



AUCOTEC
Create Synergy – Connect Processes

Engineering Base

Cause & Effect

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1 General Information

On planning plants and putting them into service, you can define specifications for specific process flows or safety measures. You can define these specifications for cause and effect relations in a cause and effect table (Safety Matrix).

In a cause and effect table (C&E Table), you can specify which actions are to be taken if a specific cause occurs.

This allow you to do the following:

- Definition of the causality for fault-tolerant control systems
To ensure the functional safety, you can define how many parallel, functionally identical devices must still function in the process before the overall system must be shut down.
Example: Two parallel valves are used in a process. If a voting 2oo2 (two out of two) is defined for this process in the C&E table, the process can still continue if one valve fails. The overall process is stopped only if both valves are defective. If the voting was defined to be 1oo2, the overall process would have to be stopped if one valve failed.
- Definition of the causality in case of emergencies
To ensure safety in case of emergencies, you can define which actions are to be taken.
Example: In case of a warehouse fire, the fire department must be alerted, a fire alarm must be set off in the entire production area, the inflow of flammable production goods must be stopped, and so on.
- Definition of the causality in the planning phase
In the table, you can define specifications for various process scenarios or operating modes.
Example: In the operating mode to create a liquid mixture, a vessel may only be filled to 80%. If this filling degree is exceeded (cause), an emergency valve must be opened (effect). However, in the cleaning process, the same vessel may be filled to 100%; in that case, the emergency valve must not be opened.

1.1 Term definitions

Causality

Causality is the relation between cause and effect - it describes the sequence of interrelated incidents and states.

Causal relation = Cause and effect relation (C&E relation)

- Monocausality
One cause results in either one or several effects.
- Causal chain
Strictly temporal sequence of sequential causalities.
One cause results in several sequential effects; such as dominoes falling down one after another.
- Multicausality
Several causes interact or act independently at the same time and result in several effects.

Voting

For process flows, the functional safety must often be guaranteed. For this purpose, several functionally identical devices or systems are installed in parallel.

Via the voting, you can define how many of the devices or systems installed in parallel must be fully functional to ensure the functional safety. If several of the devices or systems installed in parallel are detected to be defective, the overall system (overall process) must be shut down.

The voting is also used to, for instance, check or evaluate the measured values of sensors. In that case, you can, for instance, define how many of the sensors installed in parallel must indicate the same measured value.

- 1oo1: Single-channel processing (there is no parallel installation of functionally identical devices). If the single device fails, the overall system must be shut down.
- 1oo2: Redundant processing with cross-diagnosis. For two functionally identical devices installed in parallel, the overall system is shut down if one device is defective.
- 2oo2: Redundant processing. For two functionally identical devices installed in parallel, the overall system is shut down if both devices are defective. If one device is found to be defective, the intact device is used instead.
- 2oo3: Threefold processing with use of the majority result: Voting (selection of '2 out of 3'). If three functionally identical devices are installed in parallel, the overall system is shut down if two devices are found to be defective.
- For instance, if three functionally identical sensors are installed in parallel, you can define via this voting that two out of the three measured values must be identical for a specific action to take place.
- 2oo4: The system remains stable if two devices fail at the same time.

2 Creation of a Cause & Effect Table

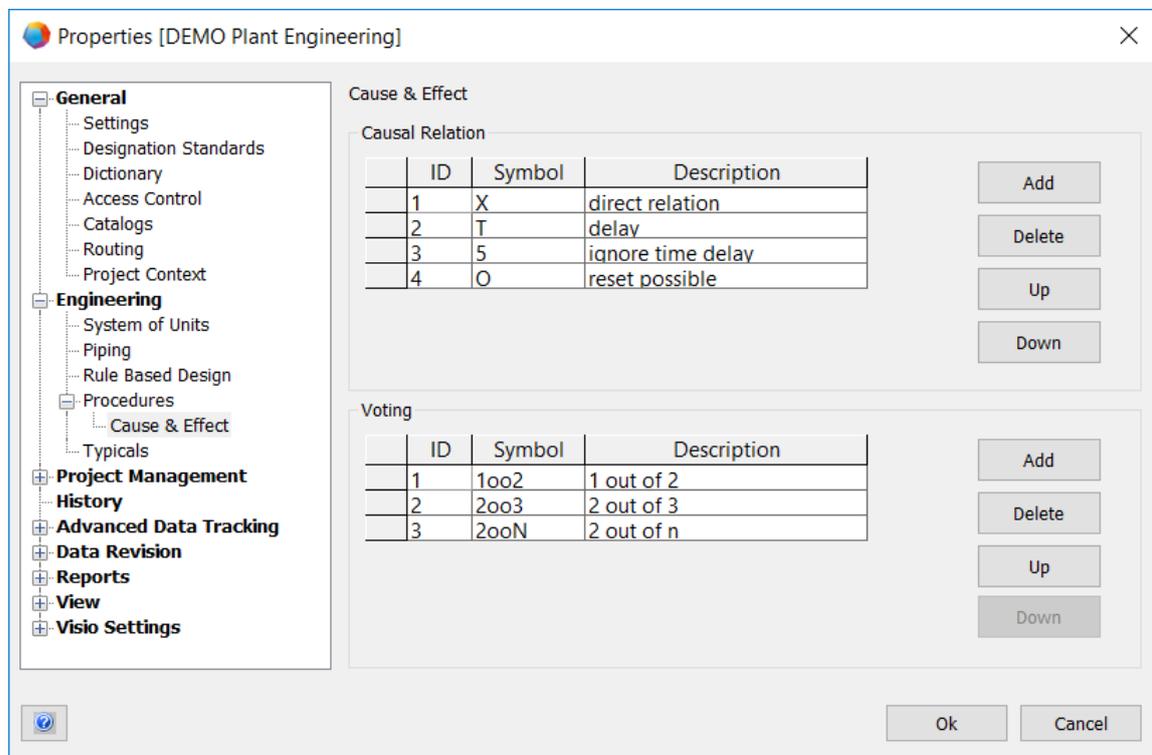
In Engineering Base, you can describe the various causalities in a C&E table. To create that table, carry out the following steps:

- Define the symbols for **causal relations** and **voteings**.
- Define the causalities in a **cause and effect worksheet**.
- Create and output the **cause and effect table** via Excel.

To define the symbols for causal relations and voteings

1. Select the project. On the shortcut menu, click **Properties**.
2. In the **Properties** dialog of the project, expand the **Engineering** folder, then expand the **Procedures** folder.
3. Click **Cause & Effect**.

This opens the **Cause & Effect** dialog.



4. Under **Causal Relation**, define the symbols for the required causal relations.
5. Under **Voting**, define the symbols for the different voteings.
6. Click **OK** to save your entries.

Meaning of the columns

ID	For the ID, you can choose a value between 1 and 50. Either you enter the ID directly or you select a value using the button  .
Symbol	Enter the symbol that is to be used in the C&E table for a causal relation or a voting.
Description	Enter a description for the defined symbol.

Meaning of the buttons

Add	Using this button, you can create a new line for the definition of a causal relation or a voting. The smallest available ID is automatically entered as ID.
Delete	Deletes the marked line in the causal relation or voting area.
Up / Down	The marked line in the causal relation or voting area is moved up or down in the displayed list. These actions do not influence the ID.

To create a cause & effect table

1. Mark a process and click **Procedures** on the shortcut menu.
2. Select a worksheet template from the list of available C&E templates.

9 Record(s)	Part of	Designation	Type	Comment	Delay (Cause)	Voting (Cause)	Cause Group (Cause)	C&E Relation	Delay (Effect)	Part of	Designati...	Type	Comment
1	42 700 02 F6004	DAH	Signal	Flow high	10,00 s	2ooN	1	T	30,00 s	42 700 02 P001 P001A	7603	Loop Control	
2	42 700 01 P0001	AL	Signal		10,00 s	2ooN	1	T	30,00 s	42 700 02 P001 P001A	7605	Loop Control	
3	42 700 01 P0001	AL	Signal		10,00 s	2ooN	1	T	35,00 s	42 700 02 T04	7301	Loop Control	
4	42 700 01 T0020	SHH	Signal		0,00 s	1oo2	2	X	0,00 s	42 700 02 P001 P001B	7601B	Loop Control	
5	42 700 01 P0001	AL	Signal		0,00 s	1oo2	2	T	10,00 min	42 700 02 T04	7602	Loop Control	
6	42 700 02 F6002	AH	Signal		0,00 s	2ooN	3	X	0,00 s	42 700 02 T04	7604	Loop Control	
7	42 700 02 F6002	AH	Signal		0,00 s	2ooN	3	X	0,00 s	42 700 02 T04	7606	Loop Control	
8	42 700 01 H0024	LH	Signal		0,00 s	2oo3	4	X	0,00 s	42 700 01 T03 T03A	7103	Loop Control	
9	42 700 02 F6002	AL	Signal		0,00 s	2oo3	4	X	0,00 s	42 700 02	F003	Mechanical Tag	

3. Fill in the table. Assign the causal relation and voting symbols (column header highlighted in light gray) of your choice to the cause objects (column header highlighted in green). Define the effect objects (column header highlighted in purple).
4. Save the worksheet via Excel. To do so, click  on the toolbar.
5. In the **Cause & Effect Editor** dialog, select the template of your choice and the storage location.

The temporary folder of Engineering Base is offered as storage location C:\ProgramData\Aucotec\Engineering Base\Tmp\XXX.

The proposed name of the created C&E table is composed as follows: Project name_process name (process for which the C&E worksheet has been created , incl. the names of the superordinate processes).

Click  to define the storage location via a selection dialog. The following options are available:

- The Processes folder
 - The Documents folder
 - The file system.
6. Click **OK** to create and save the C&E table.

Creation of a Cause & Effect Table

Project: DEMO Plant Engineering

Normal Operation

Cause Group (Cause)	Part of	Designation	Type	Comment	Delay (Cause)	Voting (Cause)	Delay (Effect)	Part of	Designation Type	Comment
1	42 700 02 F6004	DAH	Signal	Flow high	10,00 s	2ooN	0,00 s	42 700 01 T03 T03A	7103	Loop Control
1	42 700 01 P0001	AL	Signal		10,00 s	2ooN	30,00 s	42 700 02 P001 P001J	7605	Loop Control
2	42 700 01 T0020	SHH	Signal		0,00 s	1oo2	0,00 s	42 700 02 P001 P001J	7601B	Loop Control
2	42 700 01 P0001	AL	Signal		0,00 s	1oo2	30,00 s	42 700 02 P001 P001J	7603	Loop Control
3	42 700 02 F6002	AH	Signal		0,00 s	2ooN	0,00 s	42 700 02 T04	7604	Loop Control
4	42 700 02 F6002	AL	Signal		0,00 s	2oo3	35,00 s	42 700 02 T04	7301	Loop Control
4	42 700 01 H0024	LH	Signal		0,00 s	2oo3	10,00 min	42 700 02 T04	F003	Mechanical Tag
							0,00 s	42 700 02 T04	7602	Loop Control
							0,00 s	42 700 02 T04	7606	Loop Control

Legend

O	Action with possibility to reset
X	Action Normal ShutDown
T	Action if no reaction after X min
5	Ignores time delay on effects

Normal Operation

2.1 The Cause & Effect Worksheet Template

In the worksheet, you can capture all objects that are to serve as causes and effects. To do so, the cause and effect objects of other worksheets have to be inserted into the C&E worksheet.

The C&E relation and voting symbols defined in the project properties are offered for selection for the definition of the causality. In addition to that, you can also group together several relations to also reflect multicausalities.

Filter	Part of	Designati...	Type	Comment	Delay (Cause)	Voting (Cause)	Cause Group (Cause)	C&E Relation	Delay (Effect)	Part of	Designa...	Type	Comment
1	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
2	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
3	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
4	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
5	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
6	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...
7	Drop cause object here	Drop caus...	Drop c...	Drop caus...	... hr				... hr	Drop effect object here	Drop eff...	Drop effe...	Drop eff...

In the worksheet template, the column headings are highlighted in different colors:

- Green: Cause objects
- Gray: Data defining the causal relation in further detail, e.g. C&E relation, voting, delay, cause group
- Purple: Effect objects.

To increase the clarity, the columns to define the causal relations are framed.

The columns and their meaning

Column	Meaning
Part Of	These columns of cause or effect objects cannot be edited manually, they have to be filled with data of a second worksheet (e.g. Functions (Extended)).
Designation	
Type	
Comment	
Delay (Cause)	Enter a time interval that is to be kept before the subsequent actions (effect) are to be triggered. For instance, a delay of 1 minute is to be kept before an alarm sequence is started. This way, the indicated values can again be verified. Enter a value with a subsequent space character and select the time unit from the list of available units.
Voting (Cause)	Via the arrow button <input type="checkbox"/> , select a symbol from the list of defined voting symbols. The voting symbols are defined in the Project Properties/Engineering/Procedures area of the Cause & Effect dialog.
Cause Group (Cause)	You can group associated causalities into a cause group. You can select any designation for a cause group. Enter the same cause group at all associated causalities.

C&E Relation	Via the arrow button  , select a C&E symbol from the list of defined C&E symbols. The C&E symbols are defined in the Project Properties/Engineering/Procedures area of the Cause & Effect dialog.
Delay (Effect)	Enter a time delay for the start of the effect. For instance, a sensor measures faulty values. Before the automatic plant shutdown is triggered, checks can be done in the predefined time frame to find out whether the shutdown is really necessary. Enter a value with a subsequent space character and select the time unit from the list of available units.

The icons and their meaning

In addition to the functions that are available in a worksheet by default, the following functions are available in the C&E worksheet.

	Save Cause and Effect (via Excel). Starts the creation of the C&E table. In the Cause and Effect Editor dialog, you can define the Excel template to be used and the storage location of the table.
	Insert Item A new empty row is inserted after the marked row.
	Duplicate Item A new empty row is inserted after the marked row. The contents of the following columns of the marked row are inserted into the new row: <ul style="list-style-type: none"> • Delay (Cause), • Voting, • Cause Group, • C&E Relation, • Delay (Effect).
	Copy Item A new row is inserted after the marked row, and the entire content of the marked row is inserted into the new row.

Inserting Cause and Effect Objects

To insert cause and effect objects, additionally open one or several worksheets containing the data you require (e.g. Worksheet Functions (Extended)).

1. In the worksheet, mark the row containing the object (e.g. the function) that is to be taken over into the C&E worksheet.
2. Keep the left mouse button pressed and drag the object into the target row in the C&E worksheet.

The data of the object is taken over into the C&E worksheet.



One object can be both cause or effect object, but not in the same C&E relation.

Deleting a Cause or Effect Object

1. Mark a row containing object information of the cause or effect object that is to be deleted.
2. Click **DEL** or select **Remove Cause** or **Remove Effect** on the shortcut menu.
Only the object information is deleted. Any other entries in the row are kept.

Changing a Cause or Effect Object

Defined cause or effect objects cannot be overwritten. Before you can assign a new value to an object, the old object must be deleted.

Structuring the Worksheet

To improve the clarity of the worksheet or to highlight specific columns, you can display in bold the right boundary line of a column.

To define frames in the cause and effect worksheet

1. Click the header line of the column that is to be displayed with a bold right boundary line.
2. On the shortcut menu, select **Properties**.
3. In the Options dialog, click **Column/Format**.
4. In the **Frames** area, mark the option **Right Column Border**.
In the worksheet, the right boundary line of the column is displayed in bold.

2.2 The Cause & Effect EXCEL Templates

Creating a C&E table in Excel requires a specific Excel template.

The template must be stored in the **Project Templates** under **Configurations/Cause & Effect**.

2.2.1 The Settings Sheet

This sheet contains general settings to create the template.

1	Description	Value	Information
2	first footer row number	7	
3	first data row	5	
4	first data column	1	
5	orientation	VERTICAL	accepted values: HORIZONTAL, VERTICAL
6			
7			

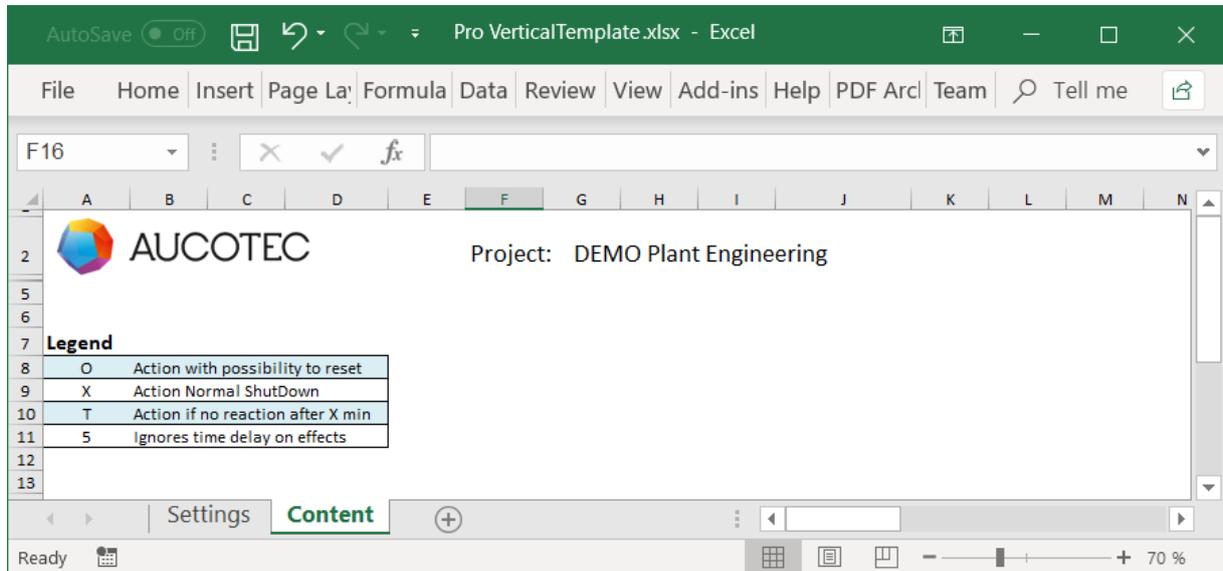
Sheet "Settings" of the standard template "Pro VerticalTemplate.xlsx"

The keywords listed in the **Description** column manage the output of the value on exporting data. The **Value** column contains the row or column number that is assigned to the keyword of the **Description** column.

Description	Meaning
first footer row number	Row number of the first row that can be used to enter a comment or, respectively, a footer after the data area.
first data row	Row number of the first cell the assistant uses to enter data into the table.
first data column	Column number of the first cell the assistant uses to enter data into the table.
orientation	Indicates the orientation of the table. The valid values are "HORIZONTAL" and "VERTICAL".

Starting from the first cell into which data is written, the assistant adds the data to the right and to the bottom.

2.2.2 The Content Sheet



Sheet "Content" of the standard template "Pro VerticalTemplate.xlsx"

User-specific Dataset Area

In the template, the dataset area is white. The first row into which the data of the C&E worksheet is inserted is defined by the settings in the **Settings** Sheet.

The following formattings carried out in the dataset area are taken into account for the export:

1. Definition of header lines
2. Definition of footers
3. Definition of the background color of the data columns (this has to be defined in the first data row)
4. Font of the entire table.