

Supplementary materials

Table S1. Database-specific search strategies and search yields. The four used database yields sum 918 records reported in the PRISMA flow diagram. The platform-specific syntax was entered using the fields shown above while preserving the same four conceptual blocks.

Source	Search field(s)	Boolean search string	Limits	Records
Scopus	TITLE-ABS-KEY	The references query in the methodology section.	English; 2010–2025;	649
IEEE Xplore	All Metadata	The references query in the methodology section.	English; 2010–2025;	54
MDPI platform	All fields	MDPI was searched using simplified combinations of a general conveyor-system anomaly and fault detection. Also additional searches using “idler” and “steel cord” were conducted to identify component-specific studies. Sensing and computational technologies were assessed during screening rather than imposed as mandatory search terms.	English; 2010–2025;	212
ACM digital Library	TITLE-ABS-KEY	The references query in the methodology section.	English; 2010–2025	3

Table S2. PRISMA 2020 Checklist

Section and Topic	Item	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title.
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract.
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Section 1.
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Section 2.1.
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Section 2.1.
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted. Specify the date when each source was last searched or consulted.	Section 2.1; Table S1. Search completed May 2026.
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Section 2.1; Table S1.
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria, including how many reviewers screened each record/report, whether independently, and any automation tools used.	Section 2.1.

Section and Topic	Item	Checklist item	Location where item is reported
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers, whether independently, and any automation tools used.	Section 2.1; Section 2.2.
Data items	10a	List and define all outcomes for which data were sought, and how results compatible with each outcome domain were selected.	Table 1.
	10b	List and define all other variables for which data were sought, and describe assumptions about missing/unclear information.	Table 1.
Study risk of bias assessment	11	Specify the methods used to assess risk of bias, including the tool(s), how many reviewers, whether independently, and automation tools used.	Section 2.2; Table S3.
Effect measures	12	Specify for each outcome the effect measure(s) used in the synthesis or presentation of results.	Not applicable. No meta-analysis was conducted.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis.	Table 1; Section 4.
	13b	Describe methods to prepare data for presentation/synthesis (handling missing summary statistics, data conversions).	Section 2.1.
	13c	Describe methods used to tabulate or visually display results of individual studies and syntheses.	Figures 2–8; Tables 1–3.
	13d	Describe methods used to synthesize results and the rationale. If meta-analysis, describe model(s) and software.	Sections 3–4. No meta-analysis. Python used for the descriptive statistics and figures.
	13e	Describe methods used to explore possible causes of heterogeneity among study results.	Not applicable. No meta-analysis was conducted.
	13f	Describe any sensitivity analyses conducted.	Not applicable. No meta-analysis was conducted.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis.	Not applicable. Not conducted.
Certainty assessment	15	Describe any methods used to assess certainty (confidence) in the body of evidence.	Not applicable. Not conducted.
RESULTS			
Study selection	16a	Describe the results of the search and selection process, ideally using a flow diagram.	Figure 1; Section 3.1.
	16b	Cite studies that might appear to meet the inclusion criteria but were excluded, and explain why.	Section 2.1.
Study characteristics	17	Cite each included study and present its characteristics.	Section 3.1; Table 2.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Figure 3; Table S3.
Results of individual studies	19	For all outcomes, present summary statistics and/or effect estimates for each study, ideally using structured tables or plots.	Section 4; Figure 5D.
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Sections 3–4.

Section and Topic	Item	Checklist item	Location where item is reported
	20b	Present results of all statistical syntheses (meta-analysis), including summary estimates and heterogeneity.	Not applicable. No meta-analysis was conducted.
	20c	Present results of all investigations of possible causes of heterogeneity.	Not applicable. No meta-analysis was conducted.
	20d	Present results of all sensitivity analyses.	Not applicable. No meta-analysis was conducted.
Reporting biases	21	Present assessments of risk of bias due to missing results for each synthesis assessed.	Not applicable. Not conducted.
Certainty of evidence	22	Present assessments of certainty (confidence) in the body of evidence for each outcome assessed.	Not applicable. Not conducted.
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Section 5; Section 6.
	23b	Discuss any limitations of the evidence included in the review.	Section 5.1.
	23c	Discuss any limitations of the review processes used.	Section 5.2.
	23d	Discuss implications of the results for practice, policy, and future research.	Section 5.2; Section 6.
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information, including register name and number, or state that the review was not registered.	Section 2. Not registered.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Section 2. No protocol prepared.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable.
Support	25	Describe sources of financial or non-financial support for the review, and the role of funders/sponsors.	Funding statement.
Competing interests	26	Declare any competing interests of review authors.	Conflicts of Interest statement.
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; extracted data; data used for all analyses; analytic code; other materials used in the review.	Data Availability Statement.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.

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Table S3. Study-level customized JBI-inspired methodological appraisal ratings. Ratings: Y = Yes; P = Partly; N = No; U = Unclear; NA = Not applicable. Domains: CO = Clear objective; SD = Study design; DD = Dataset description; GT = Ground-truth reliability; MD = Methodology detail; EP = Evaluation protocol; BC = Baseline comparison; SA = Statistical analysis; EV = External validation; RP = Reproducibility. GT and EP were treated as critical domains. The normalized score was calculated as $(2 \times Y + P)/(2 \times \text{applicable domains}) \times 100$. Overall appraisal concerns were classified as LOW when at least seven domains were rated Y and neither GT nor EP was rated N; HIGH when the normalized score was below 60% or GT/EP was rated N; and MODERATE in all remaining cases.

Study ID	CO	SD	DD	GT	MD	EP	BC	SA	EV	RP	Y	P	N/U	Score	Overall
1	Y	Y	Y	P	Y	Y	Y	P	N	U	6	2	2	70.0%	MODERATE
2	Y	Y	U	P	P	U	P	N	N	N	2	3	5	35.0%	HIGH
3	Y	Y	P	P	Y	P	P	N	N	N	3	4	3	50.0%	HIGH
4	Y	Y	U	P	Y	P	P	N	N	N	3	3	4	45.0%	HIGH
5	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
6	Y	Y	Y	P	Y	P	Y	N	N	N	5	2	3	60.0%	MODERATE
7	Y	Y	P	P	Y	P	Y	P	N	N	4	4	2	60.0%	MODERATE
8	Y	Y	Y	Y	Y	Y	Y	P	U	P	7	2	1	80.0%	LOW
9	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	9	1	0	95.0%	LOW
10	Y	Y	P	Y	Y	N	N	N	N	N	4	1	5	45.0%	HIGH
11	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
12	Y	Y	Y	Y	Y	P	Y	N	P	P	6	3	1	75.0%	MODERATE
13	Y	Y	P	Y	Y	P	Y	N	U	N	5	2	3	60.0%	MODERATE
14	Y	Y	Y	P	P	N	N	N	N	N	3	2	5	40.0%	HIGH
15	Y	Y	Y	Y	P	Y	Y	P	N	P	6	3	1	75.0%	MODERATE
16	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
17	Y	Y	Y	P	Y	N	N	N	N	N	4	1	5	45.0%	HIGH
18	Y	Y	Y	Y	Y	Y	Y	P	N	N	7	1	2	75.0%	LOW
19	Y	Y	P	Y	Y	P	Y	N	N	P	5	3	2	65.0%	MODERATE
20	Y	Y	Y	P	Y	P	Y	N	U	N	5	2	3	60.0%	MODERATE
21	Y	Y	Y	P	Y	Y	Y	N	Y	N	7	1	2	75.0%	LOW
22	Y	Y	P	P	Y	Y	Y	N	U	N	5	2	3	60.0%	MODERATE
23	Y	Y	Y	P	Y	Y	Y	N	P	P	6	3	1	75.0%	MODERATE
24	Y	Y	Y	P	P	P	Y	N	P	N	4	4	2	60.0%	MODERATE
25	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
26	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
27	Y	Y	P	Y	Y	Y	N	P	N	P	5	3	2	65.0%	MODERATE
28	Y	Y	Y	P	Y	P	Y	N	N	N	5	2	3	60.0%	MODERATE
29	Y	Y	P	P	Y	Y	Y	P	U	N	5	3	2	65.0%	MODERATE
30	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
31	Y	Y	Y	P	Y	P	Y	Y	Y	N	7	2	1	80.0%	LOW
32	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
33	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
34	Y	Y	Y	P	Y	Y	Y	P	N	N	6	2	2	70.0%	MODERATE
35	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
36	Y	Y	P	P	Y	Y	Y	N	U	P	5	3	2	65.0%	MODERATE
37	Y	Y	P	P	Y	P	Y	N	N	N	4	3	3	55.0%	HIGH
38	Y	Y	Y	P	Y	Y	Y	P	N	N	6	2	2	70.0%	MODERATE
39	Y	Y	P	P	Y	Y	Y	P	Y	N	6	3	1	75.0%	MODERATE
40	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
41	Y	Y	Y	P	Y	Y	N	P	N	N	5	2	3	60.0%	MODERATE
42	Y	Y	Y	P	Y	Y	Y	Y	N	P	7	2	1	80.0%	LOW
43	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
44	Y	Y	P	P	Y	Y	Y	N	U	N	5	2	3	60.0%	MODERATE
45	Y	Y	P	P	Y	Y	Y	N	N	N	5	2	3	60.0%	MODERATE
46	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
47	Y	Y	Y	P	Y	Y	Y	N	Y	N	7	1	2	75.0%	LOW
48	Y	Y	Y	P	Y	P	Y	N	U	N	5	2	3	60.0%	MODERATE
49	Y	Y	Y	P	Y	Y	Y	N	Y	N	7	1	2	75.0%	LOW
50	Y	Y	P	U	Y	P	Y	N	U	N	4	2	4	50.0%	HIGH
51	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
52	Y	Y	Y	P	Y	Y	Y	N	N	P	6	2	2	70.0%	MODERATE
53	Y	Y	P	Y	Y	Y	N	N	U	N	5	1	4	55.0%	HIGH

Study ID	CO	SD	DD	GT	MD	EP	BC	SA	EV	RP	Y	P	N/U	Score	Overall
54	Y	Y	Y	P	Y	Y	Y	N	N	P	6	2	2	70.0%	MODERATE
55	Y	Y	Y	Y	Y	P	Y	N	U	P	6	2	2	70.0%	MODERATE
56	Y	Y	Y	Y	Y	Y	Y	N	U	N	7	0	3	70.0%	LOW
57	Y	Y	U	P	Y	P	Y	N	N	N	4	2	4	50.0%	HIGH
58	Y	Y	Y	P	Y	Y	Y	N	U	N	6	1	3	65.0%	MODERATE
59	Y	Y	Y	P	Y	P	Y	N	N	P	5	3	2	65.0%	MODERATE
60	Y	Y	Y	P	Y	Y	Y	N	U	P	6	2	2	70.0%	MODERATE
61	Y	P	Y	U	Y	Y	Y	P	N	N	5	2	3	60.0%	MODERATE
62	Y	Y	P	P	Y	P	Y	N	N	N	4	3	3	55.0%	HIGH
63	Y	Y	Y	P	Y	Y	Y	P	N	P	6	3	1	75.0%	MODERATE
64	Y	Y	P	P	Y	P	N	N	N	N	3	3	4	45.0%	HIGH
65	Y	Y	Y	P	Y	Y	Y	N	U	Y	7	1	2	75.0%	LOW
66	Y	Y	P	P	Y	Y	Y	N	N	N	5	2	3	60.0%	MODERATE
67	Y	Y	Y	P	Y	Y	Y	N	N	P	6	2	2	70.0%	MODERATE
68	Y	Y	Y	P	Y	Y	Y	N	N	P	6	2	2	70.0%	MODERATE
69	Y	Y	Y	P	Y	Y	Y	N	Y	P	7	2	1	80.0%	LOW
70	Y	Y	Y	P	Y	Y	Y	N	Y	N	7	1	2	75.0%	LOW
71	Y	Y	Y	P	Y	Y	Y	N	N	N	6	1	3	65.0%	MODERATE
72	Y	Y	P	P	Y	Y	Y	P	N	P	5	4	1	70.0%	MODERATE
73	Y	Y	Y	P	Y	Y	Y	N	Y	P	7	2	1	80.0%	LOW
74	Y	Y	P	N	Y	Y	Y	P	P	N	5	3	2	65.0%	HIGH
75	Y	Y	P	P	P	Y	Y	N	N	U	4	3	3	55.0%	HIGH

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Table S4. Comparison of sensing modalities used for intelligent conveyor monitoring.

Sensor modality	Measurement / data	Main strengths	Main limitations	Typical conveyor applications	References
Vibration	Acceleration and vibration time series	Sensitive to bearing and roller dynamics; supports mature time-frequency and ML analysis.	Requires reliable mounting; affected by load, speed, structural transmission paths, and environmental noise.	Idler, roller, and bearing diagnosis; abnormal vibration monitoring.	[19,20,21,48]
Thermal infrared	Surface temperature and thermal images	Non-contact hot-spot localization; directly identifies overheating and friction-related anomalies.	Affected by emissivity, viewing angle, ambient temperature, dust, occlusion, and background complexity.	Overheated idlers and rollers; thermographic safety inspection.	[16,17,53,54]
Acoustic	Airborne or distributed acoustic time series	Non-contact sensing; captures early temporal signatures and can support mobile or distributed inspection.	Sensitive to background noise, microphone position, reverberation, and site-to-site acoustic variability.	Idler, roller, and bearing faults; abnormal sound and tear-related events.	[2,4,13,64]
RGB / optical vision	Images and video	Provides dense spatial information; comparatively accessible; supports localization, classification, and geometric analysis.	Performance depends on illumination, dust, occlusion, motion blur, background clutter, and camera geometry.	Surface damage, wear, deviation, tears, and foreign-object detection.	[6,7,31,57]
Multispectral / multimodal imaging	Combined RGB, infrared, or complementary image channels	Combines appearance and thermal information, improving robustness when one modality is weak.	Requires sensor calibration and synchronization; increases hardware cost, data volume, and computational demand.	Damage detection and overheated-idler localization under difficult operating conditions.	[5,27,53]
Laser / structured light	Distance, profile, displacement, and surface geometry	High geometric precision; effective for small deformation, tear profiles, micro-damage, and belt-position measurement.	Requires careful alignment and calibration; can be affected by vibration, dust, and higher installation cost.	Longitudinal-rip detection, micro-damage measurement, and deviation monitoring.	[18,59,78]
Magnetic / other NDT	Magnetic, inductive, or ultrasonic defect signals	Detects internal defects that may not be visible at the belt surface; suitable for steel-cord integrity assessment.	Specialized hardware and calibration are required; results depend on sensor position, threshold selection, and defect coverage.	Steel-cord breakage, corrosion, and internal belt-condition monitoring.	[38,60,62,63]
Embedded multi-sensor / IoT nodes	Combined telemetry, images, temperature, vibration, or acoustic data	Enables continuous monitoring, local preprocessing, event-driven communication, and multi-sensor fusion.	Integration complexity, synchronization, power, bandwidth, cybersecurity, and maintenance requirements.	System-level condition monitoring, edge inference, and predictive maintenance.	[9,24,25,27]

Figure S1. Comparison of reported classification accuracy across machine-learning and deep-learning model families. (A) Mean accuracy of classical machine-learning approaches, including support vector machine (SVM), random forest (RF), and decision tree (DT). (B) Mean accuracy of deep-learning approaches, including convolutional neural network (CNN), long short-term memory (LSTM), gated recurrent unit (GRU), autoencoder, and Gramian angular field combined with CNN (GAF+CNN). Bars represent the mean reported accuracy, diamonds indicate the maximum reported accuracy, and n denotes the number of studies contributing to each model category. The horizontal dotted line marks the 90% accuracy threshold.

