Features of assessing the efficiency of vehicle operation in port conditions using monitoring systems of various configurations

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Introduction

- Complexity of vehicle operation in port environments
- Challenges: downtime, safety, and fuel efficiency
- Growing need for advanced monitoring systems
- Goal: Present systematized methods for assessing and improving operational efficiency

Operational Challenges in Port Conditions

- High vehicle turnover and congestion
- Unpredictable delays and idle time
- Harsh infrastructure and weather conditions
- Spare parts and maintenance inefficiencies

Role of Monitoring Systems

- Real-time data acquisition from vehicles, operators, cargo, and environment
- Benefits:

- Proactive maintenance

- Improved safety

- Performance optimization

Five Hardware Groups of Functional Components of Monitoring

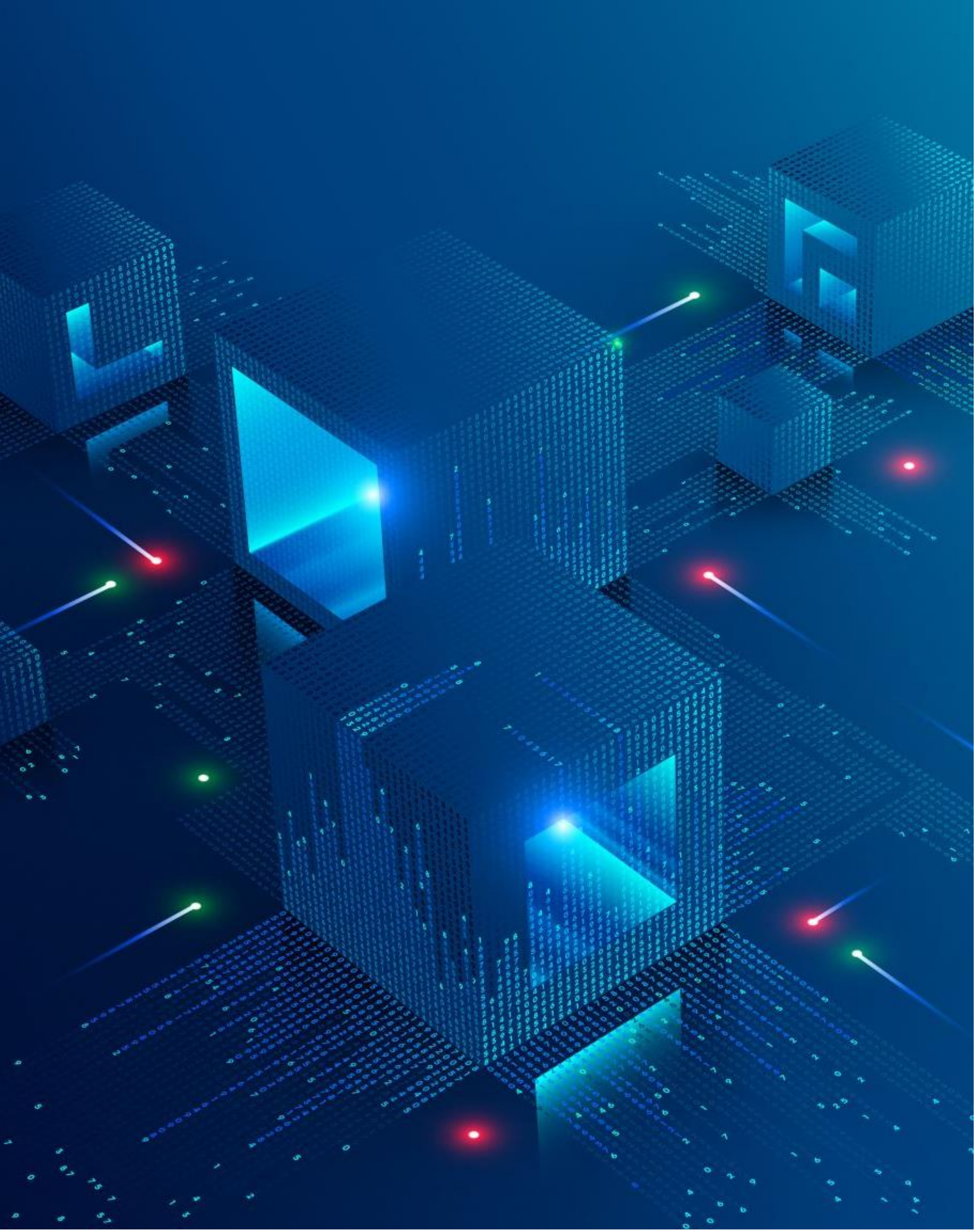
1. Operator condition monitoring
2. Vehicle technical state monitoring
3. Cargo status tracking
4. Infrastructure condition sensing
5. Data processing and consumption tools

Morphological Matrix Approach

- Introduced by Prof. Vasyl Mateichyk
- 20 morphological traits across hardware groups
- Over 450 billion possible configurations
- Allows tailored system design

$$\begin{bmatrix} (x_{14};x_{23};x_{32})+(x_{41};x_{51};x_{61};x_{72};x_{82})+ \\ +(x_{91};x_{10\,1};x_{11\,1};x_{12\,1})+(x_{13\,2};x_{14\,3};x_{15\,4};x_{16\,3}) \\ +(x_{17\,2};x_{18\,2};x_{19\,3};x_{20\,2}) \end{bmatrix}$$

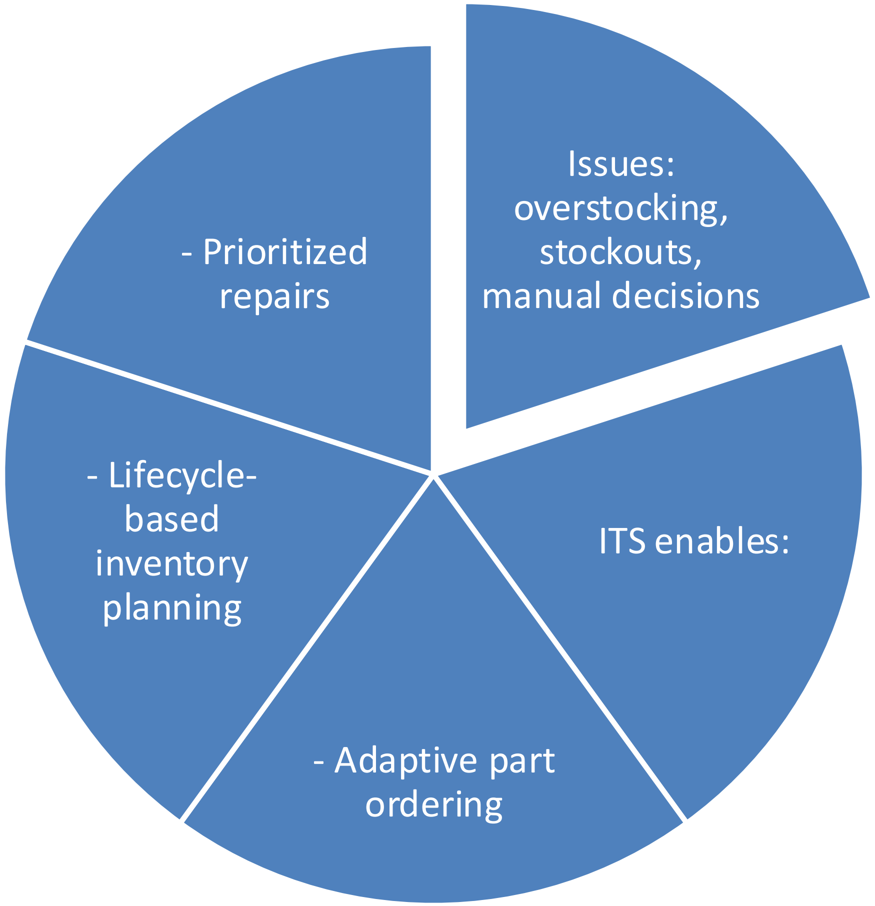
Functional Element	Morphological Trait	Options (Examples)
Operator Monitoring	Type of Information	Personal data, biometric data, status codes
	Method of Collection	Wearable sensors, cab-mounted cameras, workplace sensors
	Data Transmission	Local storage, mobile networks, hybrid
Vehicle Monitoring	Information Type	Diagnostic codes, fuel consumption, operational logs
	Sensor Type	Standard onboard sensors, added sensors, infrastructure-based detection
	Processing Location	Onboard unit, cloud server, combined
	Transmission Method	Local memory, mobile/internet, combined
Cargo Monitoring	Data Collected	Temperature, movement, shock, absence of data
	Tracking Method	RFID, IoT sensors, manual logs
	Transmission Method	Stored onboard, wireless sync, satellite
Infrastructure Data	Parameters Monitored	Road condition, traffic, weather
	Sensor Location	Vehicle-mounted, roadside, hybrid
	Data Sharing	Cable, wireless, gadgets
Data Analysis & Use	Storage Strategy	Onboard, cloud, hybrid
	Retention Period	Short-term, long-term, permanent
	Usage Level	Informational, control & diagnostics, predictive maintenance, performance evaluation



Example Configuration (Simplified)

- Operator: biometric sensors → cellular data transmission
- Vehicle: onboard diagnostics → cloud processing
- Cargo: RFID tracking → local storage
- Infrastructure: weather sensors → satellite uplink
- Output: dashboards for diagnostics and planning

Downtime & Spare Parts Optimization



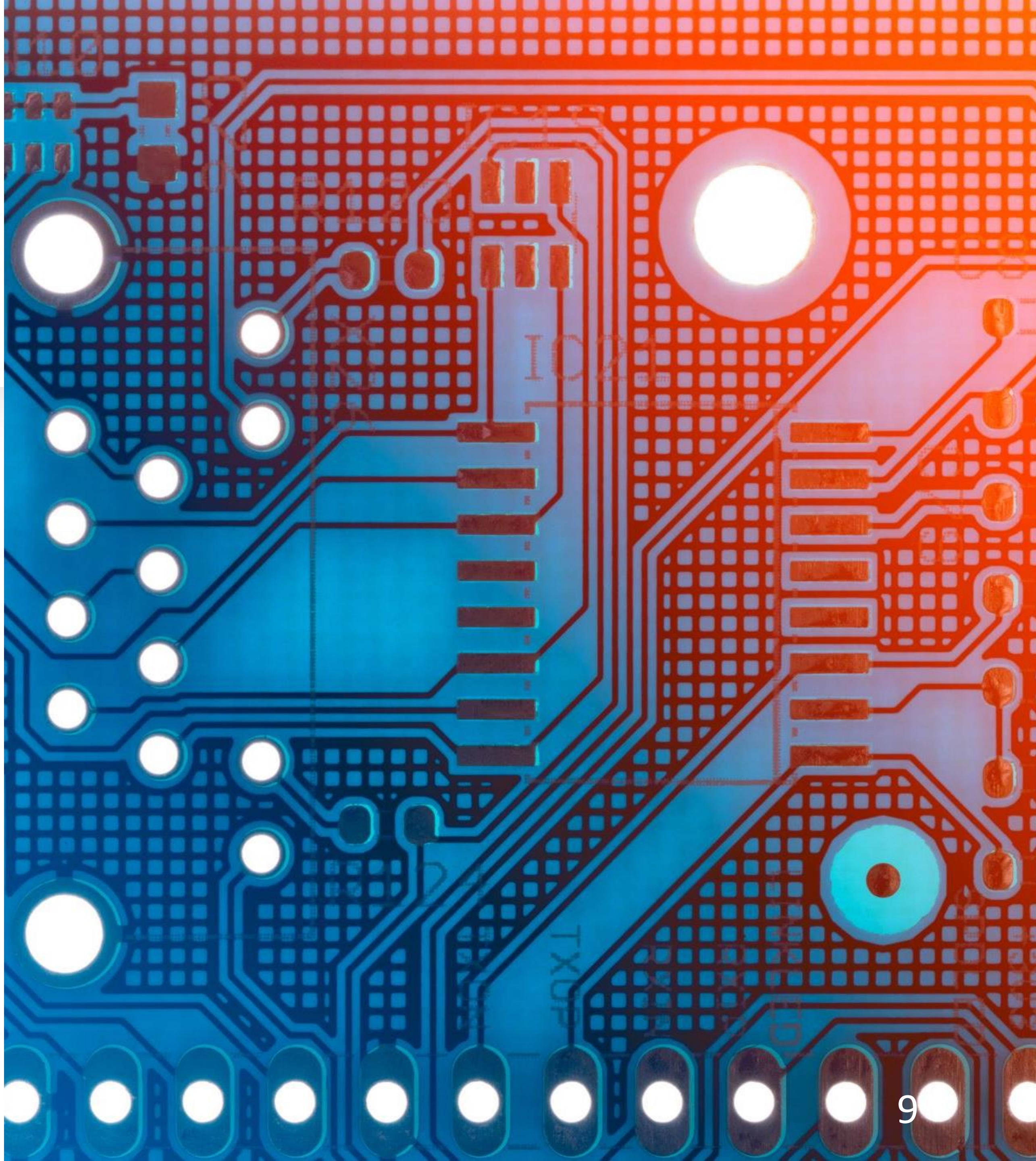
Integrated System: Vehicle + Infrastructure

Components:

- Intelligent sensors
- Remote diagnostics
- Spare parts coordination

Effects:

- Reduced fuel use and emissions
- Minimized idle time



Analytical Model

- Objective: Maximize operability *Q(GPt)*, minimize consumption *GPt*
- Factors:
- - Fuel use
- - Load
- - Infrastructure quality
- - Driver behavior
- Combines logistics and predictive analytics

$$
\begin{cases}
F_{Gtp}\left(\bar{H}_t, t, \triangle t, \bar{X}_i(t), \bar{X}_i(t-\triangle t), \ldots, \bar{X}_i(t-n\triangle t), DK_{ti}\right) = S_{GP}; \\
S_{GP} = \Omega_l^{m_i}\left(e_Q, r\right)^j; \\
S_{GP} = F_{Gtp}\left(S_{\mathrm{T}3S}; S_{\mathrm{T}3L}; S_{\mathrm{T}3M}\right); \\
S_{GP} = F_{Gtp}\left(\left(M_{i1}, M_{i2}, M_{i3}\right); \left(T_{ST3}, P_{DU}\right)\right); \\
M_{i1} = F_{i1i}\left(\bar{X}_{GMti}(t)\right); \\
M_{i2} = F_{i2i}\left(\bar{X}_{G2ti}(t)\right); \\
M_{i3} = F_{i3i}\left(\left(\bar{X}_{Mt13i}(t)\right); \left(\bar{X}_{Mt23i}(t)\right); \left(\bar{X}_{Mt33i}(t)\right); \left(\bar{X}_{Mt43i}(t)\right)\right); \\
T_{ST3} = F_{ST3i}\left(\left(\bar{X}_{GMti}(t)\right); DK_{ti}\right) \\
P_{DU} = F_{DUi}\left(\bar{X}_{DUti}t(t)\right); \\
Pr(t) = F\left(t, M_{43}\right) \rightarrow min; \\
S_{ZA}(t) = F\left(t, N_z, M_{43}\right) \rightarrow min.
\end{cases}
$$

$$
\begin{cases}
Q\left(G_{Pt}\right) = F\left(\left(M_{i1}, M_{i2}, M_{i3}\left(M_{12}, M_{23}, M_{33}, M_{i43}\right)\right); \left(T_{ST3}, P_{DU}\right)\right) \rightarrow max; \\
G_{Pt} \rightarrow min; \\
Pr(t) = F\left(t, M_{43}\right) \rightarrow min; \\
S_{ZA}(t) = F\left(t, N_z, M_{43}\right) \rightarrow min.
\end{cases}
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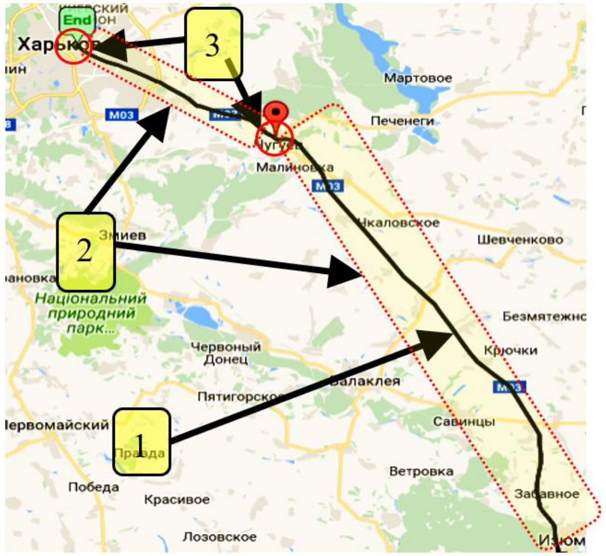
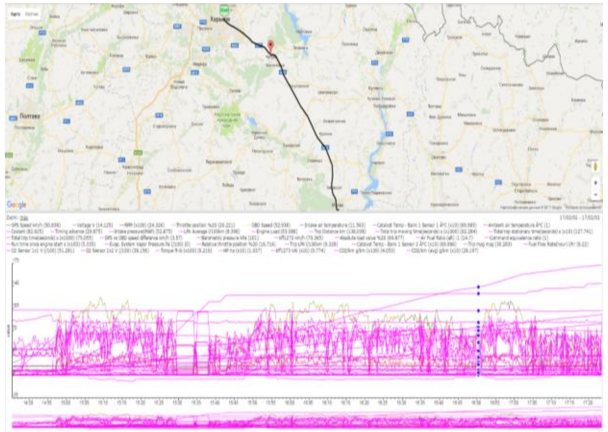
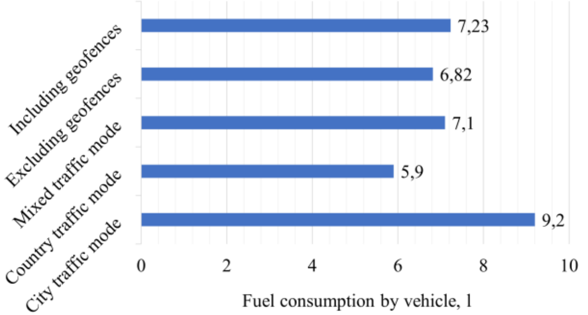
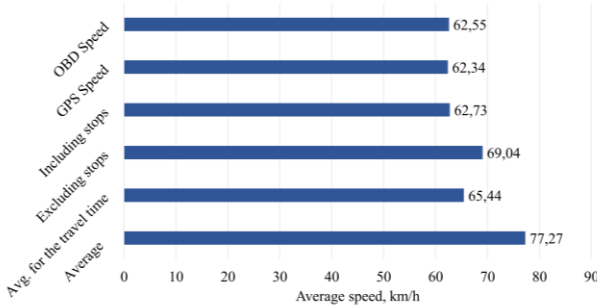
Real-world Application

- Geofencing for urban/rural differentiation
- Tracking speed and fuel consumption
- Reports enable: fault alerts, diagnostics, maintenance triggers









Practical Recommendations

- Apply hybrid ITS in port logistics
- Use morphological matrix for system design
- Focus on:

  - Reducing idle time
  - Enhancing decision support
  - Predictive diagnostics

Conclusions

Monitoring systems offer scalable solutions

Morphological method = tailored efficiency

ITS + logistics models = robust port operations

Thank you for your attention