Ergonomics Research Techniques

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Week 11: Lec 39- Human reliability

Cognitive Reliability and Error Analysis Method (CREAM)

CREAM

Cognitive Reliability and Error Analysis Method

Welcome back. Today, we will be talking about another method which is going to help us to understand the human reliability. In last class, we talked about human reliability, what is the importance of human reliability in a particular system and then we tried to understand one particular technique that was named as HEART. Now this class we are trying to understand a very peculiar or typical technique which is common and practiced in industry to understand the human reliability as well as we are talking about human error to analyze that human error. So name of the technique is cognitive reliability and error analysis method. So, cognitive reliability and error analysis method, we call it in short form as CREAM.

Introduction

- Developed by Hollnagel 1998.
- Human Reliability Analysis (HRA), the mostly widely utilized second generation HRA technique.
- Based on three primary areas of work:
  - Task analysis
  - Opportunities for reducing errors
  - Possibility to consider human performance with regards to overall safety of a system.
- Used in HRA for the purpose of evaluating probability of a human error occurring throughout completion of a specific task.
- To reduce likelihood of errors occurring within a system.
- Lead to an improvement in the overall levels of safety.

So let us understand the background of this particular tool. So it is not very old tool, it is developed in 1998 and human reliability analysis, the mostly widely utilized second generation HRA technique. Among these all kind of techniques that we have, this is one of the in the second generation. So what are the background of these techniques? Mainly the task analysis, then finding out the opportunities to reduce the error and the possibilities to consider human performance with regard to overall safety of a particular system. So this use in HRA that is the human reliability analysis for the purpose of evaluating the probability of a human error occurring throughout the completion of a specific task. So to reduce the likelihood of errors occurring within a particular system. So when we understand that what are the possibilities are there error to occur, then we can definitely take a precautionary measure that we should not do that error. So if we beforehand we understand, then definitely there will be an easy method that we can take and we can reduce the number of error happening in the particular system. So these techniques actually help us to do that and it also lead to an improvement in the overall level of safety. Of course if we can reduce the level of accidents, number of accidents, we can improve the safety. So CREAM is very important tool to understand the whole system and from the perspective of the human error to occur in a particular system.

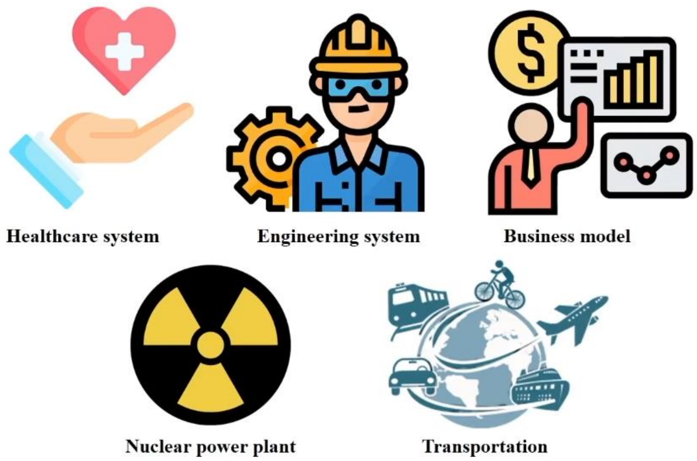
Introduction

- Two version of this techniques:
- **Basic version**
  - Provides an initial screening of human error, to understand the error probability range.
- **Extended version**
  - Uses the results of basic version to obtain the detailed value of error probability.
- The application of the extended version is needed when the probability of action failures is acceptably low.
- These have in two primary features-
  - Ability to identify importance of human performance in a given context
  - A helpful cognitive model and associated framework, usable for both prospective and retrospective analysis.
    - **Prospective analysis**- Allows likely human errors to be identified.
    - **Retrospective analysis**- Quantifies errors that have already occurred.

So two versions of these techniques are available. We should do first the basic version. Once we get the result of it, then we can go ahead with the extended version. So what is the basic version? It provides an initial screening of human error to understand the error probability range. So very first line what we are going to do, we are going to understand the probability of human error in that particular situation. So that is the basic one. In the second one what it happens that it uses the results of the basic version to obtain the detailed value of the error probability. So actually we are trying to do in the extended version detailing out those probabilities and finding out the minor issues over there so that we can improve the whole system. So the application of the extended version is needed when the probability of action failures is acceptably low. So if it is very low, then only we can go ahead. So these have in two primary features. Ability to identify the importance of human performance in a given context and a helpful cognitive model and the associated framework which is usable for both prospective and retrospective analysis. When we do prospective, so it allows the likely human errors to be identified and when it is retrospective, it quantifies the errors that have already occurred. So we can do it after accidents and we try to find out what are the things went wrong and how do we improve in future that is one and if we are doing prospective. So once we have the system ready, we try to foresee what are the possibilities are there to do an error and how do we minimize it. So both way this particular tool is applicable and we can get the result.

- Utilized in a range of industries

Introduction



So where do we use them? May be in the healthcare system, engineering system, business model, nuclear power plant, any kind of transportation, so aviation, railway, road transport, everywhere this type of CREAM method can be used and we can evaluate the error happened in that particular system or the whole process.

Introduction

- Based on a cognitive model
- Presents an error classification that integrates individual, technical and organizational factors.
- Provides a step by step description of operator performance analysis.
- Classification based on two principles:

Phenotypes

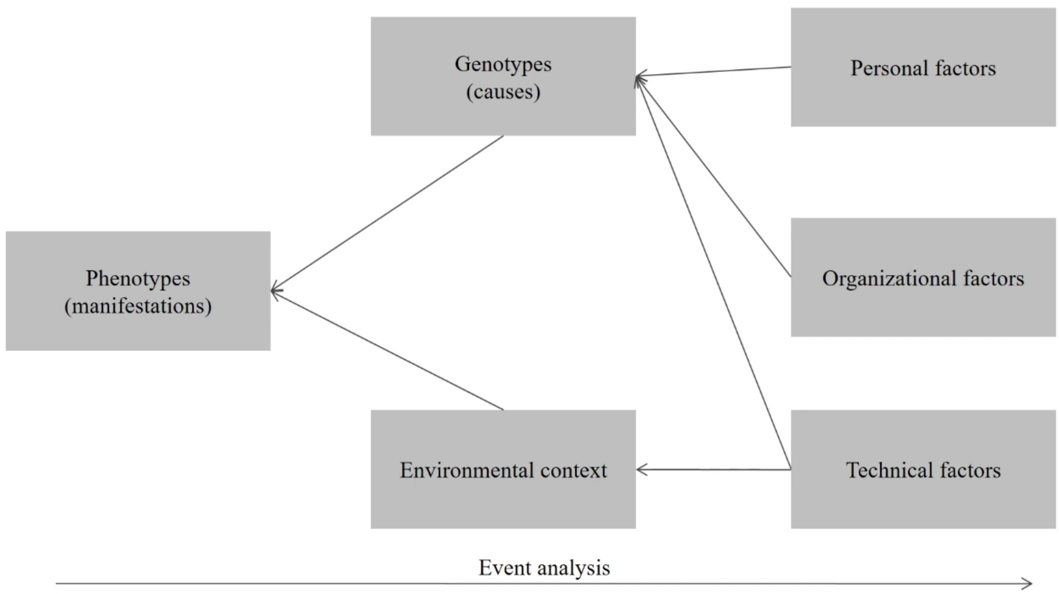
- Human error may be related with its manifestation

Genotype

- The manifestation causes human error

- Phenotypes are result of interaction between genotypes and environment

So the whole method is based on a cognitive model. It presents an error classification that integrates the individual technical and organizational factors. It also provides a step by step description of operator performance analysis and this whole thing is classified into two, one is phenotype, another is genotype. So in phenotype what we are trying to understand that the human error may be related with its manifestation whereas in genotype the manifestation, a particular manifestation which is the causes of any kind of human error. So both way we are trying to understand the cause and the effect, so that way we try to get or analyze the data which is available in the cream. So phenotypes are the results of interaction between the genotypes and the environment. So that is the common understanding of it.



Interaction between phenotypes and genotypes

Now let us look at the kind of interaction it has in a particular system if you talk about this particular cream and the human reliability analysis that is the HRA and in a particular system. So here you can see that if we are having a typical manifestation here, we have major two impacts. One impact it comes from genotypes that is the causal factors and of course the contextual or environmental context where this is happening. Is it happening indoor? Is it happening outdoor? Is it happening at the transportation sector? Where? So that is the environmental context. Now both genotype and environmental context are the major causal factors and which is going to get reflected in the phenotypes. Now when we understand these two things, we need to understand also that these also are having some kind of external influences. What are those? If we talk about genotypes we have the personal factors of course, organizational factors and technical factors. So when I am talking about the genotype of a system, it is highly connected with the person. Person means the operator, how the operator is actually acting upon it. Then the organizational factors, what are the peers, how the job demands are and all those things and the technical factors. So knowledge, availability of the resources, materials, machines and everything. So these all are the influencing factors of the genotype and definitely technical factor is connected with your environmental context. So this is how the genotypes and phenotypes are interacting with each other.

- Determine requested cognitive functions levels in order to implement the analysed performance.
- Use of four basic control modes
  - Identify differing levels of control
  - An operator has given context and characteristics which highlight occurrence of distinct conditions.
- The control modes which may occur are as follows-

Contextual Control Model (CoCoM)

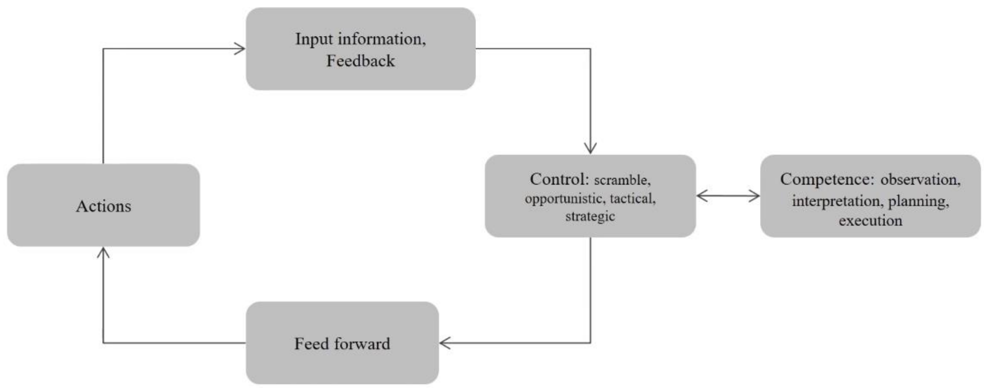
Scrambled control
- Choice of forthcoming action is unpredictable or haphazard

Opportunistic control
- Next action is determined by superficial characteristics of situation
- Possibly through habit or similarity matching

Tactical control
- Performance typically follows planned procedures

Strategic control
- Plentiful time is available to consider actions to be taken in light of wider objectives to be fulfilled and within given context

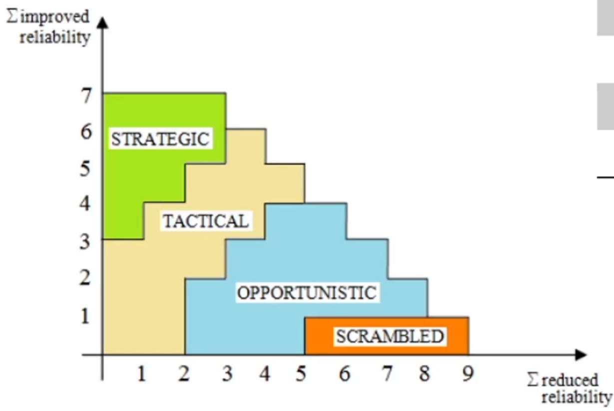
Now before we go ahead with the example and steps of the CREAM method, we need to understand one important model that is the contextual control model which is going to be major part of this particular method. So this particular model actually determine the requested cognitive function level in order to implement the analyzed performance. It also use of the four basic models that is the scrambled control, opportunistic, tactical means related to your techniques and the procedures and all those things and then strategic control. So what it does, they identify the differing levels of control and also an operator has given the context and the characteristics which highlights the occurrence of distinct conditions. So control models as I mentioned these are the four things or four controls to be taken care. So these all four controls are used in the CREAM model. So let us understand one by one. So what is scrambled control? It is a choice of forthcoming action is unpredictable and haphazard. So something is going to happen but you do not know. So it is completely unpredictable and it is haphazard. It is not coming in sequence. Once this is happening, then another thing is happening, then again first thing is happening, then maybe another fourth elements is coming. So all are scrambled. So that is why it is called scrambled control. Then is the opportunistic. So if it is a scrambled control, you really need lot of attention and there is high chance of missing something or doing some kind of error. The second one is the opportunistic control. So what it is? Next action is determinded by superficial characteristics of the situation. So you have some kind of guideline. If this happen you are going to do this. If that happens you are going to do that. So action 1, action 2 they are connected with each other. Then it is opportunistic. So it says that here we have the possibility through habit and similarity matching. So lot of cognitive understanding is also involved in this particular case. Next is tactical that is the performance typically follows the planned procedure. And last one is the strategic control which says the plentiful time is available to consider actions to be taken in light of wider objectives to be fulfilled and within given context. So these are the four component of your contextual control model.



Contextual Control Model (CoCoM)

- The identified cognitive model for CREAM methodology is called Contextual Control Model (CoCoM).

Now this is how it looks. So it is a closed loop system. It is a completely closed loop system. So if you have some kind of action which is going to give you the information feedback and based on the information feedback, you have the control mechanism here. All these control that we discussed in our earlier slide and then it will give your feedback which is going to affect the further actions which need to be taken. And everything is based on your observation, interpretation, planning and execution of the result or of the understanding. So this is the CoCoM or CoCo model or we can say contextual control model.



Relation between Common Performance Conditions (CPSs) scores and control modes

Table 1

Control modes	Error probability interval
Strategic	0.5E – 5 < p < 1E – 2
Tactical	1E – 3 < p < 1E – 1
Opportunistic	1E – 2 < p < 0.5E0
Scrambled	1E – 1 < p < 1E0

Error probability interval

- Error probability intervals are classified on the basis of the various control modes.
- The particular control mode determines levels of reliability that can be expected in a particular setting

Now this is a kind of understanding from this particular figure that how the common performance condition scores and the control model are connected with each other. Now here you can see all the probabilities are mentioned for each case, for strategic, for tactical, for opportunities and for scramble and these are the value. So what it says that error probability intervals are classified on the basis of the various control mode like above and the particular control mode determines the level of reliability that can be expected in a particular setting. So here you can see if this particular axis is saying the reduced reliability and here it says the improved reliability, how the locations of this contextual model, how it is happening. You can see if you have the improved reliability this whole thing is here. So if you can do a strategic planning and if you have time to do that of course reliability of the whole system increased or it is good. Whereas if you do not have time and every information is coming one by one in a haphazard manner then it is very much scramble and reliability is like in a reduced state.

Procedure

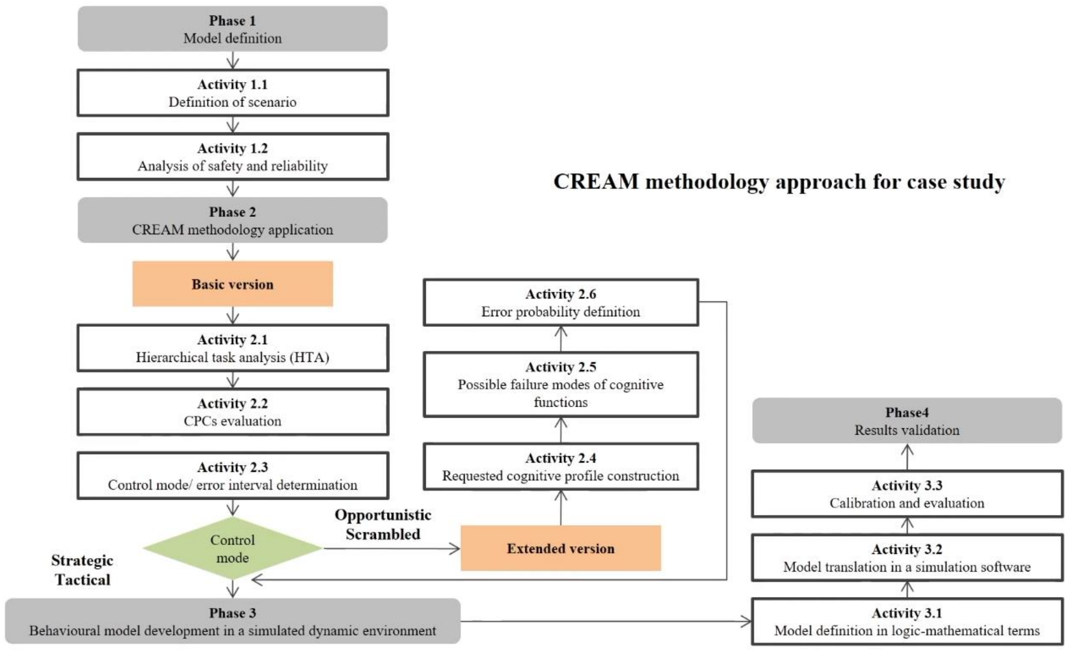
- CREAM methodology consist of following steps:
  - **Phase 1**- Model definition
    - Step 1- Definition of scenario
    - Step 2- Analysis of safety and reliability
  - **Phase 2**- CREAM methodology application
  - **Phase 3**- Behavioural model development in a simulated dynamic environment
  - **Phase 4**- Results validation

So CREAM methodology basically consist of these steps. First is the model definition, then CREAM methodology application, then behavioral model development in a simulated dynamic environment and the results validation. Under the model definition what you have to do? You have to define the scenario and you have to analyze the safety and reliability.

Procedure

- CREAM methodology can be divided into two versions:
  - **Basic version**
    - Step 1- Hierarchical task analysis (HTA)
    - Step 2- CPCs evaluation
    - Step 3- Control mode/ error interval determination
  - **Extended version**
    - Step 4- Requested cognitive profile construction
    - Step 5- Possible failure modes of cognitive functions
    - Step 6- Error probability definition

Now when we are talking about CREAM as I mentioned that we have two version- one is basic another is extended. So in basic we have major first three steps that is the it starts with the hierarchical task analysis. We discuss HTA in our initial you know general techniques that is the HTA and then CPC evaluation then the control mode or error interval determination. In the extended version, we have what you have to do that requested cognitive profile construction then you have to do possible failure modes of cognitive function and the error probability definition. So these are the basic steps for basic version and extended version of CREAM.



Here I mentioned it in detail. So you can see in phase one if we are talking about the model definition what you have to do define this scenario that is the 1.1 because it is under phase number one step and then it is the analysis of safety and reliability. In phase two what you have to do that CREAM methodology application. When we are talking about CREAM methodology application there comes first basic and then extended. So here you can see the basic one HTA CPC evaluation and the control mode and error interval determination ok. So that we do and once we finish that, we have all these things strategic, technical, tactical and then here we get the opportunities and the scrambled method ok. So when we are talking about control mode any one of them will be taken care and it comes for the phase three. Now here you can see that phase three results comes from the influenced by the extended version. Extended version already we discussed here. This one we discussed. So here also it is mentioned in the same way requested cognitive profile construction, possible failure modes of cognitive function and the error probability definition. Once we get the whole thing done, it is going to impact here and then this results of this phase three will go here for the activity that is the model definition in logic mathematical terms because you have to give the understanding if this is happening then this if it is happening then this. So logical connection need to be established. Once it is done what you have to do that is the model translation in a simulation software and then calibration and evaluation finally you need to do the result validation. This is how you are going to detail the CREAM methodology and you can use this technique to get an understanding of the human error available in a particular system.

Case study

- **Phase 1- Model definition**
- In the present phase, the model is defined.
- Example- A model in the mechanical sector
  - **Activity 1.1- Definition of the scenario**
  - The aim of the activity is
  - *The reference organizational scenario of mechanical sector*
    - Analysis of main organizational and productive aspects including
      - Time and processing methods
      - Duty cycles
      - Human aspects of works
    - Outline a description of the mechanical sector organization
  - *The sample survey definition (SMEs)*
    - Identify the most significant realities form the point of view of safety management in the workplace.

Now let us do a small or let us discuss a small case study. All the data here I tried to discuss from a previous case which is being analyzed for different purpose. However, I have quoted them here to understand how the CREAM can be performed in a practical scenario. So the first one that is the phase one what you need to do you have to define the model. Here in this particular case what we did? In the present phase the model is being defined. What was the model? A model in a mechanical sector. We will see that we actually used the lathe machine for example. So a model in a mechanical scenario or sector. So what we did definition of the scenario we tried to do the aim of the activity, what was the aim of that particular activity, the reference organizational scenario of mechanical sector and the analysis of main organizational and productive aspects which includes the time and processing method, duty cycle and the human aspect of the worker that we had carried out. Once we complete that what we did we outline the description of the mechanical sector organization. So it must this particular lathe machine that we had taken as a case, so we did here in a mechanical workshop. So the sample survey definition that we created and identify the most significant realities from the point of view of safety management in that particular workplace. So safety was a major concern and the significant reliability in doing so. So when somebody is working in a lathe machine what is the kind of safeties to be taken care of if we come try to understand the operation on a lathe machine from the human reliability perspective.

Case study

- **Phase 1- Model definition**
- In the present phase, the model is defined.
- Example- A model in the mechanical sector
  - **Activity 1.2- Analysis of safety and reliability**
  - The most critical activities are analyzed (e.g., welding, lathing, drilling, punching, stamping, pressing)
  - Check list and safety data sheets are defined according to risks associated for each activity.

Name	**LATHING**
Description	The lathe is a machine tool used for the machining of a workpiece placed in rotation.
Risks	Accidental contact.
Prevention and Protection	The machine must not be used in an explosive atmosphere. Safety shields Interlocking devices

So next what we did? The analysis of the safety and reliability. Here you can see we have given the description, the available risk and how do we conduct the prevention and the protection. So the most critical activities were analyzed like welding, lathing, drilling on all those things and the checklist and the safety data sheet are defined according to the risk associated with each activity when we are performing it.

Case study

- **Phase 2- CREAM methodology application**
  - **Basic version**
    - **Activity 2.1- Hierarchical task analysis (HTA)**
    - Specific operator's tasks are ordered in a logical time sequence.
    - Here the lathing process of a specific SME is analyzed

Turning – Task Analysis

ID	GOAL	ID	ACTIVITY
1.01	Machine set-up and work piece positioning	1.01.01	Open spindle
		1.01.02	Position and progress bar
		1.01.03	Close spindle
1.02	Machine assistance	1.02.01	Start spindle
		1.02.02	Approach the tool
		1.02.03	Cutting depth setting
		1.02.04	Select automatic feed
1.03	Work-piece removing	1.03.01	Stop the machine
		1.03.02	Space out the tool
		1.03.03	Remove and store the work-piece

Table 2

- Each ID indicates each goal.
- Under each goal, theree are some ID which indicates sub-activities.

In phase 2, once we complete the phase 1 then we will go for the phase 2 and we will start with the basic version. So again I will go back and show you this one. So this is up to this first one. Now we are going to the all other portion is on the phase 2. This portion is under phase 2. So what we are going to do here? First we will do basic and then slowly we will go ahead with the advanced, the other one. So in basic what we are doing HTA. The same process we will look at the step by step process and we will break it down in the small elements and create the hierarchy. We will create the tree. So specific operator's tasks are ordered in a logical time sequence and here the lathing process of the specific SME is analyzed. Here you can see these are the IDs means activity numbers and under that what is being done. So if you talk about ID number 1.01 which is the machine setup and work piece positioning under that you have sub IDs. These are all sub IDs. So what is open the spindle? Position and progress the bar and close the spindle. So this is the one ID. ID is the machine setup and the work piece positioning under that you have sub IDs. So you actually from the hierarchical task analysis, you will create the whole task or you will map the whole task in a paper. So here I try to mention that each ID indicates each goal. So this is the ID and this is the goal. Under each goal, there are some IDs which indicates the sub IDs. So these are the sub IDs. Now in the next step that is the CPC evaluation. What is the CPC evaluation? Let us go back and check again. So this is the common performance condition that is the CPC evaluation. So you have to understand is it scramble, is it opportunistic, is it tactile or strategic. So that part you have to find out.

Case study

- **Phase 2- CREAM methodology application**
  - **Basic version**
    - **Activity 2.2- CPC evaluation**
    - CPC evaluation is made which is shown in following table.

Table 3

CPCs	Qualitative level	Expected effect
Adequacy of organisation	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Reduced
	Deficient	Reduced
Working conditions	Advantageous	Improved
	Compatible	Not significant
	Incompatible	Reduced
Adequacy of man-machine interaction and operational support	Supportive	Improved
	Adequate	Not significant
	Tolerable	Not significant
	Inappropriate	Reduced
Feasibility of procedures and plans	Appropriate	Improved
	Acceptable	Not significant
	Inappropriate	Reduced
Number of simultaneous goals	Fewer than capacity	Not significant
	Matching current capacity	Not significant
	More than capacity	Reduced
Available time	Adequate	Improved
	Temporarily inadequate	Not significant
	Continuously inadequate	Reduced
Time of day	Day time	Not significant
	Night time	Reduced
Adequacy of training and preparation	Adequate (high experience)	Improved
	Adequate (low experience)	Not significant
	Inadequate	Reduced
Crew collaboration quality	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Not significant
	Deficient	Reduced

So CPC evaluation is made which is shown in this following table. So here you can see it is like insufficient, then advantageous, inappropriate. So all these things is being taken care. So adequacy of the organization, working conditions, these are the points to be taken and the quality level and what is expected here. So that is being done in the next step.

- Here one common performance condition- Working condition
- The working condition is expressed into three levels- Advantageous, compatible and incompatible.
- So here the advantageous working condition must be improved and
- The incompatible conditions must be reduced.

Case study

Table 4

CPCs	Qualitative level	Expected effect
Adequacy of organisation	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Reduced
	Deficient	Reduced
Working conditions	Advantageous	Improved
	Compatible	Not significant
	Incompatible	Reduced
Adequacy of man-machine interaction and operational support	Supportive	Improved
	Adequate	Not significant
	Tolerable	Not significant
	Inappropriate	Reduced

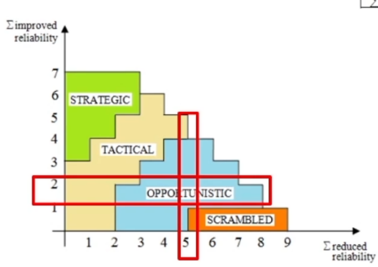
Now further what we did? Here one common performance condition that is the working condition to be chosen and the working condition is expected into three level that is the advantageous, compatible or incompatible, either advantageous or compatible or incompatible. So here you can see it is mentioned like that only. So here the advantageous working condition must be improved and the incompatible conditions must be reduced. So that is the requirement. So wherever you see that something is in advantageous condition what you need to do? You need design intervention. If you see there is something incompatible condition to reduce the incompatible condition, what design changes you can do? You can take a decision over there.

- **Phase 2- CREAM methodology application**
  - **Basic version**
    - **Activity 2.3- Control mode/ error interval determination**

Case study

Common Performance Conditions	Associated Judgment
Appropriateness of organization	Reduced
Work place conditions	Improved
Appropriateness of man/machine interaction	Reduced
Feasibility of the procedures and planning	Reduced
Number of simultaneously tasks carried out by the operator	Not significant
Available time	Improved
Time of day in which the activity is carried out	Reduced
Adequacy of training and experience of worker	Not significant
Level of collaboration and interaction of department staff	Reduced
∑ Improved	**2**
∑ Reduced	**5**

Table 5



- Improved reliability = 2
- Reduced reliability = 5
- According to the previous result, the control mode is “Opportunistic”.
- It is necessary to apply the extended version.

So for example, for this particular lathe machine you see here we calculated that improved reliability is 2 and reduced reliability is 5. So here is the cross section and we see that according to this particular result, we are in the opportunistic section, bisection, okay and it is necessary to apply the extended version because you can apply it and you can get more result of it, advances up to this particular portion it is basic version.

Case study

- **Phase 2- CREAM methodology application**
  - **Extended version**
    - **Activity 2.4- Requested cognitive profile construction**
    - The purpose of this step is to define the Cognitive profile considering dependencies between cognitive activities and contextual control model (CoCoM) functions as shown in the following-

COGNITIVE ACTIVITY	CoCoM Functions			
	Observation	Interpretation	Planning	Execution
Coordinate			X	X
Communicate				X
Compare		X		
Diagnose		X	X	
Assess		X	X	
Execute				X
Identify		X		
Maintain			X	X
Monitor	X	X		
Observe	X			
Plan			X	
Set		X		X
Adjust	X			X
Examine	X			
Verify	X	X		

Table 6

In advance or extended version what you have to do? You have to find out the requested cognitive profile construction. What you have to do? You have to do a cognitive profile construction. So the purpose of this step is to define the cognitive profile consideration, dependencies between cognitive activities and that contextual control model function as shown in this particular figure. So what it is being done? In this you have observation, you have interpretation, you have planning and this you have execution. Now these all are the cognitive activities available there and you have to map where it is. So suppose I am talking about observe, so it is the observation only, okay. Whereas if it is monitored then it is not only observation also interpretation. So if you are monitoring that means you are looking at something, interpreting something, right. So that way you have to give the description of all the cognitive activities available in that particular task.

Case study

- In the specific case of lathing-

GOAL	ACTIVITY	Cognitive activity	CoCoM Functions			
			Observation	Interpretation	Planning	Execution
Machine set-up and work piece positioning	Open spindle	execute				X
	Position and progress bar	execute				X
	Close spindle	execute				X
Machine assistance	Start spindle	execute				X
	Approach the tool	set		X		X
	Cutting depth setting	adjust	X			X
	Select automatic feed	execute				X
Work piece removing	Stop the machine	execute				X
	Space out the tool	execute				X
	Remove and store the work piece	execute				X

Table 7

- One of the **goal**- Machine assistance
  - The **activity** under this specific goal- Cutting depth setting
    - The **cognitive activity** required for this action- Adjustment
      - The **control** need for this cognitive activity- Observation

Once we do that what we have to do for this particular case of lathe machine? We see that these are the cognitive activities identified because these were the activities and these are the cognitive activities identified for this particular case. You can just do by yourself and you can get the similar value. So one of the goal is the machine and assistance. The activity under the specific goal is the cutting depth setting and then cognitive activity required for this section is the adjustment and control need for the cognitive activity is the observation. So that way the cognitive part is being taken care for this particular case of lathe machine. In the next step here what we did that requested cognitive profile construction. So now we know that what is the cognitive profiling is required for this particular lead machine operation, right.

- **Phase 2- CREAM methodology application**
  - **Extended version**
    - **Activity 2.5- Possible failure modes of cognitive functions**
    - The error of cognitive function is identified through the use of the following error modes, relating lathing operations.

Case study

Cognitive Function	CoCoM Functions	
	Error Modes	Mode description
Observation	O1	Observation of the wrong object
	O2	Mistaken identification due to errors or partial identification
	O3	Not carried out observation due to oversights
Interpretation	I1	Wrong and incomplete diagnosis
	I2	Decision errors due to not carried out or incomplete analysis
	I3	Not timely interpretation
Planning	P1	Wrong target identification
	P2	Inadequate and incomplete planning
Execution	E1	Wrong actions execution
	E2	Not timely actions execution
	E3	Performing actions on wrong items
	E4	Performing actions without exact sequence
	E5	Non-execution of actions

Table 8

Now what we have to do? We have to find out the possible failure model of the cognitive function. What we did here? Here all these contextual control model from there all mode of description is given and here the cognitive functions are given as per our previous table and we narrated the error of modes, okay.

Case study

ACTIVITY	Cognitive Activity	CoCoM Functions												
		Observation			Interpretation			Planning		Execution				
		O1	O2	O3	I1	I2	I3	P1	P2	E1	E2	E3	E4	E5
Open spindle	execute										X			
Position and progress bar	execute									X				
Close spindle	execute										X			
Start spindle	execute												X	
Approach the tool	set									X				
Approach the tool	set				X									
Cutting depth setting	adjust		X											
Cutting depth setting	adjust										X			
Select automatic feed	execute										X			
Stop the machine	execute												X	
Space out the tool	execute													X
Remove and store the work piece	execute										X			

Table 9

- The activity- Open spindle
- Cognitive activity- Execute
  - Executioner error 2 (E2)- Not timely actions execution

Now here you can see that if we are talking about open the spindle that is the first activity, here you can say it is just an execution. There is no observation, it is not interpretation or it is not planning, it is just execution, open it, right. So that is why we counted here. So executioner's error to not timely action execution. So if you do not execute in on time then definitely there can be an error, okay. So that particular part is being identified.

Case study

- **Phase 2- CREAM methodology application**
  - **Extended version**
    - **Activity 2.6- Cognitive Failure Probability (CFP) definition**
    - Starting from the CFPs table (Table 10) and nominal values of CFPs (Table 11) are determined "weighting factor" (Table 12) to adjust nominal values of CFPs.
    - Obtain final values of Cognitive Error Probability

CPCs	Qualitative level	Expected effect	OBS	INT	PLA	EXE
Adequacy of organization	Very efficient	Improved	1.0	1.0	0.8	0.8
	Efficient	Not significant	1.0	1.0	1.0	1.0
	Inefficient	Reduced	1.0	1.0	1.2	1.2
	Deficient	Reduced	1.0	1.0	2.0	2.0
Working conditions	Advantageous	Improved	0.8	0.8	1.0	0.8
	Compatible	Not significant	1.0	1.0	1.0	1.0
	Incompatible	Reduced	2.0	2.0	1.0	2.0
Adequacy of man-machine interaction and operational support	Supportive	Improved	0.5	1.0	1.0	0.5
	Adequate	Not significant	1.0	1.0	1.0	1.0
	Tolerable	Not significant	1.0	1.0	1.0	1.0
	Inappropriate	Reduced	5.0	1.0	1.0	5.0
Feasibility of procedures and plans	Appropriate	Improved	0.8	1.0	0.5	0.8
	Acceptable	Not significant	1.0	1.0	1.0	1.0
	Inappropriate	Reduced	2.0	1.0	5.0	2.0
Number of simultaneous goals	Fewer than capacity	Not significant	1.0	1.0	1.0	1.0
	Matching current capacity	Not significant	1.0	1.0	1.0	1.0
	More than capacity	Reduced	2.0	2.0	5.0	2.0
Available time	Adequate	Improved	0.5	0.5	0.5	0.5
	Temporarily inadequate	Not significant	1.0	1.0	1.0	1.0
	Continuously inadequate	Reduced	5.0	5.0	5.0	5.0
Time of day	Day time	Not significant	1.0	1.0	1.0	1.0
	Night time	Reduced	1.2	1.2	1.2	1.2
Adequacy of training and preparation	Adequate (high experience)	Improved	0.8	0.5	0.5	0.8
	Adequate (low experience)	Not significant	1.0	1.0	1.0	1.0
	Inadequate	Reduced	2.0	5.0	5.0	2.0
Crew collaboration quality	Very efficient	Improved	0.5	0.5	0.5	0.5
	Efficient	Not significant	1.0	1.0	1.0	1.0
	Inefficient	Not significant	1.0	1.0	1.0	1.0
	Deficient	Reduced	2.0	2.0	2.0	5.0

Table 10

In the next step that is the cognitive failure probability definition that is the CFP, what we are going to do that starting from CFP table, this is the specific table and the nominal values of CFP table are need to be identified in the next table that I am going to describe in the next, okay. So here you can see that if it is the adequacy of organization and the qualitative level is insufficient, expected effect is reduced, then this is the area where is your problem lying and you have to find out that.

Case study

- **Phase 2- CREAM methodology application**
  - **Extended version**
    - **Activity 2.6- Cognitive Failure Probability (CFP) definition**
    - Starting from the CFPs table (Table 10) and nominal values of CFPs (Table 11) are determined "weighting factor" (Table 12) to adjust nominal values of CFPs.
    - Obtain final values of Cognitive Error Probability

Cognitive Function	CoCoM Functions		
	Error Modes	Mode description	Nominal value
Observation	O1	Observation of the wrong object	1.0E-3
	O2	Mistaken identification due to errors or partial identification	7.0E-3
	O3	Not carried out observation due to oversights	3.0E-3
Interpretation	I1	Wrong and incomplete diagnosis	2.0E-1
	I2	Decision errors due to not carried out or incomplete analysis	1.0E-2
	I3	Not timely interpretation	1.0E-2
Planning	P1	Wrong target identification	1.0E-2
	P2	Inadequate and incomplete planning	1.0E-2
Execution	E1	Wrong actions execution	3.0E-3
	E2	Not timely actions execution	3.0E-3
	E3	Performing actions on wrong items	5.0E-4
	E4	Performing actions without exact sequence	3.0E-3
	E5	Non-execution of actions	3.0E-2

Table 11

So in this table that is we call it as the nominal values for CFP, what we can see that for this particular case that is the lathe machine operation not timely action execution and error is 3.0 error minus 3, okay. So that is being taken care only for that particular operation. For all other operation you have to use this table and you have to find out the value, okay.

- **Phase 2- CREAM methodology application**
  - **Extended version**
    - **Activity 2.6- Cognitive Failure Probability (CFP) definition**
    - Starting from the CFPs table (Table 10) and nominal values of CFPs (Table 11) are determined "weighting factor" (Table 12) to adjust nominal values of CFPs.
    - Obtain final values of Cognitive Error Probability

Case study

Common Performance Conditions	Associated Judgment	CoCoM function			
		OBS	INT	PLA	EXE
Adequacy of organization	Reduced	1.0	1.0	1.0	1.0
Working conditions	Improved	0.8	0.8	1.0	0.8
Adequacy of man/machine interaction and operational support	Reduced	5.0	1.0	1.0	5.0
Feasibility of procedures and plans	Reduced	2.0	1.0	5.0	2.0
Number of simultaneously goals	Not significant	1.0	1.0	1.0	1.0
Available time	Improved	0.5	0.5	0.5	0.5
Time of day	Reduced	1.2	1.2	1.2	1.2
Adequacy of training and preparation	Not significant	1.0	1.0	1.0	1.0
Crew collaboration quality	Reduced	2.0	2.0	2.0	5.0
TOTAL INFLUENCE OF CPCs		9.6	0.96	6.0	24

Table 12

So now then again this is the adequacy of organization, you can see it is reduced and these are the values to be taken care and then you see that if you add all these execution values here and you know in total then you will get the value of 24. Now here concern is you have to have a cumulative data. So for each one you can map, you can get those values and finally at this end you will get this particular cumulative number, okay.

ID	Task	Error mode	Weighting factor	Adjusted CFP
1.01.01	Open spindle	E2 (3.0E-3)	24	7.2E-2
1.01.02	Position and progress bar	E1 (3.0E-3)	24	7.2E-2
1.01.03	Close spindle	E2 (3.0E-3)	24	7.2E-2
1.02.01	Start spindle	E4 (3.0E-3)	24	7.2E-2
1.02.02	Approach the tool	I1 (2.0E-1)	0.96	1.92E-1
		E1 (3.0E-3)	24	7.2E-2
1.02.03	Cutting depth setting	O2 (7.0E-3)	9.6	6.72E-2
		E2 (3.0E-3)	24	7.2E-2
1.02.04	Select automatic feed	E2 (3.0E-3)	24	7.2E-2
1.03.01	Stop the machine	E4 (3.0E-3)	24	7.2E-2
1.03.02	Space out the tool	E5 (3.0E-2)	24	7.2E-1
1.03.03	Remove and store the work piece	E2 (3.0E-3)	24	7.2E-2

- ID 1.01.01
- Task- Open spindle
- Error- Execute error 2 (E2)
- Error mode nominal value = 3.0E-3
- Total influence of CPCs = 24
- Final possible Cognitive Failure Probability (CFP) = 7.2E-2
- The probability value is include in the "opportunistic" control mode range (1.0E-2 < p < 0.5E0)

So if we talk about the ID number 1.01.01 that is the open the spindle and you see the error mode is this, this value is like 24, so it is here and the adjusted CPC is 7. 2 error minus 2, okay. So these values are from example. Now you may ask exactly how we calculated, I tried to describe it in these slides. However, when you start doing each part it may take longer time, okay. It is not that fast, you have to understand and perform, so it may take little longer hours.

Case study

- **Phase 3- Behavioural model development in a simulated dynamic environment**
  - **Activity 3.1- Model definition in logic-mathematical terms**
  - The implemented logical-mathematical model provides the determination of the organization CPCs.
  - The questionnaire is performed according to the specifies organizational conditions.
  - The logical mathematical model provides:
    - Production process cycle defining
    - Formulation of question about CPSs
    - Translation of answers in numerical terms of quality level achieved in the CPCs evaluation
    - Determination of MTO reliability and the identification of control mode (strategic, tactical, opportunistic, scrambled)
    - The extension of model numerical evaluation, in case the reliability interval is not satisfactory
    - Identification of actions to be implemented to improve reliability, with evaluation of the probability of error in numerical term

The next is the model definition in logical mathematical term. So what we are going to do here that implemented logical mathematical model provides the determination of the organization CPC and the questionnaire is performed according to the specific organizational condition. So here the development of the questionnaire also is the separate task. So the logical mathematical model may provide you the production process cycle definition, then formulation of questions about the CPC, translation of answers in numerical terms of quality level achieved in the CPC evaluation, determination of MTO reliability and the identification of control mode, the extension of model numerical evaluation in case the reliability interval is not satisfactory and the identification of action to be implemented to improve the reliability with evaluation of the probability of error in numerical term. So this we are going to do.

CPCs	Evaluation Questionnaire
Adequacy of organisation	Are the work-spaces well organized?
	Is the available equipment status checked regularly?
	Does the organization adopt safety management systems?
	Does the organization adopt quality management system?
Working conditions	Are the physical spaces for handling adequate?
	Are the work-station lightning condition adequate?
	Is the environmental noise level, which is subjected the operator, acceptable?
Adequacy of man-machine interaction and operational support	Are the machine controls easily accessible?
	Is the work-station designed according to ergonomic principles?
	Is the work-station equipped with a easily visible control panel?
	Is the work-station equipped with computerized controls?
Feasibility of procedures and plans	Are manual and/or documents relating to operational procedures available?
	Do the documents contain detailed procedures for machines operation?
	Do the documents contain detailed procedures for safety devices control?
Number of simultaneous goals	Does the operator perform simultaneous control tasks?
	Does the work-programming involve the monitoring of a single work-station?
	Is the work-loads distribution appropriate?
Available time	Are the displacement and execution times commensurate with appropriate ergonomic positions?
	Does the processing cycle provide a minimum rest period for the operator?
	Were assigned times evaluated with analytical procedures?
Time of day	Are there only day-shifts?
	Is the activity carried out in a single shift?
Adequacy of training and preparation	Is provided a minimum period of supervised training for non-expert operators?
	Is the staff trained about the use of machinery and related risks?
	Is the use of the machinery allowed only to operators with five years of proven experience?
Crew collaboration quality	Is the collaboration quality between operators sufficient and adequate to the tasks?
	Is the cooperation quality between operators satisfactory?
	Is the level of trust between the department operators satisfactory?
	Is the social climate good inside the department?

CPCs	Improvement Performance Actions
Adequacy of organisation	Reorganization of work-spaces
	Implementation of a quality management system
	Implementation of a safety management system
	Periodic checks program of equipment
Working conditions	Adaptation of physical space and layout of work-station
	Improvement of workstations lighting
	Reduction of noise levels and/or adoption of appropriate protection devices
Adequacy of man-machine interaction and operational support	Adaptation of machines controls accessibility
	Adaptation of work-place ergonomic conditions
	Adaptation of work-station control panel
	Endowment of computerized controls in work-station
Feasibility of procedures and plans	Predisposition of manuals and written procedures
	Predisposition of handling procedures with visual details
	Predisposition of controls safety devices procedures with visual details
Number of simultaneous goals	Linearization procedures of control tasks
	Tasks assignment on a single work-station, if possible
	Work-loads redistribution and balancing
Available time	Time adaptation to favourable ergonomic conditions
	Rest time adaptation in processing cycles
	Time assessment with analytical procedures
Time of day	Reduction of night shifts, if possible
	Reduction in double shifts, if possible
Adequacy of training and preparation	On the job training and tutoring
	Theoretical and practical professional training
	Specialization plans for department
Crew collaboration quality	Actions of promotion and encouragement of collaboration
	Improvement actions and training for collaborative work
	Actions to encourage the improvement of confidence level among workers
	Actions to encourage social cohesion among department workers

Tables for Evaluation questionnaire and Improvement Performance Actions on CPSs analysis

So here you can see that table for evaluation the questionnaire and the improvement performance action on the CPC analysis. This is pre-computed, it is readily available so you can use them as it is. I should not read it out, you can refer from any open source access of this particular model, so that is available, okay. So this is available.

Case study

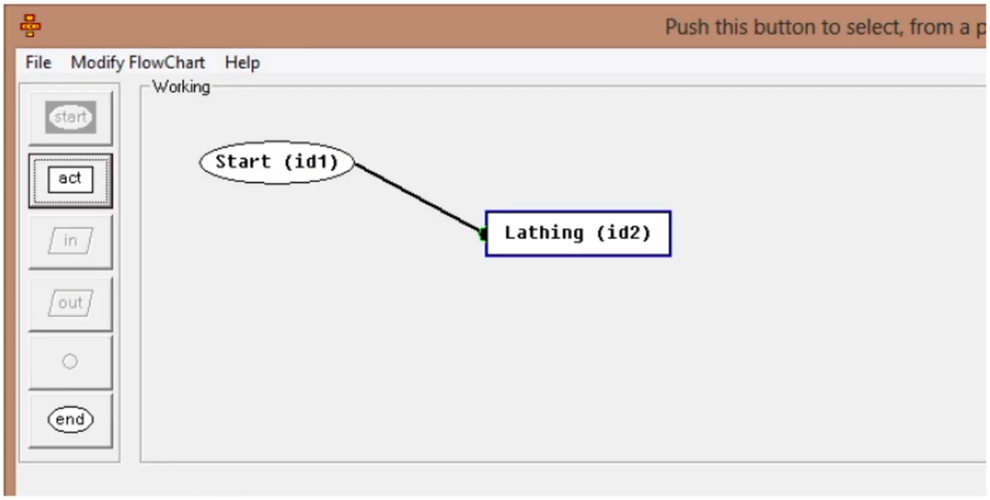
- **Phase 3- Behavioural model development in a simulated dynamic environment**
  - **Activity 3.2- Model translation in a simulation software**
  - Allows a self-evaluation of productive organization reliability (Decision Support System; DSS)
  - Able to determine the safety characteristics in the workplace
  - The application can be developed in Microsoft Visual Basic referring to configuration parameters on a database created in Microsoft Access.
  - This software provides, after the administration of evaluation questions, the identification of action to improve safety that affecting the Reliability Index (RI).

Now in the next step when we are talking about the model translation in a simulation software, what we are going to do? So what you have to do? You have to allow a self-evaluation of proactive organizations reliability that is the decision support system and it should able to determine the safety characteristics in this particular workplace and the application can be developed in Microsoft Visual Basics which is referring to the configuration parameters on a database created in the Microsoft Access. So it is easy to do that. And this particular software provides the, after the administration of the evaluation questionnaire questions, the identification of action to improve the safety that affecting the reliability index, okay. So ultimately we are going to understand what is the impact of it on the reliability index.

Case study

- **Phase 3- Behavioural model development in a simulated dynamic environment**
  - **Activity 3.3- Calibration and evaluation**
  - Through some user interface screen-shots, the evaluation and calibration of simulation software is presented.
  - Following steps are followed:
    - Block diagram of analyzed production process
    - Questionnaire elaboration
    - Determination of error index with any improvements
      - **Block diagram of analyzed production process**
      - The user selects blocks relative to the processes flow to be analyzed, always starting from the 'start' symbol.
      - The meaning of available block:
        - **Start**- Start process
        - **Act**- Process activities
        - **In**- Materials input
        - **Out**- Materials output
        - **End**- Stop process

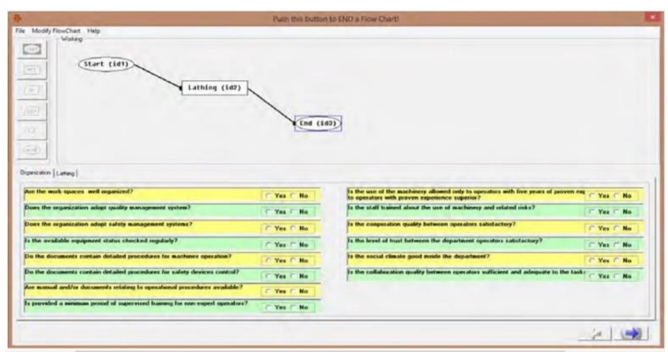
Then once you do that, then you have the calibration and evaluation. So through some user interface screenshot and the evaluation and calibration of the simulation software you need to present and these steps, like these steps to be followed. What first is the block diagram of analyzed production process, questionnaire elaboration, determination of error index with the improvements, okay. When we are talking about the block diagram of analyzed production, what we are going to do? User selects blocks relative to the process flow to be analyzed and always starting from the start symbol, okay. So start the process, act that is the process activities, in means material input. So you are actually describing the system and the output is the out and the end means you stop it. So close the button or switch off this machine or something like that.



Block diagram definition- Lathing process

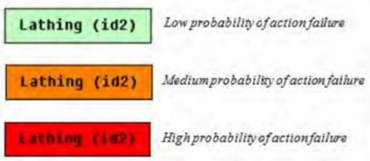
Case study

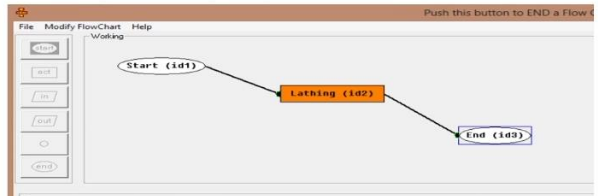
- **Phase 3- Behavioural model development in a simulated dynamic environment**
  - **Activity 3.3- Calibration and evaluation**
  - Through some user interface screen-shots, the evaluation and calibration of simulation software is presented.
    - **Questionnaire elaboration**
    - After the definition of process block diagram, are proposed questions developed in the simulation model.



Case study

- **Phase 3- Behavioural model development in a simulated dynamic environment**
  - **Activity 3.3- Calibration and evaluation**
  - Through some user interface screen-shots, the evaluation and calibration of simulation software is presented.
    - **Determination of error index with any improvements**
    - After answering all questions, the algorithm give the results

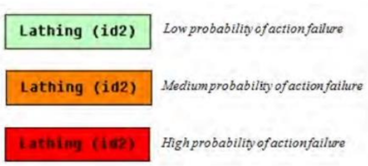


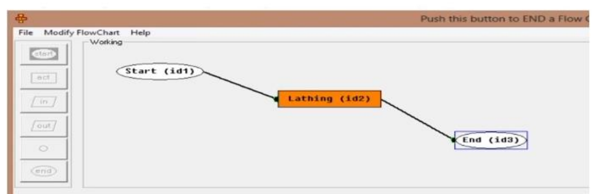


Application Field	Recommended Action	R.I. start	R.I. final
Organization	Actions of promotion and encouragement of collaboration	2,88	2,88
Organization	Improvement actions and training for collaborative work	2,88	0,576
Organization	Predisposition of controls safety devices procedures with visual details	1,12	1,344
Organization	Predisposition of handling procedures with visual details	1,12	0,672
Organization	Theoretical and practical professional training	0,56	0,336
Organization	Predisposition of manuals and written procedures	0,28	0,2688
Organization	On the job training and tutoring	0,224	0,21504
Organization	Implementation of a quality management system	0,1792	0,1792
Organization	Implementation of a safety management system	0,1792	0,14336
Organization	Actions to encourage the improvement of confidence level among workers	0,1792	0,14336
Organization	Actions to encourage social cohesion among department workers	0,1792	0,07168
Lathing	Endowment of computerized controls in work-station	0,0896	0,07168
Lathing	Adaptation of work-place ergonomic conditions	0,0896	0,03584
Lathing	Linearization procedures of control tasks	0,0448	0,03584

Case study

- When the block turns orange
  - The probability action failure is medium
  - There is need to act by using improvement actions proposed in the software.





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Lathing	Adaptation of work-place ergonomic conditions	0,0896	0,03584
Lathing	Linearization procedures of control tasks	0,0448	0,03584

Case study

- **Phase 4- Results validation**
  - In this case, the colour of process block is orange
  - The probability of action failure is included in the "opportunistic" control mode range.
  - Thus the simulation, through running several iteration, proposes a lost of actions to improve the reliability index., in order to move the control mode from "opportunistic" to "tactical" ($1E - 3 < p < 1E - 1$)

So this way in a lathing machine you can see these block diagrams are present, okay. Now under this calibration and evaluation you have to have a questionnaire elaboration. So after the definition of the process of the block diagram are proposed questions to be developed in a simulation model, okay. Once you do that, then you should determine the error index with any kind of improvement. So if you have any kind of error, error index, then how do you improve that? This screen is from that only, okay. So if you experiment, you may get the similar results. So when the block turned orange like you know this is the low probability of action failure, medium probability of action failure and this is the high probability of action failure. So this way you can get that. So the probability action failure is medium if it is orange, okay and you can see it is medium. It is just for example, for our case it was medium, okay and then the results validation. In this particular case, the color of process block is orange. Of course we saw that and the probability of action failure is included in the opportunistic control mode range. We explained it earlier that where it is reduced and then here you can see so block is in the opportunistic model, okay. So thus the simulation through running several iteration proposed a lost of action, some lost of action to improve the reliability index. So if something is being, the sequence of action is lost, then definitely if we can find out that we can improve the human reliability in this particular case.

Advantages

- The technique uses the same principles for retrospective and predictive analysis.
- The approach is very conscious, well-structured
- Follows a well laid out system of procedure.
- The technique allows for the direct quantification of Human Error Probability (HEP).
- It also allows evaluator using the CREAM method to specifically tailor the use of technique to contextual situation.

Now coming to the advantages of this particular system or this particular technique. So the technique uses the same principle for retrospective and predictive analysis, prospective analysis because you can do it after accident or when you have a system you can predict also, okay. The approach is very conscious and well structured. It follows a well laid out system of procedure. The technique allows the direct quantification of the human inner probability and it also allows the evaluator using the CREAM method to specifically tailor the use of technique to contextual situation. So these are the advantages, but it has some disadvantage. What is, it is very lengthy. As I mentioned, I was showing you the result one by one, but it is so quick, appears to be so quick, but no, when you actually perform it, it is very, very lengthy. It takes a lot of time to get into one point, okay. So it is a very lengthy process and CREAM also requires an initial expertise in the field of human factors. If you are not expert in this field, you will not be able to perform it, okay.

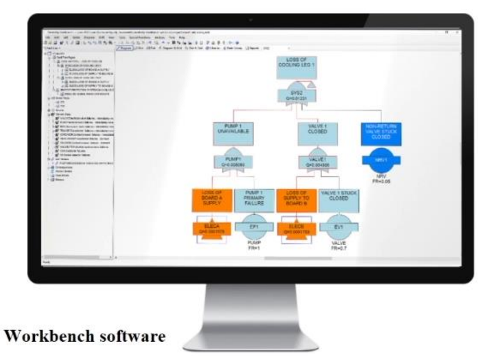
Disadvantages

- This technique requires a high level of resource use
  - Lengthy time period for completion
- CREAM also requires an initial expertise in field of human factors.
- It may appears rather complex for an experienced user.
- CREAM does not put forth potential means by which identified errors can be reduced.

So that is disadvantages and it may appear rather complex for an experienced user. It happens as you go into detail, it becomes more complex in nature and CREAM does not put forth potential means by which identified errors can be reduced, okay. So we do not know how do we do. Maybe we can get a direction, but it is very difficult to exactly pinpoint that what do we do and then how do you reduce it, okay. So these are the disadvantages.

Tools needed

- Pen & paper
- Spreadsheet
- Reliability software (e.g., Reliability Workbench)



Reliability Workbench software

So what do we need? We need pen, paper, spreadsheet and the reliability software. So here we have an example of the reliability workbench, you can work out with this, maybe you can have some other software which is in this particular field, okay. That is all for this particular tool and I believe we are almost at the end of different tools and techniques discussion about the cognitive and behavioral ergonomics, okay. So that is all and maybe we have some more tool or small discussion about the environment that we will go ahead in the last week of our program. Thank you, okay.

Summary

- A modelling application for cognitive reliability and error analysis method.
- A novel approach and promising tool useful in order to manage the "human factors" in production process.
- It is desirable to develop more precise frameworks and empirical testing of the performance measures, action research.
- It is necessary to develop more industry studies.

Coming before concluding this about, you know, this particular tool I would like to summarize it as it is a modeling application. Of course, it is a modeling application for cognitive reliability and error analysis method. Of course, it is a novel approach and promising tool useful in order to manage the human factors in production process. It is very important and it is desirable to develop more precise framework and empirical testing of the performance measure and action research and it is necessary to develop more industry studies. So here we have lot of scope in the field of, you know, doing lot of research here. Many of my students are actually working in this particular field and they are developing different, doing the case studies and trying to understand this human reliability concept in complex situation or situation awareness, how that can improve the whole system performance and reduce the accidents or some kind of incidents in a system, okay. That is all for CREAM and that is all for human reliability as a whole, whatever tools and techniques available here. Thank you.