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Risk Of Maintenance Resource Sharing In Transport Systems

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HR EXCELLENCE IN RESEARCH

Agenda

- Introduction

- Classification of main maintenance strategies – dichotomous division

- Uncertainty in operation and maintenance

- Maintenance resource sharing in transport systems

- Case study

- Conclusions
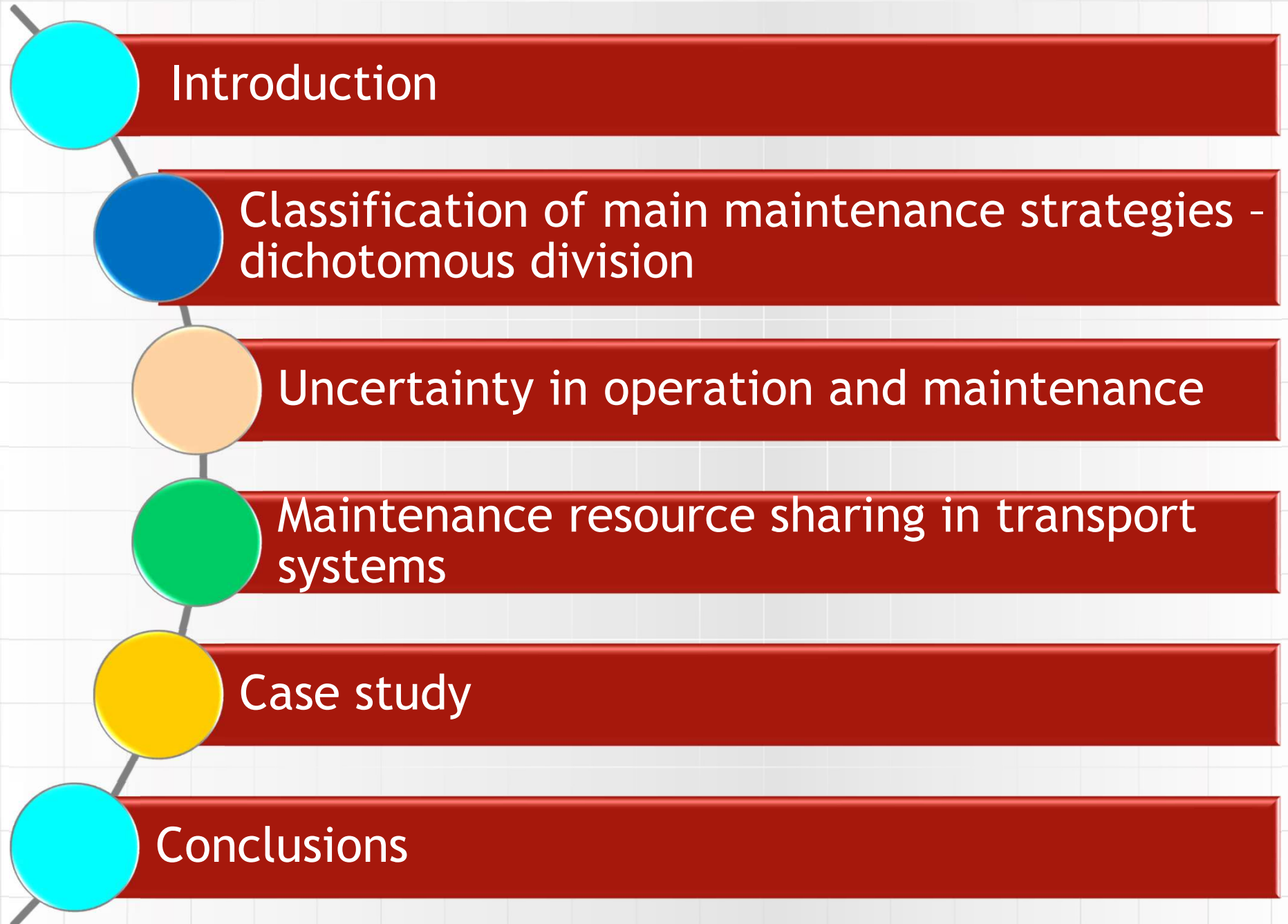
Introduction

Following the European Standard PN-EN 13306:2010, maintenance management may be defined as *all activities of the management that determine the maintenance objectives, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control, and supervision, improvement of methods in the organization including economic aspects.*

Maintenance process according to the European Standard EN 17007:2017
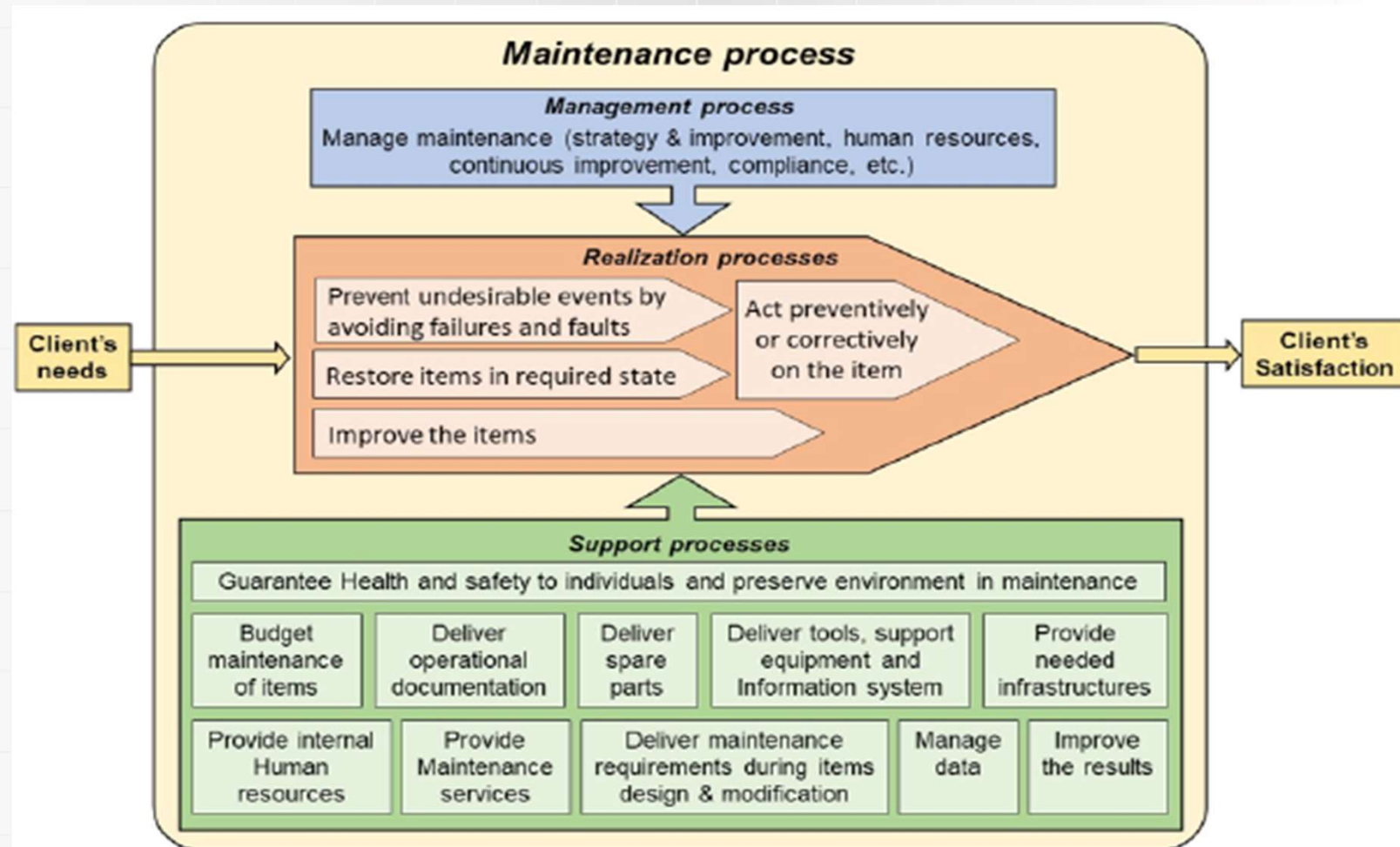
Classification of main maintenance strategies

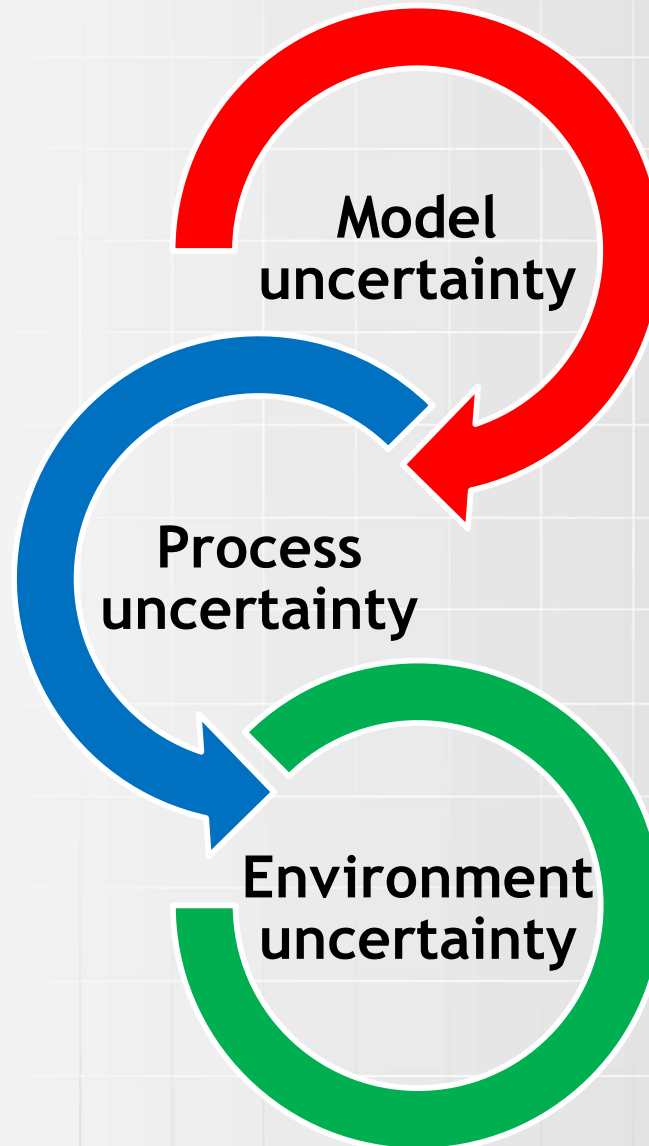| Criterion	Dichotomous division	
Diagnosing	During operation (e.g. Condition-based M. - CBM)	During machine downtime (e.g. First Time M. – FTM)
Forecasting	Probabilistic (e.g. Predictive M.)	Deterministic (e.g. Shutdown M.)
Planning	Scheduled (e.g. Time-based M.)	Unscheduled (e.g. Breakdown M.)
Complexity	Low or medium (e.g. production systems)	High or very high (e.g. infrastructure networks)
Uncertainty	Limited (low or medium)	Deep (high or very high)
Impact	Non-critical	Critical

Risk-oriented policy for systems operating under conditions of limited uncertainty

Uncertainty in operation and maintenance

Uncertainty and variability are one of the fundamental characteristics of systems and processes.

Model uncertainty

Uncertainty due to modeling process, physical properties, assumed safety factors, data availability, etc.

Uncertainty of the ongoing operational/ management process and its associated phases

Process uncertainty

Environment uncertainty

Uncertainty related to external conditions (e.g., pricing, regulations, customer safety/ reliability requirements), environmental impact on process/system

Uncertainty in operation and maintenance

The consequence of knowledge imperfections is the **uncertainty in the maintenance process**.

The concept of uncertainty is understood here as a situation of having limited knowledge, such as:

- the order, nature, or state of things is unknown, and
- the consequence, extent, or magnitude of circumstances, conditions, or events is unpredictable.

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

Risk-oriented policy

System types with maintenance policy recommendations

System Type	System behavior	The purpose of the system	Response to disruption	Maintenance policy	System example
Passive	static or quasi-static	preservation of the state	resistance	Corrective Maintenance	non-repairable modules
Reactive	dynamic; predictably variable	maintaining system availability	robustness	Reliability- or Risk-Based Maintenance	technical systems
Active	dynamic; unpredictably variable	ensuring system continuity	resilience	Resilience Based Maintenance	cyber-physical systems

Problem of maintenance resource availability in the context of risk assessment performance

Maintenance resource sharing concept
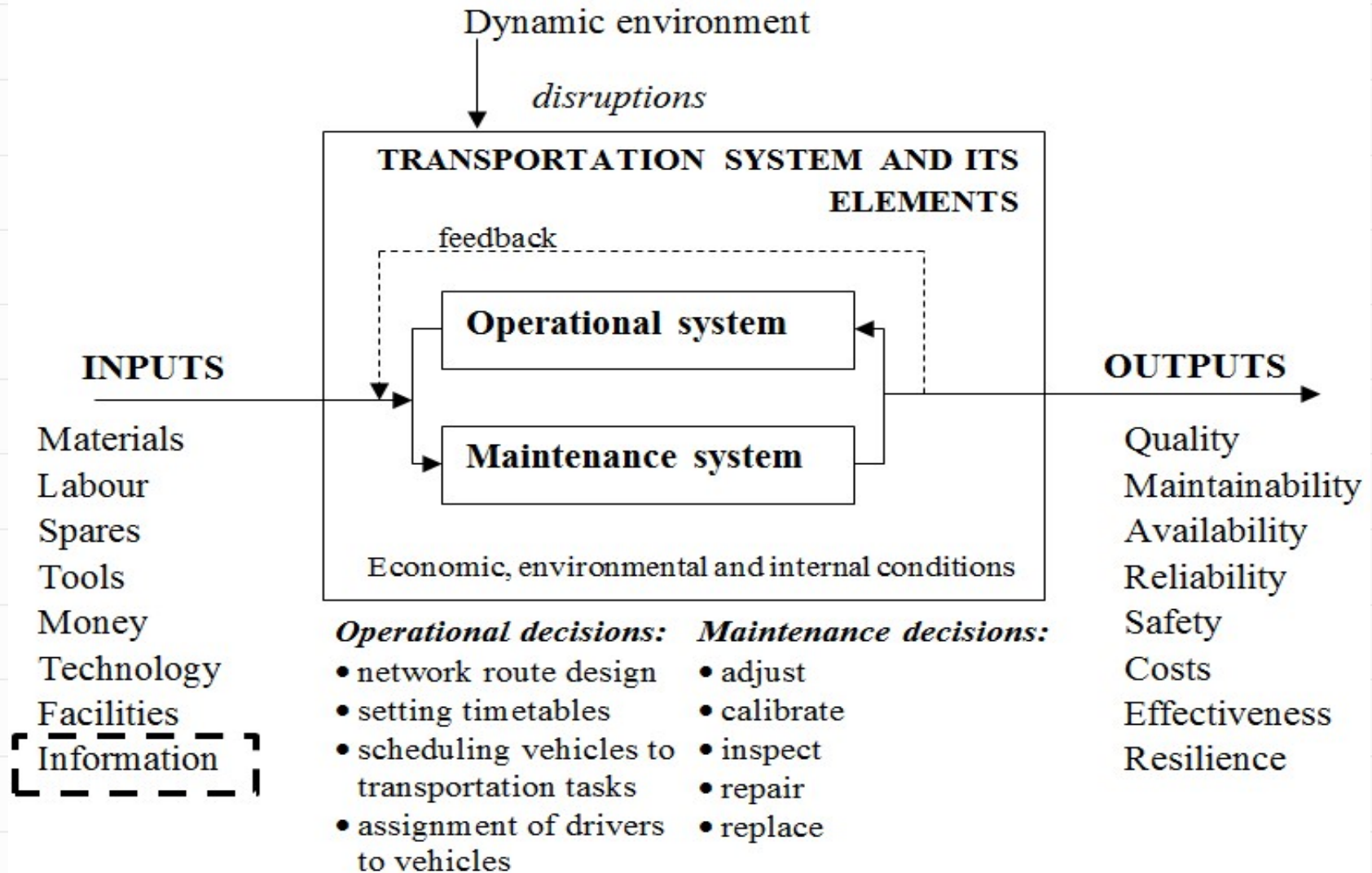
Transportation system and its operation and maintenance system elements

Maintenance resource sharing concept

Dynamic environment

disruptions

TRANSPORTATION SYSTEM AND ITS

Primary maintenance resources that can be shared include:

o Maintenance teams/service stations – availability of maintenance service stations and accessibility of specialists who have extensive knowledge of vehicle maintenance performance. However, periodic shortages may occur during times of holidays or increased sickness periods.

o Spare parts – each company maintains a specific safety stock of strategic spare parts to ensure continuity of transportation service performance in the event of failure.

o Available fleet – in case of failure, there is a possibility to use other vehicles available in a transportation company or based on outsourcing processes.

o Maintenance documentation – internal procedures and manufacturer's guidelines for vehicle fleet maintenance performance.

elements

Maintenance resource sharing concept

The estimated risk may be expressed as the product of three measures:

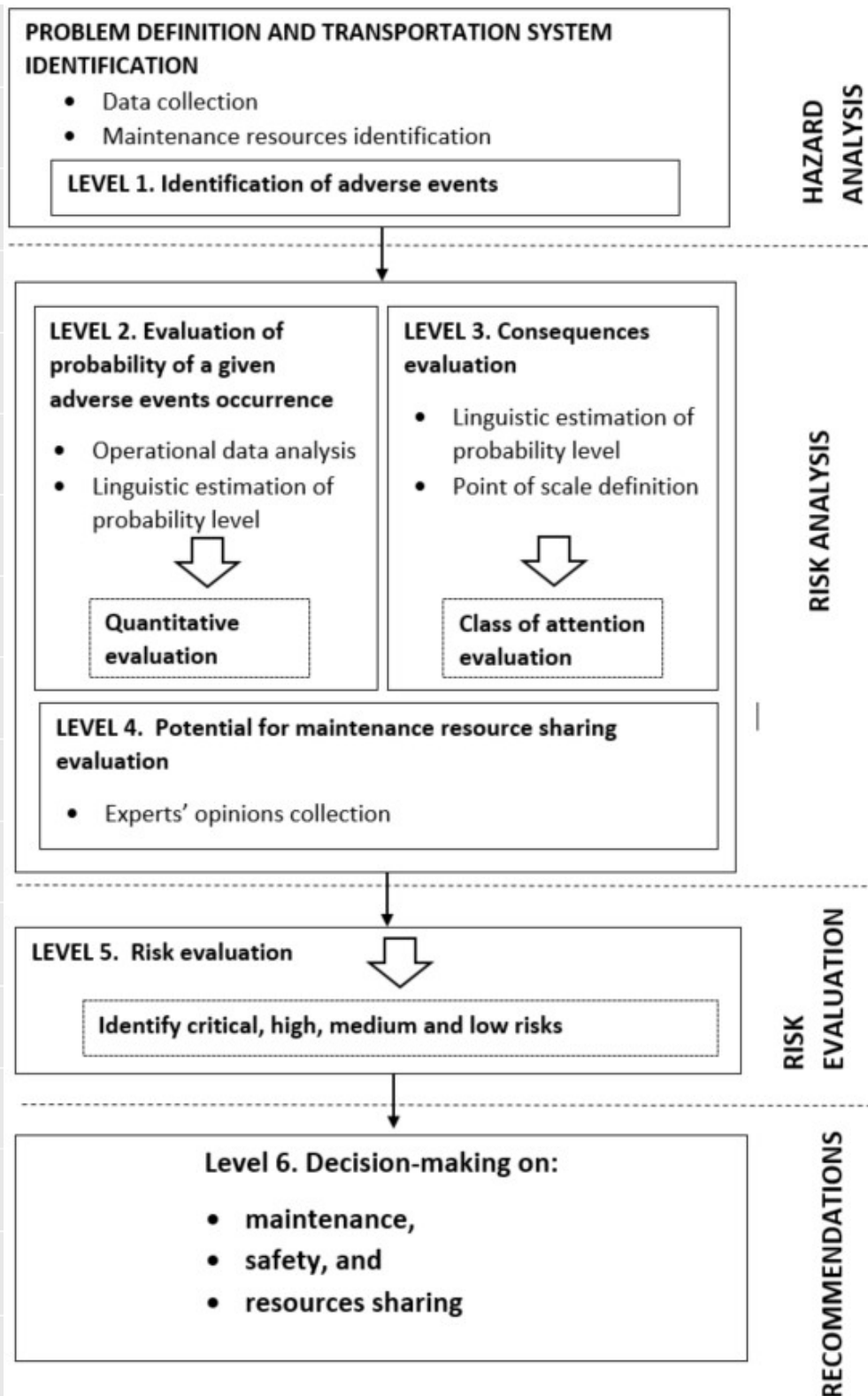$$R = P \cdot S \cdot A \qquad (1)$$

where:

R – risk ratio

P – a measure of the probability of occurrence of an adverse event

S – a measure of the consequences of the occurrence of an adverse event failure

A – a measure characterizing available alternative resources

PROBLEM DEFINITION AND TRANSPORTATION SYSTEM IDENTIFICATION
- Data collection
- Maintenance resources identification

LEVEL 1. Identification of adverse events

LEVEL 2. Evaluation of probability of a given adverse events occurrence
- Operational data analysis
- Linguistic estimation of probability level

Quantitative evaluation

LEVEL 3. Consequences evaluation
- Linguistic estimation of probability level
- Point of scale definition

Class of attention evaluation

LEVEL 4. Potential for maintenance resource sharing evaluation
- Experts' opinions collection

LEVEL 5. Risk evaluation

Identify critical, high, medium and low risks

Level 6. Decision-making on:
- maintenance,
- safety, and
- resources sharing

HAZARD ANALYSIS

RISK ANALYSIS

RISK EVALUATION

RECOMMENDATIONS

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Maintenance resource sharing concept

The obtained results give the possibility to propose a single aggregated measure for assessing the availability of maintenance resources. Thus, an assessment of the availability of maintenance resources may be estimated according to:

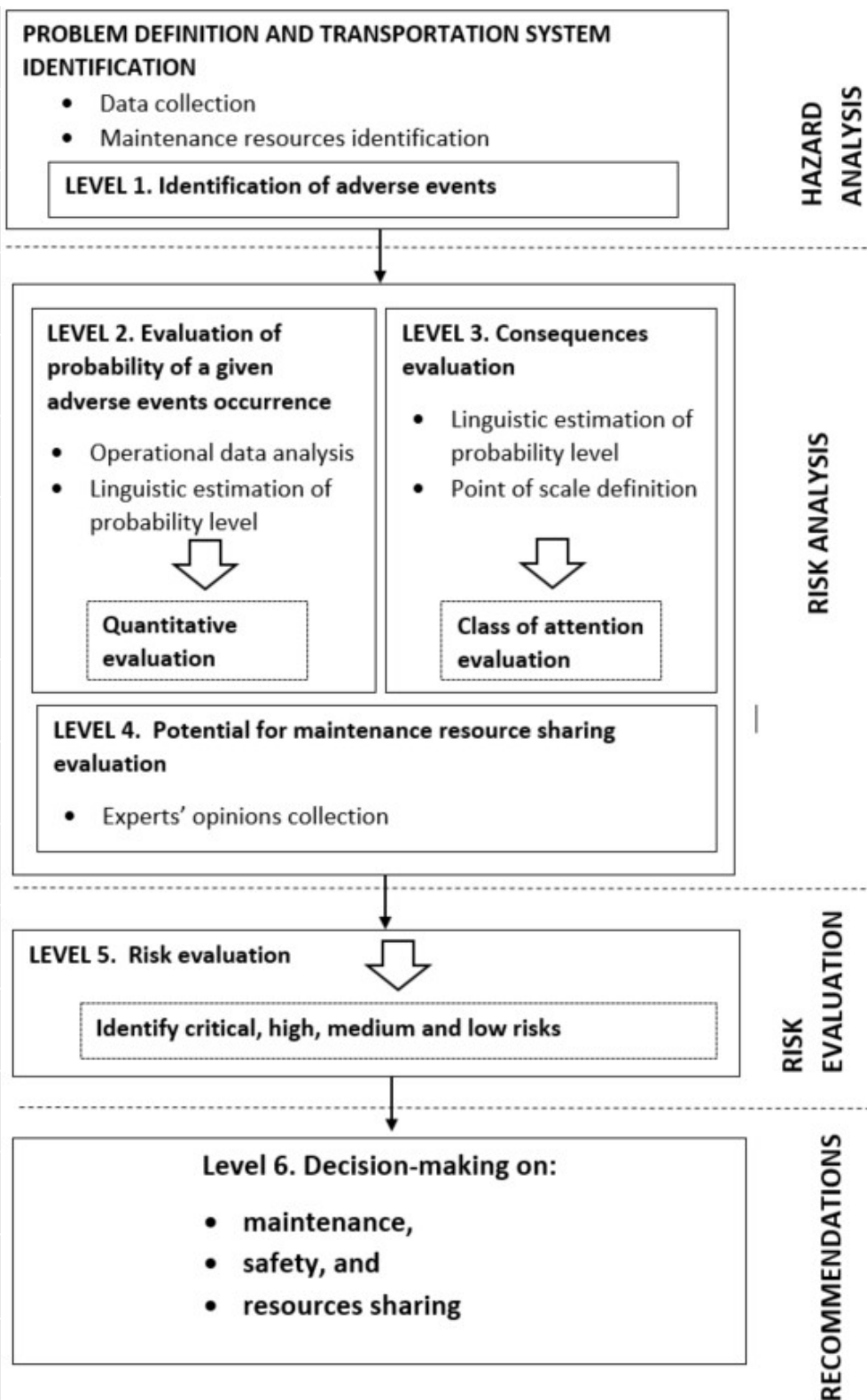$$A = \frac{\sum_{i=1}^{n} A_i \cdot \omega_i}{\sum \omega_i} \qquad (2)$$

where:

A – a measure characterizing available alternative resources,

A_i – a measure characterizing available ith resource,

ω_i – the weight assigned to the ith resource, where

$\sum \omega_i = 1$; n – number of maintenance resources analyzed

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HAZARD ANALYSIS

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RISK EVALUATION

RECOMMENDATIONS

Case study

- A case study for resource sharing potential assessment is presented for a group of companies providing passenger transport services in Poland.
- The presented example presents a risk assessment for transport processes performed at a selected route between two cities located in the Lower Silesia region.

Classification of hazard events in the analyzed company

GENERAL HAZARD EVENTS	
For vehicle	
OP1	Vehicle failure that makes unable to continue transport process performance
OP2	Vehicle failure that results in travel delays
OP3	Insufficient number of seats in the vehicle
OP4	Lack of proper order in the vehicle
OP5	Traffic incident that makes unable to continue transport process performance
OP6	The vehicle unsuited to the required travel conditions
For driver	
OK1	Poor health of the driver
OK2	Lack of route knowledge
OK3	Failure to follow with traffic rules
OK4	Improper behaviour towards passengers
OK5	Stop the vehicle in a place not designated as a stop
OK6	Exceeded driver's working time
OK7	No drivers that have permission to use the vehicle
For process	
OPP1	Travel delay
OPP2	Course cancellation
OPP3	A necessity for route change
HAZARD EVENTS BEING SPECIFIC TO THE ROUTE	
S1	Taking potential passengers by accelerated/delayed vehicle of the Competitor
S2	A too-small number of passengers resulting in a lack of profitability of transport

Case study

The probability of hazard event occurrence definition

P_n level	Estimated likelihood	Short description
1	Very high	The threat occurred in the last month
2	High	The threat occurred in the last 3 months
3	Medium	The threat occurred in the last 6 months
4	Low	The threat occurred in the last year
5	Very low	The threat occurred once in the last two years or more

Consequence level definition

S_n level	Estimated consequence	Short description
1	High	High financial losses
2	Medium	Medium financial losses
3	Low	Low financial losses, loss of image
4	Almost negligible	No financial losses, loss of image

Case study

The probability of hazard event occurrence definition

P_n level	Estimated likelihood	Short description
1	Very high	The threat occurred in the last month
2	High	The threat occurred in the last 3 months
3		
4		
5		

Potential for maintenance resource sharing for the case group of companies

Maintenance resources sharing availability		
Maintenance resource type	Points	Short discussion
Maintenance teams/service stations	2-3	The companies are located in different parts of the region, but the maximum travel time is 2.5 hours. This means that it is possible to move team members between the service stations of individual companies in an emergency. At the same time, if a vehicle fails during the service, repairs can be carried out at the nearest station based on partnership agreements.
Spare parts	2	The distance between the companies is such that transporting spare parts for regular repairs would be a high cost in the service process and, therefore, not a competitive offer to current purchasing procedures. However, when the availability of specific components is limited (which translates into an inflated price of parts) or the time to obtain them is too long, the alternative of sharing these resources may be a beneficial solution.
Available fleet	2-3	The companies do not have an extensive fleet of vehicles, and any spare capacity is usually directed to serve additional orders. Therefore, sharing this resource is only possible in crises, possibly in emergencies, but only concerning the available free capacity.
Maintenance documentation	4-5	Maintenance documentation has a high potential for sharing. Today, much of the documentation is available electronically, allowing it to be delivered quickly and cost less to the required location.

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Case study

- Special attention should be focused on these events, which have the lowest risk ratio value. They are, in fact, events in which incidence is high, the consequences are significant, and, at the same time, they have the lowest potential for providing maintenance resource sharing.
- The acceptable level of risk determined based on an interview with the management and leadership of the company was set at $R = 12.5$.
- 10 identified hazard events obtained the acceptable level of the risk ratio. The remaining 8, with an R level below 12.5 points, require the company's intervention.

The summary of obtained results

Event	P_n	S_n	A_n	R_n
OP1	4	1	2.5	10.0
OP2	2	3	2.5	**15.0**
OP3	2	3	2.5	**15.0**
OP4	1	4	2.5	10.0
OP5	3	1	2.5	7.5
OP6	2	3	2.5	**15.0**
OK1	2	3	3.25	**19.5**
OK2	4	4	3.25	**52.0**
OK3	3	2	3.25	**19.5**
OK4	1	3	3.25	9.75
OK5	2	2	3.25	**13.0**
OK6	4	2	3.25	**26.0**
OK7	4	3	2.5	**30.0**
OPP1	1	3	2.5	7.5
OPP2	1	2	3.0	6.0
OPP3	4	4	3.0	**48.0**
S1	2	2	2.5	10.0
S2	1	2	2.5	5.0

Conclusions

- The article presents a concept of risk assessment in the transport system based on three parameters. A novelty in the assessment is introducing a third parameter - describing the potential for sharing maintenance resources.

- The greater the potential of a maintenance resource to be shared, the greater its availability in the crucial period, and thus the lower the risk of taking the vehicle out of service.

- The analysis of the sharing potential of selected maintenance resources in the analyzed group of transport companies is presented to confirm the adopted thesis.

- The presented results of the assessment procedure are the starting point for further research work aimed at assessing the risk in transport companies considering maintenance potential. The possible future research activities will be connected with fuzzy logic implementation with multi-criteria decision methods use.

Thank you for attention

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