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# Methods of Risk Assessment and their suitability in a logistic environment

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## ABSTRACT

Complex logistic systems and autonomous logistic objects are more fault-prone than previously assumed. The reason for this is the interaction between the quantity of autonomous entities which leads to incalculable states on a local and a system level. In this context, the existence of possible hazards and chances has to be regarded. In order to handle the existing risks of complex logistic systems and autonomous logistic objects a proactive risk management system seems to be an adequate supplementation of a holistic process management system, because it supports the design of processes which are robust and insusceptible to existing and occurring anthropogenic and environmental hazards. Furthermore, it enables the entities to prepare decisions on their own and realize them. For this reason, the development of a proactive risk management system can be considered as a relevant success factor for complex logistic systems and for autonomous logistic objects. To develop a proactive risk management system which fulfils it is important to generate a consistent understanding of risk and to choose the suitable methods of risk assessment. This paper analyzes essential parts for a convenient risk definition and examines methods that allow the adequate management of system and process related risk.

## KEYWORDS

Risk, Logistics, Risk Concept, Autonomous Objects, Identification, Risk Assessment,

## Complex logistic systems and autonomous logistic processes

Globally distributed production networks and unbounded trade between several enterprises lead to higher requirements for the management of logistic systems and processes because shorter response times in relation to customer requirements and shortened delivery times affect the logistic system’s reduced buffer time i.e. The reduction of the size of goods that have to be transported and as a consequence thereof an increasing amount of transports are main reasons for a relative shortage of logistic infrastructure and lead also to rising utilization of existing logistic processes and to more complex logistic systems [1].

The question how to measure the complexity of logistic systems arises and furthermore how this complexity influences the design of logistic processes.

The complexity of logistic systems depends on the amount of the embedded entities. Entities can be sources and sinks for logistics objects and also logistic carriers and the logistic objects themselves. The amount and the character of the relations within logistic systems affect also the complexity of the logistic system and the number of logistic processes. The third factor, which is an important influencing factor for logistic systems, is the dynamic of the system. This dynamic is displayed by the number of system states. However, the complexity of a logistic system allows still no conclusion regarding the sensitivity of the system in relation to the malfunction of individual entities or relations. The integration of strategic planning may enable the system to compensate a temporary or unlimited malfunction of an entity or a system relevant relation between two or more entities. The increased use of modern ICT doesn't necessarily assure the constant availability and high quality of data and information to plan and control the logistic processes. A malfunction or a loss of information- and communication systems can lead to substantial negative consequences.

The increased complexity of logistic systems is followed by a more complicated planning and control of logistic systems and of the related processes. The hazard of delayed delivery and reduced adherence to delivery dates are results of complex system structures and increased customer requirements. All numerated risks and changed conditions clarify that logistic systems and the related logistic processes are very fragile and the contained hazards and chances have to be managed to ensure the success of the logistic processes.

The problem in practice is a mainly unsystematic management of the hazards and chances in logistics which is not sufficient to obtain a robust logistic system.

A possibility to resolve this problem is the development and implementation of a proactive risk management system which is able to:

- interpret new information
- identify possible risk
- analyze the possible risk and
- evaluate the process related risk

A modern concept of risk management in logistics will be developed in the Collaborative Research Center (CRC) 637: Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations at the University of Bremen (www.sfb637.uni-bremen.de).

In order to develop a suitable risk management system it is essential to generate a consistent understanding of risk and risk management

## Understanding and concept of risk

The combination of an adequate risk concept which is represented by a definition of risk and the usage of a risk management method which is able to consider and classify all relevant risk factors is the base for a successful risk management system.

It is mandatory to define a risk term in the context of autonomous logistic objects, because the risk management system has to analyze specific logistic related risk factors. After intense examination of existing approaches of risk definitions and analyzing their advantages and their disadvantages it can be said that they provide interesting input but they are not sufficient for logistic purposes. For this reason, a new definition of the term risk had to be developed. A definition which seems to fulfill the requirements of a proactive risk management system for a logistic purpose is the following:

*"Risk is the contingency that the result does not correspond to the goals of the system due to differences."*[3]

This definition was developed last year and is part of the paper "Risk Management in self controlled logistic processes" published and presented at the Symposium on Risk Management and Cyber-Informatics: RMCI '04.

This definition includes:

- uncertainty
- upside und downside risk
- technical, economic and process related risk and
- internal and external risk

Following this definition, it is essential to examine different risk concepts and their impact on the definition of risk. Haerterich [6] divides risk in three main areas:

1. risk as goal deviation
    - risk as a possibility of a wrong decision
2. risk as a deficit of information and
3. risk as a combination of deficit of information and possible goal deviation

These concepts have a different orientation and understanding of risk and risk management.

<u>Risk as goal deviation:</u>

A goal deviation is the common denominator in this concept. Risk comprises the possibility of a goal deviation and not the realized goal deviation. This concept has a high fit with respect to complex system structures with different impacts and probabilities. The goal deviation is a neutral factor which contains hazard and chance.

<u>Risk as a possibility of a wrong decision:</u>

This concept is part of the goal deviation approach. It also includes a correlation to given goals, because a decision can not be assessed as wrong without goal analysis. It is difficult to measure decision oriented risk, because the risk assessment can be conducted after analyzing what really happened and how other decisions would have influenced the result under the existing conditions.

Risk as a deficit of information:
Risk is characterized as a lack of information in situations where a decision has to be made. The disadvantage of this concept is the limitation to situations where decisions have to be made. Risk always exists and it is not limited to selected situations.

Risk as a combination of a deficit of information and goal deviation:
This concept follows from the combination of the goal deviation approach and the information deficit approach. The risk is divided into two components:

1. description through objective and subjective probability distribution and
2. a possible goal deviation for symmetric or asymmetric risk

The approach of a risk concept in a logistic environment has to fulfill several requirements. The first requirement is the measurability of the risk and the contained risk factors. In the approach that considers risk as a goal deviation this problem can be solved by splitting the total risk. The risk may be divided in:

1. time risk
2. cost risk
3. quality risk

The possible split up of relevant risk factor is shown in the following figure:

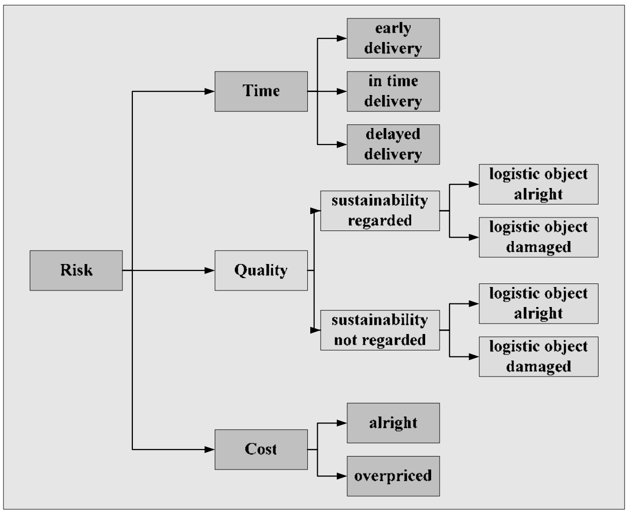


**Figure 1: Split up of risk**

It is possible to measure the relevant risk factor for a sufficient risk assessment with this idea. The "Risk as a deficit of information" approach is not able to fulfill the requirement of measuring risk adequately, because risk is reduced to a probability distribution but the flexible characteristics (additional cost, delay in delivery, damaged object) remain unconsidered.

After consideration of these facts we have the highest fit for autonomous logistic objects by usage of the goal oriented approach or the approach where risk is defined as a combination of a deficit of information and goal deviation. The subset "risk as a possibility of a wrong decision "of the goal oriented approach is not sufficient for a risk management approach which fulfills the requirements for future oriented logistics, because in this approach risk is limited to the decision points and can not occur during the realization of a decision. Another reason which constricts this concept for an application in a logistic environment is the fact that the real risk can only be assessed after a logistic process has finished and all states and decision that lead to an optimal result are known. Yet, another reason for the refusal of the subset "risk as a possibility of a wrong decision "is the difficulty in allocating unexpected events and certain decisions. The difference between these related concepts will be pointed out in figure 2:

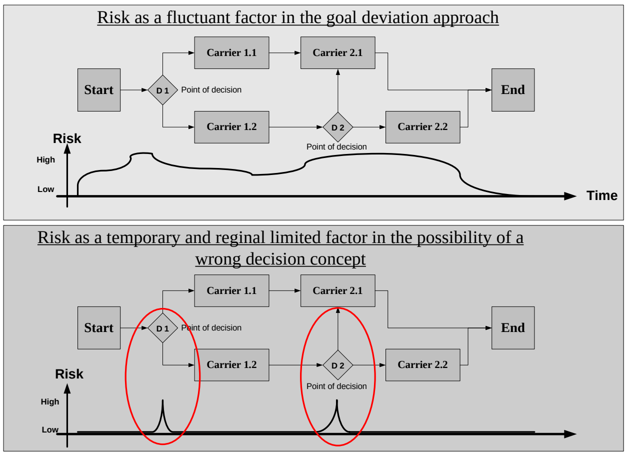


**Figure 2: Difference between two risk concepts**

But the possibility to assess risk during the planning phase and the accomplishment of logistic processes is a necessary feature for a proactive risk management. To enable a proactive risk management in complex logistic systems and for autonomous logistic processes it is indispensable to conduct a well structured and broad risk analysis. The purpose of this risk analysis is the identification of information which is relevant for the risk assessment. It is the point of origin of the risk management process that is the base for all following processes [6]. At an early stage risk identification enables the exertion of influence on the logistic process for that it is possible to avoid or to reduce risk which may endanger the success of the process. For this reason it is necessary to identify all possible risk factors. The identification is a qualitative analysis where the causes of the risk factors remain unconsidered. After the interpretation of new information and the identification of possible risk factors it is essential to analyze and weight the identified risk factors to obtain a qualitative and quantitative risk analysis. For the evaluation of the required information it is possible to use several risk analysis methods.

## Methods of Risk Assessment

To obtain an overview and information about existing methods of risk assessment some common methods of risk assessment will be evaluated with respect to their abilities regarding reduction and management of risk in a logistic environment. The analyzed methods are:

- **Fault Tree Analysis**
- **Event Tree Analysis**
- **Failure Mode and Effect Analysis**
- **Markov Model** (Chain) and
- **Hazard and Operability Study**

The analyzed methods will be introduced for a better understanding:

<u>Fault Tree Analysis (FTA):</u>
This is a technique that provides a systematic description of the combinations of possible occurrences in a system, which can result in an undesirable outcome. This method can combine hardware failures and human failures [9].

<u>Event Tree Analysis (ETA):</u>
Event tree analysis is based on binary logic, in which an event either has or has not happened or a component has or has not failed. It is valuable for analysis of the consequences that arise from a failure or undesired event. An event tree begins with an initiating event, such as a component failure, increase in temperature/pressure or a release of a hazardous substance. The consequences of the event are followed through a series of possible paths. Each path is assigned a probability of occurrence and the probability of the various possible outcomes can be calculated [8].

<u>Failure Mode and Effect Analysis:</u>
Failure Mode and Effect Analysis is a method that examines potential product or process failures, evaluates risk priorities, and helps determine remedial actions to avoid identified problems [10].

<u>Hazard and Operability Study (HAZOP):</u>
The Hazard and Operability Study, known as HAZOP, is a standard hazard analysis technique used in the preliminary safety assessment of new systems or modifications to existing ones. The HAZOP study is a detailed examination of components within a system that is conducted by a group of specialists. The aim is to determine what would happen if that component were to operate outside its normal design mode.
Each component will have one or more parameters associated with its operation such as pressure, flow rate or electrical power. The HAZOP study looks at each parameter in turn and uses guide words to list the possible off-normal behaviour such as 'more', 'less', 'high', 'low' or 'no'. The effects of such behaviour is then assessed and noted down on study forms [2].

<u>Markov Methods (Chain):</u>
Markov Chains are able to describe the chronological development of objects, circumstances, states and systems which are able to adopt one flexible characteristics of a finite number [11]. A continuous-time Markov chain is a stochastic process that enjoys the Markov property and takes values from amongst the elements of a set called the state space [4].

The evaluation of the introduced methods is conducted in differentiated parts. The ability to analyze forward or backward will be the first topic of this evaluation. The features of every method including their specific advantages and disadvantages will be evaluated accordingly. After all, it will be examined whether and how the methods can be used in complex logistic systems and for autonomous logistic objects.
There are different possibilities to assess the risk in complex logistic systems and for autonomous logistic objects. One possibility is to analyze potential nonconformities and malfunctions in relation to their cause and the other possibility is to analyze process relevant events in relation to their impact on the logistic system or on the logistic objects.
This leads to a classification of methods into two directions:

1. forward oriented methods which analyze occurring events and
2. backward oriented methods which analyze the causes for malfunctions

The classification for the analyzed methods will be pointed out in the following figure:

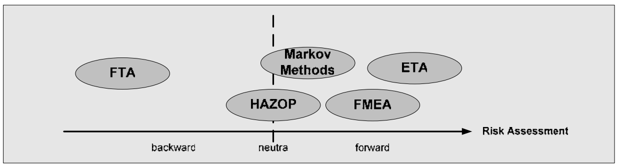


**Figure 3: Classification of analyzed methods**

The Fault Tree Analysis is a backward oriented method which enables the user to search for specific reasons which may lead back to a mistake.
The Event Tree Analysis is almost the obverse method of FTA because the influence on the process of suddenly occurring events can be analyzed. HAZOP is a neutral method with respect to this criterion because in relation to the guide words it enables the user to identify possible effects and results of occurring events and also the identification of reasons for occurred mistakes [5]. Markov Chains permit the identification of possible malfunctions and other states which the system can assume without consideration of the history of the process. FMEA is also a method of risk assessment with a forward orientation because it considers the influence of occurring events on the total system or the process.
After the classification of the introduced methods into forward or backward oriented methods their specific advantages and origin will be examined and in short form exemplified:

FMEA:
The usage of this compact method leads to clearly arranged results and gives a good overview. The main disadvantages are high work effort by experienced users or teams, the unstructured acting and the mainly subjective assessment.

FTA:
The Fault Tree Analysis allows a good structuring of the analyzed system or process and enables the users to visualize complex relations in a clear manner. Fault trees are normally intuitively comprehensible but it is a high effort to build a complete fault tree in complex system structures and for every malfunction and potential nonconformities.

ETA:
Almost the same arguments as for FTA apply to Event Tree Analysis because they use nearly the same methodology.

HAZOP:
The usage of this method leads to results which can be used by a team to identify possible effects and results of occurring events. The main disadvantage is the subjectivity of this analysis, the high work effort and the reduction to some guide words which may not be sufficient for a logistic purpose.

Markov Methods:
Markov methods offer flexibility with regard to the analyzed system or process. It is a simplistic modelling approach because the models are easy to generate although they do require a more complicated mathematical approach. The major drawback is the explosion of the number of states as the size of the system increases. The resulting diagrams for large systems are extremely large and complicated, difficult to construct and computationally extensive.

After the examination the specific advantages and disadvantages of these five methods of risk assessment they have to be verified with respect to their use in complex logistic systems or for autonomous logistic objects.
As a result of their subjectivity it is very crucial to use FMEA and HAZOP in complex logistic systems or by autonomous logistic objects which are highly supported by Information and Communication Technology (ICT).
The Event Tree Analysis and the Fault Tree Analysis are consistent in the ability to be used in complex logistic systems because they use almost the same methodology and need the same ICT resources. These methods have relative ambitious requirements at the needed ICT resources because building a complete set of fault trees or event trees is a high effort for the system.
As mentioned before the Markov Method needs a more complicated mathematical approach but this could be integrated easier into a complex logistic system or a logistic object than the other models because of its symbolic logic.

To fulfil the requirements for the development of a proactive risk management system in complex logistic systems or for autonomous logistic objects it is required that the method is forward oriented and can be well integrated into an ICT supported system architecture. It is also important that the method which will be used is able to assess risk as a permanent factor during the whole process and has the ability to regard:

- uncertainty
- upside und downside risk
- technical, economic and process related risk and
- internal and external risk
-

The following figure will point out which of the examined methods fulfils the required abilities best:

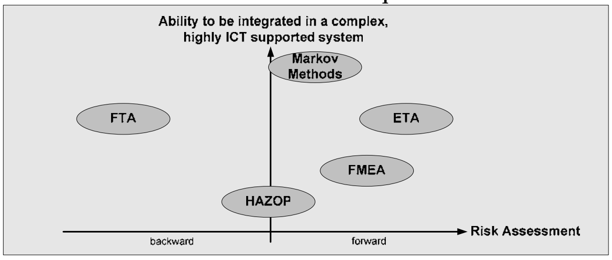


**Figure 4: Overview about examined methods with regard to their use**

After closer examination of the partial results about the suitability of the analyzed methods and the figure above it seems that the Markov Method fits best because it fulfils the requirements very well although it is difficult to construct and computationally extensive. The final result of the assessment is shown in figure 5:

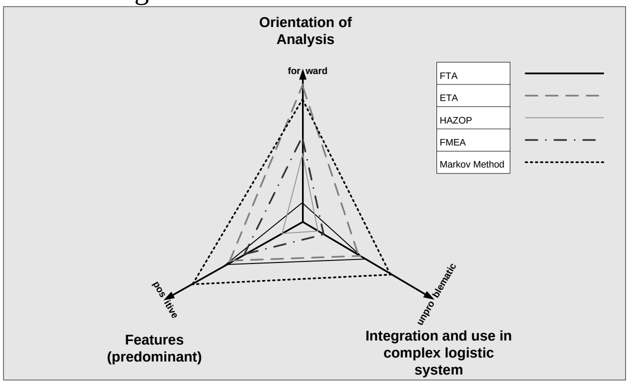


**Figure 5: Final assessment result**

The evaluation of results and a conclusion will be the basis for following research work on complex logistic systems and autonomous logistic objects.

## Evaluation of results and conclusion

The analysis of the introduced methods (ETA, FMEA, FTA, HAZOP and Markov Method) has shown that the use of the Markov Method leads to the most promising results for the development of a pro active risk management in a complex logistic environment or for autonomous logistic objects. On the basis of these results the Markov Method can be adjusted to generate a still higher fit to the requirements of such a dynamic system. This will be conducted in the sub project “Risk Management” as a next task in realizing an agent based proactive risk management in relation to a knowledge management system for autonomous logistic objects. Due to a fast developing computer technology it might be possible to implement the complete Markov Method into a single agent which is able to select alternatives autonomously and decide within a given framework of goals on its own.

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