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Situation Awareness and Governed Trust in Partner Networks: A Hierarchical Conceptual Model

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Abstract

This research was motivated by numerous challenges of collaboration in loosely connected partnership networks and strived to propose suggestions, applicable especially for critical cross-border infrastructures. Such need was induced by the necessity of secure and uninterruptible character of their services, significant of even dangerous impacts of possible malfunctions and inherent presence of nationally specific differences. As a possible solution, we propose a conceptual model of a governing framework for such types of industrial partnerships, considering several types of their structural and behavioural aspects. In the organizational context, situation awareness was included as a physical function in the second level of the Work domain analysis framework (WDA) in a form of a qualitative knowledge-based model. Its layered structure allows interconnection of situation awareness with principles of organizational performance, cybersecurity and trust, as well as the synthesis of related joint metrics. Toward the collaborating partners, there are two main outputs from WDA framework, performance and availability. Based on the continuously shared set of momentary values of these indicators, governing level of partnering network can efficiently plan further joint steps and develop or optimize own collaborative procedures.

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Methodologically the presented solution combines WDA with traditional methods and tools of system thinking into the resultant Causal loop diagram, characterizing dynamics of mutual trust among collaborating partners. This diagram can be either analysed directly or conveniently adjusted for specific cases. Its individual or team analyses can provide a useful insight into the dynamic aspects and consequences of efficient extra-organizational collaboration. Besides the optimization of joint performance, such a complex knowledge-based model can also decrease the overall vulnerability and help organizations to safely recover from undesirable effects of fast global dynamics, including, e.g., the total impacts of the ongoing pandemics.

Keywords – Situation awareness, Partner network, Trust, Mental model, Governance

Paper type – Academic Research Paper

1 Introduction

At first sight, the concept of situation awareness (SA) seems to be straightforward. However, a deeper consideration enlightens the complexity and wide spatio-temporal context of this phenomenon. Its main characteristics, applicable to individuals, teams or organizations, can be summarized as follows:

- The primary role of situation awareness is the support of the right decisions. From the organizational point of view, well-developed SA is useful especially for planning and fulfilment of SMART objectives on the level of executive management,
- Managerial decisions usually combine the truth-preserving deductive, i.e., knowledge-based and inductive, i.e., data-driven inference. Consequently, SA requires a firm base of valid, relevant and diversified knowledge, extended with secured, correct, reliable and consistent data.
- Real-world problems are holistic and multidimensional with numerous subjective factors, represented with nonlinear utility functions. Also, causality and a wide range of internal dynamism, are fundamental challenges, accompanying the decision making processes.

1.1 Situation awareness

As the overall unifying paradigm, this research adopted principles of the Maslow's hierarchy of needs (Bridgman *et al.*, 2018; Maslow, 1943), applied to the corporate environment. In such context, the crucial prerequisite for any type of

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cooperation is functional organizational metabolism, representing the conversion of industrial inputs into expected outputs and expressed, e.g., in terms of productivity or, in a broader context, performance. This vital transformation is located on the ground level of the hierarchy, as it is shown in the left part of Figure 1. For effective and repeatable production, an organisation must feel secure in all its value-creating phases. This essential requirement concerns both its internal processes and external inputs, influenced by the market or environmental changes, governmental regulations or interaction with collaborating subjects. While at the first and partially also at the second level of Maslow hierarchy the organisation is mainly concerned with its own needs, all subsequent levels also assume different types of social bindings. Nevertheless, this research dealt mainly with the third level, because the performance management, widely explained in the literature (Davies, 2016; Lee and Snyder, 2017), was out of its scope. The same purposely done omission holds also the cybersecurity domain, research and scientific analysis of which is presented in (Edgar and Manz, 2017; Metcalf and Spring, 2021). Our approach, directly applicable also in WDA hierarchy, was presented in (Voracek *et al.*, 2020). Concerning the upper two levels of Maslow's pyramid it is evident that they can be added to this framework later. Both research and practice (Kenrick *et al.*, 2010; Krech *et al.*, 1962; Maslow, 1942; Uchejeso, 2019) distinctly indicate that for a standard-functioning organisation, the level of fulfilment of its own needs increases over time and its composition and scope changes.

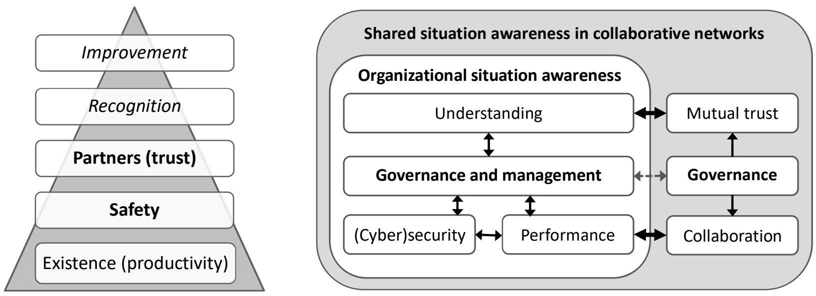

Figure 1 Maslow hierarchy and situation awareness in a wider context

1.2 Modelling of situation awareness

There are numerous models of individual situation awareness, derived from the seminal paper (Endsley, 1995). This model distinguishes three generic SA phases,

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perception, comprehension and projection, forming the desired decisions and actions, as it is schematically shown in Figure 2.

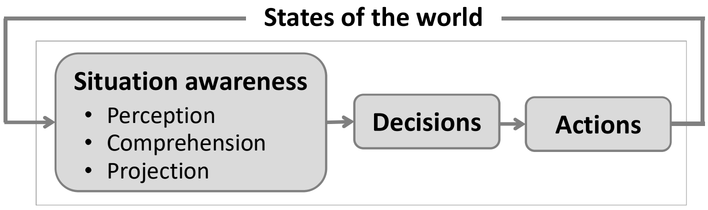

Figure 2 Simplified Endsley's model of situation awareness

Many consecutive modifications of this originally air-traffic model were introduced to fit better to more complex and technically oriented SA models, useful for phased processing of multi-input semi-autonomous systems, typical for the Internet of things, Industry 4.0 or cybersecurity. Their characteristic representative is the Observe-Orient-Decide-Act (OODA) model, informally introduced by Boyd and further developed by (Luzwick, 2000; Lytvyn *et al.*, 2020). Extended models of individual SA can also be used for work in teams (Endsley and Jones, 2001).

1.3 Shared situation awareness

The stronger the scope and responsibility, the higher need for well-formalized situation awareness. This evident fact also concerns the presented case of network collaboration. As the network usually represents rather governing than managing superstructure, its role typically insists on overall coordination and harmonization, and not in the generation of core performance. Thus, the challenging situations arise when cooperating organizations need to share their specific states of SA. This is impossible in terms of the model itself because its individual architectures and parameterizations are unique and contain mainly private, formally and semantically specific information. Inspirative characteristics of distributed SA were presented in (Salmon *et al.*, 2017) and applicable shared mental models of secured situation awareness were proposed in (Gawron, 2019; Noran and Bernus, 2018).

Networking matters can be solved based on the Resource dependence theory (RDT) presented in (Hillman *et al.*, 2009; Loasby, 1979; Pfeffer and Salancik, 2003). The RDT states that an organisation can be in a specific way dependent on

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resources that it does not own in sufficient quantities. Thus, it must rely on resources of another organisations, especially in critical situations. Hence, shared resources can become a tool of particular power in such communities. This theory was further developed into general models of collaboration, where the Resource Dependence Institutional Cooperation (RDIC) model described in (Hoefsmit *et al.*, 2013; de Rijk *et al.*, 2007) was adopted for this research. Figure 3 shows that it also preserves all three stages of the individual SA model, where perception and comprehension are located at level 3 and level 2 is a result of their projection.

Instead of complex metrics, the status of external collaboration is expressed just with two descriptors, the real ability to cooperate and the corresponding willingness. The former represents the level of ready to share capabilities and resources, the latter indicates the real motivation to cooperate, resulting from the trust. When analysing this pair of determinants in terms of bilateral relations, the following four possible combinations emerge:

- Correspondence in ability and willingness: efficient collaboration with added synergy,
- Correspondence in ability, differences in willingness: quantitative, mainly administratively additive form of cooperation,
- Differences in ability, correspondence in willingness: societal effort to cooperate without explicit commercial interests,
- Differences in ability and willingness: random, inconsistent collaboration with non-deterministic added value.

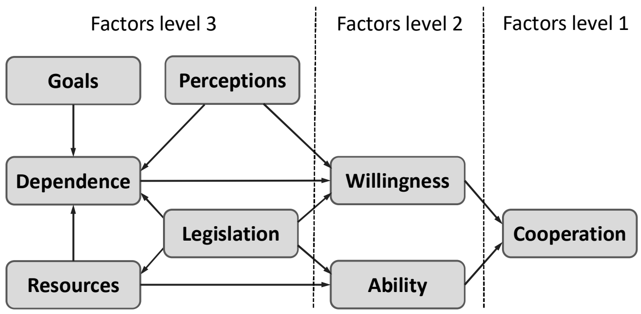

Figure 3 Schematic representation of RDIC model

The generic RDIC model for collaborating organizations must be appropriately implemented. Practically this means, that the metrics, continuously provided outside, must be centralised, regularly processed and results used for future

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optimization of network performance. Similarly, the applicable model of such agile network governance must respect the local habits, actual means and capabilities. According to the literature focusing on governance (Laimer, 2016; Provan and Kenis, 2008; Raab *et al.*, 2015), there are three following concepts of network governing structures, illustrated also in Figure 4:

- Organizationally arranged and administratively linked partners share the common governance, executed by individual management structures. This option is suitable for tight global organisations or supply chains. In case of loosely coupled units, the centralized way of policymaking violates the assumption of individual independence.
- Consortium represents a federative form of governance and preserves individual kevels of management. The main weakness of consortium is the identification of the most convenient way of federalized decision-making.
- Coalitional structure does not have an explicit level of governance; however, partners are informally coordinated at their own governance and management levels. While this arrangement maximises autonomy and ensures information sharing, it may have problems with implementation of common decisions.

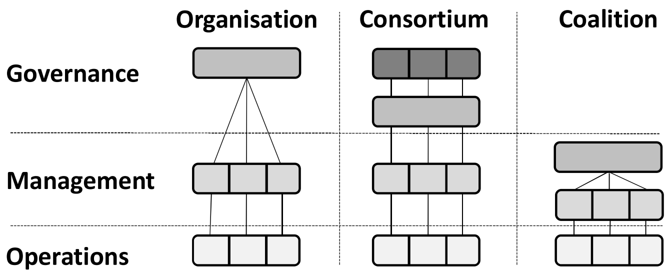

Figure 4 Different structures of network governance

1.4 Understanding and trust

The willingness to collaborate is the key enabler, determining the real scope of shared services or resources, provided by an organization to its partners. To explicitly analyse and share this crucial soft category with partners, its transparent quantification is unavoidable. Thus, we propose to express the willingness with

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the two explicitly defined indicators, mutual (terminological) understanding and trust.

2 Terminological unification and reduction

The notion of mutual understanding expresses the fact that the cooperating organisations understand each other both syntactically and semantically. Syntax refers to the set of related terminology, semantics concerns the overall meaning of particular concepts. Standardization of both communication aspects mitigates linguistic and cultural differences and minimisation of shared dictionary properly structures and simplifies the collaboration. This process results in the following four combination of communication compatibility, which must be early recognized, managed and optimised:

- Consensus, when syntax and semantics and understood similarly,
- Correspondence, resulting in the commonly understood meaning, expressed with different terminology. This is an acceptable and usual situation, because the definition of common descriptors for joint concepts is a technical matter,
- Conflict means that involved parties are used to present different topics in the same words. This risky situation usually requires thorough redefinition of the ambiguous concepts,
- Contrast indicates that the members of the working group cannot agree either on common issues or terminology, which usually indicates an inappropriate composition of the working group or incorrectly designed structure of the set of the modelled concepts, pairing them with inappropriate descriptors.

Another effect of the unification phase is the possible reduction of total number of shared concepts and terms. The irrelevant items can be removed, and the close ones merged. This is usually realized by the numeric clustering of initial sets of concepts (semantics) and constructs (terms), after which the resultant sets are personally analysed. The Repertory grid (Kelly, 1991; Ryle, 1975; Stewart *et al.*, 1990) can be used for these purposes.

3 Trust

Trust is defined as the will to accept potential risks based on the positive expectations, intentions or behaviour of another entity (Cui *et al.*, 2018).

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According to (Thanetsunthorn and Wuthisatian, 2020), trust is recognised as one of the most significant determinants of both organisational development and success. Nevertheless, increased performance, productivity, creativity, innovativeness, inner satisfaction, motivation or the willingness to share knowledge are the positive consequences of trust within an organisation (Pirson and Malhotra, 2011). From the static point of view and primarily at the individual level, it is challenging to quantify trust because of its hardly distinguishable causes and effects. Hence, this is the specificity of trust, compared, e.g., to the quality, which is also intangible but can be straightforwardly expressed as a degree of non-compliance with the explicitly given standards. Therefore, it is better to analyse trust dynamically, because in such case it evolves within interconnected feedback loops, where the role of initial causal relations is important mainly at the beginning of analysis. Trust T is frequently characterized by the Trust equation (TE) (Maister *et al.*, 2001) as follows:

$T = (C * R * I) / O,$ where:

C is Credibility, which represents the joint level of past perceived trustworthiness and expertise,

R is Reliability and can be measured as a level of fulfilment of past commitments,

I is Intimacy as a metric of ability to preserve secret or sensitive information,

O is Self-orientation, i.e., level of preferring personal benefits over the team ones.

Although trust among organisations is based on similar principles; the structure of operands in TE must be derived directly from organisational processes. A number of specifically targeted publications are devoted to this matter, analysing the possibilities and tools of forming and evaluating trust in specialised organisational structures (Aydogan *et al.*, 2014; Radomska *et al.*, 2019; Ward *et al.*, 2014). Interesting are also conclusions from the extensive review of methods and tools for trust modelling, presented in (Cho *et al.*, 2015). It states that trust is determined with close synergy between corporate governance and management, whereby the implemented strategies clearly respect the mission, values and general goals. Furthermore, trust needs to be continually evaluated, primarily through simple, unambiguous, easily understandable and transferable metrics. In addition, adequate and explicit resources should be dedicated for trust-building

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initiatives and should be carried out on an ongoing, regular and personal basis. Finally, the following dimensions of composite trust were presented:

- Communication trust, in our case referring to the overall quality of network services, including, e.g., their stability, availability, timeliness, reliability, scalability, effectiveness, maintainability or bandwidth,
- Information trust, expressing the level of information sharing and its quantitative and qualitative aspects, concerning the intrinsic (accuracy), contextual (relevance), representational (interpretability) and accessibility (security) characteristics. This dimension correlates with the intimacy component of the trust equation (TE),
- Social trust: indicates the trust between individuals in virtual networks, measured with selected indicators of their interactions. This metrics concern practically all internal, performance related processes and any form of business-oriented digital networking (supply chains, critical infrastructures, global businesses) and it is close to TE reliability component,
- Cognitive trust, acquired from any kind of cognitive processes, established among partners, such as the internal learning and growth processes or personal development of network collaboration. The cognitive component of composite trust is vaguely related to credibility and self-orientation elements of TE.

Dimensions of trust can naturally evolve within the organizational structure and over time. Such levels of maturity, applicable gradually on teams, organizations and the whole network, can be characterized as follows:

- Basic maturity, implemented at the level of organizational management and including regular monitoring and control of trust reflecting metrics, derived either from the overall performance or from its specific BSC-like sectors (operations, learning and growth, customers, finances),
- Intermediate maturity, implemented at the level of organizational governance, expecting definition of trust-driving values, policies and strategies, compliant with adopted industrial standards,
- Advanced maturity, implemented at the level of network governance and assuring harmonization and optimization of all aspects of single trust dimensions.

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2.1 Work domain analysis

The above-presented structural elements can be further refined and integrated into the hierarchical structure of the Work domain analysis (WDA) framework, presented and applied in (Burns *et al.*, 2009; Lintern and Naikar, 2000; Wang *et al.*, 2017). WDA is the first stage of Cognitive work analysis framework (Rasmussen, 1985; Vicente, 1999), capable to modelling structure, behaviour, strategies, social interactions and competencies of complex socio-technical systems. As an architectural diagram, it deals entirely with structural elements, disregarding their specific functionality. It is the bidirectional means-end type of abstraction-decomposing architecture with two physical and three domain layers, ordered in a vertical direction. Sometimes, WDA diagram is structured also in the horizontal direction, showing different levels of decomposition, from whole to parts.

Inner nodes of vertical layers represent structural function or constraint as follows:

- Domain purpose: the main focus of the analysed system,
- Domain values and priority metrics: the key qualitative and quantitative descriptors of system purpose, either collected from lower layers or passed there from the upper level,
- Domain functions: general functions, synthesizing the system purpose based on outputs from physical functions or adjusting these functions,
- Physical functions: specific capabilities, generated or requested by underlying social or technical systems,
- Physical resources or constraints: different types of system inputs and outputs.

3 Methods

The main methodological goal of this research was to review, systemize and merge the extensive and thematically heterogeneous resources to address the following topics:

- Weak situation awareness of loosely collaborating organizations,
- Lack of simplistic formalization and standardization of their daily interactions,
- Absence of common cohesive structural elements, that would guarantee an appropriate level of governance for the whole network.

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Results of literature review and personal interviews indicated that the routine processing of organisational knowledge as well as sharing it with partners is not a common practice. Valuable information and practical experience were found also in extensive deliverables of EU projects, concerning mainly infrastructural resilience and containing results of workshops with stakeholders (DARWIN, 2018; IMPROVER, 2018; RESILENS, 2015; SMR, 2018). Furthermore, these resources also state that there are multiple reasons for such a closedness, from mutual procedural incompatibility to unsolved political, economic, social, technological, legislative and ecological (PESTLE) differences.

Consequently, the dentification of appropriate ways of creating and developing a suitable coordination platform is crucial for harmonising synergies across the network. We propose to eliminate these bottlenecks through the following qualitative outputs:

- Structural standardization of situation awareness of single partners in the form of WDA framework, as a specification of RDIC model,
- Identification and dynamic formalization of shared trust as the key prerequisite for efficient collaboration in partner networks, using the Causal loop diagram.

Such qualitative models established the initial common understanding of the researched problem, which will be further specified and quantified. The complex networking problems, characterized as functionally and managerially independent, geographically distributed, intrinsically complex and evolving over time, are typically analysed using the System of systems framework (Cantot and Luzeaux, 2013; Kopetz *et al.*, 2016; Lane and Epstein, 2013; Nielsen and Nielsen, 2013; Thacker *et al.*, 2017; Yang *et al.*, 2009).

We, however, adopted the more aggregate System dynamic (SD) approach, especially because of its relative simplicity and possibility of straightforward computational implementation. The system dynamic approach for the compact study of complex socio-technical systems was introduced in (Forrester, 1961). This powerful framework helps to approximately evaluate the multidimensional time-varying problems involving delays, feedbacks and nonlinearities (Meadows and Wright, 2015). It combines three main modelling methods, Causal loop diagrams (CLD), System sequence diagrams (SSD) and Stock and flow diagrams (SFD), based on which it is possible to create high-quality models of the real-world problems (Sterman, 2014). Although system dynamics methodology is used mainly in the areas of economic and social sciences, it also has numerous

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successful applications in natural or technical sciences. Qualitative SD models, usually in the form of CLDs, can efficiently support individual or team decisions, safely train decision-makers or validate dynamic hypotheses, concerning the temporal evolution of selected variables. Quantitative instances of SD diagrams, SFDs, generate numerical predictions, analyse internal sensitivity, evaluate and compare different external scenarios or parametrically optimize initial configurations (Morecroft, 2015; Warren, 2008).

4 Results and discussion

Besides the problem systemization, presented in the introductory part, we also designed two qualitative models, illustrating the inclusion of a knowledge-based model of situation awareness into the abstract architectural WDA hierarchy, presented in Table 1. For representational clarity, the tabular format was used instead of the more usual graphical scheme. Thus, 42 links between the adjacent layers were omitted. This model follows the proposed duality of purposes and maintains both aspects of performance/availability and trust/willingness. It starts from the physical objects, providing a secure bidirectional interface for raw data and information, altogether with the necessary drivers and enablers of performance. At the physical functional level, belonging inputs and outputs are transactionally processed in accordance with the prescribed objectives. Moreover, this level also technically implements the knowledge-based model of situation awareness, proposed as a CLD diagram in this research. Its requirements are defined and adjusted in the upper parts of the WDA model. Domain functions synthesize domain values, constrains and have a character of configurable services. Standard performance is incorporated with nontrivial functionality of organizational learning and marketing. Furthermore, this level functionally establishes principles of trusted networking. Both sets of activities are supported with organizational managerial frameworks and adopted decision making procedures. Domain purposes are monitored or controlled through a usually extensive set of concrete values, collectively derived from/or affecting domain functions.

The final presented result, dynamic model of shared trust among collaborating partners, is composed of the seven mutually interconnected and internally structured subsystems, shown in Figure 5.

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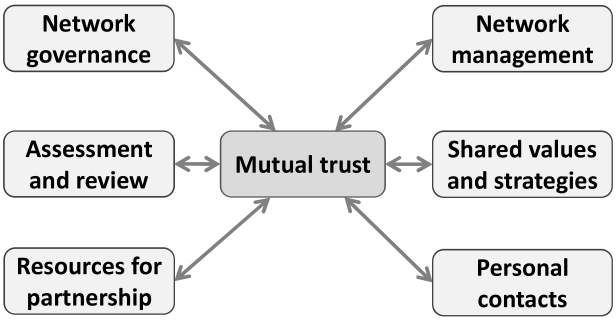

Figure 5 Subsectors of Causal loop diagram, representing mutual trust in networks

Implementation CLD thus contains 45 variables interconnected with 220 oriented and polarized edges, which form 32600 loops with the length varying from 2 to 25 edges. Such a complex chart cannot be presented as a whole, and its analyses require specialized tools. On the other hand, such purposely introduced redundancy stimulates analytical thinking and encourages team discussions. For example, the ordered horizontal histogram of the variables, appearing simultaneously in different subsystems is in Figure 6. Trust, as the key concept, is a natural part of all sectors. Similarly, the following three busy variables, Governance, Agility and Knowledge sharing, illustrate the most desirable initiatives.

Table 1 Work domain analysis of situation awareness and trust in partner networks

Domain purpose	▫ Efficient collaboration with partners ▫ Maximization of own performance
Domain values	▫ Dynamics, complexity, sensitivity, regulations ▫ Level of sharing and collaboration ▫ Predictions and projections ▫ Risks, (cyber)security, resilience ▫ Internal and networking workload ▫ Trust, understanding, transparency ▫ Performance
Domain functions	▫ Selection and analysis of relevant information and knowledge ▫ Decision-making and execution of decisions (management) ▫ Organizational learning and marketing ▫ Networking
Physical functions	▫ Automated knowledge modelling across physical objects ▫ Data and information distribution and batch processing ▫ Operations and financing

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Physical objects	▫ Cybersecurity ▫ Data, information, and knowledge resources ▫ Organizational, information and communications systems ▫ Human performance drivers (knowledge, skills, experience) ▫ Non-human performance enablers (infrastructure, resources)

Finally, the first two levels of an unrolled set of the *Mutual trust* related loops are proposed in Figure 7. For technical reasons, the right part (causes) and left part (uses) were captured separately and thus the notation of variables in parentheses (.), meaning their second and further occurrence in the diagram, was evaluated independently on both sides of the diagram. Even such a limited cut-out shows many short and so temporally fast trust-related loops, demonstrating the dynamic fragility of this concept. Change of any of the closely neighbouring variables can affect the mutual trust and invoke the domino effect. Beyond the trust itself, also other, topologically closely variables are interrelated (parenthesised) which increases the overall trust volatility, too.

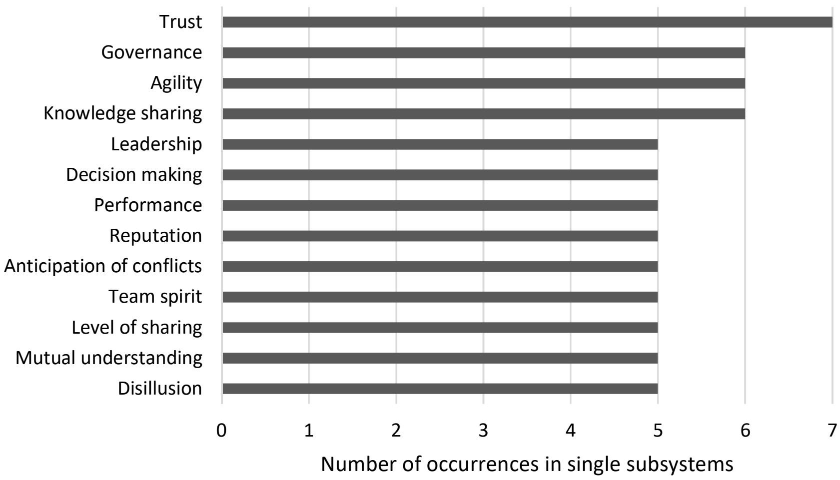

Figure 6 The most frequently occurring variables in single modelled sectors

To illustrate the overall complexity, randomly selected loop of the most frequent length 16 looks as follows and its starting and ending sequences can be found in Figure 7:

Trust → *Organisational learning* → *Shared values* → *Shared knowledge* → *Effectiveness of network monitoring* → *Mutual understanding* → *Networking strategy* → *Mutual social cohesion* → *Disappointment* → *Mutual commitment* →

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Agility → Network governance → Access to and sharing of information → Local performance → Shared accountability → Organizational flexibility → Trust

5 Conclusions

Digital communication, process automation, purposely established coalitions of business partners or shared resources and services are sample challenging characteristics of the contemporary world. Besides their indisputable benefits, there are also related bottlenecks that must be minimised. This research reflected the need for comprehensive and coherent orientation in a rapidly changing environment by means of a flexible, transparent and shareable model of situation awareness.

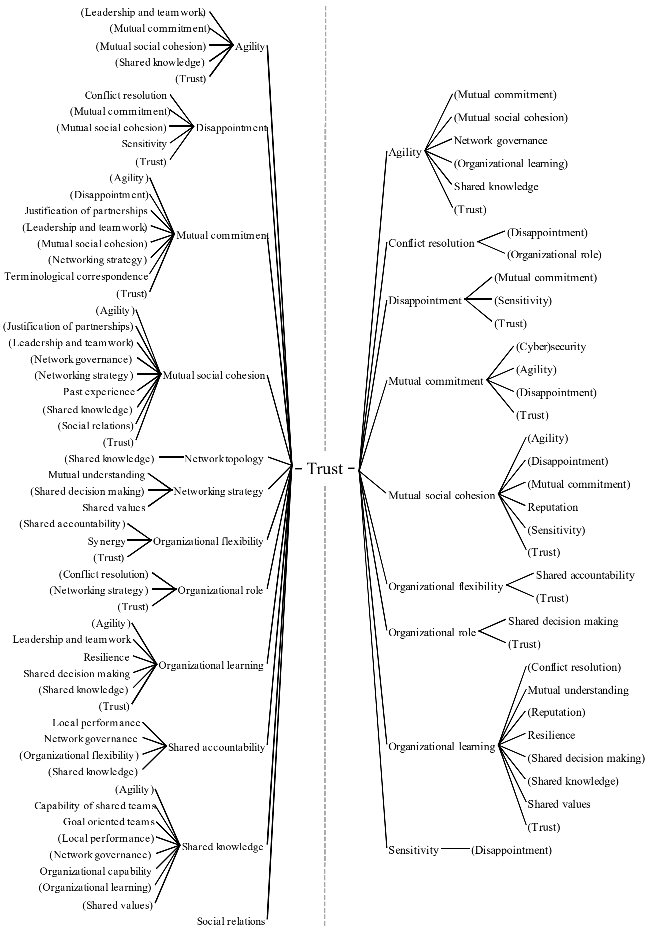

Figure 7 Partially unrolled loop of dynamic model of SA for variable Trust

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The proposed conceptual solution uses the hierarchical structure of Works domain analysis as the unifying framework, within which all the key functionalities can be efficiently displaced and mutually interconnected. Such approach allows to combine highly specialized and continuously developing knowledge-intensive technologies with more or less traditional ways of business administration. Besides, this paper also distinguishes between internal and external utilization of situation awareness. The former uses any kind of perceived and contextually interpreted information for maximization of own performance, while the latter indicates the institutional availability and willingness towards the collaborators. In such case, we argue that explicit networks of repeatably interacting firms must have their own governing structure, flexible enough to maintain the desired level of cohesion and simultaneously be able to preserve the desirable level of partners' autonomy. The importance of mutual understanding of the shared terminology was discussed, too.

Thus, the presented solution systemizes and integrates a wide range of topics, substantial for loosely associated organizations. The main emphasis was given on a credible model of situation awareness interlinked with standard management and governance frameworks. Such architecture makes the vertical communication better structured, more deterministic and trustworthy. As a result, external readiness indicators of involved organizations are uniformly quantified and easy to understand. Moreover, for the governance on this extra-organizational level, a thorough trust-based dynamic model for continuous harmonization of overall interoperability was developed. It incorporates details of all presented aspects of situation awareness, divided into seven subsectors. Interactive analysis of its behaviour can identify the main sources of collaboration dynamics and determine their sensitivity and robustness with respect to external scenarios.

The originally set goals were fulfilled and viable solutions for existing gaps suggested. However, there are research limitations that need to be addressed in future research. They concern mainly general structure of suggested results, which requires further specifications. Also, the currently indirect influence of users' feedback needs to be concretized with the real data and expertise from industrial partners, namely operators of critical infrastructures. As the extension of this work, a closer mapping between strategic management platform Balanced Scorecard and governance framework COBIT (Control Objectives for Information and Related Technologies, (Information Systems Audit and Control Association, 2019) will be studied, as well as the inclusion of an explicit capability and maturity

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improvement model to SA WDA architecture. Finally, the resultant model will be implemented in the executable form of a Stock and flow diagram and applied to a practical case.

We believe that the proposed hierarchical, systemic representation of common transnational, cross-sectoral and intercultural aspects of collaboration among numerous partnering organizations, presented in the context of their regular business, could support involved managers and governors in searching for appropriate internal and external policies. The innovativeness of the proposed concept lies in the fact that it tightly connects performance with trust in a structured and quantifiable manner, which can be appropriately integrated into existing administrative and decision-making processes. Chosen system dynamic way of implementation supports this approach with an intrinsically understandable representation of the modelled processes, user-friendliness, interactivity and support of teamwork. It is a natural reflection of the current digital practice where technical solutions with high degree of independence are increasingly introduced into regular managerial processes.

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References

Aydogan, R., Sharpanskykh, A. and Lo, J. (2014), "A Trust-Based Situation Awareness Model", available at:https://doi.org/10.1007/978-3-319-17130-2_2.

Bridgman, T., Cummings, S. and Ballard, J. (2018), "Who Built Maslow's Pyramid? A History of the Creation of Management Studies' Most Famous Symbol and Its Implications for Management Education", *Academy of Management Learning & Education*, Academy of Management, Vol. 18 No. 1, pp. 81–98.

Burns, C., Torenvliet, G., Chalmers, B. and Scott, S. (2009), "Work Domain Analysis for Establishing Collaborative Work", *Human Factors and Ergonomics Society Annual Meeting Proceedings*, Vol. 53, pp. 314–318.

Cantot, P. and Luzeaux, D. (2013), Simulation and Modeling of Systems of Systems, Simulation and Modeling of Systems of Systems, p. 378.

Cho, J.-H., Chan, K. and Adali, S. (2015), "A Survey on Trust Modeling", *ACM Computing Surveys*, Vol. 48, pp. 1–40.

ISBN 978-88-96687-14-7 || ISSN 2280-787X

Cui, V., Vertinsky, I., Robinson, S. and Branzei, O. (2018), "Trust in the Workplace: The Role of Social Interaction Diversity in the Community and in the Workplace", *Business & Society*, SAGE Publications Inc, Vol. 57 No. 2, pp. 378–412.

DARWIN (2018), Deliverable D7.8. Final project report. Available at: http://www.h2020darwin.eu/project-deliverables.

Davies, R.H. (2016), *Value Management Translating Aspirations into Performance*, Taylor and Francis, Abingdon, Oxon.

Edgar, T.W. and Manz, D.O. (2017), *Research Methods for Cyber Security*, 1st edition., Syngress, Cambridge, MA.

Endsley, M. (1995), "Endsley, M.R.: Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors Journal 37(1), 32-64", *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 37, pp. 32–64.

Endsley, M. and Jones, W.M. (2001), "A model of inter and intra team situation awareness: Implications for design, training and measurement. New trends in cooperative activities: Understanding system dynamics in complex environments", *CA*, pp. 46–67.

Forrester, J.W. (1961), *Industrial Dynamics.*, M.I.T. Press, Cambridge, Mass.

Gawron, V.J. (2019), *Human Performance and Situation Awareness Measures*, 3rd edition., CRC Press, Boca Raton, FL.

Hillman, A., Withers, M. and Collins, B. (2009), "Resource Dependence Theory: A Review", *Journal of Management*, Vol. 35, available at:https://doi.org/10.1177/0149206309343469.

Hoefsmit, N., Rijk, A. and Houkes, I. (2013), "Work resumption at the price of distrust: A qualitative study on return to work legislation in the Netherlands", *BMC Public Health*, Vol. 13, p. 153.

IMPROVER (2018), Deliverable D7.6. Project report: operationalisation of resilience to critical infrastructure. Available at: https://cordis.europa.eu/project/id/653390/results.

Kelly, G. (1991), *The Psychology of Personal Constructs*, Routledge in association with the Centre for Personal Construct Psychology, London; New York.

Kenrick, D.T., Griskevicius, V., Neuberg, S.L. and Schaller, M. (2010), "Renovating the Pyramid of Needs: Contemporary Extensions Built Upon Ancient Foundations", *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, Vol. 5 No. 3, pp. 292–314.

Kopetz, H., Bondavalli, A., Brancati, F., Frömel, B., Höftberger, O. and Iacob, S. (2016), "Emergence in Cyber-Physical Systems-of-Systems (CPSoSs)", pp. 73–96.

Krech, D., Crutchfield, R.S. and Ballachey, E.L. (1962), *Individual in Society: A Textbook of Social Psychology*, McGraw-Hill, New York, NY, US, pp. x, 564.

Laimer, C. (2016), "Governance of interorganizational relationships: The case of science and technology parks", *Cuadernos de Administracion*, Vol. 32, pp. 20–35.

Lane, J. and Epstein, D. (2013), "What is a System of Systems and Why Should I Care", *Undefined*, available at: /paper/What-is-a-System-of-Systems-and-Why-Should-I-

Care-Lane-Epstein/efbb38647605f9c3e264eb20306bdd37b371cc8e (accessed 26 December 2020).

Lee, Q. and Snyder, B. (2017), *The Strategos Guide to Value Stream and Process Mapping*, 1st edition., Productivity Press, Bellingham, WA.

Lintern, G. and Naikar, N. (2000), "The Use of Work Domain Analysis for the Design of Training Systems", *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 44, available at:https://doi.org/10.1177/154193120004400153.

Loasby, B.J. (1979), "The External Control of Organizations. A Resource Dependence Perspective", *The Economic Journal*, Vol. 89 No. 356, pp. 969–970.

Luzwick, P. (2000), "Situational Awareness and OODA Loops: Coherent Knowledge-based Operations Applied: Last in a series of 4 articles", *Computer Fraud & Security*, Vol. 2000 No. 4, pp. 15–17.

Lytvyn, V., Dosyn, D., Vysotska, V. and Hryhorovych, A. (2020), "Method of Ontology Use in OODA", pp. 409–413.

Maister, D.H., Green, C.H. and Galford, R.M. (2001), *The Trusted Advisor*, Illustrated edition., Touchstone, New York.

Maslow, A.H. (1942), "The Dynamics of Psychological Security-Insecurity", *Journal of Personality*, Vol. 10 No. 4, pp. 331–344.

Maslow, A.H. (1943), "A theory of human motivation", *Psychological Review*, American Psychological Association, US, Vol. 50 No. 4, pp. 370–396.

Meadows, D.H. and Wright, D. (2015), *Thinking in Systems : A Primer*.

Metcalf, L.B. and Spring, J.M. (2021), *Using Science in Cybersecurity*, World Scientific Publishing Company, Hackensack, NJ.

Morecroft, J.D.W. (2015), Strategic Modelling and Business Dynamics : A Feedback Systems Approach, Wiley, Hoboken, New Jersey.

Nielsen, S. and Nielsen, E. (2013), "Transcribing the balanced scorecard into system dynamics: From idea to design", *Int. J. of Business and Systems Research*, Vol. 7, pp. 25–50.

Noran, O. and Bernus, P. (2018), "Improving Digital Decision Making Through Situational Awareness".

Pfeffer, J. and Salancik, G.R. (2003), *The External Control of Organizations: A Resource Dependence Perspective*, 1st edition., Stanford Business Books, Stanford, Calif.

Pirson, M. and Malhotra, D. (2011), "Foundations of Organizational Trust: What Matters to Different Stakeholders?", *Organization Science*, INFORMS, Vol. 22 No. 4, pp. 1087–1104.

Provan, K. and Kenis, P. (2008), "Modes of Network Governance: Structure, Management, and Effectiveness", *Journal of Public Administration Research and Theory*, Vol. 18, available at:https://doi.org/10.1093/jopart/mum015.

Raab, J., Mannak, R.S. and Cambré, B. (2015), "Combining Structure, Governance, and Context: A Configurational Approach to Network Effectiveness", *Journal of Public Administration Research and Theory*, Vol. 25 No. 2, pp. 479–511.

Radomska, J., Wołczek, P., Sołoducho-Pelc, L. and Silva, S. (2019), "The Impact of Trust on the Approach to Management-A Case Study of Creative Industries", *Sustainability*, Vol. 11, available at:https://doi.org/10.3390/su11030816.

Rasmussen, J. (1985), "The role of hierarchical knowledge representation in decisionmaking and system management", *IEEE Transactions on Systems, Man, and Cybernetics*, available at:https://doi.org/10.1109/TSMC.1985.6313353.

RESILENS (2015), Deliverable 1.1. Resilience Evaluation and SOTA summary report. Available at: http://resilens.eu/publication/.

de Rijk, A., van Raak, A. and van der Made, J. (2007), "A new theoretical model for cooperation in public health settings: the RDIC model", *Qualitative Health Research*, Vol. 17 No. 8, pp. 1103–1116.

Ryle, A. (1975), Frames and Cages: The Repertory Grid Approach to Human Understanding, International Universities Press, New York.

Salmon, P.M., Stanton, N.A. and Jenkins, D.P. (2017), *Distributed Situation Awareness: Theory, Measurement and Application to Teamwork*, 1st edition., CRC Press.

SMR (2018), Deliverable 7.9. Final conference report. Available at: https://smr-project.eu/deliverables/.

Sterman, J.D. (2014), Business Dynamics: Systems Thinking and Modeling for a Complex World, Irwin, Boston.

Stewart, V., Stewart, A. and Fonda, N. (1990), *Business Applications of Repertory Grid*, Institute of Personnel Management (South Africa), Johannesburg.

Thacker, S., Barr, S., Pant, R., Hall, J.W. and Alderson, D. (2017), "Geographic Hotspots of Critical National Infrastructure", *Risk Analysis: An International Journal*, Wiley-Blackwell, Vol. 37 No. 12, pp. 2490–2505.

Thanetsunthorn, N. and Wuthisatian, R. (2020), "Trust and Culture: Applications for Organization Development", *Organization Development Journal*, Organization Development Institute, Vol. 38 No. 1, pp. 33–43.

Uchejeso, O. (2019), "Abraham Maslow‟s Hierarchy of Needs Dynamics in the Administration of Public Organizations under the President Buhari‟s Democratic Dispensation in Nigerian Health Sector", Vol. Volume III, pp. 284–290.

Vicente, K.J. (1999), Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work, 1st edition., CRC Press, Mahwah, N.J.

Voracek, J., Pribyl, A. and Schroeder, J. (2020), "Cybersecurity management: a knowledge-based perspective", *Proceedings of 15th International Forum on Knowledge Asset Dynamics*, presented at the Knowledge in Digital Age, University of Basilicata, Matera, IT, pp. 219–234.

Wang, H., Lau, N. and Gerdes, R. (2017), "Application of Work Domain Analysis for Cybersecurity", pp. 384–395.

Ward, D., Kourti, N., Lazari, A. and Cofta, P. (2014), "Trust building and the European Reference Network for Critical Infrastructure Protection community", *International Journal of Critical Infrastructure Protection*, Vol. 7 No. 3, pp. 193–210.

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Warren, K. (2008), *Strategic Management Dynamics*, 1 edition., Wiley, Chichester, West Sussex, England ; Hoboken, NJ.

Yang, K., Zhao, Q., Lu, Y. and Huang, W. (2009), "The Research of System of Systems Requirement Modeling and Toolkits", *2009 11th International Conference on Computer Modelling and Simulation*, presented at the 2009 11th International Conference on Computer Modelling and Simulation, pp. 107–110.