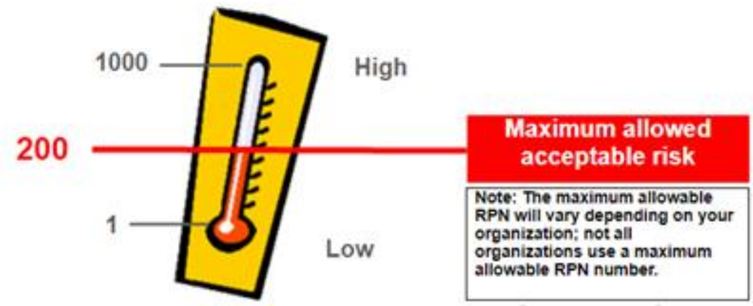
# Laboratory 6

## STEP 8 - Develop the Action Plan

Once the RPNs have been determined, the DFMEA team is ready for Step 8, Develop the Action Plan. The RPNs are used to prioritize the risks to be reduced.

You're probably wondering what is considered an acceptable RPN. The answer to that question depends on the organization. For example, an organization may decide any RPN above a maximum target of 200 presents an unacceptable risk and must be reduced. If so, then an action plan identifying who will do what by when is needed.




Some organizations have the FMEA teams take action on the top 20% of the high RPN failure modes. And some organizations require teams take action on all failure modes with high severity rankings (ranking of 9 or 10) regardless of the actual RPN values.

For an FMEA, action means reducing the RPN. The RPN can be reduced by lowering any of the three rankings (severity, occurrence, or detection) individually or in combination with one another.

a. A reduction in the Severity Ranking for a DFMEA is often the most difficult to attain. It usually requires a design change.

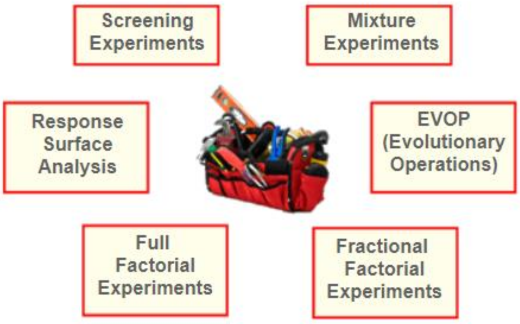
b. Reduction in the Occurrence Ranking is accomplished by removing or controlling the potential causes or mechanisms of failure.

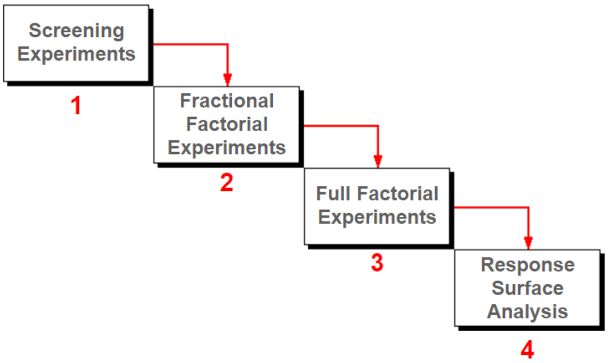
c. And a reduction in the Detection Ranking is accomplished by adding or improving prevention or detection controls.

In our hose example, a summary of the first action the team planned is shown. In this case, while the severity of the failure could not be addressed, both the frequency of the occurrence and the detection rankings could be impacted with the action planned.

There are many tools to aid the DFMEA team in reducing the relative risk of failure modes requiring action. Among the most powerful tools for DFMEAs are Design of Experiments, Mistake-Proofing, Design for Assembly or Design for Manufacturability techniques, and Simulations.

Design of experiments, or DOE for short, are a family of powerful process and product improvement techniques that can identify the power factors. For a DFMEA, the power factors would be the most important variables in your design. Design of experiments can help us to identify the power factors and the best settings for them.




There is a natural progression to effective use of DOEs. We recommend starting with screening experiments. Screening experiments provide lots of information with relatively few experimental runs. Most of the time, screening experiments will provide enough information so that more thorough experimental designs will not be needed.

For product design, a screening experiment can identify the most important factors for optimizing product performance. The same type of experiments can be used to determine the basic settings of the variables to make a product more robust, or more forgiving of potential variations in process and environmental conditions.

The results, called responses, are analysed using statistical techniques to determine which variable or variables are the power factors of the design. The analysis will also indicate whether the high or low setting for each power factor gives the best response and whether any of the power factors are related. If power factors are related, we may see interactions between them.

Mixture experiments are special types of designed experiments that are used for evaluating product compositions or mixtures of chemicals. Product compositions have formulation constraints that product assemblies and processes do not. For instance, one constraint is that the weight fraction of all components in the composition must always add up to 1.0 or 100%.

Next, we'll look at mistake-proofing. Mistake-proofing, in its purest form, eliminates the chances of a failure mode occurring. If a failure mode can't occur, then its RPN value becomes 0 for all practical purposes. However, since FMEA scales do not allow a ranking of 0, if a failure mode has been mistake-proofed and there is no chance of failure, the occurrence ranking would be set at a 1 and the detection ranking could also be lowered at the same time.

We see many things that have been mistake-proofed in everyday life especially for safety reasons. Here are some, but you can probably think of dozens of other mistake-proofing examples.

Irons have been mistake-proofed so that they shut themselves off after a certain time.

Cars with manual transmissions can't be started without the clutch engaged. This prevents the car from lurching forward unexpectedly when being started.

An excellent example of mistake-proofing is the design of electrical plugs and outlets shaped so that a 120-volt appliance cannot be plugged into a 240-volt outlet.

Mistake-proofing is especially important when we have a severity ranking of 10 for the effect of a failure mode. For most severity ranking scales, a rating of 10 means someone will get hurt. We obviously don't want to take any chance of an injury occurring, so we'd want to mistake-proof that failure mode so that it could not occur.

There are four main categories or effects of mistake-proofing methods: Forced Control, Shutdown, Warning, and Sensory Alert. The different shapes for 120V & 240V electrical outlets and the need to engage a clutch before starting a manual transmission car are both Forced Control effects. The iron auto-shutoff is an example of a Shutdown effect. The microprocessor in the iron shuts it off after it counts to a fixed time interval. The use of Forced Control and Shutdown effects lead to powerful mistake-proofing solutions.

| Relative Mistake-Proofing Power | Effect | Trigger |
|---|---|---|
| HIGH 10 | Forced Control | Automatic & Compulsory |
| 9 | ↓ | ↓ |
| 8 | ↓ | ↓ |
| 7 | ↓ | ↓ |
| 6 | Shutdown | ↓ |
| 5 | ↓ | ↓ |
| 4 | ↓ | ↓ |
| 3 | Warning | Operator Dependent & Discretionary |
| 2 | ↓ | ↓ |
| 1 | Sensory Alert | ↓ |
| 0 LOW | ↓ | ↓ |

Incorporation of design for assembly (or DFA) and design for manufacturability (or DFM) techniques in a product design can both reduce the occurrence rating and improve the detection rating of a product. Important subsets of DFA/DFM are ease of assembly, modularity of product sub-assemblies, and commonality and standardization of components.

Product design dictates much of the product assembly practices. If the design requires ineffective, cumbersome assembly methods, the frequency of failure will rise. And if defect detection cannot be easily and simply designed into the product, the detection rating will be high, raising the RPN.

Designing products using modularity concepts is an important aspect of DFA. The use of modules or sub-assemblies that are built-up in a final assembly operation often reduces failure frequency as long as in-process detection is part of the sub-assembly steps. Incorporation of fast connect or disconnect hardware and fastening systems in a product design help reduce failure frequency as well.

Designing products to use components common to other products manufactured at the same site are an aid to manufacturability. Additionally, designs that use standard fasteners and connectors aid manufacturability issues.

## STEP 9 - Take Action

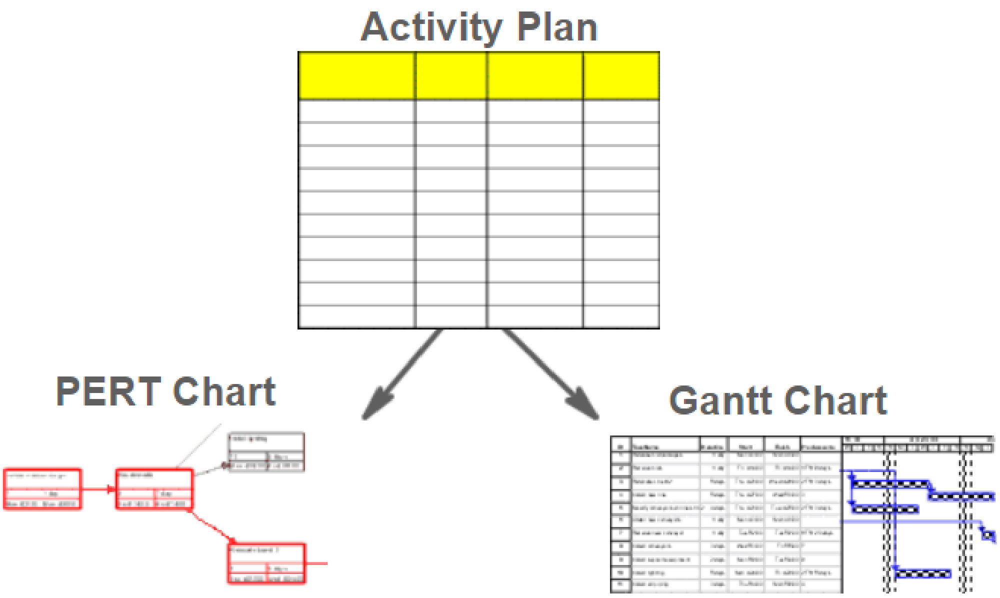
Step 9 is "Take Action." The DFMEA team carries out the action plan developed in step 8.

The Action Plan outlines what steps are needed to implement the solution, who will do them and when they will be completed. A simple solution will only need a Simple Action Plan while a complex solution needs more thorough planning and documentation.

In our washing machine hose example, the Action Plans identified were all Simple Action Plans. They are shown on the DFMEA Analysis Worksheet.

| Failure Mode | RPN | Recommended Action | Responsibility | Action Taken |
|---|---|---|---|---|
| Hose blocked | 120 | None at this time | — | — |
| ↓ | 60 | None at this time | — | — |
| ↓ | 140 | None at this time | — | — |
| Leaking hose | 300 | Replace w/hose resist. to low temp | Switch to braided PE hose: Robin by 7/28 | Resourced hose. Specs & stock in-place by 7/25. |
| ↓ | 90 | ↓ | ↓ | ↓ |
| ↓ | 60 | None at this time | — | — |
| ↓ | 270 | Replace w/hose resist. to low temp | Switch to braided PE hose: Robin by 7/28 | Resourced hose. Specs & stock in place by 7/25. |
| ↓ | 81 | ↓ | ↓ | ↓ |
| ↓ | 54 | None at this time | — | — |

Sometimes, the Action Plans can trigger a fairly large-scale project. If that happens, conventional project management tools such as PERT Charts and Gantt Charts will be needed to keep the Action Plan on track.

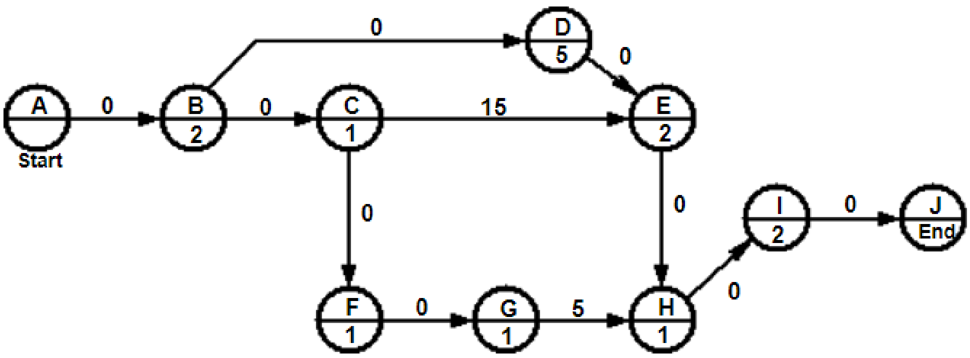



Development of an Activity Plan precedes the development of the PERT Charts and Gantt Charts used to manage and monitor Complex ACTION Plans.

1. List all activities.
2. List immediate predecessors for each activity.
3. Estimate how long each activity will take.
4. Identify lag time between activity and its predecessor.
5. Identify who will complete the activity.

Creating an Activity Plan is a team activity although it can be pulled together by a subcommittee of the team and then approved by the entire team. Everyone's involvement is critical especially if many of the team members have activities that need their skills. The Activity Plan leads to a PERT chart or Gantt chart.

A PERT chart can help us quickly identify the critical path. The critical path is the path on the chart from start to finish that takes the longest time. On a computer-based PERT chart, the software will usually change the colour of the activity and the activity paths to show the critical path. The critical path is the shortest time the project can be completed in. If any activity on this path slips, the project will take longer to complete.




Path A-B-D-E-H-I-J = 0+2+0+5+0+2+0+1+0+2+0 = 12

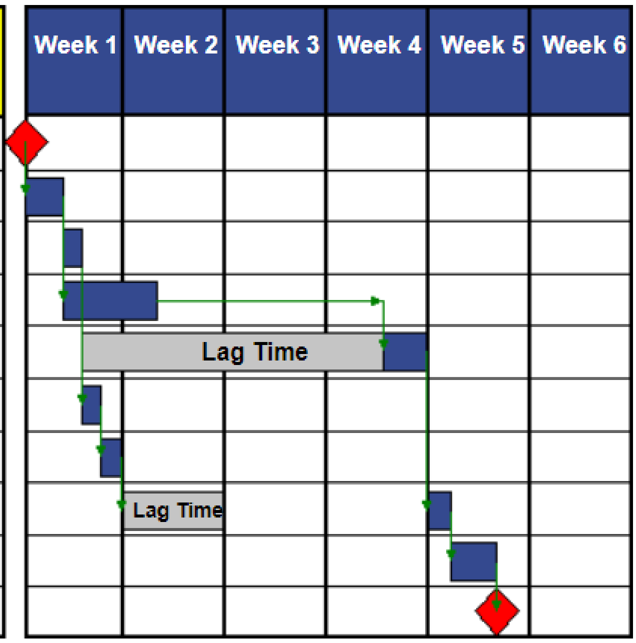
**Critical Path:** **Path A-B-C-E-H-I-J = 0+2+0+1+15+2+1+0+2+0 = 23 days**

Path A-B-C-F-G-H-I-J = 0+2+0+1+0+1+0+1+5+1+0+2+0 = 13 days

A Gantt Chart is simply a series of time lines of the activity steps. It shows when activities need to be started and how long they are expected to last. The arrows on the Gantt Chart between activities also show immediate predecessors. If we add the initials of who is going to do the different tasks (activities), then we also can see where we have someone overloaded with tasks. We can rebalance activities so that we can complete them on-time.

Use arrows between activities to show links between them. With an arrow in place, we know that we can't start an activity until all of its immediate predecessors are complete.

| Activity | Time to Complete (days) | Imm. Pred. | Lag Time (days) |
|---|---|---|---|
| A. Start | None | None | None |
| B. Determine new layout | 2 | A | 0 |
| C. Order pallet racks | 1 | B | 0 |
| D. Prepare warehouse | 5 | B | 0 |
| E. Install racks | 2 | C, D | 15 - C, 0 - D |
| F. Select labeling | 1 | C | 0 |
| G. Order labels | 1 | F | 0 |
| H. Mount labels | 1 | G, E | 5 - G, 0 - E |
| I. Fill racks | 2 | H | 0 |
| J. End | None | I | None |



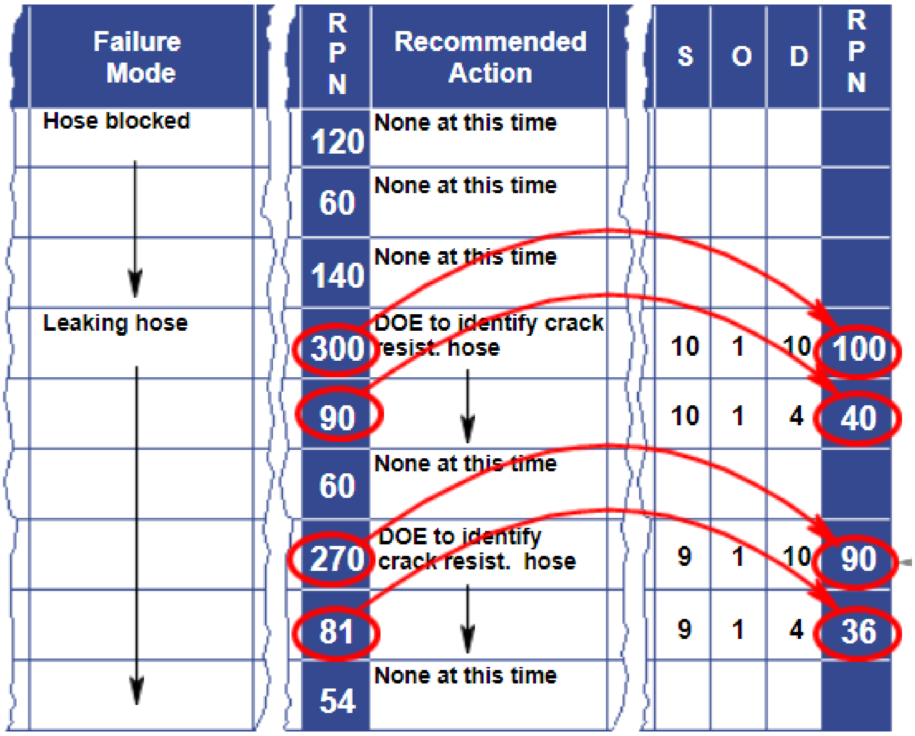

Our PERT and Gantt Charts aren't just display tools to be used at the beginning of the implementation. They are tools to help us make sure we are on track with the implementation. As activity tasks are completed, they should be coloured in, so we have a visual signal how we are doing.

## STEP 10 - Recalculate the Resulting RPNs

The final step to a DFMEA is to confirm the action plan had the desired results by calculating the resulting RPN.

To recalculate the RPN, your team will need to reassess the severity, occurrence, and detection rankings for the failure modes after the action plan has been completed.

In our example, the action taken for the "Leaking hose" failure mode reduced the Occurrence ranking from 3 to 1. All RPNs are safely below the company's target maximum of 200. The DFMEA action plan has clearly improved the product reliability.



| Failure Mode | RPN | Recommended Action | S | O | D | RPN |
|---|---|---|---|---|---|---|
| Hose blocked | 120 | None at this time | | | | |
| | 60 | None at this time | | | | |
| | 140 | None at this time | | | | |
| Leaking hose | 300 | DOE to identify crack resist. hose | 10 | 1 | 10 | 100 |
| | 90 | | 10 | 1 | 4 | 40 |
| | 60 | None at this time | | | | |
| | 270 | DOE to identify crack resist. hose | 9 | 1 | 10 | 90 |
| | 81 | | 9 | 1 | 4 | 36 |
| | 54 | None at this time | | | | |