RCM++ Version 10 First Steps Example

This example provides a quick introduction to the RCM++ software by allowing you to experiment with the application's data management, analysis and reporting features.[1] *These instructions were prepared with RCM++ 10, but you can perform the same steps in Version 9. The appearance of a few icons and screenshots will vary slightly.*

A Note About RCM Terminology in the Software: RCM++ combines RCM capabilities and FMEA capabilities together in the same software interface. Although there are many similarities between the two analysis methodologies, there are some basic differences in the terminology that affect the application interface. Note that:

- **FMEA and Functional Failure Analysis**: Regardless of whether you are performing an RCM analysis or an FMEA, all of the information related to the functions and failure modes will be displayed in the FMEA tab of the Analysis panel, and you will use the commands in the FMEA tab of the ribbon to manage this information. In other words, the term "FMEA" is often used within the software interface in place of "functional failure analysis."
- **Functional Failures, Failure Modes and Causes**: Although the property names within the software are fully configurable to fit the specific analysis terminology used by your organization, the ribbon commands, icons and window names are not. When a name is not configurable, the term "Failure" is used for the second level in the analysis hierarchy and "Cause" is used for the fourth level. If you are performing a functional failure analysis, you might refer to these levels as the "Functional Failure" and "Failure Mode."

1.1 Open an Existing Database

If you haven't started RCM++ already, choose **Start > All Programs > ReliaSoft >** and then select the RCM++ application.

When you launch RCM++, the Backstage view (File tab) is the first view you will see. This Backstage view provides a quick way to create and open databases (called *Synthesis repositories*). In Synthesis applications *standard repositories* are Microsoft Access® databases. These are easy to create and maintain without any special IT infrastructure or support, but there are limitations to the amount of data they can store and the number of users who can access the repository simultaneously. *Enterprise repositories* require implementation of Microsoft SQL Server® or Oracle® (which require separate licensing, support and

[1] For this example, you will work with a project that contains part of an RCM analysis for a standard pump. The analysis was performed using the RCM logic diagrams published in the SAE JA1012 guidelines.

maintenance), but are a more robust platform that can store much more analysis information in the same database and support access by many more simultaneous users.

For this example, you will use a standard database that is installed with the software (called "RCM10_Examples.rgz10") that contains several sample projects. (If you are using Version 9, the file is called "RCM9_Examples.rgz9".) To access this file, choose **File > Help**, click **Open Examples Folder**, then browse for the file in the RCM sub-folder.

> **Tip:** To preserve the integrity of the shipped example files, the software creates a copy of the file each time you access a repository in the Examples folder. The copy has the same name as the original file and is saved in the default documents folder for your computer (e.g., My Documents\ReliaSoft\Files). Use the copy to work on the example projects and save your changes. Any changes you make in the copy will not affect the original file.

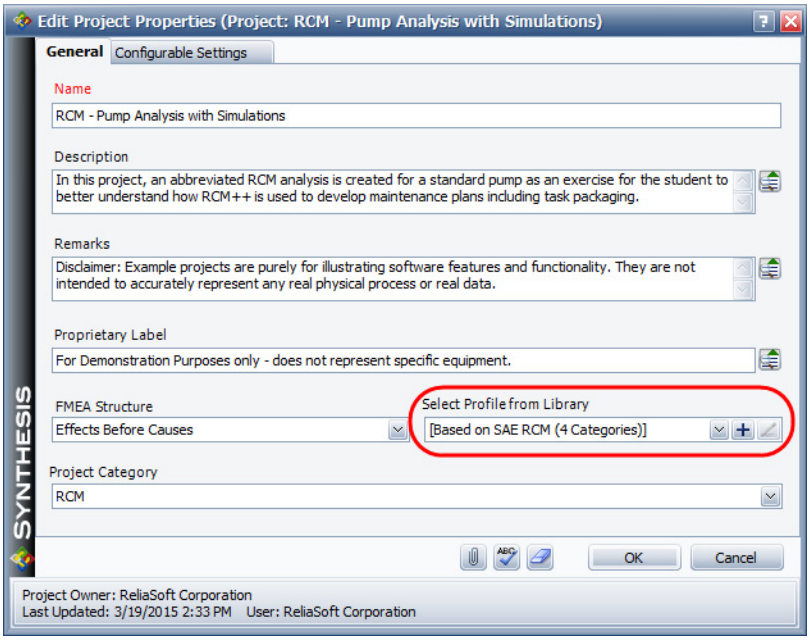
1.2 View the Project Properties

In all Synthesis applications, *projects* give you the flexibility to manage your analyses to fit the particular needs of your organization. You can have one or many projects in the same database.

Every RCM++ analysis within a given project will have the same configurable settings, including the fields that are enabled/disabled in the interface and reports, the rating scales or questions that are available for risk assessment and the options that are available for codified information (such as FEC logic, task selection logic, etc.).

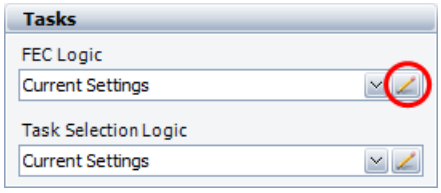
To save time and ensure consistency, these configurable settings can be set automatically based on predefined *profiles* that are managed by authorized users. They can also be viewed or modified directly in each individual project.

- Select the **RCM - Pump Analysis with Simulations** project in the Project Manager and choose **Project > Management > Edit Project Properties** to open the Project Properties window, as shown next.

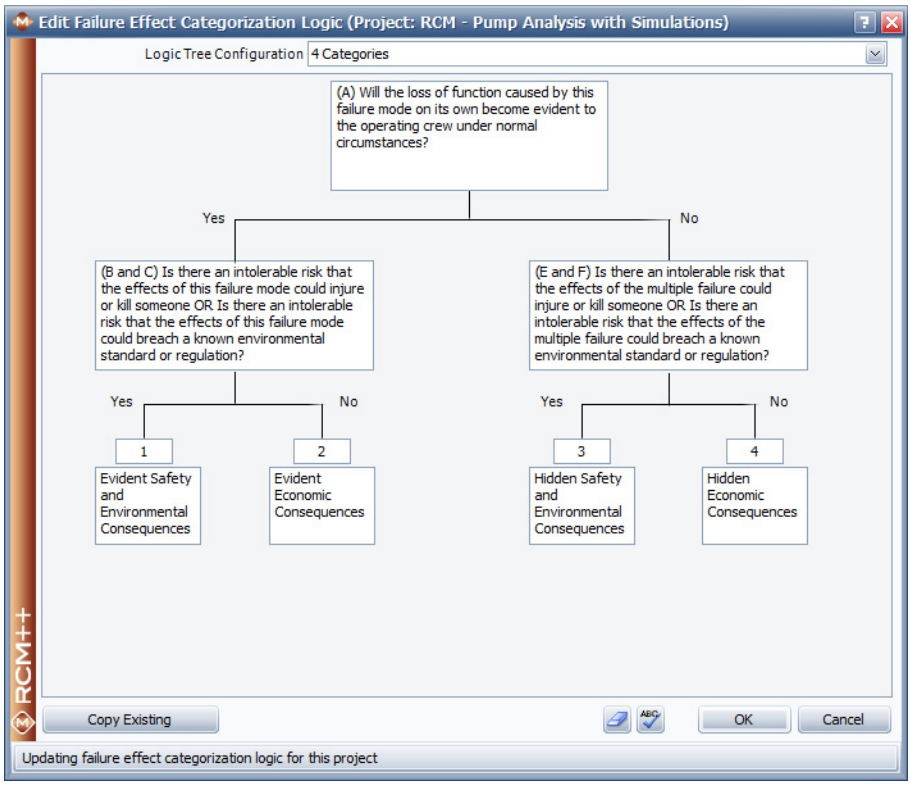


As can be seen in the **Select Profile from Library** field, the configurable settings in this project are based on the SAE RCM (4 Categories) profile. This predefined profile is shipped with the software and can be used to quickly configure the project to use the data fields and logic diagrams specified in the SAE JA1012 "A Guide to the Reliability-Centered Maintenance (RCM) Standard" guidelines for RCM.

- Now click the **Configurable Settings** tab. This page provides one way that you can view (and edit) the configurable settings that have been copied into the current project from the predefined SAE profile. (Note that the settings are also accessible when you are working in the project by choosing **Project > Management > Configurable Settings** or by clicking any of the **Configurable Settings** icons.)
- As an example, click the **View/Edit Settings** icon for **FEC Logic**.



You can see that the project has been configured to use the 4-category failure effect categorization diagram from the SAE standard.

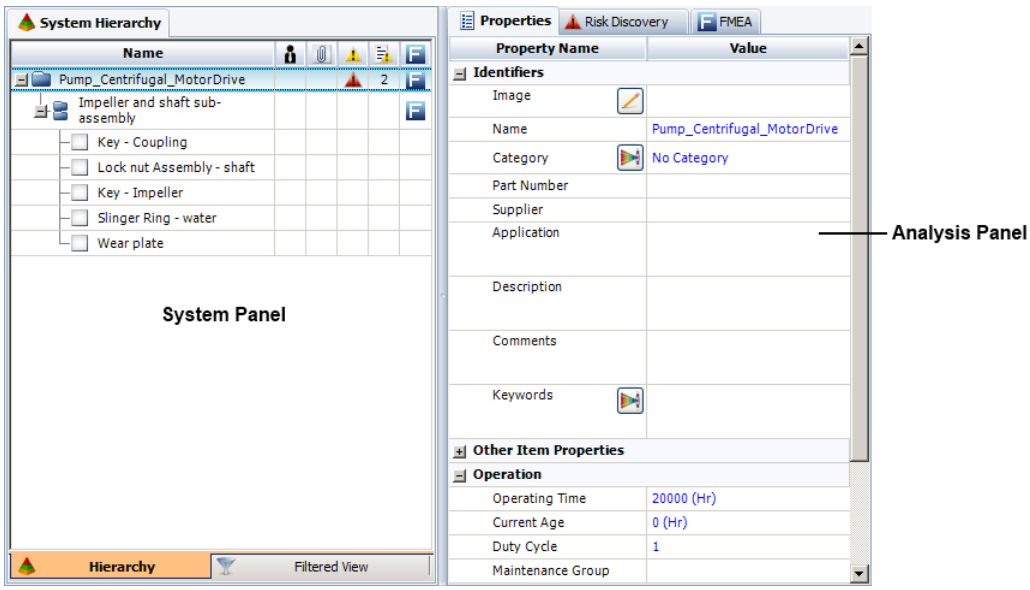


- Click **Cancel** to close the failure effect categorization logic window without saving any changes.
- If desired, you can click the other **View/Edit Settings** icons to see the rest of the configurable settings that have been predefined for this project. When you are finished exploring these settings, click **Cancel** to close the Project Properties window without saving any changes.

1.3 Open a Project

- With the RCM - Pump Analysis with Simulations project still selected in the Project Manager, open the project either by double-clicking the project name or by choosing **Project > Management > Open Project**.

The Project window is the main interface that you will use to perform your analyses. It is divided into two panels, as shown next.



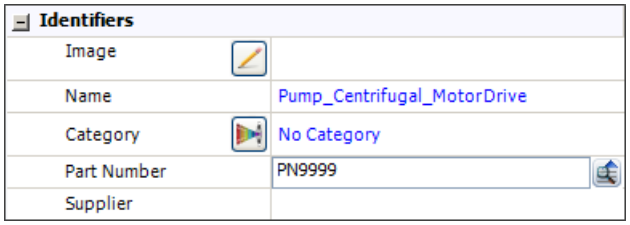
The System panel displays the system hierarchy, which includes all items that have been defined in the project. The Analysis panel displays information and analyses associated with the item that is currently selected in the hierarchy. Depending on your preferences, these panels can be displayed side-by-side, or with one panel above the other.

1.4 View the Item Properties

The Properties tab in the Analysis panel displays the item properties fields that are enabled for the current project, along with some settings that can be used for reliability calculations (if desired) and information about when the item record was created and last updated.

You can click inside any field with blue text to edit it. Fields shown in italics cannot be edited, either because they are populated by the application or because they are based on inputs that you make elsewhere in the software.

- If the item properties are not already displayed, click the **Properties** tab at the top of the Analysis panel.
- As an example, click inside the **Part Number** field and type **PN9999**, as shown next.



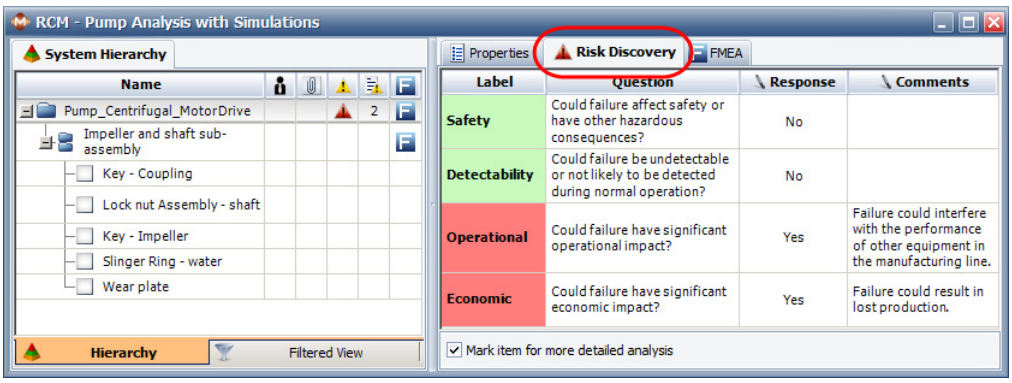
- If desired, you can edit any of the other item properties. When you are finished exploring these properties, proceed to the next section.

1.5 View the Equipment Selection

RCM++ supports two configurable methods for evaluating potential risk and selecting which items will receive further analysis. The Risk Discovery tab displays the questions or ratings that have been defined for the current project. For this example, the project uses a set of four yes/no questions to select which equipment should receive RCM analysis.

> **Note:** A project can also be configured to use the Risk Ranking method for equipment selection (which uses a set of configurable rating scales). This is determined by the option that is selected in the Risk Discovery area on the Configurable Settings tab of the Project Properties window (Use Risk Discovery Questions or Use Risk Discovery Ratings).

- Click the **Risk Discovery** tab in the Analysis panel to view the equipment selection analysis for the pump.



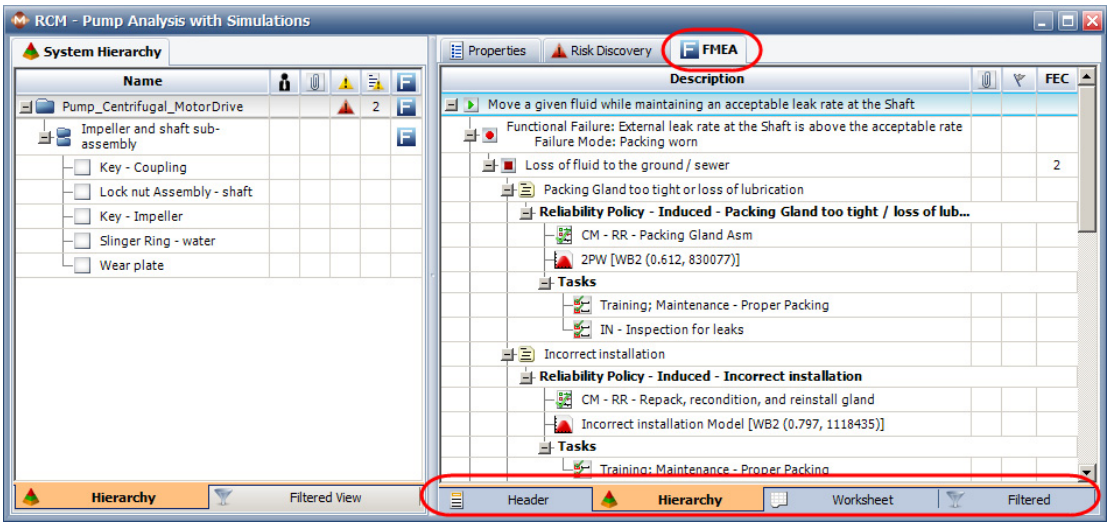
In this utility, you can click inside the **Response** column to toggle the answer between "Yes" and "No." The label will be displayed in green to indicate a "No" answer (not critical) or in red to indicate a "Yes" answer (critical). If desired, the team can use the **Comments** column to record any additional information relevant to the responses.

- To see the colors change, click inside the **Response** column to toggle both of the current "Yes" answers to "No." You can see that the **Mark item for more detailed analysis** check box is cleared automatically and the risk discovery icon in the System panel changes from red to green.
- Now click the check box to select the option again. You can see that the risk discovery icon in the System panel changes back to red. In other words, the application will automatically update this icon based on your answers to the selection questions, but you have the option to override this setting if desired.
- Before proceeding to the next section, click inside the **Response** column again to toggle the Operational and Economic answers back to the original "Yes" answers.

1.6 View the Functional Failure Analysis

The FMEA tab in the Analysis panel allows you to view/edit the functional failure analysis for the currently selected item.

- Click the **FMEA** tab to view the functional failure analysis for the pump. There are now four tabs at the bottom of the Analysis panel. Each tab displays the analysis information in a different way to facilitate data entry and decision making.

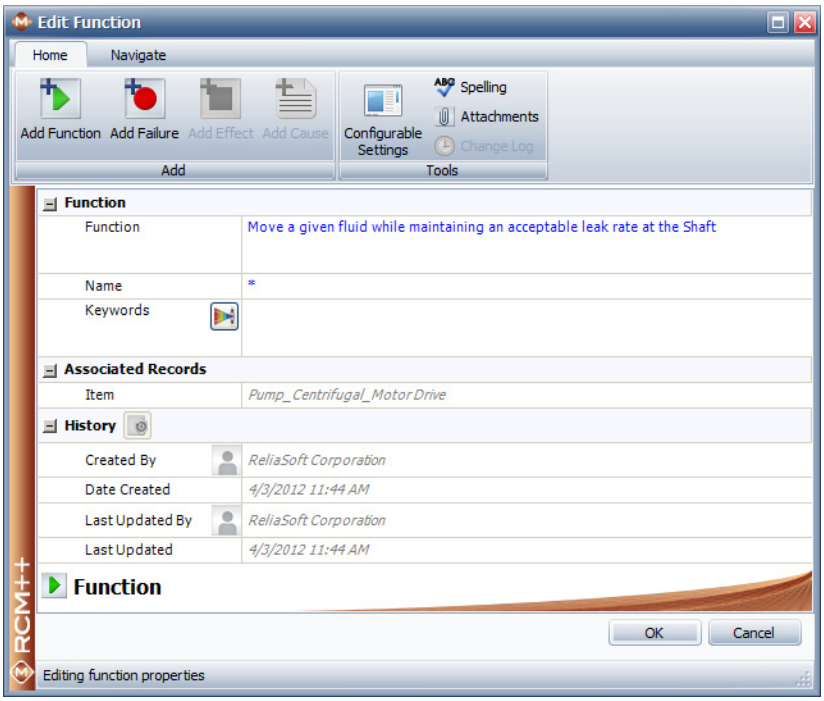


1.6.1 The Hierarchy View

The hierarchy view displays the analysis records in a hierarchical tree, which tends to be good for viewing a lot of information in a small amount of space. It can be especially useful when copying and pasting data or when scanning the analysis to find a particular section.

- If the hierarchy view is not already displayed, click the **Hierarchy** tab to view it.

- Double-click the “Move a given fluid...” function record at the top of the tree. The function properties window will appear, as shown next.



- With the properties window still open, click the first functional failure (“Functional Failure: External leak rate at the Shaft...”) in the FMEA hierarchy. You can see that the window updates automatically to display the properties for the record that is currently selected.
- If desired, you can continue clicking different records in the hierarchy to view their properties. Note that this approach works for any record type except tasks, which have a specialized interface to facilitate integration with other Synthesis applications (such as BlockSim). When you are finished exploring, click **Cancel** to close the properties window without saving any changes.
- Now create a new branch in the hierarchy by right-clicking the “Move a given fluid...” function and choosing **Add Function** from the shortcut menu.

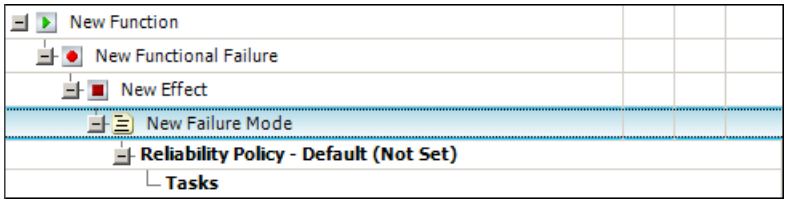
- In the properties window, type “New Function” in the **Function** field and then click the **Add Failure** icon at the top of the window.

- The properties window is now prepared to define a new functional failure. In the **Functional Failure** field, type “New Functional Failure” and then click the **Add Effect** icon.

- Now you can define a new effect. In the **Effect** field, type “New Effect” and then click the **Add Cause** icon.

- Now you can define a new failure mode. In the **Failure Mode** field, type “New Failure Mode” and then click **OK** to close the properties window.

  You can see that there is a new branch at the bottom of the hierarchy with the new records you just created.

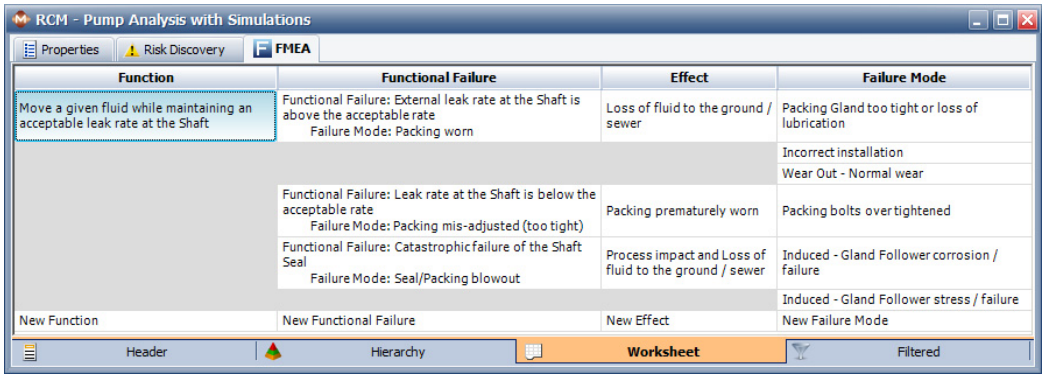


1.6.2 The Worksheet View

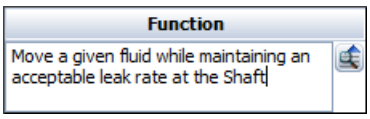
The worksheet view provides an alternative way to view/edit the same analysis information displayed in the hierarchy view. This view allows you to type directly into the worksheet cells and tab through the analysis as you would in a spreadsheet application such as Microsoft Excel®.

- To give more space in the Analysis panel before switching to the worksheet view, first choose **View > Workspace Layout > Hide System Panel**.

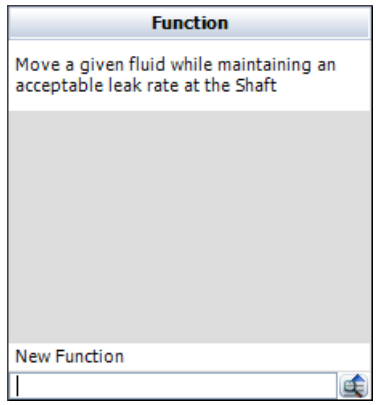
- Now click the **Worksheet** tab at the bottom of the Analysis panel.



- Double-click inside the first function description. You can see that the cell switches from “select mode” (with a blue background) to “edit mode” (with a white background and a blinking cursor so you can modify the text).



- Press **ENTER**. Note that the blinking cursor now appears in the second function description. Press **ENTER** again and the application will automatically create a new row so that you can type a new function description at the bottom of the worksheet, as shown next.



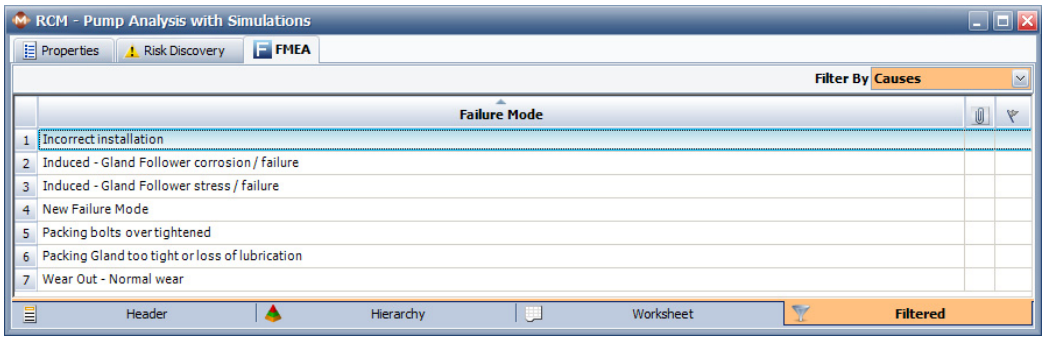
- This time, instead of typing the function description, you can use the Select Existing utility to reuse text that is already stored in the database. While the cell is in "edit mode," click the **Select Existing** icon.

- In the Select Existing window, look at the Projects and Phrase Sets drop-down list. This list allows you to specify the source(s) for the list of existing descriptions that you can select from.
- Look in the list of descriptions and double-click any existing description from the list. This automatically enters the selected text into the worksheet cell. This convenient feature is available for text fields throughout the application.
- If desired, you can continue to explore the worksheet view by adding and editing records. When you are finished, proceed to the next section.

1.6.3 The Filtered View

The filtered view allows you to generate sortable lists of different types of records. For example, you can view a list of all failure modes in the analysis, all tasks sorted by type, etc.

- Click the **Filtered** tab at the bottom of the Analysis panel.
- From the **Filter By** drop-down list at the upper right corner, choose **Causes**. The Analysis panel will change to display all of the failure modes that have been defined in the current analysis (sorted in alphabetical order by default).



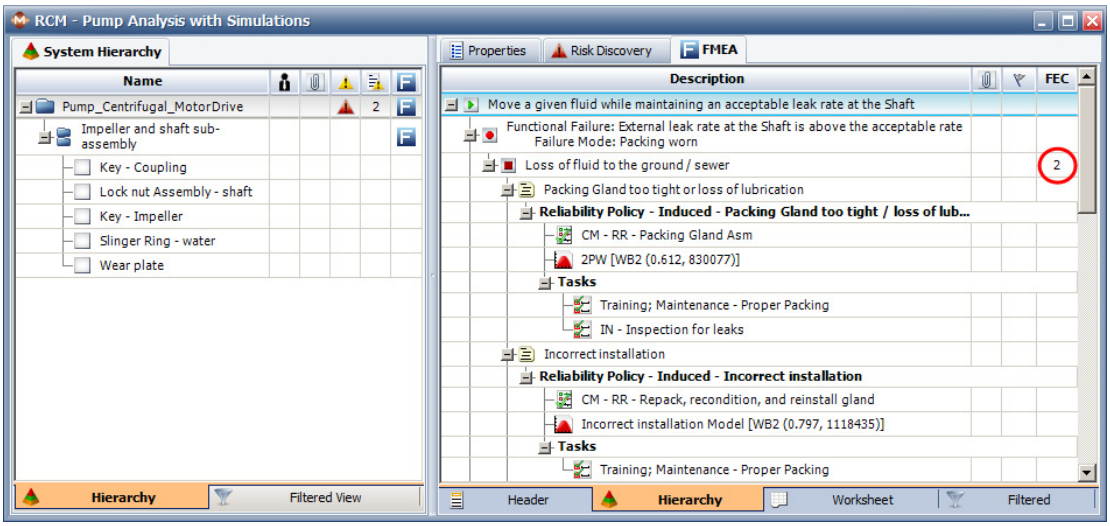
- You can sort the records by clicking any of the column headers. You can also double-click any record to open its properties window.

- If desired, you can continue to explore the filtered view by changing the filter or sorting by different columns. When you are finished, click the **Hierarchy** tab to return to the hierarchy view.
- To show the System panel again, choose **View > Workspace Layout > Split Panels**.

1.7 View the Failure Effect Categorization

The FEC column displays the failure effect categorization for each failure effect. (If the FEC column is not displayed on your computer, right-click a column header in the FMEA and choose **Customize Columns**. In the Customize Columns window, select the **FEC** column, and then click **OK**.)

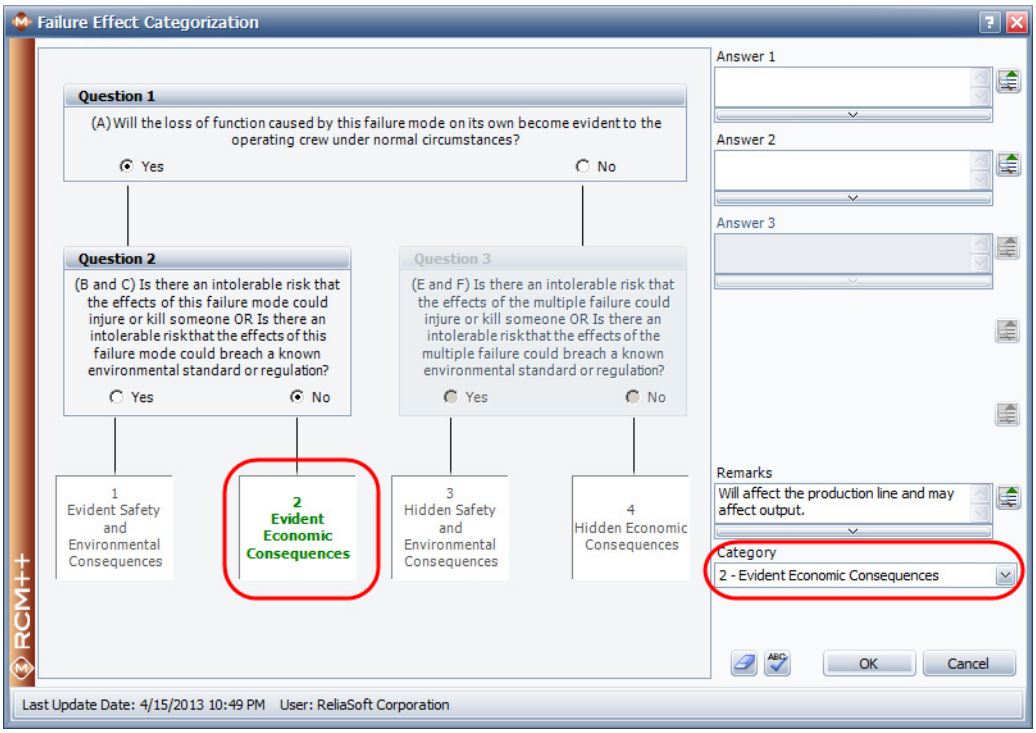
- With the FMEA hierarchy displayed, double-click inside the **FEC** column for the "Loss of fluid to the ground / sewer" effect.



The Failure Effect Categorization window displays the FEC logic diagram that is being used for all RCM analyses in the current project. There are two ways to select the category:

1. Answer each individual question until a category is highlighted.
2. Select a category directly from the **Category** drop-down list in the bottom right corner.

If desired, you can use the text fields on the right side of the window to record any additional information relevant to a particular response (use the **Answer** fields) or the categorization overall (use the **Remarks** field). The following picture shows the failure effect categorization that has been performed for the "Loss of fluid..." effect.

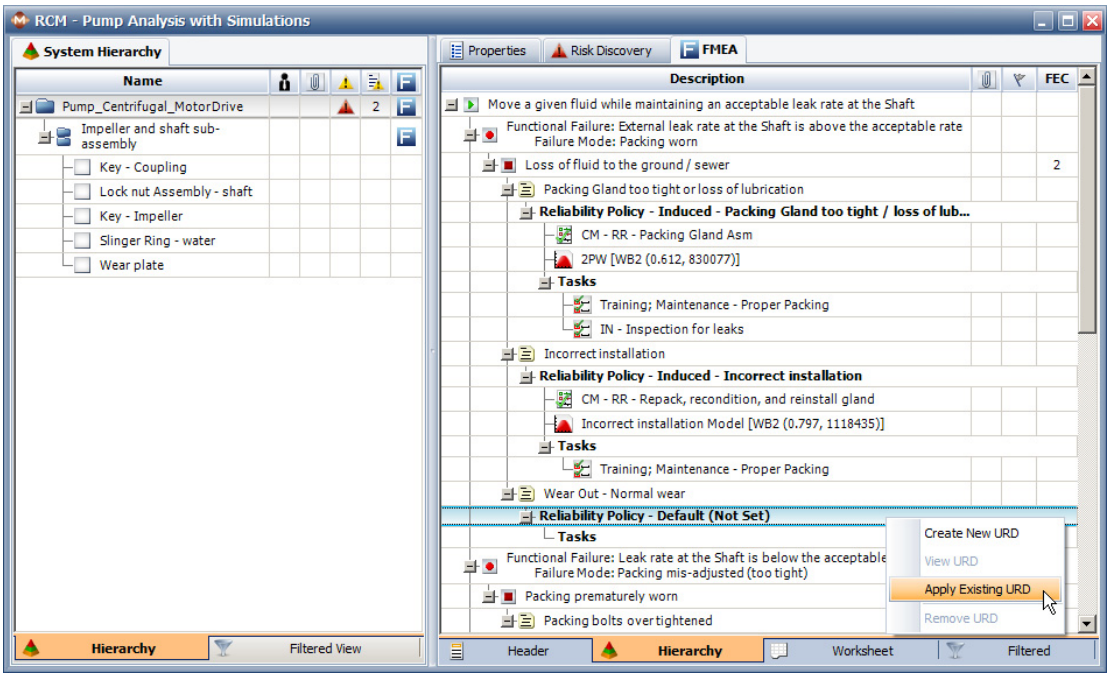


- To see the categorization change, select **No** for Question 1. When Question 3 becomes enabled, select **No** again. You will see that the "4 - Hidden Economic Consequences" category is now highlighted.
- To return to the original categorization, choose **2 - Evident Economic Consequences** from the **Category** drop-down list.
- Click **Cancel** to close the window without saving any changes.

1.8 Assign the Reliability and Corrective Maintenance Policies

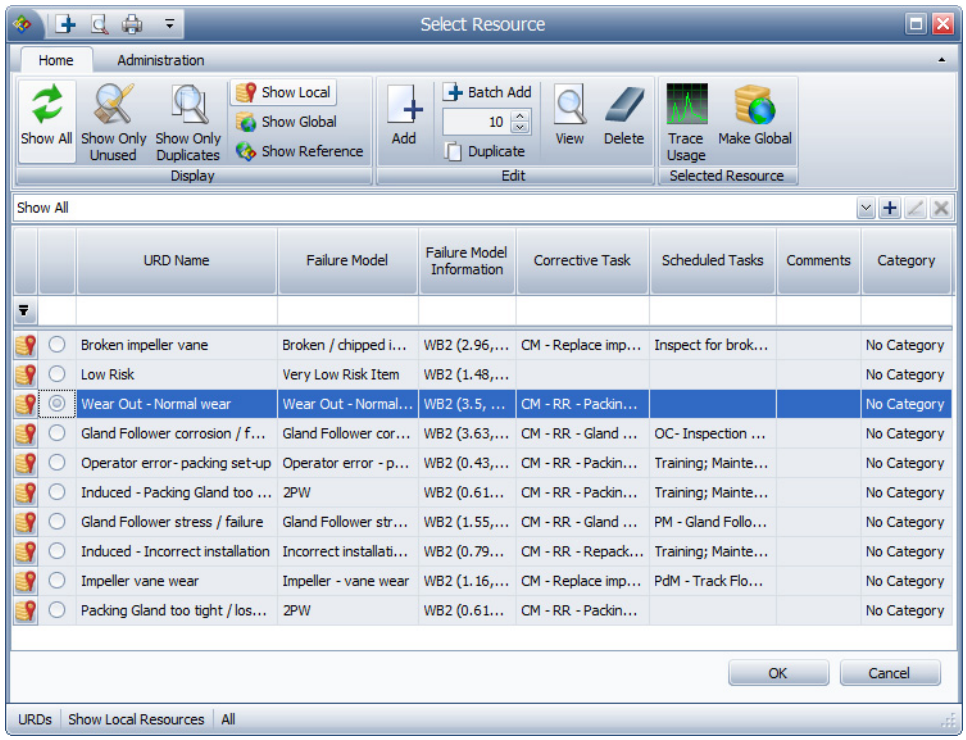
For this project, the team is using a combination of RCM design logic and availability/cost calculations to select the appropriate maintenance strategies. As an example, you can complete the sample analysis by entering the data for the "Wear Out - Normal wear" potential failure mode.

- Right-click the **Reliability Policy** node under the "Wear Out - Normal wear" failure mode and select **Apply Existing URD**.

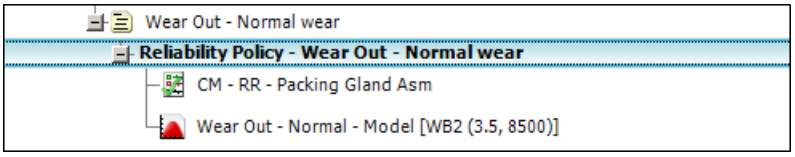


A universal reliability definition (URD) is a resource that describes a set of reliability and maintainability properties. It can be shared by all analyses in a given Synthesis project. You have the option to create these Synthesis resources as needed while performing an analysis, or select to use resources that have already been defined.

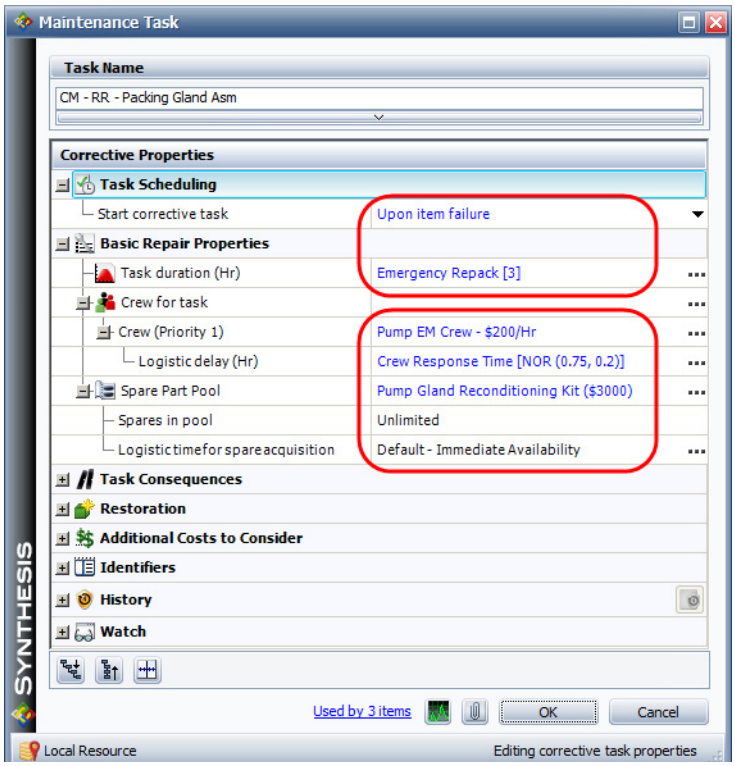
- The Select Resource window displays a list of all the URDs that have already been created for this project. Select **Wear Out - Normal wear** and click **OK**.



- When you return to the FMEA hierarchy, you can see that this URD defines the probability of failure for this mode (using a 2-parameter Weibull distribution with Beta = 3.5 and Eta = 8,500 hours) and the unplanned (corrective) maintenance logistics and costs.



- Double-click the "CM - RR - Packing Gland Asm" task to open the Maintenance Task window for the corrective maintenance task, as shown next.

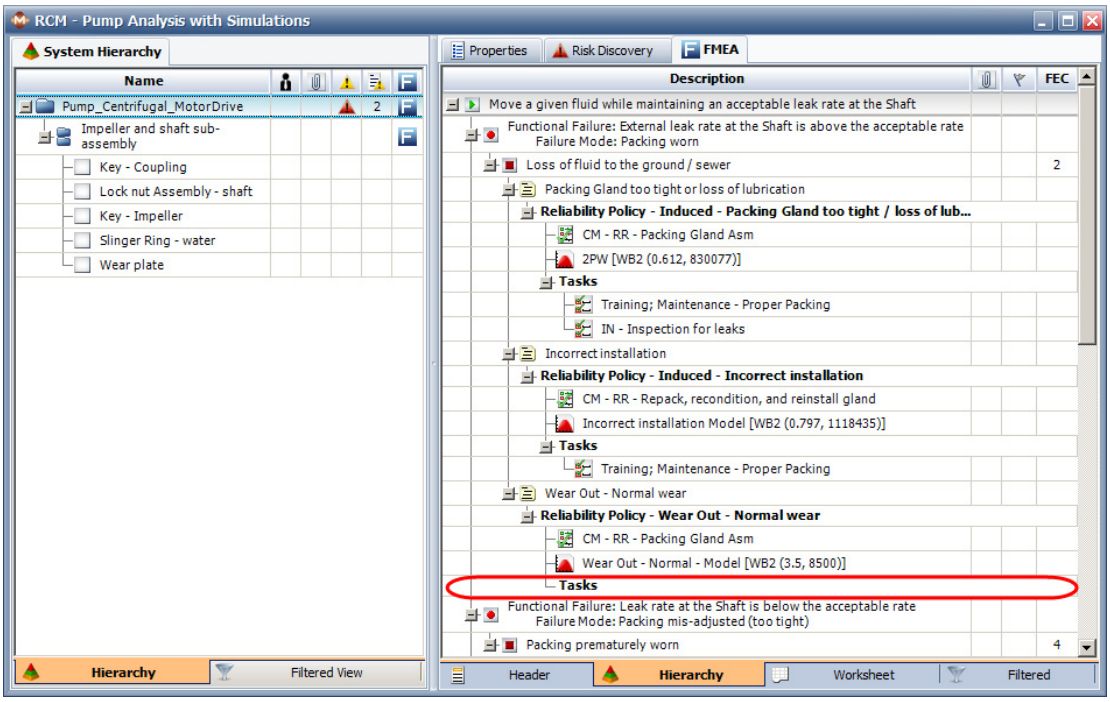


- As you can see, the task includes the following properties:
  - The "Emergency Repack" corrective task will be performed upon item failure and the task duration is 3 hours.
  - When the pump has to be correctively repaired, there is a delay before the emergency maintenance (EM) crew can respond, and the cost for their time is $200 per hour. The "Pump Gland Reconditioning Kit" used to repair the pump costs $3,000.
- Click **Cancel** to close the window without saving any changes.

1.9 View the Maintenance Task Selection

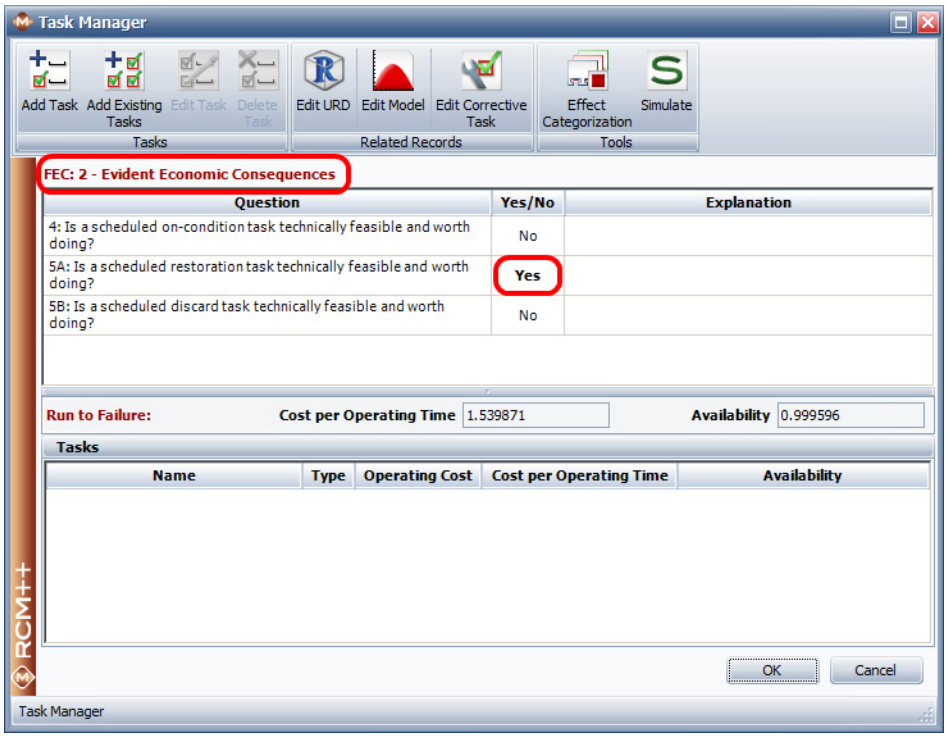
The **Tasks** node in the FMEA hierarchy provides access to the tools available in RCM++ to assist with maintenance task selection. It also displays the maintenance tasks that have been defined in the analysis for a particular failure mode.

- To open the Task Manger window for the “Wear Out - Normal wear” failure mode, double-click the **Tasks** node under that record.



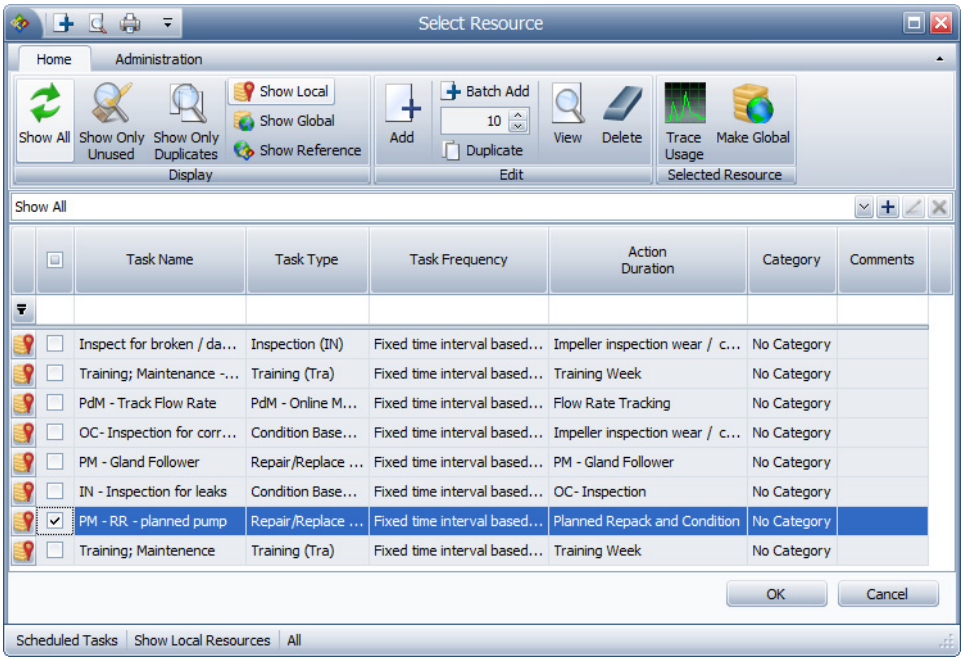
The top section of the Task Manager window displays the failure effect categorization for this failure mode, along with the maintenance task selection questions that are applicable for that FEC. (This is based on the configurable maintenance task selection logic that has been defined for all RCM analyses in the current project.)

You can see that the team has indicated that a scheduled restoration task (i.e., a planned preventive maintenance) may be applicable and effective to address this potential failure mode.

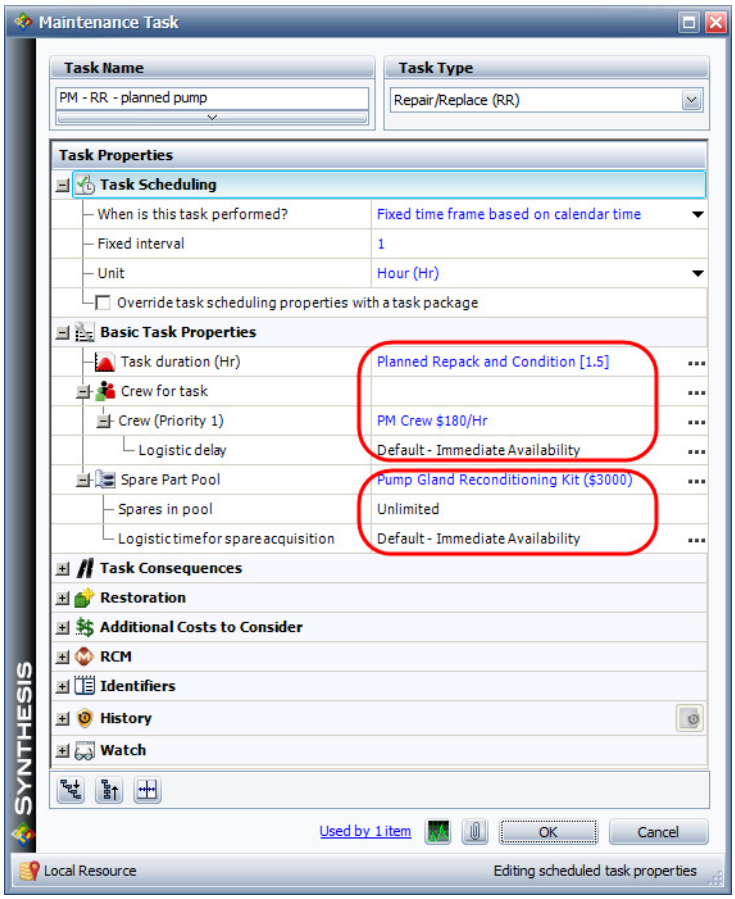


The preventive maintenance task that the team wants to consider for this issue has already been saved as a resource in the sample database. To select it, choose **Add Existing Tasks**.

The Select Resource window displays a list of all the scheduled maintenance tasks that have already been created for this project. Select **PM - RR - planned pump** and click **OK**.



Notice that the task is now visible in the Tasks section of the Task Manager window. Double-click the task to view its properties.



As you can see, the spare parts logistics are the same as they were for the corrective maintenance. Notice, however, that the repair time duration is only 1.5 hours and that the planned maintenance (PM) crew is less expensive (as it is only $180 per hour).

You will also notice that the scheduled task interval is temporarily set to 1 as a placeholder for the actual value. You can use the Failure Modes and Reliability Analysis (FMRA) interface to calculate the optimum replacement time. The FMRA interface is available in multiple Synthesis applications (including BlockSim, Xfmea, RCM++ and RBI) and it facilitates a variety of system reliability, availability and maintainability calculations.

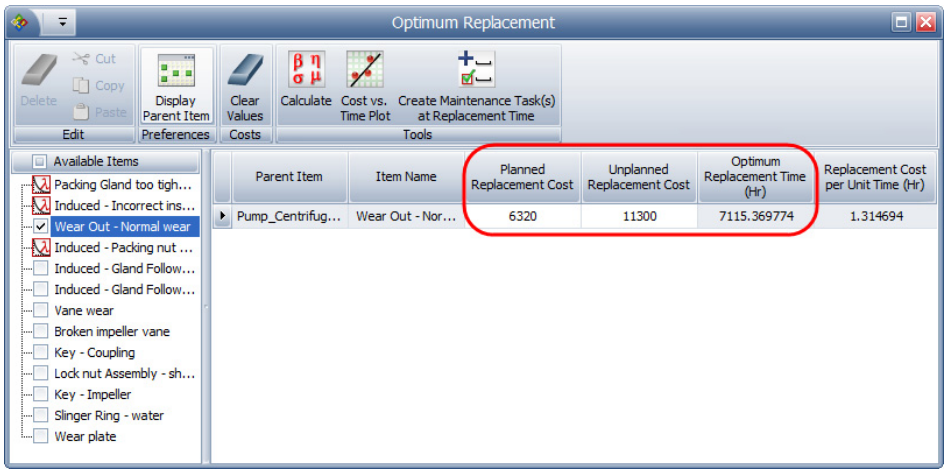
After you are done viewing the properties, close the Maintenance Task and the Task Manager windows.

- To display the FMRA for the sample project, **View > Show > Show FMRA**.

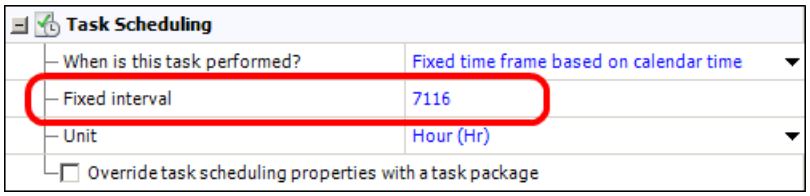
- With the system item selected, open the Optimum Replacement window by choosing **FMRA > RAM Analysis > Optimum Replacement**.

The Optimum Replacement window displays all of the maintenance tasks that are defined in the current project. You can choose to calculate the optimum replacement time for a single task, or you can select multiple tasks to optimize together. For this example, you will perform the calculation for a single task, where the planned replacement cost is $6,320 and the unplanned replacement cost is $11,300.

- Select the **Wear Out - Normal wear** failure mode and enter the planned replacement cost and the unplanned replacement cost.
- Click **Calculate** to open the Optimum Replacement Calculations window. Choose the **Individual - Blocks can use different times** option, then click **OK**. In the Optimum Replacement window, notice that the **Optimum Replacement Time** column now shows the calculated result of ~7,116 hours.

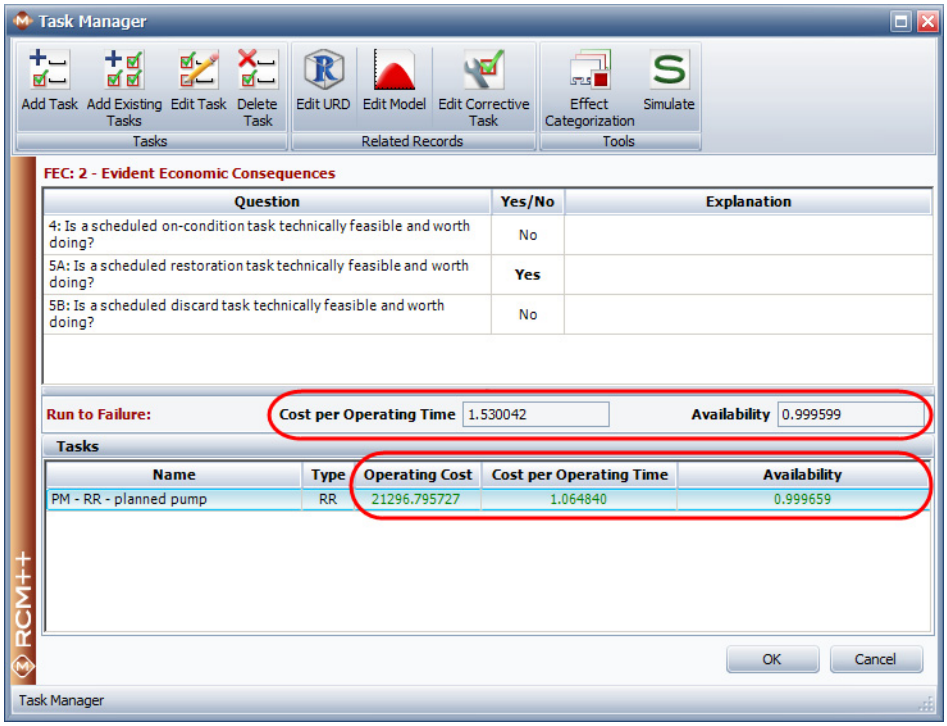


- Close the Optimum Replacement window, then return to the system hierarchy view and click the **FMEA** tab to open the FMEA.
- Open the Task Manager window, then open the "PM - RR - planned pump" task and enter the calculated time in the **Fixed interval** field.



- Close the Maintenance Task window, and then click **Simulate** on the Task Manager window to determine which maintenance strategy (run-to-failure or preventive maintenance) will provide better results.

- When prompted, accept the simulation value for the hours of operation (20,000), and select to run 1,000 simulations and then click **OK**. When the simulation completes, the run-to-failure (corrective maintenance only) results are displayed above the table and the results for the preventive maintenance strategy are displayed with the task. As you can see, the availability is very similar between the run to failure and PM options, but the cost per operating time is less when using PM. For a mission of 20,000 hours, this will result in significant cost savings.

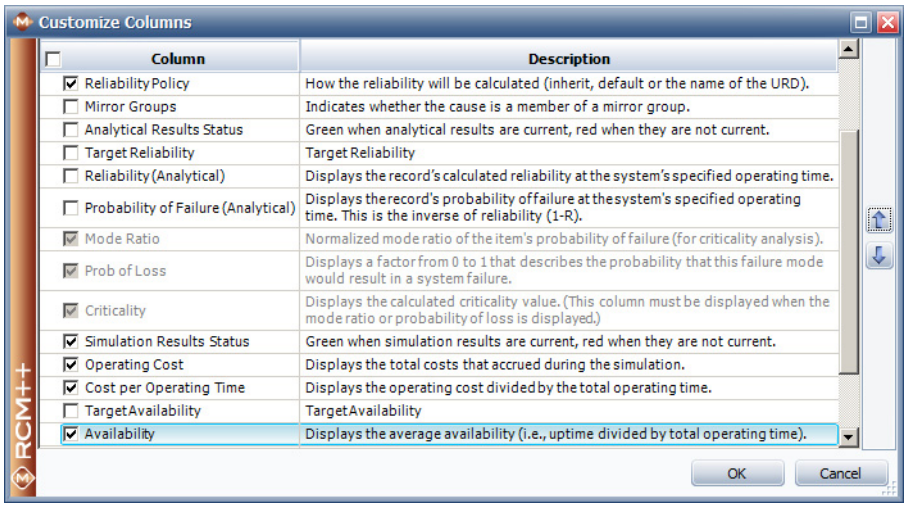


- Click **OK** to close the window.

1.10 Calculate System Reliability and Availability

Return to the FMRA view so you can simulate the entire system and calculate the availability with the potential failure modes and maintenance tasks that are currently specified.

- To select which columns in the FMRA to show on your computer, right-click a column header in the FMRA and choose **Customize Columns**. Enable only the fields that are shown in the following picture (**Reliability Policy**, **Simulation Results Status**, **Operating Cost**, **Cost per Operating Time** and **Availability**), then click **OK**.



- To give more space in the System panel before calculating the costs, choose **View > Workspace Layout > Hide Analysis Panel**.

- Choose **FMRA > RAM Analysis > Simulate (Availability)**.

- Use the same operating time of 20,000 hours and the same number of simulations (1,000), and then click **OK**. The calculated results are shown next.

RCM - Pump Analysis with Simulations

System Hierarchy | FMRA

Name	Reliability Policy	Operating Cost	Cost per Operating Time	Availability
Pump_Centrifugal_MotorDrive	Inherit	370576.309784	18.528815	0.911592
Move a given fluid while maintaining an accepta...	Inherit	108916.877171	5.445844	0.999408
Functional Failure: Ext. leak at input shaft	Inherit	70759.294097	3.537965	0.999659
Packing Gland too tight / loss of lubrication	Induced - Packing Gland too tight / lo...	25618.317134	1.280916	0.999990
Induced - Incorrect installation	Induced - Incorrect installation	24884.574722	1.244229	0.999996
Wear Out - Normal wear	Wear Out - Normal wear	20256.402241	1.012820	0.999673
Functional Failure: Leak rate at the Shaft is b...	Inherit	24685.385865	1.234269	0.999998
Induced - Packing nut over tightened	Operator error-packing set-up	24685.385865	1.234269	0.999998
Functional Failure: Catastrophic failure of the...	Inherit	13472.197209	0.673610	0.999752
Induced - Gland Follower corrosion / failure	Gland Follower corrosion / failure	12536.304882	0.626815	0.999768
Induced - Gland Follower stress / failure	Gland Follower stress / failure	935.892327	0.046795	0.999985

You can see that the estimated availability with the current maintenance strategy is about 91% and the cost per operating time is $18.53. For a period of 20,000 hours, that is a total operating cost of $370,576.31. Packaging the tasks into more efficient intervals may provide better results, as discussed next.

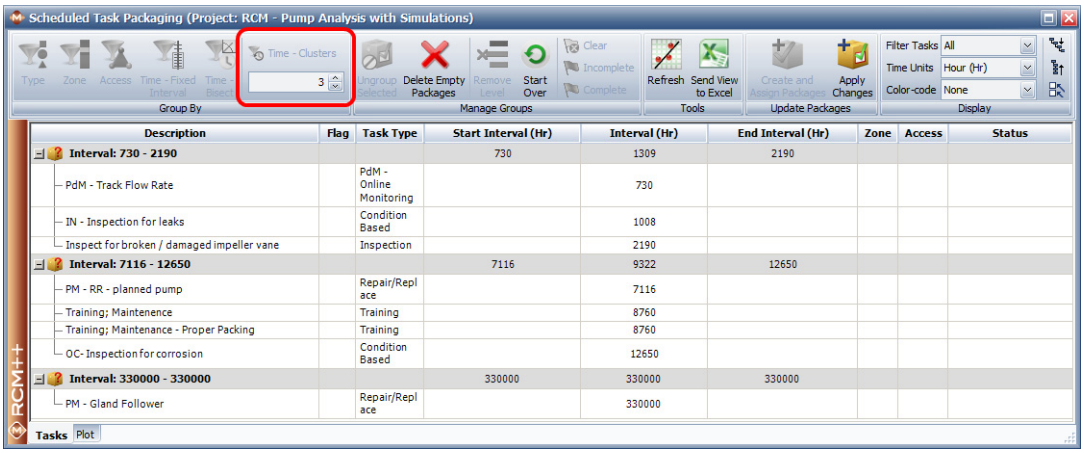
1.11 Using Task Packaging

For a given project, you can use the Scheduled Task Packaging window to review all of the tasks that have been proposed to be performed at fixed intervals, choose which ones to incorporate in the final maintenance plan and, if desired, group tasks into packages for the most efficient allocation of resources.

- Return to the system hierarchy, then choose **System Hierarchy > Tools > Task Packaging**.

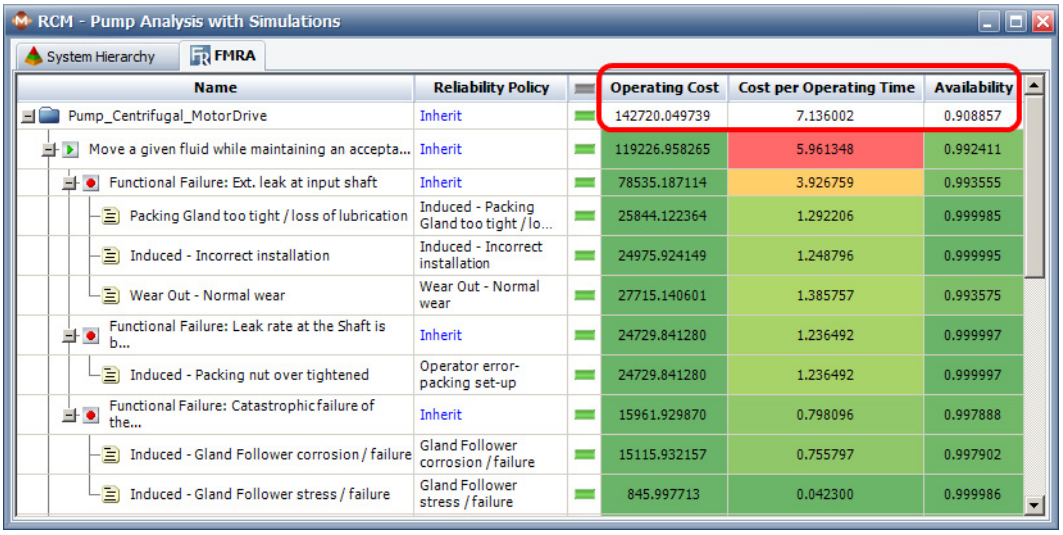
This utility provides several flexible tools to help you select the most effective maintenance packaging plan. For this example, you will use the time clusters feature, which automatically groups tasks into a specified number of intervals.

- Under "Time - Clusters" enter **3** and click **Time - Clusters**. The utility will automatically propose the three packages shown next.



- Click the **Apply Changes** command on the ribbon to create these packages in the database to automatically override the task intervals for the affected maintenance tasks.

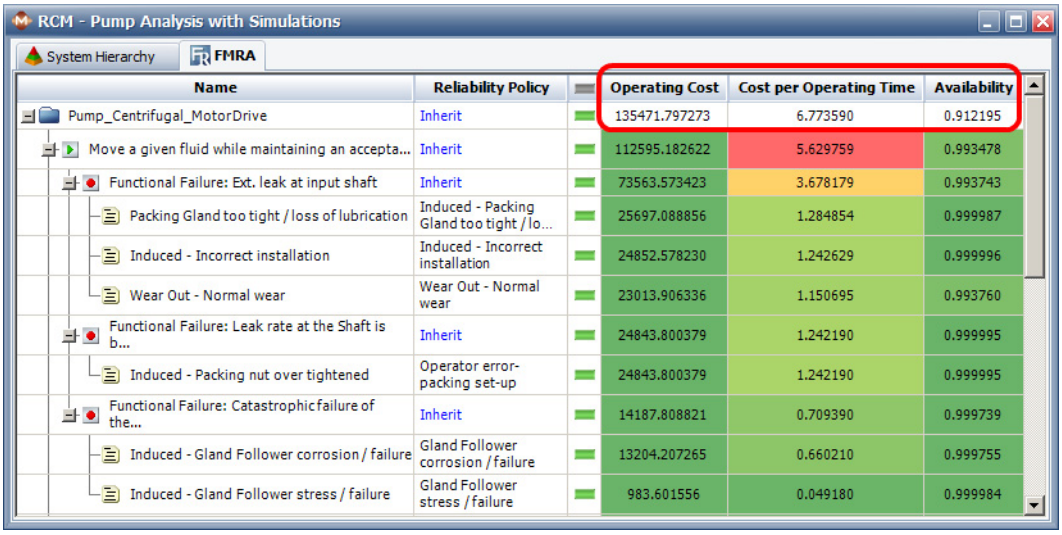
- Close the window, then return to the FMRA and simulate the results again. You can see that the availability is still around 91% and that the cost per operating time has decreased to $7.14. For a period of 20,000 hours, that is a total operating cost of $142,720.05.



- To see what the results would be if there were four packages, return to the Task Packaging window. Select each package and click **Ungroup Selected**.

- When all of the tasks are back to being unassigned, click **Delete Empty Packages** to clear the old groupings.

- Set the number of packages to **4** and click **Time - Clusters** to automatically regroup the tasks into four packages.
- Click **Apply Changes** to save the new packages and override the task intervals.
- Close the window, then return to the FMRA and simulate the results again. You can see that the availability is still around 91%, but the cost per operating time has decreased to $6.78. For a period of 20,000 hours, that is a total operating cost of $135,471.80.



Name	Reliability Policy	Operating Cost	Cost per Operating Time	Availability
Pump_Centrifugal_MotorDrive	Inherit	135471.797273	6.773590	0.912195
Move a given fluid while maintaining an accepta...	Inherit	112595.182622	5.629759	0.993478
Functional Failure: Ext. leak at input shaft	Inherit	73563.573423	3.678179	0.993743
Packing Gland too tight / loss of lubrication	Induced - Packing Gland too tight / lo...	25697.088856	1.284854	0.999987
Induced - Incorrect installation	Induced - Incorrect installation	24852.578230	1.242629	0.999996
Wear Out - Normal wear	Wear Out - Normal wear	23013.906336	1.150695	0.993760
Functional Failure: Leak rate at the Shaft is b...	Inherit	24843.800379	1.242190	0.999995
Induced - Packing nut over tightened	Operator error-packing set-up	24843.800379	1.242190	0.999995
Functional Failure: Catastrophic failure of the...	Inherit	14187.808821	0.709390	0.999739
Induced - Gland Follower corrosion / failure	Gland Follower corrosion / failure	13204.207265	0.660210	0.999755
Induced - Gland Follower stress / failure	Gland Follower stress / failure	983.601556	0.049180	0.999984

- You can continue to experiment with the cost and availability calculations, if desired. When finished, proceed to the next section.

1.12 Generate a Report of the Analysis

RCM++ provides a complete set of reports for your analysis. Reports can be generated in Microsoft Word® and/or Excel, which provides maximum flexibility for customization and the ability to create HTML and/or PDF versions of the reports.

- To open the Reports window, choose **Home > Reporting > Reports**.

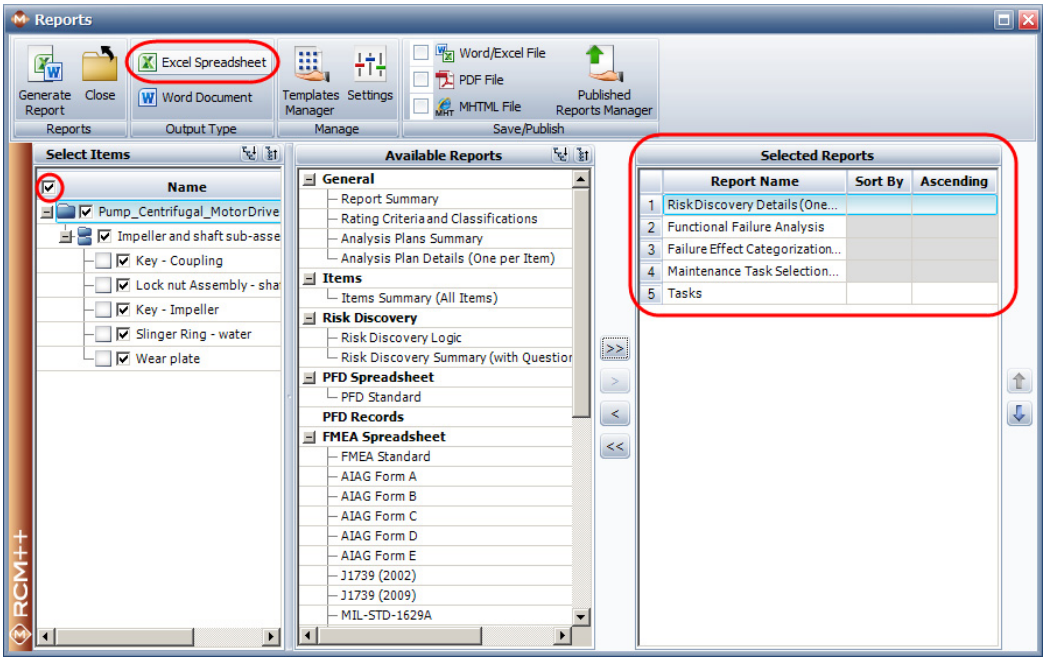
- The Select Items area (on the left) allows you to specify the item(s) from the system hierarchy that will be included in the report. Make sure that all seven items are selected.
- The Available Reports area (in the middle) displays the report forms that are available to be included in the report document, while the Selected Reports area (on the right) displays the report forms that will be included in the new report you are generating now. Click the **Exclude All** icon (<<) to clear the Selected Reports area so you can start building the new report from scratch.
- In the Available Reports area, press **CTRL** and click each of the following report forms so they are all selected at the same time.
  - Under the Risk Discovery heading, select **Risk Discovery Details (One per Item)**.
  - Under the RCM heading, select:
    - **Functional Failure Analysis**
    - **Failure Effect Categorization (One per Effect)**

- **Maintenance Task Selection (One per Cause)**
- **Tasks**

- Click the **Select** (>) icon to move all five of these report forms into the Selected Reports area.

> **Tip:** You can also drag and drop or double-click the report form names to move them back and forth between "available" and "selected."

- Finally, select to generate the report as an **Excel Spreadsheet**. The Reports window will look like the one shown next.



- Click **Generate Report** and specify a name and location for the document. When you click **Save**, a progress bar will appear. After the report is complete, it will open automatically in Microsoft Excel. When you are finished reviewing the reports, close Excel and the Reports window.

1.13 Close the Repository

Congratulations! You have completed the First Steps Example for RCM++.

- To close the sample database, choose **File > Close Repository**.

Note that if you do not close the database, it will be closed automatically when you create or open a new one.