Event Chain Diagrams

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Relationships between project risks can be very complex. Risks can be assigned to different activities and resources, have different probabilities and impacts, and have correlations or act as triggers with each other. Due to this complexity, we recommend visualizing project events and event chains using event chain diagrams. Event chain diagrams use the familiar structure of a Gantt chart to visualize the relationships between project risks. State tables are also a useful tool and can be used to define the state of an activity. This paper provides a specification of Event chain diagrams and State tables along with advice on how to use them effectively.

Event Chain Methodology

Event chain methodology is an extension of "traditional" and event-based quantitative risk analysis. Event chain methodology is an uncertainty modeling and schedule network analysis technique that is focused on identifying and managing events and event chains that affect project schedules. It is a logical formula to model and analyze a wide variety of different problems related to managing uncertainties in project schedule (Virine and Trumper 2007, Virine and Trumper 2013).

According to Event chain methodology activities in project schedule are affected by external events that transform them from one state to another (Virine 2013). The notion of state means that activity will be performed differently as a response to the event. This process of changing the state of an activity is called excitation. For example, an activity may require different resources, take a longer time, or must be performed under different conditions. As a result, this may alter the activity's cost and duration. The original or planned state of the activity is called a ground state. Other states, associated with different events are called excited states. For example, in the middle of an activity requirements change. As a result, a planned activity must be restarted. Similarly to quantum mechanics, if a significant event affects the activities, it will dramatically affect the property of the activity; for example, cancelling the activity (Agarwal and Virine 2017).

Each state of activity in particular may subscribe to certain events. It means that an event can affect the activity only if the activity is subscribed to this event. For example, an assembly activity has started outdoors. The ground state the activity is subscribed to the external event "Bad weather". If "Bad weather" actually occurs, the assembly should move indoors. This constitutes an excited state of the activity. This new excited state (indoor assembling) will not be subscribed to the “Bad weather”: if this event occurs it will not affect the activity.

Some events can cause other events. These series of events form event chains, which may significantly affect the course of the project by creating a ripple effect through the project. Here is an example of an event chain ripple effect:

- Requirement changes cause a delay of an activity.
- To accelerate the activity, the project manager diverts resources from another activity.
- Diversion of resources causes deadlines to be missed on the other activity
- Cumulatively, this reaction leads to the failure of the whole project.

Events can also cause execution of activities and group of activities. Risk response efforts are considered to be events, which are executed if an activity is in an excited state. Risk response events may attempt to transform activity from excited state to the ground state.

Analysis of project schedules with event and event chain are performed using Monte Carlo simulation. The result of analysis is a risk adjusted project schedule. The event and event chains can be ranked as a result of analysis. Events and event chains, which affect the project the most are called critical events or event chains.

Information about events and event chains, particularly probabilities and impacts of risks should be monitored and updated as part of project control.

Why Event Chain Diagrams

In science, engineering, management and even or ordinary life people prefer to use plans, diagrams, and charts as opposed to written descriptions. Why does it happen? In business, including project management, we tend to talk about concepts rather than objects and we are much more likely to be remember concepts if they are presented as pictures rather than as words. In psychology this effect is called the *picture superiority effect*. In fact, our brain processes visual and verbal information differently (Paivio 1971, Paivio 1986, Sternberg 2006). When we store and retrieve information from our memory, we use both words and images. For example, when we hear the words “Project Schedule” we also retrieve am image of the schedule, probably in the familiar form of a Gantt chart. Psychologists also found that images are more distinct from each other than words, which increases the chance that they will be retrieved from memory. The picture superiority effect is used in learning, user interfaces, and advertising.

Now that we have convinced you that pictures can be better than words, let’s see how it can help you to describe risk events in project management.

Diagrams in Business Processes

Diagrams in business analysis can show three things:

- actions, such as activities on the Gantt chart
- data, such as information in data flow diagrams, and
- combinations of actions and data.

Traditional visualization techniques include bar charts or Gantt charts and various schedule network diagrams (Project Management Institute, 2016). Other visualization techniques of project schedules include various network diagrams, which are essentially flow charts that show relationships between activities. Gantt charts may present uncertainties in project schedules. For example, a triangle on a risk adjusted project schedule can show low and high durations of activities as a result of risk analysis (Figure 1).

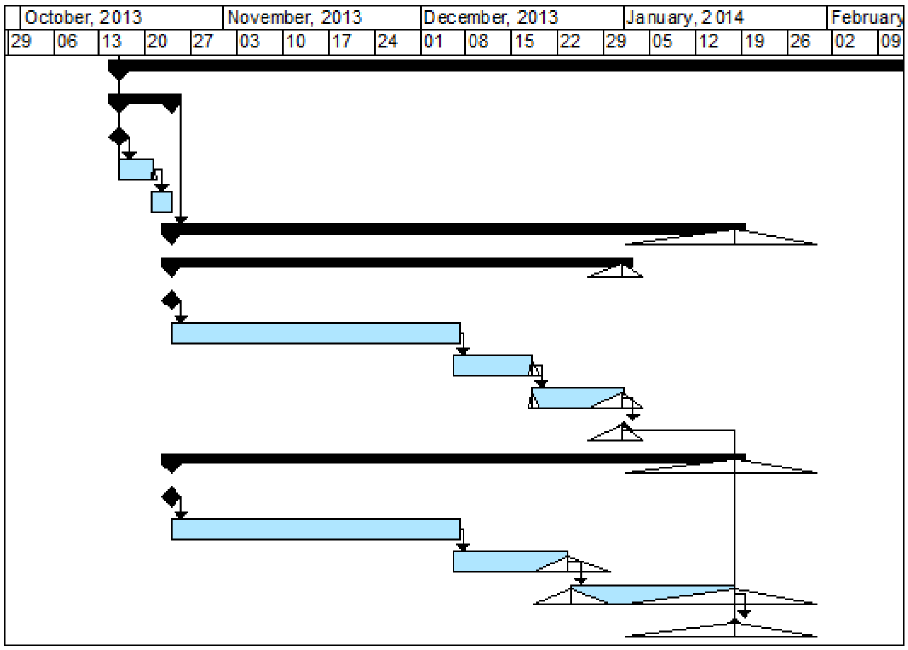

Figure 1. Gantt chart with uncertainties in task durations as a result of project risk analysis

In project risk management, analytical models also include events, decisions, various conditions, and many other parameters. These types of business models can be very complex and should be visualized. Here are the key ideas behind many diagramming tools:

- Diagrams should be *standardized*. Everybody should have a common understanding of the elements. To support standardization, the diagrams should have a specification or set of rules that outlines how the diagram will appear and the meaning of each component
- Diagrams must be *intuitive*; not everybody will read the specification and not everybody will follow specification precisely: therefore, people who use these diagrams should find them easy to understand.
- Diagrams must be *simple*; if it takes too much time to create or interpret a diagram, the value of the diagram is diminished.

Visual Tools for Probabilistic Business Problems

Visual modeling tools are widely used to describe complex models in many industries. Here are few examples. Unified modeling language (UML) is actively used in the software design (Arlow and Neustadt, 2003; Booch, Rumbaugh, and Jacobson, 2005). Visual modeling languages are the next step above just individual diagrams. It involves many diagrams related to each other. It is also used to present sequence of certain activities, system states, and interactions between different components of the system. Essentially UML is intended to provide a standard way to visualize the design of a system. In particular, this visual modeling language approach was applied to defining relationships between different events.

Another solution for modeling complex business and technology projects is Object-process methodology (OPM) (Yaniv and Dory 2013). It is a bimodal visual and textual conceptual modeling language and an emerging ISO Standard (ISO- 19450 "Automation systems and integration -- Object-Process Methodology") for system modeling and design. OPM is easy to use and understand set of standardized diagrams, which help to visualize complex systems in different industries including project management.

A number of diagrams actively used in the field of decision and risk analysis and risk management. We already discussed some risk management visual tools, such as risk matrix with different types of information presented on it, frequency histograms and cumulative probability plots which present results of Monte Carlo simulation, and risk mitigation waterfall charts.

In addition a number of diagrams are used for project decision analysis. Among them are decision trees, strategy tables, cause-and-effect diagrams, force-field diagrams, mind maps, and various flow charts. Some of them became valuable tools in project management and added to the Project Management Body of Knowledge (Project Management Institute 2016). All these diagrams are intended to simply our understanding of a system, which is in our case are projects with uncertainties. Visual modeling languages and diagrams are also applied to probabilistic business problems (Virine and Rapley, 2003; Virine and McVean, 2004). Uncertainties associated with project variables, relationships between uncertain variables and result of analysis, as well as calculation algorithms can be displayed using these diagrams.

Event Chain Diagram Specification

Event Chain Diagrams are one of the principles of Event chain methodology. They are intended to show events that affect project schedules. Below is a specification of these diagrams.

1. Single Events.
   a. Single events are presented as arrows on the activity's bars on a Gantt Chart (Figure 2). Arrows pointing down represent *threats*. Arrows pointing up on the Gantt chart represent *opportunities*. In addition to opportunities arrows pointing up can represent events e.g. "Risk Response Plan is executed". It occurs when response plan activity and group of activities are completed. Two arrows starting at the same location but pointing in opposite directions represent a threat and opportunity for the same risk[1]. The particular horizontal position of the arrow on the Gantt bar is not relevant.

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[1] It occurs if one risk belongs to multiple categories. For example, one risk can threat of it affect cost and opportunity if it affects technology.

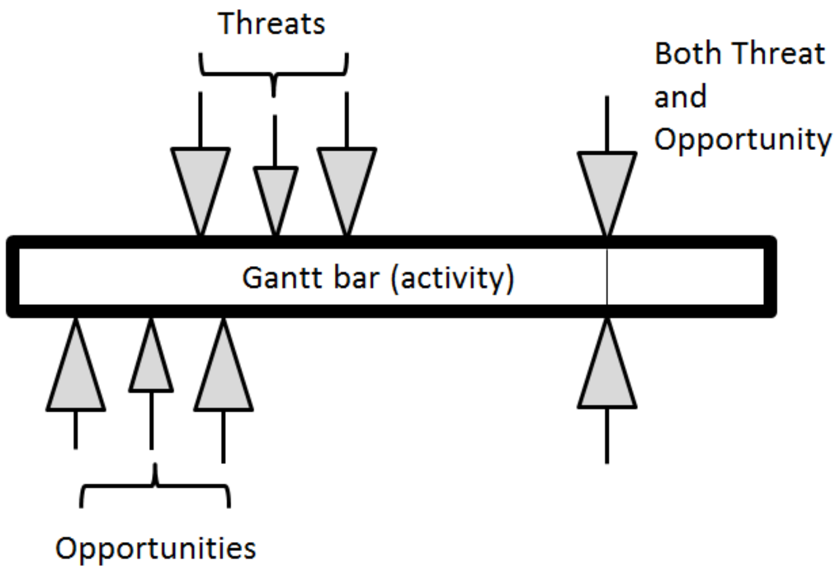

Figure 2. Showing threats and opportunities

b. The size of the arrow represents probability. If the arrow is small, the probability of the event is correspondingly small. Colors represent the calculated the impact of the risk[2]. Higher impact risks have red or darker color. Low impact risks have green (lighter) color. Risk probability and impacts are before mitigation unless it is otherwise explicitly noted on the diagram (Figure 3).

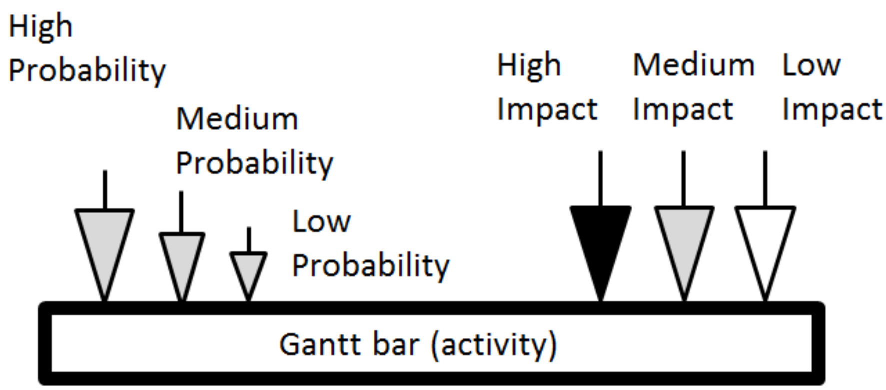

Figure 3. Showing risks with different probabilities and impacts

c. Optional Rule. Excited states are represented by elevating the associated section of the bar on the Gantt chart (Figure 4). The height of the state's

[2] In project risk analysis calculated impact can be different than original (user-defined) impact of the risks. For example, is task is not on the critical path, calculated impact of risk on project duration can be zero, while original impact can be greater than zero. In this case calculated impact is determined by schedule risk analysis using Monte Carlo simulations.

rectangle represents the relative impact of the event, which leads to the excited state. All excited state of activities should have a textual description. Only states that have different event subscriptions than ground states should be shown.

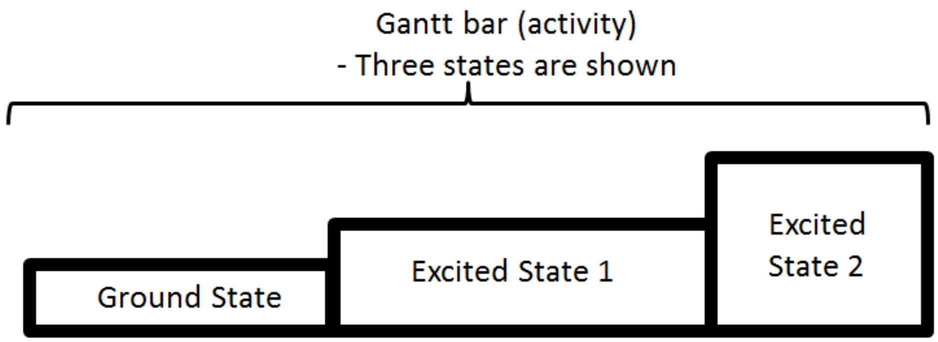

Figure 4. State of the activity

d. Issues are shown as arrow in the circle (Figure 5). Issues are shown at the beginning of excited state rectangle because it transforms activity from one state to another. Closed or transferred risks are shown using dashed lines[3]. Color of arrow is white. Closed issue is shown in the circle with dashed border line.

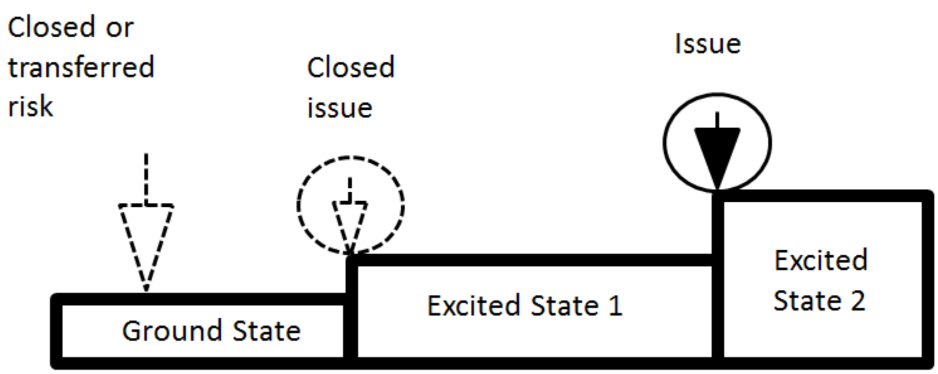

Figure 5. Issues, closed, or transferred risks

e. Optional Rule. Statistical distribution of moment of risk may be shown above activity bar (Figure 6). Is it recommended not to show uniform distributions for moment of risk as they are the default in many cases.

[3] Risks can be transferred from one activity to another or from one project to another as part of risk management strategy. In original activity where the risk is transferred from the arrow will be shown with solid lines.

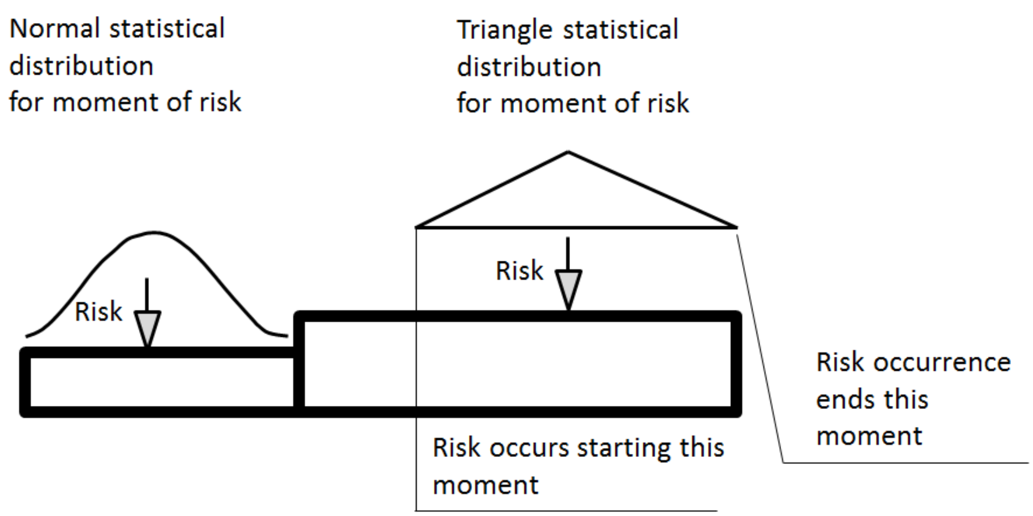

Figure 6. Statistical distribution for the moment of risk

f. In Event chain methodology risks can be local and global. Local risks impact a particular activity. Global risks impact all activities. Global threats are shown at the top of the diagrams pointing down. Global opportunities are shown at the bottom of diagrams pointing up. Both threats and opportunities belonging to the same global risk are placed at the top and at the bottom of the diagram along the same vertical line (Figure 7).

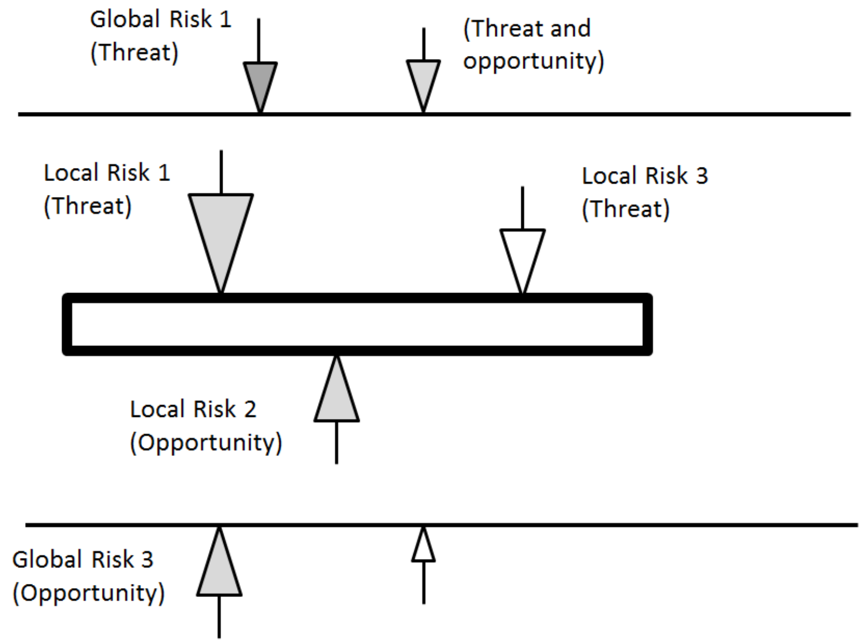

Figure 7. Local and global threats and opportunities

g. Time-dependent global risks, or risks affecting activities running during a certain time period have a vertical dashed line associated with them. Statistical distribution for moment of risk can be shown around that arrow, representing time-dependent global risk (Figure 8).

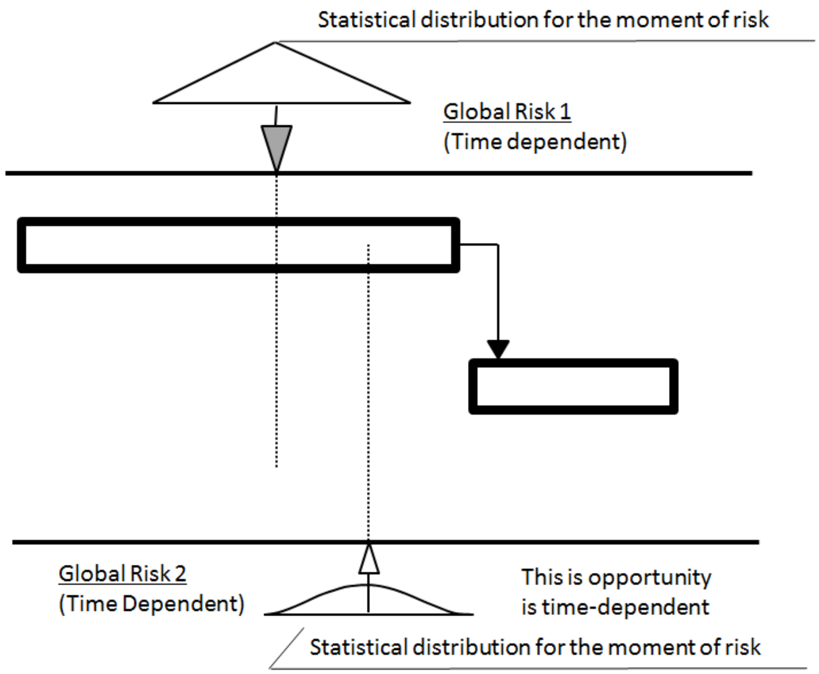

Figure 8. Time dependent global risks

a. Optional Rule. Name of risk can be shown next to the arrow and highlighted, in addition, probability, impact or risk ID can be shown. Sometimes the same risk will be assigned to different tasks. In this case the name of risk will be the same for different arrows pointing to different bars. Risk ID can also be shown next to the arrow.

b. Optional Rule. Risk probability and impact can included with the risk arrow. It is possible to cut names “Probability:” to “Prob:”, or just “P:”, and “Impact:” to “Imp:”, or just “I:”.

c. Optional Rule. Before mitigation and after mitigation risk probability and impact can be written together separated by slash “/”. For, example: “P: 50%/40%” means “Probability before mitigation is 50%; Probability after mitigation is 40%”.

Since many different risks can be shown on the same Gantt bar, if there is no space to show all arrows, risks with lower probability and impact can be omitted.

Figure 9 presents two global and three local risks. Particularly, Local Risk 1 (threat) is mitigated: probability reduced from 70% to 30% and impact reduced from 10% to 5%. Local Risk 2 (opportunity) is enhanced. Probability increased from 40% to 50% and impact increased from 10% to 15%. Global Risk 1, Global Risk 2, and Local Risk 3 are unmitigated.

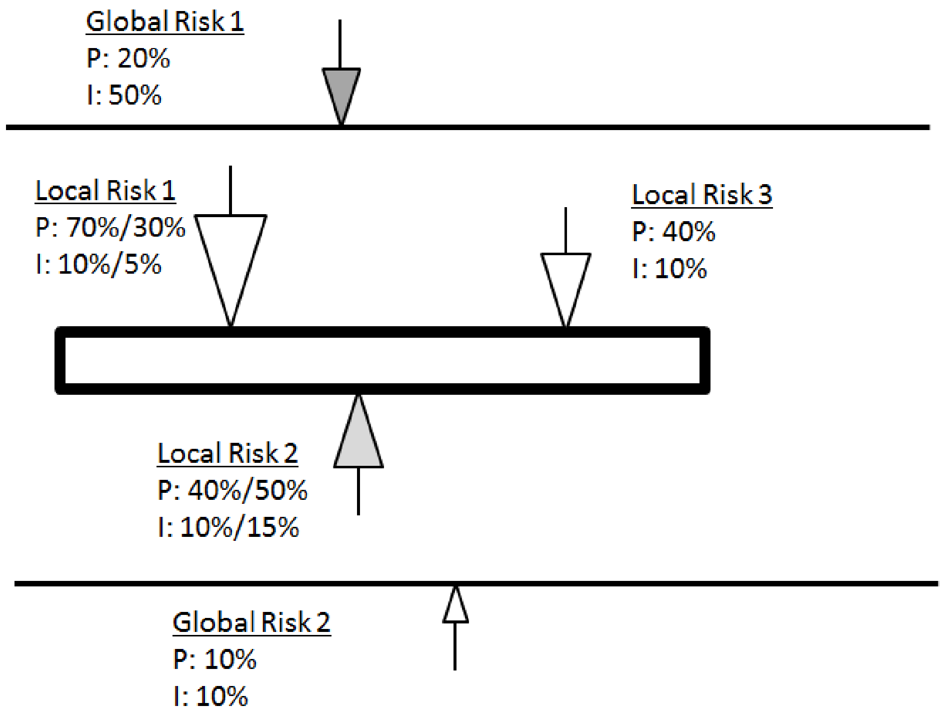

Figure 9. Local and global risks with different probabilities and impacts

2. Event Chains

   a. Event chains are shown as lines connecting arrows depicting events. Both curved line or line containing multiple straight segments are acceptable.

   b. Optional Rule. Event chains may have a textual description

   c. Critical event chains are highlighted[4]. Textual description (e.g. word "Critical") may be included.

   d. Optional Rule. Different event chains are presented using different colors or line types.

   e. If one event triggers another event, event chain lines will have an arrow pointing to the triggered event. If an event chain line does not have any arrows, it means that the chain does not have any triggers; rather, events are correlated with each other.

   f. Optional Rule. Correlation coefficient or probability that one event is triggered by another event is presented on event chain in the rectangular box.

   g. Event chains may trigger another activity. In this case event chain line will be connected with the beginning of activity with optional arrow.

[4] Critical event chain affects the project schedule the most. Critical event chains are determined based on schedule risk analysis as a result of Monte Carlo simulations.

h. Event chains may trigger a group of activities. In this case, this group of activities will be surrounded by a box or frame and an event chain line will be connected to the corner of the box or first activity within a frame.

Here is an example of event chain diagram with two event chains (Figure 5). "Event Chain 1" includes Event 1 that triggers "Event 2". "Event 2" triggers "Event 4" with probability 50%. "Event Chain 2" is shown using different line type. It includes "Event 1" which triggers "Event 3". This event chain is critical. This is an example of multicasting where one event triggers two events.

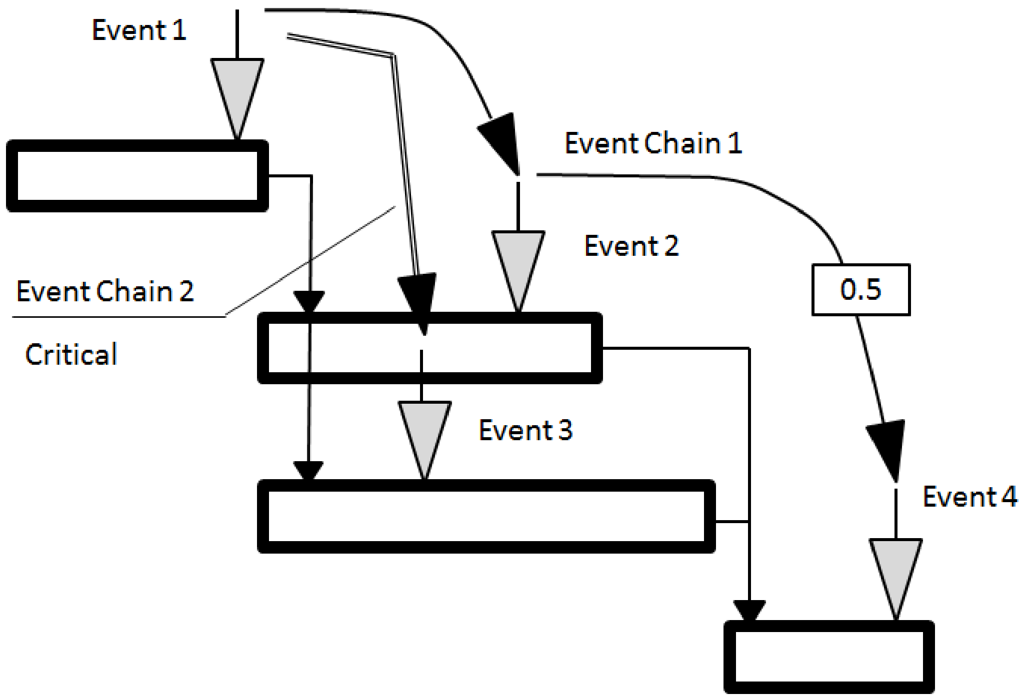

Figure 10. Two event chains with multicasting

Figure 11 shows one event chain. Event 2 triggers an activity with a probability of 50%.

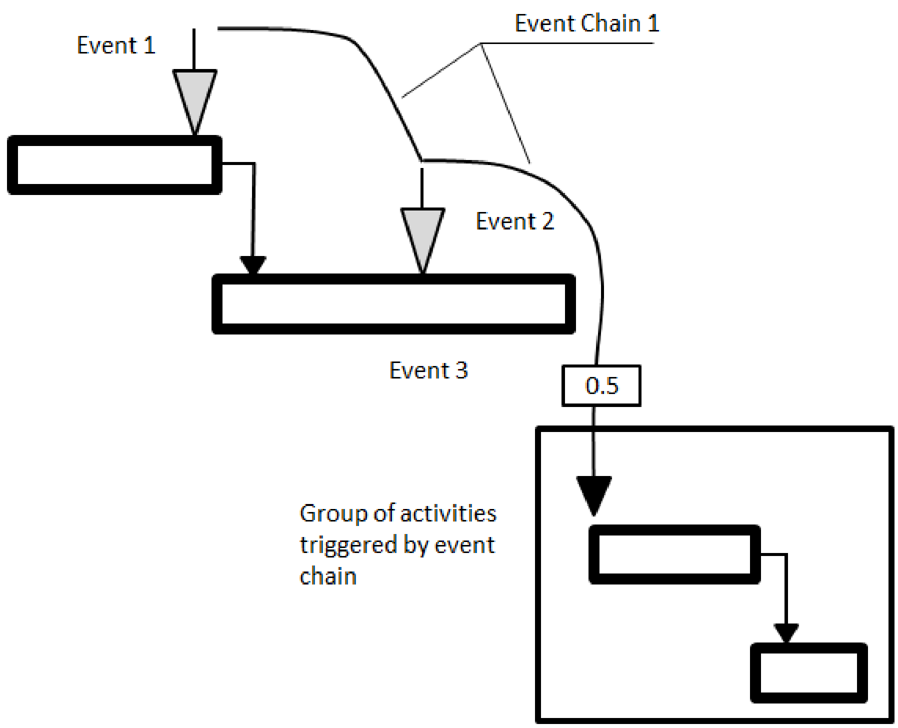

Figure 11. Event chains with correlated events and the group of activities triggered by event

Figure 12 shows event chains related to execution of risk response plan. Here we have an event chain with three events:

1. Original Event, which triggers a response
2. Event “Execute Response Plan”, which executes a group of activities
3. Event “Risk Response is Completed”. It is can be depicted as an opportunity because it moves activities to lower excited state.

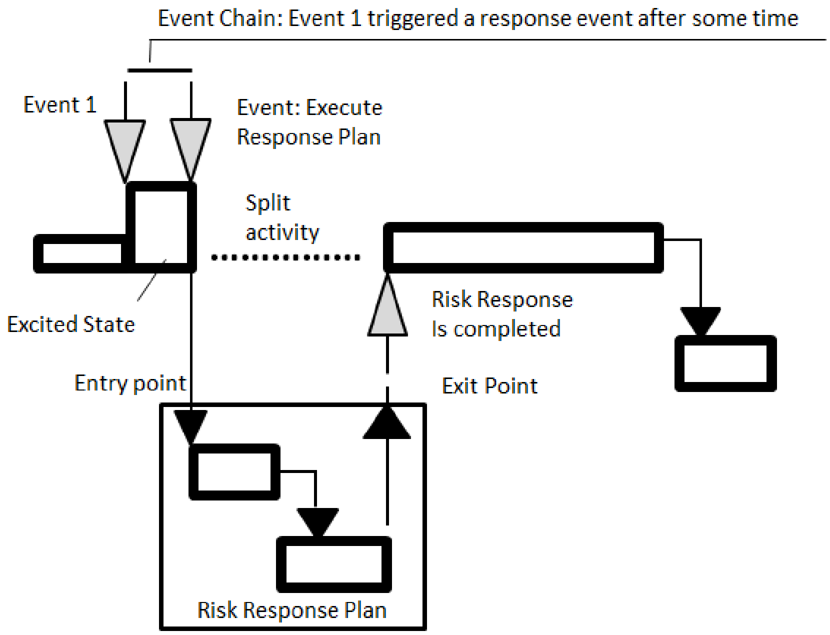

Figure 12. Execution of risk response plan

How to Use Event Chain Diagrams

The central purpose of event chain diagrams is not to show all possible individual events. Rather, event chain diagrams can be used to understand the relationship between events. Therefore, it is recommended the event chain diagrams be used only for the most significant events during the event identification and analysis stage.

Event chain diagrams can be updated once the project has started. Updates can include the probability and impact of events, events may be removed or altered if they do not occur or are avoided, risks can be converted to issues or lessons learned etc. It is important to save different versions of diagrams during the course of a project for reviews of lessons learned.

Multiple diagrams may be required to represent different event chains for the same schedule because a Gantt chart may become crowded. To avoid busy and difficult to interpret diagrams the following information is not included to Event chain diagram specification:

- Mitigation plans. The only way to show risk mitigation is by showing probability and impact before and after mitigation.
- Residual risks
- Risk cost, risk description, risk categories, impact types, and other risk properties
- Information about risk alternatives
- Lessons learned. Analysis of lessons learned could be performed using the original diagrams with updates
- In case of large schedules, only high level task may be included to the Gantt chart for event chain diagram.

All this information in theory could be shown in the diagram, but it would in unintuitive and offer too much information.

Event chain diagrams can be used as part of the risk identification process, particularly during brainstorming meetings. Members of project teams can manually draw arrows between activities linked on the Gantt chart, as well as use any suitable project management or diagramming software. Event chain diagrams can be used together with other diagramming tools.

State Tables

State table is used to simplify the definition of events and states of the activities. Columns in the state table represent events affecting the activity; rows represent the states of an activity. Information for each event in each state includes four main properties of event subscription:

- probability of the risk
- moment of risk
- excited state of the activity
- impact of the event.

If a cell is empty the state is not subscribed to the event.

An example of a state table for a construction development activity is shown on Table 1. The ground state of the activity is subscribed to two events: “Broken Equipment” and “Low quality of prefabricated element”. If either of these events occurs, they transform the activity to a new excited state called “Repair”. “Repair” is subscribed to another event: “Delay with constructor”. Two previous events are not subscribed to the “repair” state and therefore cannot reoccur while the activity is in this state.

	Event Subscription		
	Event 1: Broken Equipment	Event 2: Low quality of prefabricated element	Event 3: Delay with constructor
Ground state	*Probability*: 20% *Moment of event*: any time *Excited state*: repair *Impact*: delay 1 week	*Probability*: 10% *Moment of event*: any time *Excited state*: repair *Impact*: delay 1 week	
Excited state 1: repair			*Probability*: 10% *Moment of event*: beginning of the state *Excited state*: replacing constructor

			Impact: delay 2 days
Excited state: replacing constructor			

Table 1. Example of State Table

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