Deriving Failure and Effect Data of New Machinery for Preventive Maintenance (PM) Planning – A Case Study

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Abstract

Having effective Preventive Maintenance (PM) planning is very crucial in both maintenance and manufacturing systems. PM planning plays a major role in preparing and recognizing the problems of machinery/process earlier before failure occurrence. Considering the new machinery setup with less data provided a framework of deriving failure and effect data is presented in three stages, namely machine identification, failure analysis and maintenance improvement requirement. Three basic analysis tools such as prioritization matrix, machinery FMEA-based approach and tree diagram are utilized to generate data and knowledge of selected machines, failure types and failure components process as well as PM improvement tasks. The data derived is very useful to be used in the latter PM planning and improvement. The framework is applied to a case study conducted in a semiconductor company.

Keywords
PM planning, FMEA, prioritization matrices, tree diagram, failure and effect, PM tasks, Knowledge Management

1. Introduction

The importance of maintenance planning received growing attention in modern manufacturing systems due to anticipated changes in technology as well as complexity of technical in maintenance systems. Maintenance planning is basically the process for carrying out maintenance job by which all the maintenance resources such as material requirements, labor requirements, duration to perform tasks and technical references related to equipment, are constructed and prepared prior to starting the job (Duffuaa and Al-Sultan, 1997). Adopting Preventive Maintenance (PM) is pertaining to maintenance planning which required having a long term plan for executing maintenance within predetermine interval to ensure machine continue to fulfill their intended functions (Mirghani, 2003). The purpose of having PM planning is basically for the decision making and determines the future actions to accomplish the objectives and goals of effective maintenance operations. Literature on PM planning is available from various aspects such as planning for maintenance activities, prioritizing spare parts and components, and setting up machines and components by optimizing models and methods in achieving the effectiveness of maintenance operations.

Machinery and plant are the main elements in modern manufacturing system that provides a lot of information and record based on their operations and performance. The information gathered in the form of data acquisition from the machinery performance is an aid to plan the future actions and made decision in relation to maintenance and improvement operations. Literatures on machinery mostly based on the information of breakdown machines, materials and labor are essential to improve maintenance operations in manufacturing plant. Talukder and Knap (2002) assigned the machinery to multiple overhaul blocks in series systems based on input features of PM interval and the total maintenance-related costs such as failure cost and cost of materials and parts for overhaul. Weibull distribution is used in the approach to represent failure rates of the machinery. In addition, Almomani et al (2012) presented a PM planning based on the grouping machines according to its failure types in a case study of mining industry. The failures that occur on machines in plant are the main input to trigger the process of grouping machine that lead to the execution of maintenance operations in a group of machines. Therefore, data such as downtime record, work order and current PM tasks for the long run plant are essential information prior to develop effective PM operations.

Despite many approaches have been conducted in relation to PM planning, data gathering must not be disregarded which lead to the difficulties from the fact of insufficient data. Previous data information of downtime record, work order and all current PM tasks for machinery are essential to be compiled together into historical record prior to developing PM planning. The historical data provides valuable information of the machinery in their life cycle that clearly understood; hence ease the process of updating and accessing PM planning (Márquez and Herguedas, 2004). However, new machinery with spick-and-span production plant environment has less data and resources available, especially downtime records which lead to inadequate information for PM planning. In addition, no studies or framework are available to develop effective PM planning that focusing on new machinery. Therefore, it is essential to derive the data from new machinery condition in terms of failure and effect instead of waiting for machinery to breakdown. The process on how the data can be acquired and methods involved should be presented in the form of framework. Deriving the data based on possible failure and effect for new machinery can assist to determine the future actions if the breakdown occur.

The main aim for this paper is to develop an effective framework on deriving failure and effect data for new machinery to be used in the latter PM planning. The framework consists of methods such as prioritization matrix, failure mode and effect analysis (FMEA) and tree diagram. Each method used will provide the acquired data for new machinery such as machine and components, failure types as well as maintenance tasks; thus achieved the objective in this paper.

In particular, this paper is structured into sections and sub-sections. The framework of deriving data in new machinery is elaborated in the next section. The following sub-sections including all stages in the framework. The case study is then elaborated in Section 3. Discussion is provided in the Section 4 and Conclusion in the final section.

2. Framework of data derivation for new machinery

"Prevention is better than cure" is the best essence to be applied in solving maintenance problem, especially in the new machinery installation environment which requires proper planning or preparation step to the possible failures that may occur in manufacturing facilities (Ab-Samat et al., 2012). From the aforementioned, data information must not be disregarded. Preparing data for maintenance job required hierarchical steps to obtain the acquired data. Hence, a framework of data derivation for new machinery is presented in this paper. The framework is based on possible failures and effects of new machinery in plant to determine the desired data through some thorough analysis, as depicted in Figure 1.

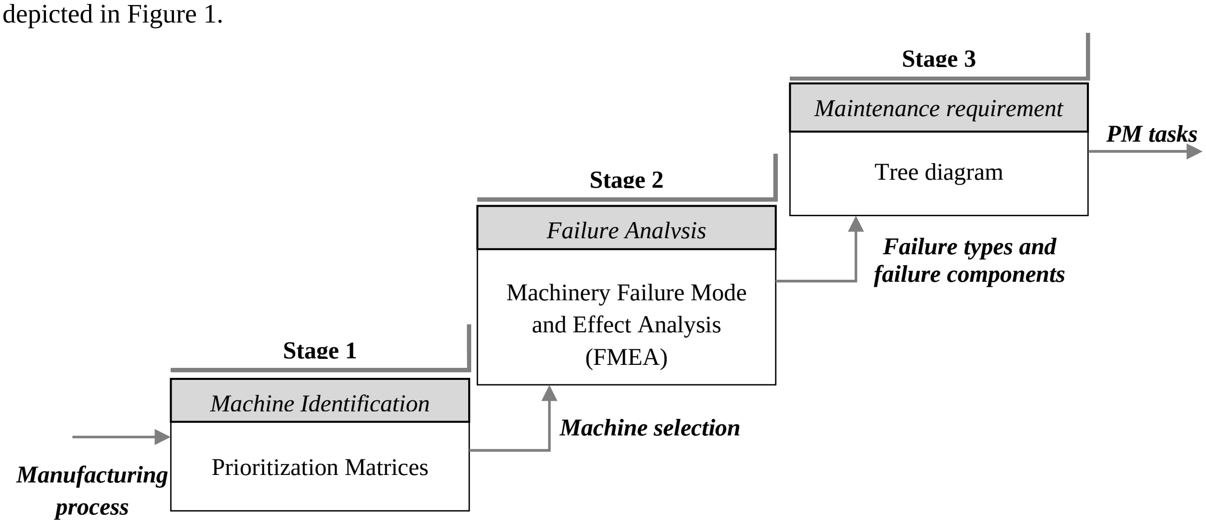


Figure 1 Framework of data derivation for new machinery

Figure 1 shows that the framework of data derivation for new machinery consists of three main stages. Stage 1 is the machine identification is based on the manufacturing processes information to focus on the machines that need critical attention. Therefore, a prioritization matrix is one of the new seven quality tools that employed in this stage. The procedure involves benchmarking process that evaluates the selected machine to be focused. Once the information accumulated, failure analysis stage will be initiated based on the selected machines. In this stage, a Failure Mode and Effect Analysis (FMEA) is then implemented to acknowledge the failure types and failure components involved. Final stage of maintenance requirement will proceed by developing PM tasks through tree diagram analysis. The PM tasks will provide the necessary maintenance actions by concerning machines, failure types, components and recommended actions from FMEA. The proposed framework is implemented through a case study.

3. Case study

Based on the facts of data derivation for new machinery discussed earlier, a case study was conducted in a semiconductor company situated in Penang, Malaysia. The company is equipped with highly automated state-of-art facilities and leading technologies in designing, prototyping and manufacturing of printed circuit board (PCB). Currently, the company has two manufacturing plants encompasses of PCB design and manufacturing in Plant 1 and PCB assembly performs in Plant 2. For this case study, the improvement of PM was conducted; focusing on the Plant 2 which is involved with the process of assembling electronic circuits by directly mounted the electrical components onto the surface of the PCB. This plant comprises of two processes that is the surface mount technology (SMT) and back end. The production line for the SMT processes is arranged into three parallel lines and connected with a back end process that is the quality inspection. Operation sequence and process specifications normally depend on the customer requirements.

During the case study, a team of maintenance is formed comprises external and internal members to for identifying the failure of the machinery by using the proposed the framework as in Figure 1. The external members encompasses panel of experts such as original equipment manufacturer (OEM), whereas the internal members include the planners, supervisors and technicians. The members are group together due to thier expertise and knowledge and experience that will be used for understanding, identifying, and adapting the best maintenance practices onto the new machinery in Plant 2. In addition both external and internal members are dependable for evaluating and analyzing the suitability of the tools and techniques in the proposed framework. A detailed description and verification of the framework proposed through the case study will be further discussed in the following sections.

3.1 Stage 1: Machine Identification

The commencement phase for the proposed framework is a machine identification stage. It is a vital stage where the production line is scrutinize in term of the processes and machines. As refereeing to Plant 2 of the case study company, the production floor consist of 11 machines for both SMT and back end processes. The lines are arranged into three parallel lines that each line is making up of 3 machines. The parallel line is connected with a single backend process that makes use of two machines. In carrying out the detail analysis for verifying and validating the proposed framework only one production line and the backend process will be the main interest. The whole SMT and backend line is depicted in Figure 2. The machine is coded as M1, M2, M3, M4 and M5.

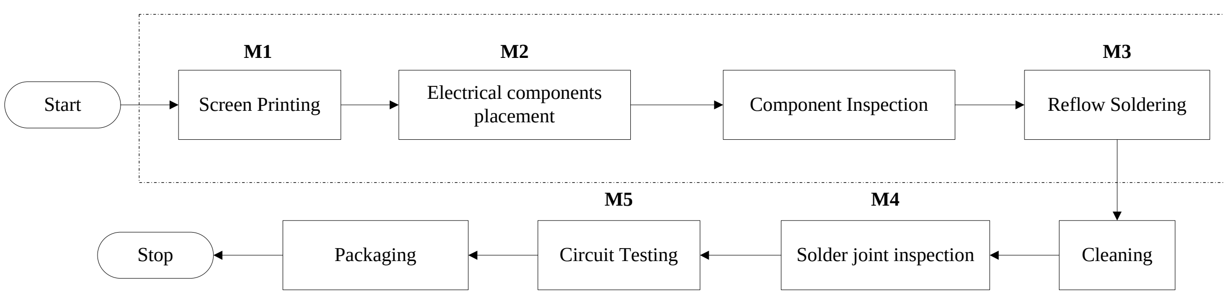


Figure 2 SMT and backend processes with machines involved

As shown in Figure 2 the processes involved mostly is carried out machines. The assembly processes begin with screen printing machine (M1). The process involve is applying solder paste to the solder pads. The process continues by using pick-and-place machine (M2) to take up the electrical components from a tape or tube and placed it onto the PCB. Then, the PCB boards are conveyed into a reflow soldering (M3) oven after the inspection process. During the reflow soldering process it will heat up the boards and components to melt the solder paste, thus bonding of the component will occur. The process continues by cleaning up the boards from dust. Next, solder joint inspection (M4) is carried. It follows by a circuit testing process (M5). Both of the processes are crucial to ensure the quality of the PCB assembled. The process ended at the packaging prior to deliver to the customer.

After the understanding of the whole processes, selection of possible problematic machines through a failure analysis can be identified by using a prioritization matrix. The prioritization matrix involved the selection of problematic machines through structure evaluation criteria (Wang et al, 1998). Therefore in adopting the prioritization matrix numerous group meetings and discussions are conducted from time to time to extract and fill the matrix based on panel experts' opinions particularly in determining the possible criterion for new machinery setup. The evaluation procedure is conducted through the discussions among both internal and external members to rank the evaluation criteria based on guidelines provided. The ranking and guidelines for prioritization matrix are tabulated as Table 1 and Table 2 respectively. In ensuring the constructed matrix is unbound from predisposed judgment a Delphi method is adopted.

Table 1 Prioritization Matrix of SMT process

Process / Evaluation	Quality issue	Safety or exposure to hazard	Risk of failure	Equipment reliability	Machine utilization	*Rating*
Screen printing	3	2	3	3	1	12
Electrical component placement	3	2	3	3	1	12
Component inspection	2	2	1	2	1	8
Reflow soldering	4	4	3	3	1	15
Circuit testing	1	1	1	1	1	5

Table 2 Guideline for evaluation SMT process

Score	Description
1	Excellent. No effect on the machinery
2	Good. Some effect but still under control
3	Medium. Noticeable effect
4	Poor. Required critical attention

As shown in Table 1, the prioritization matrix of the manufacturing processes is presented based on the related machines in a production line as depicted in Figure 2. In particular, the evaluation criteria consist of quality issue, safety, risk of failure, equipment reliability and machine utilization. The sum of scores is accumulated as rating, by which highest rating may contribute to failures in the future. Among five main processes, only three processes of the three machines identified as a priority due to their total rating exceeding 10. From the analysis, the three machines identified are selected for further analysis in stage 2, as tabulated in Table 3.

Table 3 Selected machines and their functions

Machines	Process
M1	Screen solder paste onto PCB
M2	Place board range of electric components onto PCB
M3	Reflow soldering of surface mount electronic components to PCB

3.2 Stage 2: Failure analysis

According to Cassanelli et al, (2006), failure analysis involves the process of gathering and analyzing data to determine the possible cause of failure. Method of Failure Mode and Effect Analysis (FMEA) is one of the basic methods in failure analysis to identify potential failure modes of a product or a process, the effects of failures and evaluate the criticality of these effects on product functionality (Teoh and Case, 2004) . The evaluation of failure in FMEA encompasses examining process of Risk Priority Number (RPN) to indicate the criticality of machinery or components either in design, process or concept phase. However, evaluating failures on the new machinery in the case study company, machinery FMEA-based concept introduced by Ford Motor Company (1996) is employed to analyze and evaluate machinery and customized selection of component parts and machine structure to improve operator safety, reliability and robustness of machinery. Furthermore, the machinery FMEA-based concept only focused on the severity ranking of potential effect of failure, evaluated through discussion with both external and internal members. The outcome of the failure analysis is tabulated in Table 4. The outcomes are based on the three identified machines in previous stage.

Table 4 Machinery FMEA-based in SMT process

Machine function	Possible failure mode	Potential failure cause	Component/ Parameter cause the failure		Potential failure effect(on product/process/machine)	Potential Severity	Recommended Act	
M1 - Screen solder paste onto PCB	**F1**: Solder ball formation	Poor solder paste printing alignment	C1 C2		Solder paste may i. solidify across two adjacent pads causing undesirable bridge ii. get smeared on the bottom side of the stencil	6	**A1**	i. Verify print alignm consistent basis ii. Ensuring frequent c the bottom of stenci
M3 – Reflow soldering of surface mount electronic components to PCB	**F2** :Spattering	Solder balling may moisture contaminated solder paste which splatters during reflow solder spheres behind. Excessive oxide on the solder powder in the solder paste that inhibits solders coalescence during reflow.	C3 C4 C5 C6		Causing functional problems to electrical circuits	6	**A2**	Minimize solder paste high temperature and h
M2 - Place broad range of electric components onto PCB	**F3** :Tombstoning	Improper placement of electrical components on both pads	C7 C8		Imbalance wetting force on both pads to the electric components during reflow	7	**A3**	Check components pla accuracy, if shifted edi manually
M3 – Reflow soldering of surface mount electronic components to PCB		i. Uneven heating of solder on the PCB ii. Uneven paste deposition on the two solder pads iii. Insufficient tack force of the solder paste to hold component iv. Excess movement during and after reflow operation	C3 C4 C5		Differential across the electrical component terminals	7	**A4**	i. Proper controlling o parameter ii. Select suitable sold and pads iii. Avoid inefficient ta from environmenta iv. Minimize amount o
M1 - Screen solder paste	**F4** :Bridging	Poor gasketing, misalignment, bad cleaning, dented squeegee	C1 C2		Electric component contact with solder paste	7	**A5**	i. Ensure paste depos good resolution

onto PCB		blade, incorrect print speed	C4		may skew the deposit			ii. Check print speed
M2 - Place broad range of electric components onto PCB		Inaccurate placement of component	C7 C10		Built a narrow gap between pads	6	**A6**	i. Verify actual compo against data entered ii. Ensure proper press accuracy for compo placement
M3 – Reflow soldering of surface mount electronic components to PCB		Extended soak which is more heat to the solder paste	C5 C9		Form a paste hot slump phenomenon	6	**A7**	i. Operating temperatu supplier's recomme ii. Use appropriate refl
M2 - Place broad range of electric components onto PCB	**F5** :Machine unable to pick electrical parts	Loss of vacuum Poor quality of nozzles	C7 C8 C10		Electrical components not being presented to the nozzle in a consistent position	6	**A8**	i. Frequently check th ii. Monitor the progran

As shown in Table 4, since the machines in the plant are still new. Thus there is no failure date has been recorded so far. Therefore the rates of seriousness of failure effect for potential of severity are requiring. The decision is reach in accordance to the confirmation from the external members. The internal members play major role in deciding the correct actions to be taken if the failure occur. Through the study on machinery form the FMEA-based sheet, possible failure modes and possible failure components can be the outcomes from the failure analysis carried out thoroughly. In addition, the top five of possible failures and the possible components involved were identified and highlighted. These failures will be further scrutinized especially for new machine setup, as shown in Table 5 and Table 6 respectively.

Table 5 Possible failures in SMT process

Failure	Possible failure	Description
F1	*Solder ball formation*	The formation of very small spherical particles trapped along the outside edge of the flux residue
F2	*Spattering*	Similar to solder ball formation but particles of solder that are formed away from the solder pads.
F3	*Tombstoning*	Electrical component that primarily or completely lifted off one end of the surface of solder pads.
F4	*Bridging*	Solder connecting cause by the excess solder that form a 'bridge' across two conductors
F5	*Shift electrical parts*	Machine unable to pick electrical parts consistently or hold on the components during transport

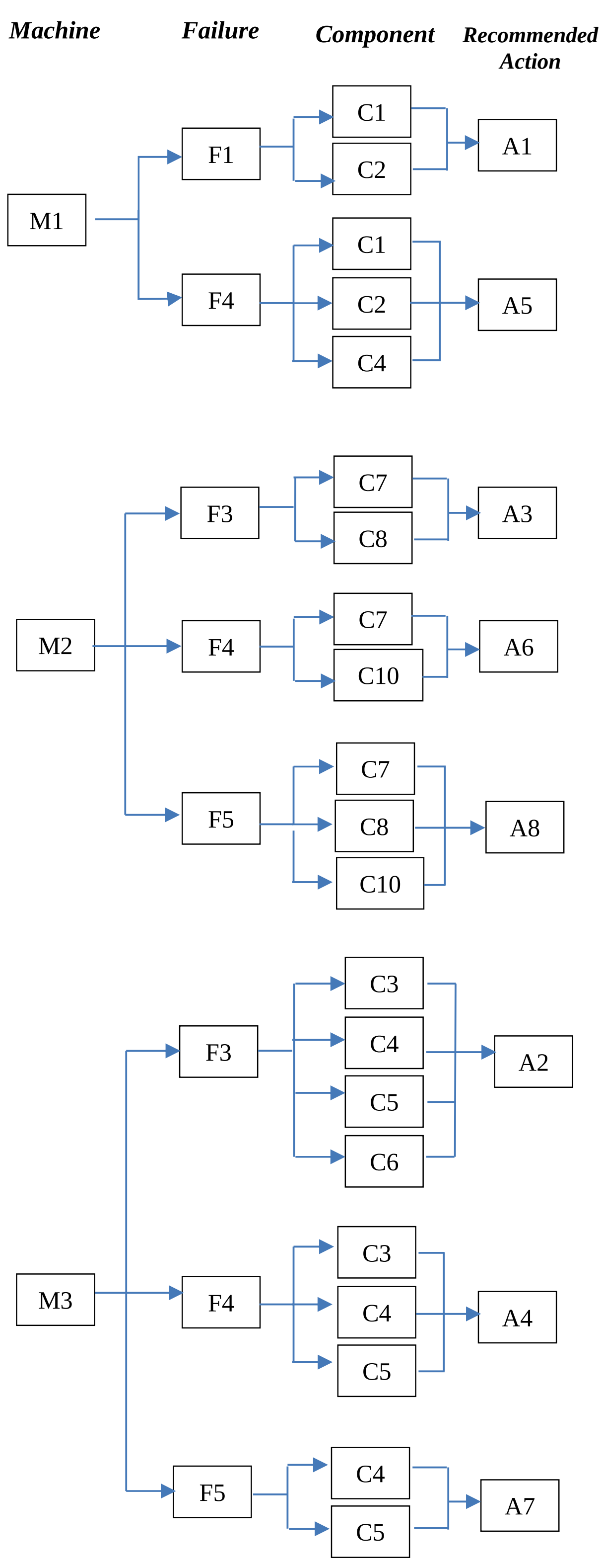
Table 6 Organized structured of machine and component according to possible failure

POSSIBLE FAILURE	MACHINE	COMPONENT
F1	M1	C1 C2
F2	M3	C3 C4 C5 C6
F3	M2	C7 C8
	M3	C3 C4 C5
F4	M1	C1 C2 C4
	M2	C7 C10
	M3	C5 C9
F5	M2	C7 C8 C10

The outcome from FMEA-based concept has resulting into valuable information that can be related to maintenance point of view. All the information provided will be used in the next stage in order to determine the applicable PM tasks as the main requirement of deriving data.

3.3 Stage 3: Maintenance improvement requirements

In order to determine appropriate PM tasks, it is important to determine the maintenance requirement that suits maintenance action. Therefore, in the previous stage of data derivation for new machinery, it has provide such valuable and useful information such as the machinery failure mode (types), failure component and recommended actions to be used in developing PM tasks. In carrying out the analysis in a more structure manner a tool from the new seven new quality tools will be utilized namely the tree diagram. The tool is used to strategically having a robust decision making process on the basis of the information yield and relates them to propose effective PM tasks. The outcomes of this stage in the form of tree diagram are depicted in Figure 3.



Preventive Maintenance Tasks

Duration	***Tasks***
Weekly	i. Frequent cleaning C1 and C2 ii. Check C2 printing surface wear and tear
Monthly	i. Cleaning and greasing the C4 load/unload of Print Table, Backup and all 2 axes tables ii. Clean and greasing C2 unit for linear guide and shaft for C2 moving up and down

Duration	***Tasks***
Weekly	i. Check and cleaning C7 ii. Regular cleaning, lubrication and calibration of C8 iii. Remove and clean dust or stain on machine iv. Check board clamp condition
Monthly	i. Cleaning and greasing the C4 in all 3 axes tables ii. Inspecting and cleaning push up shaft iii. Inspecting and cleaning conveyor belt

Duration	***Tasks***
Weekly	i. Clean and check the entrance and exit sensor ii. Check all C6 condition iii. Clean and lint out all C6 iv. Clean residue of flux from entrance/ exit areas v. Clean and clear dropped component, foreign material and dust inside and surrounding machine vi. Take and check C5 and C9
Monthly	i. Cleaning and greasing internal conveyor ii. Width lead screw and guide shaft iii. Check condition of C3

Figure 3 PM tasks development using Tree diagram

Figure 3 shows the analysis that embarking on connecting all the machines, possible failures and possible failure components with the recommended actions from machinery FMEA-based sheet. The recommended actions are indicated by numbering form from A1 to A8, as presented in Table 4. In general the procedure begins by relating the possible failures of selected new machinery with the components that have possibility to fail in the future. Then, the recommended actions are connected with the maintenance requirement to generate the possible solutions for the PM tasks. The tasks for PM are segregated according to the duration of weekly and monthly, which based on the requirement for maintenance operations. Thus, PM can be performed based on duration identified.

4. Discussion

Framework of data derivation for new machinery is presented in this paper to outline the required data to be derived and used for the PM planning particularly in the new shop floor environment. In the framework a structure way of gathering data for new machinery is introduced. Hence it can solve the problem of non availability of data and resources for new machinery setup. A standard process plan also can be developed considering the capability of machine either in usage or new setup condition. The standard process plan includes the desired machine and components for further planning procedure. From the case study company perspective, the framework can assist to establish the data bank for improvement of available PM operations in the manufacturing plant. Furthermore, steps to derive data by using the seven new quality tools and machinery FMEA-based can ease maintenance personnel in determining the possible failures, causes and strategies during the production operations. The data gathered from all the tools used in the framework proposed can contribute to the easiness of detecting failure rather than the need to gain experienced from failure occurrence.

In addition the framework is directed to generate data from manufacturing processes to the PM tasks by considering the condition of new machinery setup. Adopting the new seven quality tools and FMEA can abridge and structurally form a better analysis procedure. Therefore it will lead to new dimension for both organization and academic perspectives involving data generation for new shop floor environment. The data obtained from the analysis process is very useful to prepare and plan maintenance operations rather than waiting failure to occur. The framework also can assist in planning an accurate procedure for PM based on an organized and comprehensive data acquisition for new machinery setup in the semiconductor company.

5. Conclusion

The development of data derivation framework for new machinery setup is presented in this paper. The proposed framework will work as an initial phase by which data acquired is utilized to develop an effective PM planning in the future. Future research will be directed toward investigating the next phase in developing effective PM planning based on the data generated in new machinery setup. By using the prioritization matrix, machinery FMEA-based concept and tree diagram which based on failure and effect of machinery, provides significant outcomes for each stage of the analysis. ON the other hand the other failure analysis method also can be used such as Anticipatory Failure Determination (AFD) which defined the failure analysis and failure occurrence in a systematic way.

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Biography

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