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Risk based approach for procedures' optimization

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Despite an increase in the process automation, different activities remain mainly operator driven, as the loading and unloading of tankers, maintenance operations, and so on. In these cases, the activities performed by the operator can be critical, both for the safety and for the product quality. Optimizing the operational procedures is thus a key factor for quality and safety.

A risk assessment of the procedure can be adopted as a base for optimisation, highlighting which of the tasks within the procedure mainly contributes to the risk of the working activity. Usually the analysis of the procedures is carried on through a task analysis as in Builes et al. (2014).

In this paper the task analysis is used as a starting point for a quantitative risk assessment carried on through an integrated dynamic decision analysis. The logical-probabilistic model of the procedure is elaborated jointly with a consequences analysis, obtaining a risk assessment for all the sequences of tasks of the work procedure under analysis. The risk assessment considered both possible equipment failures and the potential operational errors in executing the tasks.

The proposed approach is in this paper demonstrated through the application of the integrated decision analysis for the operation of unloading of ammonia in a plant for the production and storage of fertilizers.

Keywords: Risk based decision making; operational procedure optimisation; integrated dynamic decision analysis

1 Introduction

In production companies, different activities are carried out according to written and consolidated procedures, in most of cases the written procedures are built on the worker experiences, design indications and technical standards; the design based only on expert judgement can bring possible inefficiencies and safety issues (Comberti et al., 2018).

In particular, in case of frequent procedures, also small inefficiencies can have high impacts on the plant productivity.

One way to optimize the procedure is to analyse step by step the procedure identifying the the critical activities, both in terms of probability and of risk value.

In this paper it is suggested to analyse the procedure first through the Task Analysis technique, in order to investigate in detail the different steps. Then the Integrated Dynamic Decision Analysis is proposed to assess the probability of occurrence of unwanted events and the related risk value.

On the basis of probability and risk figures, optimisations are proposed for the procedure, then the optimized procedure is analysed again to highlight the optimization benefits.

The proposed approach is tested on the procedure for the unloading of an ammonia truck and the transfer of the product to the storage tank, in a fertilizer production plant.

2 Material and methods

The optimisation approach is made of two steps. In the first, the procedure is analysed step by step through a Task Analysis. Then, through the Integrated Dynamic Decision Analysis, the probability of occurrence of unwanted events and their risk are assessed. These values will be then used for a risk-based decision making process.

2.1 Task Analysis

Task analysis is a widely adopted tool for the analysis of working activities and procedures (Builes et al., 2014). Different types of Task Analysis are cited in literature: Hierarchical Task Analysis (Annett and Duncan, 1967), Operational Sequences Diagram (Kirwan and Ainsworth, 1992), Link Analysis (Chapanis, 1996) and Cognitive Task Analysis (Stanton et al., 2005). In

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this work a Task Analysis HAZOP like (McDonald et al., 2011) has been adopted.

A Task Analysis proceeds analysing a procedure step by step, describing the worker actions and the interaction between worker and the environment.

For each task, a detailed description of the activity is reported, that can include both physical and mental duties (Comberti et al., 2019), together with critical environmental condition where relevant, as for Murè et al. (2017) and the activity characteristics, as its duration and frequency (Kirwan and Ainsworth, 1992).

The Task Analysis is used as a base for further steps in the analysis.

2.2 Integrated Dynamic Decision Analysis

The Integrated Dynamic Decision Analysis (IDDA) is a method for risk assessment, that was developed by Galvagni and Clementel (1984, 1989). IDDA was used for the risk assessment in different application: for the tank overflow (Demichela & Piccinini 2008), for a risk-based design on an allyl-chloride production plant (Demichela & Camuncoli 2014), for the reliability - based comparison of competing technologies for the VOC treatment in process system (Baldissone et al. 2016), etc.

IDDA requires a logical-probabilistic model of the system under study, in this case of the procedure, to be built. The logical-probabilistic model allows to evaluate each possible series of events can occur during the procedure, in case both of human error and equipment failure.

The logical – probabilistic model was built, identifying the possible deviations from the expected conditions, according to the following steps:

1. Analysis of the deviation that can occur during the procedure and their possible effects on the procedure itself.
2. The events are described through question or affirmation, that shape the basic structure of the analysis and are called “levels”. The elaboration of the network they create allows identifying all the possible and alternative sequences of events that can derive from the description of the procedure (stories).
3. At each level a probability of occurrence is assigned and, if available, the uncertainty ratio, which represents the distribution of the probability. Therefore, each sequence of events can be characterized with a probability of occurrence.
4. The logical or probabilistic constrains are defined, in order to take into account the inter-dependencies of the events.

Following this type of description of the system, it is possible to obtain all the possible sequences of events the system could undergo: to each sequence will describe the possible dynamics of the system with the respective probability.

The logical-probabilistic model can be integrated with a phenomenological model. It allows a more accurate description of the system, allowing the process variable behaviour to be represented and a value of the consequence of the deviation considered to be associated to each sequence.

In this way IDDA allows a direct evaluation of the risk value of each sequence.

2.3 Case study

The above described approaches have been applied to the unloading procedure of an ammonia truck in a fertiliser production plant, as sketched in Fig. 1.

Ammonia is a toxic and flammable substance, which is transported as a gas liquefied by pressure. The transfer of the ammonia from the truck to the tank is carried out by increasing the pressure inside the truck through introducing nitrogen at 14 bar. To avoid any release, the vapours contained in the tank are sent to an absorption system, out of the scope of this case study.

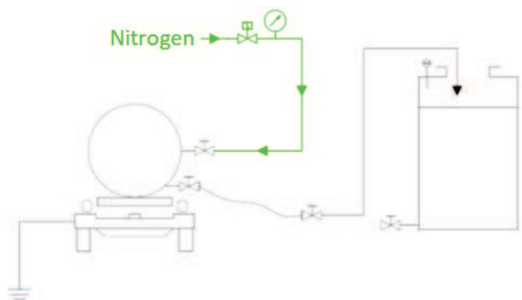

Fig. 1. Plant sketch

3 Results

3.1 Task analysis

The unloading procedure has been divided in 10 main tasks:

1. Truck arrival and positioning;
2. Truck and tank conditions check (e.g. pressure, level, …);
3. Preliminary activities (e.g. connect the earthing system, close the sectional door);
4. Check and wearing of PPE;

Table 1. Extract of the task analysis

Main task	Sub tasks	Deviation	Consequences
1.1. Truck arrival and positioning;	1.1. Check document of the truck	• Document not available; • Document complete.	Delay
	1.2. Open the entrance gate	• Gate not completely open.	Delay
	1.3. Place the truck in the correct place	• Incorrect entry maneuverer; • Truck incorrect position.	Delay

5. Connection of the liquid hose;
6. Connection of the gas hose;
7. Ammonia transfer;
8. End of the ammonia transfer;
9. Hoses detachment;
10. Truck exit.

Each task has been divided in relevant subtasks; for each of them possible deviations and hazards has been identified.

Table 1 Extract of the task analysis shows an extract of the task analysis for task 1 Truck arrival and positioning

3.2 Integrated Dynamic Decision Analysis

On the basis of the Task Analysis the logical-probabilistic model for IDDA has been built. For each task and sub task the possible effect of a human error, an equipment fault and any possible recovery action has been considered.

The probability data for each event were gathered from the literature: for the equipment failure from Center for Chemical Process Safety (1989), and for the operator error the HEART method (Williams, 1992) was used.

In the analysed procedure the unwanted consequences are divided in:

- Ammonia release;
- Ammonia release - not contained;
- Fire;
- Incorrect ammonia transfer;
- Delay.

The logical- probabilistic model used a cut-off value of 1×10^{-22}, in this way 14,966,348 different sequences of events were developed, with a residual probability of 2.68×10^{-14}. The results of the probability of each unwanted consequence is reported in Table 2.

Once the probabilistic analysis has been completed, the more critical tasks for each consequence has been identified. Those tasks have been object of an optimisation activity, made in agreement with the plant management.

After the optimisation, the procedure has been analysed again to demonstrate quantitatively the effectiveness of the actions devised.

Table 2. Unwanted consequences probability of occurrence.

Unwanted consequences	Probability
Ammonia release	6.37×10^{-4}
Ammonia release not contained	4.27×10^{-5}
Fire	2.86×10^{-6}
Incorrect ammonia transfer	4.78×10^{-3}
Delay	0.23

With a cut off value of 1×10^{-21}, 13,081,396 of sequences of events were founded, with a residual probability of 4.49×10^{-14}. Table 3 shows the probability of occurrence of the relevant consequences, after the optimisation of the procedure.

Table 3. Unwanted consequences probability of occurrence for the optimized procedure.

Unwanted consequences	Probability
Ammonia release	5.86×10^{-4}
Ammonia release not contained	2.72×10^{-7}
Fire	2.55×10^{-6}
No correct ammonia transfer	3.04×10^{-3}
Delay	0.079

In general terms, the optimisation has brought to a relevant decrease in the probability of occurrence of a release of ammonia not contained, whose probability can now be considered as negligible. A relevant reduction of probabilities of occurrence has been obtained also for delays, but they are still probable events.

Thus, for the delays an optimization phase was made also on the risk value. The consequence value in terms of delay for each possible human error and equipment fault were provided by the company management and has been used to assign a value of risk to the different sequences.

In the following sections the results are discussed for each consequence.

3.2.1 Ammonia release

The label "ammonia release" includes also the events labelled as "Ammonia release not contained" and "Fire", in fact before having a fire, an ammonia release must occur, the flammability limits have to be reached and an ignition has to trigger the reaction.

An ammonia release can occur only during the ammonia transfer, because only in this phase the ammonia flows in the system, despite it being initiated by previous failures or errors.

From the analysis it appears that one of the more critical task for the ammonia release is the liquid hose connection. To reduce the probability of ammonia release the plant manager was suggested to adopt new connection systems: fast and leakproof connections will simplify the operation reducing the error probability.

The improvement in the probability is summarized in table 3.

3.2.2 *Ammonia release not contained*

The unwanted events labelled "Ammonia release not contained" describe the critical cases in which an ammonia release occurs and the system to control the ammonia cloud (e.g. sectional door) does not intervene or does not work correctly.

From the analysis it appears that the more critical task is the loading bay gate closing, a subtask of task number 3.

The measure proposed to further reduce the probability of occurrence was to add an alarm system alerting the operator about the status of the gate at the transfer start-up. For there more the update of the operator training about the changes in the unloading procedure as been considered.

3.2.3 *Fire*

The case in which the ammonia cloud is ignited is considered here. After the release, the cloud can find different ignition sources in the plant, as from the truck engine or electrostatic sparkles. From the analysis it appears that one important ignition source is the electrostatic energy discharged in case the truck is not connected to the grounding system.

Since this problem can be traced to an operational error, to reduce the probability of fire it was suggested to increase the training on the importance to use the PPE and the grounding system.

3.2.4 *Incorrect ammonia transfers*

Fig. 2 shows the cumulative probability bringing to the incorrect ammonia transfer. From the analysis it appears that the critical task is the one of maintaining the nitrogen pressure during transfer. To reduce the probability, it was suggested to add an alarm alerting the operator at pre-defined pressure set points, highlighting possible problems during the ammonia transfer.

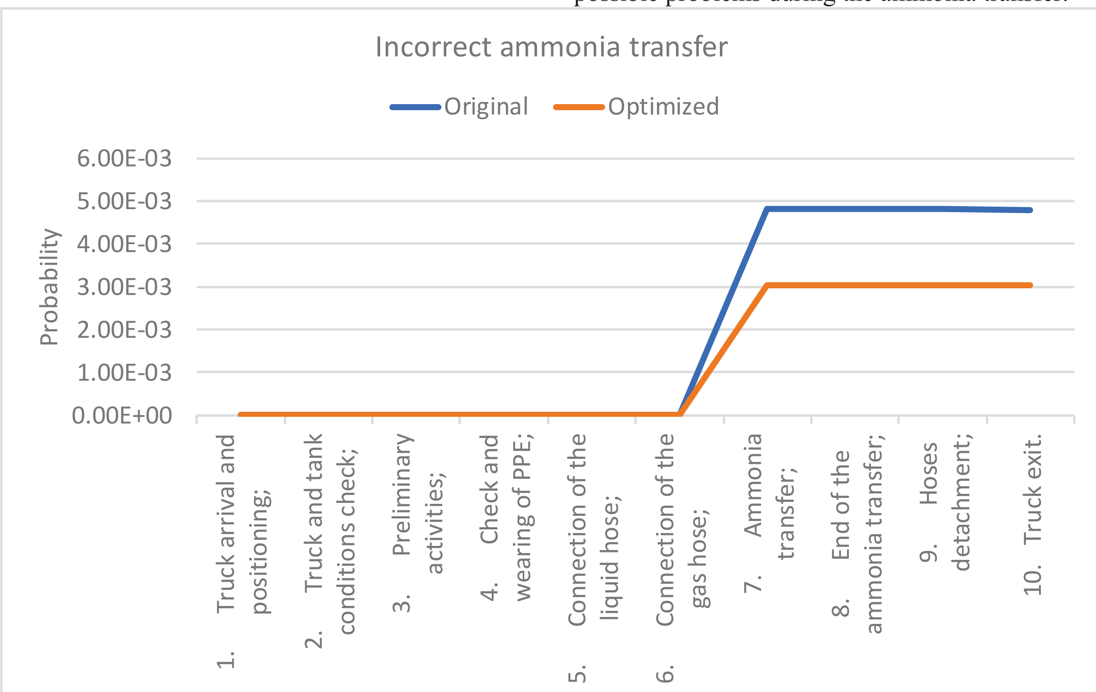

Fig. 2. No ammonia transfer probability cumulative distribution

3.2.5 *Delay*

Delays are more probable unwanted outcomes, but have the lower magnitude of consequences. Fig. 3 shows the cumulative probability of delays.

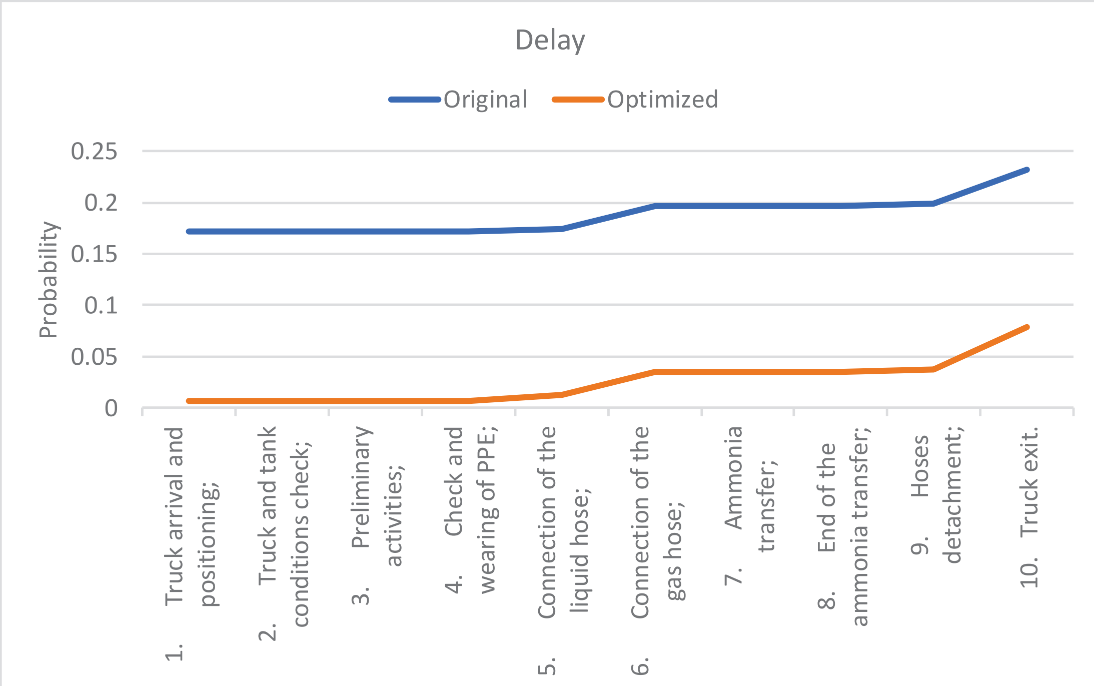

Fig. 3. Delay probability cumulative distribution

Form the analysis appear that for the delay an important task is the truck arrival, the position and document check.

To reduce the delay opportunities, it was suggested to modify the truck entrance signs and entrance routes. It was also suggested to improve the operator training. In this way the probability of delay is strongly reduced.

Since the probability of delay is still not neglectable a second step of optimization is performed on the base of the risk of delay, according to the data provided by the plant management.

The risk of delays, after the first optimisation on probabilities, is 0.05 in terms of hours.

Fig. 4 shows the cumulative distribution of the risk value. It appears that the more critical tasks are the "Connecting the liquid hose" and "Truck exit". To reduce the delay risk it was suggested to improve the training of the operators about the sealing test of the liquid hose and to re-organize the storage system of the safety and grounding cables.

With these further improvements, the risk of delays decreased to 0.02 h, that was considered as tolerable by the plant management.

4 Conclusion

In order to avoid that the operational procedures, when developed only on the basis of expert experience or standard indications should introduce in the work environment undetected risks or lack of effectiveness, an optimisation strategy based on a risk based approach has been proposed and tested.

The operational procedures are analysed with a Task Analysis to define in detail the operational domain, its limits and possible deviations and consequences.

Then the Integrated Dynamic Decision Analysis is adopted: the logical – probabilistic model, built on the task analysis, provides all the possible sequences of events that can occur with their probability and the expected consequences.

Integrating the model with consequences estimation, it is possible to obtain the risk of each sequence and, cumulating the values of sequences bringing to the same outcome, of the final consequences.

The proposed approach allows performing optimisation decisions based on probabilities and on risk values.

The proposed approach has been tested on a case study related to the ammonia truck unloading procedure in a fertilizers production company. In the case study some corrective measures were proposed.

The suggested measures have been partially adopted and the initial results show encouraging returns in terms of control of operation delays.

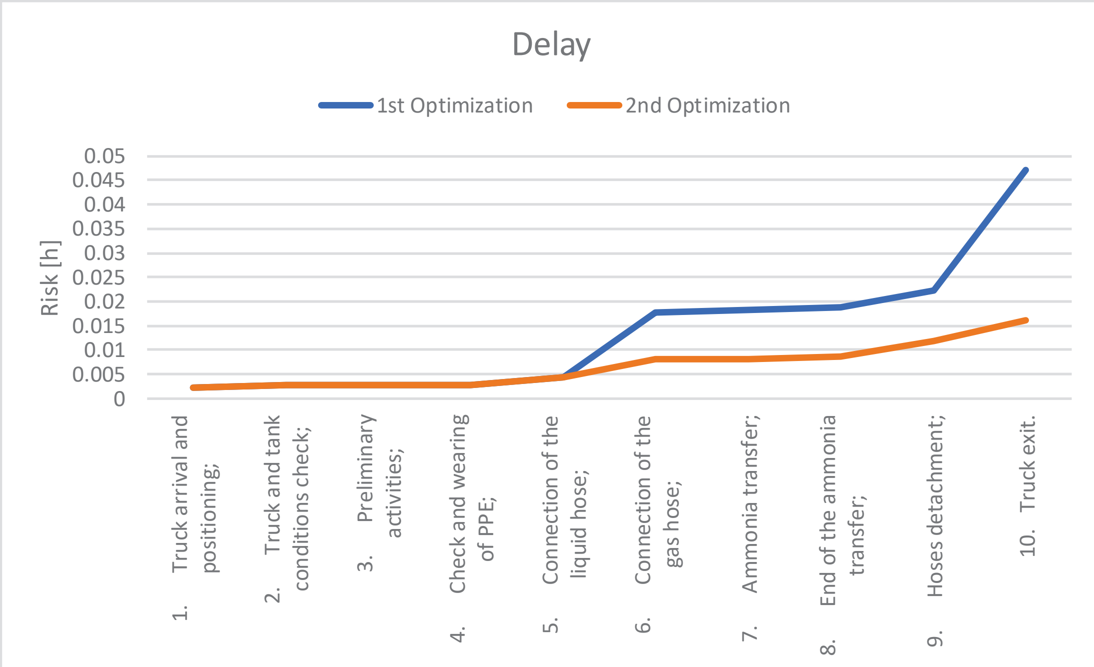

Fig. 4. Delay risk cumulative distribution

References

Annett J., Duncan K.D., (1967). Task analysis and training design. Occup. Psychol. 41, 211–221.

Baldissone G., Fissore D., Demichela M., (2016), Catalytic after-treatment of lean VOC–air streams: Process intensification vs. plant reliability. In: Process Safety and Environmental Protection 100: 208-219.

Builes Y., Balfe N., Leva M. C. and Douglas E., (2014), Inclusive Task Analysis and Risk Assessment in High-Risk Industrial Cleaning: A Case Study Using SCOPE Software, Irish Ergonomics Society Annual Conference, 17 May 2014, Galway, Ireland

Center for Chemical Process Safety (1989). *Guidelines for Process Equipment Reliability Data with Data Tables.* American Institute of Chemical Engineers.

Chapanis A., (1996). Human Factors in Systems Engineering. John Wiley & Sons, New York.

Clementel S., Galvagni R., (1984). The use of the event tree in the design of nuclear power plants. Environ. Int. 10, 377–382.

Comberti, L., Baldissone, G., Demichela, M., (2018) A combined approach for the analysis of large occupational accident databases to support accident-prevention decision making. Safety Science 106, pp 191-202 (2018)

Comberti, L., Leva, M.C., Demichela, M., Desideri, S., Baldissone, G., Modaffari, F., (2019), An Empirical Approach to Workload and Human Capability Assessment in a Manufacturing Plant: Second International Symposium, H-WORKLOAD 2018, Amsterdam, The Netherlands, September 20-21, 2018, Revised Selected Papers. pp 180-201

Demichela M., & Piccinini N., (2008). Integrated dynamic decision analysis: a method for psa in dynamic process system. CISAP 3. 13, p. 249-256. Milano: AIDIC.

Demichela M. and Camuncoli G., (2014), Risk based decision making. Discussion on two methodological milestones. In: Journal of Loss Prevention in the process industries, 28(1): 101-108

Galvagni R., Clementel S., (1989). Risk analysis as an instrument of design. In: Cumo, M., Naviglio, A. (Eds.), Safety Design Criteria for Industrial Plant. CRC Press, Boca Raton, pp. 78–120.

McDonald, N., Morrison, R., Leva, M.C., Atkinson, B., Mattei, F., Cahill, J., 2011. Operational modeling and data integration for management and design. In: Cacciabue, C. et al. (Eds.), Human Modeling in Assisted Transportation. Springer, pp. 55–63

Murè, S.; Comberti, L.; Demichela, M. (2017), How harsh work environments affect the occupational accident phenomenology? Risk assessment and decision making optimisation. Safety Science 2017, 95, pp.159–170.

Kirwan B., Ainsworth L.K., (1992). A Guide to Task Analysis. Taylor & Francis, London

Stanton N.A., Salmon P.M., Walker G.H., Baber C., Jenkins D.P., (2005). Human Factors Methods: A Practical Guide to Engineering and Design. Ashgate, Aldershot, UK <www.humanreliability.com> (accessed 2.2.2016).

Williams, J.C., (1992). A User Manual for HEART, Human Reliability Assessment Method. Prepared for Nuclear Electric plc, DNV Technica.