the industry, the approaches of the analysis can be different and also the intervention necessary to identify can be exogenous or internal respect to the assigned specifications.

Usually the inputs should be selective, simple to identify, precise, recursive and usable also for other phases or actions.

Once setted the specification to achieve, somehow we've identified the bound where our analysis has to regard; this means that everything is arriving from outside the bound must be considered correct, the bound determination is also part of the semantic cause is individuating the limit of the project.

The bound identification is necessary also to restrict the number of specific single variables to consider, otherwise the excess of variables would generate a universe too big to analyze in a proper way, limit that should be adequate to identify the specifications we have.

Define the bound of the action, and of the system, also means to be able to identify which ones can be the input of the subject of our actions the action performed and what we should expect out of the transformation of the system.

One of the aspects of the semantics can also be interpreted as a possible further replanting of the process in a shorter or more secure ones. Is also possible that there can be more effective disposition of the activity, this still staying inside the operability limits imposed on us, redefining a possible sub-division of every single phase.

The characteristic of the semantic interpretations are necessary to understand the nature of the fluxes and their mix between each other, like physics actions, logic information's, responsibilities and relations.

A correct semantic understanding permit it drastically reduce the amount of action, which token alone, could be represented more than once because they could be repetitive.

An example of systematic approach to the semantic of the process is the following one shown in the Figure 4.15 where is defined a basic question and then is evaluated each important variable.

Table 20.1 Questions to be asked before process fluids are admitted to a new plant

1. Have the following been removed from the new plant area?
   (a) Contractors' huts, tarpaulins, etc.;
   (b) Non-flameproof equipment;
   (c) Rags, paper, wood, rubbish, dry grass, weeds.
2. Are the following in place and ready for use?
   (a) Perimeter fence and gate(s);
   (b) Security gateman and cabin;
   (c) Hazard and safety notices (no smoking, matches, general vehicles, etc.);
   (d) Nitrogen and/or other inert gas purge systems;
   (e) Oil/water separators and effluent-treatment plant;
   (f) Fire alarm system;
   (g) Fire main, hydrants, hoses, monitors and foam system and supplies;
   (h) Fire extinguishers;
   (i) Eye-wash bottles, first-aid boxes and kit;
   (k) Emergency personal showers;
   (l) Water sprinklers and deluge systems;
   (m) Steam hoses;
   (n) Gas detectors;
   (o) Plant lighting (normal and emergency);
   (p) Pressure relief, flare and/or blowdown system;
   (q) Instrument air and electrical supplies and back-up;
   (r) General utilities, water, power, steam, fuel, etc.
3. Have the following been informed of the plant start-up and its consequences?
   (a) Construction personnel (including restrictions on smoking, welding, etc.);
   (b) Fire services;
   (c) Local authorities;
   (d) Neighbouring plants;
   (e) Records section.
4. Other questions
   (a) Are operating and maintenance personnel properly trained and organised?
   (b) Have drains been flushed and checked free of obstructions?
   (c) Can isolation blinds, etc. at battery limits be readily turned or removed?
   (d) Have shift fire and first-aid teams been nominated and trained?
   (e) Has all welding been done?
   (f) Is there an effective permit system [18] for further engineering work, particularly welding, which may be required?

Figure 4.15 Pre-commisioning questions (King, 1998)

4.11 The F.A.S.T. (Functional Analysis System Techniques)

This technique is a recent technique developed to help the analyst in his work creating a vision on intervention and providing a first convention of symbols and best practice.

The idea is that each function is generated and will generate other function in a specific and coded way in a 2 dimensional approach.

This approach has been conceived for being multi-disciplinary and it propose a language easy to understand also for not expert providing the opportunity to be easy to understand also for other members of the investigation team.

The typical graphical mode is represented by the Figure 4.16

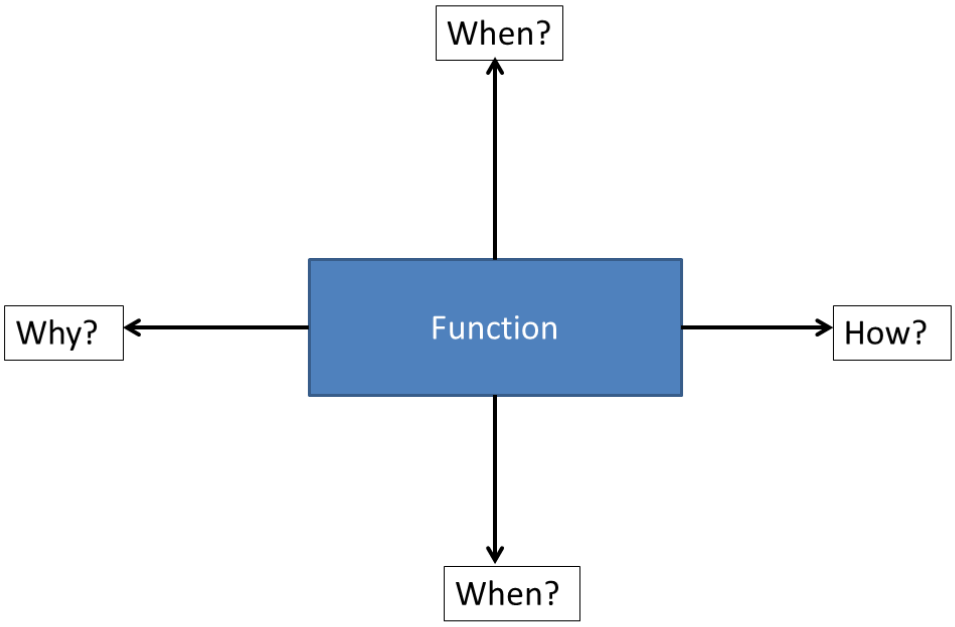


Figure 4.16 F.A.S.T. description

The heart of these method is the action or task as center of 4 directions are managed by the following questions:

-How is the (Funtion) to be accomplished? By (B)

-Why is it necessary to the (funtion) ? So you can (A)

-When (function) occours what else can happen? (C) or (D)

This approach is allowing to made structural the definition of each passage isolating each of the passages from the other making it distinguishable from the rest of the actions, each function is characterized by four directions each of them is just the keyword for the next step.

4.12 Cognitive analysis

The cognitive analysis is that analysis where under evaluation is the mental task process and can be used to simulate or predict the human performance or behavior comparing the tasks with similar one already modeled.

When you are analyzing the cognitive side of the humans is necessary to mix different knowledge's such as psychological, language understandings and artificial intelligence. (Hollnagel, 1991)

Is pretty simple a scheme like the S-O-R one, Figure 4.17, in this case the stimulus are received by the organism which gives a response, more complex is trying to understand which can be the possibilities for different stimulus and how organism are responding.

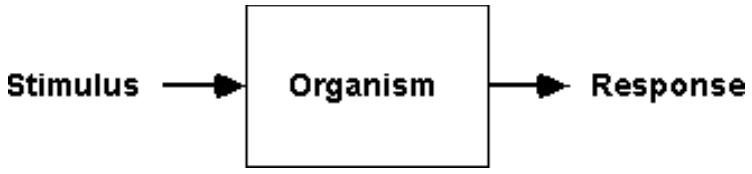


Figure 4.17 S.O.R. model

Several models have been studied and produced to be able to correctly predict human behaivour and the one we tried to use has been the Step Ladder Model, also called S-L-M and shown in Figure 4.18, this model is showing the mental process between the activation of a stimulus and the execution of an action or task.

Comparing the SLM with the Rule-Skill-Knowledge based model, called R-S-K model, is possible to see that every actions performed is following a different way before to be executed.

Depending by the experience of the operator the flow of information would be different and also his ability to operate and interact with the system object of analysis.

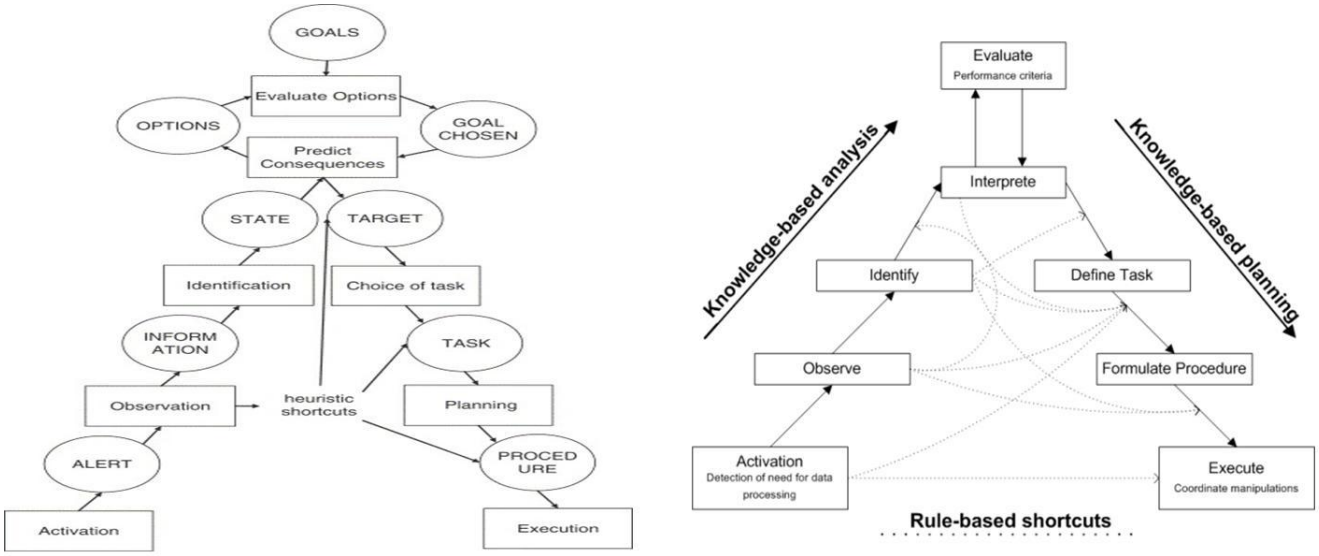


Figure 4.18 Step Ladder Model and R-S-K based model

The Contextual Control Model instead is comparing the actions from which is composed the system with a set of possible general actions already valued.

CoCoM basic's concepts are represented by a set of four different options such as: Observation, Interpretation, Planning and Execution.

Its strengthens is that after the division of functions is easy to assign the cognitive resource to each of the functions and evaluate its possible failure to insert in our model for the probabilistic evaluation of the plant.

Activity type	COCOM function			
	Observation	Interpretation	Planning	Execution
Co-ordinate			●	●
Communicate				●
Compare		●		
Diagnose		●	●	
Evaluate		●	●	
Execute				●
Identify		●		
Maintain			●	●
Monitor	●	●		
Observe	●			
Plan			●	
Record		●		●
Regulate	●			●
Scan	●			
Verify	●	●		

Cognitive function	Generic failure type	Lower bound (.5)	Basic value	Upper bound (.95)
Observation	O1. Wrong object observed	3.0E-4	1.0E-3	3.0E-3
	O2. Wrong identification	2.0E-2	7.0E-2	1.7E-2
	O3. Observation not made	2.0E-2	7.0E-2	1.7E-2
Interpretation	I1. Faulty diagnosis	9.0E-2	2.0E-1	6.0E-1
	I2. Decision error	1.0E-3	1.0E-2	1.0E-1
	I3. Delayed interpretation	1.0E-3	1.0E-2	1.0E-1
Planning	P1. Priority error	1.0E-3	1.0E-2	1.0E-1
	P2. Inadequate plan	1.0E-3	1.0E-2	1.0E-1
Execution	E1. Action of wrong type	1.0E-3	3.0E-3	9.0E-3
	E2. Action at wrong time	1.0E-3	3.0E-3	9.0E-3
	E3. Action on wrong object	5.0E-5	5.0E-4	5.0E-3
	E4. Action out of sequence	1.0E-3	3.0E-3	9.0E-3
	E5. Missed action	2.5E-2	3.0E-2	4.0E-2

Figure 4.19 Activity type, CoCom resources and generic failure bound

To base our evaluation we took inspiration from (Man Cheol Kima, 2006) (Tim Bedford, 2013).

5 Which Instruments are necessary to create the Tool Box: Diagrams.

5.1 P&IDs diagram: Where?

The piping and instrumentation diagrams/drawings (P&ID) are defined by the institute of instrumentation and control with the following words:

"*A diagram which shows the interconnection of process equipment and the instrumentation used to control the process. In the process industry, a standard set of symbols is used to prepare drawings of processes. The instrument symbols used in these drawings are generally based on international society of automation (ISA) Standard S5.1"*.

Is used as a schematic drawing for laying out the installation of the equipment used in the plant.

P&IDs nowadays plays a significant role in the maintenance and modification of the process that they are born to describe. It is critical to demonstrate the physical sequence of equipment and systems, as well as how these systems connect. During the design stage, the diagram also provides the basis for the development of system control schemes, allowing for further safety and operational investigations.

When we're dealing with facilities of the process, P&IDs representation is allowing us to show trough images some of the following:

- Key piping and instrument details
- Control and shutdown schemes
- Safety and regulatory requirements
- Basic start up and operational information

The Standard diagrams are designed starting from the following list of items, and each of them is characterized by a specific design and picture:

- Instrumentation and designations
- Mechanical equipment with names and numbers
- All valves and their identifications numbers

- Process piping, sizes and identification number
- Miscellanea
- Vents, drains, special fittings, sampling lines, reducers, increasers and swagers
- Permanent start-up and flush lines
- Flow directions
- Interconnections references
- Control inputs and outputs, interlocks
- Interfaces for class changes
- Computer control system input

Identification of components and subsystems delivered by others

In our case our diagram, Figure 5.1, is pretty easy and simple and is formed by some tank where are stored the solvents, some weight control, two mixers, one condenser, few pumps, one filter, one cyclone, some vents and few lines for to move the materials.

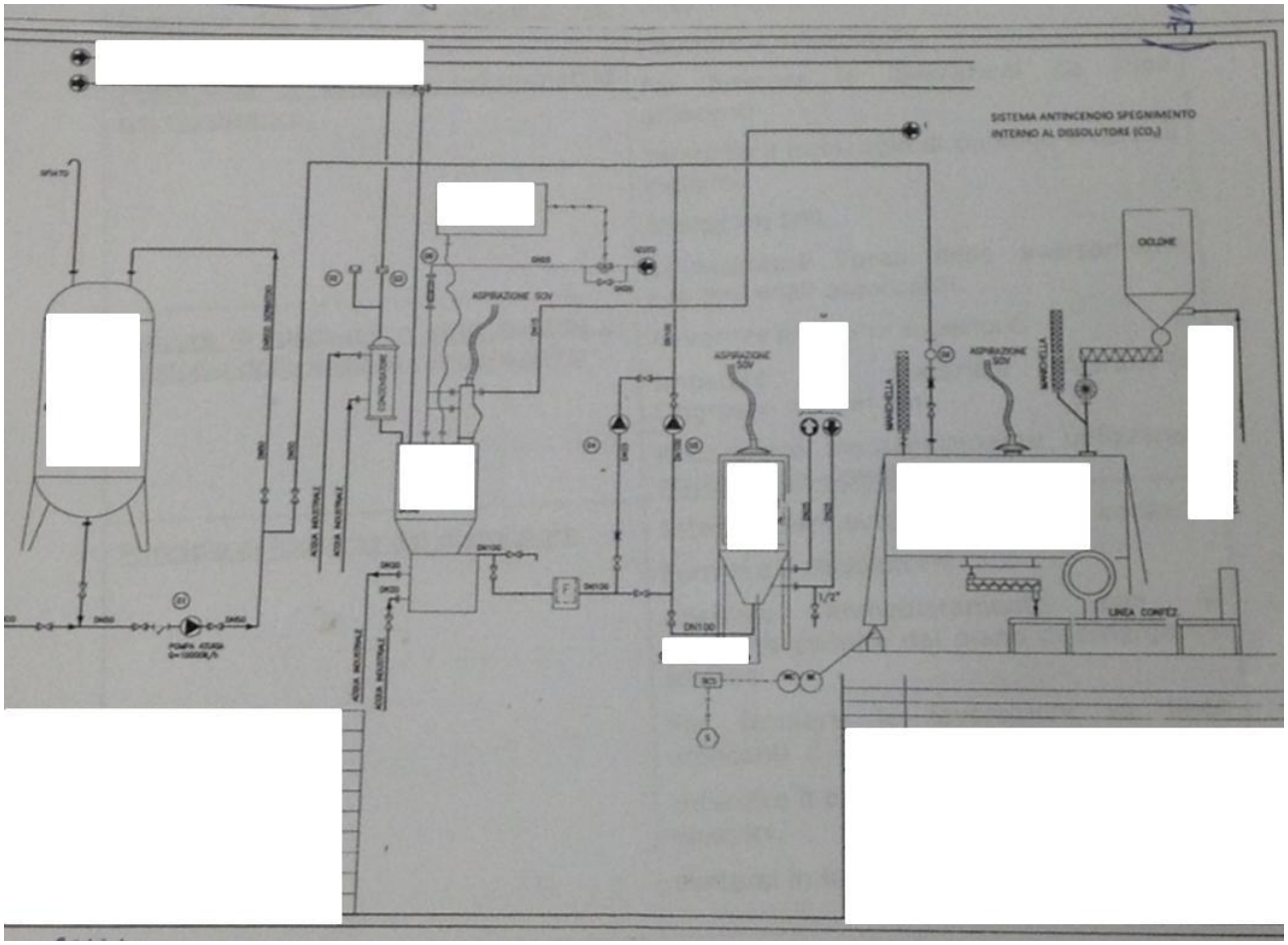


Figure 5.1 Example of a Process and Identification diagram (also called P&Ids), property of Mapei

5.2 H.T.I. Human Technology Interfaces: How?

The Human and Technology Interactions are, as expressed by the words, all the possible interactions that the employee can have with the machines and the explanation of what are, those interaction, permitting to achieve.

Those interactions are not specify in any diagram by their self are just expressed in the manual for the use of the machines and this reason why is necessary to put a lot of attentions in what is written on the manuals for to not miss any possible bottleneck of the process.

H-T-I are all the relations between the subject Human and the subject Technology, the relationship is usually managed by the Humans that normally are in a key position because are the one which are letting the system going on taking the decision to continue.

A typical example is the lecture of a display given by the technology, the human has to understand the information and analyze, for example, the degree of development after the interpretation

given by his knowledge the human is taking the decision that needs to be communicated to the technology through a machine controller

Usually the H.T.I. are allowing to perform not many action for interaction and can be pretty good represented by buttons or keyboard, but they can also be valve actuators or any sort communications between the humans and the machines, also a managing software of the plant can fall into this definition or the keyboard of the computer.

Often those interactions are not considered so much important but lately are receiving more and more importance due to the ergonomic-studies and the values that they receive in the evaluation and preventions of the risks.

The mental work load in this case can be well represented by Richard (1990)

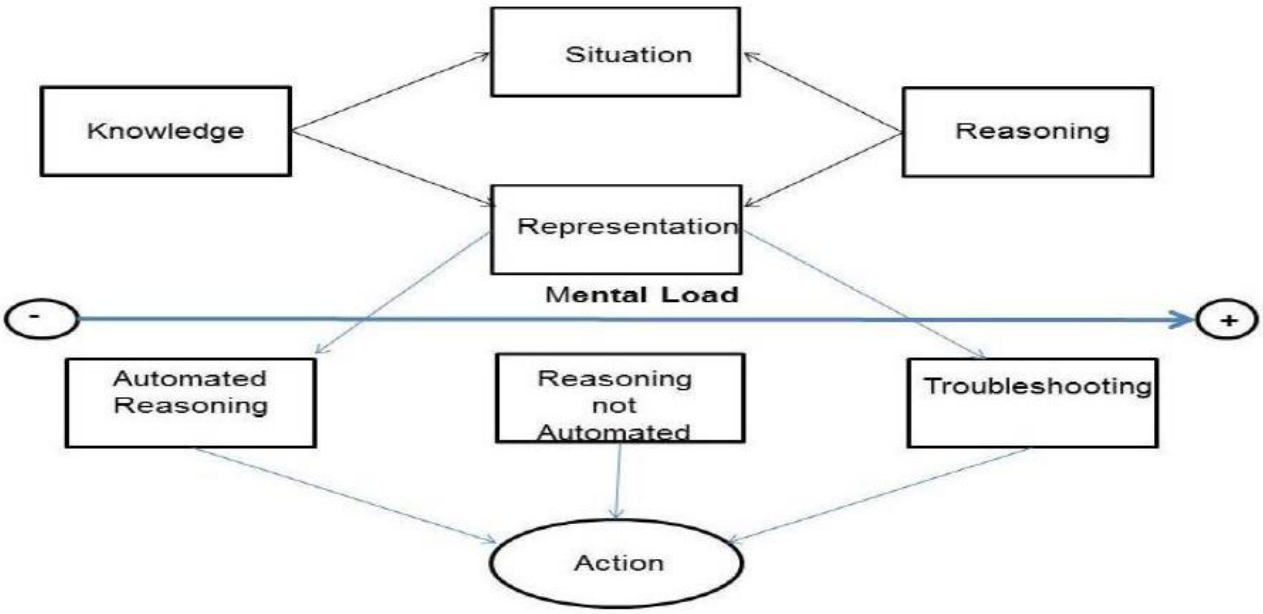


Figure 5.2 Cognitive architecture associated to a mental workload (Daiana Martins Vitório, 2012).

The Human technology interfaces can be considered as the actuators of the action expressed by the operator, so How the operators are acting on the plant.

Figure 5.3 Example of a Human Machine Interaction, peroperty of Mapei

5.3 D.A.D Decision Action Diagram (hierarchical scale): Who?

The decision action diagram is the diagram explanation of how is divided the division in terms of workers and it connect everyone showing the organization process and the level of dependencies defining how the decisions are tooken, any level is characterized by a certain amount of responsibilities and decisional level of freedom.

D.A.D. are particularly useful for representing decisions which would otherwise involve cumbersome planning in a HTA format. The main format of the diagram is represented by boxes for the stages and diamonds for the decisions, D.A.D. can be extremely usefull to describe decision-making scenarios because is possible to define various decisions, shows the necessary information and criteria to apply while operator are taking decisions. A good DAD diagram is thus highlighting the potencial sources of mistake for the operator due to the potencial review out of the diagnosis.

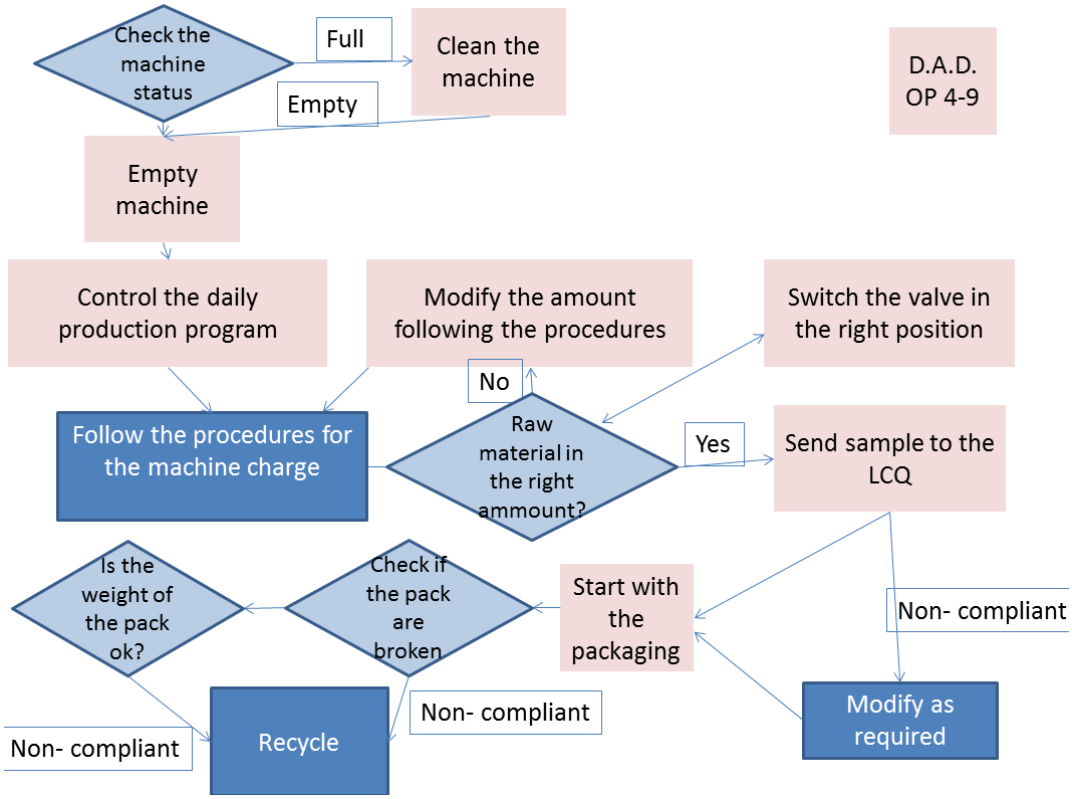
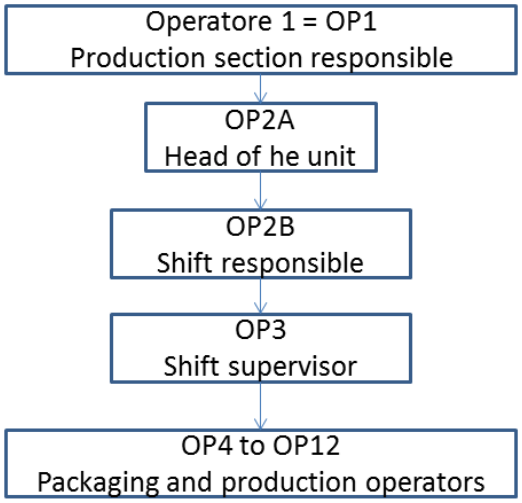


Figure 5.4 Example of D.A.D. for the operator

In a general case is the detailed explanation of what is shown in the organic of the department.

In our specific case (taken from the "Document of Risk Evaluation" introduced by the Italian Law *D.Lgs. 81/2008 also called "Consolidated Safety at Work Text")* the department we are observing is divided in 5 levels basically in order of decisional power to than move into the detail of time



OP1 = 1
OP2A = 1
OP2B = 2
OP3 = 5
OP4 to OP12 = 49
Shifts = 3

Figure 5.5 Hierarchical description of the Human Operators, property of Mapei.

Every single operator is demanded to achieve specific actions based on the different knowledge's and ability he's owning.

Every single operator is specified assigned to a defined position with its responsibilities and goals to achieve more or less as is happening for the mental process to execute some actions and as expressed in the Chapter 4.12 Cognitive analysis.

5.3.1 Competences and control

In our case are defined 13 different groups and in our department are present just 8 different kinds of operators that work in the Mediglia Plant, distinguished by action that they can execute and problems that they can solve.

Op1 is the "Production Manager", he have to answer to the plant direction, he's en charged of the organizations and also of coordination between the activities of the area he's delegate, he have to respect the law limit's he's managing the shift responsible, he have to work also for the human resources but he's not involved in the production itself.

Op2/a is the “Area Manager” is undergraduate in respect to the plant’s directions and the “production manager” he coordinate the activity between the department assigned, he assigned the task to the workers and he’s responsible for the training and the respects of the security and environmental protections laws, he have access to the productions areas even if he’s not producing anything “with his hands”.

Op2/b is the “Shift Responsible” he assists theOp1 and Op2/a in the management of Human Resources he verify the documents concerning the productions he ensure the respect of the regulations about security and environment, he can check the regular proceedings of the operations of productions and he, sometimes, regulate the machines even without properly working on the products and he participate to the training of the employees.

Op3 is the “Shift Supervisor”, he’s charged of the supervision of the activities of the areas where he can enter and he can verify the right functioning of the machines and the security disposal , he can visually check the characteristic of the product and he participate to the training of the employees.

Op 4 “Employees of production and packaging of adhesive” for moquettes and parquets, they can select the quantity of product and they can control the doses, control the mixing and can inspect the machines for to evaluate the degree of mixing, they can also set the parameters of the packaging move the products and their buckets and they can manually move the final products into columns. Also they can have the mechanical and pneumatically help in the movement of heavy drums.

Op9 “Employees various productions” they set and control the automatic dosage of the solvent and control of the dispersion, verification of the standards and manual addition in case of needs of raw materials, visual inspections of the mixer, sometimes also two Op9 they can move some raw material for a maximum amount of 200/300kg.

Op10 “Packaging employees” they set the parameters for the packaging and manual pose of the cover of the buckets, they create the pallets manually, they prepare the Resin C charge breaking the bags and spilling it into the mixer, they move Resin C max in the order of 25 kg for maximum of 60 minutes

Op11 “Forklift employee”, the main task that they have to achieve is to move around the industrial plant every heavy material necessary to be moved around.

6 Software A.L.B.A.(Algoritm Logic Bayesian Analysis)

This method is possible make a model of the entire process in order to consider all interactions between single activities. In fact, IDDA is based on the idea that every random variable could be analyzed like a set of events and that every event could be, by definition, true or false. So the probability value defines a sort of "prevision" about events result (p it's the prevision that the event may be false and (1-p) is prevision that the event may be true) and represents the expectation value. Once probability values are defined for every event, a prevision of the entire process success can be done though a structure function that link together single events probability value in a logical way.

In our case random variable is the cure process success and the events are represented by every single action to do in ward to carry on the process.

Obviously, probability values calculated this way must satisfy the coherence conditions or "fundamental laws of inductive rationality", which as are as follows:

1. Convexity condition: $0 \leq p \leq 1$ Eq. 4.1

2. Simple additional: $p_i = 1_i$ Eq. 4.2

Probability of a random variable, constituted by a set of mutually exclusive event, is the sum of probability values of its constituent events. For the whole universe of events, this sum must be like 1, in so far as whole set of possible events represent "certainty".

3. Bayesian law: $p\ (A|B) = (AB)/\ (B)$ Eq. 4.3

To fulfill these properties, which are assumed like axioms in a logic system, means to fulfill the principle of coherence: the probability values are univocally assigned in a given universe of events. For that reason, these properties are known like "fundamental lows of inductive logic".

From these assumptions, is quite clear that formal classic logic, or deductive logic, is only a particular case of the more general "common sense logic".

In fact, deductive logic can unveil only tautological courses, starting from a general observation to particular deductions. For that, methods that are founded on deductive logic are inherently unable to make more new information or knowledge, and is so clear why, before making deductive

analysis like FT, is necessary use some inductive instrument of analysis like ROA or IROA to comprehend the problem to solve. Otherwise the solution will never be coherent and complete.

Therefore with IDDA, being an inductive method is possible to identifying, in a coherent and systematic way, all likely alternatives of the whole significant chosen events.

Like said before, every single event is considered in their extreme conditions: necessary event or impossible event. This way, for coherence, event a_i must be considered like $(a_i + \neg a_i) = 1$.

So, for the third coherence law: $U = \prod_{i=1}^{N} (a_i + \neg a_i) =$. This certainly is a universe of event because of U= 1.

This product can be developed like the sum of 2^N constituents that represent the partition of the universe of event. These are mutually exclusive and incompatible; these mean that only one is possible.

For this reason, every constituent can be supposed like orthogonal linear space axis that represents the universe of interest: every likely event is represented by single constituents or its vector addiction. Once that the entire constituents are developed, ie the partition that characterizes the universe of a problem, every event, describable within that universe, it simply identifies with the set of constituents that it implies (which is present). These constituents represent all possible alternative ways of system realization. The difficulty is simply the proper choice of the elementary events of basic events in elective Boolean condition, defining scope and meaning in the universe of discourse. Once the partition of events is delivered, some constituents may be analyzed looking for potential logical or probabilistic errors.

The elementary events are linked together through logic relations that imply logic bonds that leave out the entire constituent with no logic sense, even if possible. This way constituent number is reduced from the theoretical value, holding back binomial explosion.

Residual constituents are however a partition of the whole universe, and are still now mutually exclusive: their sum is still like 1.

There are also some elements that provide redundant information and so are negligible because of its presence added no more advice about the problem. This way binomial explosion is reduced once again.

Further is possible add probabilistic ties that allows to reduce the number of logic history, or system conditions, that have probability occurrence bigger than a limit chosen value.

So, Boolean logic can be completely simulated trough appropriate orientations to successive questions or assertions and trough logic and probabilistic bounds that influence successive questions or assertions states. These questions and assertion have only two states, true or false, and so can be indicated like events.

For all the reasons said before, IDDA method, contrasted by other deductive risk analysis methods could see all the events that make the universe so it's represent a more realistic and comprehensive method of analysis of all possibly causes of a specific system condition whether failure state or not. (Mazzù, 2012)

6.1 DETA program

To generate all the constituents, DETA program is used. Like said before, random variable are used: the problem must be represented by a sequence of questions, that will be nouns decisional levels or simply "levels", which have associated the consequence of their outcomes. These consequences influence trough probabilistic and logic devices, outcomes of following levels.

The questions must be formulated like the set of questions that a normal person could pose itself in order to understand the phenomena associated to the problem and must be ordered with the purpose of minimize their number and explain as well as possible real phenomena. This node is an inductive process that changes with analyst knowledge with the assistance of the outcomes of constituent generated and their logic and probabilistic structure.

The procedure to draft input file is set out below like Remo Galvagni's art manual instructions about IDDA explain.

6.1.1 Syntax of input files

All random events (or question or logical level) will be identified by Computer trough line‟s number of event‟s matrix. Actually the number will be included to 1 at 999.

1	0.01	1.	2	2	3	'Comp1'	'work'	'NoWork'

Table 6.1 Typical A.L.B.A. Input chain

The Line is structured:

a. Event‟s number. A sequential number that characterize for the computer the random event.

b. Probability. A real number included to 0 at 1 that represent the failure probability.

c. Distribution dispersion level that can be associated at his probability value.

d. The number of the event where that level must come when the answer is „yes".

e. The number of the event where that level must come when the answer is „no".

f. Press instruction. 0 to never press; 1 to press only for affirmative answer; 2 to press only for negative answer; 3 to press always.

g. The question

h. Affirmative answer

i. Negative answer

Between different levels there is a free line that indicates the end of the previous command.

This line of command indicates only the logical way to proceed from a level to another without logical or probabilistic ties.

6.1.2 Logical Contrains

There are two types of logical devices:

Logic level structure variation caused by previous logic levels outcomes

1	0.01	1.	2	2	3	'Comp1'	'work'	'NoWork'
2	0	10	2	3				

Table 6.2 Typical A.L.B.A. Input chain and constrain

The line is structured so:

a. Level condition. 1 for success; 2 for failure; 3 for both success and failure

b. The number of the event where conditioned level must go if conditioning level is in „success"

c. The number of the event where conditioned level must go if conditioning level is in „failure"

d. The first conditioned event

e. The last conditioned event

To change more than 1 event, these must be consecutive because this condition is applied to every event between the first and the last indicated.

Every event can support only one condition like this

Success or failure imposition to logic level caused by previous logic level outcomes

1	0.01	1.	2	2	3	'Comp1'	'work'	'NoWork'
2	0	10	2	3				
26	4	0.	1.					

Table 6.3 Typical A.L.B.A. Input chain and double constrain

The line is structured so:

a. 11: for success of conditioning event must be success of conditioned event

b. 21: for failure of conditioning event must be success of conditioned event

c. 12: for success of conditioning event must be failure of conditioned event

d. 22: for failure of conditioning event must be failure of conditioned event

e. If the message must be more strong the second number of the couple could be 3 (success) or 4 (failure); 5 (success) or 6 (failure)

f. Conditioned event.

g. Real number useful only to make right lecture by the program

h. Real number useful only to make right lecture by the program

6.1.3 Probabilistic devices

Variation in probabilistic value caused by previous outcomes

1	0.01	1.	2	2	3	'Sens.S1'	'work'	'NoWork'
2	0	10	2	3				
26	4	0.	1.					
26	6	0.	1.					
10	2	0.009	1.					
10	3	0.009	1.					
20	2	0.1081	1.					
20	3	0.9257	1.					

Table 6.4 Example of input and different constrains

a. Level condition. 10 for success, 20 for failure

b. Conditioned event number

c. New probability value

d. Distribution dispersion level that can be associated at new probability value

6.2 Integration with Gantt and with the functional tree

This analysis is guided by a finite number of “questions”, those are the fundamental bricks of the wall created by this approach, the total amount of those “questions” are representing the centerpiece of the process.

The centerpiece of the plant has to be structured trying to be the more objective as possible reproducing in the most realistic way possible the “semantics behind the actions” performed in the line into a “logic of connections” between the single piece necessary to link, this is the biggest issue to solve in order to have a model that will perfectly fit with the reality to show the right result of happenings.

The analyst has to take into account all those bones which have to be complete and satisfactory of the process under control, and also, those pieces has to be the most defined as possible in order that there are no option missing in the results, always remembering the complementary rules resulting by a specific question higher prize if we realize the event but also a higher possibility that we will not earn anything.

Here the Gantt Diagram performed before plays his fundamental role, because it structures a time dependent line sequence of actions necessary to proceed in order to achieve our products. The way on how we descript our process and its interactions also permits us to amplify the importance of some task with respect to others that can feel as important as the others but, in reality, they don’t represent any criticality in the final shoot of the plant.

Our focus is to understand which one are the actions that can be considered as a backbone of the line under investigation.

It means that we have to completely understand the process and eliminate the useless tasks that are not necessary to the definition of the plant.

Moreover when we find some key points we also have to be able to define the one that can be listed as reusable in a case that a recursive task has been used more than once and it will be asked twice.

6.3 How to connect the questions?

In many cases we would have to deal with necessary actions that must be achieved together or separately, in this case the structure of the input file should be as in the Figure 6.1 and in the Figure 6.2.

```
:Domanda 1
1       0.5     0       2       3       'Domanda1'      'LogicAnd'      'LogicOr'

:Domanda 2
2       0.5     0       4       5       'Domanda2'      'LogicAnd'      'LogicOr'

:Domanda 3
3       0.5     0       104     105     'Domanda3'      'LogicAnd'      'LogicOr'
```

Figure 6.1 Logic And

```
:Domanda 1
1       0.5     0       2       3       'Domanda1'      'If 1'          'Than 1'

:Domanda 2
2       0.5     0       4       5       'Domanda2'      'If 2'          'Than 2'

:Domanda 3
3       0.5     0       104     105     'Domanda3'      'Than 1'        'Else 1'
```

Figure 6.2 If, Than, Else Configuration

7 Work development

7.1 Task analysis

“Task analysis is the process of breaking a skill into smaller, more manageable steps in order to teach the skill” (Franzone, (2009))

The task analysis is that kind of analysis that has as a goal the, full and complete, description of how you accomplish the action in mental and physical way, it also has the goal to understand how much a task is frequent, what is necessary to allocate, how complex it is, which are the environmental conditions, describe the clothing and equipment necessary, and every single factors involved in or required for one or more people to perform the given task.

These information are necessary for us to understand the procedures of the plant and to describe the check-list necessary to perform the activity under investigation.

The word task, in the general assumptions is also a synonymous of activity, for single and easy tasks, or as synonymous of process for more complicated actions to perform.

Task analysis is also useful in order to understand which ones are the necessary level to describe the system completely, starting from the most basically points.

The extreme flexible approach of this kind of analysis is given by the fact that is providing the opportunity to use it in the most different environments like industrial engineering to understand how many time and what is necessary to do for to create a product, in the cognitive way this approach can also made us understand what a supervisors has to monitor in order to take decisions or answer to a planning or while someone is executing an action following a checklist.

The approach is also useful in the understanding of the process that has to deal with the understanding of something.

“*Task analysis analyses what a user is required to do in terms of actions and/or cognitive processes to achieve a task. A detailed task analysis can be conducted to understand the current system and the information flows within it. These information flows are important to the maintenance of the existing system and must be incorporated or substituted in any new system. Task analysis makes it possible to design and allocate tasks appropriately within the new system. The functions to be*

included within the system and the user interface can then be accurately specified." (usabilitynet.com)

7.2 Gantt Development

7.2.1 First vision

The first diagram we developed it was a raw and unstructured diagram written after a quick conversation with the plant manager.

The diagram it was just a list of actions made by the operator without any link between areas and over-crossing the same timeline, without documents to use as a base our diagram it was composed by 25 single elements.

	Modali attività	Nome attività	Durata	Inizio	Fine	Pre
1		**prima vision**	**1 g**	**lun 05/11/12**	**lun 05/11/12**	
2		decisione ricetta	0,05 g	lun 05/11/12	lun 05/11/12	
3		apertura aria	0,01 g	lun 05/11/12	lun 05/11/12	
4		solventi	0 m	lun 05/11/12	lun 05/11/12	10F
5		scelta solventi	0,3 g	lun 05/11/12	lun 05/11/12	
6		movimentazione solventi	0,01 g	lun 05/11/12	lun 05/11/12	5
7		pesa solventi	0,01 g	lun 05/11/12	lun 05/11/12	6
8		pesa solvente + secondo	0,01 g	lun 05/11/12	lun 05/11/12	7
9		pesa solvente + terzo	0,01 g	lun 05/11/12	lun 05/11/12	8
10		iniezione solventi	0 m	lun 05/11/12	lun 05/11/12	9
11		inertizzo dissolutore	0,01 g	lun 05/11/12	lun 05/11/12	
12		resina	0 m	lun 05/11/12	lun 05/11/12	
13		decisione quantità	0,18 g	lun 05/11/12	lun 05/11/12	
14		pinzatura carrelli	0,22 g	lun 05/11/12	lun 05/11/12	13
15		pesa resina	0,1 g	lun 05/11/12	lun 05/11/12	14
16		movimentazione carrelli con resina	0,43 g	lun 05/11/12	lun 05/11/12	15
17		posa resina miscelatore	0,48 g	lun 05/11/12	lun 05/11/12	
18		inertizzazione 2	0,01 g	lun 05/11/12	lun 05/11/12	
19		verifica post-scarico	0,01 g	lun 05/11/12	lun 05/11/12	21
20		verifica pre-carico	0,13 g	lun 05/11/12	lun 05/11/12	21I
21		miscelazione	0,44 g	lun 05/11/12	lun 05/11/12	
22		addizione plastificante	0,73 g	lun 05/11/12	lun 05/11/12	
23		mix finale governato da plc	0,75 g	lun 05/11/12	lun 05/11/12	
24		stoccaggio	0,3 g	lun 05/11/12	lun 05/11/12	
25		controllo qualità	1 g	lun 05/11/12	lun 05/11/12	

Figure 7.1 First raw vision of the model and its function, not grouped.

7.2.2 The second diagram: Where? When?

The approach to the second diagram it started creating an almost completely brand new work-paper, helped by the documents given by Mapei we started structuring our diagram.

We first identify the areas of the line under investigation which actually were 4 different ones:

A. The drawing materials
B. The drawing of the half-processed
C. The Mixture creation
D. The Packaging of the products

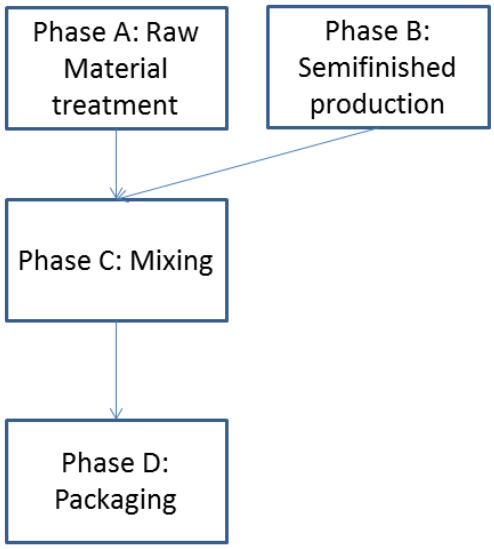


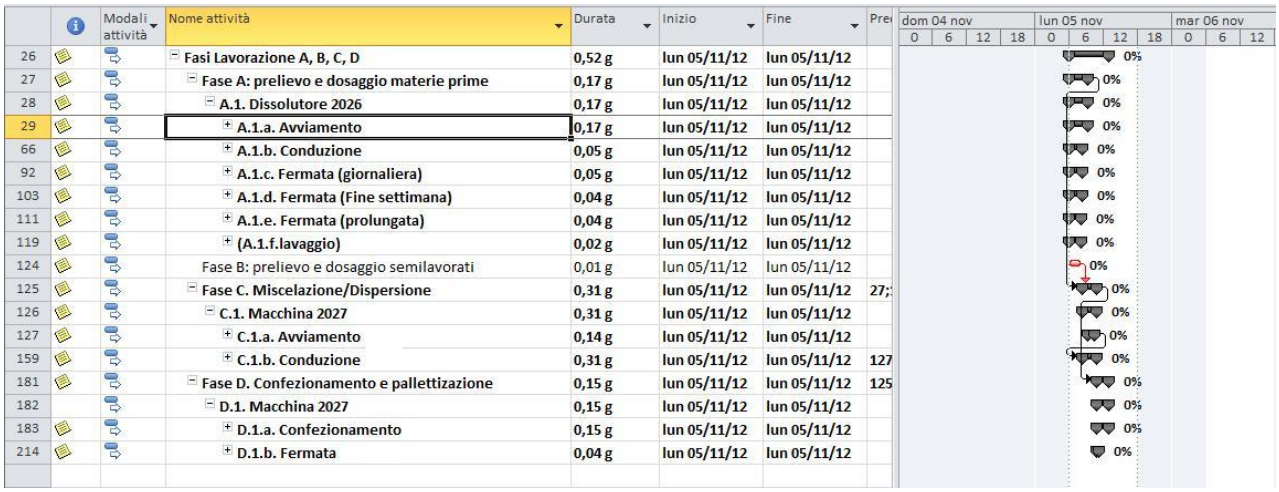
Figure 7.2 How the different Phases are connceted with each other, property of Mapei

All of those 4 different areas logically were connected to each other, even if each one was following its timeline, timeline that approximately was divided in these 3 macro-groups of elements:

1. Start-up
2. Conduction
3. Shut-Down

Actually the Shut-Down group was always subdivided in more than one different modality: the Shut-Down of the batch, the extended closing or the season closing of the plant.

In this way creating a quick obvious skeleton focused to give order between the actions we reached immediately more than 200 different lines of diagram.



	Modali attività	Nome attività	Durata	Inizio	Fine	Pre
26		Fasi Lavorazione A, B, C, D	0,52 g	lun 05/11/12	lun 05/11/12	
27		Fase A: prelievo e dosaggio materie prime	0,17 g	lun 05/11/12	lun 05/11/12	
28		A.1. Dissolutore 2026	0,17 g	lun 05/11/12	lun 05/11/12	
29		A.1.a. Avviamento	0,17 g	lun 05/11/12	lun 05/11/12	
66		A.1.b. Conduzione	0,05 g	lun 05/11/12	lun 05/11/12	
92		A.1.c. Fermata (giornaliera)	0,05 g	lun 05/11/12	lun 05/11/12	
103		A.1.d. Fermata (Fine settimana)	0,04 g	lun 05/11/12	lun 05/11/12	
111		A.1.e. Fermata (prolungata)	0,04 g	lun 05/11/12	lun 05/11/12	
119		(A.1.f.lavaggio)	0,02 g	lun 05/11/12	lun 05/11/12	
124		Fase B: prelievo e dosaggio semilavorati	0,01 g	lun 05/11/12	lun 05/11/12	
125		Fase C. Miscelazione/Dispersione	0,31 g	lun 05/11/12	lun 05/11/12	27;
126		C.1. Macchina 2027	0,31 g	lun 05/11/12	lun 05/11/12	
127		C.1.a. Avviamento	0,14 g	lun 05/11/12	lun 05/11/12	
159		C.1.b. Conduzione	0,31 g	lun 05/11/12	lun 05/11/12	127
181		Fase D. Confezionamento e pallettizzazione	0,15 g	lun 05/11/12	lun 05/11/12	125
182		D.1. Macchina 2027	0,15 g	lun 05/11/12	lun 05/11/12	
183		D.1.a. Confezionamento	0,15 g	lun 05/11/12	lun 05/11/12	
214		D.1.b. Fermata	0,04 g	lun 05/11/12	lun 05/11/12	

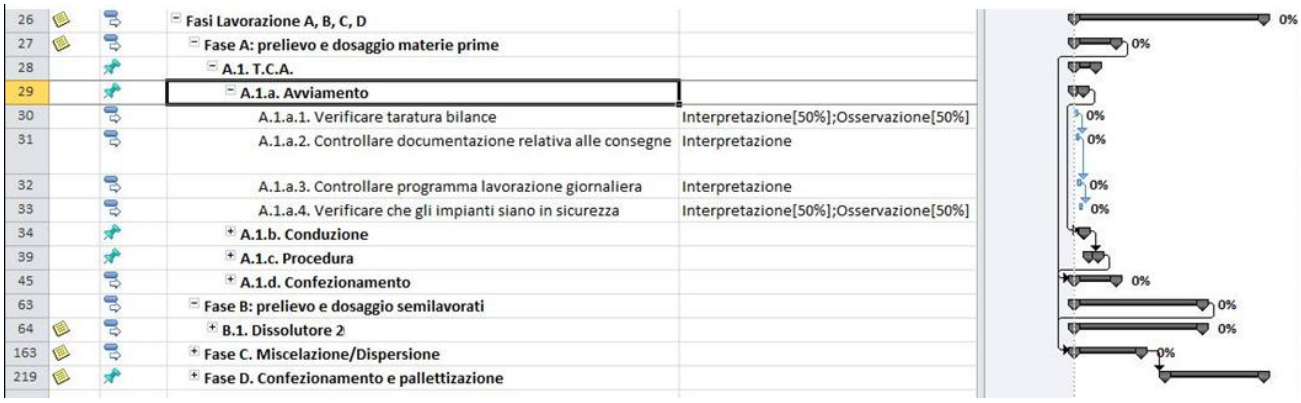
Figure 7.3 Brief description of the single elements and their sub-systems File Gantt 2012.11.29

7.2.3 The Third Diagram: Who?

The idea behind the third version of the Gantt we developed has been the one to assign to any action a "resource" like permitted by Microsoft Project, the most typical program of project management used in the world.

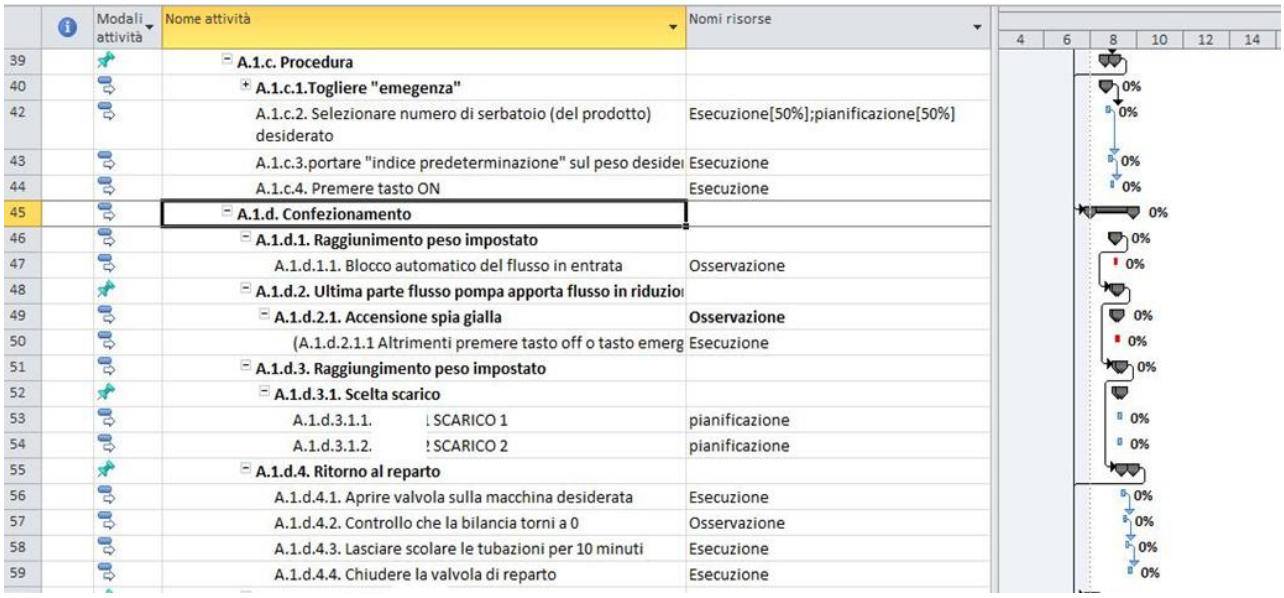
This approach was developed in order to understand how much the operator could be stressed while the batch process is on-going, and it has been based on the Cognitive resources of the operator, studies implemented by Hollnagel during his research.

Mainly, Hollnagel, define the possible action performed by the operators in 4 different groups: Observation, Interpretation, Planning and Execution typical of the different levels of mental workload necessary to accomplish the action under investigation.



26	Fasi Lavorazione A, B, C, D	
27	Fase A: prelievo e dosaggio materie prime	
28	A.1. T.C.A.	
29	A.1.a. Avviamento	
30	A.1.a.1. Verificare taratura bilance	Interpretazione[50%];Osservazione[50%]
31	A.1.a.2. Controllare documentazione relativa alle consegne	Interpretazione
32	A.1.a.3. Controllare programma lavorazione giornaliera	Interpretazione
33	A.1.a.4. Verificare che gli impianti siano in sicurezza	Interpretazione[50%];Osservazione[50%]
34	A.1.b. Conduzione	
39	A.1.c. Procedura	
45	A.1.d. Confezionamento	
63	Fase B: prelievo e dosaggio semilavorati	
64	B.1. Dissolutore 2	
163	Fase C. Miscelazione/Dispersione	
219	Fase D. Confezionamento e pallettizzazione	

Figure 7.4 Expansion of one element in its sub-procedures



	Modali attività	Nome attività	Nomi risorse
39		**A.1.c. Procedura**	
40		**A.1.c.1.Togliere "emegenza"**	
42		A.1.c.2. Selezionare numero di serbatoio (del prodotto) desiderato	Esecuzione[50%];pianificazione[50%]
43		A.1.c.3.portare "indice predeterminazione" sul peso desidei	Esecuzione
44		A.1.c.4. Premere tasto ON	Esecuzione
45		**A.1.d. Confezionamento**	
46		**A.1.d.1. Raggiunimento peso impostato**	
47		A.1.d.1.1. Blocco automatico del flusso in entrata	Osservazione
48		**A.1.d.2. Ultima parte flusso pompa apporta flusso in riduzio**	
49		**A.1.d.2.1. Accensione spia gialla**	**Osservazione**
50		(A.1.d.2.1.1 Altrimenti premere tasto off o tasto emerg	Esecuzione
51		**A.1.d.3. Raggiungimento peso impostato**	
52		**A.1.d.3.1. Scelta scarico**	
53		A.1.d.3.1.1. ! SCARICO 1	pianificazione
54		A.1.d.3.1.2. ! SCARICO 2	pianificazione
55		**A.1.d.4. Ritorno al reparto**	
56		A.1.d.4.1. Aprire valvola sulla macchina desiderata	Esecuzione
57		A.1.d.4.2. Controllo che la bilancia torni a 0	Osservazione
58		A.1.d.4.3. Lasciare scolare le tubazioni per 10 minuti	Esecuzione
59		A.1.d.4.4. Chiudere la valvola di reparto	Esecuzione

Figure 7.5 Maximum expansion of the level until its basics funtions

The resources has been assigned following what shown in figure 4.19.

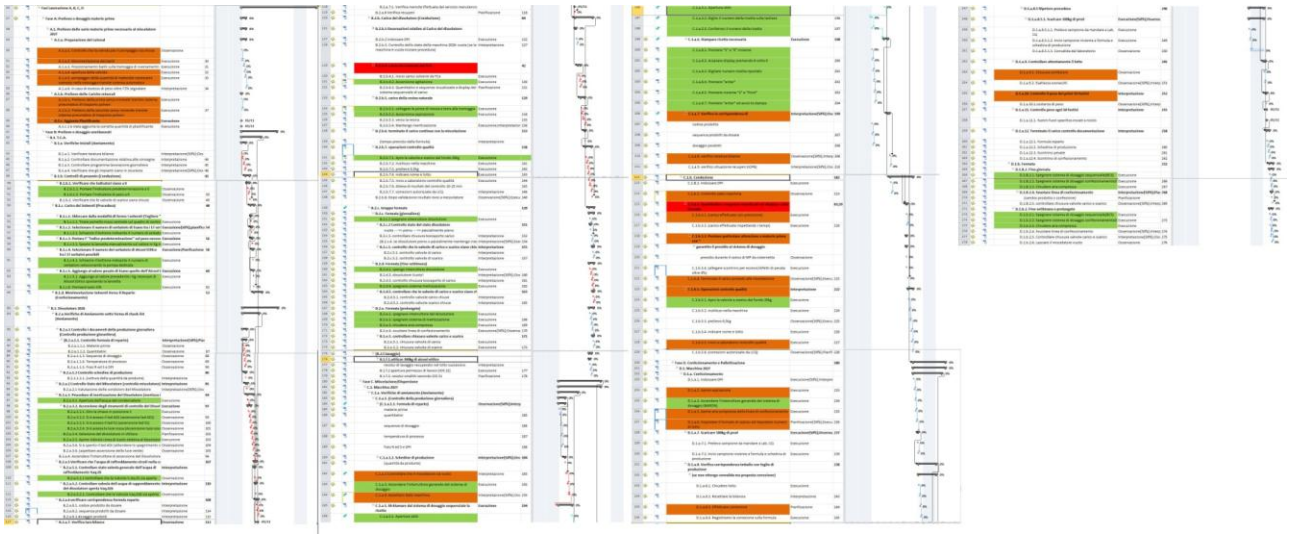
7.2.4 The final version

In the final version of our diagram we decided that we should structure our time line like a timeline of the operator during his shift.

According with the focus of this version we had to modify the order of many actions that before were structured as a unique block because they were regarding a specific area of our production line.

Even more we try to analyze in a more specific way the actions performed by the operator to understand which one could be the action that we could split in more under actions not completely specified in advance.

As is possible to see below the amount of actions is really big, so we decided to show just a quick example of the first 21 raws from where to start the analysis.



		Mod attiv	Nome attività	Nomi risorse
27			**Fase A: Prelievo e dosaggio materie prime**	
28			**A.1. Prelievo delle varie materie prime necessarie al miscelatore 2027**	
29			**A.1.a. Preparazione del Lutonal**	
30			A.1.a.1. Controllo che la valvola per il pompaggio sia chiusa	Osservazione
31			A.1.a.2. Movimentazione dei barili	Esecuzione
32			A.1.a.3. Posizionamento barili sulla tramoggia di sversamento	Esecuzione
33			A.1.a.4. apertura della valvola	Esecuzione
34			A.1.a.5. pompaggio della quantità di materiale necessario sversato nella tramoggia tramite sistema automatico	Esecuzione
35			A.1.a.6. In caso di eccesso di peso oltre l'1% segnalare	Interpretazione
36			**A.1.b. Prelievo delle Cariche minerali**	
37			A.1.b.1. Prelievo della prima carica minerale tramite sistema pneumatico di trasporto polveri	Esecuzione
38			A.1.b.2. Prelievo della seconda carica minerale tramite sistema pneumatico di trasporto polveri	Esecuzione
39			**A.1.c. Aggiunta Plastificante**	**Esecuzione**
40			A.1.c.1 è stata aggiunta la corretta quantità di plastificante	Esecuzione
41			**Fase B: Prelievo e dosaggio semilavorati**	
42			**B.1. T.C.A.**	
43			**B.1.a. Verifiche Iniziali (Avviamento)**	
44			B.1.a.1. Verificare taratura bilance	Interpretazione[50
45			B.1.a.2. Controllare documentazione relativa alle consegne	Interpretazione
46			B.1.a.3. Controllare programma lavorazione giornaliera	Interpretazione
47			B.1.a.4. Verificare che gli impianti siano in sicurezza	Interpretazione[50

Figure 7.6 Immage of the last Gantt Diagram Explosed and extract of the first functions

7.2.5 Standard used in the Gantt

The standard for the development used in the resources are defined as a reduced representation of the diagrams.

The first level of the diagram is divided in order to identify the different working areas.

Starting from the second level of layer we assumed to divide the workload in order to express the timeline of the process itself.

The milestones we used are used as a “must to do” like bottleneck of the process not dependent by the operator.

To understand the task used in the development of the final gantt diagram we used the 3 different convention of () [] and ?? to describe how any action was used:

Symbol	Necessity to describe
()	was used for the activity that’s correct and that can or not happen
[]	any possible action to investigate in order to understand if it can be performed
??	any action that can provide some dubt that have to be investigate

Table 7.1 Symbols Used

7.3 The interface between the Gantt diagram and the A.L.B.A. software

Once the Gantt diagram is completely developed we had to find a way to reduce the amount of actions into functions and select the one most important to integrate in the A.L.B.A. algorithm.

Generally the functions we have selected were combining some typical characteristics and for this reason we decided that these characteristics were the one to select for the input files to use for the evaluation of the process.

The main characteristics of the function selected can be resumed in eight different groups:

1- The time order of the actions performed in the Gantt Diagram and its module defined by the grouping of the actions.

2- All the actions that were part of a sequence are taken as a fundamental to perform the all sequences of actions a sort of Feed Forward to control all the single steps necessary to complete the sequence itself.

3- The actions that are representing a sort of control of the previous actions performed in advance are investigated as a Feed Back first we ask about the control and then about the action before the control.

4- We insert all the actions that are not completely specified in the dossier that we received that we discovered in the unique visit to the plant.

5- We defined the actions that logically represent the ending of the working process.

6- Actions that can be assumed as a physical block to the ongoing process or to its operations.

7- Action that can bring errors in the indicated sequences of productions.

8- Over-control of the previous-phases.

Once we've got characterized those actions we can have the ideas of all the questions that we have to write and the logical connections between them.

With this standard necessary for the election at important variables of the process we could be able to reduce the total amount of actions from more than 300 to less than 60 reducing significantly the possible interactions of the system to the most necessary one.

7.4 Excel Develpment

7.4.1 First input files

The first input of file has been written in Excel (copyright Microsoft) and it was written in a very easy way.

The first operation we did was to identify all the actions constituent the Gantt and then image which one could be the possible deviation from the expected value we had to receive as output, so this first screening brought us to identify 59 possible actions to base our work on.

The possible deviations we pointed out were mainly regarding these 5 possible groups:

- Breaking of instruments, as the action coded A.1.a.5
  "Pumping of the right amount of material's to spill in the Mixer" that can bring to a malfunctioning system if the pump is broken ;
- Mismatching in the equipment required for the delivery, as the action coded B.1.d.5.1,
  "Selection of the discharge Machine 1" the selection of the wrong number between T.C.A.1 or T.C.A.2 can cause flooding due to the pre-mixer already on use;
- Presence of possible external block in the supply lines, like the action A.1.b.1,
  "extraction of the first mineral charge from the pneumatic system" this action can be blocked by the presence of some external not wanted blocks in the pipe;
- Wrong decision making, as the B.1.c.4.1,
  "push the button indicating the number of the tank of the raw material" the not accurate selection of the right pump can bring to unwanted materials inside the process;
- Structural problems and failing of the security barriers, as the B.1.d.5.1,
  "push the button off for the pumping of the liquids" this can bring to extra pumping into the mixer of extra materials not necessary;

In additions were also present some redundant actions, which actually were not possible in reality, but were written just because the manuals were repeating this action for different equipment, even if were performed just once.

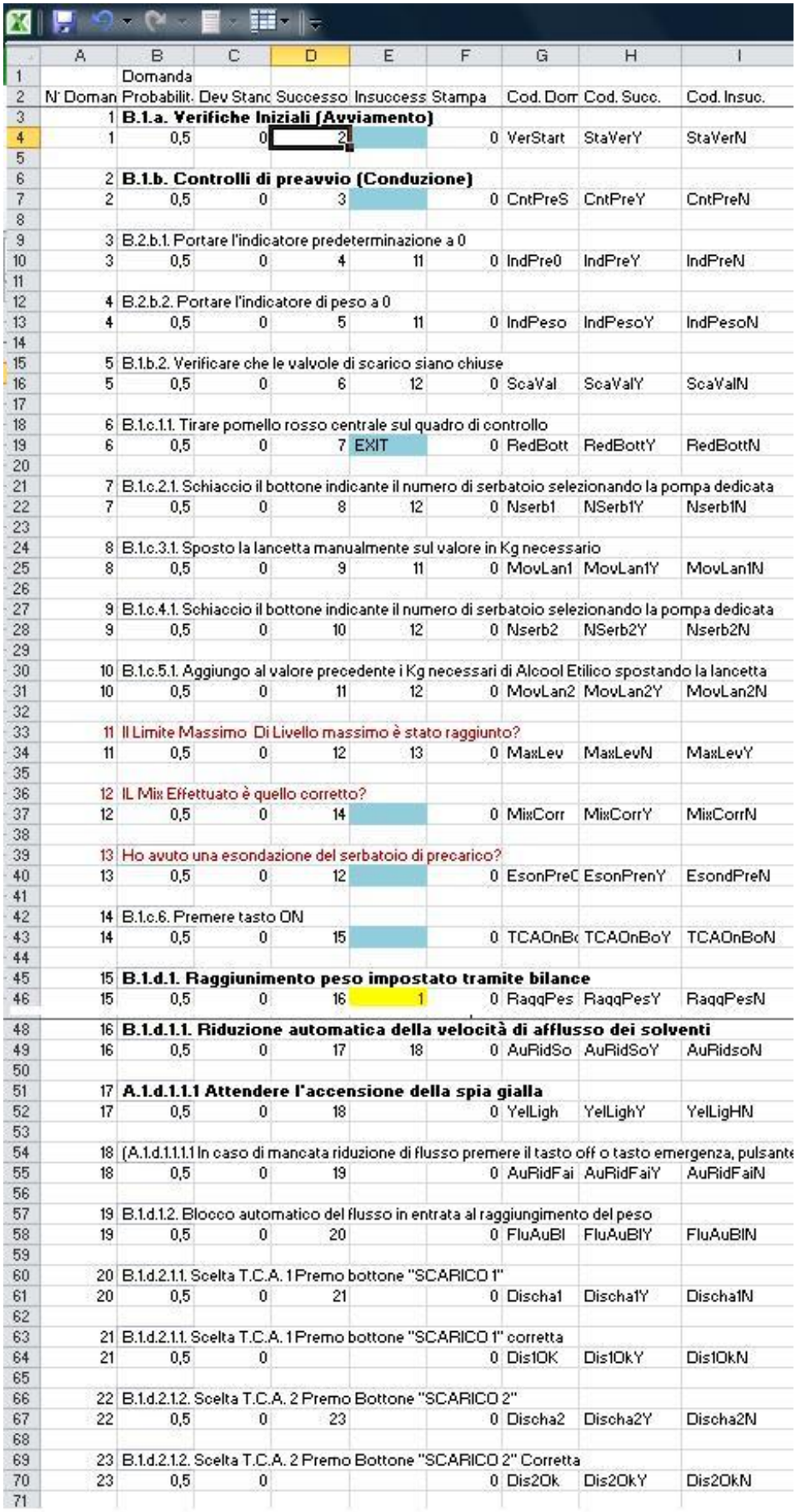
Below in the Figure 7.7 are written all the actions we identified as possible deviations and also the effects that the action is producing on the process in terms of mistakes, problems or also situations that can bring to this situation.

Instead the Figure 7.8 is showing the first model used to describe the connections between the questions, is instinctive to see that below the line of description of the question there are shown the probability of negative answer (until a perfect adherence to the reality the value will be set on 0,5) and the links with the next question, this in the output file will be represented by the path of the single story, is also represented a short code for the definition of the question and its answer.

possibili domande F - Microsoft Excel

	A	B
1	A.1.a.3. Posizionamento barili sulla tramoggia di sversamento	rottura tramoggia
2	A.1.a.5. pompaggio della quantità di materiale necessario sversato nella tramoggia tramite sistema aut	rottura pompa
3	A.1.b.1. Prelievo della prima carica minerale tramite sistema pneumatico di trasporto polveri	intasamento polveri sistema di trasposto pneumatico
4	A.1.b.2. Prelievo della seconda carica minerale tramite sistema pneumatico di trasporto polveri	intasamento polveri sistema di trasposto pneumatico
5	B.1.c.2.1. Schiaccio il bottone indicante il numero di serbatoio selezionando la pompa dedicata	pulsante errato
6	B.1.c.3.1. Sposto la lancetta manualmente sul valore in Kg necessario	se sposto la lancetta oltre il valore definito rischio esondazione
7	B.1.c.4.1. Schiaccio il bottone indicante il numero di serbatoio selezionando la pompa dedicata	pulsante errato
8	B.1.c.5.1. Aggiungo al valore precedente i Kg necessari di Alcool Etilico spostando la lancetta	se sposto la lancetta oltre il valore definito rischio esondazione
9	**B.1.d.1.1. Riduzione automatica della velocità di afflusso dei solventi**	malfunzionamento delle celle di carico
10	B.1.d.1.2. Blocco automatico del flusso in entrata al raggiungimento del peso	malfunzionamento delle celle di carico
11	B.1.d.2.1.1. Scelta T.C.A. 1 Premo bottone "SCARICO 1"	scelta serbatoio già carico
12	B.1.d.2.1.2. Scelta T.C.A. 2 Premo Bottone "SCARICO 2"	scelta serbatoio già carico
13	B.1.d.4.1. Aprire valvola sulla macchina desiderata	creazione di sovrappressione se valvola chiusa
14	B.1.d.4.4. Chiudere la valvola di reparto	al prossimo carico solvente potrei inquinare il prodotto
15	B.1.d.5.1. Premere pulsante OFF	pompaggio eccessivo
16	B.2.a.2.1 Valutazione delle condizioni del Miscelatore	errore di valutazione e possibile overflow
17	B.2.a.3.1. Apertura dell'acqua del condensatore	se non ho raffreddamento potrei avere eccesso di produzione di volatili
18	**B.2.a.3.2. Accensione degli strumenti di controllo del Dissolutore**	se mancata accensione non posso proseguire
19	B.2.a.3.2.1. Giro la chiave in posizione 1	se mancata accensione non posso proseguire
20	B.2.a.3.4. Selezione del dissolutore in Utilizzo	scelta dissolutore già carico
21	B.2.a.3.5. Aprire Valvola Linea di Azoto relativa al dissolutore selezionato	mancanza di inertizzazione
22	B.2.a.4. Accendere l'interruttore di accensione del Dissolutore	se non accendo il dissolutore non posso "diluire"
23	B.2.a.5.1.1 controllare che la Valvola V.Aq.01 sia aperta	mancanza di raffreddamento
24	B.2.a.5.2.1. Controllare che la Valvola Vaq.026 sia aperta	mancanza di raffreddamento
25	B.2.b.3. Controllo dello stato della macchina 2026: vuota (se la macchina è vuota iniziare procedura)	possibile overflow
26	B.2.b.4.1. Inizio carico solventi da TCa	senza solventi non faccio niente
27	B.2.b.4.2. Accensione agitazione	se non agito avrò mix ridotto
28	B.2.b.5.1. collegare le pinze di messa a terra alla tramoggia	possibile carica dell'operatore
29	B.2.b.5.2. Accensione aspirazione	evacuazione parte volatile
30	B.2.b.5.3. Mantengo inertizzazione	se non rimane inertizzato possibile miscela esplodibile
31	**B.2.b.6. terminato il carico continuo con la miscelazione**	se non miscelo possibilità di bad mix
32	B.2.b.7.1. Apro la valvola e scarico dal fondo 20kg	se non apro non posso avere controll qualità
33	B.2.b.7.4. indicare nome e lotto	possibili problemi nel riconoscimento dei campioni
34	B.2.b.7.5. invio a Laboratorio controllo qualità	non posso proseguire
35	B.2.b.8. Dopo validazione risultati invio a mescolatore	se non attendo la validazione possibili problemi di qualità
36	B.2.c.1 spegnere interruttore dissolutore	se non spengo posso avere problemi di
37	**B.2.c.2 Controllo stato del stato dissolutore**	possibile problema futuro
38	B.2.c.5.2. controllo valvole di scarico	possibile sversamento se non finito prima
39	B.2.d.1. spengo interruttore dissolutore	se non spengo il dissolutore continuerà a lavorare senza presidio
40	B.2.d.2. dissolutore Vuoto!	possibile problema alla riutilizzo dell'impianto
41	B.2.d.4. spegnere sistema inertizzazione	continuo a pompare azoto
42	B.2.e.1. spegnere interruttore del dissolutore	possibile problema alla riutilizzo dell'impianto
43	B.2.e.2. spegnere sistema di inertizzazione	possibile problema alla riutilizzo dell'impianto
44	B.2.e.3. chiudere aria compressa	possibile problema alla riutilizzo dell'impianto
45	B.2.e.4. svuotare linea di confezionamento	possibile problema alla riutilizzo dell'impianto
46	**B.1.f.1.utilizzo 300kg di alcool etilico**	se utilizzato male criticità lato sicurezza
47	C.1.b.2. Controllo stato macchina	se non vuota la macchina possibili problemi
48	C.1.b.3.1. (carico effettuato con precisione)	mancanza dovuta al non presidio della macchina
49	**C.1.b.3.3. Prestare particolare attenzione a materie prime con ***	se in presenza di eccessi superiori al 1% possibili problemi
50	C.1.b.5.1. Apro la valvola e scarico dal fondo 20kg	se non apro la valvola non posso fare CQ
51	C.1.b.5.3. prelievo 0,5kg	minimo necessario per il controllo qualità
52	C.1.b.5.4. indicare nome e lotto	se mancanza problema di identificazione del campione
53	D.1.a.2. Aprire aspirazione	se non apro l'aspirazione non posso provvedere al confezionamento
54	D.1.a.3. Accendere l'interruttore generale del sistema di dosaggio (BARON)	se non ho il sistema di dosaggio il confezionamento non viene
55	D.1.a.5. Aprire aria compressa della linea di confezionamento	senza aria compressa non posso provvedere al montaggio dei coperchi
56	D.1.a.6. Impostare il formato di scarico ed impostare numero di lotto	senza numero di lotto non posso controllare la qualità del prodotto
57	D.1.a.7.1. Prelevo campione da mandare a Lab. CQ	senza il prelievo del campione non posso fare il CQ
58	D.1.a.8.5.1.5. Convalida dal laboratorio	senza convalida non posso proseguire
59	D.1.a.11. fustini fuori specifica inviati a riciclo	mantenimento della qualità
60		

Figure 7.7 List of the possible question to be asked in the model.



	A	B	C	D	E	F	G	H	I
1		Domanda							
2	N° Doman	Probabilit.	Dev Stanc	Successo	Insuccess	Stampa	Cod. Dom	Cod. Succ.	Cod. Insuc.
3	1	**B.1.a. Verifiche Iniziali (Avviamento)**							
4	1	0,5	0	2		0	VerStart	StaVerY	StaVerN
5									
6	2	**B.1.b. Controlli di preavvio (Conduzione)**							
7	2	0,5	0	3		0	CntPreS	CntPreY	CntPreN
8									
9	3	B.2.b.1. Portare l'indicatore predeterminazione a 0							
10	3	0,5	0	4	11	0	IndPre0	IndPreY	IndPreN
11									
12	4	B.2.b.2. Portare l'indicatore di peso a 0							
13	4	0,5	0	5	11	0	IndPeso	IndPesoY	IndPesoN
14									
15	5	B.1.b.2. Verificare che le valvole di scarico siano chiuse							
16	5	0,5	0	6	12	0	ScaVal	ScaValY	ScaValN
17									
18	6	B.1.c.1.1. Tirare pomello rosso centrale sul quadro di controllo							
19	6	0,5	0	7	EXIT	0	RedBott	RedBottY	RedBottN
20									
21	7	B.1.c.2.1. Schiaccio il bottone indicante il numero di serbatoio selezionando la pompa dedicata							
22	7	0,5	0	8	12	0	Nserb1	NSerb1Y	Nserb1N
23									
24	8	B.1.c.3.1. Sposto la lancetta manualmente sul valore in Kg necessario							
25	8	0,5	0	9	11	0	MovLan1	MovLan1Y	MovLan1N
26									
27	9	B.1.c.4.1. Schiaccio il bottone indicante il numero di serbatoio selezionando la pompa dedicata							
28	9	0,5	0	10	12	0	Nserb2	NSerb2Y	Nserb2N
29									
30	10	B.1.c.5.1. Aggiungo al valore precedente i Kg necessari di Alcool Etilico spostando la lancetta							
31	10	0,5	0	11	12	0	MovLan2	MovLan2Y	MovLan2N
32									
33	11	Il Limite Massimo Di Livello massimo è stato raggiunto?							
34	11	0,5	0	12	13	0	MaxLev	MaxLevN	MaxLevY
35									
36	12	IL Mix Effettuato è quello corretto?							
37	12	0,5	0	14		0	MixCorr	MixCorrY	MixCorrN
38									
39	13	Ho avuto una esondazione del serbatoio di precarico?							
40	13	0,5	0	12		0	EsonPreC	EsonPrenY	EsondPreN
41									
42	14	B.1.c.6. Premere tasto ON							
43	14	0,5	0	15		0	TCAOnBo	TCAOnBoY	TCAOnBoN
44									
45	15	**B.1.d.1. Raggiunimento peso impostato tramite bilance**							
46	15	0,5	0	16	1	0	RaqqPes	RaqqPesY	RaqqPesN
48	16	**B.1.d.1.1. Riduzione automatica della velocità di afflusso dei solventi**							
49	16	0,5	0	17	18	0	AuRidSo	AuRidSoY	AuRidsoN
50									
51	17	**A.1.d.1.1.1 Attendere l'accensione della spia gialla**							
52	17	0,5	0	18		0	YelLigh	YelLighY	YelLigHN
53									
54	18	(A.1.d.1.1.1.1 In caso di mancata riduzione di flusso premere il tasto off o tasto emergenza, pulsante							
55	18	0,5	0	19		0	AuRidFai	AuRidFaiY	AuRidFaiN
56									
57	19	B.1.d.1.2. Blocco automatico del flusso in entrata al raggiungimento del peso							
58	19	0,5	0	20		0	FluAuBl	FluAuBlY	FluAuBlN
59									
60	20	B.1.d.2.1.1. Scelta T.C.A. 1 Premo bottone "SCARICO 1"							
61	20	0,5	0	21		0	Discha1	Discha1Y	Discha1N
62									
63	21	B.1.d.2.1.1. Scelta T.C.A. 1 Premo bottone "SCARICO 1" corretta							
64	21	0,5	0			0	Dis1OK	Dis1OkY	Dis1OkN
65									
66	22	B.1.d.2.1.2. Scelta T.C.A. 2 Premo Bottone "SCARICO 2"							
67	22	0,5	0	23		0	Discha2	Discha2Y	Discha2N
68									
69	23	B.1.d.2.1.2. Scelta T.C.A. 2 Premo Bottone "SCARICO 2" Corretta							
70	23	0,5	0			0	Dis2Ok	Dis2OkY	Dis2OkN
71									

Figure 7.8 First screening of the questions and development of the model

7.4.2 Second input files

The natural development of the previous input has been to identify groups of similar deviation and create a specific group of errors and the possible consequences that will be possible following the timeline of result achievement in our process.

Important has been also highlight the blocks representing the sequences of the actions and define also their sub-action necessary for the fulfillment of the group.

At this moment the links between the questions are extremely linear except for few groups, these exceptions were represented by the actions at the same level of deepness in the Gantt, this was possible because the positive outcome of questions were bringing to a question of the same level, and in the negative outcome the links could be with a lower level question or otherwise to a new group of errors or alarms.

The levels were distinguished by the list of actions, necessary to be performed, in order to complete the level itself.

Every action is connected with the others in a way that is possible to skip the block of question of the lower level, basically because if the action was performed correct is not necessary to investigate on how the action was done, just because the action has done correctly.

We also introduced some extra barer to understand which could be the possible actions performed in the plant, even if not literally written in the final manual, furthermore were also written some procedures that were not extremely necessary but we find them helpful to complete the description of every detail.

We just want to stand out that, in this input file, there is still present some extra control of variables not immediately necessary for the process.

At the end of the file we also expressed the procedures necessary for the shutdown of the process, following in this way a complete timeline of the process.

The main modification generated to this input increased the number of questions from 59 to 126.

The questions which are not identified by a code but from a yellow color, are the questions which are not written in the manuals, an example are the questions from 15 to 17:

15 have we reached the maximum level possible for the pre-mixer?

16 is the mix in the correct proportions?

17 I had a flooding in the pre-mixer?

Is also interesting to evaluate the presence of 3 possible exits the switch between the exits can help the analyst to better understand, or to shape, the system depending on the gravity of the possible results given by the system.

The exits are: one that will be dedicated to the actions that can provide the production problem (n°997), one a little bit more complex that will be used to show the quality problems (n°998) and the third one typical of the safety problem (n°999).

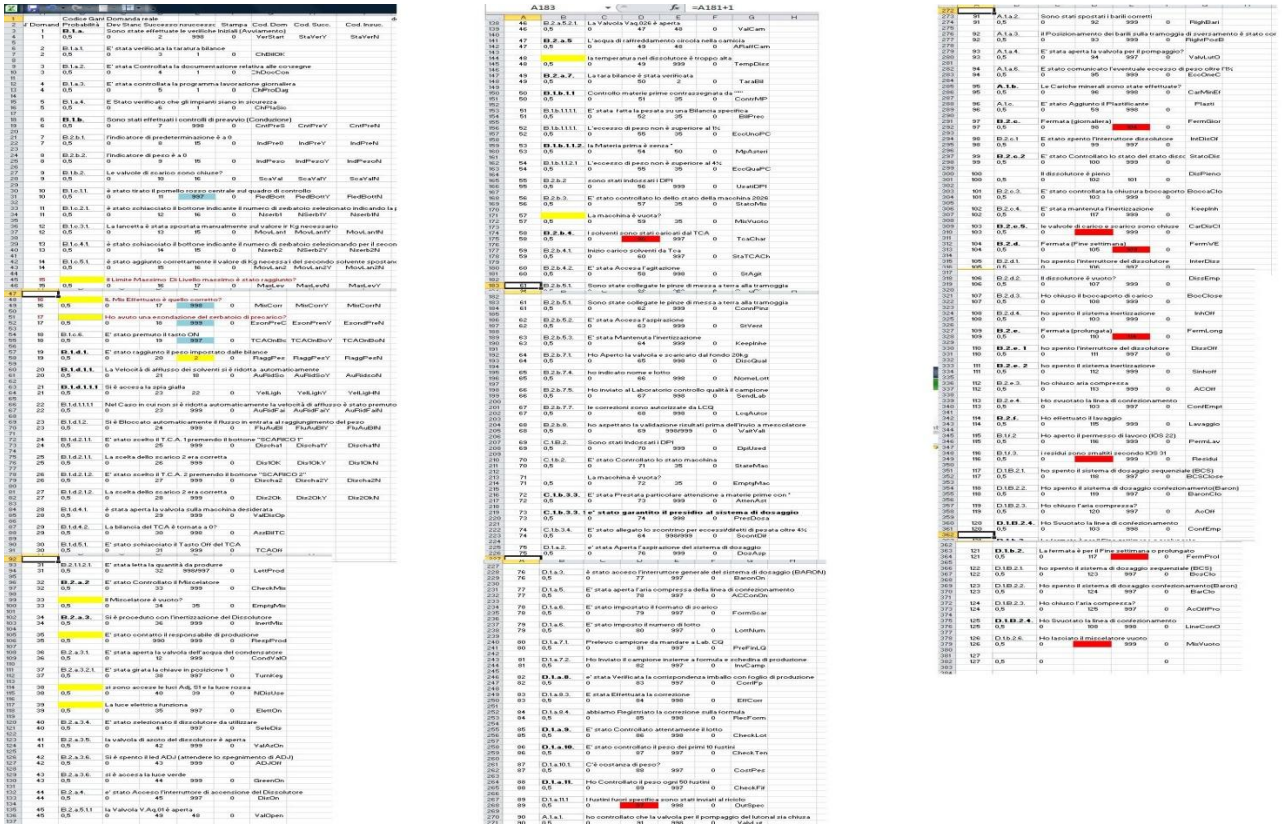


Figure 7.9 List of the 125 possible questions and their connections.

		Codice Gant	Domanda reale							domanda		998	Qu
2	N° Domanda	Probabilità	Dev Stand	Successo	Insuccesso	Stampa	Cod. Dom.	Cod. Succ.	Cod. Insuc.	997	Produzione	999	Sicu
3	1	**B.1.a.**	Sono state effettuate le verifiche Iniziali (Avviamento)										
4	1	0,5	0	2	998	0	VerStart	StaVerY	StaVerN				
6	2	B.1.a.1.	E' stata verificata la taratura bilance										
7	2	0,5	0	3	1	0	ChBilOK						
9	3	B.1.a.2.	E' stata Controllata la documentazione relativa alle consegne										
10	3	0,5	0	4	1	0	ChDocCon						
12	4	B.1.a.3.	E' stata controllata la programma lavorazione giornaliera										
13	4	0,5	0	5	1	0	ChProDay						
15	5	B.1.a.4.	E Stato verificato che gli impianti siano in sicurezza										
16	5	0,5	0	6	1	0	ChPlaSic						
18	6	**B.1.b.**	Sono stati effettuati i controlli di preavvio (Conduzione)										
19	6	0,5	0	7	998	0	CntPreS	CntPreY	CntPreN				
21	7	B.2.b.1.	l'indicatore di predeterminazione è a 0										
22	7	0,5	0	8	15	0	IndPre0	IndPreY	IndPreN				
24	8	B.2.b.2.	l'indicatore di peso è a 0										
25	8	0,5	0	9	15	0	IndPeso	IndPesoY	IndPesoN				
27	9	B.1.b.2.	Le valvole di scarico sono chiuse?										
28	9	0,5	0	10	16	0	ScaVal	ScaValY	ScaValN				
30	10	B.1.c.1.1.	è stato tirato il pomello rosso centrale sul quadro di controllo										
31	10	0,5	0	11	997	0	RedBott	RedBottY	RedBottN				
33	11	B.1.c.2.1.	è stato schiacciato il bottone indicante il numero di serbatoio selezionato indicando la pompa dedicata										
34	11	0,5	0	12	16	0	Nserb1	NSerb1Y	Nserb1N				
36	12	B.1.c.3.1.	La lancetta è stata spostata manualmente sul valore in Kg necessario										
37	12	0,5	0	13	15	0	MovLan1	MovLan1Y	MovLan1N				
39	13	B.1.c.4.1.	è stato schiacciato il bottone indicante il numero di serbatoio selezionando per il secondo solvente indicando la pompa dedicata										
40	13	0,5	0	14	15	0	Nserb2	NSerb2Y	Nserb2N				
42	14	B.1.c.5.1.	è stato aggiunto correttamente il valore di Kg necessari del secondo solvente spostando la lancetta										
43	14	0,5	0	15	16	0	MovLan2	MovLan2Y	MovLan2N				

		Codice Gant	Domanda reale						
2	N° Domanda	Probabilità	Dev Stand	Successo	Insuccesso	Stampa	Cod. Dom.	Cod. Succ.	Cod. Insuc.
339	113	B.2.e.4.	Ho svuotato la linea di confezionamento						
340	113	0,5	0	103	997	0	ConfEmpt		
342	114	**B.2.f.**	Ho effettuato il lavaggio						
343	114	0,5	0	115	999	0	Lavaggio		
345	115	B.1.f.2	Ho aperto il permesso di lavoro (IOS 22)						
346	115	0,5	0	116	999	0	PermLav		
348	116	B.1.f.3.	i residui sono smaltiti secondo IOS 31						
349	116	0,5	0		999	0	Residui		
351	117	D.1.B.2.1.	ho spento il sistema di dosaggio sequenziale (BCS)						
352	117	0,5	0	118	997	0	BCSClose		
354	118	D.1.B.2.2.	Ho spento il sistema di dosaggio confezionamento(Baron)						
355	118	0,5	0	119	997	0	BaronClo		
357	119	D.1.B.2.3.	Ho chiuso l'aria compressa?						
358	119	0,5	0	120	997	0	AcOff		
360	120	**D.1.B.2.4.**	Ho Svuotato la linea di confezionamento						
361	120	0,5	0	103	998	0	ConfEmp		
363	121	**D.1.b.2.**	La fermata è per il Fine settimana o prolungato						
364	121	0,5	0	117		0	FermProl		
366	122	D.1.B.2.1.	ho spento il sistema di dosaggio sequenziale (BCS)						
367	122	0,5	0	123	997	0	BcsClo		
369	123	D.1.B.2.2.	Ho spento il sistema di dosaggio confezionamento(Baron)						
370	123	0,5	0	124	997	0	BarClo		
372	124	D.1.B.2.3.	Ho chiuso l'aria compressa?						
373	124	0,5	0	125	997	0	AcOffPro		
375	125	**D.1.B.2.4.**	Ho Svuotato la linea di confezionamento						
376	125	0,5	0	108	998	0	LineConO		
378	126	D.1.b.2.6.	Ho lasciato il miscelatore vuoto						
379	126	0,5	0		999	0	MixVuoto		

Figure 7.10 Detail of the first and last fourteen questions

7.4.3 The third version

7.4.3.1 Main process

The main characteristic of this file with respect to the others has been to introduce the indentation between the 10 main blocks identified with their specific sub-actions and itself under-level actions.

The deeper level of definition necessary to explain completely the process has been 4 and the lowest has been 1.

The total amount of question has been reached 52 binary answer questions divided in

Questions	Level
9	1°
28	2°
11	3°
4	4°

Table 7.2 Questions and level division

Starting from the higher level necessary to define the complete unit we zoomed in into the specific equipment highlighting exactly 42 secondary questions necessary for the right understanding of the actions performed by this specific equipment

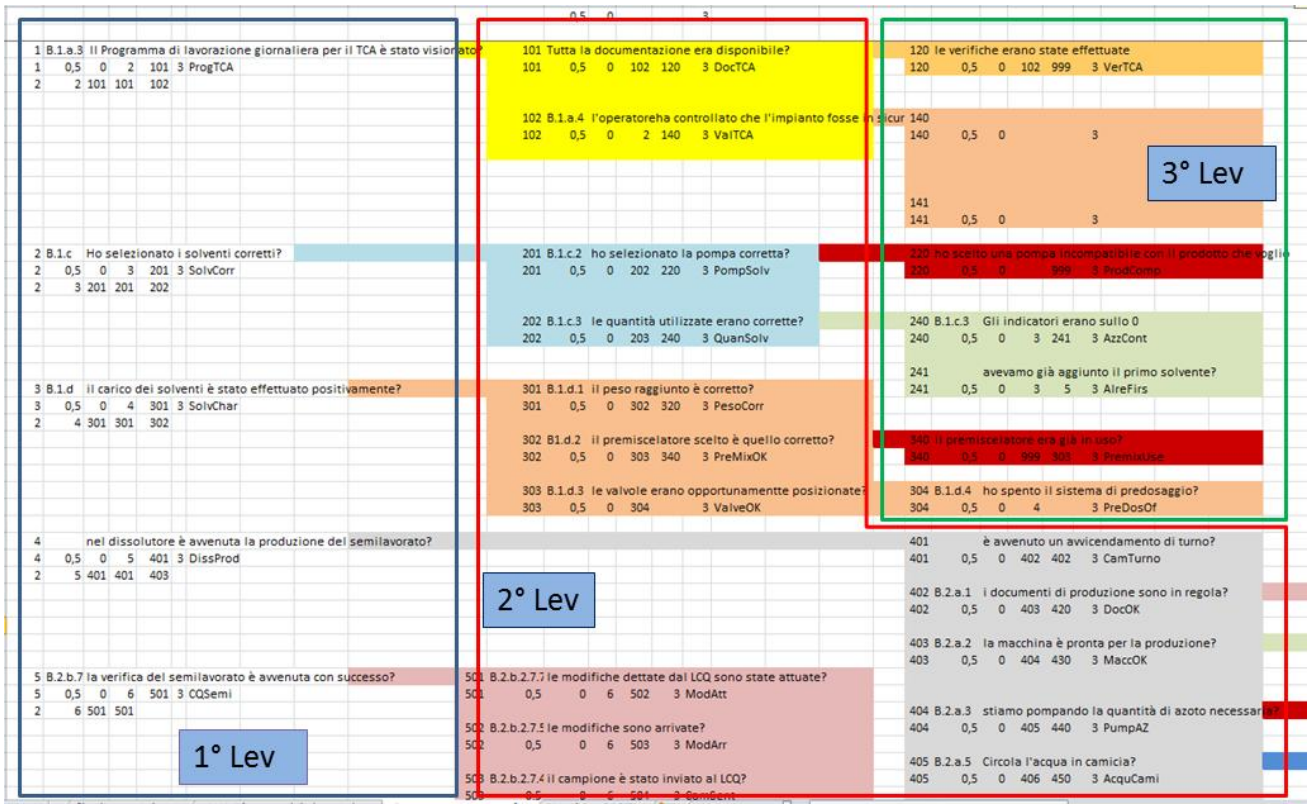


Figure 7.11 Quick overview of the deepness of the system.

7.4.3.2 Focus on the machine 2

In this second description of the plant we obviously find just 3 level of deepness from the 4 of the previous version:

16 for the first level, 13 for the second level and 13 for the 3 level of depth-analysis.

In this analysis all the nodes of the analysis, or questions, are basically still structured as action and not yet as a function necessary to be execute to fulfill for the process undergoing.

In the definition we still kept in count also some modification for the manual of the process that could be performed as a shortcut and that could be due to the experience of the operator.

First level:

Ques	Italian	English
1	i macchinari sono accesi?	Are the equipments on?
2	le quantità dei prodotti inseriti corrispondono ai codici della ricetta?	are the product in the right quantity and corresponding to their codes?

3	l'operatore ha vigilato durante il versamento dei prodotti con l'asterisco?	Is the operator paying attention while the * product are charging?
4	sono state apportate delle modifiche dovute all' "esperienza" rispetto la ricetta iniziale?	Has the receipt been modified by the operator due to his experience?
5	il processo di miscelazione è iniziato?	Is the mixing process started?
6	per il laboratorio di controllo qualità (LCQ) il prodotto rispetta gli standard?	is the product respecting the standards?
7	accensione aspirazione	Is the Aspiration switched on?
8	accensione aria compressa	is the Air conditioned on?
9	è stato impostato il numero di lotto?	is setted up the lot number?
10	è stato inviato nuovamente un campione al LCQ	Is the Sample sent back to the Labs?
11	i lotti sono stati controllati attentamente?	Are, the lots, checked?
12	il peso risulta costante?	is the weight stable?
13	la documentazione è stata redatta in maniera opportuna?	are the documents edited in the right way?
14	raggiunta la fine della produzione ho spento il sistema di dosaggio	Is the dosage system switched off at the end of the production?
15	devo cambiare prodotto?	do I have to change product?
16	ho chiuso tutte le valvole?	Do i closed all the valves?

Table 7.3 First level of question in the excel File

Second level:

Ques	Italian	English
51	ho verificato lo stato dei macchiari/della macchina 2?	Do i verified the state of the machine 2?

52	è stato fatto il passaggio di consegne con il turno precedente?	Is the shift passage been done?
61	il procedimento per ottenere la stampa della ricetta è corretto?	is the process to obtain the receipt correct?
62	le bilance funzionano?	does the balance are functioning?
63	è stata verificata la taratura di tutte e 3 le bilance?	do i calibrate the balance?
71	l'operatore ha vigilato durante il versamento dei prodotti senza l'asterisco?	does the operator controlled while the product where charged?
72	qual'ora le variazioni siano superiori al consentito è stato allegato lo scontrino?	in case that the variance is bigger than possible do i add the ticket?
100	le modifiche definite dal LCQ sono state apportate?	do I modify as suggested by the LCQ?
140	Sono state impostate le modalità di scarico?	Do i selected the discharge mode?
150	è stata registrata la correzione della formula?	do i register the correction of the formula?
160	le confezioni sono integre?	are the pack intact?
161	i sovracolli sono in regola?	do i checked the sticker on the lots?
170	i fustini fuori norma sono inviati al riciclo?	do i sent the pack out of law to recycle?

Table 7.4 Second level of Functions

Third level:

Ques	Gantt	Italian	English
250	C.1.a.5.1.	Apertura oblò	Do I opened the window?
251	C.1.a.5.2.	Digito il numero della ricetta sulla tastiera	Have i digit the number of receipt on the keyboard?
252	C.1.a.5.3.	Confermo il numero della ricetta	do i confermed the number of receipt?
253	C.1.a.6.1.	Premere "S" e "0" insieme	do i pressed “S” and ”0” togheter
254	C.1.a.6.2.	Azzerare display premendo 6 volte 0	Do i set to 0 the display pushing six times the 0
255	C.1.a.6.3	Digitare numero ricetta riportato	do i digit the number of receipt?
256	C.1.a.6.4	Premere "enter"	do i pushed enter?

257	C.1.a.6.5.	Premere insieme "S" e "Print"	do i pushed together “S” and ”Print”
258	C.1.a.6.7.	Premere "enter" ed avvio la stampa	Do i pushed “Enter” again to start the printing?
260	D.1.a.8.1.	Chiudere lotto	do i close the lot?
261	D.1.a.8.2.	Resettare la bilancia	Did i reset the balance?
262	D.1.a.8.3.	Effettuare correzione	do i made corrections?
263	D.1.a.8.4.	Registriamo la correzione sulla formula ?	do i registered the correcion to the formula?

Table 7.5 Third level of functions

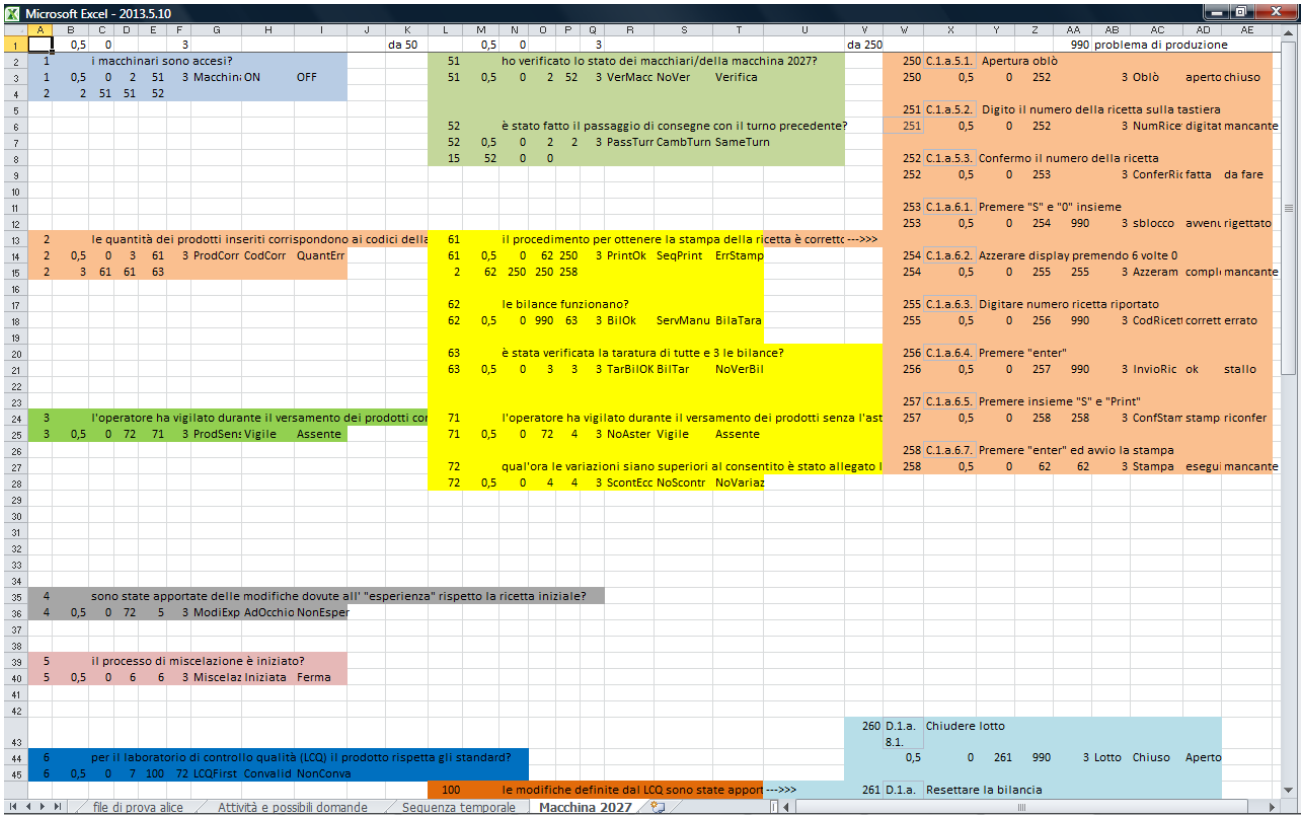


Figure 7.12 Quick overview of the model focused on the machine 2

7.4.4 The fourth version

7.4.4.1 Machine 2

This configuration is characterized by the 6 less question from the previous model with this values:

Functions	Level
16	1st level
13	2nd level
7	3rd level

Table 7.6 Functions division into levels

This reduction can be just appointed to the evaluations that we can call them as supported actions and not fundamentals one.

Those actions were:

250 C.1.a.5.1. Apertura oblò

252 C.1.a.5.3. Confermo il numero della ricetta

253 C.1.a.6.1. Premere "S" e "0" insieme

255 C.1.a.6.3. Digitare numero ricetta riportato

256 C.1.a.6.4. Premere "enter"

257 C.1.a.6.5. Premere insieme "S" e "Print"

This actions can be considered in this way because are preparatory to the other so they can be considered as a lower level of importance even if not meaningless.

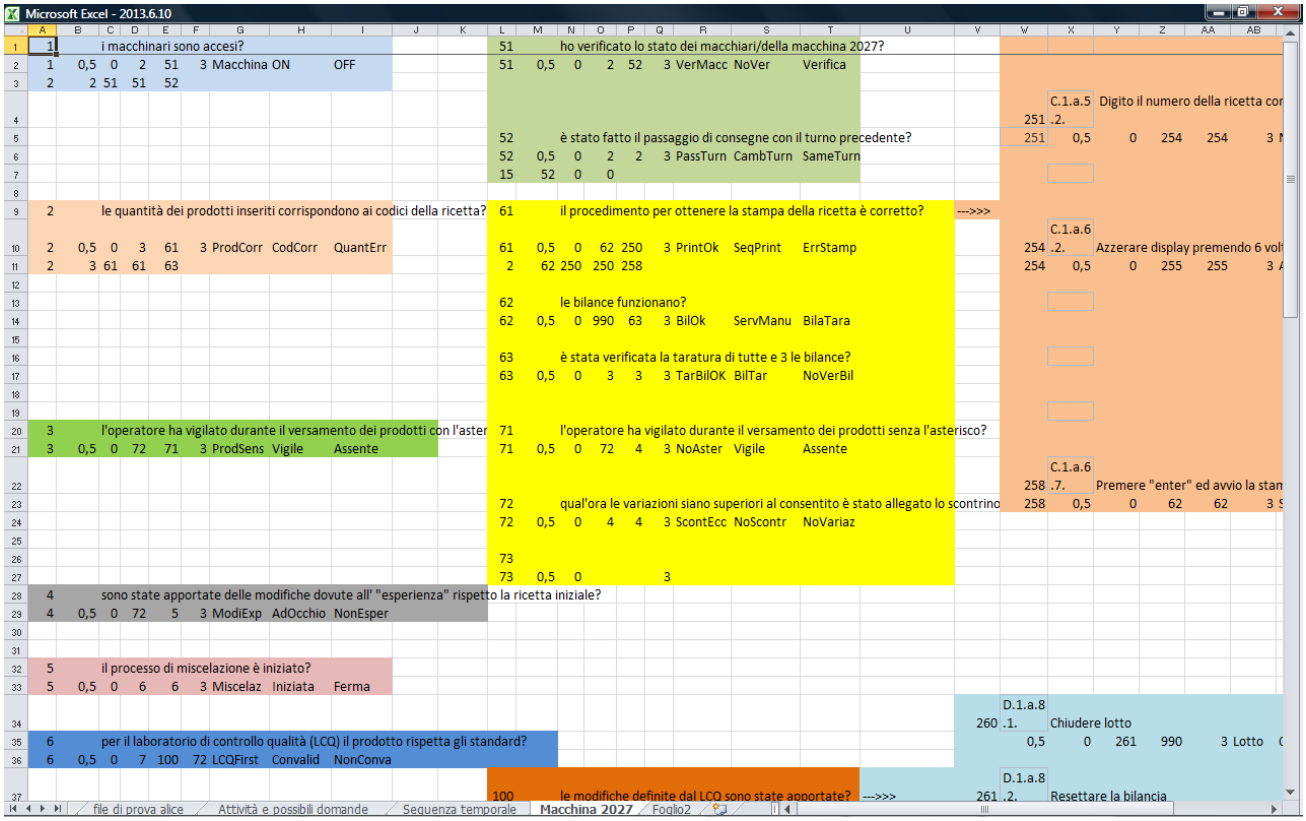


Figure 7.13 Final model developped for the machine 2

7.5 A.LB.A. (Algoritm Logic Bayesian Analysis)

7.5.1 First A.LB.A. Input File (Mapei2)

The ALBA's input file has been written, starting from the above explained excel files, integrating the actions highlighted with the specific logic of interactions typical of this software.

The software is characterized by the possibility to constrain the binary explosion shaping the way that the outcome has to show; in this "learning mode" we can insert the bind necessary for the right reconstruction of the output and designing, like this, the desired reality.

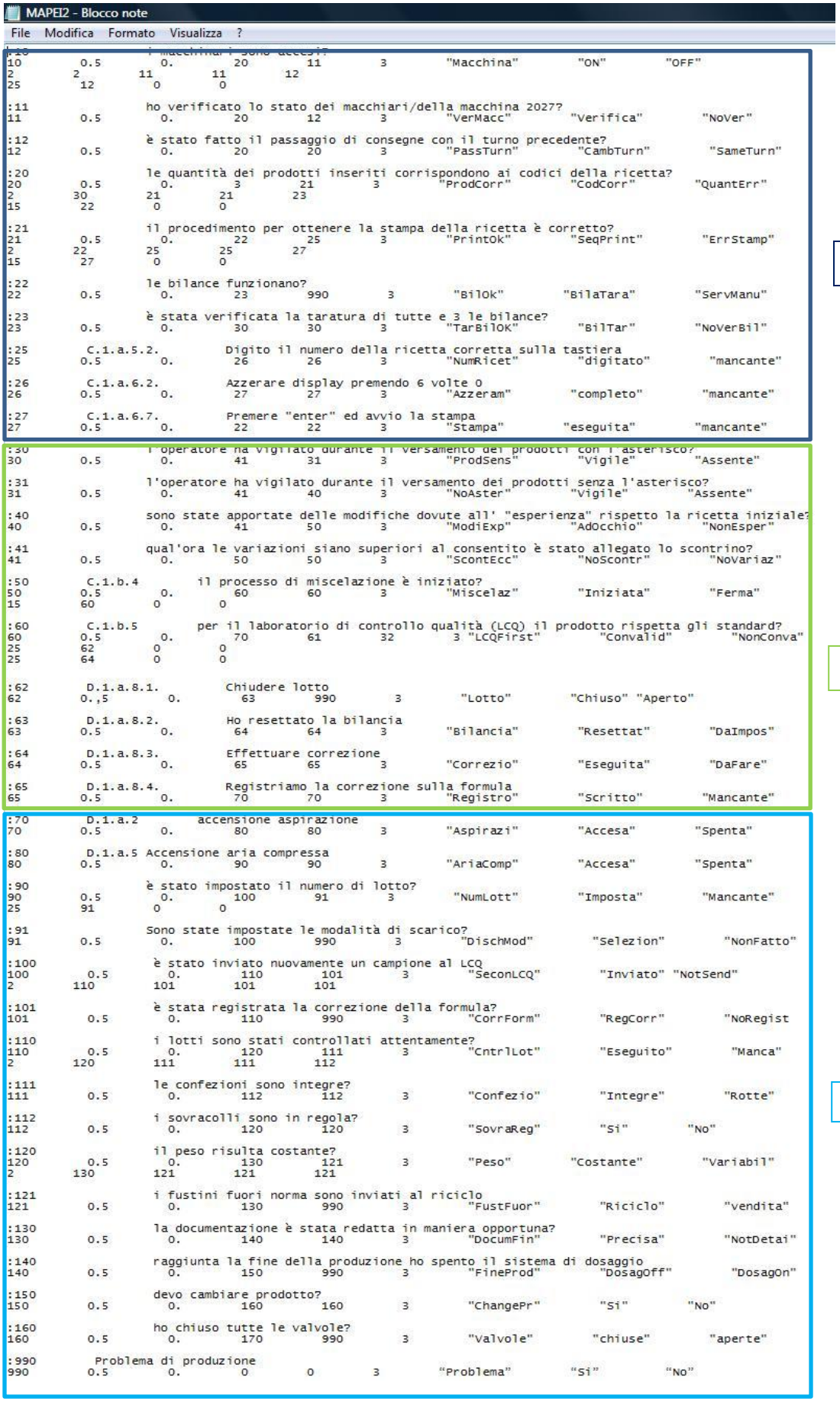
This first model has been composed by 36 different actions representing different hierarchical levels of the process that are going from the analysis of the mixing process (Macro actions or phases), to push of a specific button (micro actions or sub-actions) and we can also involve some pro-future actions, like a planned changing of production.

Obviously, the possibility to change the timeline imposed, defining questions to different level of specifications is a high value option, is extremely important for us to modify the possible outcomes in the most adherent way to the reality.

In the Figure 7.14 we can see all the components, the basic questions, the logic of connection, how the questions can be recognizable and also the answer that the software will give us in both of the binary cases.

This model is following all the fundamental action necessary to perform without useless "support actions", the support actions, as already mentioned, are that kind of actions that are not having the "key" for the next function so are not extremely important and for this reason we cannot write them explicitly.

Some of the actions are showing a code before the definition of the question and some other not, if the code is not visible it means that are not actions present in that specific form in the Gantt even if in the Gantt diagram are expressed in a different way.



MAPEI2 - Blocco note

File Modifica Formato Visualizza ?

```
:10                 i macchinari sono accesi?
10          0.5       0.          20          11          3          "Macchina"          "ON"          "OFF"
2           2         11          11          12
25          12        0           0

:11                 ho verificato lo stato dei macchiari/della macchina 2027?
11          0.5       0.          20          12          3          "VerMacc"           "Verifica"          "NoVer"

:12                 è stato fatto il passaggio di consegne con il turno precedente?
12          0.5       0.          20          20          3          "PassTurn"          "CambTurn"          "SameTurn"

:20                 le quantità dei prodotti inseriti corrispondono ai codici della ricetta?
20          0.5       0.          3           21          3          "ProdCorr"          "CodCorr"           "QuantErr"
2           30        21          21          23
15          22        0           0

:21                 il procedimento per ottenere la stampa della ricetta è corretto?
21          0.5       0.          22          25          3          "PrintOk"           "SeqPrint"          "ErrStamp"
2           22        25          25          27
15          27        0           0

:22                 le bilance funzionano?
22          0.5       0.          23          990         3          "BilOk"          "BilaTara"          "ServManu"

:23                 è stata verificata la taratura di tutte e 3 le bilance?
23          0.5       0.          30          30          3          "TarBilOK"          "BilTar"          "NoVerBil"

:25          C.1.a.5.2.          Digito il numero della ricetta corretta sulla tastiera
25          0.5       0.          26          26          3          "NumRicet"          "digitato"          "mancante"

:26          C.1.a.6.2.          Azzerare display premendo 6 volte 0
26          0.5       0.          27          27          3          "Azzeram"           "completo"          "mancante"

:27          C.1.a.6.7.          Premere "enter" ed avvio la stampa
27          0.5       0.          22          22          3          "Stampa"          "eseguita"          "mancante"

:30                 l'operatore ha vigilato durante il versamento dei prodotti con l'asterisco?
30          0.5       0.          41          31          3          "ProdSens"          "Vigile"          "Assente"

:31                 l'operatore ha vigilato durante il versamento dei prodotti senza l'asterisco?
31          0.5       0.          41          40          3          "NoAster"           "Vigile"          "Assente"

:40                 sono state apportate delle modifiche dovute all' "esperienza" rispetto la ricetta iniziale?
40          0.5       0.          41          50          3          "ModiExp"           "AdOcchio"          "NonEsper"

:41                 qual'ora le variazioni siano superiori al consentito è stato allegato lo scontrino?
41          0.5       0.          50          50          3          "ScontEcc"          "NoScontr"          "NoVariaz"

:50          C.1.b.4          il processo di miscelazione è iniziato?
50          0.5       0.          60          60          3          "Miscelaz"          "Iniziata"          "Ferma"
15          60        0           0

:60          C.1.b.5          per il laboratorio di controllo qualità (LCQ) il prodotto rispetta gli standard?
60          0.5       0.          70          61          32         3 "LCQFirst"          "Convalid"          "NonConva"
25          62        0           0
25          64        0           0

:62          D.1.a.8.1.          Chiudere lotto
62          0.,5      0.          63          990         3          "Lotto"          "Chiuso" "Aperto"

:63          D.1.a.8.2.          Ho resettato la bilancia
63          0.5       0.          64          64          3          "Bilancia"          "Resettat"          "DaImpos"

:64          D.1.a.8.3.          Effettuare correzione
64          0.5       0.          65          65          3          "Correzio"          "Eseguita"          "DaFare"

:65          D.1.a.8.4.          Registriamo la correzione sulla formula
65          0.5       0.          70          70          3          "Registro"          "Scritto"          "Mancante"

:70          D.1.a.2          accensione aspirazione
70          0.5       0.          80          80          3          "Aspirazi"          "Accesa"          "Spenta"

:80          D.1.a.5 Accensione aria compressa
80          0.5       0.          90          90          3          "AriaComp"          "Accesa"          "Spenta"

:90                 è stato impostato il numero di lotto?
90          0.5       0.          100         91          3          "NumLott"          "Imposta"          "Mancante"
25          91        0           0

:91                 Sono state impostate le modalità di scarico?
91          0.5       0.          100         990         3          "DischMod"          "Selezion"          "NonFatto"

:100                è stato inviato nuovamente un campione al LCQ
100         0.5       0.          110         101         3          "SeconLCQ"          "Inviato" "NotSend"
2           110       101         101         101

:101                è stata registrata la correzione della formula?
101         0.5       0.          110         990         3          "CorrForm"          "RegCorr"          "NoRegist

:110                i lotti sono stati controllati attentamente?
110         0.5       0.          120         111         3          "CntrlLot"          "Eseguito"          "Manca"
2           120       111         111         112

:111                le confezioni sono integre?
111         0.5       0.          112         112         3          "Confezio"          "Integre"          "Rotte"

:112                i sovracolli sono in regola?
112         0.5       0.          120         120         3          "SovraReg"          "Si"          "No"

:120                il peso risulta costante?
120         0.5       0.          130         121         3          "Peso"          "Costante"          "Variabil"
2           130       121         121         121

:121                i fustini fuori norma sono inviati al riciclo
121         0.5       0.          130         990         3          "FustFuor"          "Riciclo"          "vendita"

:130                la documentazione è stata redatta in maniera opportuna?
130         0.5       0.          140         140         3          "DocumFin"          "Precisa"          "NotDetai"

:140                raggiunta la fine della produzione ho spento il sistema di dosaggio
140         0.5       0.          150         990         3          "FineProd"          "DosagOff"          "DosagOn"

:150                devo cambiare prodotto?
150         0.5       0.          160         160         3          "ChangePr"          "Si"          "No"

:160                ho chiuso tutte le valvole?
160         0.5       0.          170         990         3          "Valvole"          "chiuse"          "aperte"

:990          Problema di produzione
990         0.5       0.          0           0           3          "Problema"          "Si"          "No"
```

Checks

Production

Pack

Figure 7.14 File Input IDDA Mapei 2

7.5.2 Mapei 9

This model, is taken as an example of also the previous one not just because is shown a reduction of 1 question in comparison with the other, which is actually a sub-action (number 61) absorbed by the previous action, by a better semantic or definition of the questions but because we wanted to show which one were the typical outputs of the software.

Are visible, here below, how the software is showing the results, first with an overview of our model:
the number of stories can be represented by the number of point of our model if it would be a graph, than are also meaning full the residual probability which literally represent the amount of not considered options of stories, somehow is our error of evaluation, and the entropy of the system.

Below we also showed an example of story, performed by our software, that needs to be analyzed to understand which can be the deviations not taken into account until that moment but needs to be represented cause are possible stories or events that can be performed in the plant.

```
                ANALYSIS of "MAPEI9  "
               ====================
    GENERAL PICTURE on the SET of POSSIBLE ALTERNATIVES
    ===================================================
    SOURCE FILE NAME       : MAPEI9.INP
    STORAGE FILE NAME      : XMAPEI9.OUT
    STARTING LEVEL         :  10
    LOWEST PROBABILITY     : 1.0000E-12
    HIGHEST PROBABILITY    : 1.0000E+00
    MISSION TIME           :
    CONSTITUENT TOTAL NUMBER :    45712
    CUMULATIVE PROBABILITY   : 9.99999980E-01
    RESIDUAL PROBABILITY     : 2.004580E-08
    Partition Entropy      : 3.468711E+00
```

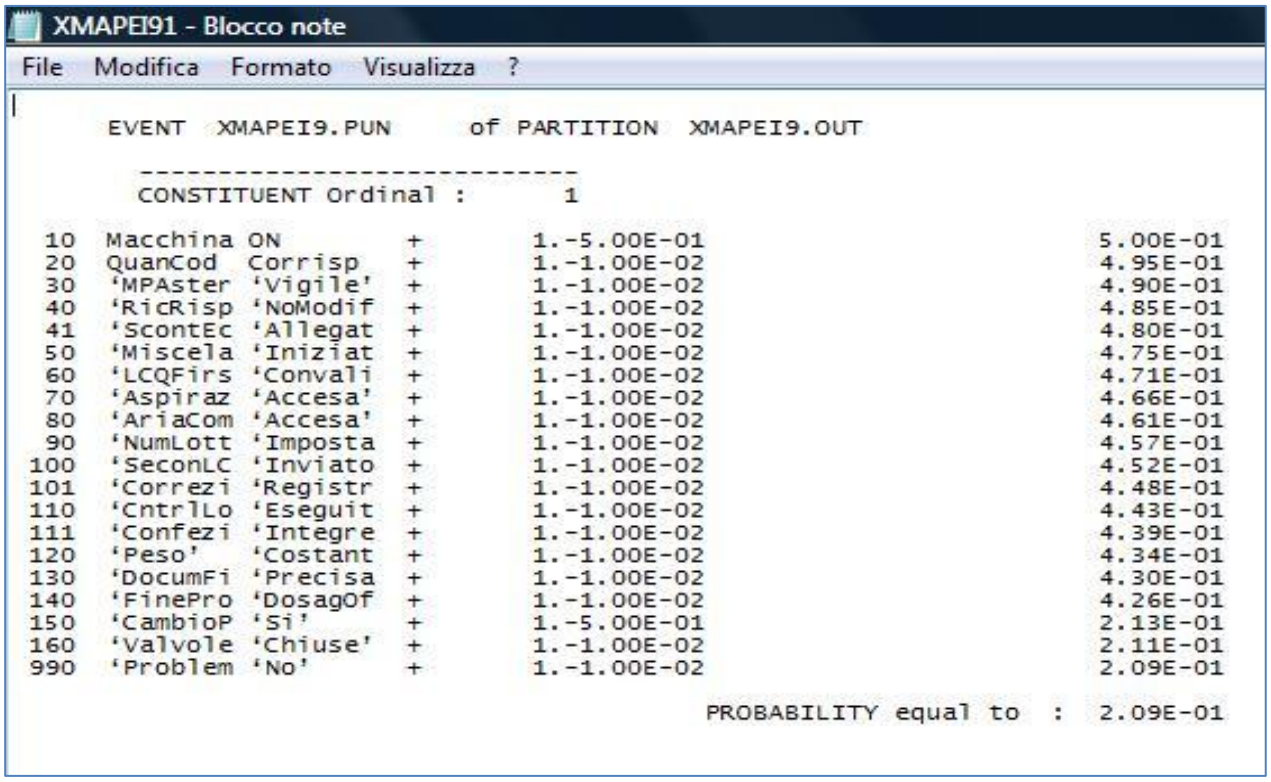


Figure 7.15 Example of a "story", output of the Idda Software

7.5.3 Mapei 10

The difference in this model that we want to show is not represented by the extra question added which is "the change of the product" and we also inserted again the question 61 but we wanted to show how a mistake in the perception of the model can provoke a multiple error.

Unfortunately, modifying the links between the questions necessary to create a more adherent model, we have created a loop in the connections, this loop has to be attribute to the mistakes in the definitions of the bonds, the problem has been identification in the multiple recall of the question 112 until its negative answer:

:110	D.1.a.9	i lotti sono stati controllati attentamente?						
110	0.01	0.	120	111	3	'CntrlLot'	'Eseguito'	'Manca'
2	112	111	111	112				
15	112	0	0					
:111	D.1.a.9.1.	le confezioni sono integre?						
111	0.01	0.	112	112	3	'Confezio'	'Integre'	'Rotte'
:112	D.1.a.9.2.	i sovracolli sono in regola?						
112	0.01	0.	120	120	3	'SovraReg'	'Si'	'No'

Table 7.7 Mapei 10 modification

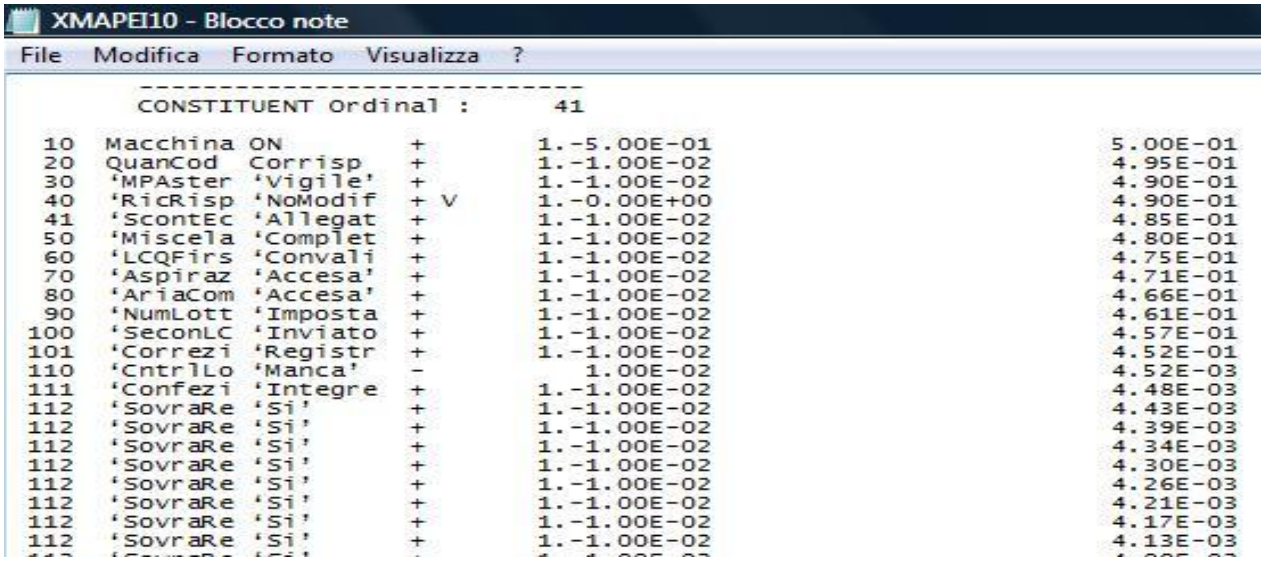


Figure 7.16 Perfect Example of a loop generated by a wrong connection in the recalls of the model

7.5.4 Mapei 11

The main improvement brought by this version has been the split into 3 different questions, as shown in the example below, the core of the machine under investigation represented by the right amount of material to put into the mixer; before we were asking only if the amount of a specific raw material were correct, now we are also asking if there has been brought some manual modification and if this modification has been recorded somewhere.

:D		l'operatore ha controllato lo sversamento della quantità indicata di Materiale?						
D	0.01	0	D+1	D+3	3	'Material'	'Controll'	'Automati'
:D+1		l'operatore non ha modificato manualmente la quantità sversata nella macchina?						
D+1	0.01	0	D+3	D+2	3	'MateManu'	'No'	'Si'
:D+2		Differenza oltre l'1% rispetto alla ricetta registrata?						
D+2	0.01	0	D+3	70	3	'DeltaMat'	'Registra'	'NoRegist'
26	70	0	0					
15	70	0	0					
:70	C.1.b.3.4.	qual'ora le variazioni siano superiori al consentito è stato allegato lo scontrino?						
70	0.01	0.	80	80	3	'ScontEcc'	'Allegato'	'NoScontr'

Table 7.8 Mapei file 11 main modification

Also we added a question concerning the possible malfunction of the pneumatic system, possibility that wasn't expressed until now, this passage can be critical because its play a fundamental role in the supply of the carbonates to the mixer.

The total amount of question has been pushed than up to 61/62 describing, this amount is depending also because we token into account all the possible deviation from the standard of the product.

7.5.5 Mapei 12-13

In this two versions of the input files we tried to work analyzing the previous output files.

From each output we selected a sample varying from 350 to 600 outcomes points, normally the first and the last 100-150, the same amount from the 50% of the outcomes and also from the 25% and 75% (first and third quartile), to identify which are the possible deviation from the logic of connection of what is happening in reality.

The critical point is due to the high number of outcomes we have to manage, almost 900.000, to understand and investigate before to bring modification in the following input file.

```
                ANALYSIS of "MAPEI12 "
               ====================
GENERAL PICTURE on the SET of POSSIBLE ALTERNATIVES
=====================================================
SOURCE FILE NAME        : MAPEI12.INP
STORAGE FILE NAME       : XMAPEI12.OUT
STARTING LEVEL          :   10
LOWEST PROBABILITY      : 1.0000E-12
HIGHEST PROBABILITY     : 1.0000E+00
MISSION TIME            :
CONSTITUENT TOTAL NUMBER :    846073
CUMULATIVE PROBABILITY   : 9.99999386E-01
RESIDUAL PROBABILITY     : 6.136944E-07
Partition Entropy        : 4.828697E+00
```

```
:10 C.1.a.3 i macchinari sono accesi?
10 0.5 0. 20 11 3 'Macchina' 'ON' 'OFF'

:11 è stato fatto il passaggio di consegne con il turno precedente?
11 0.01 0. 20 12 3 'Consegne' 'Passate' 'DaFare'

:12 C.1.b.2 ho verificato che la macchina 2 sia vuota?
12 0.01 0. 20 990 3 'StatoMac' 'Vuoto' 'DaVerifi'
26 990 0 0

:20 C.1.a.7 le quantità dei prodotti da inserire corrispondono ai codici della ricetta?
20 0.01 0. 30 21 3 'QuanCod' 'Corrisp' 'NonCong'
26 990 0 0

:21 C.1.a.5/6 la stampa della ricetta è corretta?
21 0.01 0. 26 22 3 'Print' 'SequeOK' 'ErrStamp'

:22 C.1.a.5.2. Digito il numero della ricetta corretta sulla tastiera
22 0.01 0. 23 990 3 'NumRicet' 'Digitato' 'Mancante'
26 990 0 0

:23 C.1.a.6.2. Azzerare display premendo 6 volte 0
23 0.01 0. 24 24 3 'Azzeram' 'Completo' 'Mancante'
26 990 0 0

:24 C.1.a.6.7. Premere 'enter' ed avvio la stampa
24 0.01 0. 26 26 3 'Stampa' 'Eseguita' 'Mancante'

:26 C.1.a.8 è stata verificata la taratura di tutte e 3 le bilance?
26 0.01 0. 30 990 3 'Taratura' 'Verifica' 'ChiamMan'
26 990 0 0

:30 è stata accesa l'agitazione?
30 0.01 0. 31 990 3 'Agitazio' 'Iniziata' 'Ferma'
26 990 0 0

:31 C.1.b.3.3 l'operatore ha controllato lo sversamento della quantità indicata di resina C?
31 0.01 0. 32 34 3 'ResinaC' 'Control' 'Automati'

:32 l'operatore non ha modificato manualmente la quantità preimpostata sversata nella macchina?
32 0.01 0. 34 33 3 'ResCManu' 'No' 'Si'

:33 Differenza oltre l'1% rispetto alla ricetta registrata?
33 0.01 0. 35 70 3 'DeltaC' 'Registra' 'NoRegist'
26 70 0 0
15 70 0 0

:34 La valvola del Resina l è stata aperta dopo aver chiuso quella della resina C?
34 0.01 0. 35 990 3 'InvCL' 'Si' 'No'
26 990 0 0

:35 l'operatore ha controllato lo sversamento della quantità indicata di resina l?
35 0.01 0. 36 38 3 'Resina l' 'Controll' 'Automati'

:36 l'operatore non ha modificato manualmente la quantità sversata nella macchina?
36 0.01 0. 38 37 3 'ResLManu' 'No' 'Si'

:37 Differenza oltre l'1% rispetto alla ricetta registrata?
37 0.01 0. 38 70 3 'DeltaL' 'Registra' 'NoRegist'
26 70 0 0
15 70 0 0

:38 è stata chiusa la valvola del resina l?
38 0.01 0. 39 39 3 'ValvL' 'Chiusa' 'aperta'

:39 è stato verificato il funzionamento del sistema pneumatico di carico polveri?
39 0.01 0. 40 990 3 'SistPneu' 'Funzion' 'Intoppi'
26 990 0 0

:40 l'operatore ha atteso 5 minuti prima dello sversamento della quantità preimpostata di polvere O?
40 0.01 0. 41 41 3 'Polvere O' 'Controll' 'Automatico'

:50 l'operatore ha controllato lo sversamento della quantità indicata di resina C *
50 0.01 0. 51 53 3 'ResinC2' 'Controll' 'Automatico'

:51 l'operatore non ha modificato manualmente la quantità sversata nella macchina
51 0.01 0. 53 52 3 'ReC2Manu' 'No' 'Si'

:52 Differenza oltre l'1% rispetto alla ricetta registrata?
52 0.01 0. 53 70 3 'DeltC2' 'Registra' 'NoRegist'
26 70 0 0
15 70 0 0

:53 l'operatore ha atteso 5 minuti prima dello sversamento della quantità indicata di Plast P?
53 0.01 0. 54 54 3 'Plast' 'Controll' 'Automatico'

54 l'operatore non ha modificato manualmente la quantità preimpostata da versare nella macchina?
54 0.01 0. 70 55 3 'PlasManu' 'No' 'Si'

:55 Differenza oltre l'4% rispetto alla ricetta registrata?
55 0.01 0. 70 70 3 'DeltPla' 'Registra' 'NoRegist'
26 70 0 0
15 70 0 0

:70 C.1.b.3.4. qual'ora le variazioni siano superiori al consentito è stato allegato lo scontrino?
70 0.01 0. 80 80 3 'ScontEcc' 'Allegato' 'NoScontr'

:80 C.1.b.4 si sono attesi 20 minuti dopo lo sversamento del palatinol prima di fermare la miscelazione?
80 0.01 0. 90 90 3 'Miscelaz' 'Completa' 'InCompl'

:90 C.1.b.5 il campione da 20 kg Per il laboratorio di controllo qualità (LCQ) il prodotto rispetta gli standard?
90 0.01 0. 100 91 3 'LCQFirst' 'Convalid' 'NonConva'

:91 C.1.b.5.6. le modifiche definite dal LCQ sono state apportate?
91 0.01 0. 100 92 3 'LCQModif' 'Modific' 'NoModif'
25 92 0 0
25 94 0 0

:92 C.1.b.5.6. Effettuare correzione
92 0.01 0. 95 93 3 'Correzio' 'Eseguita' 'DaFare'

:93 Ho resettato la bilancia
93 0.01 0. 94 94 3 'Bilancia' 'Resettat' 'NonTarat'

:94 C.1.b.5.4. Chiudere lotto
94 0.01 0. 95 990 3 'Lotto' 'Chiuso' 'Aperto'
26 990 0 0

:95 C.1.b.5.6. Registriamo la correzione sulla formula
95 0.01 0. 100 100 3 'Registro' 'Scritto' 'Mancante'

:100 D.1.a.2 accensione aspirazione
100 0.01 0. 110 110 3 'Aspirazi' 'Accesa' 'Spenta'

:110 D.1.a.5 Accensione aria compressa
110 0.01 0. 120 120 3 'AriaComp 'Accesa' 'Spenta'
26 990 0 0

:120 D.1.a.6 è stato impostato il numero di lotto?
120 0.01 0.130 121 3 'NumLott' 'Imposta' 'Mancante'
25 121 0 0

:121 D.1.a.6. Sono state impostate le modalità di scarico?
121 0.01 0. 130 990 3 'Scarico' 'Impostat' 'NoPronto'

:130 D.1.a.7.1. è stato inviato nuovamente un campione al LCQ dal prelievo di 100kg
130 0.01 0. 131 140 3 'SeconLCQ' 'Inviato' 'NotSend'

:131 D.1.a.8.4. è stata registrata la correzione della formula?
131 0.01 0. 140 990 3 'Correzi' 'Registr' 'NonRegis'
26 990 0 0

:140 D.1.a.9 i lotti sono stati controllati attentamente uno ad uno?
140 0.01 0. 141 150 3 'CntrlLot' 'Eseguito' 'Manca'
```

:41 l'operatore non ha modificato manualmente la quantità sversata nella macchina? 41 0.01 0. 43 42 3 'OCManu' 'No' 'Si' :42 Differenza oltre l'4% rispetto alla ricetta registrata? 42 0.01 0. 43 70 3 'DeltaOC' 'Registra' 'NoRegist' 26 70 0 0 15 70 0 0 :43 l'operatore ha controllato che lo sversamento della quantità indicata di polvere a sia avvenuto? 43 0.01 0. 44 46 3 'Polvere a' 'Controll' 'Automatico' :44 l'operatore non ha modificato manualmente la quantità sversata nella macchina? 44 0.01 0. 46 45 3 'AManu' 'No' 'Si' :45 Differenza oltre l'4% rispetto alla ricetta registrata? 45 0.01 0. 46 70 3 'DeltaA' 'Registra' 'NoRegist' 26 70 0 0 15 70 0 0 :46 l'operatore ha atteso 10 minuti prima di inserire la seconda quantità indicata di polvere O nella macchina? 46 0.01 0. 47 47 3 'OC2' 'Controll' 'Automatico' :47 l'operatore non ha modificato manualmente la quantità preimpostata versata nella macchina? 47 0.01 0. 49 48 3 'OC2Manu' 'No' 'Si' :48 Differenza oltre l'4% rispetto alla ricetta registrata? 48 0.01 0. 49 70 3 'DeltOc2' 'Registra' 'NoRegist' 26 70 0 0 15 70 0 0 :49 La valvola per il carico della resina C è stata perta nuovamente dopo aver aspettato 10 minuti dal secondo carico di Polvere O? 49 0.01 0. 50 990 3 'ValvColo' 'Aperta' 'Chiusa' 26 990 0 0	:141 D.1.a.9.1. tutte le confezioni sono integre? 141 0.01 0. 142 142 3 'Confezio' 'Integre' 'Rotte' :142 D.1.a.9.2. tutti i sovracolli sono in regola? 142 0.01 0. 150 150 3 'SovraReg' 'Si' 'No' :150 D.1.a.11 il peso risulta costante? 150 0.01 0. 160 151 3 'Peso' 'Costante' 'Variabil' :151 D.1.a.11 i fustini fuori norma sono inviati al riciclo 151 0.01 0. 160 160 3 'FustFuor' 'Riciclo' 'Vendita' 26 990 0 0 :160 D.1.a.12. la documentazione è stata redatta in maniera opportuna? 160 0.01 0. 170 170 3 'DocumFin' 'Precisa' 'Incomple' :170 D.1.b.2.5 raggiunta la fine della produzione ho spento il sistema di dosaggio 170 0.01 0. 180 180 3 'FineProd' 'DosagOff' 'DosagOn' 26 990 0 0 :180 D.1.B.2.4. devo cambiare prodotto 180 0.5 0. 190 181 3 'CambioPr' 'No' 'Si' :181 passo da F57 a Super 181 0.01 0. 190 182 3 'Cambio' 'Compatib' 'Incompat' :182 Ho lavato con tetraidrofurano? 182 0.01 0. 190 990 3 'Lavaggio' 'Si' 'No' 26 990 0 0 :190 D.1.B.2.5. ho chiuso tutte le valvole? 190 0.01 0. 990 990 3 'Valvole' 'Chiuse' 'Aperte' :990 Problema di produzione 990 0.01 0. 0 0 3'Produzio' 'Si' 'No'

Table 7.9 File input Mapei 12

7.5.6 Mapei 14

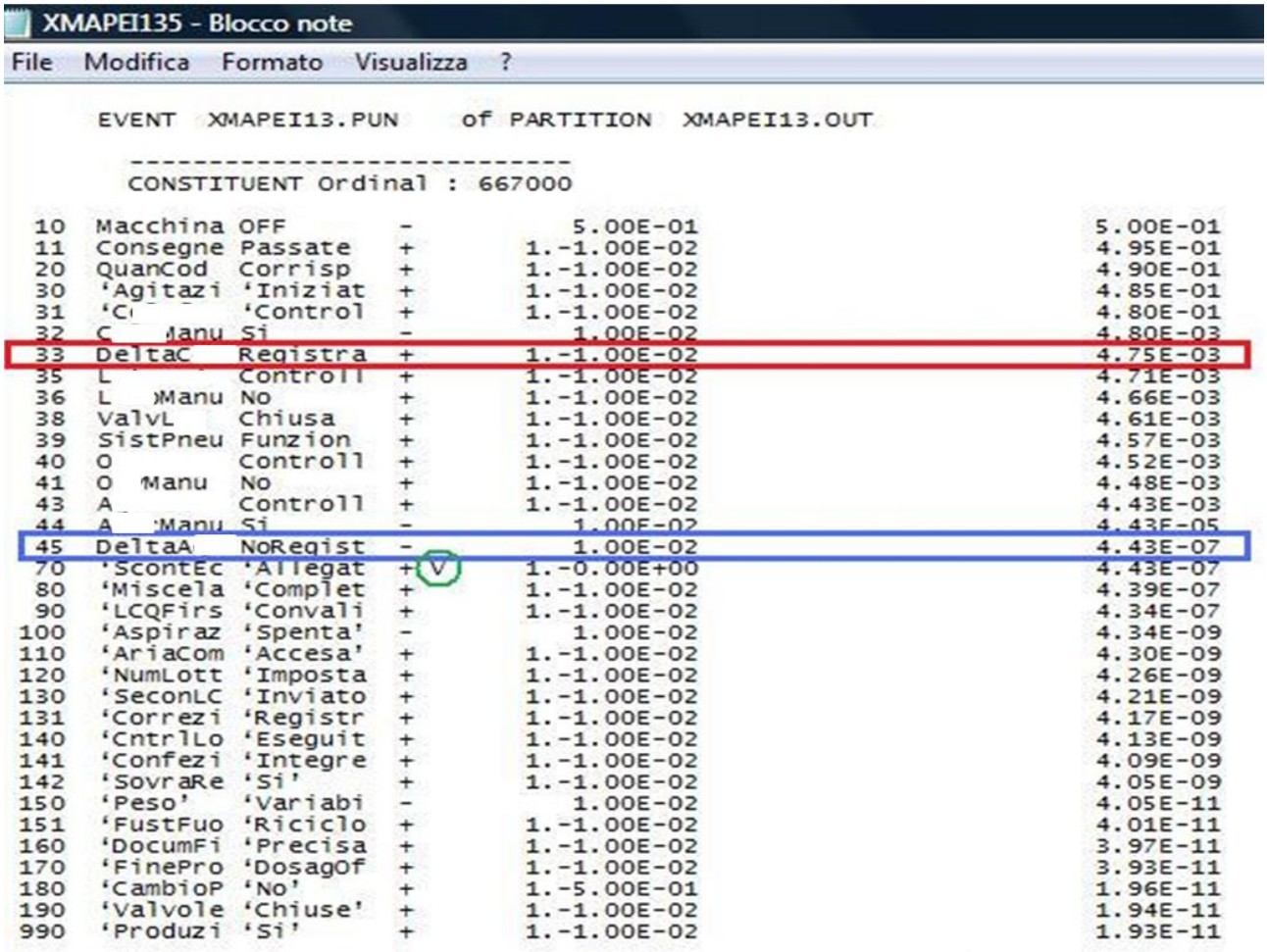
The first modification from the previous file has been represented by the restriction between two questions, more in the detail between the question 38 and the 49.

:38		è stata chiusa la valvola della resina L?						
38	0.01	0.	39	39	3	'ValvLut'	'Chiusa'	'aperta'
2	50	990	49	49				
:49		La valvola per il carico della resina C è stata aperta nuovamente dopo aver aspettato 10 minuti dal secondo carico di OC?						
49	0.01	0.	50	990	3	'ValvColo'	'Aperta'	'Chiusa'
26	990	0	0					

Table 7.10 Main modification of the input file 14

Afterword we had to deal with some possible stories that could not bring macroscopic errors but that could be still sensible for the correct evaluation of the system, one of this can be easily

expressed by one story, the S.667000 where an error should be recorded and signalized (D.45) but it reality this is not happening due to a previous obligation expressed above in the model (D.33).


XMAPEI135 - Blocco note

File Modifica Formato Visualizza ?

EVENT XMAPEI13.PUN of PARTITION XMAPEI13.OUT

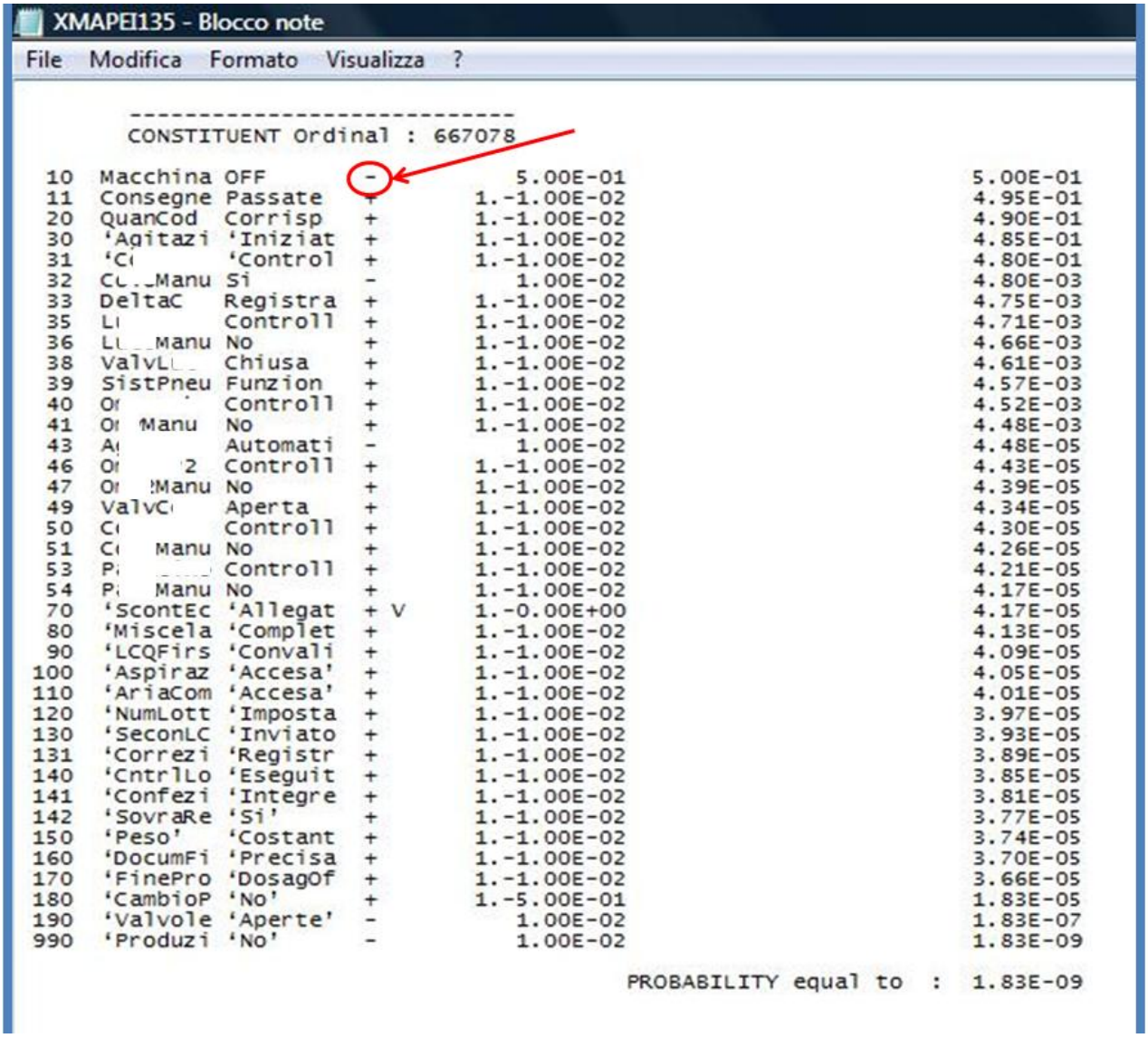
CONSTITUENT Ordinal : 667000

10	Macchina	OFF	-	5.00E-01	5.00E-01
11	Consegne	Passate	+	1.-1.00E-02	4.95E-01
20	QuanCod	Corrisp	+	1.-1.00E-02	4.90E-01
30	'Agitazi	'Iniziat	+	1.-1.00E-02	4.85E-01
31	'C	'Control	+	1.-1.00E-02	4.80E-01
32	C Manu	Si	-	1.00E-02	4.80E-03
33	DeltaC	Registra	+	1.-1.00E-02	4.75E-03
35	L	Controll	+	1.-1.00E-02	4.71E-03
36	L Manu	No	+	1.-1.00E-02	4.66E-03
38	ValvL	Chiusa	+	1.-1.00E-02	4.61E-03
39	SistPneu	Funzion	+	1.-1.00E-02	4.57E-03
40	O	Controll	+	1.-1.00E-02	4.52E-03
41	O Manu	No	+	1.-1.00E-02	4.48E-03
43	A	Controll	+	1.-1.00E-02	4.43E-03
44	A Manu	Si	-	1.00E-02	4.43E-05
45	DeltaA	NoRegist	-	1.00E-02	4.43E-07
70	'ScontEc	'Allegat	+	1.-0.00E+00	4.43E-07
80	'Miscela	'Complet	+	1.-1.00E-02	4.39E-07
90	'LCQFirs	'Convali	+	1.-1.00E-02	4.34E-07
100	'Aspiraz	'Spenta'	-	1.00E-02	4.34E-09
110	'AriaCom	'Accesa'	+	1.-1.00E-02	4.30E-09
120	'NumLott	'Imposta	+	1.-1.00E-02	4.26E-09
130	'SeconLC	'Inviato	+	1.-1.00E-02	4.21E-09
131	'Correzi	'Registr	+	1.-1.00E-02	4.17E-09
140	'CntrlLo	'Eseguit	+	1.-1.00E-02	4.13E-09
141	'Confezi	'Integre	+	1.-1.00E-02	4.09E-09
142	'SovraRe	'Si'	+	1.-1.00E-02	4.05E-09
150	'Peso'	'Variabi	-	1.00E-02	4.05E-11
151	'FustFuo	'Riciclo	+	1.-1.00E-02	4.01E-11
160	'DocumFi	'Precisa	+	1.-1.00E-02	3.97E-11
170	'FinePro	'DosagOf	+	1.-1.00E-02	3.93E-11
180	'CambioP	'No'	+	1.-5.00E-01	1.96E-11
190	'Valvole	'Chiuse'	+	1.-1.00E-02	1.94E-11
990	'Produzi	'Si'	+	1.-1.00E-02	1.93E-11

Figure 7.17 Output file Xmapei135 S.667.000

Starting from this point we've been focus in more and more to the possible false positive of true negative that could happen in the definition and perception of the model, this is can bring more than often to a tricky logic possibilities that can easily bring you to a loop of question that can never stop so we have to be able into not creating questions that can provide this kind of problems.

The problem of the right shaping the connections can create also wrong stories that could bring problems of productions which in reality are not happening, as shown in the S.667.078, in this situation the most of the actions are performed positive or are modificated by the checks presented during the timeline, still if the machine is not switched on we can't work until the machine would be switched on but in this case wait until the positive answer would generate a loop in the answer of the system.



XMAPEI135 - Blocco note

File Modifica Formato Visualizza ?

```
      ----------------------------
      CONSTITUENT Ordinal : 667078

 10  Macchina OFF       -          5.00E-01                    5.00E-01
 11  Consegne Passate   +        1.-1.00E-02                   4.95E-01
 20  QuanCod  Corrisp   +        1.-1.00E-02                   4.90E-01
 30  'Agitazi 'Iniziat  +        1.-1.00E-02                   4.85E-01
 31  'C       'Control  +        1.-1.00E-02                   4.80E-01
 32  C  Manu  Si        -           1.00E-02                   4.80E-03
 33  DeltaC   Registra  +        1.-1.00E-02                   4.75E-03
 35  L        Controll  +        1.-1.00E-02                   4.71E-03
 36  L  Manu  No        +        1.-1.00E-02                   4.66E-03
 38  ValvL    Chiusa    +        1.-1.00E-02                   4.61E-03
 39  SistPneu Funzion   +        1.-1.00E-02                   4.57E-03
 40  O        Controll  +        1.-1.00E-02                   4.52E-03
 41  O  Manu  No        +        1.-1.00E-02                   4.48E-03
 43  A        Automati  -           1.00E-02                   4.48E-05
 46  O     2  Controll  +        1.-1.00E-02                   4.43E-05
 47  O  Manu  No        +        1.-1.00E-02                   4.39E-05
 49  ValvC    Aperta    +        1.-1.00E-02                   4.34E-05
 50  C        Controll  +        1.-1.00E-02                   4.30E-05
 51  C  Manu  No        +        1.-1.00E-02                   4.26E-05
 53  P        Controll  +        1.-1.00E-02                   4.21E-05
 54  P  Manu  No        +        1.-1.00E-02                   4.17E-05
 70  'ScontEc 'Allegat  + V      1.-0.00E+00                   4.17E-05
 80  'Miscela 'Complet  +        1.-1.00E-02                   4.13E-05
 90  'LCQFirs 'Convali  +        1.-1.00E-02                   4.09E-05
100  'Aspiraz 'Accesa'  +        1.-1.00E-02                   4.05E-05
110  'AriaCom 'Accesa'  +        1.-1.00E-02                   4.01E-05
120  'NumLott 'Imposta  +        1.-1.00E-02                   3.97E-05
130  'SeconLC 'Inviato  +        1.-1.00E-02                   3.93E-05
131  'Correzi 'Registr  +        1.-1.00E-02                   3.89E-05
140  'CntrlLo 'Eseguit  +        1.-1.00E-02                   3.85E-05
141  'Confezi 'Integre  +        1.-1.00E-02                   3.81E-05
142  'SovraRe 'Si'      +        1.-1.00E-02                   3.77E-05
150  'Peso'   'Costant  +        1.-1.00E-02                   3.74E-05
160  'DocumFi 'Precisa  +        1.-1.00E-02                   3.70E-05
170  'FinePro 'DosagOf  +        1.-1.00E-02                   3.66E-05
180  'CambioP 'No'      +        1.-5.00E-01                   1.83E-05
190  'Valvole 'Aperte'  -           1.00E-02                   1.83E-07
990  'Produzi 'No'      -           1.00E-02                   1.83E-09

                                          PROBABILITY equal to  :  1.83E-09
```

Figure 7.18 Example of a story that cannot be real.

7.5.7 Mapei 15

This new version of the input file it has been developed trying to define the variables in the most independent way possible between each other.

In the logic of connections we also discover some mistakes in the link between the different questions; this has only been possible thanks to an accurate analysis of the output and is necessary to constraint some result.

We always have to be extremely careful while we're connecting the different questions and its constrains, the problem is that we can be afoul of some other question while reducing or shaping the model in the most coherent way to the reality.

In the question number 90, the sample can be tested wrong by the laboratory of the quality control, is than necessary to find the better way to define the false positive or the true negative and evaluate also its contribute to the final evaluation, but we decided to not investigate more in detail the "control check list of the quality labs"

We inserted one question defined "Is the valve of Resin C open?" before the real question of the pour of the solution itself.

Unfortunately we also written a wrong link into the question D.110 that was generating a loop so we correct this mistake before the next simulation.

7.5.8 Mapei 17 (after meeting with Mapei)

Finally at this moment we could manage a meeting with Mapei to discuss about the model proposed and also to understand if were necessary modification to the model proposed, modification determined by the perception of the action to perform or also determined by an usual managing of the line due to the experience and the high optimization of the production we're analyzing.

Starting from the previous model, we modify the structure of the input following the instruction that the responsible of the unit suggested us in order to better shape the model in the most consistent way possible.

The first modification has been switching the D.10 and the D.11 and put them at the same level of detail and not the second consequent to the first.

:10		è stato fatto il passaggio di consegne con il turno precedente?						
10	0.01	0.	11	11	3	'Consegne'	'Passate'	'DaFare'
26	989	0	0					
:11	C.1.a.3	i macchinari sono accesi?						
11	0.5	0.	20	12	3	'Macchina'	'ON'	'OFF'

Table 7.11 Input file change after meeting with mapei/1

We also inverted the order of the D.20 with the D.21; we have to add a question about the correct selection of the resin L from the package of the raw materials.

:20	C.1.a.5/6	la stampa della ricetta è corretta?						
20.	0.01	0.	26	21	3	'Print'	'SequeOK'	'ErrStamp'
:21	C.1.a.7	le quantità dei prodotti da inserire corrispondono ai codici della ricetta?						
21	0.01	0.	30	22	3	'QuanCod'	'Corrisp'	'NonCong'
26	990	0	0					

Table 7.12 Input file change after meeting with mapei/2

The head of the department also suggested us to eliminate the bind about the evaluation of the deltas of the pour of the substances, he's saying that are always pointed out.

Even more is always working on the lines a sort of bookkeeper of the unit to evaluate, ex-post, the total amount of substances used the day before.

Is also highlighted that the pressure of the lines in the unit always has to be higher than 4 Bar, we also receive the suggestion to add another exit of the “block of production”, pointing out a block of delay production, option that can happen for example when the pressure in the lines is not high enough.

Other problems that can occur are the wrong spilling of the raw materials in the silos of storage, the usage of the pneumatic service from other units, is also repeated that the formula can be modified only by the operator together with the shift responsible.

We eliminate also the question D. 99, D.120, D.130, D.141, D.142, D.160, D.170 and D.190, even if the D.170 could be used if the focus of the project would also be the optimization of the energy in the process plant, but is possible to think over problems that the lack of electricity could provide to the plant.

:99		Le procedure per la convalida del lotto sono state rispettate?						
99	0.01	0.	100	990	3	'Procedur'	'Rispetta'	'NonRisp'
:120	D.1.a.6	è stato impostato il numero di lotto?						
120	0.01	0.	130	121	3	‘NumLott’	‘Imposta’	‘Mancante’
25	121	0	0					
:130	D.1.a.7.1.	è stato inviato nuovamente un campione al LCQ dal prelievo di 100kg						
130	0.01	0.	131	140	3	‘SeconLCQ’	‘Inviato’	‘NotSend’
:141	D.1.a.9.1.	tutte le confezioni sono integre?						
141	0.01	0.	142	142	3	‘Confezio’	‘Integre’	‘Rotte’
:142	D.1.a.9.2.	tutti i sovracolli sono in regola?						
142	0.01	150	150	0.	3	‘SovraReg’	‘Si’	‘No’
:160	D.1.a.12.	la documentazione è stata redatta in maniera opportuna?						
160	0.01	0.	170	170	3	‘DocumFin’	‘Precisa’	‘Incomple’
:170	D.1.b.2.5	raggiunta la fine della produzione ho spento il sistema di dosaggio						
170	0.01	0.	180	180	3	‘FineProd’	‘DosagOff’	‘DosagOn’
26	990	0	0					
:190	D.1.B.2.5	ho chiuso tutte le valvole?						
190	0.01	0.	990	990	3	‘Valvole’	‘Chiuse’	‘Aperte’

Table 7.13 Input file change after meeting with mapei/3

We had to add a reduction of connections at the question D.100 because this question can be a critical path of the safety on the plant.

Is recommended to write that the weight of the tub has to be between specifics law limits like for the 25kg package: 3 package between 24,5kg < P < 25,0kg and no one behind (p < 24,48) otherwise the lot has to be thrown away.

The passage of the consignment actually is not extremely explained, is basically applied the good sense in the passage of information's.

In the meeting emerged also the possibility to introduce a sort of double check for the throw of the powders but until now it has not been identify the mode of identification (for example identify a physical medium which has not been identify yet).

Starting from this criticality of the plant we evaluate the necessity to understand which could be the product that could enter, in the line if the electricity would be off , for gravity and also which are the valves that if can be found open in the fail position.

Is necessary also a mayor attention in the questions concerning the shift manager, to understand which can be the problem related to his presence in the moment of the decision making by the operator.

The necessary focus is the production of a great product in safety conditions.

A good remark is also the process: revealing of errors, print of the errors, control from the operator, and evaluation of results from the laboratory.

One big problem is due to the high experience of the user of the product, the predilection for this product is also due to his technical characteristics and the innovations are not seen in a good way by the users because are not recognizing the product as good as the other times is "el spuza no, el taca no".

```
:10                    è stato fatto il passaggio di consegne con il turno precedente?
10 0.01 0 11 11 3 'Consegne'   'Passate'   'DaFare'
26 989 0 0

:11        C.1.a.3     i macchinari sono accesi?
11 0.5 0. 20 12 3    'Macchina"ON'        'OFF'

:12        C.1.b.2     ho verificato che la macchina 2027 sia vuota?
12 0.01 0. 20 990 3 'StatoMac"Vuoto'     'DaVerifi'
26 990 0 0

:20        C.1.a.5/6   la stampa della ricetta è corretta?
20. 0.01 0. 26 21 3 'Print'       'SequeOK' 'ErrStamp'

:21        C.1.a.7     le quantità dei prodotti da inserire corrispondono ai codici della ricetta?
21 0.01 0. 30 22 3 'QuanCod'  'Corrisp'   'NonCong'
26 990 0 0

:22        C.1.a.5.2. Digito il numero della ricetta corretta sulla tastiera
22 0.01 0. 23 990 3'NumRicet' 'Digitato''Mancante'
26 990 0 0

:23        C.1.a.6.2. Azzerare display premendo 6 volte 0
23 0.01 0. 24 24 3   'Azzeram''Completo' 'Mancante'
26 990 0 0

:24        C.1.a.6.7. Premere 'enter' ed avvio la stampa
24 0.01 0. 26 26 3 'Stampa'   'Eseguita' 'Mancante'

:26        C.1.a.8     è stata verificata la taratura di tutte e 3 le bilance?
26 0.01 0. 30 989 3'Taratura' 'Verifica'  'ChiamMan'
26 990 0 0

:30                    è stata accesa l'agitazione?
30 0.01 0. 31 989 3 'Agitazio' 'Iniziata'  'Ferma'
26 989 0 0
26 990 0 0


:31        C.1.b.3.3 l'operatore ha controllato lo sversamento della quantità indicata di resina c?
31 0.01 0. 32 34 3   'Resina c' 'Control'  'Automati'

:32                    l'operatore non ha modificato manualmente la quantità preimpostata sversata nella macchina?
32 0.01 0. 34 33 3   'ResCManu''No'        'Si'

:33                    Differenza oltre l'1% rispetto alla ricetta registrata?
33 0.01 0. 35 70 3   'DeltaC'   'Registra'  'NoRegist'
15 70 0 0

:34                    La valvola del Resina L è stata aperta dopo aver chiuso quella della resina c?
34 0.01 0. 35 990 3 'InvCL'    'Si'          'No'
26 990 0 0

:35                    il fustino di resina L sversato è quello corretto?
35 0.01 0. 36 990 3 'FustL'    'Corretto' 'Errato'

:36                    l'operatore ha controllato lo sversamento della quantità indicata di resina L?
36 0.01 0. 38  39 3 'Resina L'  'Controll' 'Automati'

:37                    l'operatore non ha modificato manualmente la quantità sversata nella macchina?
37 0.01 0. 39 38 3 'LutoManu''No'         'si'

:38                    Differenza oltre l'1% rispetto alla ricetta registrata?
38 0.01 0. 39 70 3   'DeltaLum' 'Registra''NoRegist'
15  70 0 0

:39                    è stata chiusa la valvola del resina L?
39 0.01 0. 40 40 3 'ValvL'     'Chiusa'    'aperta'
2 50 990 49            49

:47                    l'operatore ha atteso 10 minuti prima di inserire la seconda quantità indicata di polvere Onella macchina?
47 0.01 0. 48 503    'OC2'     'Controll' 'Automatico'

:48                    l'operatore non ha modificato manualmente la quantità preimpostata versata nella macchina?
48 0.01 0. 50 49 3   'O2Manu'  'No'         'Si'

:49                    Differenza oltre l'4% rispetto alla ricetta registrata?
49 0.01 0. 50 70 3   'DeltO2'   'Registra'  'NoRegist'
15 70 0 0

:50                    La valvola per il carico della resina c è stata perta nuovamente dopo aver aspettato 10 minuti dal secondo carico di Polvere O?
50 0.01 0. 51 990 3 'ValvC'    'Aperta'    'Chiusa'
26 990 0 0

:51                    l'operatore ha controllato lo sversamento della quantità indicata di resina c *
51 0.01 0. 52 54 3 'Resina c2'  'Controll' 'Automatico'


:52                    l'operatore non ha modificato manualmente la quantità sversata nella macchina
52 0.01 0. 54 53 3 'C2Manu'   'No'         'Si'

:53                    Differenza oltre l'1% rispetto alla ricetta registrata?
53 0.01 0. 54 70 3 'DeltC2'    'Registra'  'NoRegist'
15          70          0           0

:54                    l'operatore ha atteso 5 minuti prima dello sversamento della quantità indicata di plastificante P?
54 0.01 0. 55 70 3 'Plast'     'Controll' 'Automatico'

:55                    l'operatore non ha modificato manualmente la quantità preimpostata da versare nella macchina?
55 0.01 0. 70 56 3 'PlasManu' 'No'         'Si'

:56                    Differenza oltre l'4% rispetto alla ricetta registrata?
56 0.01 0. 70 70 3'DeltPala'   'Registra'  'NoRegist'
15 70 0 0

:70        C.1.b.3.4. lo scontrino é stato inviato insieme al lotto al controllo qualità?
70 0.01 0. 80 80 3 'ScontEcc' 'Allegato''NoScontr'

:80        C.1.b.4     si sono attesi 20 minuti dopo lo sversamento del plastificante P prima di fermare la miscelazione?
80 0.01 0. 90 90 3'Miscelaz'  'Completa''InCompl'

:90        C.1.b.5     il campione da 20 kg Per il laboratorio di controllo qualità (LCQ) il prodotto rispetta gli standard?
90 0.01 0. 100 91 3 'LCQFirst''Convalid''NonConva'
26 989 0 0

:91        C.1.b.5.6. le modifiche definite dal LCQ sono state apportate?
91 0.01 0. 100 92 3 'LCQModif' 'Modific' 'NoModif'
25 92 0 0
25 94 0 0

:92        C.1.b.5.6.  Effettuare correzione
92 0.01 0. 95 94 3   'Correzio''Eseguita''DaFare'

:94        C.1.b.5.4. Chiudere lotto
94 0.01 0. 95 990 3'Lotto'   'Chiuso'   'Aperto'
26 990 0  0

:95        C.1.b.5.6.  Registriamo la correzione sulla formula
95 0.01 0. 100 100 3'Registro' 'Scritto'   'Mancante'

:100       D.1.a.2     accensione aspirazione
100 0.01 0. 110 110 3 'Aspirazi''Accesa''Spenta'
26 990 0 0
```

:40 il sistema pneumatico di carico polveri è disponibile? 40 0.01 0. 41 989 3 'SistPneu' 'Funzion' 'Intoppi' 26 989 0 0 :41 l'operatore ha atteso 5 minuti prima dello sversamento della quantità preimpostata di polvere O? 41 0.01 0. 42 44 3'Polvere O' 'Controll' 'Automatico' :42 l'operatore non ha modificato manualmente la quantità sversata nella macchina? 42 0.01 0. 44 43 3 'OManu' 'No' 'Si' :43 Differenza oltre l'4% rispetto alla ricetta registrata? 43 0.01 0. 44 70 3 'DeltaO' 'Registra' 'NoRegist' 15 70 0 0 :44 l'operatore ha controllato che lo sversamento della quantità indicata di polvere A sia avvenuto? 44 0.01 0. 45 47 3'Polvere A' 'Controll' 'Automatico' :45 l'operatore non ha modificato manualmente la quantità sversata nella macchina? 45 0.01 0. 47 46 3'AManu''No''Si' :46 Differenza oltre l'4% rispetto alla ricetta registrata? 46 0.01 0. 47 70 3 'DeltaA' 'Registra' 'NoRegist' 15 70 0 0	:110 D.1.a.5 Accensione aria compressa 110 0.01 0. 120 120 3 'AriaComp' 'Accesa''Spenta' 26 990 0 0 :120 D.1.a.6. Sono state impostate le modalità di scarico? 120 0.01 0. 130 990 3'Scarico' 'Impostat''NoPronto' :130 D.1.a.8.4. è stata registrata la correzione della formula? 130 0.01 0. 140 990 3 'Correzi''Registr' 'NonRegis' 26 990 0 0 :140 D.1.a.9.1. tutte le confezioni sono integre? 140 0.01 0. 150 150 3 'Confezio''Integre''Rotte' :150 D.1.a.11 il peso risulta costante? 150 0.01 0. 180 151 3 'Peso' 'Costante''Variabil' :151 D.1.a.11 i fustini fuori norma sono inviati al riciclo 151 0.01 0. 180 180 3 'FustFuor' 'Riciclo''Vendita' 26 990 0 0 :180 D.1.B.2.4.devo cambiare prodotto 180 0.5 0. 989 989 3'CambioPr' 'No' 'Si' :989 Ritardo di produzione 989 0.01 0. 990 990 3 'Ritardo''No' 'Si' :990 Problema di produzione 990 0.01 0. 0 0 3 'ProduzOK''Si' 'No'

Table 7.14 File Inputt ALBA Mapei 17 after the modification with the HSEQ responsible

7.5.9 Mapei 18

This model is still showing some not perfect agreement with the reality, even if after the modification generated after the meeting with Mapei we reduced the amount of possible outcomes of the process from more than 800.000 stories to 235.000.

We also modify some error of connection like some redirections, D.36 in the negative case to d.70, or the D.90 positive to the correction of the formulas and are still necessary some binds like at the D.40 and the D.120 to redirect at least to the 989 negative.

7.5.10 Mapei 19

In this file we have to arrange something that has drown our attention to a big security problem like what can show to the operator that the aspiration is not working?

We inverted also the question 22 and 21 cause if the codes are not the correct ones we have to stop the production, we also have to stop the line of the production in case that the D.24 will answer as negative and so we don't have the receipt.

After a discussion we also decided to eliminate the D.10 and D.11 basically because we're working on a batch production where the previous conditions of working are not so important as the continue productions, the question of the delay has to be focused on the delays of the critical paths and not to the simple plant delay, and also to invert the question concerning the quantities that first has to be asked if are correct or not and then if the operator notice it.

We also redesigned the block of the raw matherials from:

:31	C.1.b.3.3	l'operatore ha controllato lo sversamento della quantità indicata di resina C?						
31	0.01	0.	32	34	3	'Resina C'	'Control'	'Automati'
:32		l'operatore non ha modificato manualmente la quantità preimpostata sversata nella macchina?						
32	0.01	0.	34	33	3	'ResCManu'	'No'	'Si'
:33		Differenza oltre l'1% rispetto alla ricetta registrata?						
33	0.01	0.	34	34	3	'DeltaC'	'Registra'	'NoRegist'
15	70	0	0					

to:

:D		La quantità di MP risulta entro i limiti imposti dalla ricetta?						
D	0.01	0.	D+3	D+1	3	‘MPi’	‘OKl’	‘OutLimiti’
25	80	0	0					
:D+1		L'operatore si è accorto della differenza di valori?						
D+1	0.01	0.	D+2	D+3	3	‘Differen'	'Segnala'	NonVista'
26	90	0	0					
:D+2		Differenza oltre l'1% rispetto alla ricetta registrata?						
D+2	0.01	0.	D+3	D+3	3	'Correttol'	'Si'	'No'
15	80	0	0					

Table 7.15 Modification for the raw matherial

And also after the d.100 we inserted if, in case of negative answer, the sistem overgoing the aspiration is working or not, from small too big to make it simple.

```
:12        C.1.b.2   ho verificato che la macchina 2027 sia vuota?
12 0.01 0. 20 990 3 'StatoMac''Vuoto'    'DaVerifi'
26 989 0 0

:20        C.1.a.5/6 la stampa della ricetta è corretta?
20. 0.01 0. 26 21 3  'Print'     'SequeOK' 'ErrStamp'


:21                  l'operatore si è accorto che la ricetta è sbagliata?
21 0.01 0. 26 26 3   'ErrRicet'  'Ristampa''Continua'
26 990 0 0

:26        C.1.a.8   è stata verificata la taratura di tutte e 3 le bilance?
26 0.01 0. 30 989 3 'Taratura' 'Verifica'  'ChiamMan'
26 990 0  0

:30                  è stata accesa l'agitazione?
30 0.01 0. 31 989 3 ‘Agitazio’ ‘Iniziata’  ‘Ferma’
26 9890   0
26 9900   0

:31                  La quantità di Soluzione di Resina C risulta entro i
limiti imposti dalla ricetta?
31 0.01 0. 34 32 3 ‘Resina C'  ‘Ok’      ‘OutLimit’
25 80 0   0

:32                  L'operatore si è accorto della differenza di valori?
32 0.01 0. 33 34 3‘Differen'   ‘Segnala’  ‘NonVista’
26 90 0   0

:33                  L'operatore ha corretto manualmente la differenza?
33 0.01 0. 34 34 3‘Corretto'   ‘Si’       ‘No’
15 80 0   0

:34                  La valvola del Resina L è stata aperta dopo aver
chiuso quella della Resina C?
34 0.01 0. 35 990 3 'InvCL'    'Si'       'No'
26 989 0  0
26 990 0  0
```

```
:50                  La valvola per il carico della Resina C è stata
aperta nuovamente dopo aver aspettato 10 minuti dal secondo carico di
Polvere O?
50 0.01 0. 51 990 3 'ValvColo''Aperta'   'Chiusa'
26 989 0  0
26 990 0  0

:51                  La seconda quantità di Soluzione di Resina C
risulta entro i limiti imposti dalla ricetta?
51 0.01 0. 54 52 3 ‘ColoFon2''Ok’       ‘OutLimit’
25 80 0 0

:52                  L'operatore si è accorto della differenza di valori?
52 0.01 0. 53 54 3  ‘Differen' ‘Segnala’  ‘NonVista’
26 90 0 0

:53                  L'operatore ha corretto manualmente la differenza?
53 0.01 0. 54 54 3 ‘Corretto'  ‘Si’       ‘No’
15 80 0 0

:54                  La quantità di Plastificante P risulta entro i limiti
imposti dalla ricetta?
54 0.01 0. 70 55 3 ‘Palatino'  ‘Ok’       ‘OutLimit’
25 80 0   0

:55                  L'operatore si è accorto della differenza di valori?
55 0.01 0. 56 70 3  ‘Differen' ‘Segnala’  ‘NonVista’
26 90 0   0

:56                  L'operatore ha corretto manualmente la differenza?
56 0.01 0. 70 70 3 ‘Corretto'  ‘Si’       ‘No’
15 80 0   0

:70        C.1.b.4   Si sono attesi 20 minuti dopo lo sversamento del
plastificante P prima di fermare la miscelazione?
70 0.01 0. 80 80 3 ‘Miscelaz’  ‘Completa’‘InCompl’

:80        C.1.b.3.4. lo scontrino é stato inviato insieme al lotto al
controllo qualità?
80 0.01 0. 90 81 3 ‘ScontEcc’ ‘Allegato’‘NoScontr’
```

```
:35 il fustino sversato è quello di Resina L con la giusta composizione?
35 0.01 0. 36 36 3 'FustL' 'Corretto' 'Errato'
26 990 0 0

:36 La quantità di Resina L risulta entro i limiti imposti dalla ricetta?
36 0.01 0. 39 37 3 'ResinL' 'Ok' 'OutLimit'
25 80 0 0

:37 L'operatore si è accorto della differenza di valori?
37 0.01 0. 38 39 3 'Differen' 'Segnala' 'NonVista'
26 90 0 0

:38 L'operatore ha corretto manualmente la differenza?
38 0.01 0. 39 39 3 'Corretto' 'Si' 'No'
15 80 0 0

:39 è stata chiusa la valvola del Resina L?
39 0.01 0.40 40 3 'ValvL' 'Chiusa' 'aperta'
2 50 990 49 49

:40 il sistema pneumatico di carico polveri è disponibile?
40 0.01 0. 41 41 3 'SistPneu' 'Funzion' 'Intoppi'
26 989 0 0

:41 La quantità di Polvere O risulta entro i limiti imposti dalla ricetta?
41 0.01 0. 44 42 3 'Polvere O' 'Ok' 'OutLimit'
25 80 0 0

:42 L'operatore si è accorto della differenza di valori?
42 0.01 0. 43 44 3 'Differen' 'Segnala' 'NonVista'
26 90 0 0

:43 L'operatore ha corretto manualmente la differenza?
43 0.01 0. 44 44 3 'Corretto' 'Si' 'No'
15 80 0 0

:44 La quantità di Polvere A risulta entro i limiti imposti dalla ricetta?
44 0.01 0. 47 45 3 'Polvere A' 'Ok' 'OutLimit'
25 80 0 0

:45 L'operatore si è accorto della differenza di valori?
45 0.01 0. 46 47 3 'Differen' 'Segnala' 'NonVista'
26 90 0 0

:46 L'operatore ha corretto manualmente la differenza?
46 0.01 0. 47 47 3 'Corretto' 'Si' 'No'
15 80 0 0

:47 La quantità di Polvere O risulta entro i limiti imposti dalla ricetta?
47 0.01 0. 50 48 3 'Polvere O' 'Ok' 'OutLimit'
25 80 0 0

:48 L'operatore si è accorto della differenza di valori?
48 0.01 0. 49 50 3 'Differen' 'Segnala' 'NonVista'
26 90 0 0

:49 L'operatore ha corretto manualmente la differenza?
49 0.01 0. 50 50 3 'Corretto' 'Si' 'No'
15 80 0 0

:81 l'operatore si è dimenticato di allegare lo scontrino?
81 0.01 0. 90 82 3 'Operatore' 'Dimentica' 'ErrStampa'
26 989 0 0
16 989 0 0

:82 Malfunzionamento Stampante
82 0.01 0. 90 90 3 'StampaEcc' 'Rotta' 'AltriErr'

:90 C.1.b.5 Il campione da 20 kg Per il laboratorio di controllo qualità (LCQ) il prodotto rispetta gli standard?
90 0.01 0. 100 91 3 'LabQuali' 'Convalid' 'NonConva'
26 989 0 0

:91 C.1.b.5.6. le modifiche definite dal LCQ sono state apportate?
91 0.01 0. 94 100 3 'LCQModif' 'Modific' 'NoModif'
25 94 0 0

:94 C.1.b.5.4. Chiudere lotto
94 0.01 0. 95 990 3 'Lotto' 'Chiuso' 'Aperto'
26 990 0 0

:95 C.1.b.5.6. Registriamo la correzione sulla formula
95 0.01 0. 100 100 3 'Registro' 'Scritto' 'Mancante'

:100 D.1.a.2 L'aspirazione è accesa?
100 0.01 0. 110 101 3 'Aspirazi' 'Accesa' 'Spenta'
26 990 0 0

:101 il sistema di recupero vapori funziona?
101 0.01 0. 110 102 3 'RecVapor"Funziona"Rotto'
26 990 0 0

:102 Il tubo dell'aspirazione è rotto?
102 0.01 0. 990 103 3 'Tubo' 'Rotto' 'Funziona'
16 990 0 0

:103 La corrente elettrica si è staccata?
103 0.01 0. 990 990 3 'ProblElet' 'Si' 'NoAltro'
26 990 0 0

:110 D.1.a.5 Accensione aria compressa
110 0.01 0. 120 120 3 'AriaComp' 'Accesa' 'Spenta'
26 990 0 0

:120 D.1.a.6. Sono state impostate le modalità di scarico?
120 0.01 0. 140 990 3 'Scarico' 'Impostat' 'NoPronto'
26 989 0 0

:140 D.1.a.9.1. tutte le confezioni controllate sono integre?
140 0.01 0. 150 150 3 'Confezio' 'Integre' 'Rotte'

:150 D.1.a.11 il peso risulta costante nei limiti di legge?
150 0.01 0. 180 151 3 'Peso' 'Costante' 'Variabil'

:151 D.1.a.11 i fustini fuori norma sono inviati al riciclo?
151 0.01 0. 180 180 3 'FustFuor' 'Riciclo' 'Vendita'
26 990 0 0

:180 D.1.B.2.4.devo cambiare prodotto
180 0.5 0. 989 989 3 'CambioPr' 'No' 'Si'

:989 Ritardo di produzione
989 0.01 0. 990 990 3 'Ritardo' 'No' 'Si'

:990 Problema di produzione
990 0.01 0. 0 0 3 'ProduzOK' 'Si' 'No'
```

Table 7.16 File Inputt Mapei 19

7.5.11 Mapei 20

From the simulation Mapei 19 the development of the output stories between the s. 35835 to the S. 35839 is pretty interesting.

Has to be clear that the possible deviation from the standard conditions due to external mistakes like the supply of products or the procedures of the laboratories are not under this specific investigation.

Interesting to note is that due to a correction in one of the last question we eliminate almost the 10% of possible outcomes, where probably the probabilistic cut has intervened

We always point out that for us the questions are not “X has been done” but “Is X necessary to Y”

We also inserted some question related to the possible errors of wrong system configurations, the focus of this operations are D.34 - D.39 and D.50, and we managed it with:

:34		La valvola della resina L è stata aperta dopo aver chiuso quella della resina C?						
34	0.01	0.	35	290	3	'InvCL'	'Si'	'No'
26	989	0	0					
:290		la Pompa funziona in modalità automatica?						
290	0.01	0.	291	35	3	'PompMod'	'Automatico'	'Manuale'
:291		la pompa sta ancora caricando resin C?						
291	0.01	0.	35	990	3	'Pompa'	'resin C'	'Cavitaz'
26	990	0	0					
16	90	0	0					

Table 7.17 Modification in Mapei 20

This modification is necessary to evaluate the possible wrong positioning of the working mode of the pumps before the mixer, and also its possible false positive.

7.5.12 Mapei 21

This model is performed only for academic porpoises inserting some bond like a negative to negative from the D.12 and D.120 to the d.990 and D.989 and also from theD.35 on the D.90.

:12	C.1.b.2	ho verificato che la macchina 2 sia vuota?						
12	0.01	0.	20	20	3	'VerifMac'	'Vuoto'	'DaVerifi'
26	989	0	0					
:120	D.1.a.6.	Sono state impostate le modalità di scarico?						
120	0.01	0.	140	990	3	‘Scarico’	‘Impostat’	‘NoPronto’
26	990	0	0					
:35		il fustino sversato è quello della resina L con la giusta composizione?						

35	0.01	0.	36	36	3	'FustL'	'Corretto'	'Errato'
26	990	0	0					
26	90	0	0					

Table 7.18 Some modification of the file 21

The negative to positive for the D.34 to the 39, and a simple link of the D.190 to the D.103

:190		il sistema pneumatico è usato da un altro reparto?						
190	0.01	0.	41	103	3	'Blocco'	'Reparto'	'NoPress'
16	989	0	0					
26	990	0	0					
:103		La corrente elettrica si è staccata?						
103	0.01	0.	990	990	3	'ProblElet'	'Si'	'NoAltro'
26	990	0	0					

Table 7.19 Pneumatic system and electrical energy

7.5.13 Mapei 22

For this version is interesting to report the questions that in case of negative answer can bring unsafety are still a considerable amount d.12 – d.21 - d.26 - d.35 - d.100 - d.291 - d.391.

:12	C.1.b.2	ho verificato che la macchina 2 sia vuota?						
12	0.01	0.	20	20	3	'VerifMac'	'Vuoto'	'DaVerifi'
26	989	0	0					
:21		l'operatore si è accorto che la ricetta è sbagliata?						
21	0.01	0.	26	26	3	'ErrRicet'	'Ristampa'	'Continua'
26	990	0	0					
:26	C.1.a.8	è stata verificata la taratura di tutte e 3 le bilance?						
26	0.01	0.	30	989	3	'Taratura'	'Verifica'	'ChiamMan'
26	990	0	0					
:35		il fustino sversato è quello di resina L con la giusta composizione?						
35	0.01	0.	36	36	3	'FustL'	'Corretto'	'Errato'
26	990	0	0					
:291		la pompa sta ancora caricando resina C?						
291	0.01	0.	35	990	3	'Pompa'	'ResinaC'	'Cavitaz'
26	990	0	0					
:391		la pompa sta ancora caricando resina L?						
391	0.01	0.	51	990	3	'Pompa'	'resinaL'	'Cavitaz'
26	990	0	0					
:100	D.1.a.2	L'aspirazione è accesa?						
100	0.01	0.	110	101	3	'Aspirazi'	'Accesa'	'Spenta'
26	990	0	0					

Table 7.20 Modification of file 22

We eliminate the bond with the D.90 of the questions related to the deviation from the value assigned for the receipt.

We also insert a possible evaluation, in the post production, of a mismatching product.

7.5.14 Mapei 23

This file has been used as a base for the right evaluation of the consequences out of the output.

In the evaluation of the consequences we introduce also a division between the probability of failure of humans and technology setting humans errors as 0.01 and technology to 0.0001.

The main goal has been to highlight the most effective events for safety and quality and define the evolution structure of the possible accidents before the meeting with the Safety manager of the plant.

In the model proposed we has been able to underline several path that can provoke problems in the line and accidents to the operator, especially we modify some logic of connection concerning the requirement given us, such as:
- the operator knowingly doesn't modify the D.27, so he wouldn't call the maintenance service for the balances setting.

- Is possible to force the balance zero going forward

- Divide between the stop of the process and the delay

- Is possible that, after a wrong evaluation of the machine, the pumps will flood the solutions outside the machine

- Is possible that the two valves that are managing the flux of the two different solution can be left both open at the same time

- After is possible the charge of the wrong product is the wrong valve is left open

- If both valves are left closed is possible just a small mechanical stress and there is no possibility of cavitation

- Is possible a loss of efficiency in the aspiration but not the release in the environment

- The threshold acceptance risk level is substantially higher than the human limit of smell perception, letting the human an accurate sensor for the releases

- There is no signal for the loss of electric energy in the department that is governing the aspiration

- Eliminate the question about the broken aspiration line tube.

The possible consequences can be due to the mix of the following questions:

Consequences:

- D. 12 if the machine is not empty and any operator is verifying it is possible the flooding

- D. 20 if a wrong receipt is insert in the machine, and the operator is not paying enoght attention the product will be wrong

- D. 31-36-41-44-47-52 for these questions if is not correct the quantity of product pumped the product will not be optimal

- D. 34-39-50 if the material inserted are not correct the product will not be correct

- D. 291-391 if the pump will work without material there will be an increasing temperature in the device

- D. 32-42-45 if i'm not perceiving the difference of ammout the product that will go to the quality laboratory will not be good.

- D. 35 if the resin L tub is wrong there will be no production and the material will be thrown away

- D. 90 a wrong product can be accepted or a right product can be thrown away

- D. 91 the operator cannot modify following the requirment of the product

- D. 101 the operator could not smell the release due to an illness

- D. 103 the electricity power supply is pertaining to another sector of the plant and no sensor are reporting to this sector

- D. 120 a wrong discharge is providing a wrong lot of production

- D. 140 a broken packaging will provie a loss of product

- D. 150 the production can be equal to zero if some retail piece is out of the weight limits

- D. 151 if there is nno recycling is possible an environmental damage.

7.5.15 Mapei 26

This is the final input model-file that represent the machine 2027 in the process of production for glue of muquettes.

The final evaluation of this process has been done assigning to any possible accident deviation a value from 1 to 100 according to the specification given by Mapei

D.1	risp 1	d.2	risp. 2	d.3	risp.3	Valore
13	2	31	2			80
13	2	31	1			80
20	2	21	2			50
31	2	89	2	90	1	80
36	2	89	2	90	1	80
41	2	89	2	90	1	80
44	2	89	2	90	1	80
47	2	89	2	90	1	80
51	2	89	2	90	1	80
34	2					50
39	2					50
50	2					50
291	2					30
391	2					30
35	2					50
89	2	90	1			80
91	2					50
101	2					90
120	2					60
140	2					80
150	2					80
151	2					80

Figure 7.19 Consequences structure file with the value attribuited from the mapei safety service

8 Future development of the Functional activity

In the final Gantt diagram is interesting to underline the differences between the single actions involved in the analysis, we actually divide each task into its possible cognitive resources.

Interesting to underline is that we had to deal with a project highly related to the production side of the plant; we are highlighting this aspect because if we would have to deal with the design of the process probably this aspect would take more importance.

The increasing importance of the cognitive side in the design or re-design of the process is important to evaluate possible overcharge for the operator in some of the procedures necessary to follow.

The resources can also be seen as competences of the operator working on the plant comparing them hierarchy with the hierarchy of the plant.

The final selection of the Gantt diagram is showing a division of Resources divided in this way:

Cognitive Resources	Number of cognitive resources
Execution	7
Observation	5
Interpretation	5
Planning	1
No Assigned	2

Table 8.1 Cognitive resources

The final value of action attributed are than 20, some of them are recursive such as the pumping of the raw materials that has to be multiply 6 times, one for each material, one for the control of quality which doesn't have a resource assigned depending by the higher level of the quality control in the development of the Gantt.

Interesting idea to highlight is the evaluation of the deepness of the action to be used in the idda software, because the level we analyzed to define the questions were going from the 3rd level to the 5th level, and are divided as follow:

3 for the 3°liv divided into:

30 mixing 3°liv – interpretation, 40 pneumatic system 3°liv – observation, 90 quality 3°liv – interpretation

17 for the 4°liv divided into:

11 Execution,

5 observation

3 interpretation 13 empty machine- 20 correct receipt - 150 constant weight,

1 planning 120 discharge mode

2 for the 5°liv, 31-51 Charge of resin C

2 execution

2 without level 39 valve resin L, 50 valvola resin C (possibile 4/5 liv entrambe) osservazione

The division in level is possible to associate, as outline above, to some well-known model, such as the S-R-K from Rasmussen where the level of definition is going from a Skill-based typical of a short knowledge and understanding of the process, passing through rule based defined by the knowledge of the regulation and a higher understanding of the process, finishing with a knowledge typical of a high level of knowledge but also typical of a slower speed in the intervention.

Some of the most famous model dedicated to the cognitive approach are evaluating the importance of the actions depending by its possibility to fail, for example the CREAM model is recreating a model on where each action is evaluated and the final value of reliability can be different if the same action is performed randomly or strategically.

Here are the evaluation of the action and their performance.

Type of action	Lower probability bound	Upper probability bound
Strategic	0.00005	0,01
Tactic	0.001	0,1
Opportunistic	0.01	0,5
Scrambled	0.1	1,0

Table 8.2 C.R.E.A.M. division of cognitive resources and probability bounds

9 Final Results Discussion

The development of the model passed throught several passages shaped in the Figure 9.1, is possible to highlight the amount of story that can be used and also the residual probability.

Is interesting to see that the residual probability is always decresing and even if the amount of constituent is pretty high in the last model the amount of output is pretty low, it means that the constrains are really effective.

Model N°	n° constituent	History	prob residual	entropy
6	37	19661	0,00E+00	8,30E-03
8	37	7746176	7,35E-02	1,98E+00
9	37	45712	2,00E-08	3,47E+06
10	38	41	5,52E-01	1,63E+00
12	61	846073	6,14E-07	4,83E+00
13	61	889455	6,03E-07	4,84E+00
14	61	889455	6,03E-07	4,84E+00
15	62	1373	6,15E-01	1,70E+00
16	62	844908	5,48E-07	4,89E+00
17	53	235418	1,18E-07	4,48E+00
18	51	445566	2,74E-07	4,55E+00
19	51	71563		
20	51	46541	1,05E-07	1,97E+06
21	51	55343	1,31E-07	1,98E+00
22	51	51360	1,19E-07	1,98E+00
25	56	5041	9,51E-09	9,79E-01
26	56	5041	9,51E-09	9,79E-01

Figure 9.1 Shape of output file and probability and entropy evaluaition

After the description of the model we have designed and developed we can finally describe the results of the output and evaluate the state of the system at this moment.

Starting from the graphs later described is possible, in the future, start a sensitivity analysis before to program the re-design of the line under investigation, the sensitivity analysis will be possible just modifying the values of the elective variable associated to the questions defined for the process.

The driver of our work has been give an image of the plant evaluated and suggesting some point to implement in order to reduce the possible risk associated to this production of alcoholic glue.

In the following Figure 9.2 is possible to see the results of the Beans intended as a “Risk density function”, where is possible to describe the sequence of consequences of the stories grouped in a growing consequences way.

The total amount of beans group is ten divided by the grade of the consequences, as is possible to see in the graph of the next page.

;N. Bean	Limits	Const.	Risk	Probabil.	Risk Cum. %	Prob.Cum.	
8	2.973E+02	1	9.295437E-07	3.575167E-09	2.526703E-05	3.575167E-09	2.600000E+02
	2.500E+02	39					
9	2.500E+02	40	1.353626E-06	5.651549E-09	6.206155E-05	9.226716E-09	2.395142E+02
	2.102E+02	103					
10	2.102E+02	104	2.706836E-04	1.440133E-06	7.419834E-03	1.449360E-06	1.879573E+02
	1.768E+02	443					
11	1.768E+02	444	2.582864E-03	1.620592E-05	7.762774E-02	1.765528E-05	1.593779E+02
	1.487E+02	860					
12	1.487E+02	861	2.609996E-02	2.007668E-04	7.870817E-01	2.184221E-04	1.300014E+02
	1.250E+02	1278					
13	1.250E+02	1279	3.189555E-02	2.899594E-04	1.654073E+00	5.083815E-04	1.100000E+02
	1.051E+02	1570					
14	1.051E+02	1571	2.936959E-02	2.937902E-04	2.452402E+00	8.021718E-04	9.996790E+01
	8.839E+01	2104					
15	8.839E+01	2105	1.583051E+00	1.978814E-02	4.548318E+01	2.059031E-02	7.999997E+01
	7.433E+01	2521					
17	6.250E+01	2522	5.702996E-01	9.504994E-03	6.098518E+01	3.009531E-02	6.000000E+01
	5.256E+01	2746					
18	5.256E+01	2747	1.435305E+00	2.870613E-02	9.999991E+01	5.880144E-02	4.999995E+01
	4.419E+01	4046					

;	Total Probability =	5.880143E-02
;	Expected Consequence =	3.678880E+00

Figure 9.2 Structure of the beans

The group of beans above explained is necessary to describe the histogram of the consequences, where out of the graph is possible to understand that following different axis is possible to describe different approaches.

Obviously the best graph is where X and Y are as low as possible, but can be useful also a graph where the first and last bean can be extremely different.

Interesting to analyze is also the Complementary cumulative of the risk because is allowing the analyst to understand where a threshold limit of risk is achieved in order to reduce its probability, for example in the Figure 9.4 the value of consequences of 100 can be achieved almost 10^-3 times value that is not extremely low.

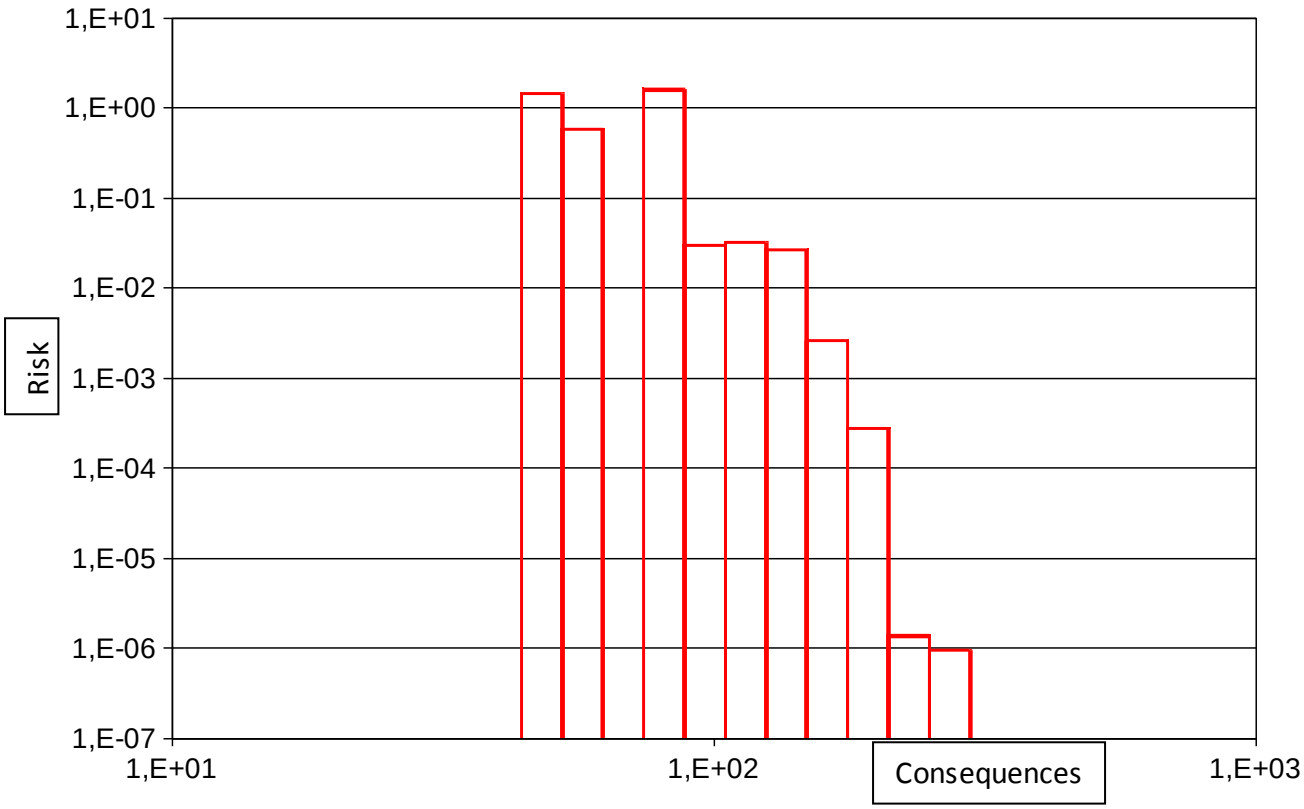


Figure 9.3 Histograms of the beans

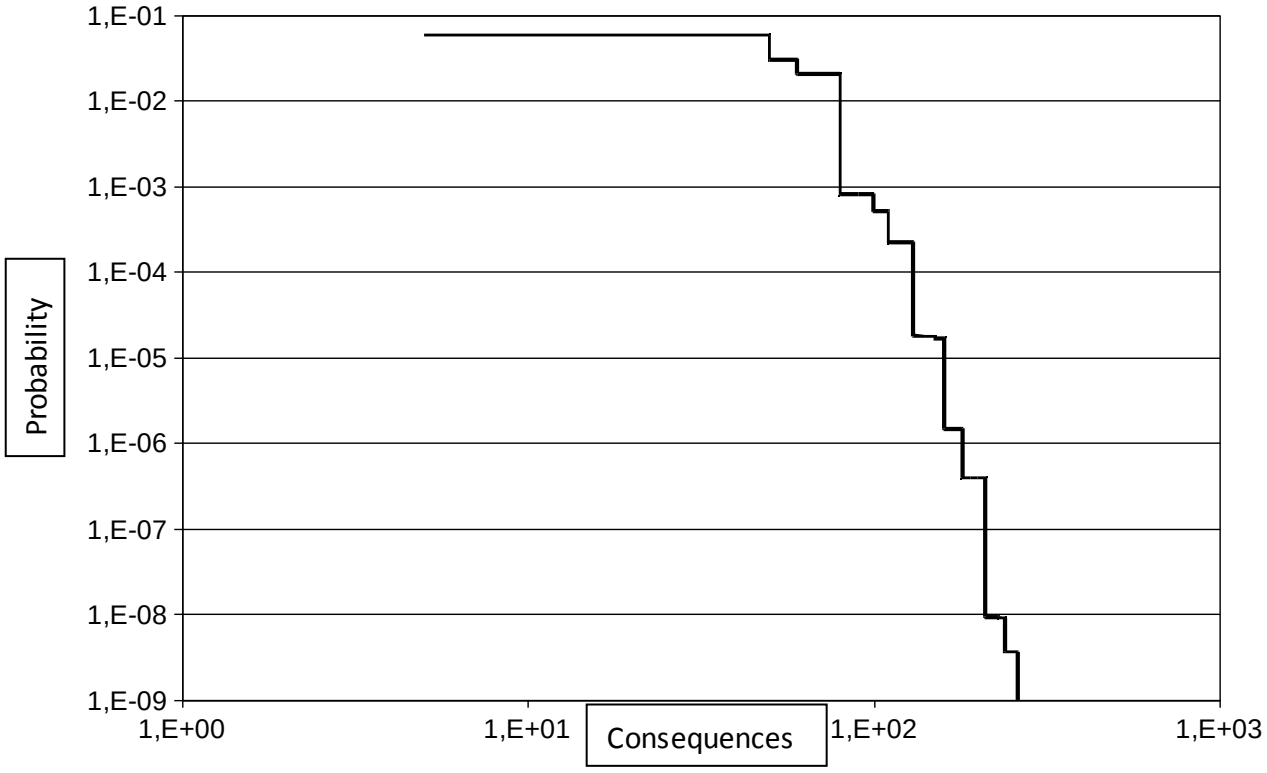


Figure 9.4 Cumulative Complementary of the Risk

9.1 Critical Components

The identification of the critical components is helped by the structure of the input file and can be the real heart of the project of analysis, in fact is helping in the identification of the components where can be more effective to invest.

The structure of this file is composed by the risk associated to the specific deviation, a probability value associated to the maximum consequences, the cumulative value and the number of stories where this deviation is involved.

```
FAILURES          RISK           RISK %          MIN. CUT.

  13 Stato    Pieno
----------------------          Priority :    1

                7.919E-01       2.15263E+01 %         1
                                2.15263E+01 %       ----
Numb. of Involved Constit. :    12            (     1 -    12)
```

Figure 9.5 First Priority Element

The most affective deviation discovered has been to start to work while the machine is still containing some product, this can be cause of flooding and is important because the machine 2 can contain only the production and not extra product.

Possible intervention(organization side): as read in some study would be significant reduce the possible accident if instead of just one person will check the machine there would be two persons or notably reduced will be the risk if three persons will check reducing 5 times the risk (HELFRICH, 1999)

```
  50 ValvC    Chiusa
----------------------          Priority :    2

                7.655E-01       2.08081E+01 %         2
                                4.23344E+01 %       ----
Numb. of Involved Constit. :    298           (    13 -   310)
```

Figure 9.6 Second Priority Element

This deviation is clear with the further Figure 9.7 and it can affect the quality of the product, a possible overheating of the pumps and these possibilities are representing a high value of risk.

Figure 9.7 The operator is opening the valve of resin L(red tube) and the valve for the resin C is closed (blue tube)

Possible intervention (Technology side): this mistake can be reduced in a really consistence amount if the bars will be inverted not allowing the double opening or the double closing.

```
 120 Scarico  NoPronto
----------------------          Priority :    3

                5.704E-01      1.55049E+01 %        3
                               5.78393E+01 %     ----
Numb. of Involved Constit. :   243           (  311 -  553)
```

Figure 9.8 Third Priority Element

This element is regarding the planning of the production and its possible delays, even if is not common is possible that the production must wait for the definitions of the lot division.

Possible Intervention (Organization side): this deviation can be effectively reduced if the standard production can be made of always the same packs.

```
  34 InvC      No
----------------------          Priority :    4

                5.167E-01      1.40456E+01 %        5
                               7.18849E+01 %     ----
Numb. of Involved Constit. : 1093           (  554 - 1646)
```

Figure 9.9 Fourth Priority Element

This element is regarding a possible mistake in the opening of the valve as shown in the Figure 9.7, this time the mistake should be done earlier than before, interesting to underline is the huge amount of time where this deviation can be present, 1093 out of 4051 possible outcomes 26,98%

Possible intervention (technologic side): this mistake can be solve adding a tree way valve, reducing the possibility of charging the wrong raw material.

```
  35 FustLi    Errato
----------------------        Priority :    5

                5.088E-01     1.38303E+01 %        4
                              8.57152E+01 %      ----
Numb. of Involved Constit. :  793           ( 1647 - 2439)
```

Figure 9.10 Fifth Priority Element

Still high effective is the use of the wrong Resin L as a raw material, this element is characterized by a specific color and composition that can change if the we decide to acquire it from another seller or if we decide to use a different composition.

Figure 9.11 Characteristic of one of the raw material and its security phrases

Possible intervention (organization side): is possible to reduce the mistake in the election of the Resin L just being sure of the shape and color of the case of our raw material.

```
  39 ValvL    aperta
----------------------        Priority :    6

                4.961E-01     1.34843E+01 %        6
                              9.91995E+01 %      ----
Numb. of Involved Constit. :  848           ( 2440 - 3287)
```

Figure 9.12 Sixth Priority Element

Another important element is still regarding the use of the valves in Figure 9.7 and a possible wrong use of it, the sum of the three elements this can bring to the 48,32% of the possible accident identification of this machine.

Possible intervention (technologic side): the possible intervention can be the same as for the inversion of the opening between resin C and resin L.

```
 100 Aspirazi Spenta
----------------------          Priority :   23
 101 RecVapor Rotto


----------------------

                8.555E-05     2.32541E-03 %      117
                              9.99949E+01 %     ----
Numb. of Involved Constit. :   27           ( 3951 - 3977)
```

Figure 9.13 Twenty third Priority Element

Something that surprised to see only at the 23rd position of importance has been that the broken aspiration of the vapor wasn't in one of the first positions and its related risk has been so low.

Probably this is depending by the construction story of the file, because we has been more focused on the safe production and not to the safety of the system, this brought us, for example, also to not evaluate the accumulation of powder in the tube of thrown and other interesting deviations not directly related to the production.

```
        ----------------------------
        CONSTITUENT Ordinal :   3912

  12  VerifMac Verifica  +       1.-1.00E-02                    9.90E-01
  13  Stato    Pieno     -          1.00E-02                    9.90E-03
  20  PrintRic Giusta    +       1.-1.00E-04                    9.90E-03
  26  Taratura Verifica  +       1.-1.00E-02                    9.80E-03
  30  Agitazio Iniziata  +       1.-1.00E-04                    9.80E-03
  31  C_______ Ok        +       1.-1.00E-04                    9.80E-03
 990  ProduzOK No        - V        1.00E+00                    9.80E-03

                                              PROBABILITY equal to  :  9.80E-03
```

Figure 9.14 Maximum Risk History

This story has been identified as the story with the high related risk, actually is the most representing story for the flooding where the machine with some product is putted on line and the charge is started.

```
----------------------------
CONSTITUENT Ordinal :    921

VerifMac Verifica  +       1.-1.00E-02                    9.90E-01
Stato    Vuoto     +       1.-1.00E-02                    9.80E-01
PrintRic Giusta    +       1.-1.00E-04                    9.80E-01
Taratura Verifica  +       1.-1.00E-02                    9.70E-01
Agitazio Iniziata  +       1.-1.00E-04                    9.70E-01
C        Ok        +       1.-1.00E-04                    9.70E-01
InvColL  Si        +       1.-1.00E-02                    9.60E-01
FustL    Corretto  +       1.-1.00E-02                    9.51E-01
L        Ok        +       1.-1.00E-04                    9.51E-01
ValvL    aperta    -          1.00E-02                    9.51E-03
SistPneu Funzion   +       1.-1.00E-02                    9.41E-03
On       Ok        +       1.-1.00E-04                    9.41E-03
A(       Ok        +       1.-1.00E-04                    9.41E-03
Or    2  Ok        +       1.-1.00E-04                    9.41E-03
ValvC(   Chiusa    -          1.00E-02                    9.41E-05
PompMod  Automati  +       1.-1.00E-02                    9.31E-05
Pompa              + V     1.-0.00E+00                    9.31E-05
C(       Ok        +       1.-1.00E-04                    9.31E-05
P(       Ok        +       1.-1.00E-04                    9.31E-05
Miscelaz Completa  +       1.-1.00E-04                    9.31E-05
Difforme No        +       1.-1.00E-04                    9.31E-05
LabQuali Convalid  +       1.-1.00E-02                    9.22E-05
Aspirazi Spenta    -          1.00E-04                    9.22E-09
RecVapor Funziona  +       1.-1.00E-02                    9.13E-09
AriaComp Accesa    +       1.-1.00E-04                    9.12E-09
Scarico  NoPronto  -          1.00E-02                    9.12E-11
ProduzOK No        - V        1.00E+00                    9.12E-11

                                    PROBABILITY equal to  :  9.12E-11
```

Figure 9.15 Higher consequences history

This story is identified as a story with the maximum value of consequences even if extremely difficult to happen (260/100) and where is presented also a logical problem due to the not recognition of a non-compliant product before the quality test in the labs.

The value of 260 has been the sum of different deviation that brought us to such a high value.

```
                ANALYSIS of "MAPEI25 "
                ======================

GENERAL PICTURE on the SET of POSSIBLE ALTERNATIVES
===========================================================

SOURCE FILE NAME          : MAPEI25.INP
STORAGE FILE NAME         : XMAPEI25.OUT
STARTING LEVEL            :    12
LOWEST PROBABILITY        : 1.0000E-12
HIGHEST PROBABILITY       : 1.0000E+00

    MISSION TIME                :

    CONSTITUENT TOTAL NUMBER    :       5041

    CUMULATIVE PROBABILITY      :  9.99999990E-01
    RESIDUAL PROBABILITY        :  9.519345E-09

    Partition Entropy           :  9.793947E-01
```

Figure 9.16 General evaluation of the input story

This is the resume slide of the total amount of stories, of the cumulative probability of all the stories represented and its possible residual probability of stories of probability not under the 10^-12 in fact in a run time without lowest probability value attributed the system has been able to work until over 15.000.000 stories situation impossible to achieve with the normal human procedures known at the moment.

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