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Risks analyses update based on maintenance events

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Abstract:
This paper will focus on the management and improvement of equipment availability with better prevention of failures. It is focused on one of process control tasks: preliminary risks analysis. The result from this study is a method which empowered engineers and managers decision about actions to implement regarding negative events in their manufacture. The article proposes a risk based maintenance method, which relies on the regular and automatic update of equipments' risk analyses including equipment failure history. The associated aided decision tool is presented. The article is structured in four parts. After a risk management domain literature overview, the paper presents the new risk based maintenance method. A case study in semiconductor industry shows that FMECA can be employed in a dynamic way for managing maintenance activities. The alternative model simplifies and makes more reliable risks identification and estimation. Results and a short discussion end the article

1. INTRODUCTION:

Semiconductor industry is characterized by complex and expensive manufacturing process, continuous technologies development and innovation. During the production cycle, equipment failures and breakdowns affect seriously cycle time, product quality and then the production cost. This context imposes to maintain a relevant, efficient, effective and dynamic control of manufacturing process. At the heart of this control plan are risks analyses. Following ISOTS recommendations, FMECA (Dod, 1980) is the recommended method for analyzing probable dysfunctions, their origins and to capitalize these information. These documents are also given to the customers in order to demonstrate that major probable risks are under control with associated action plans. However, using the FMECA method in a classical way stays a time consuming task and is often inefficient to manage risks.

This paper demonstrates that it is possible to use FMECA method in a more dynamic environment, continuously updated by operational events. This improves the risk analysis efficiency and prevents its obsolescence.

Equipment events are generally a main scrap contributor in the manufacturing process. But equipment FMECA are very hard to update and maintain in a continuous mode. Semiconductor industry fall in this case, equipments FMECA are generally complex to sustain due to the number of functional modules.

Is it possible to make a dynamic link between the daily factory events and the complex equipment FMECA?

Our approach consists to establish a continuous bond between factory events (coming from corrective maintenance) and block hardware risk analyses. This approach allows changing mind set concerning FMECA usage on the following points:

- FMECA can be updated on a regular basis.
- They can then be used has a reliable operational action plan by operational actors.
- Equipment improvement can be prioritized based on risk classification.

This study presents a method to enhance information about risks in a manufacturing facility. It connects FMECA with Comuterized Maintenance Management System (CMMS). This allows the continuous update of risks analyses with fab events' occurrences. It enables a fact based management of maintenance improvement actions.

2. LITTERATURE REVIEW:

Various studies have been done about equipment reliability improvement and management. Many maintenance policies and strategies have been developed in order to minimize failure rate and improve equipments reliability.

One can find in European standards (NF EN 13306, 2001) that maintenance is defined as all technical and administrative actions associated to an equipment life cycle. Maintenance aims to maintain or to restore the equipment in a state compatible with the achievement of the needed function. At early stage, maintenance aspects were limited to the corrective interventions. The main drawbacks of corrective interventions are non predictable aspects which impact resources mobilisation, spare parts stock, line bottleneck …

Technologies progress and process control needs push the industry to the preventive maintenance concept. It consists in carrying out repetitive and predictable maintenance operations, following pre-defined planning, by anticipation to equipment failure. Preventive maintenance frequency is fixed in accordance with criteria's like: known failure frequency, parts characteristics, costs improvement programs…

In order to improve maintenance efficiency with optimized resource amount, many preventive maintenance strategies were implemented (Higgins and Mobley, 2001). Despite these methods, processes and equipments complexity didn't allow to suppress failures and still affect cycle time at a non negligible level. Many approaches and models were developed for maintenance planning and strategy improvement (Gertsbakh, 2000). Caldeira Duarte et *al.* (2006) consider that the most critical issue is to determine the optimum preventive maintenance frequency. After a brief literature overview about reliability theory, new preventive maintenance management algorithms are proposed as well as a cost function for preventive and corrective tasks. All of these approaches mentioned above are focused on improving equipments reliability and minimizing costs. They studied equipment parts performances after failures occurrences and deduce maintenance intervals. Risk of failure is hardly integrated into planning models.

As explained in introduction, industrials are asked by their customers to deliver evidences of a process risk management policy. At the maintenance level, a first step toward this requirement is named RFM (Risk Focused Maintenance). It was developed for this purpose. It consists in defining action priority in accordance with the risk level (B. Tomic, 1993). Cassanelli and *al.* (2006) consider the analysis precision of a risk as a base for FMECA efficiency. They are describing how to update and follow FMECA documents. They advice to have a constant perfect match between: the risk document, product and equipment evolution.

Herrou and Elghorba (2005) presented a case study for compressor system that uses this FMECA approach for minimization of indirect maintenance costs. In addition, they show that this approach based on risk analysis, allow defining requirements in terms of reliability and a maintenance policy for the equipment and its components.

Redmill (2002) got more focus on risk analysis steps process (identification, analysis and assessment). He highlighted that the human factor is a key component for success of the method: "*there are many techniques for hazard identification, and all depend on human observation, judgement and creativity*". Risk analysis is presented as a tool to support decision-making.

Where RFM approaches considered risks as a part of the decision of maintaining or not, Risks Based Maintenance (RNM) approaches kept it central.

Khan and Haddara (2003) describe the method for maintenance planning improvement based on Risk-based maintenance and develop three modules: risk estimation, risk evaluation and maintenance planning module. The first module is about the development of different failure scenarios, consequences on system and determination of associated risks. Maintenance planning is then reviewed taking into account risk level aspects. A maintenance planning optimisation case study for HVAC (Heating, ventilation and air-conditioning) is shown. However this study suffers from a drawback; when a negative event occurs, risks analysis are not updated. Their obsolescence induces the maintenance planning obsolescence.

Kazunari et *al.* (2004) and Krishnasamy et *al.* (2005) show other case studies and the method was adapted to other domain.

Arunraj and Maiti (2007) made a synthesis of the RBM methods, present the different steps (Fig.1) and describe their main drawbacks. All the modules are detailed as well as factors affecting risk analysis evaluation quality. Three factors affecting risk analysis quality evaluation are highlighted and based on 25 RBM studies it is shown that few main contributors are affecting these factors:

Factor1: Hazard identification and initial consequence analysis. The main contributor is the quality of data and their retrieval during the risk analysis.

Factor 2: Risk estimation; they found three majors drawbacks: (1) the method employed for the risk calculation, (2) its application frequency (once per week, per months…) and (3) consequences attached for each ranking (which kind of action are linked).

Factor 3: Results: risks analysis impacts are not properly measured in a quantitative or qualitative way.

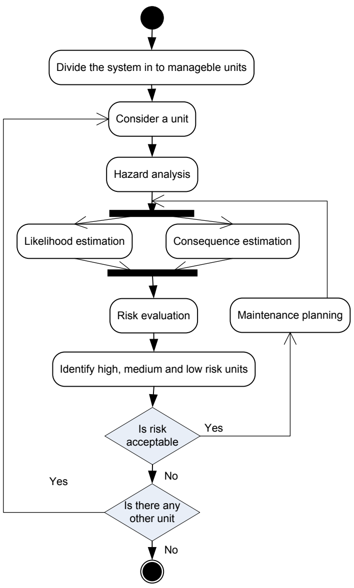

Fig.1. General risk-based maintenance (RBM) approach (Arunraj and Maiti, 2007).

These results point out the need for improving the quality of risk analysis. Source of information, update frequency and risk estimation method must be redefined.

The literature review process make an incursion into the design community, with the work of Tumer and Stone (2001). They present a method to introduce information of dysfunction during the design phase of functionalities. This method is named RED (Risk in Early Design phase). Their connection is based on three major points: (1) Parts breakdowns events storage, (2) Matrix linking parts and functions, (3) translation of parts breakdowns into risks of functional failure and database update. Their work presents an operational way to connect functional analysis into related risks and allows the automatic update of risks evaluation. Even this case study took place the design community it has been a major source of inspiration for the model proposal in the next paragraph.

This short literature review about risks based maintenance, point out that efforts need to be focused on data retrieval and updated – as automatic as possible - to prevent risks analyses obsolescence. The foundation of the proposition relies on previous analyses. A particular attention has been paid to connect as smooth as possible events and preliminary risks analyses.

3. MODEL PROPOSAL AND CASE STUDY:

A first extension was done by Bassetto et Al (2007) for connecting FMECA and process quality problem solving procedure, in semiconductor industry. The main advance was to reanalyse risks ranking regarding new issues facts. However, the main drawback of their extension was to rely on the good will of managers involved in the process to sustain the manual risk update.

A major source of event relies on process equipment. That is why we estimate that collecting real equipment events is a foundation for improving risk management. Then an additional layer of data analysis is proposed. Through heuristics, the frequency is updated bringing accuracy at risks identification and evaluation.

3.1 Proposal:

Toward a generic model: Classical RBM and risk analysis method are using human knowledge at each analysis' steps. That makes these methods quite heavy to use and in most of the cases not user friendly. Quality of the input information depends greatly on human expertise, interest to the method and capability to access the information. To overcome these issues the first step will consist to describe a model which automates as much as possible hazard estimation, data collection and risk evaluation.

Central to this model of risks, is the concept of a failure mode. It is a text. Linked at it, is its context: the equipment part or function, its effects, its causes, linked controls and their rankings – occurrence, severity, detection, redundancy… With such a structure, each real failure, occurring on tools can be compared at failure issued during preliminary risks analyses, for the same context (tool, part, function). From this comparison, failures and their ranking can be updated.

Each failure is logged and saved in CMMS database. Historical data allows classifying failures using decision criteria: Severity (downtime effect) and Occurrence (of the failure).

Model treatment method:
A risk is classified if its occurrence and severity is greater than a predefined level (Trigger Level: TL). To employ this model, a four step method is proposed:

a. Collect data from CMMS database: corrective maintenance reports.
b. Calculate occurrence and induced total downtime for each failure.
c. Select failures with decision criteria (risk quotation) higher than TL.
d. Upload risks in FMECA database & Validate decision criteria (Severity, Occurrence) for each risk.

At the end of this procedure, FMECA database is updated with risks to review and work on. Experts have to estimate detection level and define action plan. Using this model, loading procedure can be automated. FMECA contains actual (based on line inputs) and potential risks affecting the processes.

Starting from classical RBM model Arunraj and Maiti (2007), Fig.3 describes the new RBM model.

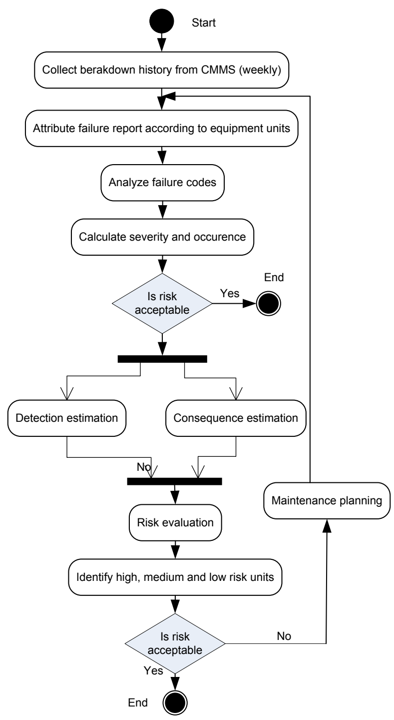

Fig.3. Risk-based maintenance approach (RBM)

3.3 Case study:

A risk is described by a particular class. The context is very structure in this case study by equipment decomposition. This leads at defining Item/function as an attribute of risks. This introduces a constraint: having the same description of Item/Function than in the equipment decomposition. An instance of the risks model mentioned in 3.2, is presented Fig 4.

The model presents also possible links between equipment failure (maintenance events) and risks descriptions. A risk can be generated by several causes and it can produce several effects on the equipment. It is modelled by a particular class. Context is included as an attribute of this class. A failure is generated by several causes and can produce several undesired equipment effects.

If the failure is properly described, it can be possible to pass from a failure to risk identification. Decision criteria are introduced in order to fully describe the association risk vs failure. These decision criteria must be verified and validated to allow the information transfer from failure to risk database.

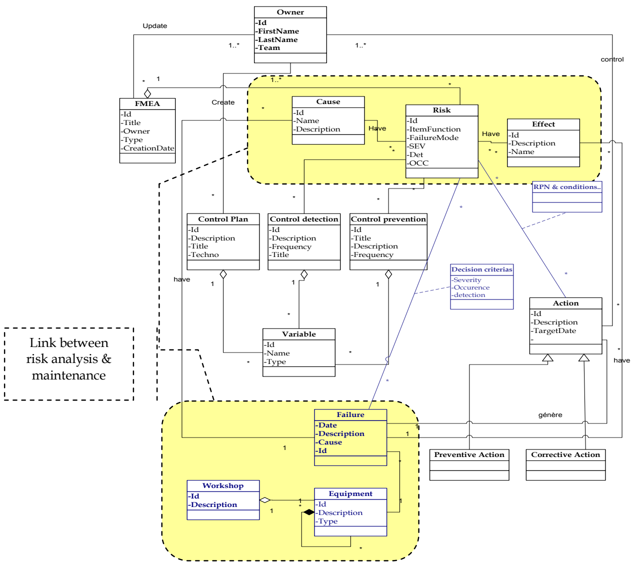

Fig 4. UML Data model

The following case study has been performed in the semiconductor domain. It shows how the proposal fig 4 allows progress compare to standard methods on the two following aspects: (1) Updating existing risk in FMECA (2) New risk edition including description, severity and occurrence. It follows the four steps of the previous method.

a. Collect data from CMMS database: corrective maintenance reports. *(**Output** of maintenance events)*

Preventive maintenance frequency and released criteria are usually fixed by workshop maintenance engineers in accordance with production constraints. In order to improve cost and cycle time, time to repair needs to be minimized in order to restart the tool in production as soon as possible.

In one hand, in the CMMS, each logged maintenance action is connected at an equipment part, involved in the breakdown. Each equipment belongs to a workshop. In the other hand, each equipment FMECA is classified by tool type and workshop. This similar structure can be synchronized so as having the same nomenclature in both software. This particular structure is illustrated Fig 5. It becomes possible to integrate each failure saved in the CMMS in the correspondent FMECA document.

To develop this study, a pilot workshop has been chosen. A first study of the maintenance events descriptions (named in the CMMS failure codes) showed that most of time, actual configuration doesn't allow a precise description of the breakdown. To ensure the relevance of information to be integrated into FMECA, a revision and modification of the "failure codes" have been carried out.

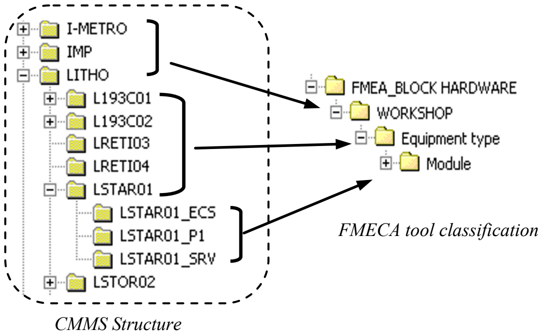

Fig.5. Arborescence coherence between FMECA and CMMS structure

[Risk!FailureMode] and [Failure!Description] (read as class!attribute) from fig. 4. are now at least in a correspondence table or at best equal. These two texts can be compared automatically.

b. Calculate occurrence and induced total downtime for each failure (Severity).

Decision criteria can be automatically proposed by using standard tables. Occurrence risk level (Rank) calculation is performed using a corporate quotation grid (Table 1) which associates number (From 1 to 10) to event frequency.

Tab1. Occurrence grid (corporate)

RANK	1	2	3	4	5	6	7	8	9	10
OCCURENCE	UNLIKELY	1EVENT/ LIFETIME	1EVENT/ YEAR	1EVENT/ QUARTER	1EVENT/ MONTH	1 EVENT/ FORTNIGHT	1EVENT /WEEK	1EVENT /DAY	1EVENT/ SHIFT	1EVENT /HOUR

Occurrence: To follow the occurrence on a monthly basis, and introduce a weight taking into account failure re-occurrence a new table using a unified scale table calculated on a 12 months period has been introduced (Table 2).

For example, if a failure mode noted FM occurs between 2 and 4 times, during the 1st month (M01) of review, its occurrence will be set at 7 (1st column, 3rd line). The second month (M02) if it doesn't occur again, this value will be "depreciated" from 7 to 6 (2nd column, 3rd line). At the opposite, if the event appears again, it can stay in this weight or pass it in the category "between 4 and 30 apparitions". In this new category, the failure mode occurrence is increased of 1, at 8.
This table allows a simple treatment of events by updating occurrence weights.

Tab2. Occurrence matrix on a period of 12 months

	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12
≤1 EVENT	5	5	4	4	4	4	4	4	4	4	4	3
≤2 EVENTS	6	5	5	5	5	4	4	4	4	4	4	4
≤4 EVENTS	7	6	6	5	5	5	5	5	5	5	5	4
≤30 EVENTS	8	8	8	8	8	8	8	7	7	7	7	7
≤90 EVENTS	9	9	8	8	8	8	8	8	8	8	8	8
≤720 EVENTS	10	10	10	10	10	10	10	9	9	9	9	9

Severity: Severity level for each failure refers also to a corporate ranking grid. Severity rank is linked to equipment downtime duration. Outlier values of failure duration can affects the average in an erratic way. In order to minimise this effect, downtime duration is calculated using the median on a monthly basis by failure type.

A monthly report is produced at this step. It contains all failures with associated Severity*Occurrence quotation.

c. Select failures with decision criteria (risk quotation) higher than TL (Input for risk analysis).

Starting from the above report, SEV*OCC greater than Trigger Level (TL) are classified to prepare FMECA data base loading. TL value is fixed according to global process control rules for the entire factory.

d. Upload risks in FMECA database & Validate decision criteria (Severity, Occurrence) for each Risk.

The output of the above procedure is loaded in the FMECA database. FMECA are updated regarding these new facts. Each updated risk can be either a new one (new FMECA line) or an existing one (involving a ranking update).

- *Update an existing Risk in FMECA database*

An automatic algorithm updates severity and occurrence values in FMECA database. These values are validated by equipment engineers. Rankings can be changed if necessary. On a monthly basis, an updated FMECA list is created for engineers. It gives priority action based on risk level. Engineers have to fill up recovery action in the FMECA data base. FMECA is integrated into daily engineering analysis and actions. It becomes by this way operational and used.

- *Add a new risk in FMECA database*

After the update of existing risks, new risks (unknown one) are added in FMECA data base. New risk lines are added into the appropriate FMECA. Four risk's attributes are automatically loaded in the data base: Item/Function, Potential Failure Mode, severity and occurrence. Engineering have to fill up the remaining information of the FMECA (Detection, action plan…). By this method, each risk update can be followed on a continuous manner.

Actual risk													
N°	Item/Function	Potential Failure Mode	Potential Effects of Failure	SEV	CLASS	Potential Cause/ Mechanism of Failure	OCC	Current Controls Prevention	Current Controls Detection	DET	Sev*Occ	RPN
6	DEFECTIVITY	PARTICLES_BACKSIDE	Rework, risk of track contamination and lots contamination (yield impact)	5 (Old value: 2)		track module dirty, particle carried by the lots from an other tool	5	PM, handling check	Visual inspection on lots	6	25	(Old value: 60)
6	DEFECTIVITY	PARTICLES_FRONSIDE	Rework	4		track module dirty, particle carried by the lots from an other tool	5	PM, handling check	Visual inspection on lots		20	
8	DEFECTIVITY	PATTERNS_RELATED		6			7				42	

Fig.6. Extract from FMECA database

Fig.6 shows an extract from FMECA database with the two cases discussed above. On line number '6' the severity was updated and RPN (Risk Priority number) changes from 60 to 150 and then it requires corrective and preventive actions. Line number '8' is a new risk line added in FMECA. It shows information loaded automatically, other information as to be filled up by the engineering.

4. RESULTS & DISCUSSION:

Results: After two months of this systematic update twenty additional critical risks in the pilot workshop have been generated. Engineers discovered that most of these risks came from repetitive failures and were not seen previously due to the systematic ranking error on occurrence. Repetitive failures are time consuming. Even if they are less critical for the product, and easier to resolve, they must be treated in order to allow maintenance resources to deep fundamental issues.

FMECA update is simplified by this new method which identifies failure sources and critical equipments dysfunctions. All aspects of dysfunction are addressed, Cycle time and Cost through SEV*OCC > TL, Yield and cost can be done through SEV*DET > TL. The new method implies a complete review of existing risk identification in order to be coherent with maintenance database structure.

A regular FMECA database update, by maintenance events allows to enhanced knowledge about in line risks in the workshop.

Discussion: Results are promising. Two months are clearly not enough to iron out properly the entire system. However, most critical points identified at that time are: the establishment of links between maintenance and risks databases as well as the coherence between failure reports and risks definition. The coherency between texts of the 'failure mode' attribute of the 'risk' class and the 'description' attribute of the 'failure' class is a start. Researches continue to smooth this link which requires an important organisational effort.

Today the FMECA update is more automatic. However, it still relies on engineering involvement during the definition of a join vocabulary between preliminary risks and maintenance teams. Managers remain key people by the emphasis they give in this new decision tool for action management, designed for them.

5. CONCLUSION & FUTUR WORK:

This paper is focused on production process improvement; it proposes a risk based maintenance tool enhancing management decisions. Using actual equipment history, a risk based maintenance model and method are developed and a case study is presented.

Establishing links between maintenance and risks databases allows improvement of failures' identification and prevention by using FMECA in a dynamic way.
As a consequence of the model implementation, aided-decision tool has been developed for maintenance managers and field engineers. It helps in the management of their daily action plans. Cycle time, Cost and yield issue, are linked to operational dysfunction through FMECA approach in a comprehensive manner. By the possible automation of FMECA loading, well known heaviness of this method disappears.

Works are now on the deployment of this connection. The focus is done on the connection between events of failure – risks analysis and resulting control plan. The possible deployment of this demonstrator, using the CRIS model (MIMOSA, 2006) is under investigation.

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