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PERSPECTIVES ON ACCIDENT MODELLING IN AVIATION

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Considerations on accident investigation methods
Linear vs. nonlinear analysis

Linear analysis methods are associated with an ensemble that restores the causes of a hypothetically outlined scenario up to the moment when its effects are revealed.

The shift from **linear sequences to systematic descriptions** associated to accident analysis, implied the introduction of new distinct sequences that can be embedded in an analysis after researching the lower levels of safety, specific to aviation systems.

Considerations on accident investigation methods
Linear vs. nonlinear analysis

The earliest beginnings of the **system theory** research have been made by Leplat, considering that it is necessary to specify the nature and the interrelations of the systems since accidents are analyzed in terms of a variety of subsystems.

Each accident model may be a little part of the total investigation process, so accident investigations may involve using of a set of analysis methods (Sklet, 2002).

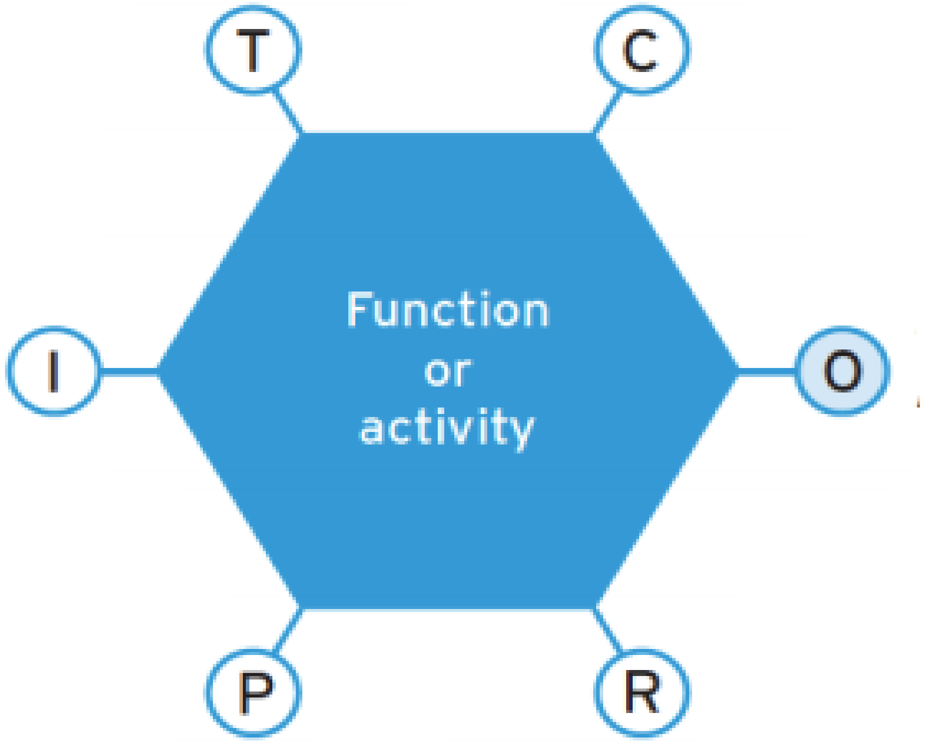
Limitations of systemic methods
A focus on FRAM model

In systemic models, the main concepts are retrieved from Rassmusen’s system’s theory and the need for improvement was demonstrated by a long-term development and evolution.

Although the attempts to expand current probabilistic risk assessment techniques into complex software activities and management issues have failed (Mosleh, 2014), the improvement of systemic models can overcome this problem.

Limitations of systemic methods
A focus on FRAM model

FRAM model is described by a series of six functions connected in a node with the purpose to describe complex interactions and close couplings.



Limitations of systemic methods
A focus on FRAM model

Considering that **normal performance** takes place as a result of adjustments, the cause of failures cannot be found in the normal actions, thus emergent phenomena (both normal performance and failures) can’t be attributed to specific components or parts.

A better description of the **“Control”** function in FRAM analysis could be addressed as in the STAMP model, since it mirrors a feedback-based control hierarchy and it is always limited by restrictions applied to the variables of the system.

Limitations of systemic methods
A focus on FRAM model

This approach might involve an optimisation of the functions with nonlinear aspects and nonlinear restrictions, even if it is a local optimisation on the levels of human performance.

$$F:\mathbb{R}^n \rightarrow \mathbb{R},\ F = f(x_1, x_2, \ldots, x_n),$$

$$\max\{F(X) \mid c_i(X) = 0, i = 1, \ldots, m^{'}; c_i(X) > 0, i = m^{'} + 1, \ldots, m\}$$

$$h_i(X) = 0, i = 1, \ldots, m^{'}$$

$$g_i(X) > 0, i = m^{'} + 1, \ldots, m$$

Limitations of systemic methods
A focus on FRAM model

Considering criterions such as **competence** and **rule violation**, studies revealed that after imposing the right goals and rules in an organisation, the mechanisms of safety information culture revealed major changes in the risk factors regarded. At the time, the quantitative analysis reflected a minimum of rule violation and maximum competence.

Table 1.Human factors performance analysis

Criterion	Occurrence (%)	Correction (%)
Rule violation	27	50
Competence	61	70

Limitations of systemic methods
A focus on FRAM model

Last generation of **nonlinear methods** may require extensive knowledge of the interaction between analysed factors, but since criticism on linear methods targeted precisely the problem of not considering interaction between elements, a new perspective on accident modelling must not reflect the difficulties or inconveniences in applying systemic models, but their shortcomings.

The development of the Functional Resonance Analysis Model has been mostly described in the literature and only a major part of the systems theory concepts are explicitly represented by FRAM functions, this shows that there is room for improvement.

A systemic substantiation of the analysis Establishing new directions

Control is a key point for achieving high performance standards and high operational capacity.

In the **organizational culture**, the **lack of control** will lead to chaos by suppressing the desideratum of reaching high levels of performance.

$$P(Abnormal\quad Conditions)\cap P(Failure\quad of\quad control) = P(Loss\quad of\quad Control)$$

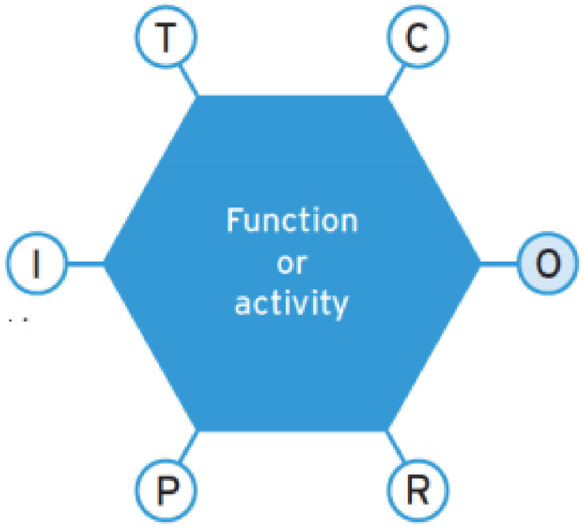
$$P(LOC) = P(AC\,|\,FOC)P(FOC) = P(FOC\,|\,AC)P(AC)$$

A systemic substantiation of the analysis
Establishing new directions

CONTROL

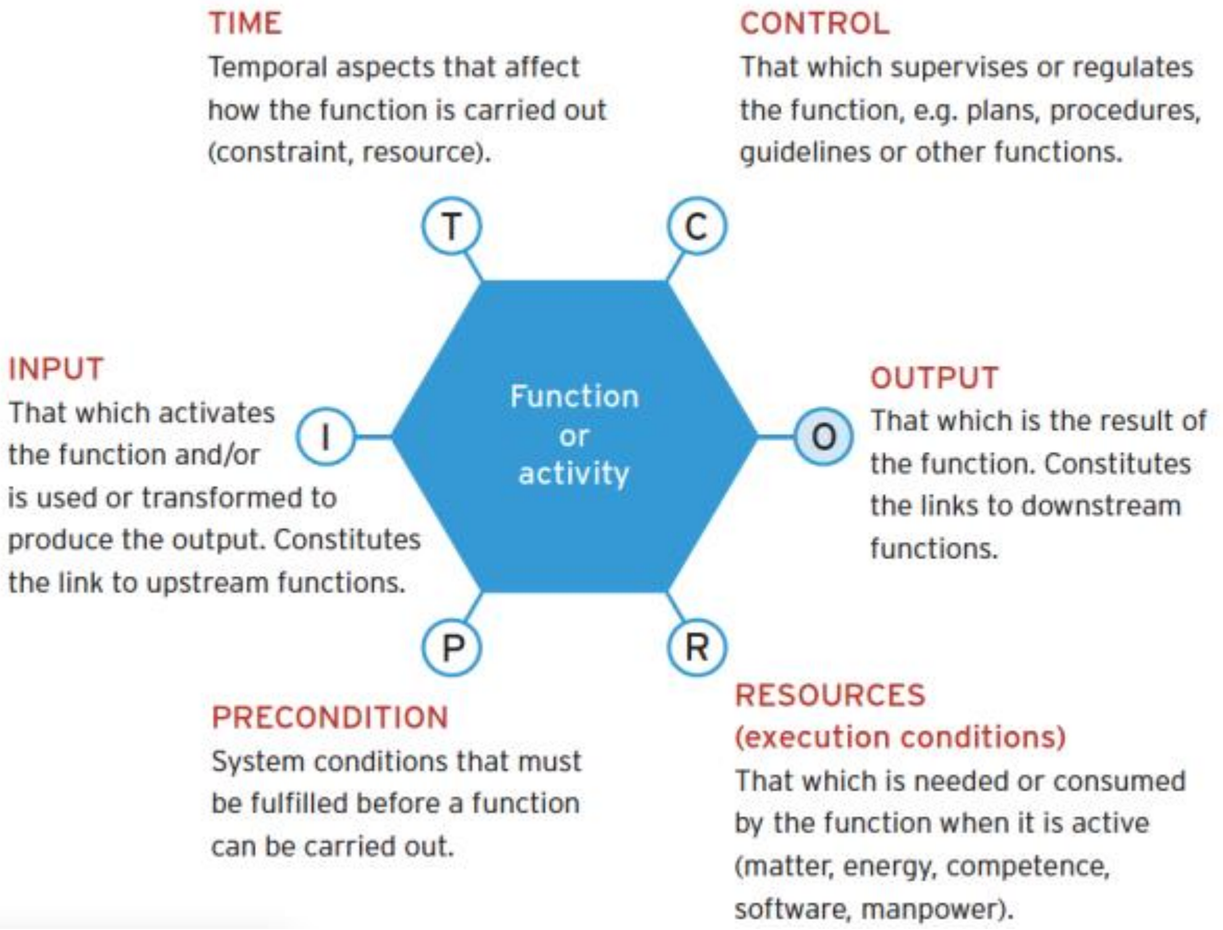
That which supervises or regulates the function, e.g. plans, procedures, guidelines or other functions.

The **Control** function in a FRAM node refers to monitoring and revising limitation on planning, on procedures, etc.



A systemic substantiation of the analysis
Establishing new directions

Neither **control**, nor other functions such as **Preconditions** or **Resources**, necessary to processing input data, answer the problems made by possible breakdowns in communication procedures.



A systemic substantiation of the analysis
Establishing new directions

A new multi-factorial analysis will impose an important (complementary) function in the node, necessary for establishing the importance of communication in the examined processes.

Table 2. CFIT Risks related to human factors (Communication) (IATA Report, 2016)

Risk Type	Value (%)
Communication environment	12%

A systemic substantiation of the analysis
Establishing new directions

Communication is involved in:

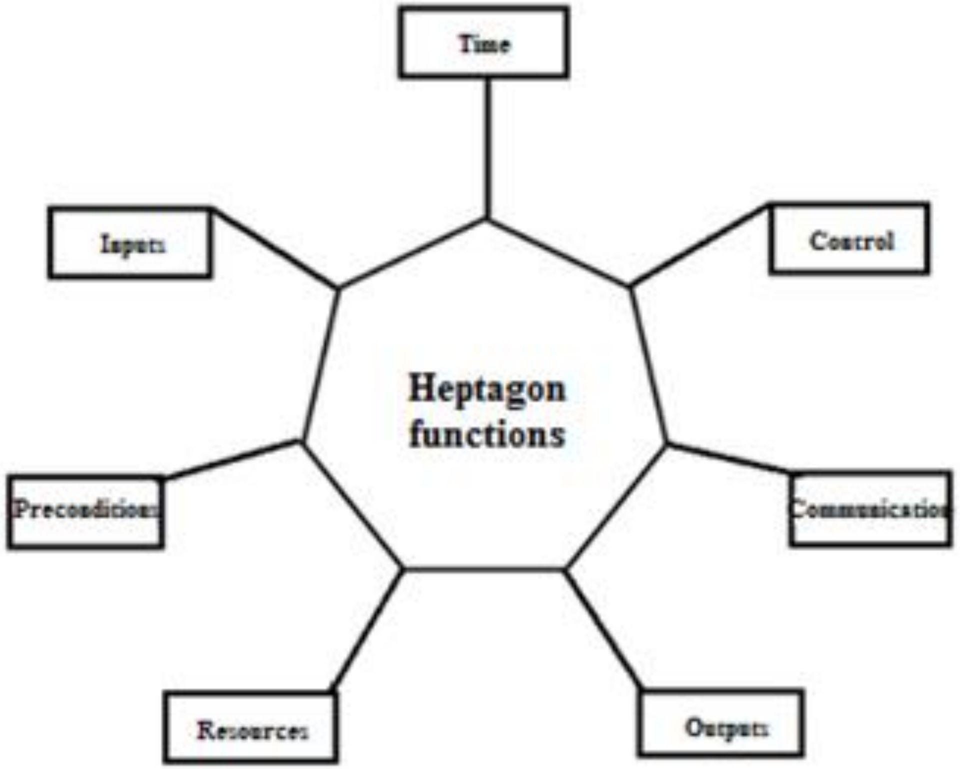
- approximately 20% of the errors that can be recorded in flight
- a significant percent is realized during takeoff procedures, but mostly (in 43% of cases) during approach and landing phases

Table 3. Flight crew errors (IATA GADM, 2017)

Flight crew errors	Percent of LOC accidents (%)
Pilot-to-pilot communication	8%

A systemic substantiation of the analysis Establishing new directions

The **hexagon** described by the information and function node will be transformed into a heptagon characteristic to key analysis system method, by adding a new function.



A systemic substantiation of the analysis
Establishing new directions

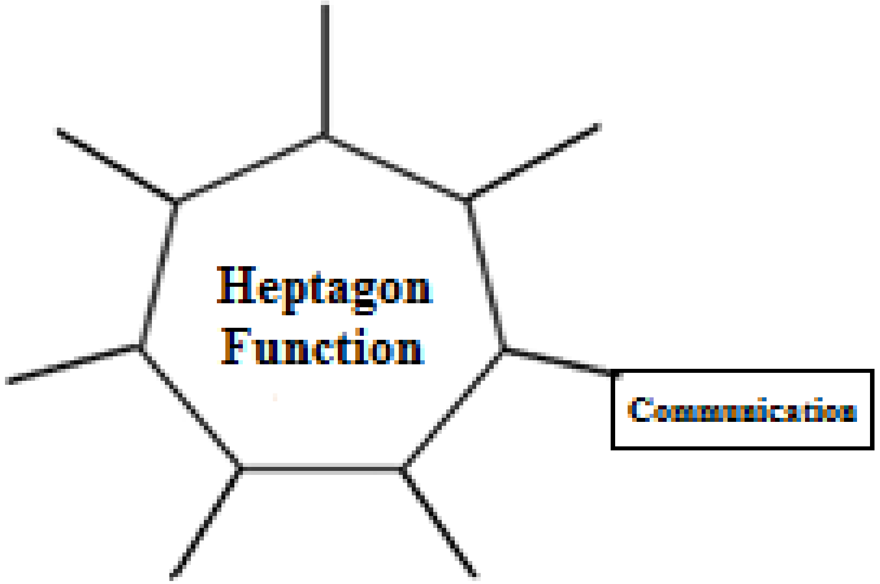
Emergent factors require the application of barriers in order to control and restrict changes in the levels of safety.

Barriers can be set even from analyzed functions **(ex. Control, Communication),** can be the data received, ATC information, visual or audible warnings, corrective actions, referral and understanding of an instance or unusual circumstances, etc.

A systemic substantiation of the analysis
Establishing new directions

From the perspective of communication, research on the human factor ought to dictate the presence of a conductive environment and the channel described.

The channel must be bilateral in order to transmit and receive technical or organizational data. These directions are useful to cancel a predisposition for a high risk manifestation imposed by an incorrect/incomplete or faulty message transmission.



A systemic substantiation of the analysis
Establishing new directions

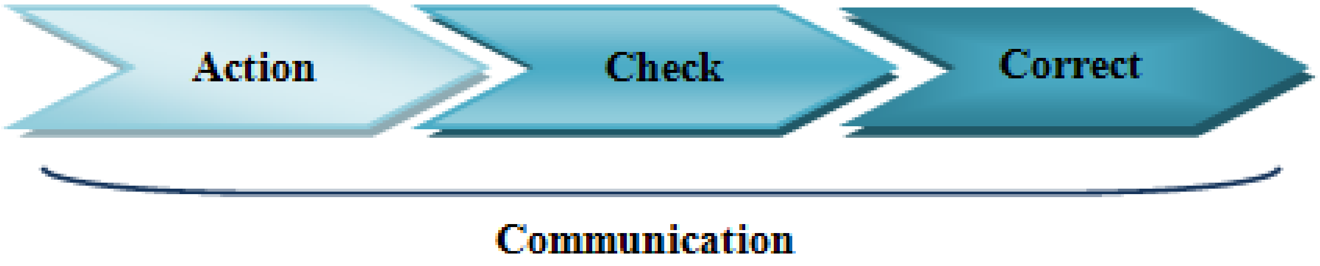
The human factor must be trained to recognize and report errors/mistakes in order to build their own learning culture, and beyond that, a safety culture.

Table 4. Conversion of safety culture characteristics regarding communication (ICAO Doc 9806)

Old model	**New model**
Closely held information	Open communication

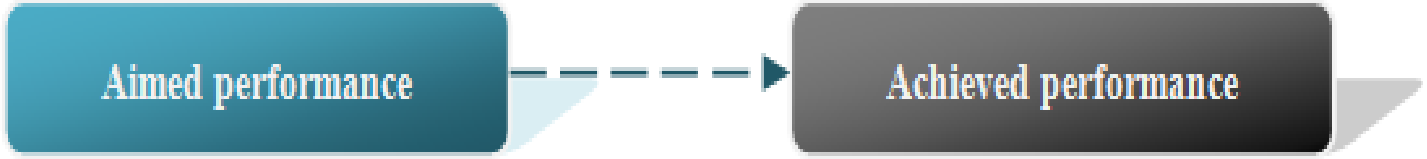
A systemic substantiation of the analysis
Establishing new directions

Procedural errors are reflected by flawed communication, therefore the implementation of CRM which concerns crew interactions and focusing on communication and verification, constitutes the response to minimize problems associated to information culture.



A systemic substantiation of the analysis
Establishing new directions

The analysis will be built in relation to **standard conditions** of flight, but also with **low performance levels.**



A systemic substantiation of the analysis
Establishing new directions

- The method will explore the following classes of elements and conditions:

- Procedures that were performed (according to standards/ regulations)
- Procedures that were not performed
- Procedures that were omitted
- Procedures that were performed incorrectly
- Procedures that were performed incompletely
- Procedures performed in certain circumstances (in order to face/solve/clarify an exceptional condition/event)

A systemic substantiation of the analysis
Establishing new directions

The proposed model is supported by **two theoretical pillars**:

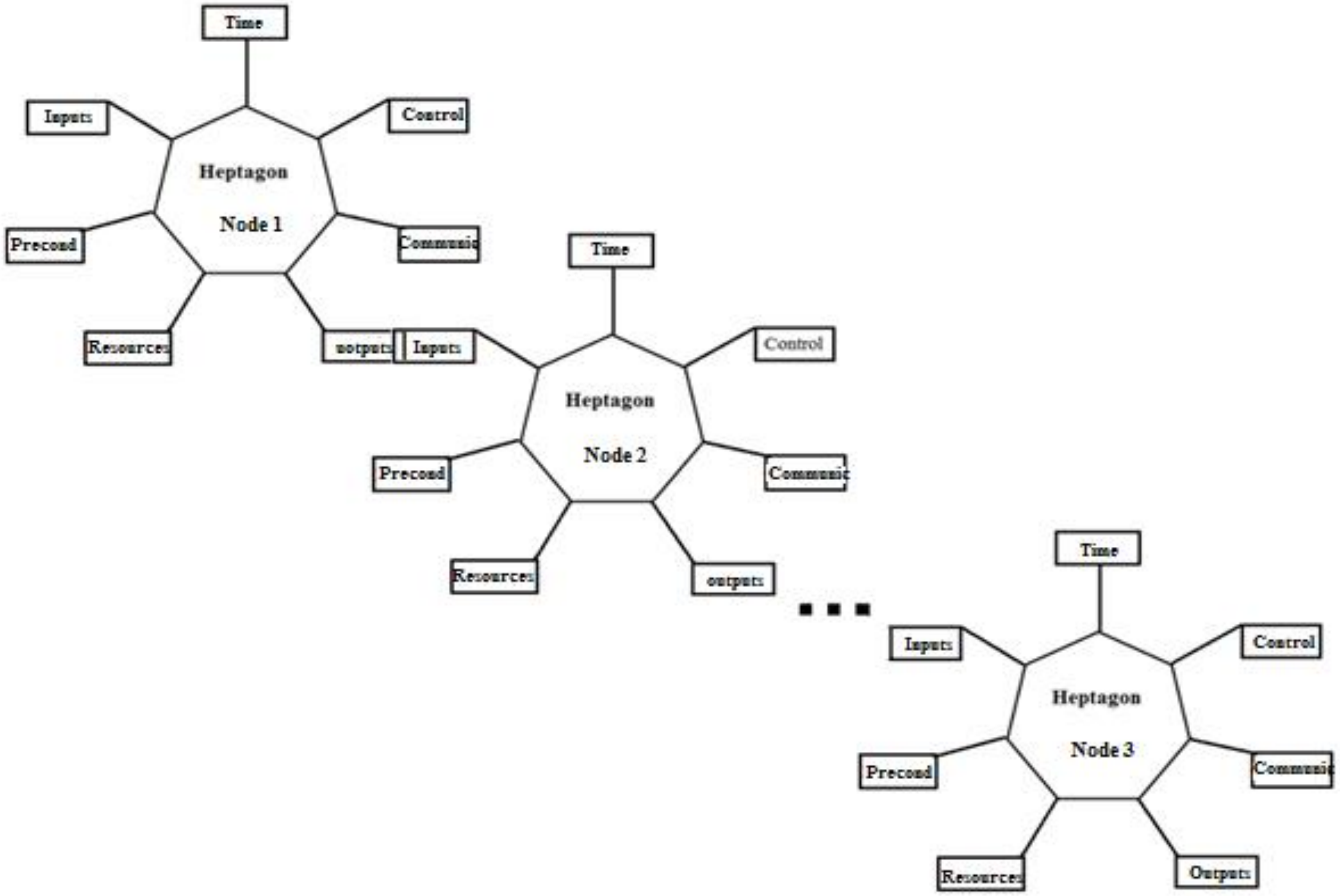
- Control Theory and

- System theory

The research also traces hypothesis and leading lines that exclude redundant tendencies of the analysis whilst clarifying the problem of performance variation and configures the connection of the functions from different nodes.

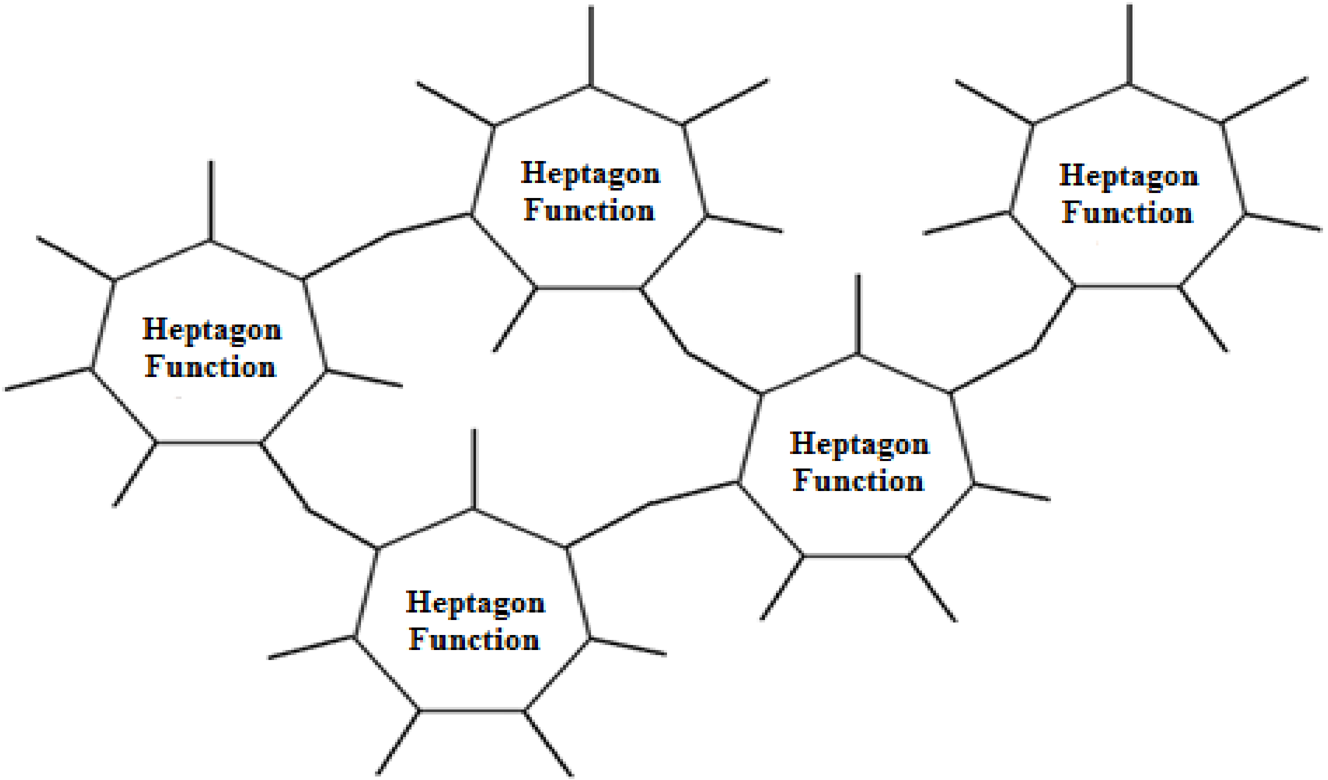
A systemic substantiation of the analysis
Establishing new directions

- Connecting these elements
- can imply a linear sequence
- where each output of a
- heptagon can represent
- an entry for the successor
- node.



A systemic substantiation of the analysis
Establishing new directions

A complete form, representative for correct configuration of the analysis requires a different approach, extended by a connection similar to neural networks, in which the functions coupling mechanisms do not aim to transform an output node in an input for a further analysis.



A systemic substantiation of the analysis
Establishing new directions

- This report has focused on highlighting the limitations of last generation nonlinear models, with reference to the Functional Resonance Analysis Method.
- Since existing systemic models must be improved in order to take into account the elements that were left uncovered, the research has determined that one of the focus points is the communication factor.
- Hence, the development of a new multi-factorial analytical modelling tool was initiated in order to analyze the conditions that influence the development of an accident scenario.
- This tool characterizes the evolution and interdependence of causal factors that exceed acceptable levels of risk and the permissible margin of safety.