I CURSO INTERNACIONAL DE CONFIBILIDADE HUMANA

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Functional Resonance Accident Model (FRAM) Exercise

A common and often repeated operation in the lifecycle of a process is called "maintenance, repair, and modification". This refers to the scheduled activities needed to ensure that the process plant is in good working conditions and that processes and components function within the tolerances specific by design and safety analyses. Maintenance, repair, and modification may be carried out either during specific outage periods or while the pant is running.

The contents of "maintenance, repair, and modification" will, of course, differ among different processes (e.g., nuclear, oil, chemical, transportation, etc.), but can nevertheless for the purpose of analysis be described as being constituted by the individual steps shown in Figure 1.

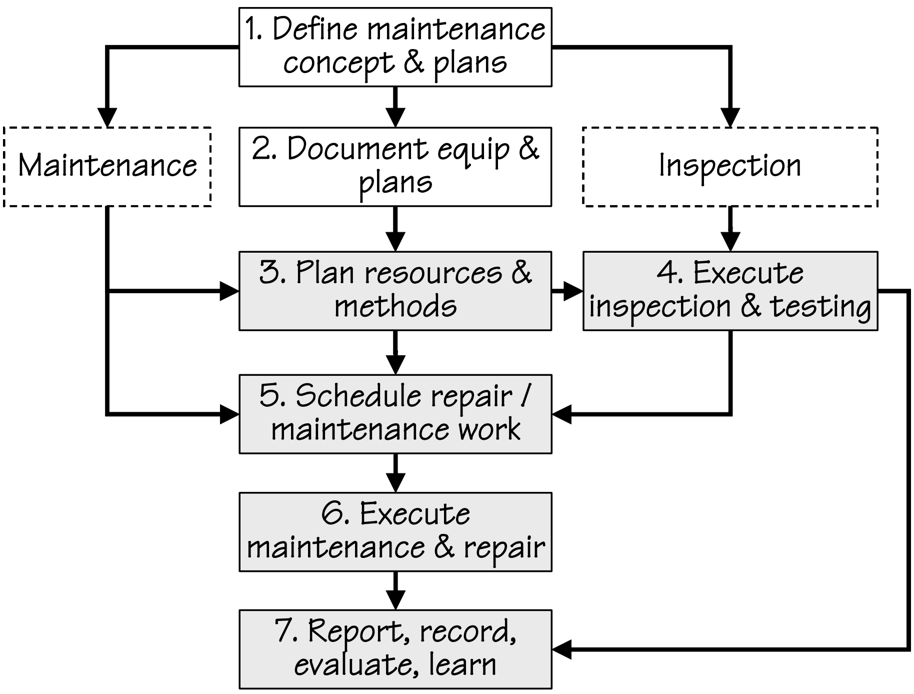

Figure 1: Generic steps in "maintenance, repair, and modification"

For this exercise, we will consider only steps 3-7, which constitute the concrete maintenance activities. The other steps are mainly of an administrative nature – although that does not make them any less important for safety.

Figure 1 shows a common rendering of the steps in "maintenance, repair, and modification", which depicts a specific ordering of the steps as indicated by the flow between them. This ordering and flow represent the normal performance, and are often the basis for writing procedures and organising the work.

A FRAM analysis comprises the following four steps:

- Identify essential system functions; characterise each function by six basic parameters.
- Characterise the potential variability using a checklist. Since the potential variability always depends on the context, this must also be specified.
- Identify functional resonance based on possible dependencies (couplings) among functions.
- Develop barriers for variability (damping factors) and specify required performance monitoring.

In this exercise, the four steps will be illustrated using the example of "maintenance, repair, and modification". Since this operation is only described on a generic level, the exercise requires that you use your own experience and "imagination" to fill in the necessary details. In real case, such details would of course require additional information gathering activities.

FRAM Analysis - Step 1

A traditional risk analysis would be based on the normal flow or normal performance, and from that try to determine if any of the component steps could go wrong, specifically if there were any opportunities for "human error".

In contrast to that, a FRAM analysis begins by identifying the functions necessary to achieve the overall goal, i.e., to ensure that the plant is a normal working condition. This would normally entail a dedicated functional analysis, for instance in the form of a goals-means analysis. For this example we shall take it as given that the five main functions shown in Figure 1 are indeed the necessary functions, i.e.:

- Plan resources and methods
- Execute inspection and testing
- Schedule repair and maintenance work

- Execute maintenance and repair
- Report, record, evaluate and learn

Each function is then described by six parameters, as follows:

Parameter	Characterisation
Input	That which is needed to perform the function. The input constitutes the link to previous functions. Input can be either transformed or used in order to produce outputs. Input is very often in the form of **information**, but may also be in the form of matter or energy.
Outputs	That which is produced by the function. The output constitutes link(s) to subsequent functions. The output may be in the form of information, energy, or matter.
Resources	That which is needed or consumed by the function to process the input (e.g., hardware, procedures, software, energy, manpower).
Pre-conditions	System conditions that must be fulfilled before a function can be carried out. Pre-conditions are often restrictions introduced to enhance safety, but may also be general enabling conditions.
Time	Time available: This can be considered as a special kind of resource, but can also be a constraint if the time available is limited. The limitation can be set by other functions or by external sources..
Control	That which supervises or adjusts a function. This can be in the form of plans, procedures, and guidelines or be another function.

To complete the first step of the FRAM analysis, describe the six parameters for each of the five main functions. Please use the tables below. (Note that not all parameters are meaningful for all functions. If that is the case, simply use the description N/A, meaning "not applicable".)

Function	PLAN RESOURCES AND METHODS
Parameter	Description
Input	
Outputs	
Resources	
Pre-conditions	
Time	
Control	

Function	EXECUTE INSPECTION AND TESTING
Parameter	Description
Input	
Outputs	
Resources	
Pre-conditions	
Time	
Control	

Function	SCHEDULE REPAIR AND MAINTENANCE WORK
Parameter	Description
Input	
Outputs	
Resources	
Pre-conditions	
Time	
Control	

Function	EXECUTE MAINTENANCE AND REPAIR
Parameter	Description
Input	
Outputs	
Resources	
Pre-conditions	
Time	
Control	

Function	REPORT, RECORD, EVALUATE AND LEARN
Parameter	Description
Input	
Outputs	
Resources	
Pre-conditions	
Time	
Control	

FRAM Analysis - Step 2

The second step of the FRAM analysis serves to characterise the potential variability of the function. This is done using a simple checklist, shown below. The answers to the checklist must reflect the characteristics of the specific process being analysed. In the example it is therefore necessary to think of a specific case, and use that as a way of determining which ratings may be appropriate.

For each rating, please give a short reason or explanation.

Common performance condition	Rating category			Functions affected		
	Adequate	Inadequate	Unpredictable			
Availability of resources				M	T	
Explanation						
Training and experience (competence)				M		
Explanation						
Quality of communication				M		O
Explanation						
HMI and operational support				M		
Explanation						
Access to procedure and methods				M		
Explanation						
Conditions of work				M	T	
Explanation						
Number of goals and conflict resolution				M		O
Explanation						
Available time / time pressure				M		O
Explanation						

Common performance condition	Rating category			Functions affected		
	Adequate	Inadequate	Unpredictable			
Circadian rhythm, stress				M		
Explanation						
Crew collaboration quality				M		
Explanation						
Quality and support of organisation						O
Explanation						

If the result of this step is that one or more performance conditions are rated as "inadequate" or "unpredictable", it must be assumed that the potential performance variability of one or more functions may be unacceptably large. In order to identify which functions are likely to be affected, indicate for each of the five main functions in the "maintenance, repair, and modification" operation whether they mainly depend on human activity (an M-function), on technology (a T-function), or on the organisation (an O-function).

FRAM Analysis - Step 3

The purpose of this step is to define where functional resonance may arise, based on possible dependencies (couplings) among functions. It is this step that the possible links between functions are identified; these include both the expected (normal) links and the unexpected (incorrect) links.

The links can be established by considered each function in turn, and ask the following questions relating the use of the output from that function:

- Which other functions uses this as input?
- Which other functions depends on this as a pre-condition?
- Which other functions depend on this for timing? (Timing can be in terms of synchronisation, of providing a reference time for when a function must start or when it must finish)
- Which other functions uses this as a resource?
- Which other functions depend on this to control what they do?

This analysis should make use of the description of the six parameters for each of the five main functions in the "maintenance, repair, and modification" operation (cf., Step 1).

The analysis may be facilitated by filling out the generic table shown below. The analysis should be done by filling out a table for each combination of functions, which in the example used here would correspond to 5*4 = 20 smaller tables. (For larger cases it may clearly be useful to introduce a computerised tool to keep track of the information.)

The output (O) of function:	can under some conditions be coupled to function	
Name:	Name:	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

As a practical help, all the "skeleton" tables for this example are provided on the following pages. It is important to consider each set of combinations, i.e., each table, with an open mind and not discard it immediately because it "does not make sense".

The output (O) of function:	can under some conditions be coupled to function	
Name: Plan resources and methods	Name: Execute inspection and testing	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Schedule repair and maintenance work	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute maintenance and repair	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Report, record, evaluate and learn	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

The output (O) of function:	can under some conditions be coupled to function	
Name: Execute inspection and testing	Name: Plan resources and methods	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Schedule repair and maintenance work	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute maintenance and repair	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Report, record, evaluate and learn	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

The output (O) of function:	can under some conditions be coupled to function	
Name: Schedule repair and maintenance work	Name: Plan resources and methods	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute inspection and testing	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute maintenance and repair	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Report, record, evaluate and learn	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

The output (O) of function:	can under some conditions be coupled to function	
Name: Execute maintenance and repair	Name: Plan resources and methods	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute inspection and testing	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Schedule repair and maintenance work	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Report, record, evaluate and learn	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

The output (O) of function:	can under some conditions be coupled to function	
Name: Report, record, evaluate and learn	Name: Plan resources and methods	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute inspection and testing	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Schedule repair and maintenance work	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	
	Name: Execute maintenance and repair	
	as either of the following (please explain when and how):	
	Input (I)	
	Time (T)	
	Control (C)	
	Pre-condition (P)	
	Resource (R)	

The outcome of this analysis defines the possible links between functions. In the example there are only five main functions, and it may therefore be convenient to render the outcome in a graphical form, i.e., a drawing. If the number of functions is much larger, it may be more convenient to use a tabular form.

Once the possible dependencies (resonance) have been identified, the next steps are to look in further detail about what kind of variability may arise and how this may lead to different unwanted outcomes. This will basically be a “what-if” exercise that requires adequate experience and competence from the analysis team. One possibility is to use a common method to identify failure modes. The critical factor in doing this is not to be constrained by assumptions about what is normal, but instead trying to be as open-minded as possible.

FRAM Analysis - Step 4

The last part of the FRAM analysis is to identify barriers for variability (damping factors) and specify the required performance monitoring.

It is a consequence of the whole approach that accidents often are emergent rather than resultant phenomena. They may therefore often defy conventional means of prevention. It is consistent with the functional approach to focus on ways in which performance variability can be detected at an early stage, and following that by ways in which this variability can be attenuated or damped. The aim is to prevent accident conditions from arising, rather than protect against the consequences of accidents once they have occurred.

This part of the analysis is more complex, and has therefore been excluded from this exercise.