



Formalization, Evaluation of non-functional properties for system of system engineering: Application to Resilience

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► To cite this version:

Behrang Moradi, Nicolas Daclin, Vincent Chapurlat. Formalization, Evaluation of non-functional properties for system of system engineering: Application to Resilience. 14th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2017), Albi, France, 21-24 May 2017., May 2017, Albi, France. hal-02016577

HAL Id: hal-02016577

<https://hal.science/hal-02016577>

Submitted on 12 Feb 2019

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Systems of Systems Engineering

A system of system (SoS) is an integration of a finite number of constituent systems which are independent and operable, and which are networked together for a period of time to achieve a certain higher goal. [Jamshidi, 2009].

SoS are composed of separate constituent systems and have a majority of the following five characteristics [Maier, 1998]:

Operational independence – constituent has a purpose of its own and can be operated independently, without the need to interact with other systems.

Managerial independence – constituent are controlled by different authorities (or system owners), they not only have operational independence but are, actually, operated independently.

Emergent behavior – behaviors are only exhibited at the SoS level and cannot be achieved by any of the constituent systems operating independently of the other constituent systems.

Evolutionary development – SoS is not created once and for all, but evolves as constituent systems, or functions thereof, are added, removed, or modified.

Geographical distribution – the concern of SoSE is primarily with the information exchange between constituent systems.

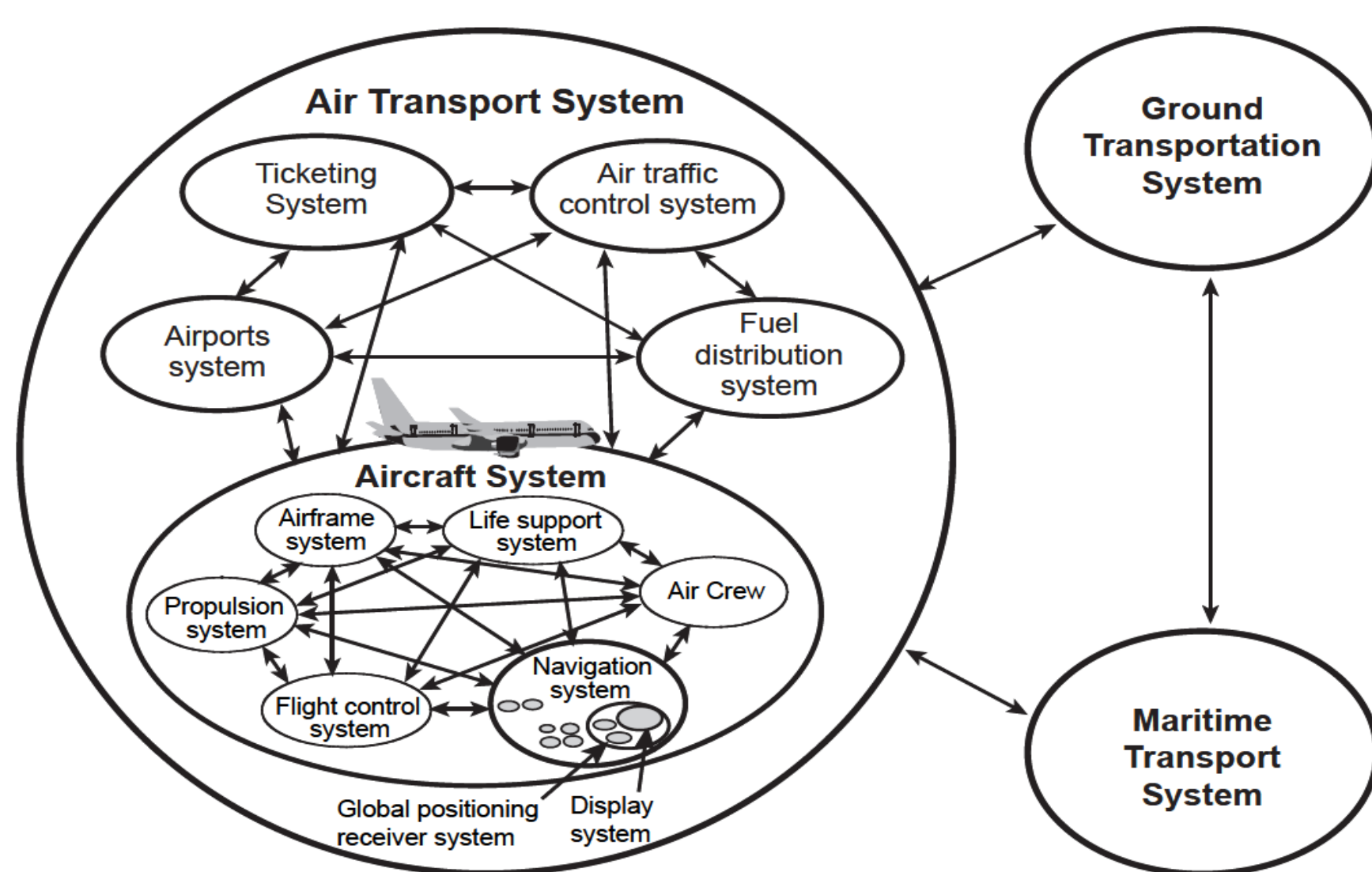


Fig.1. A Transport System-of-Systems

Resilience

Ability to prevent, prepare for, respond to, adapt to disruptions and to mitigate the consequences as well as to recover in timely and efficient manner including preservation, restoration of services [Cutter et al. 2013].

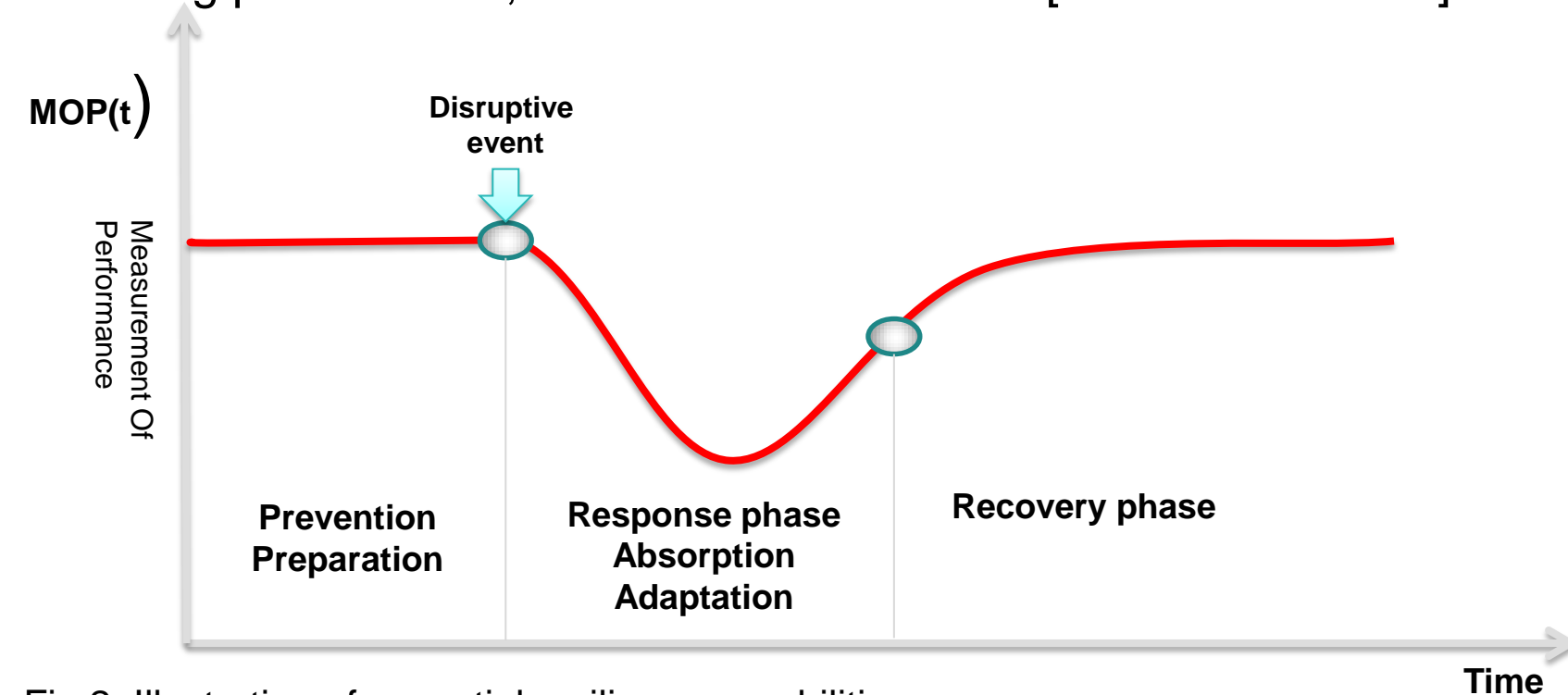


Fig.2. Illustration of essential resilience capabilities.

Prevention: Identifying and minimizing the risks posed by the Critical Infrastructure, its equipment and fittings, and the natural hazards of the environment [UNESCO 2017].

Preparation: "Getting ready to cope" [UNESCO, 2017].

Response: Following the previously established emergency procedures.

Absorption: Endogenous ability to reduce the negative impacts caused by disruptive events and minimize consequences with less effort [Nan, 2017].

Adaptation: Endogenous ability to adapt to disruptive events through self-organization to minimize consequences. It can be enhanced by using emergency systems [Nan and Sansavini 2017].

Recovery: "Getting back to normal" [UNESCO 2017].

To define, specify and develop equipped method to evaluate resilience for System of System Engineering

Relationships amongst Resilience and System Lifecycle Properties (Ilities) :

- The "-ilities" are properties that often **manifest and determine value** after a system is put into initial use (e.g. resilience, interoperability, robustness).
- Resilience is an important "-ilities" and must be **mastered and maximized** with engineering systems of systems.

Hypothesis 1: The resilience can be evaluated by defining and analysing its relations within the "-ilities" "ecosystem".

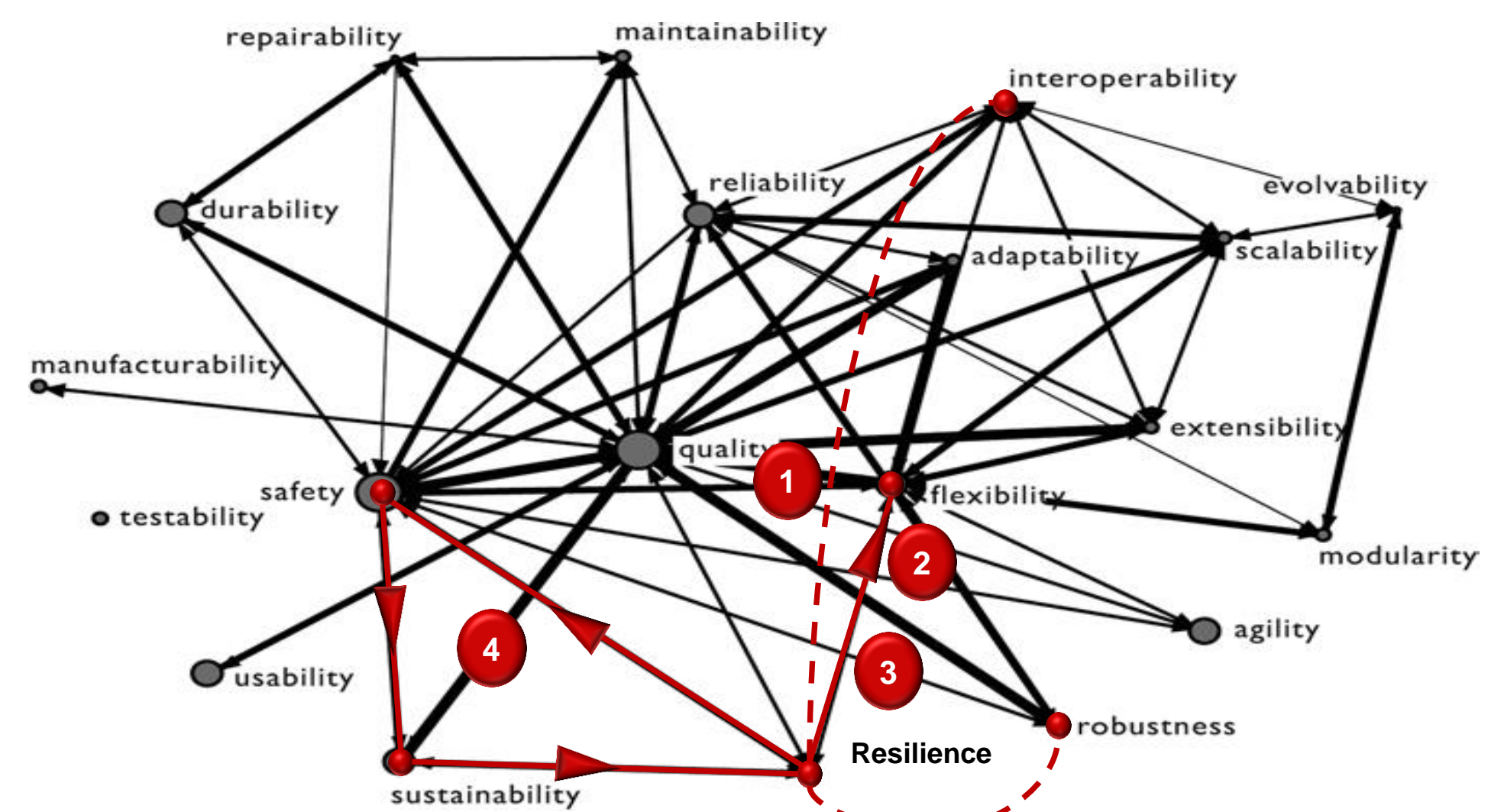


Fig. 3. Correlation network of ilities based on a normalized 2-tuple keyword analysis [De Weck, Ross, Rhodes, 2012]

- Analysis of dependencies between the other ilities and resilience
- Definition of the orientation of the dependencies (from /to resilience)
- Definition of the intensity between resilience and ilities (level of variation from of the resilience from a variation of a linked ilities)
- Definition and formalization of the propagation concept

Hypothesis 2: The evaluation of resilience is decomposed in local resilience evaluation according to its lifecycle.

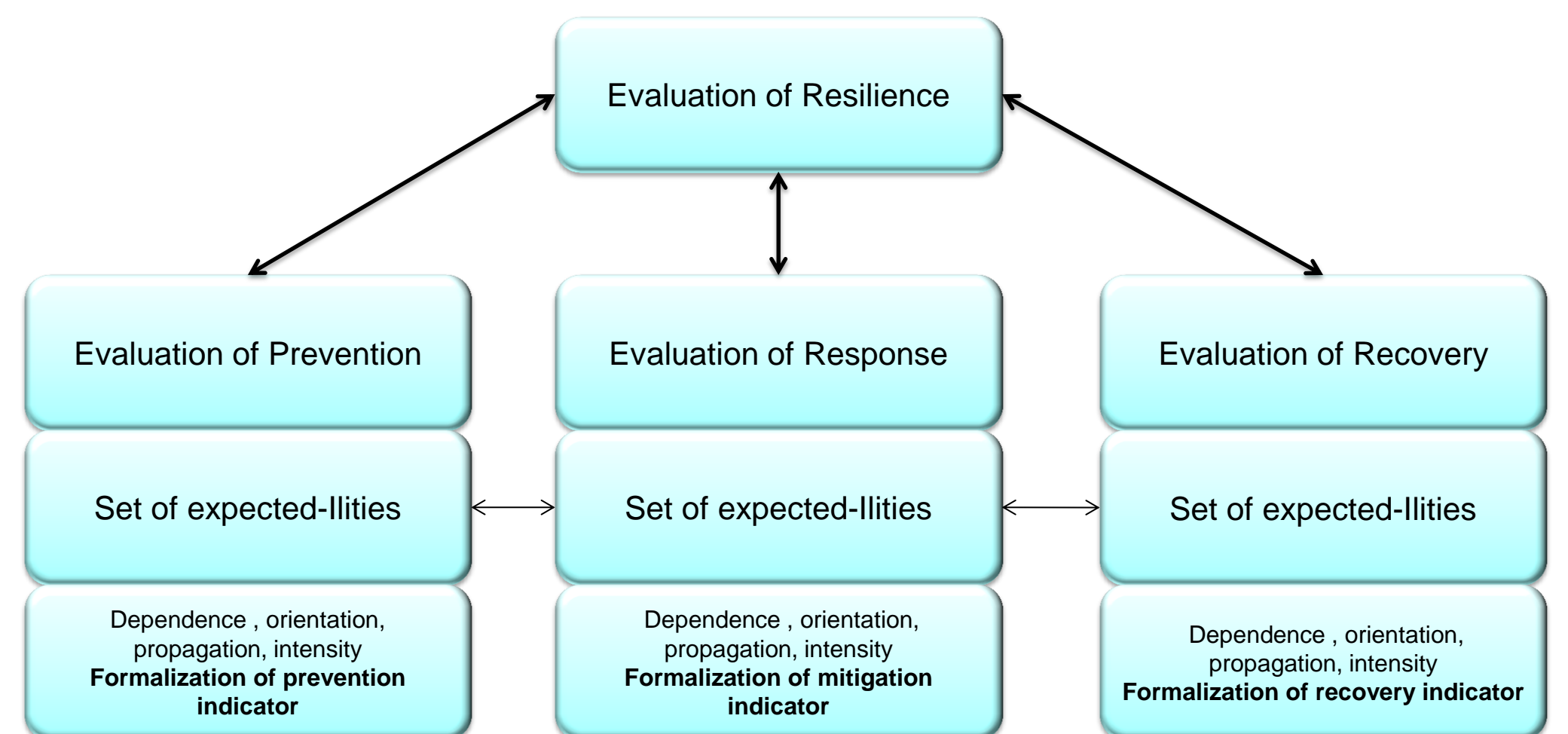
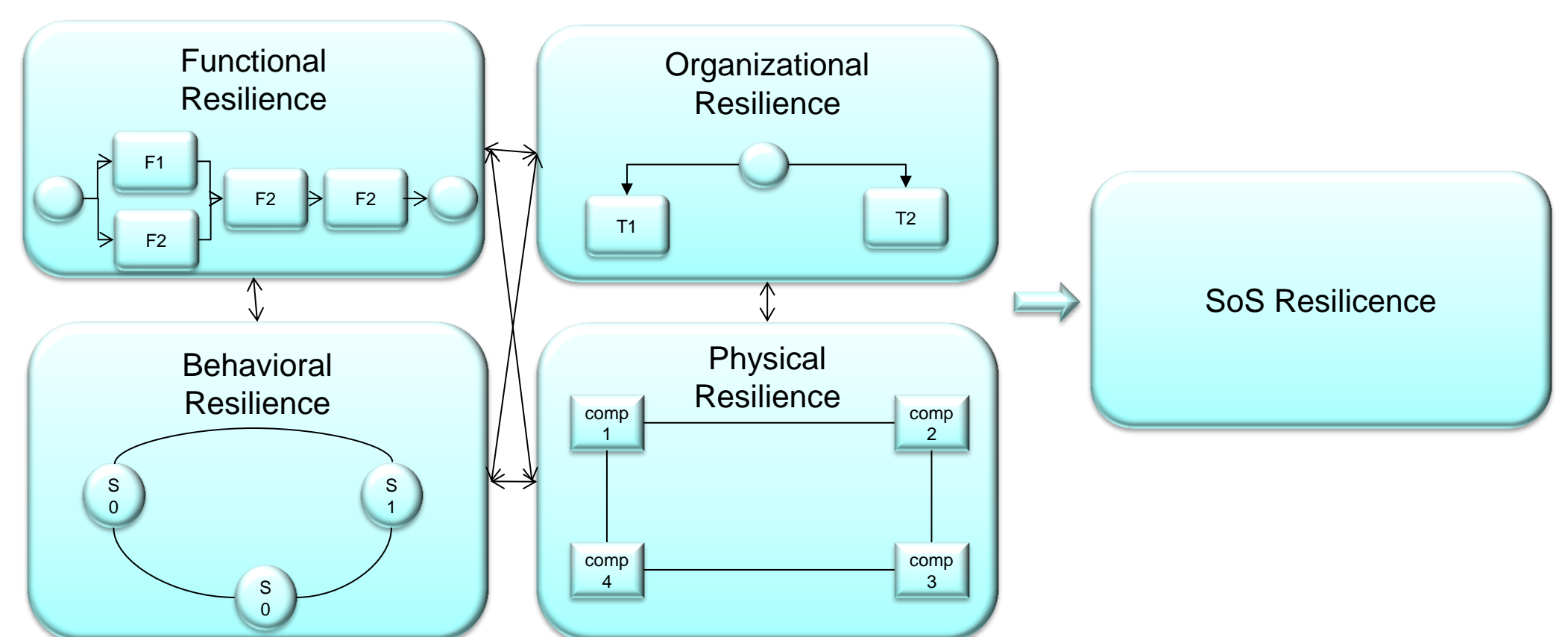


Fig. 4. Framework of evaluation of resilience

Hypothesis 3: The evaluation is done according to different points of view: organizational, physical, behavioral and functional.

- Definition of organizational, behavioral, physical and functional resilience .
- Adaptation of each indicator to the studied point of view.
- Comment**



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