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# A Systemic Approach for Simulation-based Team Training in Maritime Safety

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# A SYSTEMATIC APPROACH FOR SIMULATION-BASED TEAM TRAINING IN MARITIME SAFETY

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## 1 INTRODUCTION

Emergency Response, Crew Resource and Crisis Management are some of the most important subjects in maritime education and training of nautical officers and technical engineers. The STCW Manila Amendments coming into force on 1st January 2012 (see [8]-[10]) reflect that there is a major priority to train ship's officers and crew with sufficient skills and appropriate procedures. Skills and procedures are needed to provide adequate protection and to ensure the safety of passengers and ships' crews especially on ferries and cruise ships. One way to achieve experience and to gain corresponding skills are practice runs on specially designed simulators which realistically represent the complex shipboard conditions on such vessels after emergency alerts.

Simulators are well recognized as beneficial for ship handling training in real time on suitably equipped simulation bridges. In recent years new types of simulators were developed among others for training and research specific aspects of Maritime Safety and Security. Apart from existing regulations as e.g. SOLAS, STCW, ISM, ISPS etc. it is essential to adopt a permanent process of change and development with regard to new precautionary measures to ensure the safety of ship operation and to be prepared in case a hazard occurs. Training of human mentality and motivation is vital to create a permanent underlying safety culture.

In his research work World Maritime University's Maritime Risk and System Safety (MaRiSa) research group is dealing with the development, implementation and integration of simulation-based modules into training units and course schemes. With its new simulation laboratory providing a combined Ship Handling and a Safety and Security Simulator enhanced test and demonstration facilities are available. The safety and security training simulator contains 3D visualization of ship spaces; which virtually can be entered by trainees during exercise runs. The DNV-certified simulation system is a procedure trainer and enables the use of safety equipment and implemented emergency systems. Modeled equipment can be activated via interactive consoles on bridge or engine control room and all accessible decks as well. In cooperation with the Wismar University's Maritime Simulation Centre in Rostock-Warnemuende training concepts and scenarios are developed and tested for training on basic, advanced or management level. Functional tests of the developed system are running successfully and first practice courses have been carried out. Preliminary studies on user acceptance have shown good results. The new and enhanced simulation laboratory allows also for a wide range of scientific studies. The effects of safety and security plans and planned procedures on board can be tested in a simulation environment before its implementation in real world. More detailed evaluation of their effectiveness under varying conditions and during different courses of events are possible by different series of simulation runs [16].

This paper introduces the basic concept of the safety and security training simulator and describes ongoing research work related to the learning objective oriented development of training exercises.

## 2 SOFT- AND HARDWARE FOR INTEGRATED SIMULATION BASED TRAINING IN MARITIME SAFETY AND SECURITY

Although there are existing international regulations – as e.g. SOLAS, STCW (including the Manila Amendments), ISM, and ISPS - it is useful and necessary to apply a permanent process of correction and development with regard to improving safety and security precautionary measures both in port as well as on board. This also includes a constant review of training methods. Training is vital for creating a permanent high level of safety and security awareness on board to guard against human complacency on duty and to better motivate ships' crews.

Specifically for such training but also for research purposes a new type of simulator has been developed. Among others, the conceptual implementation of this sophisticated simulation system is characterized by 3D visualization design. This type of simulator was originally developed by simulator manufacturer Rheinmetall Defence Electronic Bremen in collaboration with the Maritime Simulation Centre Warnemuende (MSCW) of Hochschule Wismar in the frame of a funded research project (see [3]). Recently such a safety and security training simulator (SST) was also established in the Maritime Simulation Laboratory at World Maritime University in Malmö (Sweden).

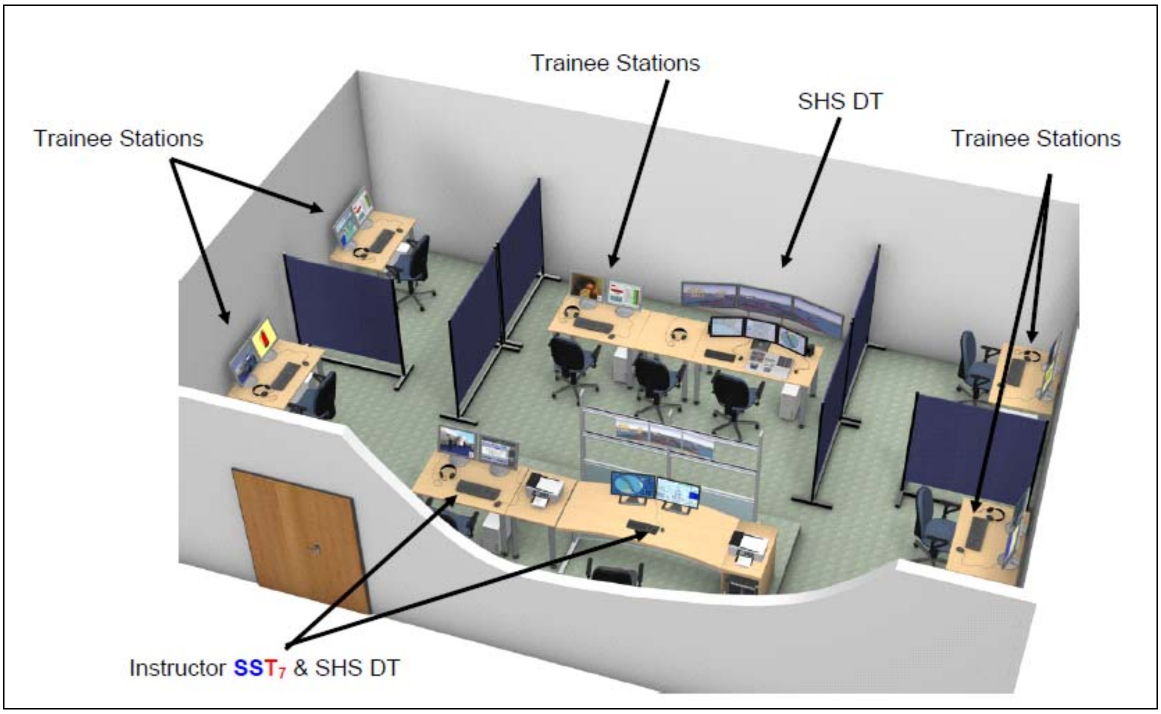


**Figure 1:** Configuration of the combined Ship-handling and Safety and Security Training Simulator at the MaRiSa-Simulation Lab of World Maritime University, Malmoe, Sweden

Presently a RoPax ferry is implemented and available for related simulation exercises.

At WMU the SST is combined with a Ship-handling simulator. This configuration allows for a wide range of applying simulation in MET, including complex team training of safety related scenarios. The combined simulator will also be used for research, e.g. for more detailed in-depth study of the effectiveness of safety and security plans and procedures on board or more profound evaluation and scientific investigation of their efficiency under different conditions and during varying courses of events that can be generated in individually created simulation runs.

However, while having available more and more sophisticated simulators with various facilities and its technical options (see e.g. [2], [4] and [7]) it becomes more and more important to thoroughly consider the processes of the accumulation of knowledge in general and to ensure effective learning. In this regard the learning environment is mainly structured by means of multimedia which itself can be seen as a different and challenging approach for learning, especially compared to the rather conventional and "traditional" methods. Therefore and in order to define the design and control functionalities of any simulation platform, it might be useful and necessary to sum up the main aspects of the related substructure. With regard to the computer simulation the next chapter is to look at the cognitive aspects of the underlying methodology.

## 3 METHODOLOGICAL APPROACH AND THEORETICAL BACKGROUND

Even today, the most common method in use for the development of simulation exercises is event-driven. Often scenarios of real accidents or near-misses (mostly experienced by one of the instructors) are implemented in order to discuss what mistakenly has been done or just gone wrong, which failures happened and should be trained to avoid by trainees in such reconstructed scenarios. In the same way as sometimes engineering is driven by the identification of a specific lack or failure that lead to the development of a new technical device or another additional sophisticated safety system, it is expected that accidents of such type and its underlying reason for human error will never happen again. But, despite new technical systems, despite new rules and regulations and despite more and more realistic simulation systems, unfortunately, accidents still occur.

Having this in mind it can be assumed, that the approach of event-driven design of training scenarios is not yet effective enough. Therefore it seems to be more appropriate to focus on the learning objective-oriented simulation and its specific scale as a tool for maritime education and training. With view to the increasing number of sophisticated simulators with various facilities and technical options, which leads to the assumption of wide-ranged options for learning effectiveness, it seems useful, first to have a look at the process of knowledge-accumulation in general and to sum up the main aspects of the educational scientific substructure, in order to identify the educational potential of the simulation platform design and its control functionalities.

With regard to the different learning theories, it seems appropriate to have a closer look at the relevant aspects of cognitivism as the preferred underlying methodology.

The way of gaining knowledge, the way how to learn and, on the other hand, the reason for learning restriction, especially in stress situation, are considered by theoretical assumptions of the so called Three-Memory-Model, which, first has been emerged by ATKINSON & SHIFFRIN in 1968 [1]. It has been developed in its main parts in the concrete context of e-learning-theories, e.g. Cognitive Load Theory [17] and focuses on three phases of memory which might be identified as the most important in the process of gaining and accumulating information, as there is

(1) Sensory-Memory,

(2) Short-Term-Memory and Working Memory, and

(3) Long-Term-Memory.

Within the context of a simulation-based, virtual training platform and its approach, to optimize reaction and communication in critical situations it seems to be useful first and foremost to consider the learning process within these memory parts in general and, with regard to human error, to have a closer look at its restrictions.

Briefly described, one of the reasons why things are not kept in mind and non-adequate problem-solving might occur is the insufficient and not deep and detailed enough processing of information. The fact, that learning objectives do not reach the Working-Memory, e.g. as a matter of non-motivation or less sense-making procedures, in case when novices have to deal with too complicated learning objectives, leads to their loss in memory. As a consequence it can be stated that the complexity-level of the simulation-scenario has to be well chosen to the expertise-level of the trainee. One of the main aspects, which are responsible for an ineffective recall of information, is stress. In this specific situation, stress hormones are discharged and are responsible e.g. for a partly blockade of the synapses. As a matter of fact, in this moment many of the information and especially expertise are more or less not available for the trainee. Referring to this it is one of the dedicated options of a simulation-scenario that it offers the option to raise the stress level during the different sessions. So the trainee can adjust and learn to cope with stressful situations, e. g. in cases of emergency. Another reason why we are forgetful lies in the so called "Interference" of the learning objectives. In this case the given information is too similar to already existing knowledge and therefore it might be mixed up with different meaning when being processed. This mixture may also be the reason that this information is not completely or insufficiently integrated in useful and sensitive connected meaning-systems. This has to be taken into account and the simulation exercise –session shall be structured by clear defined tasks with stepwise and reasonable increase of the level of difficulties.

One of the theoretical assumptions refers to the question of how the information is transferred to memory. By explanation and verbalization, especially by directly feedback, these structures are activated in a stimulating process and new information can be tied up to already gained experience. In order to support this complicated process it can be helpful to recapitulate the already existing knowledge and mental models. This can be done e.g. during the debriefing process of the simulation- session. Besides and with view to the Working-Memory, where these procedures take place, it can be stated that it has only limited capacity. Consequently, the learning approach should consider the basic idea of "less is more", which means that only a specific quantity of information should be worked on in the simulation session. Further it is recommended to have a look at a clear and concrete description of the learning objective as well as additional explanations to support the trainee in the process of creating "inert pictures".

Especially this process of "creating inert pictures" can be very well initiated and supported by 3D-simulation when the information is anchored by real action in a simulation-based training environment. This is evident for abstraction and formal logical memory patterns which ensures that the objectives become an inert knowledge quality and are not learned only "mechanically".

## 4 LEARNING OBJECTIVE ORIENTED DEVELOPMENT OF TRAINING SCENARIOS

Based on a comprehensive literature survey and further investigations into principles of development of scenarios for simulator training carried out in [11], a systematic approach for scenario development was described. The core elements of this approach are visualized in the following figure.

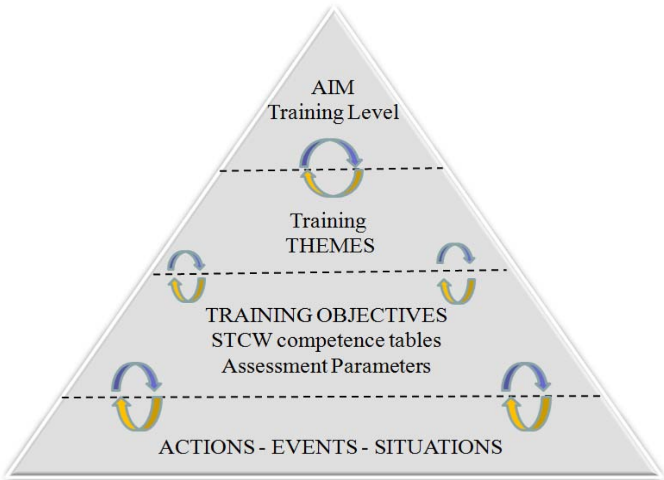


**Figure 2:** Principle layers and elements of scenario development process (acc. to [11])

There are four principle layers representing the main phases of the development process. The layers are connected by feedback loops e.g. from the training objectives to the general training aim and from the sequence of events to the training objectives. Feedback between the different layers is essential for the efficient development of well adjusted training scenarios. The first feedback loop, covering AIM and THEMES, applies between the simulator operator and the 'customer'. A company may ask for a specific training to improve certain skills and enhance the safety level on the ships or to even develop the company related safety culture. The following loops on the deeper levels are the most important ones to be carried out by the training institutions. These loops are foreseen for consideration of the appropriateness of the sequence of events in relation to the training objectives within a specifically selected theme. It becomes obvious that the training objective(s) should define the sequence and course of events of the training scenario.

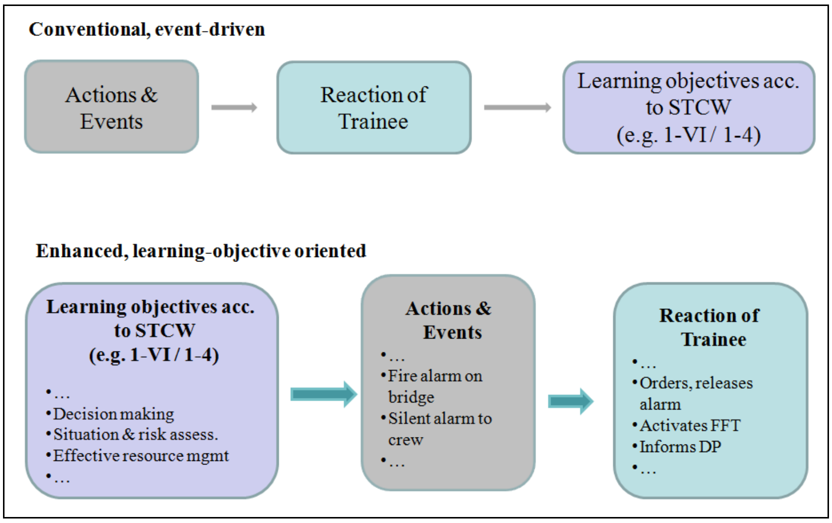


**Figure 3:** Basic steps for scenario design conventional and enhanced learning objective-oriented approach

Because each and every simulation exercise is dedicated to fulfill a well defined goal, there is a compelling need to clearly define the general objective within a certain course program. They are dependent, among others, from the trainees' initial level of qualifications and skills and the required competencies to be reached. From the general objectives several detailed objectives have to be derived. Finally, during the evaluation and assessment the trainees' performance will be mirrored and compared to the corresponding requirements.

## 5 INTEGRATION OF STCW COMPETENCE-BASED TRAINING OBJECTIVES INTO SCENARIOS

The exemplary application of the sketched method will be explained by means of the STCW required learning objective "Crowd-management" with its relevant actions in case of evacuation, which could be the final scenario of any emergency situation on board a ship. Crowd management training is listed in STCW A- V/2 as a „*mandatory minimum requirement for the training and qualification of masters, officers, ratings and other personnel on passenger ships*". In the detailed description of the required competence for this subject, the STCW – Code firstly mentions „*the awareness of life-saving appliance and control plans, including*:

1. knowledge of muster lists and emergency instructions,
2. knowledge of the emergency exits,
3. restrictions of the use of elevators.

As a competence of this STCW requirement the trainee should be able to assist passengers en route to muster and embarkation stations. On a more detailed level it is stated that the trainee should be able to:

1. "*give clear reassuring orders,*
2. *control the passengers in corridors, staircases and passageways, and*
3. *maintain escape routes clear of obstructions.*"

The further description of the required competences of the trainee in STCW mentions also the "*methods available for evacuation of disabled persons and needing special assistance*" and also the "*search of accommodation spaces*".

Finally the STCW- Code requires the knowledge of mustering procedures, which means more specifically that the trainee is able to "*use procedures for reducing and avoiding panic*". Generally he should be aware of the importance of keeping order and he should know how to use passenger list for evacuation counts. Overall the trainee should be able to ensure "*that the passengers are suitable clothed and have donned their lifejackets correctly."*

The implementation of the exemplarily mentioned learning objectives in a training scenario can be structured in different directions. With respect to available technical options of a particular training-platform it can be stated that the trainee e.g.

- can show a certain response by „interaction" with avatars (in a virtual training environment)
- gives a spoken or written answer in the scenario (alternatively reply to a multiple choice question or similar option as integrated)
- or any other option that might be helpful and suitable to demonstrate knowledge and specific competence respectively.

In general the response of the trainee might be internal and implemented in the scenario and then also modify the development and course of following events of the training scenario or it might be external by given answers as part of a direct assessment.

After clear definition of the objectives, they can be implemented into either a dedicated scenario but also combined e.g. with another complex fire fighting scenario to provide realistic situational background. A potential exercise is summarized in table 1.

| ***Draft sample exercise scenario*** | |
|---|---|
| **Identifying number** | **Shipboard Emergency Situation - FIRE -**<br>response actions after fire detection by fire-alarm system on the bridge |
| Training objective | 1.1.4.1 - 1.1.4.3 (actions to be taken relating to co-ordination , conduction of search and rescue, actions to be taken by a ship in distress and by an assisting ship) 1.1.5.1.30 (distress signals) 1.1.5.2.11 (log-book entries) 1.1.5.3 (action in the event of fire) 3.1.4.3 (handle emergencies situations) 7.2.2.1 (radio distress traffic) |
| Simulator tool | Combined ship handling simulator – with integrated Safety & Security components |
| Standard of competence | Master and chief mate (management level)<br>Chief and technical engineers |
| Configuration | Ferry ship ($L_{oa}$ > 200 m) |
| Traffic situation | Simple (e.g. only two ships are participated) |
| Environment | Coastal area, daylight, Wind: moderate, < 6 BFT; Sea state: rough; no current, good visibility |
| Duration | Long, > 30 min |
| Event description | • fire-alarm system on the bridge is indicating fire in on car deck (e.g. Advisory System Ship's Safety - indicates smoke on car deck by an acoustical alarm and CCTV screen as well)<br>• OOW starts alarming procedures<br>• FFT is preparing for investigation of situation on car deck and begins fire fighting<br>• fire cannot be distinguished, use of sprinkler system is necessary<br>• preparation for evacuation, communication with DP ashore<br>• temperature indicator indicates normal temperature on car deck<br>• fire has been extinguished<br>• … |

**Table 1:** Draft framework for a suggested simulation training scenario

## 6 FROM REAL EMERGENCY SITUATION TO SIMULATION-BASED TRAINING

During the studies and investigations performed to develop a systematic methodology for scenario design and control, comprehensive material (i.a. [6] and [13]) of a real fire onboard accident has been reviewed and analysed.
From this material a basic event chart as it is used in accident investigations has been drafted.

Based on such diagrams and additional material (as e.g.[5], [12], but also [15] and [18]) gathered during field studies on board including the participation in real life fire-fighting drills, basic input was provided for the development of the detailed reference scenario. According to the learning objectives to be applied by the customer, decision points can be integrated to further develop the event chart and the simulation scenario accordingly.

As first step for drafting the reference scenario, an actors-and-action graph for the initial situation was developed. This graph visualises the specific events and conditions with the actors with an estimated timeline for the scenario script.

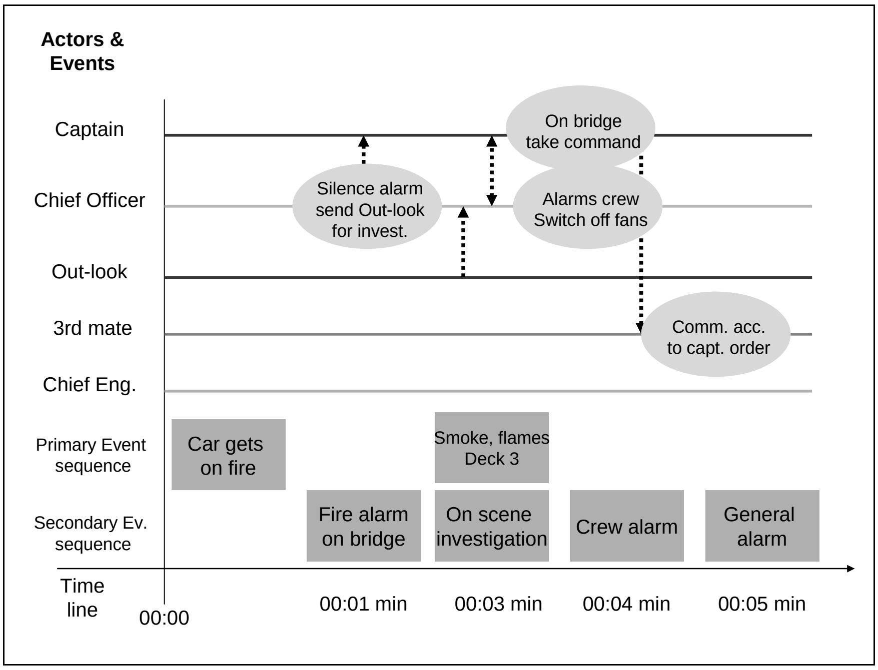


**Figure 4:** Actors- and -action graph of the reference scenario's initial situation

Following this, the processes of action and communication were drafted (see next figures) for the main chain of events. In order to create foremost a general approach the potential activities as described in the ISM procedural listings ([10]) are taken as the recommended actions. The action steps ( for OOW on bridge) up to the point when the Master takes command of the vessel are described as "Call the Master", "Bring bridge to alert status", "Raise General alarm", "Obtain charted position" and at least "Proceed to fire station". When the Master takes the Command of the ship the following step is characterized by internal and external communication.

Action and communication processes for the complete scenario needs to be drafted and decision points, e.g., for fire-fighting tactics and crowd management, have carefully and reasonably to be integrated. An example is given in the figure below.

The exemplarily shown decisions, to be made at this point of the sequence of events and actions, are foremost linked to fire fighting tactics. The main aspect of this section therefore refers to gaining information of the various parts of the ship involved (cargo information, weather condition, ships plan, etc) and, according to these information the question how to follow up with organising the fire fighting.

The leading questions in this learning break should be put with regard to company specific rules and regulations of the ISM Code implemented in the company, the further international regulations as e.g. SOLAS as relevant for the training scenario and the individual situation awareness of the trainee.

Based on the decisions made in this section and especially the decision if there is a need for evacuation and abandon the ship, the scenario should be followed up with the specific steps which are linked to the specific tactics, chosen as an alternative action.

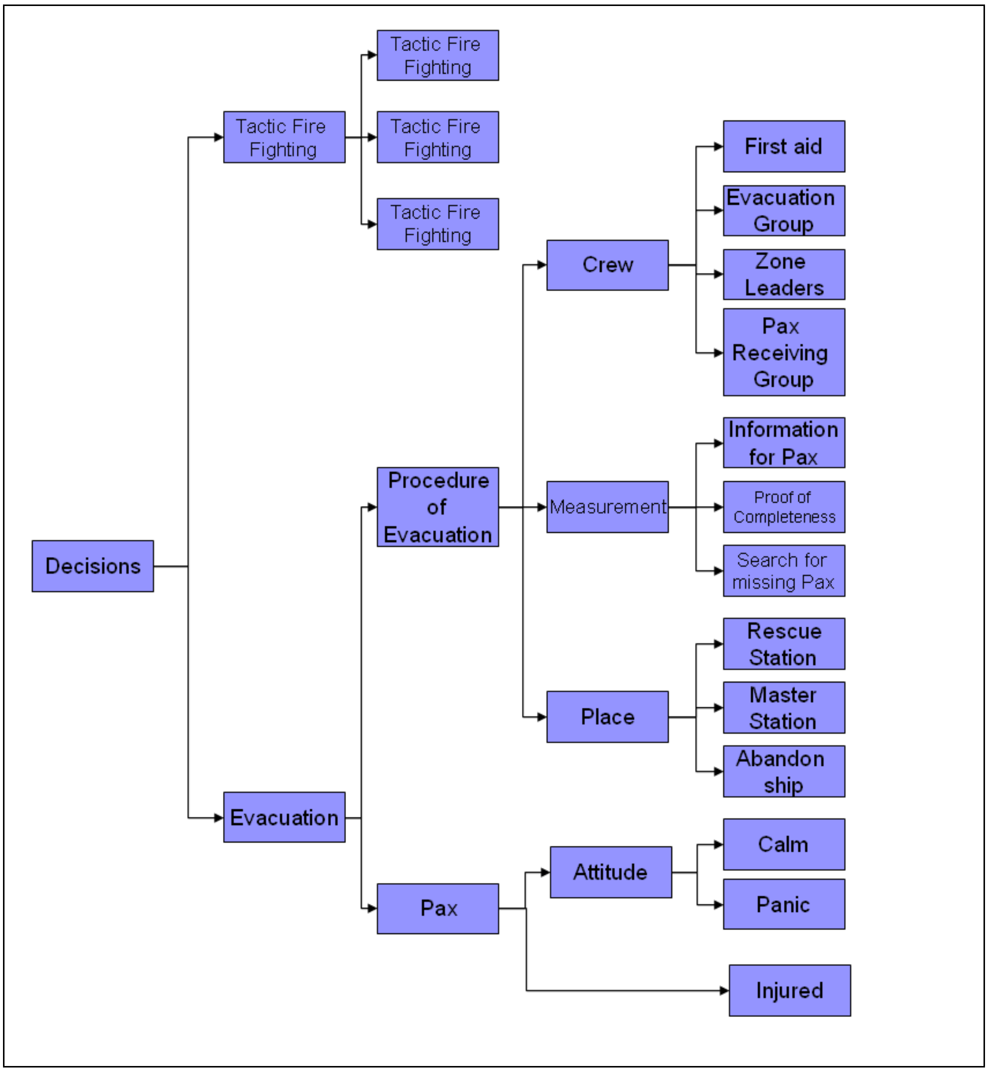


**Figure 5:** Integration of "Decision points" into a training scenario

In principle, the working steps of the methodology can be applied to every individual scenario that a shipping company wishes to be trained.

As already mentioned, one of the main aspects when determining the general learning aims with its specific learning objective (according to STCW 95), is the difficulty that every course of action generates an adjusted response and in this meaning a different continuation of the planned and constructed scenario. The difficulty is to measure the appropriateness of the chosen course of action so it might be helpful to create some kind of standard reply patterns for some different scenario- options.

When considering the various aspects of the cognitive model of the learning process it has become obvious that it is either a bottom-up and top-down process of accumulating information and several steps are developing in an unrealized way.

## 7 SUMMARY AND CONCLUSION

In this paper, research work, dedicated to the development of modern learning objective oriented simulation scenarios is described. The implementation of a training scenario into a simulation platform is discussed and necessary prerequisites for the development of a corresponding methodology for crisis scenario design and its suitable control are given.

Functional requirements and prerequisites have been identified and described in the context of learning objective based design of simulation exercises. A detailed description of the steps included in the systematic approach is presented. The exemplary application of the methodology to the chosen demonstration scenario of a fire onboard a RoRo-passenger ferry, which leads to an evacuation as final terminating situation, is given.

## 8 ACKNOWLEDGEMENTS

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