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ESReDA | European Safety, Reliability & Data Association

Creating Safe and Resilient Logistic Systems: Proceedings of the 59th ESReDA Seminar

Hosted by the Wroclaw University of Science and Technology, Wroclaw, Poland, 26-27 October, 2021.

Tubis, A., Kopustinskas, V., Simola, K.

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European Safety, Reliability & Data Association (ESReDA)

European Safety, Reliability & Data Association (ESReDA) is a European Association established in 1992 to promote research, application and training in Reliability, Availability, Maintainability and Safety (RAMS). The Association provides a forum for the exchange of information, data and current research in Safety and Reliability.

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Preface

Building safe and resilient logistics systems is currently a key research trend in economic and technical sciences. For this reason, the 59th ESReDA Seminar was an opportunity to present the research results in these areas and discuss the areas of necessary cooperation between industry, policy and science to improve current logistics systems.

Security and safety are now perceived as factors that should be evaluated and accounted for in every system. For this reason, they play a crucial role in the design, development and operation of logistics systems, and technical systems as well. The goal of actions taken by logistics managers to ensure security is to achieve a state in which every person employed in logistics systems will work in conditions where the risks are known and controlled to an acceptable level of potential harm. For this reason, threats analysis stays at the heart of operation of logistic systems [1]. Thanks to risk management techniques, it is possible to implement solutions that improve security and safety of staff, the environment, and the organization itself. Experts estimate that 80-90% of all industrial accidents can be attributed to "human factors" [2]. For this reason, it is assumed that the most effective way to reduce the number of accidents is to analyse the social and organizational factors that may affect safety and security. Therefore, it is well understood that more emphasis needs to be placed on developing a safety culture in high-risk industrial sectors (petrochemicals, chemistry, and nuclear energy) [3]. At the same time, we can observe the development of the Industry 4.0 concept, which, by automating industrial processes (including logistics), reduces human errors in routine operations and increases efficiency in handling flows of goods and processes. However, it should be noted that the introduced automation does not always mean limiting the number of threats occurring in the process but rather changing their nature and attack vectors. This was confirmed by the speakers from research, policy and industrial domains at the ESReDA 59th Seminar, who undertook analyses of the risks associated with the use of autonomous trucks and drones in logistics systems.

A development of the concept of resilient supply chains has been observed since the beginning of the 21st century. This is confirmed by numerous literature reviews that periodically appear in journals devoted to research on production, logistics, technology, and management. Examples of publications presenting a broad overview of research conducted so far in this area are included [4]. Despite numerous publications on the resilience of supply chains, there is still no clear definition of the scope of the presented concept [5]. The origins of term resilience come from research in ecological systems [6], that has lately found numerous applications in many other fields [7], however a comprehensive and accepted definition is still missing. The most comprehensive approach is the definition of Ponomarov [8], according to which Resilience Supply Chain is the adaptive capability of a firm's supply chain to prepare for unexpected events, respond to disruptions, and recover from them on time by maintaining continuity of operations at the desired level of connectedness and control over structure and function. The definition presented by Ponis and Koronis [9], states that Resilience Supply Chain is the ability to proactively plan and design the supply chain network for anticipating unexpected disruptive (adverse events), responding adaptively to disruptions while maintaining control over structure and function and transcending to a post robust state of operations, if possible a more favoured one than that before the event, thus gaining a competitive advantage.

Supply chain resilience has gained particular importance in the last two years due to the COVID-19 pandemic, as also highlighted by the key note speech from the European Commission, DG Energy. The global scale of its occurrence and the high mortality rate in the first months of development shook the stability of all industrial sectors. Before the pandemic, companies concentrated on developing agile, lean, sustainable, green, optimized, and efficient supply chains [10]. During the pandemic, managers have not forgotten these subjects. However, the most critical issue was the rapid return of logistics systems to handle product flows at the level required by customers. The effects of the pandemic first appeared in food supply chains, where shortages in some products drove consumers into panic mode and caused them to buy more than they required [11]. However, this was not a consequence of the lack of raw materials on the market but the supply chains' lack of a sufficiently quick response. For this reason, the topic of building the resilience of logistics systems supporting resilient supply chains is currently a critical issue that is being developed in science, industry and policy, as agreed and confirmed by the Seminar participants.

The 59th ESReDA Seminar took place in Wroclaw on October 26, 2021 by video conference means and was organized by the Wroclaw University of Science and Technology, a long-standing member of ESReDA. The editorial work for this report was supported by the Joint Research Centre of the European Commission in the frame of JRC support to ESReDA activities. A special thanks is due to A. Liessens (JRC) for the editorial work.

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4. Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review*, 125, 285–307.
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Dr. Kaisa Simola
European Commission, Joint Research Centre (JRC)

Resilience of complex supply chains: how to ensure continuity of logistic processes in critical situations

L. Bukowski, WSB University, Kraków, Poland

The plenary lecture focuses on the main research problems connected with definition and understanding of "resilience", and discusses the issue of global supply chains. Later, the global supply chain risk problems are investigated. The imperfect knowledge-based concept of risk is presented. At the end, the recommendations for ensuring continuity of logistic processes in critical situations are introduced. The author focuses on the three issues: a) configuring a resilient topology, b) creating a functionally resilient supply chain, c) becoming a resilient organization through Resilience-Based Maintenance.

Resilience of complex supply chains:
how to ensure continuity of logistic processes in critical situations

Lech A. BUKOWSKI
WSB University

Presentation objectives as answers to the following questions:

1. Does the practice need 'resilience' and why?
2. How do we understand 'resilience' in general and how in the logistics area?
3. Are global supply chains really that different from traditional ones?
4. Why is the risk in global supply chains greater than in traditional ones?
5. How to ensure continuity of logistic processes in critical situations?
   a) Configuring a resilient topology
   b) Creating a functionally resilient supply chain
   c) Becoming a resilient organization through RBM

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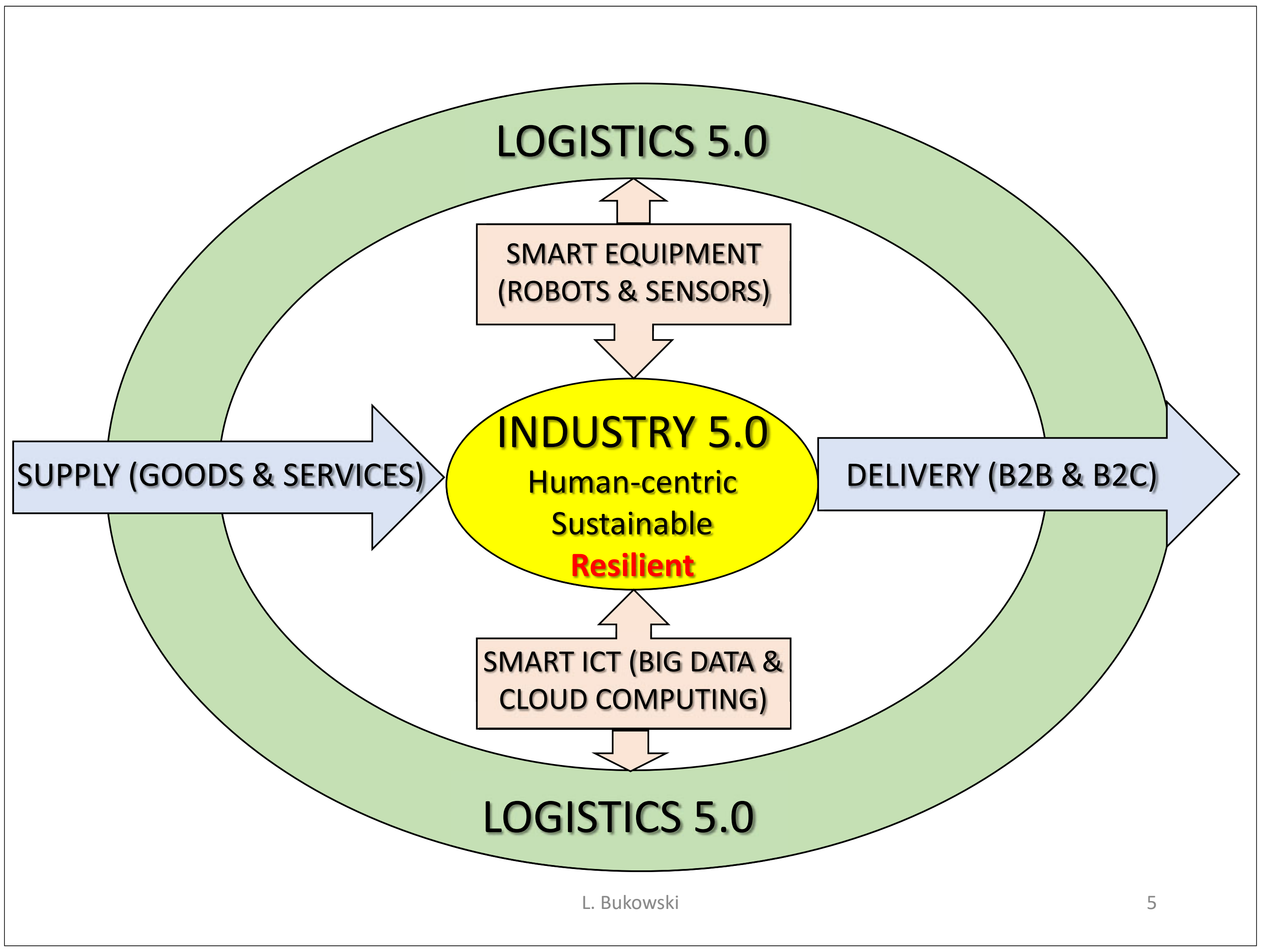
1. Does the practice need 'resilience' and why?

Towards Industry 5.0

In 2021, the European Commission formally called for the Fifth Industrial Revolution

Industry 5.0: towards a sustainable, human-centric and resilient European industry.
Luxembourg, LU: European Commission, Directorate-General for Research and Innovation; 2021

- Sustainable – circular processes (4's „R" - reuse, repurpose, recycle, reduce),
- Human-centric – from technology-driven to society-centric approach,
- Resilient – arming production and services against disruptions and crisis.



2. How do we understand 'resilience' in general and how in the logistics area?

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The power of resilience

It is not the strongest of the species that survives,
nor the most intelligent that survives,
but the one that is the most adaptable to change'*

Charles Darwin

**reacting quickly and positively – resilient*

Successful evolution thanks to resilience?

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The definition of resilience

General definition:

Resilience *– ability of complex systems to survive disruptive changes and disturbances while preserving essential services.*

Specific definition of supply chain resilience:

Supply chains resilience *- ability to withstand critical situations (e.g. disruptions) while maintaining continuity of delivery processes.*

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3. Are global supply chains really that different from traditional ones?

Complex supply chain – main characteristics

The main characteristics of a complex supply chain are:

- multidimensional complexity – nonlinear and heterogeneous structures, spatial scope of a large scale, and dynamic behavior,
- emergent behavior – the whole system performs functions that do not reside in any subsystem,
- evolutionary development - existence with functions and purposes added, removed, and modified over time on the basis of experience.

These are typical features of global supply chains.

Global supply chains - example from the clothing industry

T-shirt starts in an Egyptian cotton field (material),

it is manufactured in the Far East (production),

then shipped (transportation) to LA for packaging (logistics),

and finally sold at MIT-shop in Boston (delivery).

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Global supply chains - example from computer manufacturing

An Intel chip crosses the Pacific Ocean six times (!)

as it goes from raw material to becoming a ready Dell computer component

(process specialization & economy of scale)

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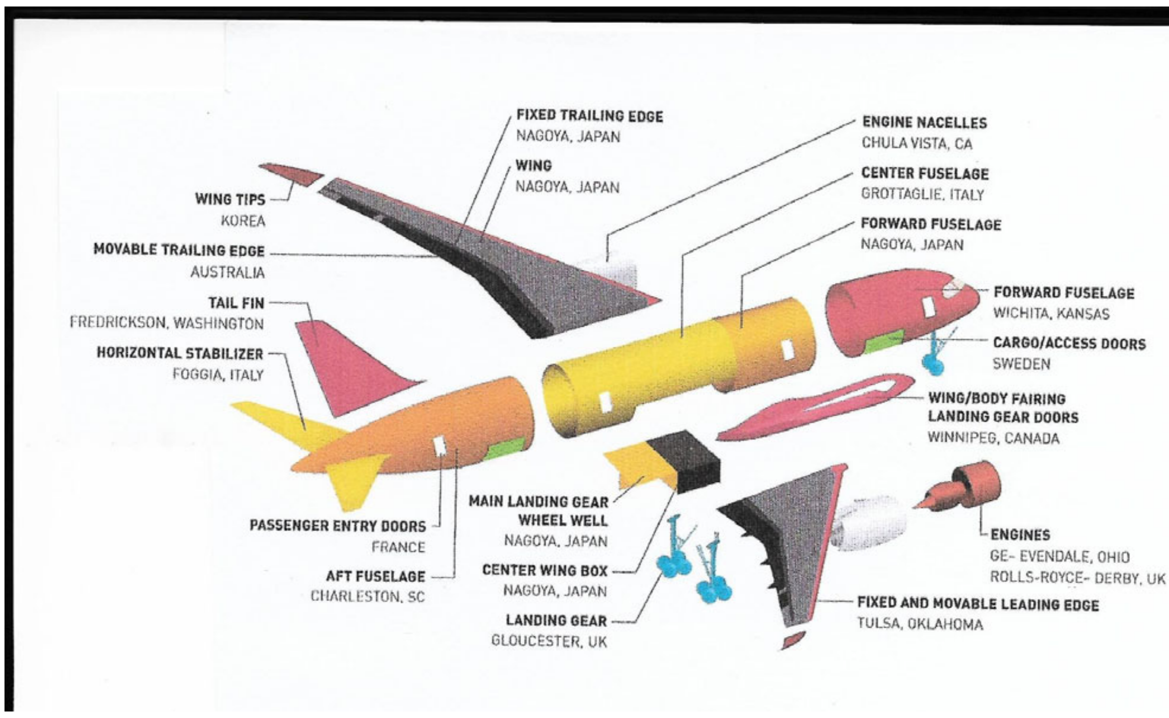
Global production logistics – example from aircraft production (Boeing 787 Dreamliner)



Australia
Canada,
France,
Italy,
Japan,
Korea,
Sweden,
UK,
USA

Subsystems production in 17 companies from 9 countries

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4. Why is the risk in global supply chains greater than in traditional ones?

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Risks in global supply chains – external threats

External disruption threats

- Natural disasters
  - Geophysical events (earthquake, tsunami, volcanic eruption)
  - Hydrological events (flooding, landslide)
  - Climatic events (extreme temperatures, drought, forest fires)
  - Meteorological events (storm, hurricane, tornado)
- Pandemic
- Terrorism
- Fraud

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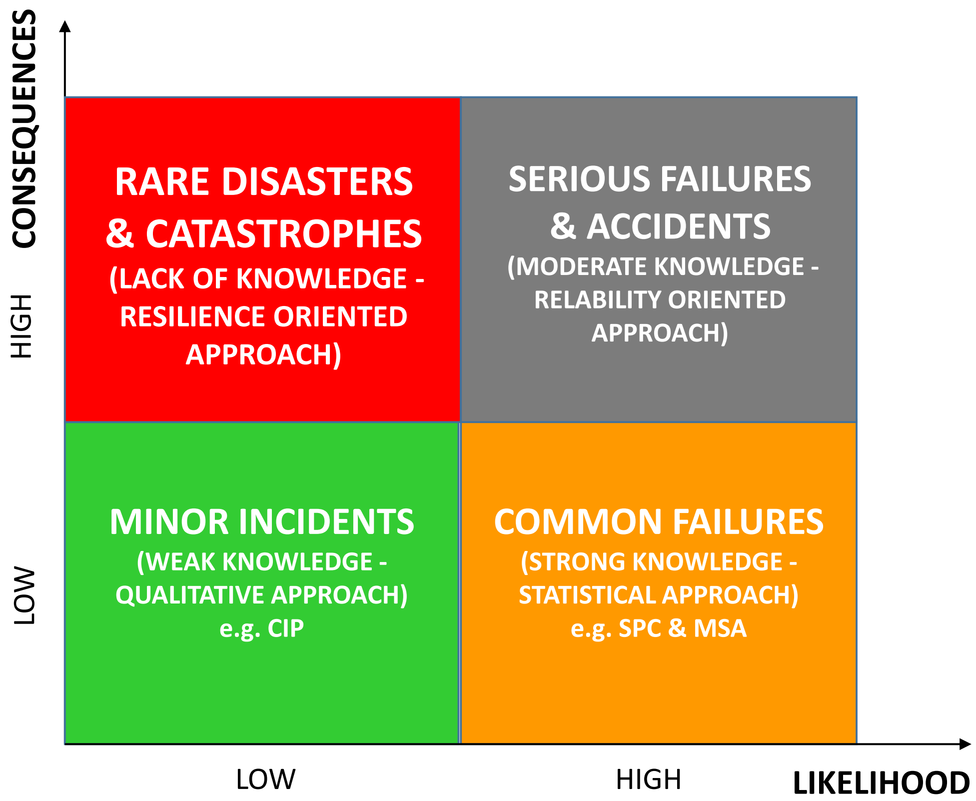
Imperfect knowledge based concept of risk*



*Bukowski L. *Reliable, Secure and Resilient Logistics Networks. Delivering products in a risky environment.* Springer 2019

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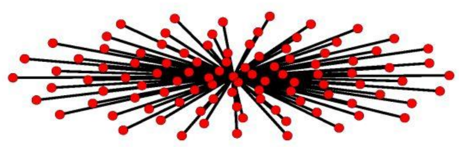
5. How to ensure continuity of logistic processes in critical situations?

a) Configuring a resilient topology

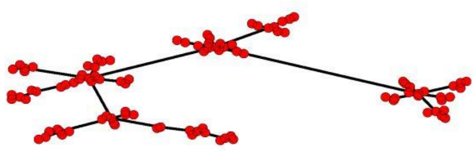
Typical network topology - theory

a)



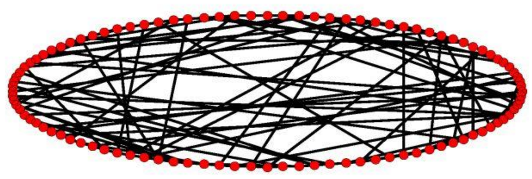
Centralized network (n = 99)
d = 99 (for central node)
d = 1 (for peripheral nodes)

b)



Scale-free network (n = 99)
$P(d) = a \cdot d^{-\alpha}$
α = (2 – 4)

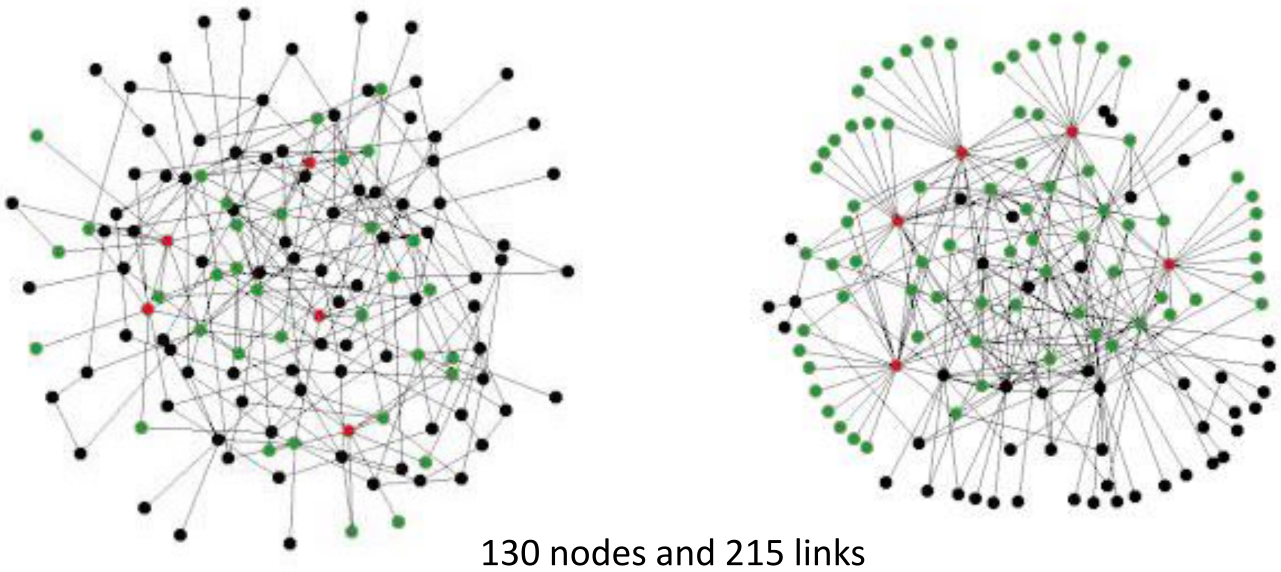
c)



Random network (n = 99)
$P(d)$ – binominal distribution (Poisson distribution for large n)
d = 1, 2, 3, … , n

n – node number; d – node degree (valence)

Exponential and a scale-free networks



130 nodes and 215 links

The random exponential network is homogeneous: most nodes have approximately the same number of links

The scale-free network is inhomogeneous: the majority of the nodes have one or two links but a few nodes have a large number of links (system is fully connected)

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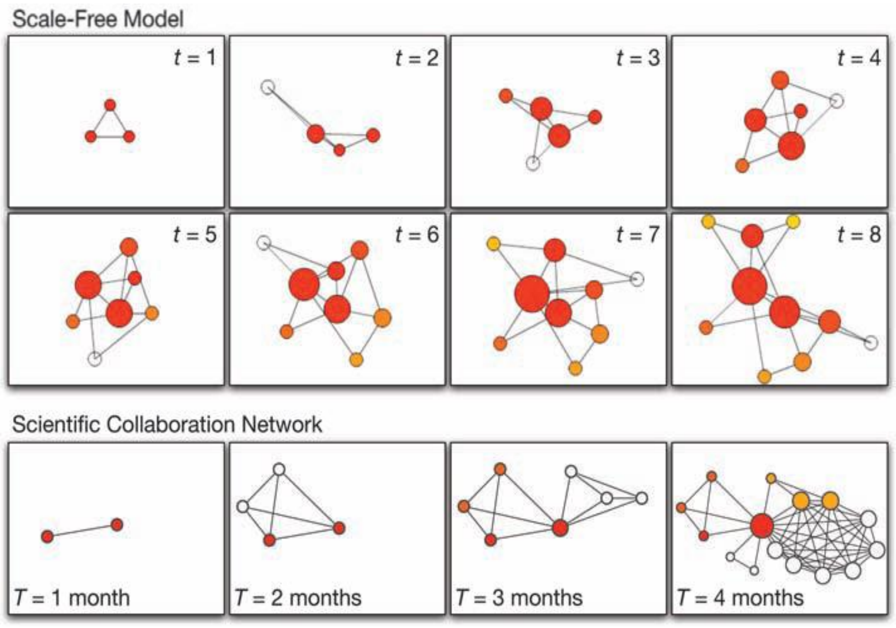
Modelling of scale-free networks

a)



b)

Power law:

$$Y = a\,x^b$$

a) New nodes prefer the more connected nodes (a rich-gets-richer), leading to the emergence of a few highly connected hubs. The degree distribution of the resulting network follows the power law with exponent $b = 3$.
b) Growth process in the co-authorship network of physicists. Each node corresponds to an individual author, and two nodes are connected if they co-authored a paper together. The network expands in time, leading to the emergence of a clear hub.

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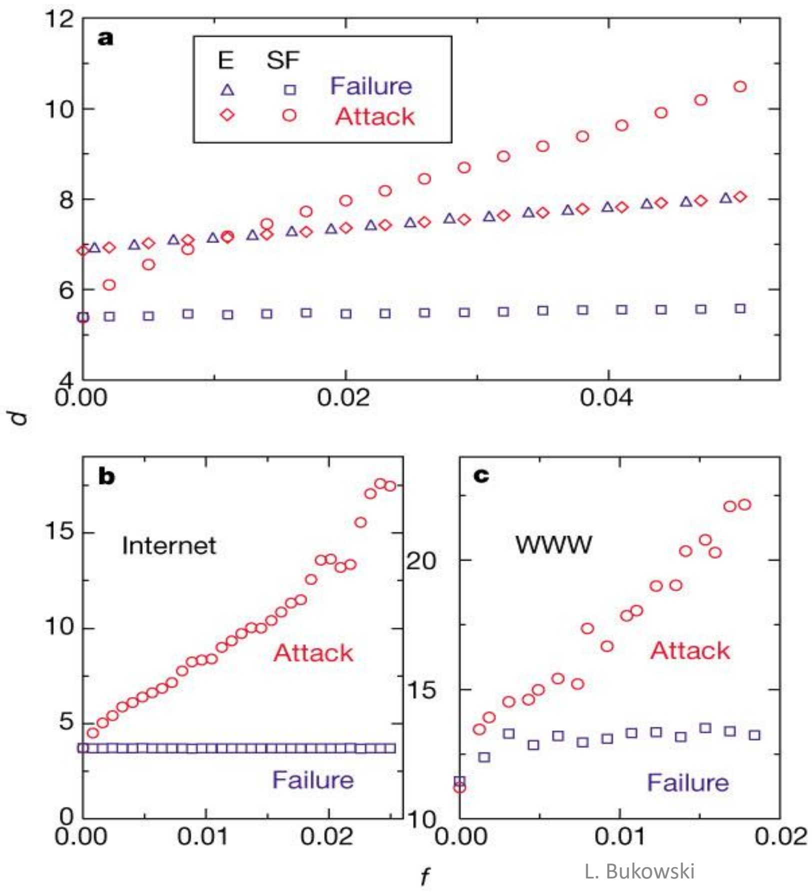
Network resilience – error tolerance*



d – network diameter
(average length of the shortest paths between any two nodes)

f – fraction of the removed nodes

E – exponential network

SF – scale-free network

*R. Albert, H. Jeong & A-L. Barabási, *Error and attack tolerance of complex networks*, Nature 406 (2000), 378-382

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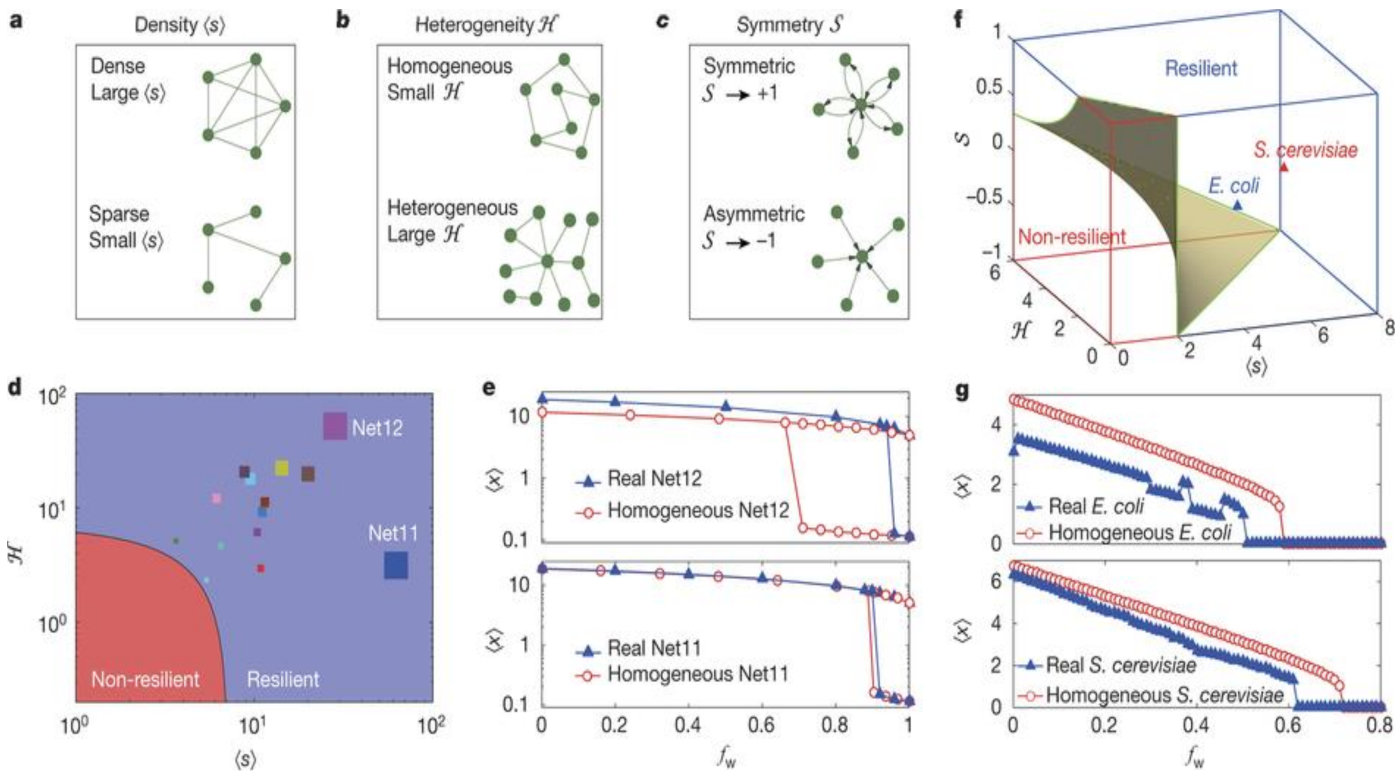
Network topology and its resilience*



*Gao J., Barzel B., Barabasi A-L. *Universal resilience patterns in complex networks*, Nature 530, Feb. 2016, 307-312

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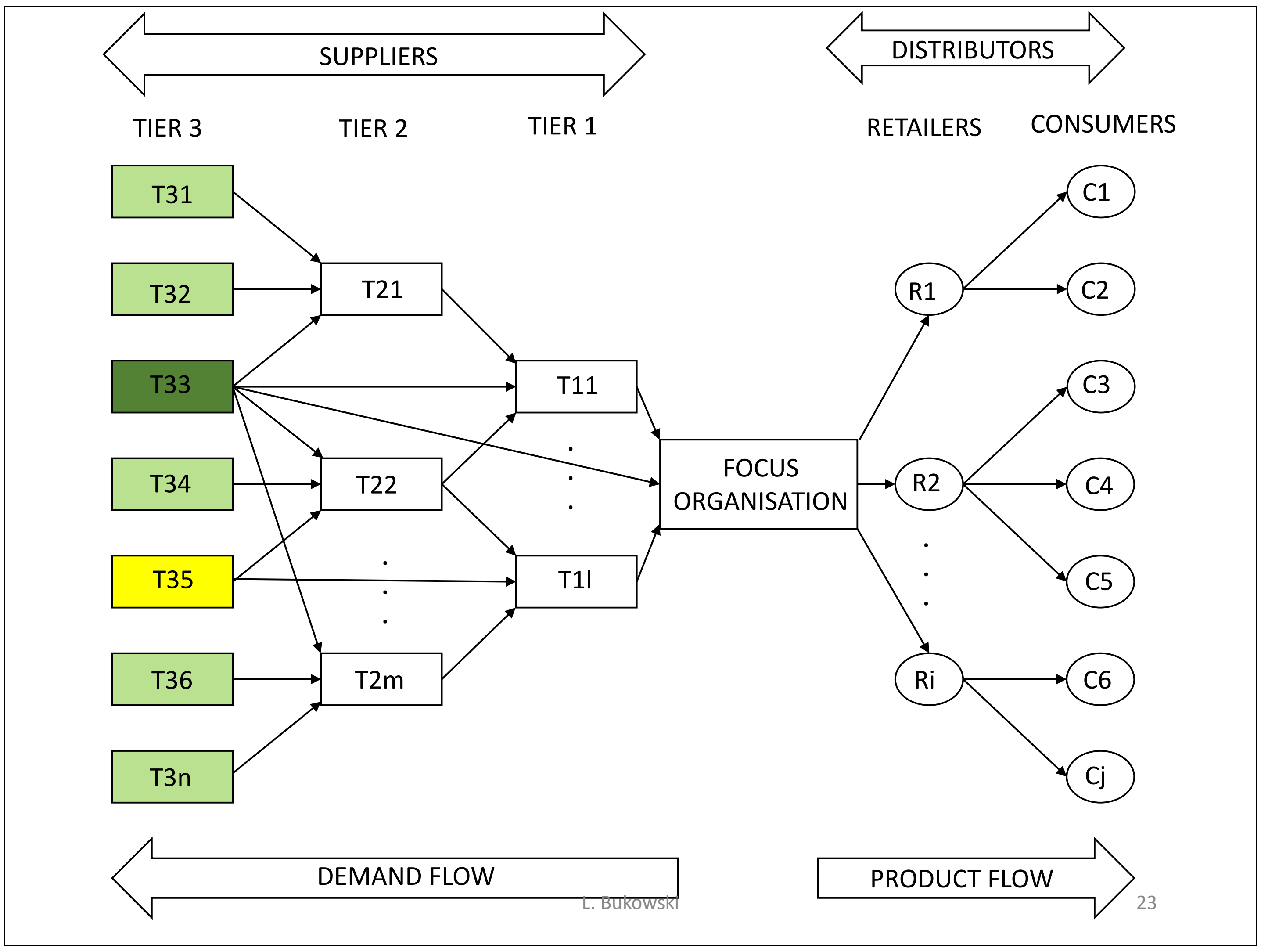
SUPPLIERS
DISTRIBUTORS
TIER 3
TIER 2
TIER 1
RETAILERS
CONSUMERS
T31
T32
T33
T34
T35
T36
T3n
T21
T22
T2m
T11
T1l
FOCUS ORGANISATION
R1
R2
Ri
C1
C2
C3
C4
C5
C6
Cj
DEMAND FLOW
PRODUCT FLOW
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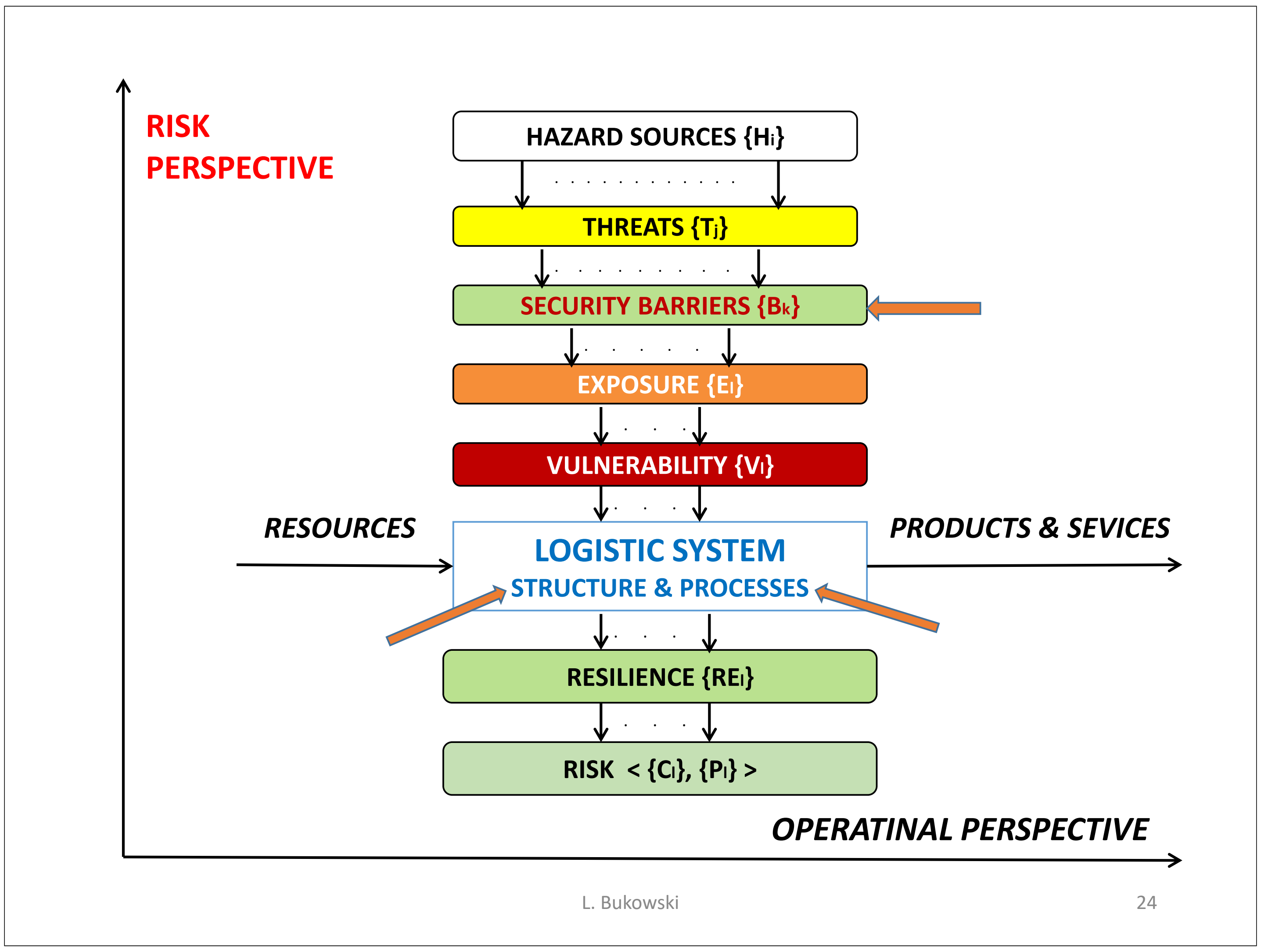
RISK PERSPECTIVE
HAZARD SOURCES {Hi}
THREATS {Tj}
SECURITY BARRIERS {Bk}
EXPOSURE {Ei}
VULNERABILITY {Vi}
RESOURCES
LOGISTIC SYSTEM
STRUCTURE & PROCESSES
PRODUCTS & SEVICES
RESILIENCE {REi}
RISK < {Ci}, {Pi} >
OPERATINAL PERSPECTIVE
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Area of study – Upper Silesian Region in Poland*

about 17 million passengers per year

*Bukowski L., Sobczak P. *Resilience assessment of heterogeneous complex transport networks – a general framework and a case study,* Proceedings of the 29th EUROPEAN SAFETY AND RELIABILITY CONFERENCE ESREL 2019

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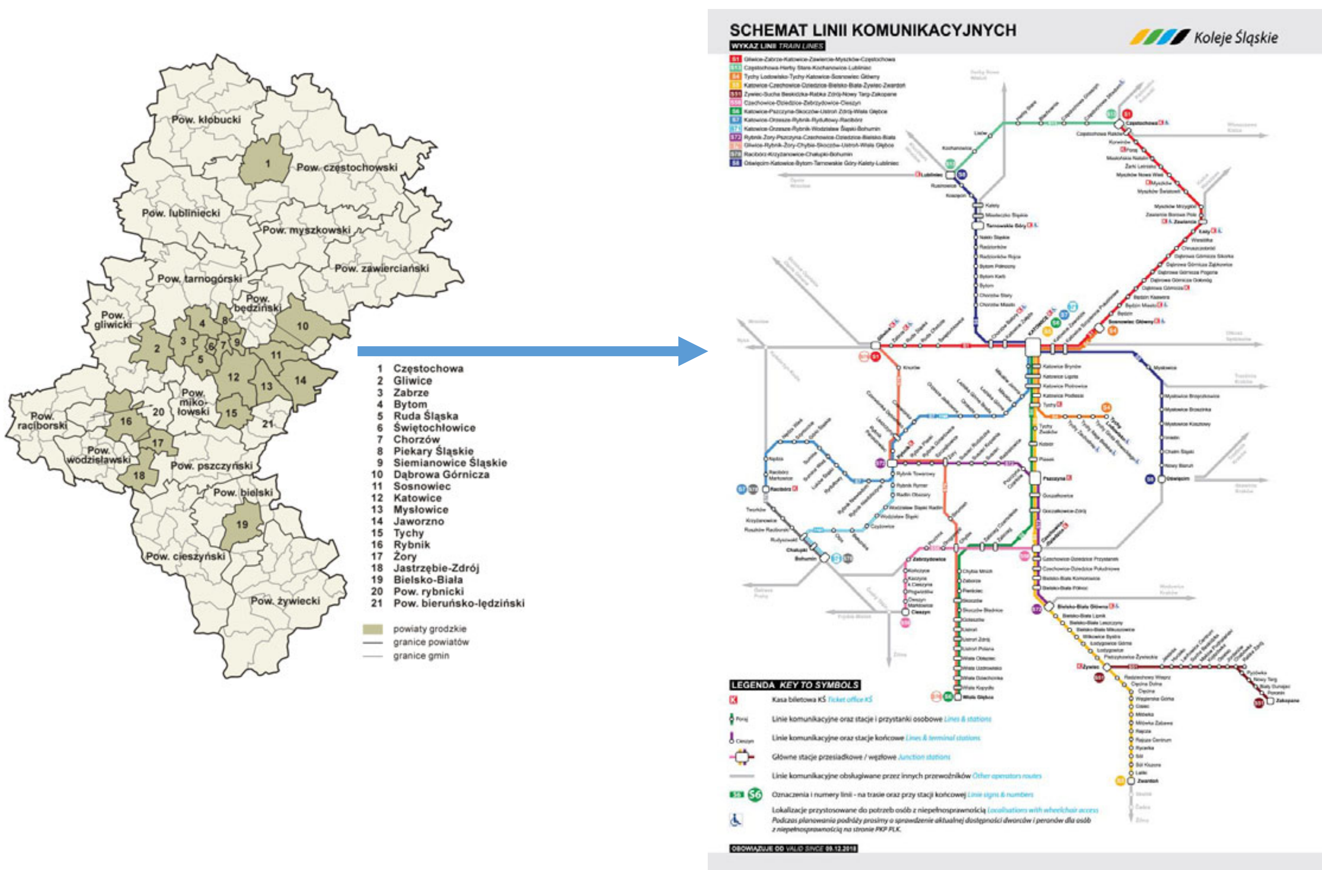
Upper Silesia Railway connections map



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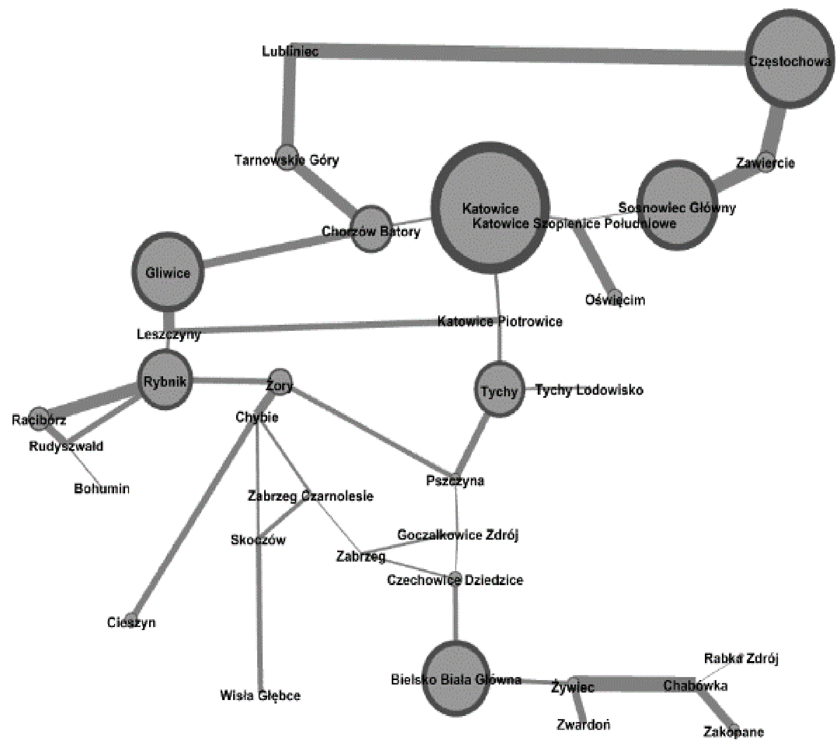
Case study – Phase I

Various scenarios of possible disturbances were simulated and following parameters calculated:

- Degree,
- Weighted Degree,
- Eccentricity,
- Closeness Centrality,
- Harmonic Centrality,
- Betweenness Centrality,
- Modularity Class,
- Clustering,
- Triangles,
- Eigen Centrality,
- PageRank.



The structure of connections including the capacity of individual railway lines and the number of inhabitants of connected cities.

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Case study – Phase I

The result of simulation studies: the most sensitive parameter for such changes in the network structure is PageRank.

City (node)	PageRank
Bielsko Biała	0,025709
Bohumin	0,006567
Chabówka	0,055446
Chorzów Batory	0,033035
Chybie	0,049219
Cieszyn	0,017285
Czechowice Dziedzice	0,025321
Częstochowa	0,037754
Gliwice	0,033273
Goczałkowice Zdrój	0,018963
Katowice	0,016720
Katowice Piotrowice	0,027365
Katowice Szopienice Pd.	0,030848
Leszczyny	0,037103
Lubliniec	0,033526
Oświęcim	0,025249
Pszczyna	0,034554

City (node)	PageRank
Rabka Zdrój	0,005049
Racibórz	0,037843
Rudyszwałd	0,031126
Rybnik	0,049168
Skoczów	0,034669
Sosnowiec Główny	0,020092
Tarnowskie Góry	0,032434
Tychy	0,033988
Tychy Lodowisko	0,008581
Wisła Głębce	0,017807
Zabrzeg	0,018784
Zabrzeg Czarnolesie	0,021982
Zakopane	0,021875
Zawiercie	0,038018
Zwardoń	0,019234
Żory	0,041354
Żywiec	0,060059
Sum	1

PageRank values for all nodes of the tested network.

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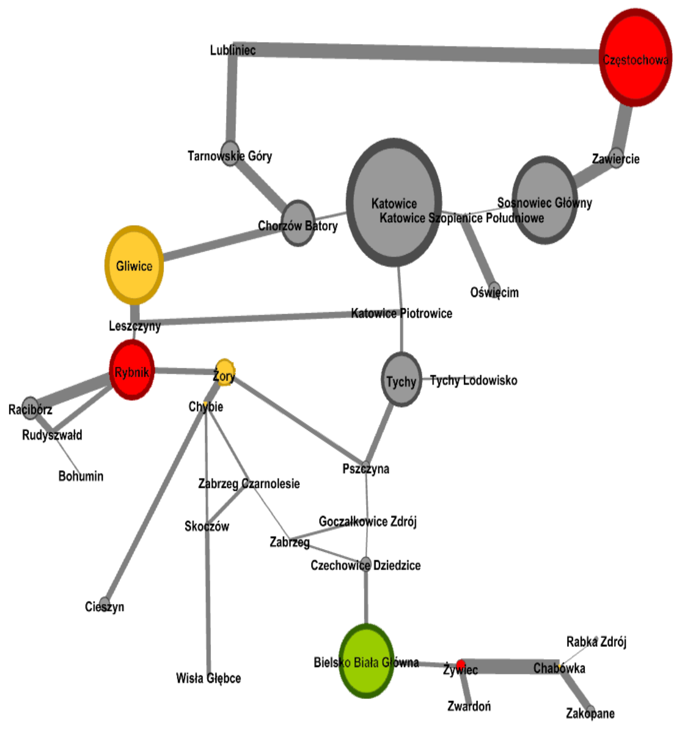
Case study – Phase II

Network vulnerability classes:

- high (> 10%) (red),
- medium (5% - 10%) (orange),
- and low (< 5%) (green).

City-node	Vulnerability value	Vulnerability class
Częstochowa	12,9 %	High
Żywiec	10,9 %	High
Rybnik	10,7 %	High
Chabówka	9,7 %	Medium
Chybie	8,5 %	Medium
Gliwice	8,3 %	Medium
Żory	7,8 %	Medium
Bielsko-Biała	3,7 %	Low



Vulnerability of the network to damages of individual nodes divided into 3 classes

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Case study – results

- In order to improve the resilience of the examined communication network, it was proposed to connect the railway network with a flexible bus network, which in the event of blockage of one of the important railway nodes would ensure the maintenance of the network capacity at the required level.
- The vulnerability index values obtained as a result of simulation tests are the basis for determining the optimal amount of redundancy in the bus network.

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5. How to ensure continuity of logistic processes in critical situations?

b) Creating a functionally resilient supply chain

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Concept of process continuity

The continuity oriented approach is closely related to the idea of *resilient enterprise** as well as the concept of disruption-tolerant operation, and based on the methodology of *service engineering***.

The model proposed in the work is based on a typical course of a service delivery process, interrupted by an occurrence of a disruptive event leading to *a disruption of process continuity*.

**Sheffi, Y.: The resilient enterprise: overcoming vulnerability for competitive advantage. MIT Press, Cambridge (2007)*

***Salvendy, G., Karwowski, W.: Introduction to Service Engineering. Wiley, Hoboken, New Jersey (2010)*

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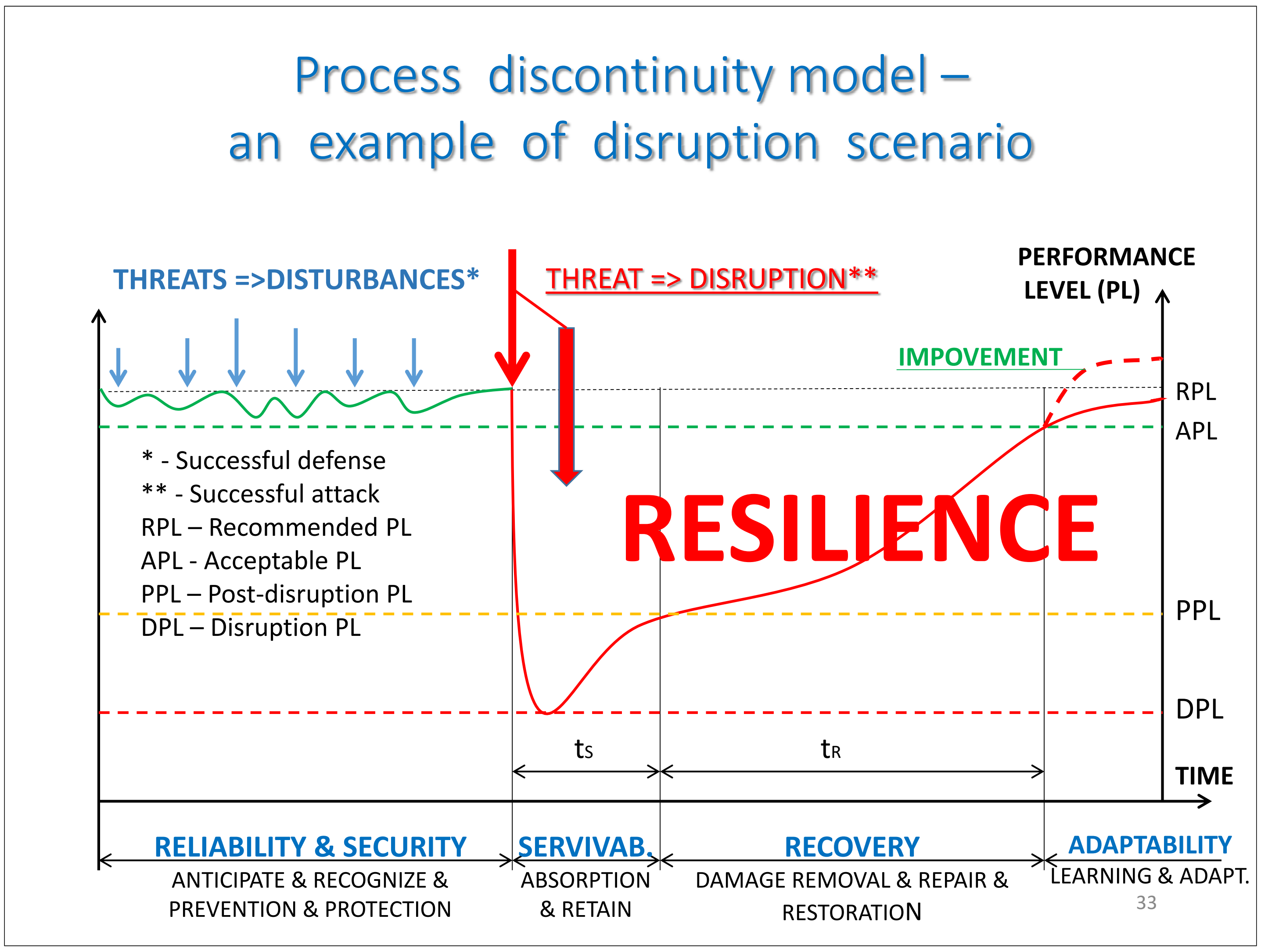
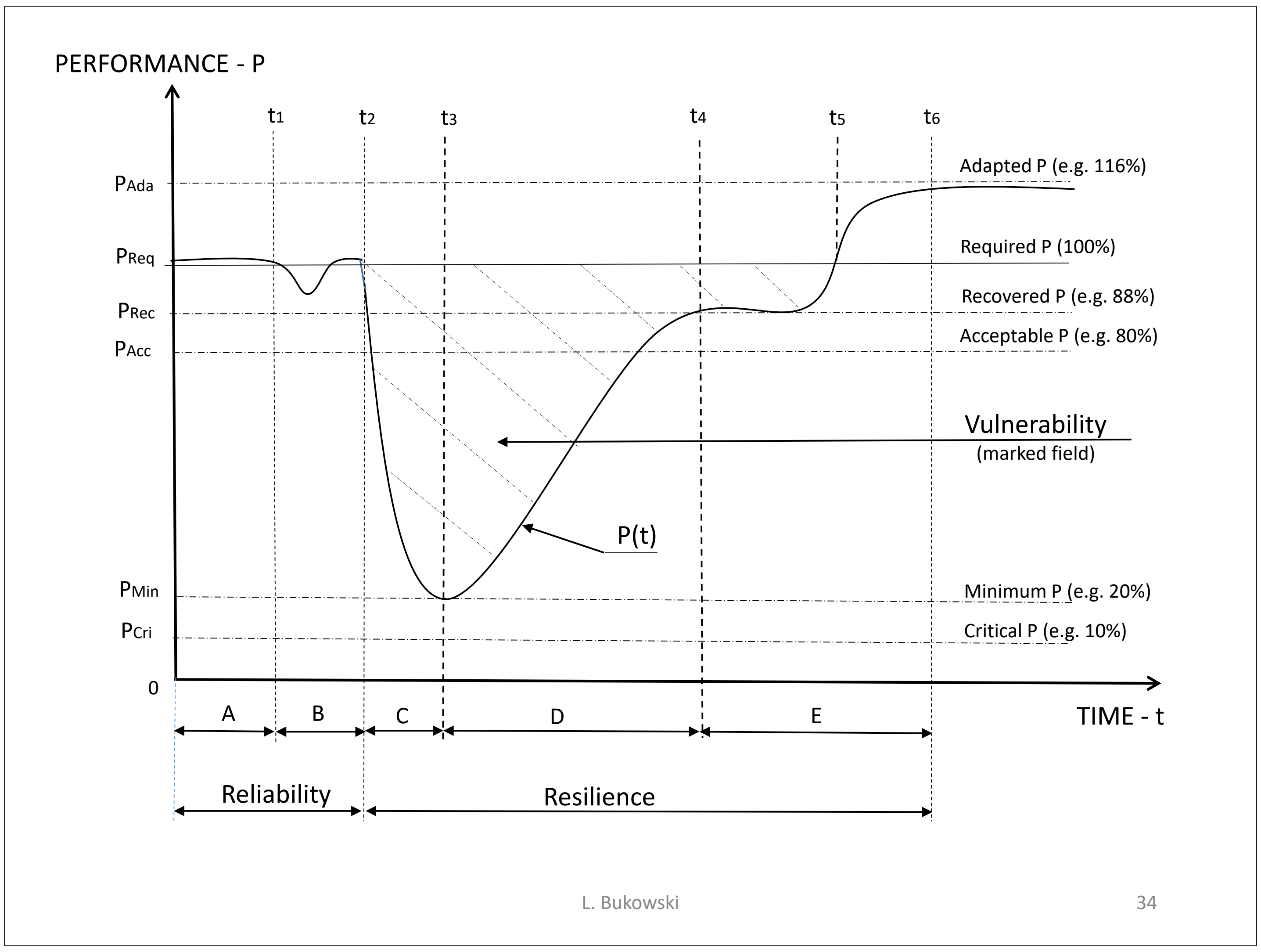

Process discontinuity model –
an example of disruption scenario
THREATS =>DISTURBANCES*
THREAT => DISRUPTION**
PERFORMANCE LEVEL (PL)
IMPOVEMENT
RPL
APL
* - Successful defense
** - Successful attack
RPL – Recommended PL
APL - Acceptable PL
PPL – Post-disruption PL
DPL – Disruption PL
RESILIENCE
PPL
DPL
tS
tR
TIME
RELIABILITY & SECURITY
ANTICIPATE & RECOGNIZE & PREVENTION & PROTECTION
SERVIVAB.
ABSORPTION & RETAIN
RECOVERY
DAMAGE REMOVAL & REPAIR & RESTORATION
ADAPTABILITY
LEARNING & ADAPT.
33


PERFORMANCE - P
t1
t2
t3
t4
t5
t6
PAda
PReq
PRec
PAcc
PMin
PCri
0
Adapted P (e.g. 116%)
Required P (100%)
Recovered P (e.g. 88%)
Acceptable P (e.g. 80%)
Vulnerability
(marked field)
P(t)
Minimum P (e.g. 20%)
Critical P (e.g. 10%)
A
B
C
D
E
TIME - t
Reliability
Resilience
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Modelling resilience - process continuity approach

The quantitative measure for *disruptive event impact (DEI)* can be described as follows:

$$DEI = \langle L_{Dis} \rangle \quad (1)$$

where:

$L_{Dis} = \int_{t2}^{t5} [P_{Req} - P(t)]dt$ – expected loss of performance *P* caused by *DE* (2)
P_{Req} – required performance level,
$P(t)$ – performance at the time t,
t_2 – beginning of disruption,
t_5 – end of disruption (return to required performance level).

The general model for resilience metric is represented as a collective term described by four dimensional vector as follows:

$$\boldsymbol{RE = \langle ABS, REC, ADA, DEI \rangle} \quad (3)$$

with:

$ABS = \langle P_{Min}, T_{Abs} \rangle$ – absorbability (4)
$REC = \langle P_{Rec}, T_{Rec} \rangle$ – recoverability (5)
$ADA = \langle P_{Ada}, T_{Ada} \rangle$ – adaptability (6)
$DEI = \langle L_{Dis}, T_{Dis} \rangle$ – disruptive event impact (7)

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Modelling resilience - process continuity approach

Model (3) and its components described by formulas (4) to (7) have a descriptive-qualitative character. Assuming that the variables describing the process are random, the following formulas can be used to quantify the resilience metric:

$$ABS_{index} = Pro[(P_{Min} > P_{Cri}) \cap (T_{Abs} < T_{Cri})] \quad (8)$$

$$REC_{index} = Pro[(P_{Rec} > P_{Acc}) \cap (T_{Rec} < T_{Cri})] \quad (9)$$

$$ADA_{index} = Pro\left[(P_{Ada} > P_{Req}) \cap (T_{Ada} < T_{Cri})\right] \quad (10)$$

$$DEI_{index} = Pro[(L_{Dis} > L_{Cri}) \cap (T_{Dis} < T_{Cri})] \quad (11)$$

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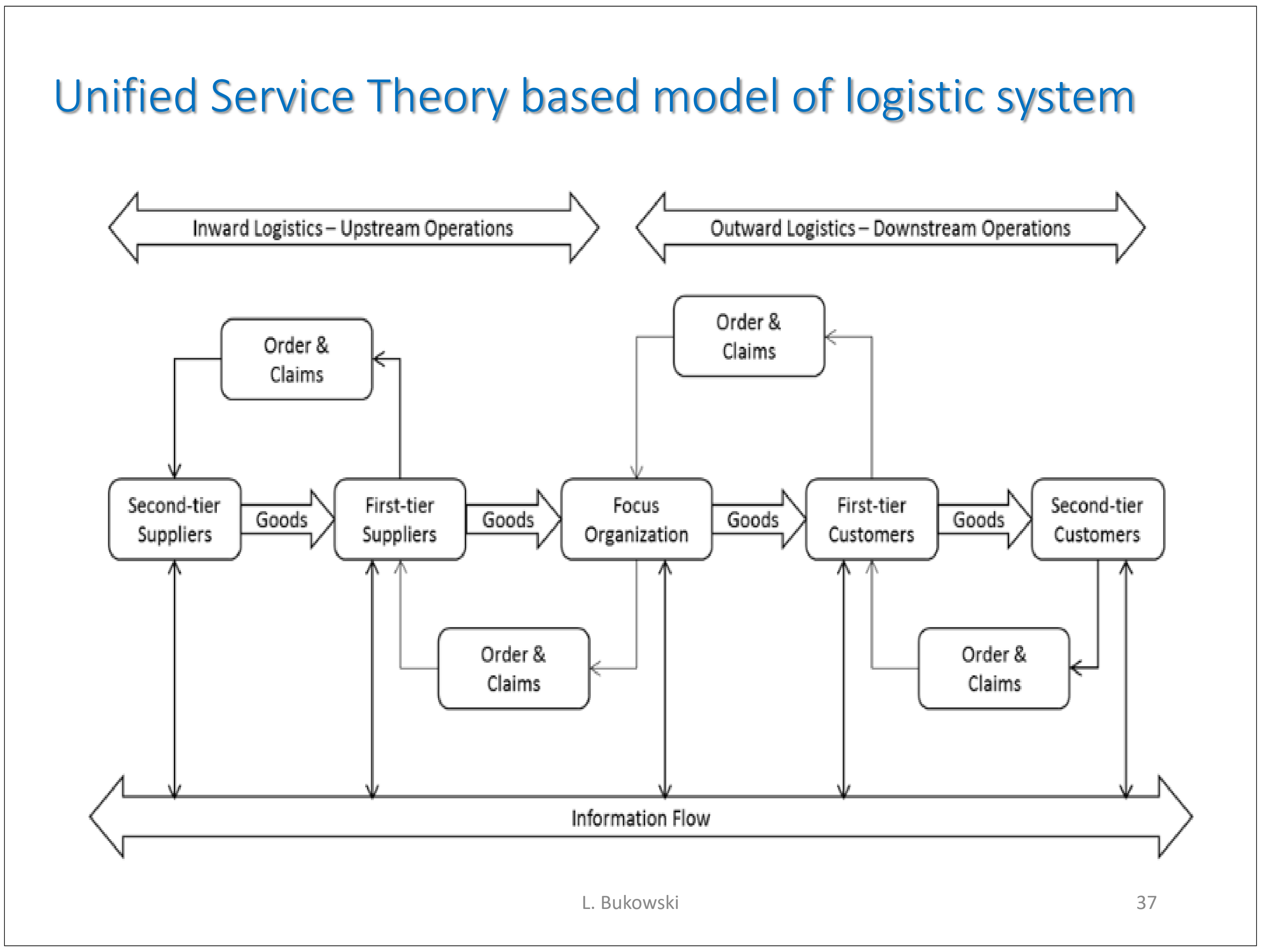
Unified Service Theory based model of logistic system
Inward Logistics – Upstream Operations
Outward Logistics – Downstream Operations
Order & Claims
Order & Claims
Second-tier Suppliers
Goods
First-tier Suppliers
Goods
Focus Organization
Goods
First-tier Customers
Goods
Second-tier Customers
Order & Claims
Order & Claims
Information Flow
L. Bukowski
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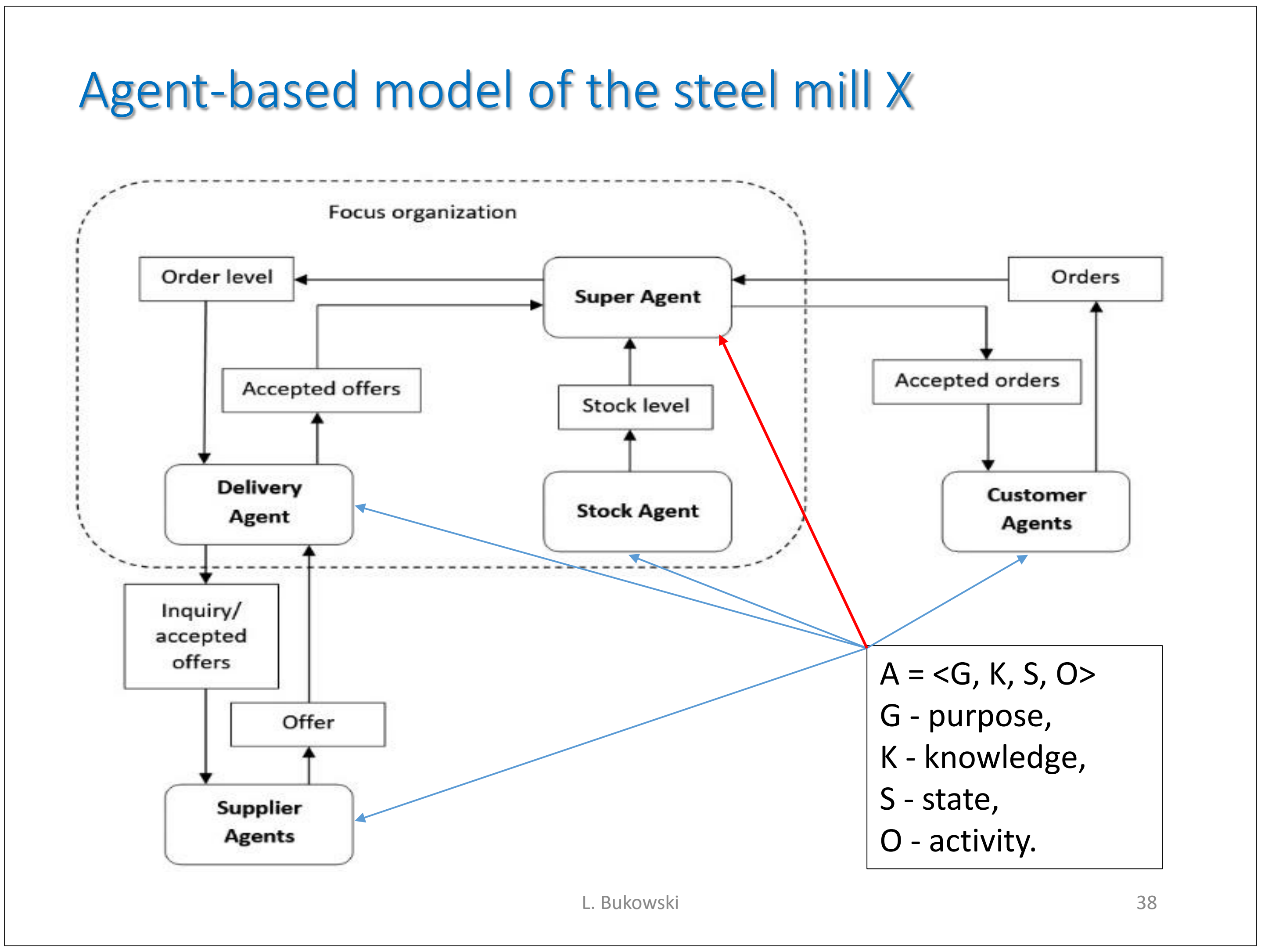
Agent-based model of the steel mill X
Focus organization
Order level
Super Agent
Orders
Accepted offers
Stock level
Accepted orders
Delivery Agent
Stock Agent
Customer Agents
Inquiry/ accepted offers
Offer
Supplier Agents
A = <G, K, S, O>
G - purpose,
K - knowledge,
S - state,
O - activity.
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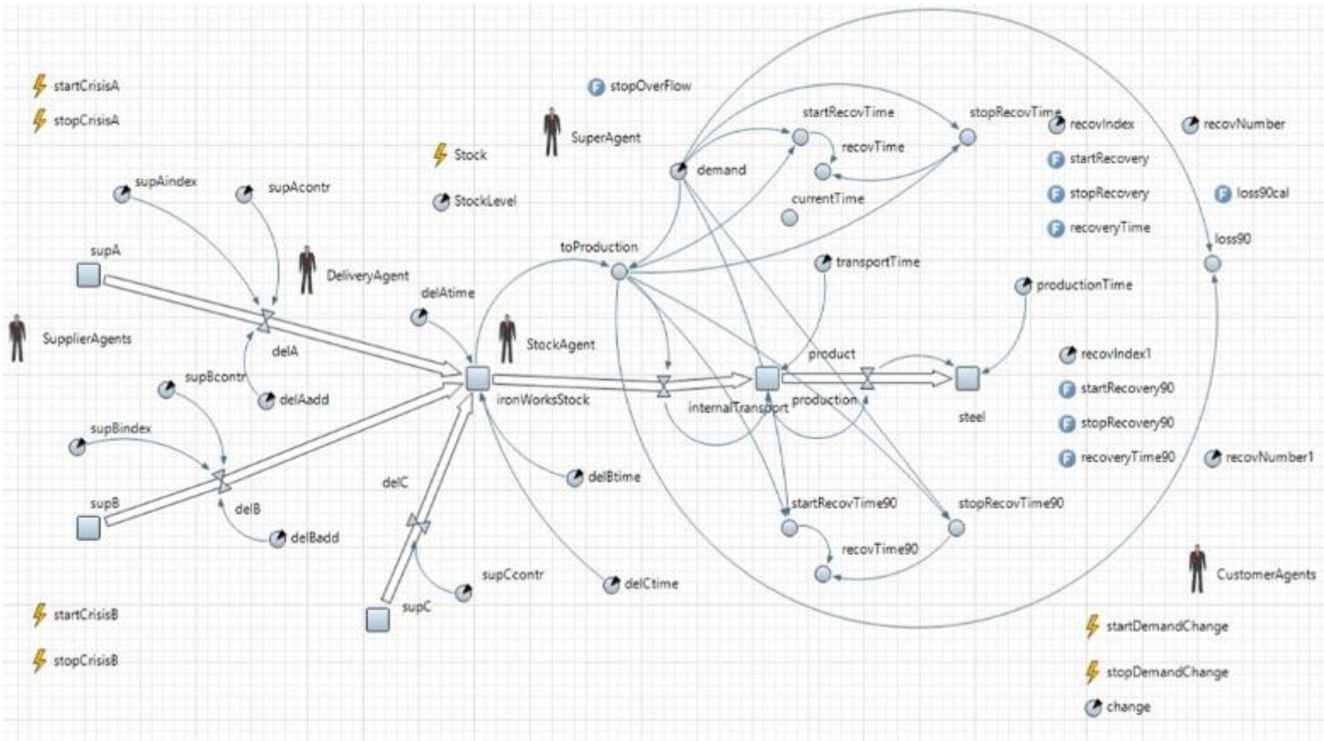
Agent-based simulation model of the steel mill X*



*Bukowski L., Feliks J., Majewska K. *Modelling and simulation of disruption risk in the complex logistic networks – a multimethod approach*, w *"Safety and Reliability of Complex Engineered Systems"*, 2015 Taylor & Francis Group, A Balkema Book, London, pp. 3911-3918

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Simulation scenarios

S1 - an increase in demand for 30 days, no additional supplies,
S2 - an increase in demand for 30 days, an additional delivery from C after 1 day (+ transport 3 days),
S3 - a break in supply, no additional delivery,
S4 - a break in supply, an extra supply from C after 5 days (+ 3 days),
S5 - an increase in demand for 30 days, then interruption in supplies, no additional delivery,
S6 - an increase in demand for 30 days, then interruption in supplies, an extra supply,
S7! - a break in supply, then an increase in demand, no additional delivery,
S8 - a break in supply, then the increase in demand, an extra supply,
S9! - a break in supply during the growing demand, no additional delivery,
S10 - a break in supply during the growing demand, an extra supply.

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Resilience vectors for 90 selected scenarios

O		O1			O2			O3	
V/S	V1	V2	V3	V1	V2	V3	V1	V2	V3
S1	‹97,1; 70,0›	‹94,4; 70,0›	‹91,8; 70,0›	‹100; 100›	‹98,1;89,0›	‹95,3; 82,3›	‹100; 100›	‹100; 100›	‹99,8; 99,0›
S2	‹99,3; 86,7›	‹98,7; 86,1›	‹98,1; 85,7›	‹100; 100›	‹98,9;89,0›	‹98,1; 82,3›	‹100; 100›	‹100; 100›	‹99,8; 99,0›
S3	‹96,0; 86,0›	‹92,1; 81,0›	‹88,1; 76,0›	‹100; 100›	‹96,0;86,0›	‹92,1; 81,0›	‹100; 100›	‹100; 100›	‹97,0; 87,3›
S4	‹96,5; 94,2›	‹95,9; 90,0›	‹95,9; 85,8›	‹99,9; 100›	‹99,9;99,5›	‹99,9; 92,5›	‹100; 100›	‹100; 100›	‹100; 100›
S5	‹90,7; 56,0›	‹86,9; 51,0›	‹83,2; 46,0›	‹94,3; 75,0›	‹90,6;70,0›	‹86,8; 65,0›	‹99,0; 90,1›	‹95,3;84,8›	‹91,5; 79,8›
S6	‹96,5; 65,6›	‹96,1; 60,9›	‹95,9; 55,9›	‹96,3; 84,2›	‹95,7;79,9›	‹95,5; 74,9›	‹99,6; 98,5›	‹98,7;92,4›	‹95,7; 87,2›
S7	‹90,7; 56,0›	‹86,9; 51,0›	‹83,2; 50,6›	‹94,4; 70,0›	‹90,7;60,6›	‹86,9; 55,6›	‹99,0; 94,0›	‹95,2;74,0›	‹91,5; 61,9›
S8	‹94,9; 71,8›	‹94,6; 70,5›	‹94,4; 65,5›	‹98,3; 80,2›	‹98,2;62,9›	‹94,9; 57,6›	‹100; 100›	‹100; 100›	‹100; 100›
S9	‹92,8; 82,5›	‹88,3; 77,5›	‹83,8; 72,5›	‹96,4; 94,5›	‹91,9;89,4›	‹87,4; 84,4›	‹100; 100›	‹96,6;94,5›	‹92,1; 89,4›
S10	‹95,8; 84,5›	‹95,1; 92,6›	‹94,9; 92,6›	‹97,7; 96,5›	‹97,1;94,9›	‹96,8; 94,9›	‹100; 100›	‹100; 100›	‹100; 100›

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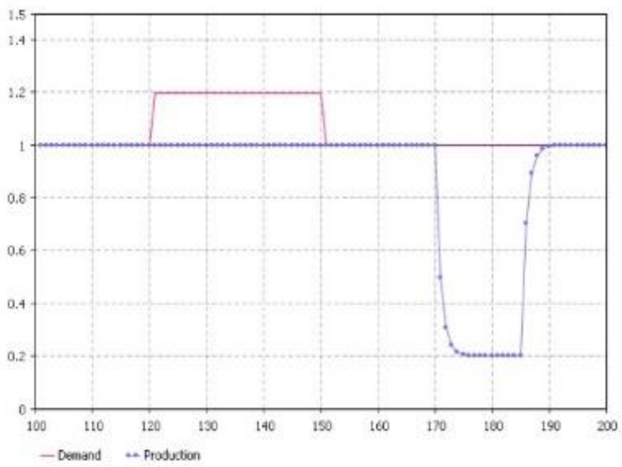
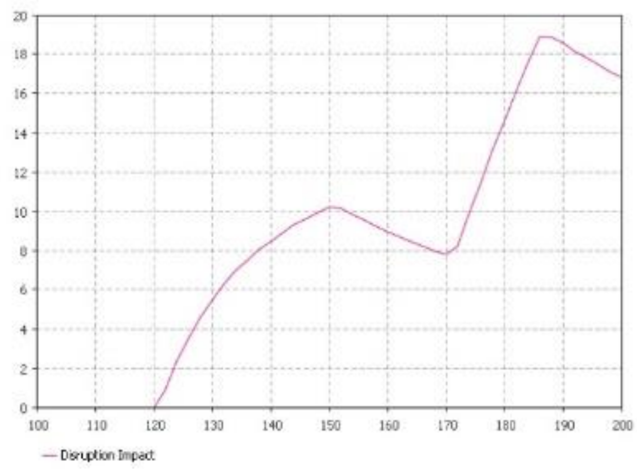
Simulation results





Scenario S5-O1-V3 (an increase in demand for 30 days, then interruption in supplies for 15 days):

- small stocks (only for 1 day),
- no action taken by agents responsible for additional supplies.

Cause: maximum loss (disruption impact 17%)
Res = <83,2; 46>

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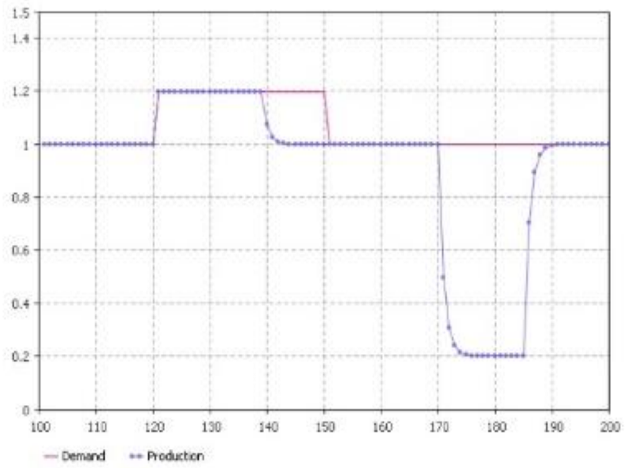
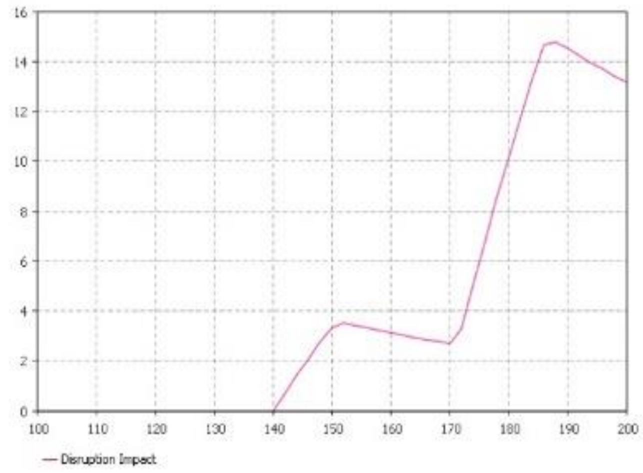
Simulation results





Scenario S6-O2-V3 (an increase in demand for 30 days, then interruption in supplies):
- larger stocks (for 5 days),
- after the interruption in supply occurs, we run additional delivery.

Cause: smaller loss (disruption impact 4,5%)
Res = <95,5; 75>

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Simulation results

Simulation studies have shown that the essential factors influencing the resilience of logistic systems are:

- the structural redundancy in the area of inward logistics,
- the sufficient level of stocks available on site in the organization,
- the organizational agility (the speed of decision-making in order to adapt the logistic system to new external conditions).

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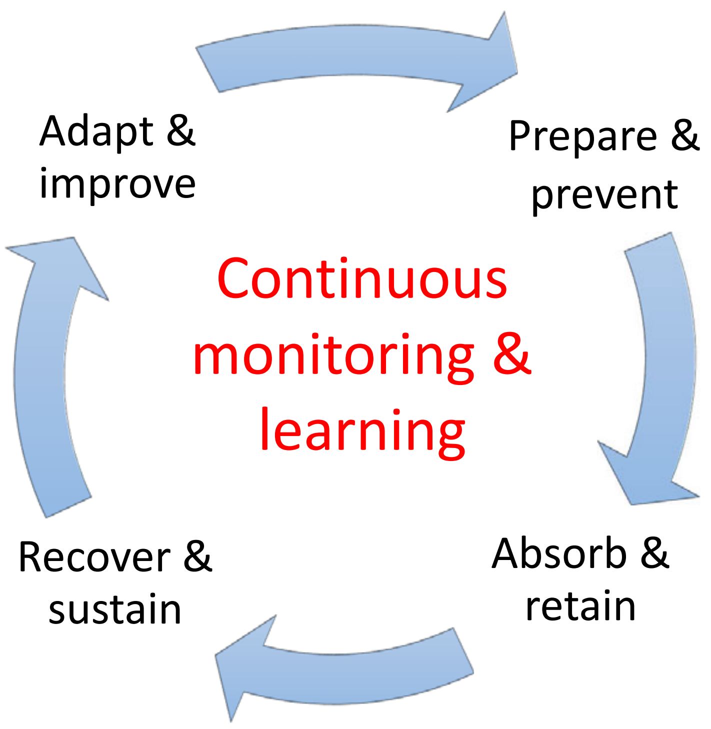
5. How to ensure continuity of logistic processes in critical situations?

c) Becoming a resilient organization through Resilience-Based Maintenance (RBM)

L. Bukowski 45

Becoming a resilient organization through RBM



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Resilience-Based Maintenance (RBM) concept*

Maintenance Support Potentials (MSP)

The potential to respond - knowing what to do and being able to react correctly to any threats and hazards by activating correctly planned and prepared actions, or by introducing new processes.

The potential to monitor - being able to monitor all signals from the internal and external environment that may affect an organization's performance in the near-term or long-term future.

The potential to learn - being able to draw conclusions from experience, in particular '*to learn the right lessons from the right experiences*'.

The potential to anticipate - knowing what to be expected and predicting future developments considering particular potential disruptions, constraints, and changing operating conditions.

*Bukowski L., Werbińska-Wojciechowska S. *Using fuzzy logic to support maintenance decisions according to Resilience-Based Maintenance concept, Maintenance and Reliability,* 2021; 23 (2): 294–307

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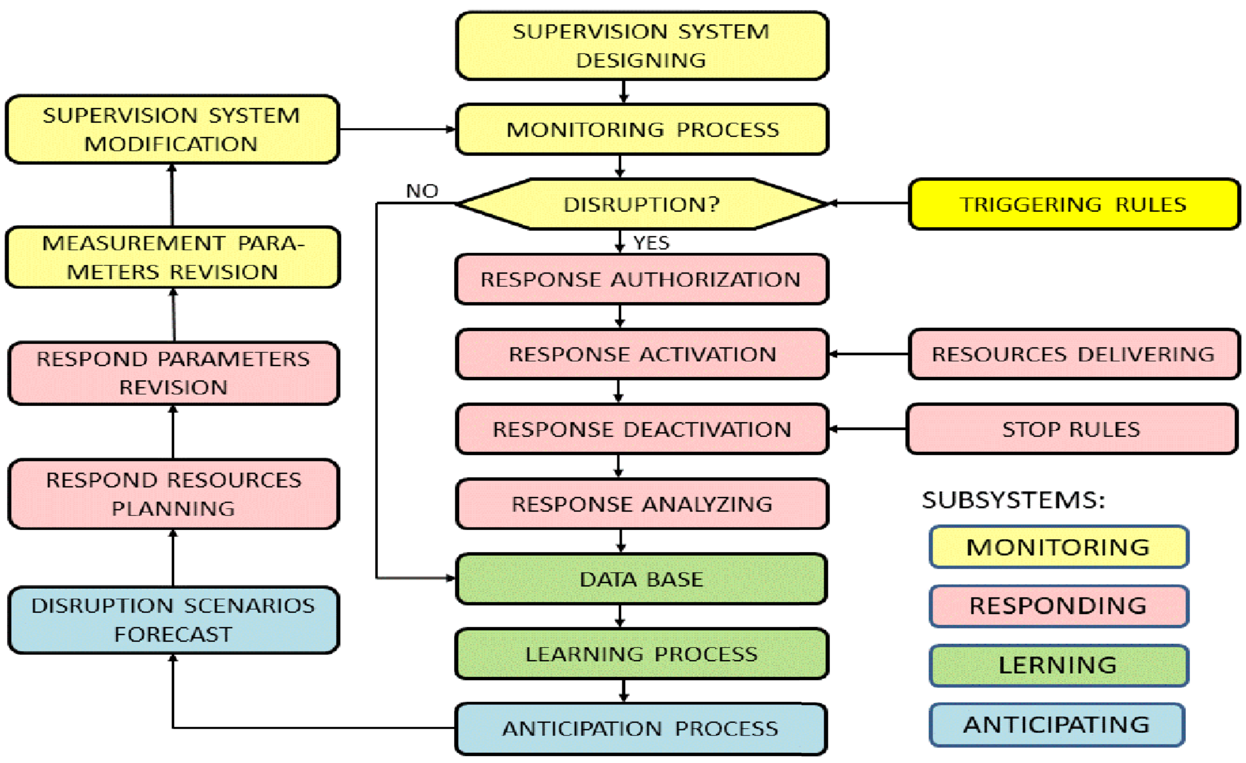
A functional diagram of the Maintenance Support System for RBM



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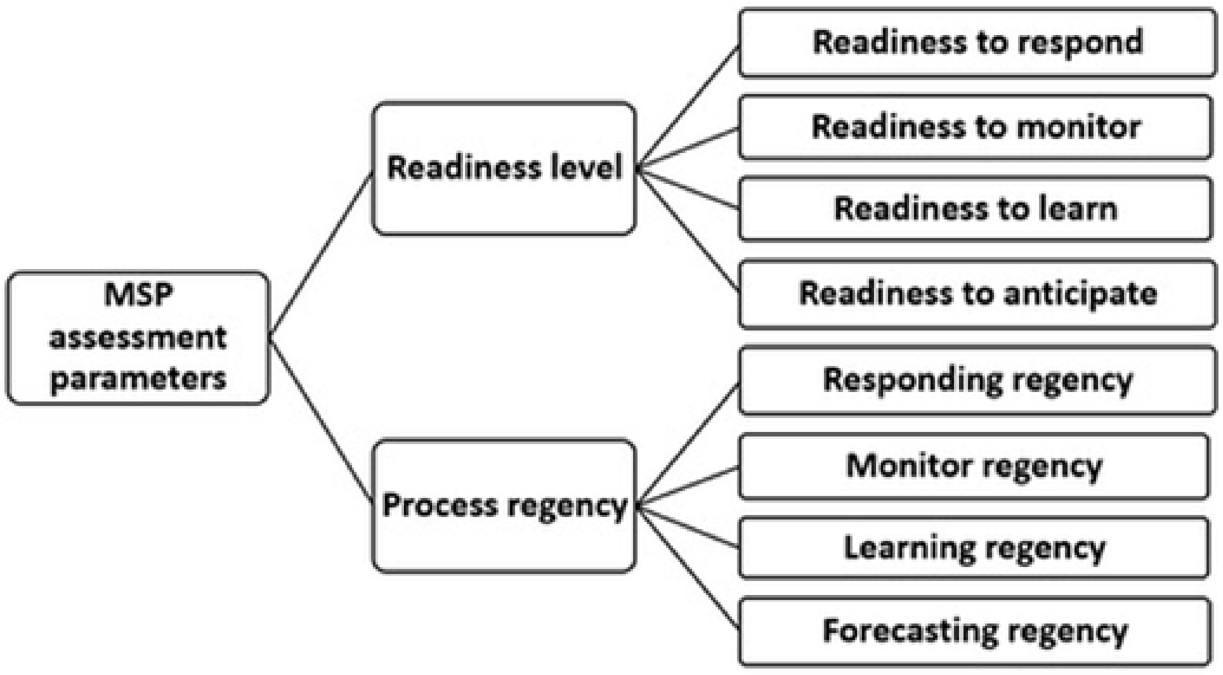
MSP assessment parameters included in the proposed methodology of RBM



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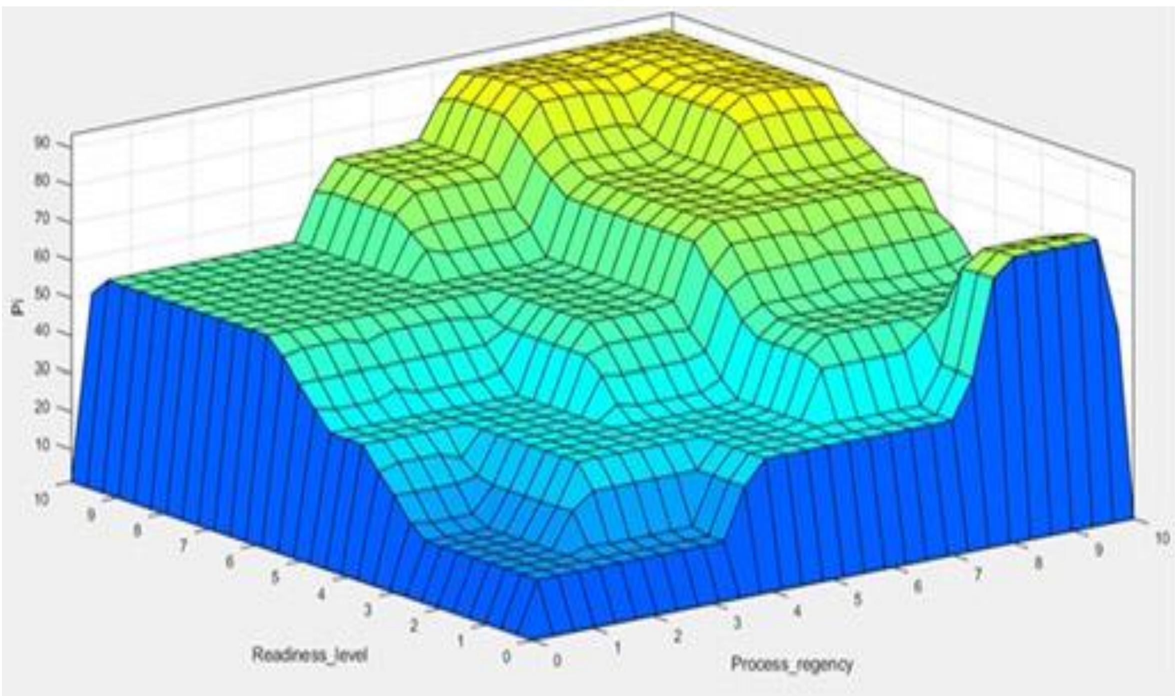
Surface view of the fuzzy inference system – an application example for automotive company



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Conclusions

- Modern logistics systems are becoming more and more sophisticated and can be described by dynamic large scale system of systems.
- Therefore, for their efficient management it is necessary to ensure continuity of logistic processes in critical situations.
- It is especially important to assess the supply chain resilience arising from the uncertainty and volatility of the environment (e.g. errors, failures and attacks).
- Let us propose a multidimensional approach to ensuring the resilience of complex supply chains, namely:
  a) Configuring a resilient topology
  b) Creating a functionally resilient supply chain
  c) Becoming a resilient organization through RBM

L. Bukowski 51

Critical supply chains for energy technologies

G. Paunescu, European Commission, Directorate-General for Energy, Energy Security and Safety Unit, Brussels, Belgium

The plenary lecture describes a study on resilience of critical supply chains for energy technologies. First, the critical supply chains of the energy sector are identified. Second, the current and potential problems of the most critical supply chains are identified and assessed. Finally, possible measures/policy proposals are identified to mitigate the identified risks and to reinforce the resilience of the critical supply chains for energy security and clean energy transition.

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Critical supply chains for energy technologies

George Paunescu
Policy Officer
Directorate-General for Energy
Energy Security and Safety Unit

59th ESReDA seminar
'Creating safe and resilient logistic systems'
26 October 2021

Background

'A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate' COM(2015) 80

Five dimensions of the Energy Union:
- Energy security, solidarity and trust;
- A fully integrated European energy market;
- Energy efficiency contributing to moderation of demand;
- Decarbonising the economy;
- Research, Innovation and Competitiveness

https://ec.europa.eu/energy/topics/energy-security_en

Energy security

Secure gas supplies
EU legislation helps to prevent and respond to potential gas supply disruptions

Diversification of gas supply sources and routes
Diversified supply routes increase security of energy

Security of electricity supply
EU legislation to prepare for and manage electricity crisis situations

EU oil stocks
EU countries are required to maintain emergency stocks of oil which can be used in case of a disruption to supply.

Offshore oil and gas safety
EU rules to prevent and respond to accidents on offshore installations.

Oil and gas licensing
EU rules governing the granting of licenses for oil and gas exploration and production.

Critical infrastructure and cybersecurity
Energy security requires adequate protection of critical infrastructure, in particular against cyberattacks.

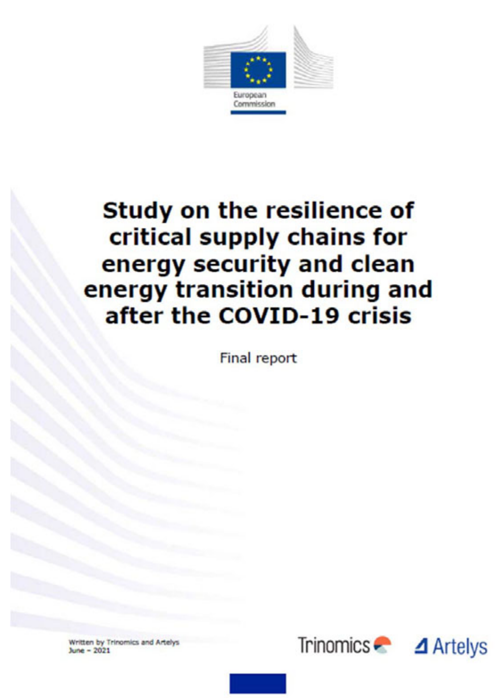
Energy supply and pandemics
The Commission collaborates with relevant energy expert groups to ensure access to energy, risk preparedness and cross-border coordination.

2

1. Study

Publications Office of the European Union

https://op.europa.eu/en/publication-detail/-/publication/b80d77b6-2a3b-11ec-bd8e-01aa75ed71a1/language-en/format-PDF/source-search



2. Wider policy framework

3

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1. Study

The study covered the following main tasks:

- 1 – Identify the critical supply chains for the energy sector
- 2 – Assess the current and potential problems for the most critical supply chains identified – four threat scenarios
- 3 – Identify possible measures / policy proposals to mitigate the identified risks and reinforce the resilience of the critical supply chains for energy security and clean energy transition.

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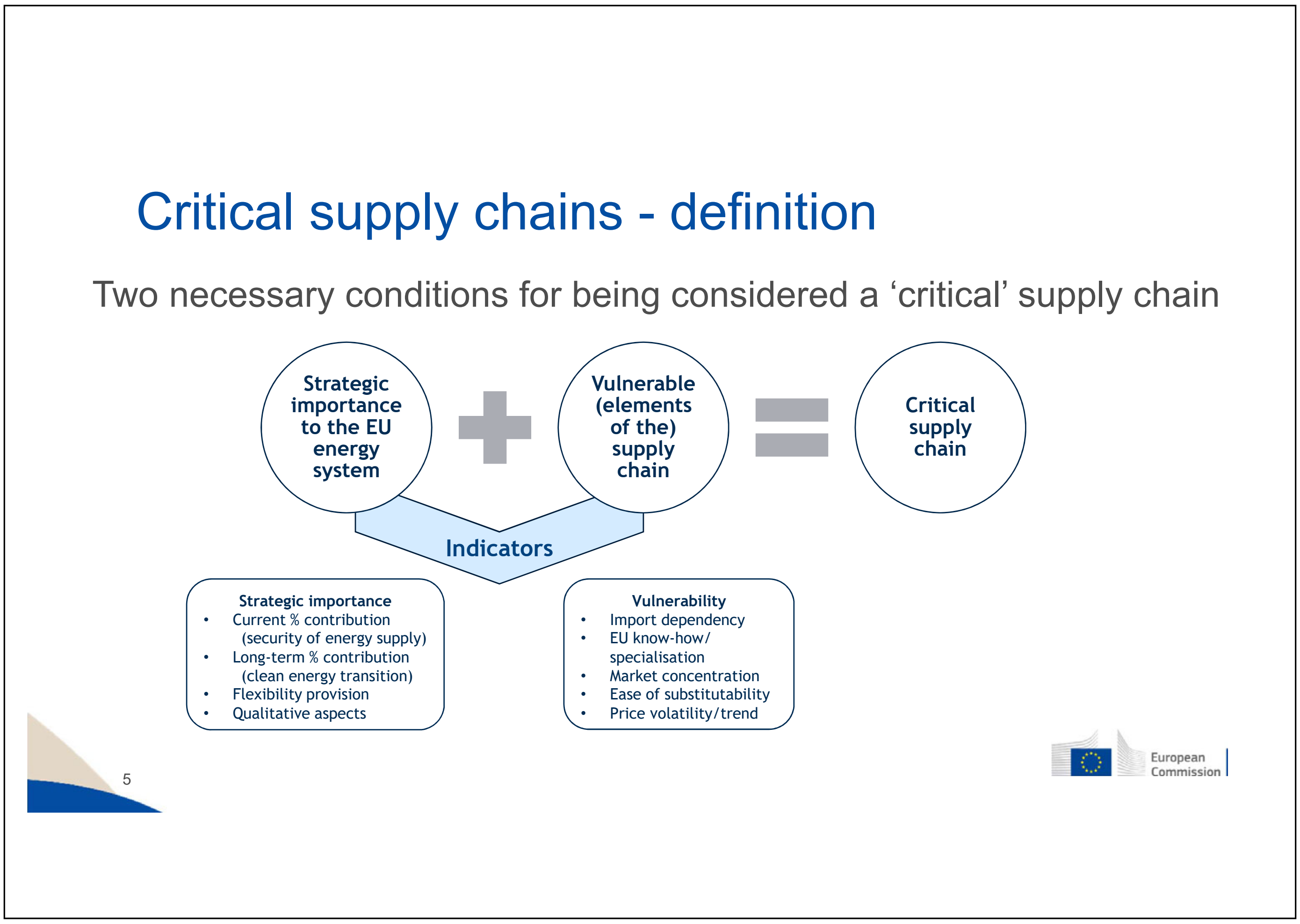
Critical supply chains - definition
Two necessary conditions for being considered a ‘critical’ supply chain
Strategic importance to the EU energy system
Vulnerable (elements of the) supply chain
Critical supply chain
Indicators
Strategic importance
• Current % contribution (security of energy supply)
• Long-term % contribution (clean energy transition)
• Flexibility provision
• Qualitative aspects
Vulnerability
• Import dependency
• EU know-how/ specialisation
• Market concentration
• Ease of substitutability
• Price volatility/trend
5
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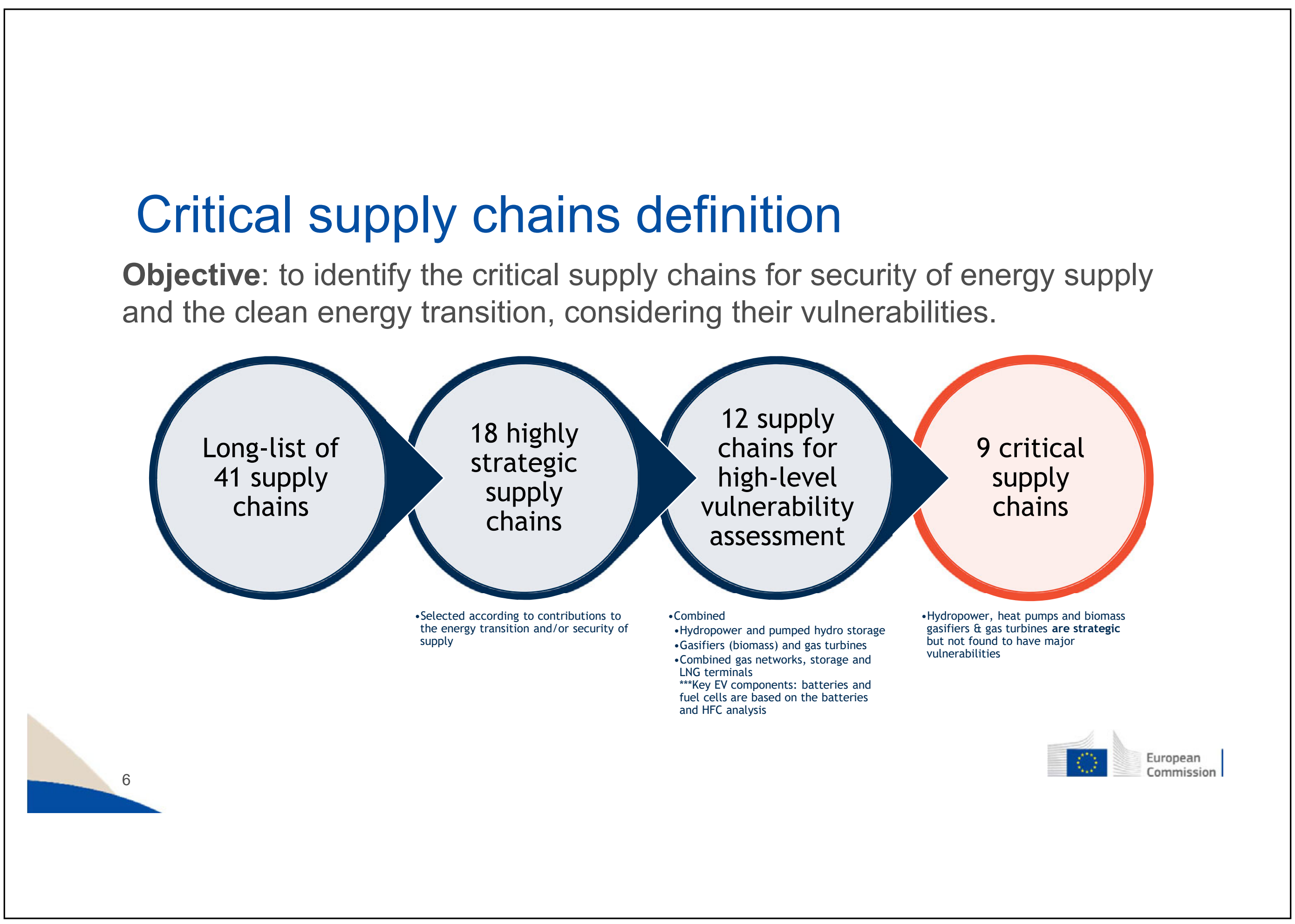
Critical supply chains definition
Objective: to identify the critical supply chains for security of energy supply and the clean energy transition, considering their vulnerabilities.
Long-list of 41 supply chains
18 highly strategic supply chains
12 supply chains for high-level vulnerability assessment
9 critical supply chains
•Selected according to contributions to the energy transition and/or security of supply
•Combined
•Hydropower and pumped hydro storage
•Gasifiers (biomass) and gas turbines
•Combined gas networks, storage and LNG terminals
***Key EV components: batteries and fuel cells are based on the batteries and HFC analysis
•Hydropower, heat pumps and biomass gasifiers & gas turbines **are strategic** but not found to have major vulnerabilities
6
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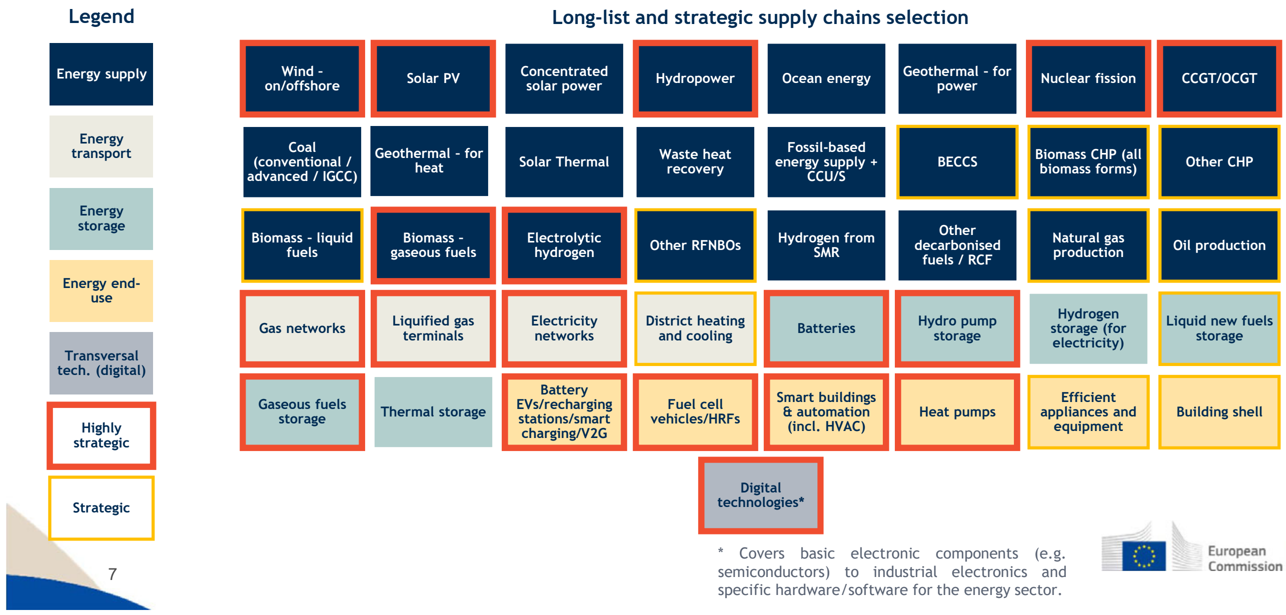
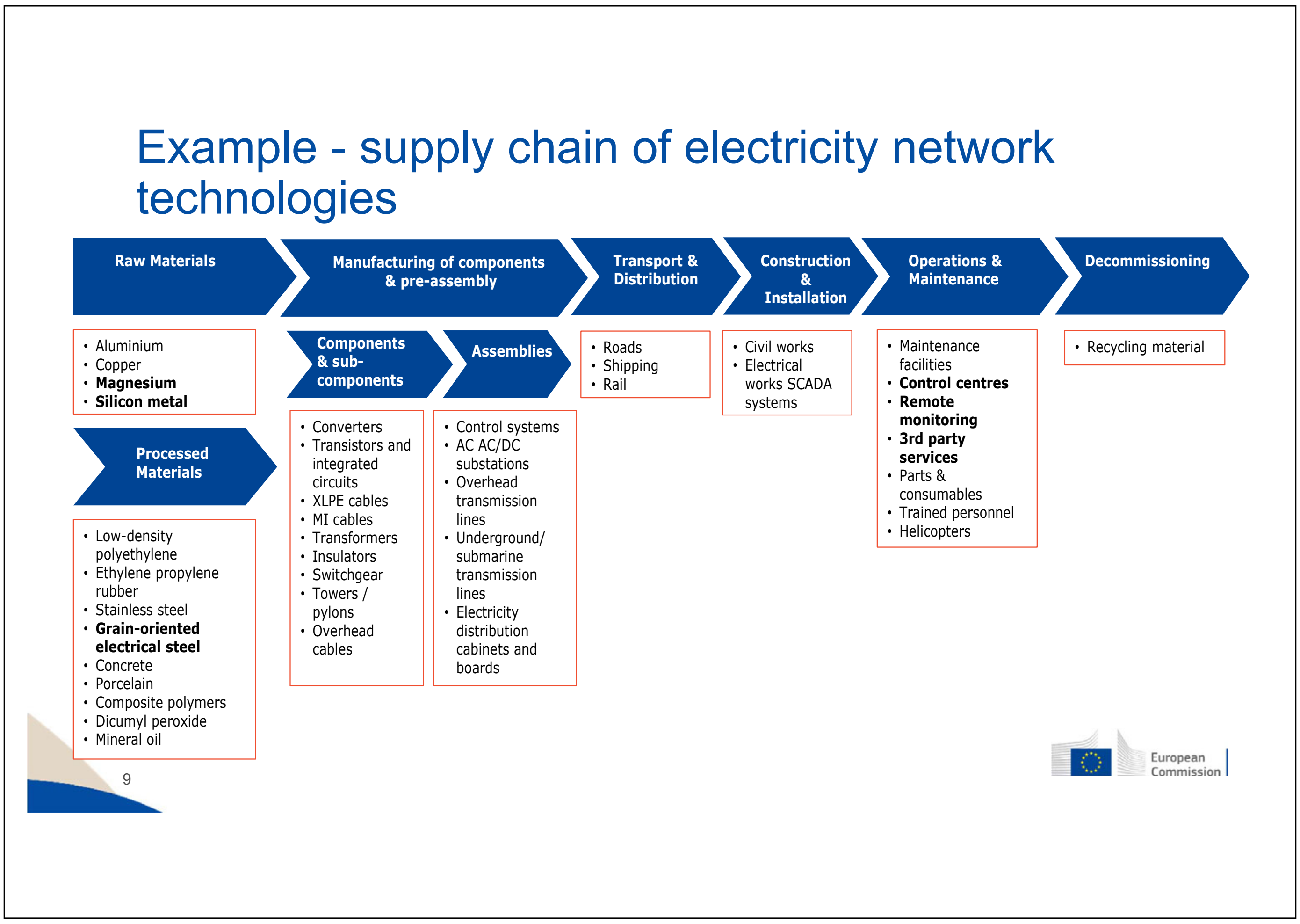
Long-list and strategic supply chains



High-level assessment of vulnerability

Strategic supply chains	Raw & Processed Materials	Manufacturing & Assembly	O&M
Wind	Cu, Dy, Nd; electrical steel		Vulnerability to cyber attacks due to increased digitalisation
Solar PV	B, Ga, Ge, In, Se, Si, Te	PV cells and modules	Potential for vulnerability to cyber attacks due to remotely controlled inverters
Hydropower and pumped hydro storage			
Nuclear fission	Ce, Cr, N, Zn; Ni-Cr-Fe alloys	Nuclear-grade certified suppliers (primary circuits, rods and other components/services for the nuclear island)	Certified service providers
Biomass gasifiers and gas turbines	Al, Pt, Cr		O&M services subject to cybersecurity risk
H2 production / storage / use	PGMs (Pt, Pd, Ru, Rh), Si, Ti		
Gas infrastructure		Ball valves, filters and purifiers	Cyber security of control systems / 3rd party service providers
Electricity networks	Bi, Mg, Si; electrical steel		Cyber security of control systems / 3rd party service providers
Batteries	Co, Si, P, F, Li, Nb, Ti, graphite	Li-ion cells, cathode, anode, electrolyte, separator	
Smart buildings	B, Co, Ga, Ge, In, Li, Mg, graphite, PGMS, Si, W	Home energy management systems	Security of home/building energy management systems and decentralised devices
Heat pumps	Cu, al, Zn; Stainless steel, PCB		
Digital technologies	B, Co, Ga, In, Li, Mg, graphite, PGMS, Si, W,	Electronic boards, semiconductors and processors Servers and data storage equipment	Related to cyber-security of digital technologies use in other supply chains

* Technologies in orange have been assessed as critical supply chain technologies


Example - supply chain of electricity network technologies
Raw Materials
Manufacturing of components & pre-assembly
Transport & Distribution
Construction & Installation
Operations & Maintenance
Decommissioning
• Aluminium • Copper • Magnesium • Silicon metal
Processed Materials
• Low-density polyethylene • Ethylene propylene rubber • Stainless steel • Grain-oriented electrical steel • Concrete • Porcelain • Composite polymers • Dicumyl peroxide • Mineral oil
Components & sub-components
• Converters • Transistors and integrated circuits • XLPE cables • MI cables • Transformers • Insulators • Switchgear • Towers / pylons • Overhead cables
Assemblies
• Control systems • AC AC/DC substations • Overhead transmission lines • Underground/ submarine transmission lines • Electricity distribution cabinets and boards
• Roads • Shipping • Rail
• Civil works • Electrical works SCADA systems
• Maintenance facilities • Control centres • Remote monitoring • 3rd party services • Parts & consumables • Trained personnel • Helicopters
• Recycling material
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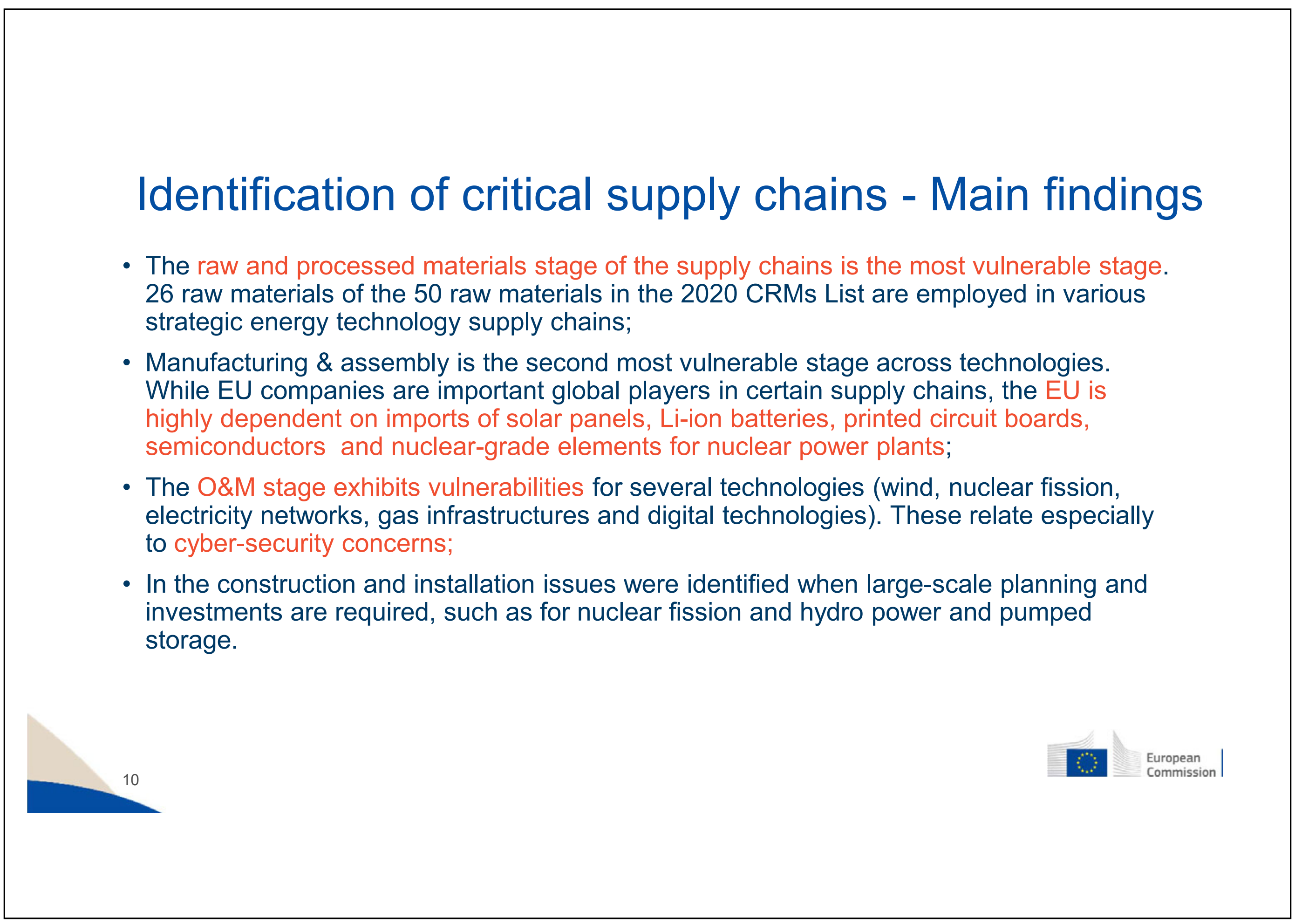
Identification of critical supply chains - Main findings
• The raw and processed materials stage of the supply chains is the most vulnerable stage. 26 raw materials of the 50 raw materials in the 2020 CRMs List are employed in various strategic energy technology supply chains;
• Manufacturing & assembly is the second most vulnerable stage across technologies. While EU companies are important global players in certain supply chains, the EU is highly dependent on imports of solar panels, Li-ion batteries, printed circuit boards, semiconductors and nuclear-grade elements for nuclear power plants;
• The O&M stage exhibits vulnerabilities for several technologies (wind, nuclear fission, electricity networks, gas infrastructures and digital technologies). These relate especially to cyber-security concerns;
• In the construction and installation issues were identified when large-scale planning and investments are required, such as for nuclear fission and hydro power and pumped storage.
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Current and potential problems - Threats and hazards to energy technology supply chains

Persistent pandemic
- Closure of extra-EU borders
- Closure of intra-EU borders
- Restricted access to work sites
- Logistical issues
- Administration delays
- Shortage of PPE

Extreme weather events
- Extreme temperatures
- Extreme precipitation
- High-intensity hurricanes

Cyber threats
- Unintentional vulnerabilities
- Lack of timely security updates
- Backdoors / Hidden functions
- 3rd party service provider vulnerabilities
- Increase in end-point equipment

Geo-political uncertainty & tensions
- Disruptions to supply routes
- Anti-dumping tariffs / other trade measures
- Trade sanctions

The three other threat scenarios have been identified as top risks, with ‘high impact’ and ‘high likelihood’.

- Confirmed by the literature and stakeholders, including World Economic Forum’s “The Global Risks Report 2020”

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Assessment of potential problems – Main findings (I)

- EU energy technology supply chains have shown to be resilient to the COVID-19 crisis
  - Business continuity plans in place;
  - Weaknesses of supply chains identified previously are sometimes passed on as added challenges during the pandemic (e.g. cobalt for battery, qualified suppliers in nuclear).
- Nonetheless, supply chains experienced many impacts (with cascading effects)
  - Disruption of trade flows from within EU and from extra-EU countries affected movement of goods and skilled labour availability;
    - e.g. 86% of Chinese imports and 74% of intra-EU imports of digital technology affected to some extent in March-April 2020
  - Supplies disruptions have led to price increases, which have affected the operating cost of some supply chains, e.g. gas infrastructure;
  - Essential sectors managed to continue operations, but still had to take significant measures to cope with the challenges faced, e.g. electricity networks
- Intra-EU difficulties were more persistent than manufacturing and logistics challenges in non-EU countries
- Stakeholders highlighted that integrated global supply chains provide multiple advantages including supply diversification and provide EU access to global markets

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Assessment of potential problems – Main findings (II)

- The threat scenarios present different risk levels, which are particular to the different energy technology supply chains and to the different supply chain stages. Custom/focused analyses are required.
- Across all threat scenarios, import reliance and supplier concentration for raw & processed materials are the key root causes of the vulnerabilities in the energy technology supply chains
- Often, stakeholders have neither considered, nor assessed the impact of supply chain-related cyber-attacks, extreme weather events or geo-political tensions on their supply chains

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Rationale for increasing SC resilience

Vulnerabilities to threats (to **pandemics, extreme weather events and geo-political uncertainties & tensions**) stem from two major causes:

- High dependence on non-EU suppliers
- In combination with high market concentration.

With this focus in mind, EU mitigation measures can follow a common logic:

1. Encourage substitution, whenever possible, of the critical elements used in EU energy technologies supply chains;
2. Diversify primary supply (intra-EU and from third countries) and develop back-up supply for raw materials as well as manufactured components. Attention should be given to ensure that the EU sources materials and components from responsible sources;
3. Develop secondary supply of critical raw materials as far as possible, i.e. recycling, in order to further reduce the external dependence on these critical raw materials, in coordination with other circular economy measures;
4. Develop EU supply capacities considering available resources, economic feasibility and social and environmental impacts;
5. Mitigate the risk of disruption of chains that cannot be diversified, through cooperation with non-EU governments and critical suppliers;
6. Ensure continuity of supplies and manufacturing in emergencies, through cooperation and other applicable measures where possible;

Cybersecurity vulnerabilities are of a different nature, arising from lack of/incomplete cybersecurity supply chain management policies and procedures. They therefore require a different approach:

7. Fostering voluntary / mandatory requirements for businesses conducting supply chain management processes to ensure the integrity of their supply chain for Information Technology (IT) and Operational Technology (OT).

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Summary of recommendations (I)

- Recommendation 1: Set up an integrated system for monitoring and reporting of vulnerabilities for critical energy technologies and supply chains
  - Set up a mechanism for integrated monitoring and reporting of vulnerabilities for critical energy technologies and supply chains
  - Address the missing critical raw materials in the Raw Materials Information System material profiles and update regularly, especially those with an expected strong increase in consumption due the EU or even worldwide uptake of strategic energy technologies
  - Expand the scope of the JRC Foresight Study on Critical Raw Materials for strategic technologies and sectors in the EU
  - Continue the identification and monitoring of vulnerable elements for critical supply chains for the transition towards 2050 in the work of the Low Carbon Energy Observatory, via the next annual reports, and possibly add gas infrastructure and turbines, which are not yet addressed in the Competitiveness Progress Report
  - Mainstream energy technologies to be tackled in the various actions set in the Commission's communication on "Critical Raw Material Resilience: Charting a Path towards greater Security and Sustainability"
- Recommendation 2: Leverage diplomacy and trade measures
  - Develop additional coalition building & increasing diplomatic outreach, focusing on regions or countries of high importance to the EU critical energy supply chains
  - Further mainstream environmental and social (incl. human rights) aspects into trade frameworks such as free trade agreements and other international frameworks
  - Further adapt the free trade agreement chapters under negotiation on energy and raw materials concerning aspects related to critical energy supply chains
- Recommendation 3: Develop EU-based production of raw materials
  - Include explicit work on the most critical raw materials for the energy systems into the workstreams of, for example, the EIT Raw Materials and, when possible, under the action points from the CRM Action Plan.
  - Ensure that EU-based programmes and instruments encourage alignment between the needs of industry and EU-based production of raw materials when identifying mining and processing projects in the EU that can be operational by 2025.

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Summary of recommendations (II)

- Recommendation 4: Leverage EU industrial alliances to address supply chain risks
  - Ensure that existing EU alliances contribute to increasing the resilience of critical energy supply chains – where relevant, and address more systematically supply risks and exposure to threats, and international trade relationships (e.g. via trade diplomacy)
  - Consider candidates for new alliances or adaptation of the scope of existing alliances
- Recommendation 5: Improve risk assessment and management by relevant entities
  - Provide a guidance for EU energy companies assessing and managing supply chain-related risks. This guidance could be of voluntary nature and detail the methodology as well as provide examples of how to assess technology supply chains.
  - Leverage the Critical Entities Resilience and Security of Network and Information Systems 2 Directive proposals to ensure certain companies conduct the risk assessment and implement corresponding measures. The proposals do contain specific requirements for relevant entities to do so, and furthermore require or empower the Commission to detail the methodology for complying with those requirements through implementing acts.
- Recommendation 6: Continue the analysis of supply chain vulnerable elements in preparatory studies for ecodesign product-specific regulations
  - Maintain and enhance, where necessary, the detailed analysis in the preparatory studies of impacts of ecodesign requirements on the product and vulnerable elements of the supply chain. If the ecodesign requirements are found to have significant impacts (positive or negative) regarding demand for vulnerable components, their production in the EU and trade (especially with non-EU partners), they should be taken up in the Commission Impact Assessment
- Recommendation 7: Further integrate circular economy measures (recycling & substitution)
  - When implementing the Circular Economy Action Plan , the most vulnerable components of the critical energy supply chains should be considered carefully
  - Carry out an update of the material-efficiency aspects of the Methodology for the Ecodesign of Energy-related Products study, also extending the scope to new materials that are relevant for the purpose of the critical energy supply chains

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2. Policies and instruments (I)

- **Clean energy competitiveness reports**

  Yearly reports, published starting with 2020 together with the State of the Energy Union reports (COM(2020)953, …)
  https://ec.europa.eu/energy/topics/technology-and-innovation/clean-energy-competitiveness_en

- **Critical raw materials**

  Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability COM(2020) 474
  (Fourth list of CRMs + Action plan)
  https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

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Policies and instruments (II)

- **New Industrial Strategy of the EU**

  A New Industrial Strategy for Europe (COM(2020) 102)
  Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery (COM(2021) 350)
  https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

- **EU Industrial Alliances**

  European Raw Materials Alliance
  European Battery Alliance
  European Clean Hydrogen Alliance
  Industrial Alliance on Processors and Semiconductor Technologies (new)
  https://ec.europa.eu/growth/industry/policy/industrial-alliances_en

- **Circular economy action plan, R&I funding**

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Thank you

Analysis of for assessment methods of supply chains resilience

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Currently, the challenges faced by modern logistics system management are the ability to identify the risk of disruptions and interruption of the logistics network, as well as to neutralize the impact of disruptions on the environment. Maintenance Support Capability (MSC) is the ability of an organisation to ensure that all its components perform their tasks effectively, efficiently and safely. These assumptions should be met both during undisturbed business conditions and during unexpected disruptions. A measure of Maintenance Support (MS) in an enterprise is the ability of an organisation to identify the right capabilities to respond to an unforeseen event. Maintenance Support Potentials (MSP) are:

- The Potential to Respond (PR) - the ability to find oneself in a crisis situation and respond appropriately to any threat, change, disruption or obstacle by activating a pre-prepared procedure, by adapting the appropriate mode of operation to the situation or by introducing new activities or processes,
- The Potential to Monitor (PM) - the ability to monitor all internal as well as external signals that may affect the company's performance in both the short and long term,
- The Potential to Learn (PL) - the ability to learn from past events,
- The Potential to Anticipate (PA) - the ability to foresee events that may adversely affect the enterprise, including disruptions, volatility of economic relationships, constraints.

The activities of enterprises in maintaining continuity of supply in a turbulent environment should take into account the requirements in terms of their impact on the environment. The article presents the results of literature analysis allowing to present current trends concerning the methods of assessment of supply chains resilience. Qualitative, as well as quantitative methods were analysed. In the group of quantitative methods, the leading role is played by simulation modelling allowing for the analysis of the impact of disruptions in supply chains in a dynamic perspective taking into account the randomness and uncertainty of model parameters.

A number of indicators were also proposed and compiled that can be used to assess the impact of actions taken in configuring supply chains taking into account their environmental impact.

Problems of inventory management in wood supply chains - case study

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One of the important issues in supply chain effective performance is warehouse and inventory management. Therefore, the main goal of the seminar presentation is to define the main problems occurring in the selected company's inventory management and the warehouse processes that lead to disruptions in the supply chain. The focus is on wood supply chain management.

The author introduces the main aspects of inventory management. Based on this, the preliminary study on identification of the main disturbances in wood supply chain in the area of inventory management and warehousing is introduced. First, the specificity of the wood supply chain is presented. The author discusses products and difficulties with their storage. Later, the importance of the wood supply chain management is investigated. The difficulties regarding the warehousing of wood products are presented, including dimensions, tonnage, costs of transport, and products ageing. The biggest company's problem in the area of warehouse management is also presented and the selected results connected with its negative consequences are discussed.

In the last part of the presentation, the author presents the possible solutions for company's problem, which are focused on decreasing the number of occurred damages during the warehousing processes performance. The presentation ends with a summary and a definition of the author's possible future research directions in the investigated research area.

System of training security control operators using eyetracking and virtual reality

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The purpose of the project is to increase the level of civil aviation security by developing an innovative method of security control operators training and assessment that eliminates the disadvantages of the existing training methods.

The main disadvantages of the current training system are: limited qualifications of operators who start working immediately after completing a training and passing exams; too long lasting process of acquiring the required level of qualifications while performing security control tasks and unsatisfactory results of the security control operators' work measured mainly by the percentage of detected prohibited items.

To achieve the assumed goal modern IT and optoelectronic technologies shall be used, including artificial intelligence, eye movement tracking technology and virtual reality technology. The new employee training and employee evaluation methods will enable faster progress of the trained employees in performing their duties, thanks to the selection of individualized training scenarios, tailored to the needs of each employee in such way that they can quickly improve their qualifications and eliminate mistakes. Simultaneously the innovative employee testing methods used will ensure the effective selection of employees with above average predispositions for the performed tasks.

Machinery safety requirements in digital management

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For the safe operation of machinery, the characteristic procedures are set in harmonized standards in accordance with the requirements of the Machinery Directive 2006/42/EC. Risk assessment is a starting point for the concept of a safe machinery. However, the user of the machine is mainly focused on the characteristics related to the business plan, i. e. achieving maximum readiness of the machine in the given working environment. Managers often see safety at best matter as obvious, but sometimes as a burdensome issue, thus an "unnecessary investment". The management of a digital (smart) organization in terms of machinery safety requirements creates a vision of unattended intelligent machinery, the advantage of which is the reduction of protective measures, and thus their more efficient use.

The requirement for machinery safety significantly changes in a digitalized space. Classical risk assessment [1] focused on human activities in a working environment will depend more on the probability of remaining in the given space. Simplifying or limiting the manipulation will decrease the impact on the musculoskeletal system. By restricting the entry into the environment, e.g.: with danger of explosion or fire (such as paint shops, welding shops, melting furnaces) on the one hand, the risk level will significantly decrease, on the other hand a high reliability of these safeguards (such as guards, interlocks, presence sensing devices) is expected.

The assessment of their parameters such as PL (Performance Level) or SIL (Safety integrity level) [2] will need to undergo a philosophical change. In an integrated system (horizontal and vertical digitalization) besides these safety standards, the requirement for their protection against external hazards or threats will considerably increase. System security level (Security level – SL) supporting data collection, processing, and management (e.g. SCADA) [3], ensuring machine communication with the environment, working process or a customer, will need to grow not only with OHS risk level, but also with business risk level (Business continuity management). For this reason, the rules and access to machinery construction must change philosophically. Current standards (such as ISO 12100) will require extending or adding the area of security hazard identification (ISO/TR 22100-4).

However, digitalization and its nine pillars (technologies), despite many benefits, bring new risks, the assessment of which will be the basis for the management of such an organization. A proactive approach to reducing the risks arising from external and internal threats/hazards requires the application of appropriate methods for their identification, description of causality and efficient and effective management [4].

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Human and autonomous guided vehicle participation in intralogistic processes – risk identification

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Possibilities to automatization caused many companies to decide changing their vehicles with operators to autonomous guided vehicle. There are many advantages of that type of solutions, but as important as benefits is the identification of areas which could be risky for both the vehicles and the working people. Implementation of autonomous guided vehicles was analyzed many times, but residual risks may be unpredictable but have significant consequences. This case shows how many interactions could exist between a worker and an autonomous guided vehicle. Vehicle is equipment in laser curtain scanner, front laser scanner, stack controller module and emergency stop buttons. The first type of unwanted events is when a vehicle collides with something. Unfortunately, there is a space in which something could appear and wouldn’t be detected by scanners. It could be obstacles or worker feet appear suddenly in the front of vehicle, which are too small to be detected by front laser scanner (diameter less than 70 mm). Also, moving objects like people or another vehicle could appear near the vehicle and wouldn't be detected, when it is restarted. Every vehicle with front and curtain scanners have blind points on both sides of vehicle, so when a vehicle is turning their front lasers couldn’t detect a worker or an obstacle, which are there. To minimize the risk of this type of situations vehicle reduce their speed before turning, to give workers enough time to react, but obstacles couldn’t react and could only be detected soon enough by front scanners. To avoid this type of risk it is recommended to install sides laser scanner, but it is optional. Also dangerous could be obstacles, which are above laser scanner and AGV could hit them. Every collision causes damages of the vehicle and dangers for workers. Another type of undesirable situations is when a vehicle automatically goes into safe mode (after detecting an obstacle, which couldn’t be omitted, after a small collision and when it lose navigation points) and turning on the mode of autonomous guided the worker is necessary. So a vehicle would wait for worker as long as it has to be. The person who firstly notices a standing vehicle has to inform the person with the appropriate permissions to start vehicle. Situations like that are a serious problem, because vehicles which are out of order affect the operation of the entire production line and are potential obstacles for other vehicles and pedestrians. To avoid this type of problems it is really important to remember to create and introduce a control and supervision system for the operation of the vehicle during the implementation of AGV in the enterprise. Sometimes in situations when a vehicle mission has been stopped it is necessary to use it in manual mode - with operator – and then every human mistake is possible, so it's important to educate workers about new safety rules for AGV and remember about this which was respected when vehicle worked only in manual mode with operator (driver).

The resilience of military fuel supply chains in conditions of limited information

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The operation of the supply chain carries the risk of possible unforeseen disruptions. The global reach of supply chains, shorter product lifecycles, and increasing customer demands have made organizations aware that disruptions to supply chains can have adverse operational and financial consequences. To reduce this risk, supply chains must be designed to: take into account the preparedness to counteract undesirable events, to provide an adequate response in the event of their occurrence, and to return to their original state as soon as possible after a disruptive event. This approach is at the heart of supply chain resilience.

For systems operating in a civil environment, disruptions at any stage of the supply chain system can primarily result in operational and financial losses to the organization. Completely different consequences cause disruptions in the supply chains operating in the military, especially during peacekeeping and stabilization operations in a foreign territory. The specificity of military operations is always associated with the conditions of limited information, e.g. information about possible disruptions and threats. Timely and complete deliveries of fuels under war conditions condition the achievement of the assumed goals of the military operation. They often determine the health and life of soldiers.

For this reason the role of building the resilience of supply chains to disruptions, the type and frequency of which is entirely different from the adverse events occurring in the flows of civil goods, is increasing. Therefore, a key concept supporting building resilience in fuel supply chains is risk management in these chains. The material presents the proprietary risk analysis method, integrating the Kaplan and Garrick approach and the fuzzy theory. The analysis identifies the occurring disturbances and assigns them to particular phases of the supply process. To illustrate the effectiveness of the applicability of the presented method, a detailed analysis of nine scenarios for the three most important stages of the delivery process was carried out to build the resilience of the entire chain: Planning, Delivery and Storage. The fuzzy theory estimates the risk level for the analyzed adverse event scenarios. The proposed method is universal. It can be implemented to analyze the resistance of the supply chains of other materials. It can also support the decision-making process of people responsible for planning, organization and proper functioning of supply systems in all high-risk conditions, not only in the zone of war and stabilization operations.

Review of standardized rules for designing safe stops on the example of Polish cities

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The aim of the material is to present the standards in force in Polish cities for the design of safe and functional tram stops. These standards are a set of rules for the preparation of design documentation, construction and renovation of the stop infrastructure. These can be basic information such as the length, width and height of the stop platform but, in some cases, there are much more precise rules, e.g. determining the location of a place to be waiting by people with disabilities in the area of the stop platform or guidelines for marking the stops (indicating the type of fonts, colours and contrasts). The guidelines may include those that define the minimum or maximum parameters of selected elements, but also precisely defined values. Some of the standards apply together with design recommendations, which most often constitute good practices or recommendations to be implemented in the case of e.g. having a sufficiently large area or other conditions affecting the possibility of implementing the stop design in a wider functional scope. There are several different types of stops in tram networks, some of the guidelines refer to a given type of stop in selected areas. It is particularly important due to the specificity of different types of stops. Information on the applicable city standards was obtained from all metropolises with tram systems. The data was collected as part of the research carried out on the assessment of the significance of the impact of selected elements of the stop on its safety and functionality. The collected guidelines allowed to determine the percentage of metropolises that have developed such solutions - it is surprisingly low. The lack of binding and unified standards in the area of a given city may lead to a wide range of possibilities for the design of stops, which in turn may have a direct impact on the safety, functionality and reliability of the entire tram system. A frequent phenomenon in several Polish cities is the failure to adapt the stop infrastructure to the newly delivered model of tram rolling stock. Having guidelines and carrying out an inventory of the stop infrastructure in terms of applicable standards allows you to avoid such situations. Despite the seemingly similar needs and parameters of the tram rolling stock operated in Polish cities, differences in the applicable guidelines for the design of tram stops can be observed. These differences are within the scope of several guidelines. On the other hand, in selected standards, one can observe an approach in which the stop infrastructure is adapted to the future changes to the rolling stock. Over the years, a tendency can be observed among public transport carriers to increase the length of the tram fleet. This is an undoubted advantage that allows you to carry a greater number of passengers in comfortable conditions at similar costs in relation to the transport of passengers using a shorter fleet. Currently, the standard length of a tram in Poland is approximately 32 meters. In their guidelines, selected cities contain a provision about stops, the length of which should be at least 45 meters. It is therefore a pre-emptive procedure aimed at adapting the stop infrastructure to the planned purchases of longer trams in the future. Such activities allow, among other things, to reduce the one-off costs of implementing a new solution in the public transport network, but also to spread them over time, which may meet with greater social acceptance. Therefore it is very important in the official design guidelines to maintain the universality and legitimacy of the established rules over the years, as well as the use of well-thought-out and proven solutions. Recommendations of good practices that work well in other cities, but also the use of research on the safety and functionality of stops available in the literature may be helpful in this.

The use of virtual reality in improving the competences of cargo handling operators at the airport

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We are currently seeing a high level of employee turnover in many industrial sectors. This problem also applies to logistics systems. The effectiveness of the implementation of processes largely depends on the competencies of human resources involved in cargo handling processes. New employees usually lack experience, knowledge, and skills. This causes delays in the implementation of current operations and an increase in human errors (including by operators). As a result of these events an increase in delays, additional costs, and the occurrence of dangerous situations is observed. The increase in these phenomena causes an increased demand for quick and effective training for new employees.

However, traditional forms of training are not attractive to modern employees. They do not want to listen to long lectures given by coaches, even if examples support them. Contemporary employees expect active forms of training that will allow them to gain knowledge and skills. Such possibilities are ensured by the use of virtual reality in training systems.

For this reason the paper will present the assumptions of the project implemented by the Wroclaw University of Technology and SimFactor. The project aims to develop and validate real conditions of an immersive system based on virtual reality (VR) for training handling operators working at airports in handling shipments and luggage. The Proposed training system includes:

- developed virtual reality environment;
- raining platform mapping the cockpits of four airport devices used for cargo handling;
- two types of training scenarios were developed;
- the possibility of implementing scenarios of occurrence of specific adverse events.

Extending the scope of training to practical classes based on virtual reality, including training in the use of transport devices, will guarantee an increase in training effectiveness and reduce the time needed to acquire the required skills by operators.

Optimization of the sugar separation process in the aspect of reliability

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Scheduling problems can be found in many industrial production systems. However, there is a negligible amount of papers concerning scheduling in sugar production. More specifically, authors do not take into consideration the final stage of sugar production, where packing processes take place. The study focuses on simplified make-and-pack production in the sugar industry as a case study. The analyzed system is characterized by parallel packing lines, which share one resource with sequence-independent setup time. Different sequences of stream splitting machine were studied to examine the system's efficiency. Two process simulations were investigated with the use of computer simulation. The occurrence of breakdowns in the process can significantly change a preferable machine sequence.

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The use of modern technologies in education at university in the area of risk management in complex production systems

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The expectation of students of the millennial generation is to acquire competences. The three dimensions of education - knowledge, skill and practice - form the foundation of a good curriculum. These dimensions coincide with the three attributes of competence: knowledge, skill and experience. One of the measures of learning outcomes is the result of the achieved efficiency in relation to the incurred input. Learning in the field of logistics and production engineering should be integrated with current technical and technological solutions. It is often difficult (sometimes even impossible) to present complex manufacturing systems holistically. Merely presenting existing solutions or emerging problems will not be as effective as an interactive action based on the principle of ACTION<->REACTION.

High learning effectiveness is achieved in activities that stimulate cognitive processes through practice (experience) and evoked reflections from the experience. The learning model based on experience was used in the development of classes in the area of logistics and production engineering in the Department of Manufacturing Systems, Faculty of Mechanical Engineering and Robotics at the AGH University of Science and Technology in Cracow. Initially, the production line was built from commercially available LEGO solutions. XXX robots were made from LEGO Mindstorms sets. In the next stage, XXX robots were developed using 3D printing technology. The whole line (XXX robots) is controlled by LabVIEW object-oriented programming. The design of the interactive production line is prepared so that each single robot simulates one manufacturing process. The whole flow forms a technological route for a given production plan. In order to visualize the impact of variations in technological times on the overall lead time of the assumed production plan, individual lead times for individual manufacturing tasks are generated from a predetermined probability distribution. Before starting the simulation, a probability distribution is defined for a given element on a specific workstation (e.g.: Normal, Triangle, PERT, beta-PERT, Gamma, etc.). The choice of probability distribution and its parameters is statistically determined on the basis of collected empirical data. A database with collected real production times for exemplary technological processes is made available to students. Once the parameters of the simulation have been defined (transition route, cycle times, order size), an interactive production line is launched. During the simulation students collect data in order to determine the values of efficiency indicators of the system operation, among others: MTTF - Mean Time To Failure; MTTR - Mean Time To Repair; MTBF - Mean Time Between Failures; OEE - Overall Equipment Effectiveness; OOE - Overall Operations Effectiveness; TEEP - Total Equipment Effective Performance (in. AU - Asset Utilization); GE - Global Efficiency; sigma level values according to the Six Sigma method. Moreover, in the statistical part, for the measured times of task realization, they make histograms and then test hypotheses H0 and H1 for a given p-value. Thanks to the use of an interactive production line, it is possible to create various scenarios of undesirable random events, such as failures, production of defective elements, lack of an input component, etc., which allow students to analyze difficult situations and build solutions limiting the probability and consequences of their occurrence in the future. Work is currently underway on the implementation of a MES (Manufacturing Execution System) that allows for verification of individual indicator values set by students against actual values from an interactive production line.

The aim of the course is for students to develop the ability to apply theoretical knowledge to solve complex real-life problems in the area of logistics and production engineering. In order to propose an appropriate lean toolbox to improve the efficiency of a system (or its separate area), it is necessary to collect relevant data, make an analysis, propose an improvement, which will be implemented. Finally students present the changes achieved after the implementation of improvements for different concepts. Such a cause-effect sequence stimulates cognitive processes through iteration in accordance with the Deming cycle. Developing students' skills in formalizing concepts on the basis of independently collected data, followed by the validation of their assumptions, influences the level and scope of their competences. This translates directly into their success in professional work.

List of authors

ESReDA European Safety, Reliability & Data Association

Polskie Naukowo-Techniczne Towarzystwo Eksploatacyjne

Wrocław University of Science and Technology

Appendix 1: Seminar Programme

Scope of the Seminar

The issues of safe and resilient logistics systems constitute the competitive advantage of supply chains. Current enterprises implement their processes in a variable and uncertain environment. These conditions significantly affect the accuracy and effectiveness of decisions. Managers' attention is focused primarily on events related to the occurrence of operational risk. In this case, the source of risks is internal disturbances in companies and processes implemented at organizations' interfaces. Today, however, in the face of the COVID-19 pandemic, disaster risk research is also gaining particular importance. The consequences of the current pandemic indicate the necessity for companies to develop also competencies concerning the assessment and management of "black swan" risks. For this reason, creating secure and resilient supply chains takes on particular importance today. For this reason, the issues to be raised during the 59th ESReDA seminar "Creating Safe and Resilient Logistic Systems" are important not only for scientific but also utilitarian reasons.

The Seminar aimed to discuss theories, concepts, and experiences of enhancing the use of knowledge for better reliability, resilience, and risk management. The presented research results, operational proposals, and case studies responded to enterprises' managerial staff's current problems throughout Europe. Thus, this Seminar brought together researchers, practitioners, specialists, and decision-makers to discuss strategies and practical experiences in the given field of research.

Seminar organization

Chairmen and Chairwoman of the Seminar

Mohamed Eid	ESReDA President
Tomasz Nowakowski	Wroclaw University of Technology, Poland
Agnieszka Tubis	ESReDA Member of Board of Directors

Technical Programme Committee

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Organized by

Wroclaw University of Science Technology, Poland
Polish Maintenance Society - PNTTE
European Safety, Reliability & Data Association (ESReDA)

Wroclaw University of Science and Technology

Wroclaw University of Science and Technology was established in 1945, mainly as a result of the involvement of the academic staff of the now-defunct Technical University of Lviv and the Jan Kazimierz University in Lviv who adapted the destroyed buildings of the German School of Technology – Technische Hochschule. Today Wroclaw University of Science and Technology is one of the largest and best technical universities in the country, one regularly ranked among the best in the national rankings. There are currently 25 thousand students and 927 doctoral students (including 342 people at the Doctoral School) pursuing their degree programs under the supervision of nearly 2200 academic teachers at WUST's 13 faculties and three branches. There are also over 1,100 international students (including 800 on full-cycle programs) from 69 countries around the world about studying at the university.

https://pwr.edu.pl/en/

Polish Maintenance Society – PNTTE

Polish Maintenance Society is an independent association of scientists and practitioners involved in the operation and maintenance of technical systems. The main activity is focused on disseminating knowledge and information about good operational and maintenance practices, their scientific foundations, and the economic and social benefits of the operation and maintenance of machines and devices, buildings, and infrastructures. The society operates within the framework of Regional Commissions (in Warsaw, Krakow, Radom-Deblin, Lublin, Poznan, Wroclaw, Katowice, Zabrze, Kielce, Plock, and Olsztyn) and Thematic Commissions (Automotive, Maintenance Audit, Digital Modelling of Maintenance, and Maintenance of the Oceanotechnical Facilities and Sea Ports). Currently, PNTTE has 270 individual members, 9 honorary members, and 6 company members. The society is an active member of EFNMS since 2005.

https://pntte.org/

European Safety, Reliability & Data Association (ESReDA)

European Safety, Reliability & Data Association (ESReDA) is a European Association established in 1992 to promote research, application and training in Reliability, Availability, Maintainability and Safety (RAMS). The Association provides a forum for the exchange of information, data and current research in Safety and Reliability.
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For more information on ESReDA, contact: ESReDA General Secretary, Dr. Inga Šarūnienė, Senior Researcher at Lithuanian Energy Institute, inga.saruniene@lei.lt
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59th ESReDA (virtual) Seminar Programme

October 26 2021

9.00 – 9.15
M. Eid, T. Nowakowski, A. Tubis: *Greeting guests. Presentation of the Wroclaw University of Science and Technology.*

09:15 – 10:45: Session 1 – Chairwoman: Agnieszka Tubis
Key speaker 1:
L. Bukowski: *Resilience of complex supply chains: how to ensure continuity of logistic processes in critical situations*
Key speaker 2:
G. Paunescu: *Critical supply chains for energy technologies*

11:00 – 12:15: Session 2 – Chairwoman: Anna Jodejko - Pietruczuk
K. Winiarska: *Optimization of the sugar separation process in the aspect of reliability*
N. Gnacy: *Problems of inventory management in wood supply chains - case study*
J. Feliks, M. Karkula: *Analysis of for assessment methods of supply chains resilience*
J. Ryczyński, A. Tubis: *The resilience of military fuel supply chains in conditions of limited information*

12:30 – 13:45: Session 3 – Chairman: Jacek Ryczyński
H. Pačaiovál1, A. Nagyová, Z. Kotianová, J. Glatz: *Machinery safety requirements in digital management*
A. Żurek: *Change in the level and type of risk of using drones in the warehouse in the next phases of the service development.*
M. Rydlewski: *Review of standardized rules for designing safe stops on the example of Polish cities*
H. Poturaj: *Human and autonomous guided vehicle participation in intralogistic processes – risk identification*

14:00 – 15:15: Session 4 – Chairman: Artur Kierzkowski
A. Tubis: *The use of virtual reality in improving the competences of cargo handling operators at the airport*
T. Kisiel: *System of training security control operators using eyetracking and virtual reality*
F. Restel: *Modern support systems for railway operation*
B. Zwolińska, J. Wiercioch: *The use of modern technologies in education at university in the area of risk management in complex production systems*

15.15 – 15:30: Seminar Closure - M. Eid, S. Werbińska-Wojciechowska

Plenary Lectures

1. **Prof. Lech A. Bukowski, WSB University**
   Resilience of complex supply chains: how to ensure continuity of logistic processes in critical situations
   The given plenary lectures focused on the main research problems connected with "resilience" definition and understanding. There was also discussed the issue of global supply chains. Later, the global supply chain risk problems were investigated. The imperfect knowledge-based concept of risk was presented. At the end, the recommendations for ensuring continuity of logistic processes in critical situations were introduced. The author focused on the three issues: a) configuring a resilient topology, b) creating a functionally resilient supply chain, c) becoming a resilient organization through Resilience-Based Maintenance.

2. **George Paunescu, Policy Officer, European Commission, Directorate-General for Energy, Energy Security and Safety Unit**
   Critical supply chains for energy technologies
   The presented plenary lecture was focused on the three main tasks. There were identified the critical supply chains for the energy sector. Later, there were identified and assessed the current and potential problems for the most critical supply chains. Based on the presented results, there were identified possible measures/policy proposals to mitigate the identified risks and reinforce the resilience of the critical supply chains for energy security and clean energy transition.

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