The management of process control deployment using interactions in risks analyses

Samuel Bassetto, Ali Siadat, Michel Tollenaere

1. Introduction

The semi-conductor industry is challenged to respond to an ever-constraining market place. The time to develop and ramp-up new technologies has been shrunk from 4 years to 1.5 years (Bean, 1997), while at the same time, quality and delivery cycle times must be mastered respectively at their highest and lowest levels.

At the heart of this ramp-up challenge is the ability to master yield (Bohn & Terwiesch, 1999), (Terwiesch & Bohn, 2001). The deployment of layers of control (Summers, 2003) is crucial for retrieving data from the production system to speed the learning process (Baud-Lavigne, Bassetto, & Penz, 2009). These layers of control (Summers, 2003), are deployed at product, process, tool and organizational levels (Schippers, 2001). A non exhaustive list can be provided (May & Spanos, 2006):

- Final acceptance tests (Electrical Wafer Sort — EWS)
- Block of process validation (parametric tests — PT)
- Statistical process control (SPC)
- Visual inspection (VI)

- Fault detection and classification (FDC)
- Tool alarms (TA)
- Preventive and predictive maintenance
- Non conformities management (especially yield issues)
- Change review
- Preliminary Risk Analysis (PRA).

Each of these layers of control is grounded by local explicit and often implicit risk analyses. All these barriers against unscheduled events can induce more than one hundred improvement actions per day. This complexity affects the choice of actions to prioritize and slows down improvements. Several organizations are usually involved in the completion of these improvement actions. It ranges from quality to yield management or production operations. Deciding on priorities is always a difficult task to complete, as organizations have different opinions and operational stakes. Productions teams are more focused on cycle time, process integration teams are driven by yield whereas quality teams concentrate on customer satisfaction and so on. Often, this leads to sub-optimal choices regarding the global organization’s stakes.

As part of these layers of control, customers expect manufacturers to provide preliminary risk analyses in order to prove their ability to master the production ramp-up. For this purpose, FMECA — Failure Mode, Effect and Criticality Analyses — (Department of defense, 1980), (Villacourt, 1992) have to be performed. However, FMECA’s actions...
and other internal improvement actions are hardly linked (Mili, Bassetto, Siadat, & Tollenaere, 2009). Risk analyses are performed, presented to customers and often forgotten until the next customer audit. The update is often experienced as a chore but required by customers for “an obscure reason”. This clearly breaks the Voice of Customer (VoC) within the organization and brings discredit upon the necessity of explicit risk analyses for operations.

This article then tackles the stake of answering the following question: How to deploy these layers of control in a coherent manner in order to globally respect customer requirements?.

The research presented in this paper takes another viewpoint on Preliminary Risks Analyses (PRA). Instead of focusing on Product or Process or Tool PRA independently, it focuses on links between these types of risks. For this purpose, a new concept, namely “typology of risks” is introduced. Its use allows us to structure risk analyses throughout the organization, in a progressive and manageable manner, from customer to tool and vice-versa. It helps progressively build knowledge about which element is risky within the production system and can impact performances, reliability or safety aspects of the product.

This article is structured in three parts. Section-1 presents a literature review about risk reuse for operations. Section-2 details the model of risk typologies. Section-3 presents and discusses the consequences and observations made from this model to master process control risks.

2. Literature review

This literature review, will focus on the operational use of risk analyses to ground decision of control deployment. The main type of risks analysis considered is FMECA. Interested readers by other types, can refer to the article of (Tixier, Dusserre, Salvi, & Gaston, 2002). Introduced by (Department of defense, 1980), FMECA has been tested and deployed, in a wide range of applications. The semi-conductor industry provides its own adaptation of FMECA through SEMATECH (Villacourt, 1992). Readers interested in some examples of classical applications using FMECA can refer to the following references (Shahrokhi & Bernard, 2004), (Kmenta et al., 1999), (Eubanks and Ishii, 1997). Much criticism can be found in the literature about this method. A good introduction of these criticisms can be found in the literature review of (Carmignani, 2009). The present literature review will concentrate on structure and reuse of risk analyses.

In the safety domain, the risks are systematically analyzed in order to defined appropriate protections. As stakes are not subject to controversy, major advances come from this domain. The Layer Of Protection Analysis (LOPA) method has been proposed to ensure that the analysis work has been performed adequately and “risks are mitigated at an acceptable level” (Summers, 2003). This method takes place in a more global safety management system for example within the ARAMIS project (Salvi & Debray, 2006). Hollalgel published an interesting essay about what is the role of barrier in safety approaches (Hollalgel, 2008) and the static aspect of defense as presented in the literature, so far. As developed in next parts of this article, the proposition made here can be presented as an answer to the classical scheme by introducing a dynamic dialogue between risks and controls. (Duijns, 2009) presented a comprehensive method to draw a consistent safety barrier diagram, linked with risk clarification. He positioned clearly FMECA analysis in the model presented as a mean to retrieve risks analyses.

In operations, the first kind of works that links process control at risks employed updated FMECA to ground decisions of control and action plan management. (Mili et al., 2009) presents the update of FMECA regarding actual occurrences of risks in semiconductor industry. Their research allows to have updated risk data and to ground actions plans regarding true risks in the manufacturing system.

The main advance of this work is to represent risk analyses under the FMECA format and actual negative events occurring throughout the plant in an integrated manner. Every type of FMECA is updated and contributes to better grounded decisions about which actions to perform. A case study has been conducted over a photolithography workshop to identify the more (respectively the less) risky tools and to allocate more (respectively less) maintenance resources. Another group studied the link between processes and risks analyses. An extension has been proposed to include also action plan management in this system (Mili, Siadat, Bassetto, Hubac, & Tollenaere, 2010). (Sienou, Lamine, Karduck, & Pingaud, 2007), proposes an UML model to sustain a joined risk and process development. From this work, authors retrieve the idea of using operationally FMECA and a model joining risks and business processes. As business processes are supposed to remove “silos-effect” in organization, their proposal, is supposed to contribute to remove organizational barriers amongst risks analyses and has been a source of inspiration for authors.

In the design community, works have been performed to reuse this updated data to ground design decisions. The purpose is to collect failure occurrences observed during the product life cycle and to take them into account during design stages of similar products. Joint to the key characteristics approach (Thornton, 1999), the FFD Method (Stone, Tumer, & Van Wije, 2005) and RED (Lough et al., 2006a) help designers to update their knowledge of functions and part failures (Tumer & Stone, 2003). These works present a taxonomy of failures to bring to the attention of designers (Tumer et al., 2003). These methods have been applied to mechanical design in the aerospace industry (Stone et al., 2002). Several metrics have been evaluated to select risks to focus on (Lough et al., 2006b). Another approach of risk taxonomy has been presented by Stamatis in his reference book (Stamatis, 2003). A selection of classic failure types, in several domains is used as a check list in order to make sure that analyses are complete. To better structure and enrich such a check list (Ebrahimipour, Poura, & Shokravi, 2010) bases FMECA on an ontology built with the tool “protégé”. A link between the design of manufacturing processes and FMECA has also been investigated by (Hassan, Siadat, Martin, & Dantan, 2010). The IRAD method has been proposed by (Chemraoui, Mathieu, & Tricot, 2009), in order to integrate requirements of safety considerations in early design instead of adding them at the end of the design process.

These researches have been a real source of inspiration for authors as the concept of typology at the readings of these authors. Another side of FMECA has also been explored in a more operational literature. It consists in linking failure modes, failure causes and failure effects of several kinds of FMECA. In the VDI Norm, the links between system and subsystems reflect as links in risk analyses (Bertsche, 2008). Failure functions can be a mode, an effect or a cause, depending on the level of decomposition of the system analyzed. These links are presented as overlaps between system decomposition levels. These overlaps ensure that a system is fully analyzed throughout different views. Bertsche presents an example that connects FMECA design, product and process. Part of products can present failures due to the chaining of operations or the failure of one of them. The cause of some module failures, lies in process operations. The effect of the failure of these operations is the failure mode of products. To extend his meaning, one can say that failures of operations are also caused by tools failure. An operation does not reach the expected result, due to failure in the chaining of steps (wrong set points) or due to the failure of a tool. Every failure mode of a particular process step is a result of a tool failure.

If we disregard issues of design we end-up with the following links between risks:

- Failure modes of products are effect of failure of operations
- Failure modes of operations are effects of failure of tools.
These links are direct consequences of the systematic decomposition of the production system (Bertsche, 2008).

In the reliability domain, (Kóczá and Bossche, 1999) implemented a tool to support the reliability analysis of a system. With their development, they can present reliability analyses with fault trees (FT) or under the FMECA template. Central to this tool is the notion of propagation of failure, from one “node” to another. The transformation of FT in FMECA is based on either the connection between several FMECAs or the generation of a local effect and a global effect of failure - concept already present in the MILSTD1929-A (Department of defense, 1980). Coupling FMECA with other analyses can reveal new point of view on risks and successfully complement first analyses.

As presented in introduction, process control system can be understood as Layers of Protection against operational fearsome events like scraps, yield loss or cycle time increase. In the safety domain, the design of layers of protection is grounded most of the time by risks analysis (Duijm, 2009).

It has been clearly identified the need of operational FMECA. Some uses checklist, others domain-ontologies. Some have developed an integrated system to feedback from the field actual risks to designers. And others have focused on the links between the risks due to the system decomposition. It seems that the connection between these articles remain a perspective. As risks analysis ground process control it could be a good candidate to achieve this task.

The authors do not retrieve any research neither about the exploitation of these links in order to create typologies of risks nor the possibilities to orient action plans with deployment of typologies. Of course, some industrialists may resort to such practices but do not make them public.

3. The model of typologies

This section introduces the notations employed to present the model of typology of risks.

- \( E_1 \) and \( E_2 \) are respectively sets of risks linked to products, processes or tools of the manufacturing system. \( E_1 \) and \( E_2 \) can be represented by tables.
- \( k \) indexes of «failure modes» attribute
- \( m \) indexes of «effect of failure»attribute.
- \( E_{km} \) is the restriction of \( E_1 \) to its component \( k \). It is noted \( A \).
- \( E_{jm} \) is the restriction of \( E_2 \) to its component \( m \). It is noted \( B \).
- The relation between \( A \) & \( B \) noted \( R_{AB} \)

The link between objects \( A \) and \( B \) is an equivalence between risk components. This equivalence is represented by a symbol of equality. The risk components are equal — at least in their meaning — and can be described by several syntaxes. Then, this relation is noted:

\[
R_{AB} : \{ ( R_1 : \forall a \in A, \exists b e B / a = b ) \& ( R_2 : \forall b' \in B, \exists a' e A / a' = b' ) \}
\]

By extension of \( A \) and \( B \), \( a, a' \) are risks of \( E_1 \) and \( b \) and \( b' \) are risks of \( E_2 \). Fig. 1 illustrates these notations. By this relation, \( R_{AB} \) is the combination of 2 relations:
- The first from \( A \) toward \( B \).
- The second from \( B \) toward \( A \).

This leads to the following inclusions: \( R_1(A) \subseteq B \) and \( R_2(B) \subseteq A \).

This relation is translated operationally by a systematic manual verification that ensures that terms in set \( A \) is taken into account in the set \( B \) and vice versa.

The failure mode of a product “thickness OOS (too thin)”, corresponds to a failure effect of the process involved in this operation. This effect is written as “thickness OOS”. Even if the syntaxes are not strictly equal, the meaning is the same. The work of (Ebrahimipoor et al., 2010), could be employed in this context in order to prevent such problem.

Links within the production system induce links between risks. However, an issue is frequently observed: \( n \) failure modes of modules generate only \( n \) failure effects of the process. This reasoning is wrong as \( n \) effects of failures have to be taken in account at least but not at most! This means that the number of failure effects has to be greater or equal to \( n \).

This subtle precision leads to mathematical relations \( R_1 \) and \( R_2 \), which translates only mutual inclusions. In order to transform these inclusions into equalities, the concept of typology of failure mode is introduced.

For an element \( E_i \), two risk analyses can be different and have components with the same meaning as illustrated in Table 1. These two risk analyses are different however they have one component in common: “Maxtime Reached”.

A typology is a meta component, a kind of class of risks. A space of dimension 1 is linked to each risk component. It is typology space of this component and it verifies the following properties:

\( \forall C, \) component of risks, \( \exists T_C, \) typology associated to \( C \), which is defined with following conditions

1. \( \text{Dim } T_C = 1 \)
2. Each element of \( T_C \) possesses at least one equal term in \( C \) (surjection from \( T_C \) in \( C \))
3. Each element of \( C \) possesses exactly one equal term in \( T_C \).
4. Each element of \( T_C \) is unique.

\( A \) can contain the same term several times. These terms comes from several different risks of \( E_i \). Property (4) insures that this is impossible in \( T_A \). Then each element of \( A \) is represented only once in \( T_A \), as illustrated in Fig. 2. The relation between \( A \) and \( T_A \) is noted \( F \), as \( G \) represents the relation between \( B \) and \( T_B \). In a pragmatic perspective, \( T_A \) is a list of terms extracted from risk analyses of \( E_i \) and can also be improved by people who know how \( E_i \) can dysfunction.

4. Consequences of typologies on process control deployment

In this section, one property of typologies will be presented together with the usage of this concept to better deploy the Voice of Customer within the organization and structure feedback from field observations.

Property: Typologies between two linked set of risks are equals: \( T_A = T_B \)

Proof: Relations between \( A \) and \( B \) have consequences on \( T_A \) and \( T_B \). Through the relation \( F \), there is: \( \forall t_A \in T_A \exists a e A / t_A = a \) (2nd property of \( T_A \)). By the relation \( R_1 \), there is: \( \forall a' e A, \exists b e B / a' = b \) then in particular for \( a = a' \), \( \exists b e B / a = b \). Through the relation \( G \), there is: \( \forall b' e B, \exists a e A / b' = a \). Then in particular for \( b' = b \), \( \exists t_B e T_B / t_B = t_B \). Then \( \forall t_A e T_A, \exists t_B e T_B / t_A = t_B : T_A \subset T_B \). As \( A \) and \( B \) can be swapped: \( T_B \subset T_A \), then \( T_A = T_B \).

This result is illustrated in the Fig. 3.

Starting from this equality it is simple to master the interactions between risks of production systems, as presented in the next paragraph.

4.1. Use of typology to deploy the Voice of Customer within the organization

As each organization team analyzes risks with its own indicators, typologies can be employed as failure mode type in each area.
It is necessary to manage the terms employed in several areas. This commonly leads at an equivalence table between two terms (for example in Fig. 1 the equivalence between “thickness OOS (too thin)” and “thickness OOS”).

Let us abstract this issue and take the notation used above again. $T_A$ and $T_B$ are represented by two tables. When a table is modified, then the relation of equality leads to the modification of the other table. Then, the second usage of this equality lies in the fact that this relation is dynamic. When a new risk of $E_i$ is introduced in $A$ with a new term, it must be taken into account in $T_A$, then in $T_B$ and in $B$. This is translated by at least one new risk creation in $E_j$. The reciprocity from $E_j$ toward $E_i$ is also true.

Then, the equality is not instantaneous but follows a dynamical process.

**Cascading controls:** When a new risk is found for a product, then a new failure mode appears in the typology table. In order to guaranty the equality relation between $T_A$ and $T_B$, at least one risk must be studied taking into account this new typology as effect of failure. This cascade of risks between $E_i$ and $E_j$ is illustrated in Fig. 4.

**Experience feedback:** When a failure occurs during the use of a process, and if it produces an unknown effect, then at the product level, this new effect has to be considered as a new failure mode. In the typology table the new effect of failure of process will appear first and then, in order to guaranty the equality, it will be treated as a new failure mode of product. Let us note this action experience feedback. This feedback is illustrated in Fig. 5. It becomes then possible to imagine an endless improvement way between $E_i$ and $E_j$'s typologies.

Then in order to control a manufacturing process plan, it is necessary to consider risks of products and cascade them as effects of the failure of processes. These effects of failure retrieve failure modes, which have to be cascade as failure effects of tools. These failure effects of tools in turn are associated at failure modes of tools.

New effects of failures of tools can be returned as new failure modes of processes. These new failure modes, can generate new failure effects that have not been anticipated during preliminary analyses. More generally, new failure effects of operations, can be fed-back as new failure modes of products.

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### Table 1

<table>
<thead>
<tr>
<th>Item/Function</th>
<th>Failure mode</th>
<th>Failure Effect</th>
<th>Cause</th>
<th>Prevention</th>
<th>Detection</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuCMP</td>
<td>MaxTime reached</td>
<td>Scrap</td>
<td>Incoming thickness too low</td>
<td>Process stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CuCMP</td>
<td>MaxTime reached</td>
<td>Rework</td>
<td>Spare parts failure (pad, Diamond disk for instance)</td>
<td>Process stop</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1.** Illustration of $R_{AB}$. 

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Through these new links, a virtuous learning cycle has been initiated, during the industrialization of a particular product, leading to global improvement of the production reliability. This method could be an answer to the paper of (Brombacher, Sander, Sonnemans, & Rouvroye, 2005) to structure knowledge about the manufacturing process and insure the spread of VoC within the manufacturing organization.

4.2. Industrial observation

An industrial experiment took place over the 2005–2009 period. It allowed us a deeper understanding of the concepts presented in this paper. During this period, authors have observed risk management practices in a semiconductor research and production plant located in France. In this plant, the classical set of semiconductor process control tools had already been implemented (May and Spanos, 2006). Researches on manufacturing methods were also carried-out there.

Risk analyses were used to pass Customers’ audits and internal technologies milestones. Risk analyses were performed in FMECA format, as presented in this paper. An Excel template was provided to FMECA teams. Analyses were stored in the local network of this company in a structured manner (stored and sorted by products/process/tools). This allowed the authors to analyze FMECA automatically, and retrieve data about typologies. A dedicated tool was developed to perform this task. It is illustrated in Fig. 6. It extracts typologies from FMECA.

Engineers in charge of risk analyses were trained for FMECA techniques by a dedicated training company. During this training the possibility of coupling FMECA was mentioned;

« during the process risks elicitation, insure that failure modes of product involving this process are first taken into account as failure effects of this process.
- during the tool risks elicitation, insure that failure modes of processes involving this tool are first taken into account as a failure effects of this tool. »

This paragraph was also mentioned within the local procedure of risk analyses. This document was communicated and used during analyses.

No other constraint was employed in order to force practitioners to steer their analyses.

5. Results

On the site where observations were made, over the period, 16,379 risk analyses were performed over 5 products (C120, C110, C090, C065 and C045). Three organizations were directly involved...
during risk analyses: product engineering, process engineering and tool engineering, for a total of more than 600 engineers. These analyzes lead to more than 3743 actions to improve detectability, or to reduce occurrences or to decrease severity of some risks.

5.1. Data pre-treatment

Several treatments have been operated over raw FMECA data in order to retrieve better typologies. &, @, over spaces, -, and other symbols (like: ; ? ! etc.) have been systematically replaced or removed. No grouping was performed. Had it been the case, aggregations would have generated a too high level of abstraction resulting in only several failure modes that would not have been representative of reality.

At the end of this pretreatment several algorithms have been applied to build typologies of failure mode and also to understand how these analyses have been naturally linked.

5.2. Typologies of failure modes

The following algorithm has been applied to build typologies from risks analyses.

Notations:

- \( N = \text{Card} \{E_i\} \) in this article \( N = 3 = \text{Card} \{\text{product, process, tool}\} \)
- \( M_i = \text{Number of risks analyses of} \ E_i \)
- \( P_i = \text{Number of components in the risks analysis of} \ E_i \) (for instance in FMECA format \( P = 7 \) for item/function, failure mode, failure effect, failure causes, detection, prevention, action)
- \( e_{ik} = \text{the} \ k^{th} \ \text{risks analysis of} \ E_i \)
- \( t_{ik} = \text{the} \ k^{th} \ \text{value of typology of the} \ k^{th} \ \text{component of the risks analysis of} \ E_i \)
- \( \text{nb}_{T_{ik}} = \text{card of} \ T_{ik} \)

Algorithm:

\[
\text{nb}_{T_{ik}} = 0 \ // \ \text{Initialization} \\
\text{For } i = 1 \ \text{to} \ N \ // \ \text{For every category of analysis} \\
\text{For } j = 1 \ \text{to} \ M_i \ // \ \text{For every analysis of} \ E_i \\
\text{For } k = 1 \ \text{to} \ P_i \\
\quad \text{if } \exists \ g / t^g_{ik} = e^g_{ik} \ // \ \text{Test if it exist a typology for the failure mode} \\
\quad \text{Then } l \leftarrow l+1 \ // \ \text{go to the next risk analysis} \\
\quad \text{else} \\
\quad \quad \text{nb}_{T_{ik}} \leftarrow \text{nb}_{T_{ik}} + 1 \ // \ \text{Add a new typology} \\
\quad \quad t^l_{ik} = e^l_{ik} \ // \ \text{Store the new typology} \\
\quad \text{end if} \\
\text{End For} \\
\text{End For} \\
\text{End For} \\
\text{End For} \\
\text{End For}
\]

This algorithm construct typology for each category (failure mode, failure effect, failure cause...) of each type of analysis (at product, process and tool level). This algorithm retrieved from pretreated data:

- 701 different failure modes for products
- 561 different failure modes for processes
- 1058 different failure modes for tools.

5.3. Evaluation of link between analyses

A syntactic comparison among failures modes and failure effects has been performed. As presented in the Section 4, the equality occurs between following typologies: \( T_{\text{failure mode, Product}} = T_{\text{failure effect, Processes}} \) and \( T_{\text{failure mode, Processes}} = T_{\text{failure effect, Tools}} \). The following algorithm compares if this equality is verified for each term in typologies.

Notations:

\[
L = \{L_{\text{failure-mode,Product}} = L_{\text{failure-effect,Process}}; L_{\text{failure-mode,Process}} = L_{\text{failure-effect,Tools}}\} \ \text{(set of links between typologies)} \\
l, \ l' \ \text{the operator that performs the link between typologies. The} \ x^{th} \ \text{specimen of the typology linked to} \ T_{ik} \ \text{is noted} \ t^x_{IK} \)
\]

LTPC: Quantity of typologies actually linked to control the process (from \( T_{ik} \) to \( T_{IK} \))
focused on performing effective risk analyses in each business area. The loose connection between FMECA is not enough to ensure that links will be followed. The weight of organization habits is too high to introduce such concepts with so few tools.

The concept of typology and the coherency of terms came later in the risk analyses. The lack of a shared ontology is clearly visible in the data-sheets. The main difficulty observed was to manage the equality presented previously by hand. Semantic divergences, syntactic differences, misunderstanding, synonyms, homonyms amongst terms are then major detractors to cope with in such documents.

A survey of 62 risk management methods performed by (Tixier et al., 2002) present a list of 8 main drawbacks of risk analyses:

- Applicability and specificity
- Importance of knowledge of people involved into the analysis
- Data validity for probabilistic analyses
- Tedious data update
- Long term data update
- Lack of description of several methods
- Specific training for several methods
- Human factor hardly taken into account.

They conclude by highlighting the “difficulty in taking into account all risks within an industrial plant”. For this reason, it seems clear that providing a way to connect and propagate risk analyses across organization can have a positive impact. However, through authors’ observation, the equality mentioned in the paper cannot be reached immediately. A preliminary risk ontology seems necessary evil, in order to simplify and to enhance risks analyses deployment. A first recommendation is then to sustain risks analyses with the deployment of an ontology tool as presented by (Ebrahimipour et al., 2010).

These links are then crucial to deploy Voice of Customer within the organization. Fearsome events for customers have to be analyzed first and cascaded at process and then tool levels. Resulting action plans gain then in priority and should be analyzed first. The concept developed in this article goes beyond product safety or product reliability only, and can also be applied for any kind of unwanted functionality of the product.

6. Conclusion

Starting from semi-conductor manufacturing systems, this article has presented an integrated vision of risks analyses. Interactions between products, their manufacturing processes and associated tools, generate interactions amongst associated risks. The paper introduces the concept of typology and underlines how its use could modify the deployment of a process control organization. This concept allows to structure controls and feedbacks inside the production. It allows to place risks analyses (especially safety and reliability) at the heart of the dialog between services inside the company. The paper also presents an observation of the practice of this concept in a best-in class semi-conductor manufacturing plant. The observation shows how far from these

<table>
<thead>
<tr>
<th>Failure effect of recipe to take into account in modules</th>
<th>Taken into account</th>
<th>List of recipes</th>
<th>Tool</th>
<th>Workshop</th>
<th>Nb of feedback from BH to recipes</th>
<th>Nb of feedback from recipes to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer breakage</td>
<td>Y</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA, CREFB</td>
<td>CMP</td>
<td>478</td>
<td>507</td>
</tr>
<tr>
<td>Over Polish</td>
<td>N</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA</td>
<td>CMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NU too high</td>
<td>N</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA</td>
<td>CMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Polish</td>
<td>N</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA</td>
<td>CMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Polish</td>
<td>N</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA</td>
<td>CMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defectivity</td>
<td>Y</td>
<td>FMEA_CMP_MP_C1,...</td>
<td>CREFA, CREFB, DPROF</td>
<td>CMP, DIEL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NLTP : Quantity of typologies actually not linked to control the process (from Tk to Tk[i])
LITFB: Quantity of typologies actually linked to perform a feedback (from Tk[i] to Tk)
NLITFB : Quantity of typologies actually not linked to perform a feedback (from Tk[i] to Tk)

Algorithm:

NLT = LT = 0 // Initialization
For m = 1 to card(L)
  For g = 1 to nbTik
    If ∃ g2, f^g2 = f^g(k)
      LITFB ← LITFB + 1
    Else
      NLT PC ← NLTPC + 1
    End If
  Next g
End For
For g = 1 to nbTk[ik]
  If ∃ g1, f^g1 = f^g(k)
    LTFB ← LTFB + 1
  Else
    NLTPC ← NLTPC + 1
  End If
Next g
End For
considerations a best-in-class (in term of process control methods) a manufacturing plant can be.

References


