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THE FTA METHOD AND A POSSIBILITY OF ITS APPLICATION IN THE AREA OF ROAD FREIGHT TRANSPORT

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Abstract

The Fault Tree process utilizes logic diagrams to portray and analyse potentially hazardous events. Three basic symbols (logic gates) are adequate for diagramming any fault tree. However, additional recently developed symbols can be used to reduce the time and effort required for analysis. A fault tree is a graphical representation of the relationship between certain specific events and the ultimate undesired event (2). This paper deals to method of Fault Tree Analysis basic description and provides a practical view on possibility of application by quality improvement in road freight transport company.

Key words

Fault Tree Analysis, fault tree, quality, transport service, quality improvement, logic gate

INTRODUCTION

Fault Tree Analysis – FTA – is based on reliability of difficult systems and comes from specified key problem – dangerous point, the process that is divided into the partial problems, events or primary acts.

The fundamental concept in fault-tree analysis is the translation of a physical system into a structured logic diagram (fault tree), in which certain specified causes lead to one specified TOP event of interest (4).

By using the possibility theory and statistic survey results, it is possible to apply this method also in the area of road freight transport.

"Fault tree" progresses systematically from symptoms of problem to their reasons and provides summary model of the faults reasons in different levels.

“The two basic units involved are the AND and OR gates. Another, less often used, element is the NOT gate. TOP events are taken from a preliminary hazard analysis, however informal it was; these events are usually strongly undesired system states that can occur as a result of sub-system functional faults. A fault-tree analysis consists of the following four steps:

1. System definition
2. Fault-tree construction
3. Qualitative evaluation
4. Quantitative evaluation” (4).

Application of the method leads to the system reliability increase, because it makes possible to study the faults reasons origin and, on the basis of the simple – primary events appearance possibility, it defines the possibility of the analysed key problem appearance. On the basis of this method results, it is possible to decrease the dangerous act appearance. There is also an factual advantage by using this method that deductions can be made also without the quantitative event possibility interpretation, what is an unreplaceable value in case of smaller companies performing in the area of road freight transport, where there is always a lack of the qualified personnel that understands the mathematical statistics and possibility area.

METHODOLOGY OF APPLICATION

FTA is one of the classical methods for identification of danger that is classified into deduction methods. It is specially used in the faults combination determination that could lead to fault and errors. There is a lot of versions of this method with the common symbols for describing the damage reason.

Fault-tree analysis begins with the statement of an undesired event, eg. a failed state of a system. To perform a meaningful analysis, the following three basic types of system information are usually needed:

1. *Component operating and failure modes: A description of how the output states of each component are influenced by the input states and internal operational modes of that component.*
2. *System chart: A description of how the components are interconnected. A functional layout diagram of the system must show all functional interconnections and identify each component.*
3. *System boundary conditions: These define the situation for which the fault tree is to be drawn. Top event, initial conditions existing or not-allowed events, and the tree top are system boundary conditions (4).*

The method can be used for qualitative also quantitative analyses. It allows relatively easy finding the system’s “weak points” and uncovers the important aspects from the reliability point of view. It is a reliable good regenerated process useable in the area of projecting and the technological processes operation.

It is very important to use this method to choose the top event properly and to compile the fault tree responsibly.

Process of this method can be divided into four or five phases. In the first phase, the top event is chosen and the possible reasons are generally identified, for example by the morphological finding or the data obtained from the earlier chronicled damages studies.

Alternatively, it is possible to use the Hazard Tree Analysis, if compiled standard fault tree should serve for specified usage. The Fault Tree Analysis and The Hazard Tree Analysis are correlated together, so the dangerous aspects could be defined in special points of operation process or operation institution.

The next step is an analysis of different "chain" faults in operation (in process or in machinery) that lead into the top event. By eliminating the individual component fault, reasons should be defined.

By using the fault tree analyses, we create an operational and systematic visual preview for identification of the way in which individual basic elements lead into system faults at the first view.

The basic tool of the FTA method is the known "fault events tree" that introduces the graphical view of relation in individual partial events (partial faults) and the final undesirable event. Stabile graphical symbolism in construction of this tree is used.

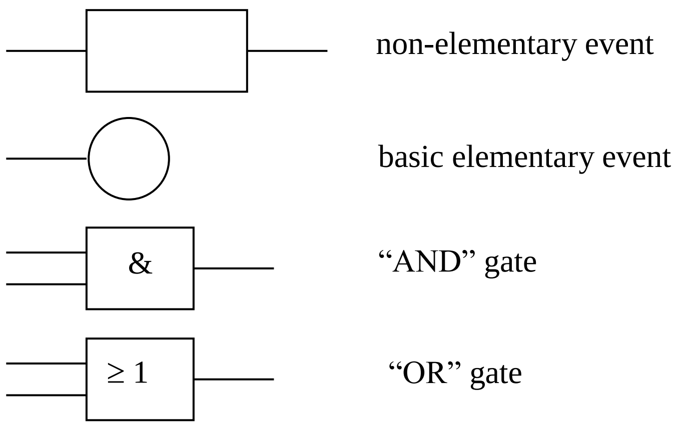

Fig. 1 *Basic graphical symbolism used in the Fault Tree construction*

The most often used graphical symbolism is displayed in Fig. 1.

ACHIEVED RESULTS

Fault-tree construction is generally a complicated and time-consuming task. Computer-aided synthesis has attracted considerable attention and several methodologies have been proposed. They differ in the modelling of components and in their objectives (4).

The fault trees can be created horizontally or vertically.

In case of vertical construction, the top event is displayed on the top and the elementary events on the bottom; in case of horizontal construction, the top event can be on the left or on the right of the page side.

Relations between individual elementary events and top event are expressed by the "gate" – junctor displayed in Figure 1.

The top event is indicated as "TOP" – event that is the main undesirable fault event.

“Quantitative fault-tree analysis consists of determining the minimal cut sets and minimal path sets and the common cause failures. Two major approaches used for determining minimal cast sets for fault trees are Monte Carlo simulation and deterministic methods” (4).

In relation with this event, we can use OR GATE for some input case. OR specifies that the output event can occur in case of any input case appears. It is a logic summary. Resulting possibility of event appearance at the output from OR gate can be expressed by the formula:

$$P_{"OR"} = 1 - (1 - \mathrm{P}(\mathrm{C}_1)).(1 - \mathrm{P}(\mathrm{C}_2)).(1 - \mathrm{P}(\mathrm{C}_3))........(1 - \mathrm{P}(\mathrm{C}_n)), \qquad [1]$$

where:

P “OR“ – probability of the event in output from “OR” gate,

C_i – events inputting into “OR” gate,

$P(C_i)$ – probability of events inputting into “OR” gate appearance.

From the listed formula, we can deduce that, in case of “OR” gate, the probability of outputting event is higher or minimally the same as the most possible event in input, so:

$$P_{"OR"} = \geq \max_{i} \mathrm{P}(\mathrm{C}_i)\,. \qquad [2]$$

It is obvious from the listed formula that the “OR” gate presence in a fault events tree is unfavourable from the point of view of possibility of undesired event appearance.

It is possible to use also the AND GATE that indicates that the output event occurs only when all inputting cases appear. It is a logic collation of possibilities of individual independent events appearance. . Resulting possibility of event appearance at the output from It is possible to formulate the resulting probability of appearance of the event outputting from AND GATE can be expressed by the formula:

$$P_{"AND"} = \mathrm{P}(\mathrm{B}_1).\mathrm{P}(\mathrm{B}_2).\mathrm{P}(\mathrm{B}_3))........\mathrm{P}(\mathrm{B}_n), \qquad [3]$$

where:

P“A“ – probability of outputting event from AND GATE appearance,

B_i – events inputting into AND GATE,

$P(B_i)$ – probabilities of events inputting into AND GATE appearance.

Considering individual probabilities are defined by value at interval ‹0,1›, we can deduce from listed relation that, in case of AND GATE, the probability of the outputting event is lower than or equal to the probability of the least probable event on input. Therefore:

$$P_{"AND"} = \leq \min_{i} \mathrm{P}(\mathrm{B}_i)\,. \qquad [4]$$

It is known from this relation that AND GATE appearance in the fault events tree is very favourable from the point of view of probability of undesirable event appearance.

The higher listed formulas of probabilities of event branching into partial events via AND or OR GATES are used for the possibility guess of dangerous event appearance and also for suitable actions to decrease the probability.

In the area of road freight transport, it is possible to define the probability of poor quality via this method application. It is possible to define also the events when we can consider provided transport service to be of poor quality.

In my opinion, in smaller transport companies, it is not suitable to deal with probabilities calculation. This part of FTA method scoring requires basic knowledge of probability theory. I can recommend ending the FTA analyses with Fault Tree creation and acceptance of actions for decreasing the undesirable events appearance.

We can apply this method in a road freight transport company for example in defining customer dissatisfaction and the reasons that likely cause this dissatisfaction. We can show a process in the following case study.

Table 1 lists individual discovered disagreements with discovered number and chosen identification. The table lists the results of claims observation in practice of the transport company providing service in road freight transport.

Table 2 shows relatively calculated possibilities of undesirable event appearance.

INDIVIDUAL DISAGREEMENTS, IDENTIFICATION AND TOTAL TRANSPORTATION IN 2013

Table 1

Individual disagreement	***Identification***	***Number***
Delivery term breach	B_1	36
Fault shipment	B_2	24
Road traffic accident	B_3	6
Transport reservations	B_4	15
Unsuitable drivers behaviour	B_5	7
Total number of disagreement		**88**
Total transportation	$\mathbf{B_T}$	**512**

By using FTA method, we can determine the individual possibilities for individual disagreement – faults of process of road freight transport service by using the formula:

$$\mathrm{P}(\mathrm{B}_1) = \frac{B_i}{B_T}, \qquad [5]$$

where:

$P(B_i)$ – possibility of failure event appearance,

B_i – individual disagreement number of appearance,

B_T – total transportation in followed time period.

We can calculate the possibilities as follows:

$P(B_1) = 36/512 = 0.0703$

$P(B_2) = 24/512 = 0.0469$

$P(B_3) = 6/512 = 0.0117$

$P(B_4) = 15/512 = 0.0293$

$P(B_5) = 7/512 = 0.0137$

The results of calculation are listed in Table 2:

POSSIBILITIES OF TRANSPORTATION DISAGREEMENTS Table 2

Disagreement B_i	**Possibility $P(B_i)$**
Delivery term breach – B_1	0.0703
Fault shipment – B_2	0.0469
Road traffic accident – B_3	0.0117
Transport reservations – B_4	0.0293
Unsuitable drivers behaviour – B_5	0.0137

The undesired event “Customer´s dissatisfaction” possibility – $P(B_6)$ can be defined via formula:

$$P(B_6) = 1 - (1 - P(B_1))^* (1 - P(B_2))^* (1 - P(B_3))^* (1 - P(B_4))^* (1 - P(B_5))$$

$$P(B_6) = 1 - (1 - 0.0703)^* (1 - 0.0469)^* (1 - 0.0117)^* (1 - 0.0293)^* (1 - 0.0137)$$

$$P(B_6) = 1 - (1 - 0.0703)^* (1 - 0.0469)^* (1 - 0.0117)^* (1 - 0.0293)^* (1 - 0.0137)$$

$$P(B_6) = 1 - 0.9297^*0.9531^*0.9883^*0.9707^*0.9863$$

$$P(B_6) = 1 - 0.8384$$

$$P(B_6) = 0.1616$$

DISCUSSION

The possibility of customer´s dissatisfaction in this case is 0.1616. Therefore, it is necessary that the company in next period concentrates on the undesirable disagreements in transportation decrease.

A fault tree is constructed by properly relating all possible sequences of events that, upon occurrence, result in the undesired event. Beginning with the most undesired (top) event, the fault tree graphically depicts the paths that lead to each succeeding lower level of the display. This does not imply that each descending fault path has a "higher probability of occurrence"; in fact, in many instances, the opposite may be the case. However, a series of "little things," each with a relatively low probability of occurrence, may trigger an event at the next higher level. This is depicted in the fault tree as a progression of events through the logic gates.

CONCLUSION

To measure the level of safety of an operational product, the initial step must be the definition of the most undesired event, i.e., the event that must be prevented from happening. Definition of the most undesired event is not always as simple as it might appear from a superficial view of any system, be it a power lawnmower or a supersonic aircraft. Injury to the operator may appear to be the most undesired event to the lawnmower manufacturer. Loss of life and destruction of the airplane could well be selected as the most undesired event for the supersonic plane designer. However, both of these obvious selections may be inappropriate. The safety of any system must be measured for a specific time and type of activity. For this reason, the system safety engineer must understand the system and its intended use. One objective of the analyst is to determine how the system, including the people involved with system operation and maintenance, could fail and cause the undesired event (4).

An appearance of undesirable event "Customer´s dissatisfaction" can be expanded by Fault Tree that is presented in Fig. 2.

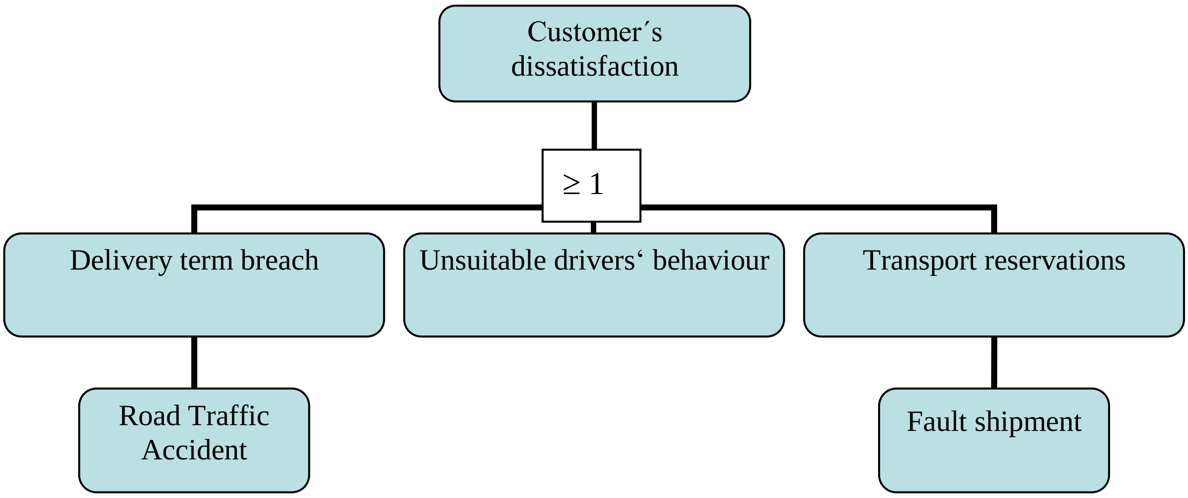

Fig. 2 *Undesired event "Customer´s dissatisfaction" Fault Tree*

Of course, the fault tree can be developed by this way, but I consider this example a fully satisfactory to illustrate its application.

By using the application of Fault Tree Analyses, we found that the most possible faults appearance is caused by the delivery term breach. The transport company should target on this problem during establishing the arrangements.

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