Human Factors Concerns in Data Collection

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Knowledge Extraction and Application for Manufacturing Operations Project

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Problem

- Maintenance is expensive ($50 billion in 2016) and expertise driven
- Smart manufacturing technologies can reduce costs [1]

- SMEs still not employing these technologies [2]
  - High Cost to implement – Risk is high with incorrect implementation
  - Lack of Support/Expertise in manufacturing
  - Leads to a lack of high quality sensor data

- No data -> Difficult to assess impacts of new technologies

[1] Thomas, D. S. (2018). *The Costs and Benefits of Advanced Maintenance in Manufacturing* (No. Advanced Manufacturing Series (NIST AMS)-100-18).
[2] Jin, X., Siegel, D., Weiss, B. A., Gamel, E., Wang, W., Lee, J., & Ni, J. (2016). The present status and future growth of maintenance in US manufacturing: results from a pilot survey. *Manufacturing review*, *3*.

Problem

Untapped source of data that *could* be used, but…

- Natural Language Documents – Maintenance Work Orders (MWOs)
  - Contain historical tacit knowledge
  - Contain domain-specific abbreviations and jargon
  - Often unstructured input

- Current Natural Language Processing (NLP) solutions … catch22?
  - Training data to automate annotation is … annotated.
  - Can be a bad value proposition to persuade stakeholders

MWO Data "Pipeline"

- **E**xtract
- **T**ransform
- **L**oad

- Collection and Storage
- Cleaning and Parsing
- Analysis and Visualization

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→

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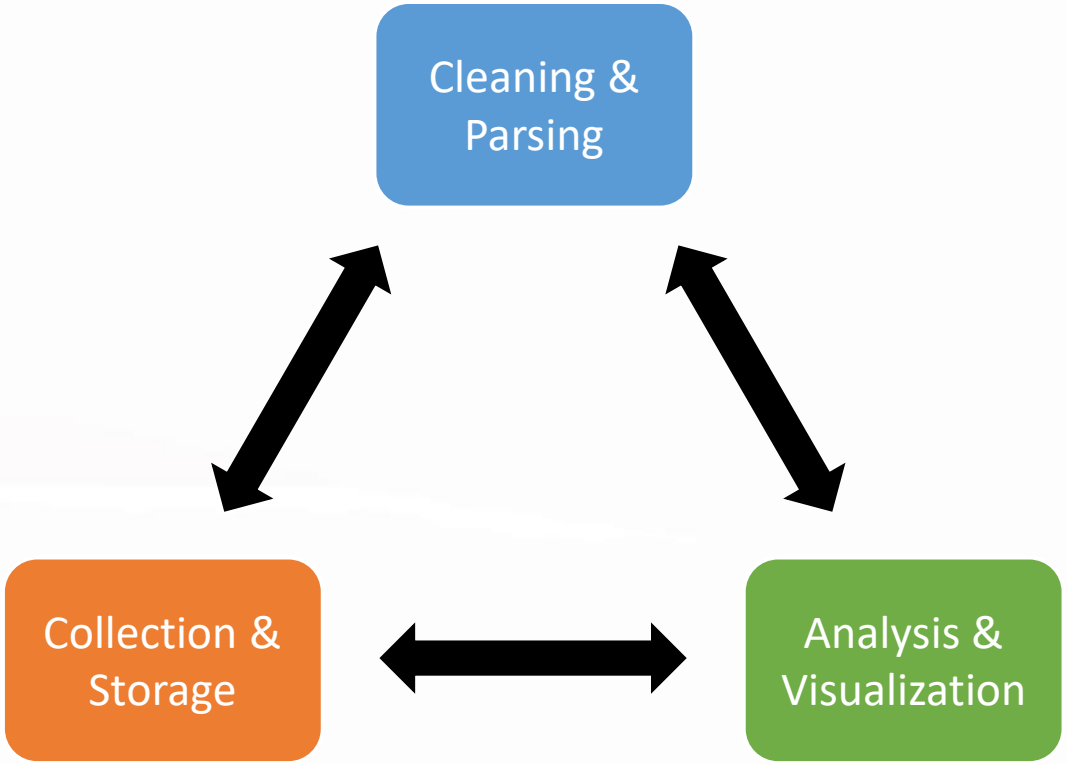
- Analysis and Visualization

MWO Data "Pipeline"

Decisions made at each stage **will impact** the strategies that are

- Available
- Efficient

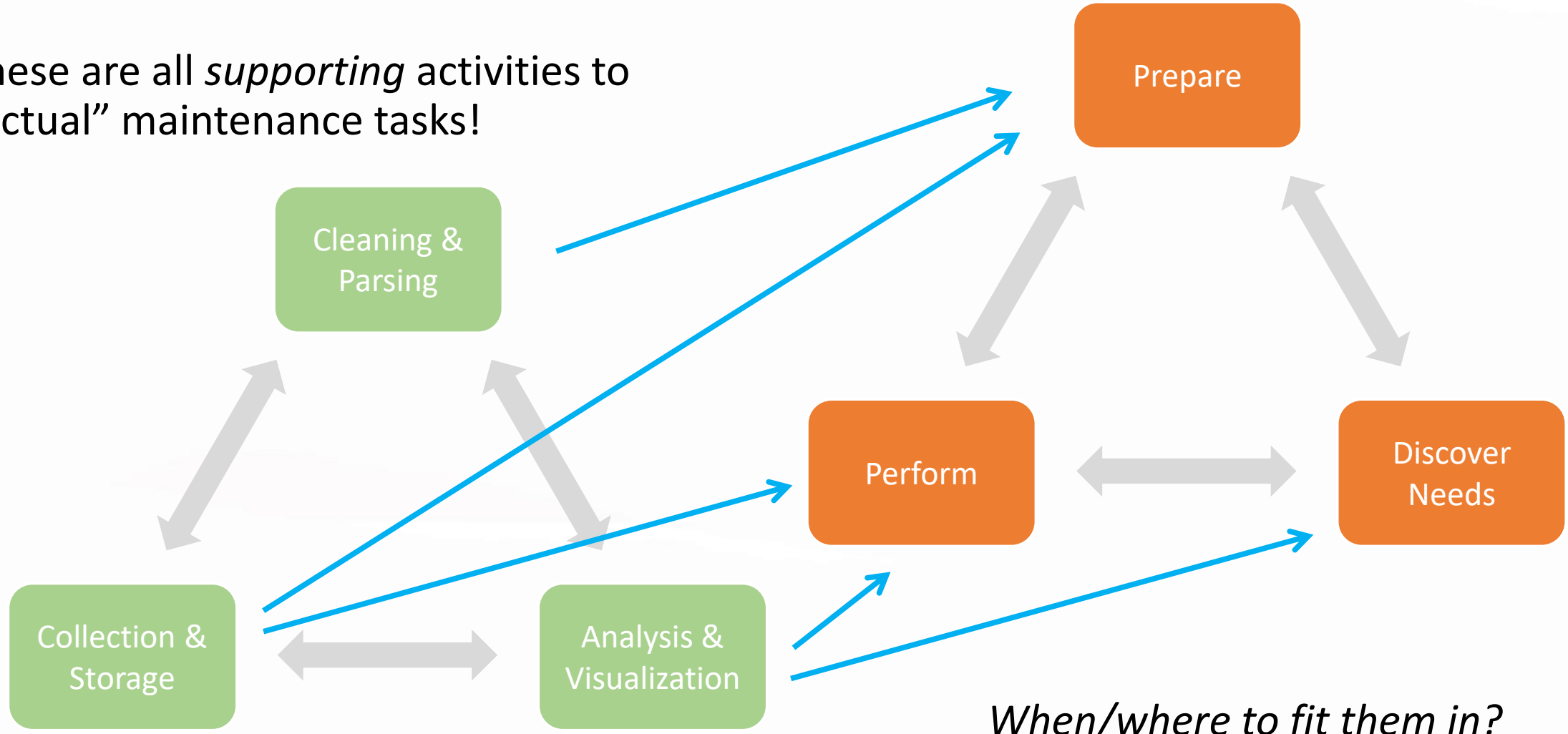
at each other stage.



Keep in mind …

MWO Data "Pipeline"

These are all *supporting* activities to "actual" maintenance tasks!



When/where to fit them in?

Interactive Case Study

Interactive Case Study

"The cutting tool snapped off. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool"

"All-around operator error. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before making that move if he/she wanted to keep that depth of cut."

"The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn't smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot."

"Too large of an engagement at tool high of a feed."

Interactive Case Study

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Tool is broken

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Depth of cut too large

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Feed rate too high

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Bad process plan

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Operator error

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Current Maintenance Paradigm

- Expertise Driven
- Sensors not always present
- Often unstructured MWOs
  - natural language; domain-specific abr. and jargon
  - “tribal” knowledge
- Little structure in non-natural language data
  - Times/Dates different formats
  - Misspellings in Technician/Asset names
  - Non-matching WO #s to other systems

Current Maintenance Paradigm

PHYSICAL PLANT
MAINTENANCE WORK ORDER

Date: _____

Requested by: _____

Building/Room: _____

Description of Needs: _____

Org. to be Charged: _____

Estimated Cost Amount: _____

Supervisor Approval: _____ Date: _____

VP of Administration Approval: _____ Date: _____

Work Completed by: _____ Date: _____

Return completed form to Administrative Services
Rev 5/01

Date	Mach	Description	Issued By	Date Up	Maint Tech Assigned	Resolution
29-Jan-16	H15	St#14 tool detect INOP	JS	29-Nov-16	SA	Slug detector at station 14 not working. Would not recognize “Start” signal.
1-Jun-16	Mitsu FT	Brakes worn -Not stopping when in gear	AB	28-Jun-16	Steve A	Repaired
1-Jun-16	H8	St#7 rotator collet broken -wait for Bob B to show him how to remove	JS	8-Jun-16	John Smith	Machine went offline on 6/8 -Mark removed and instructed Bob B on removal/install process

Data Collection and Storage

- Needs
  - MWO Terminology Definitions
    What defines its components? Who is involved? What is it recording?
  - Atomic data types and formats for information flow in MWOs
    Issue meta-data (dates, descriptions, etc.), personnel, asset IDs
  - Adaptive database schemas for storing varied MWO data
    Desirable information will shift over time—what are the core invariable relations?
  - Mapping from disparate CMMS solutions into standard data types
    Current software uses proprietary/custom schemas—unification?

Data Collection and Storage

→ Granularity can directly impact willingness to participate…*buy-in is imperative*. Culture shifts are hard!

→ How will this data benefit the shop-floor…analysis? How will it interfere with their primary responsibilities?

→ Some parts of the maintenance management workflow will benefit from data more than others…how to bootstrap cost-vs-benefit estimate?

Human Factors Concerns

“Should we implement a drop-down menu?”

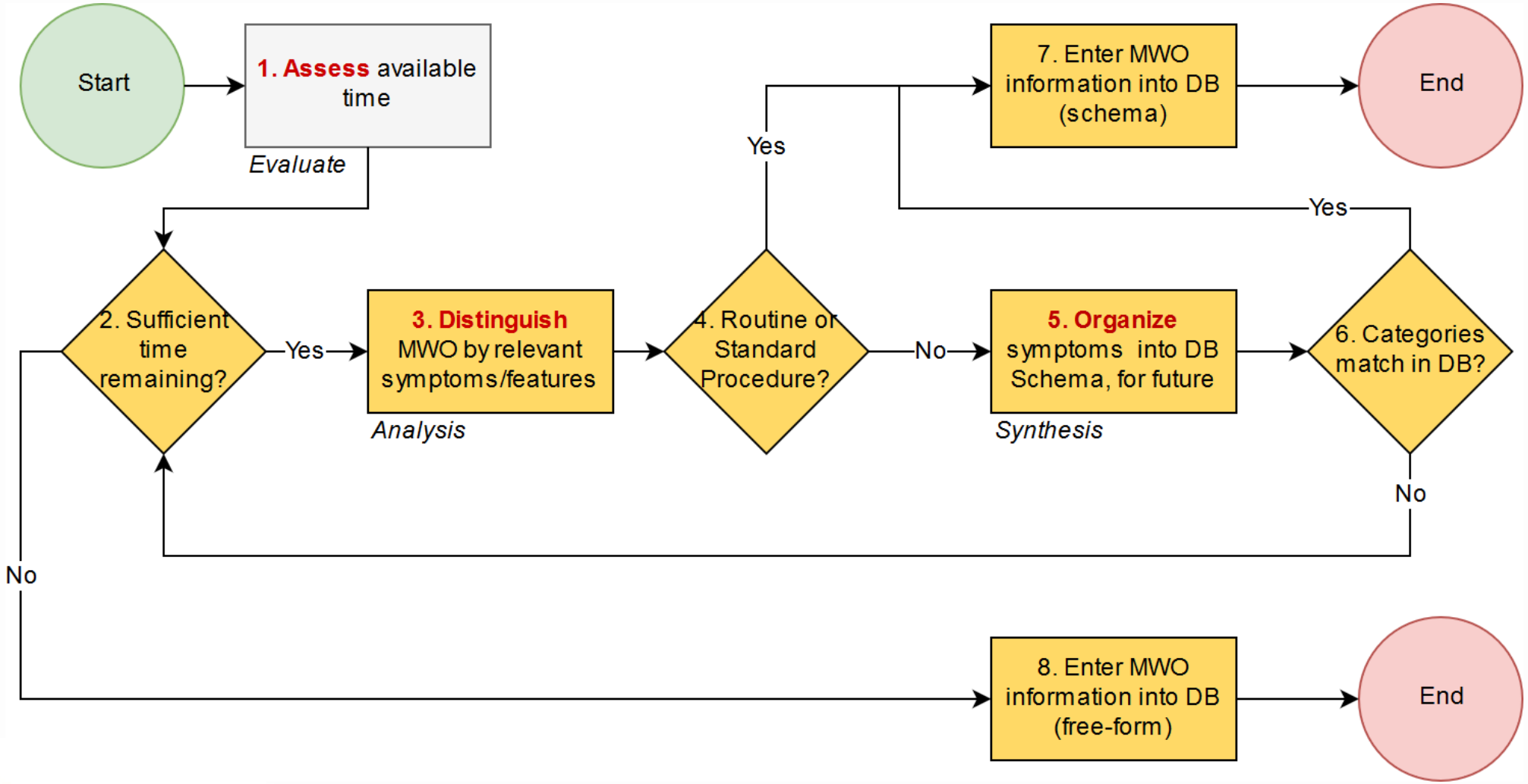
Human Factors Concerns

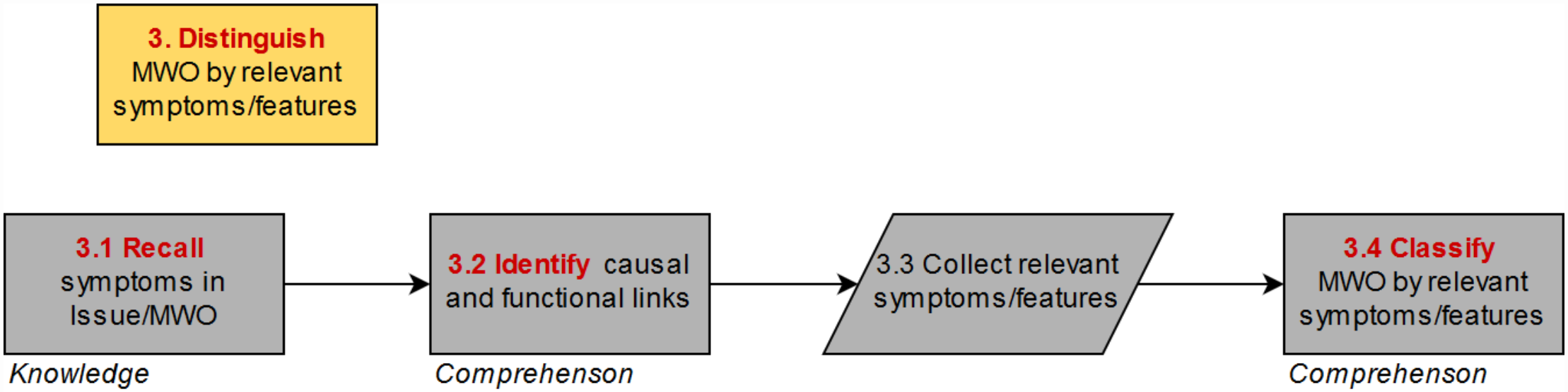
Model the "Data Quality" System

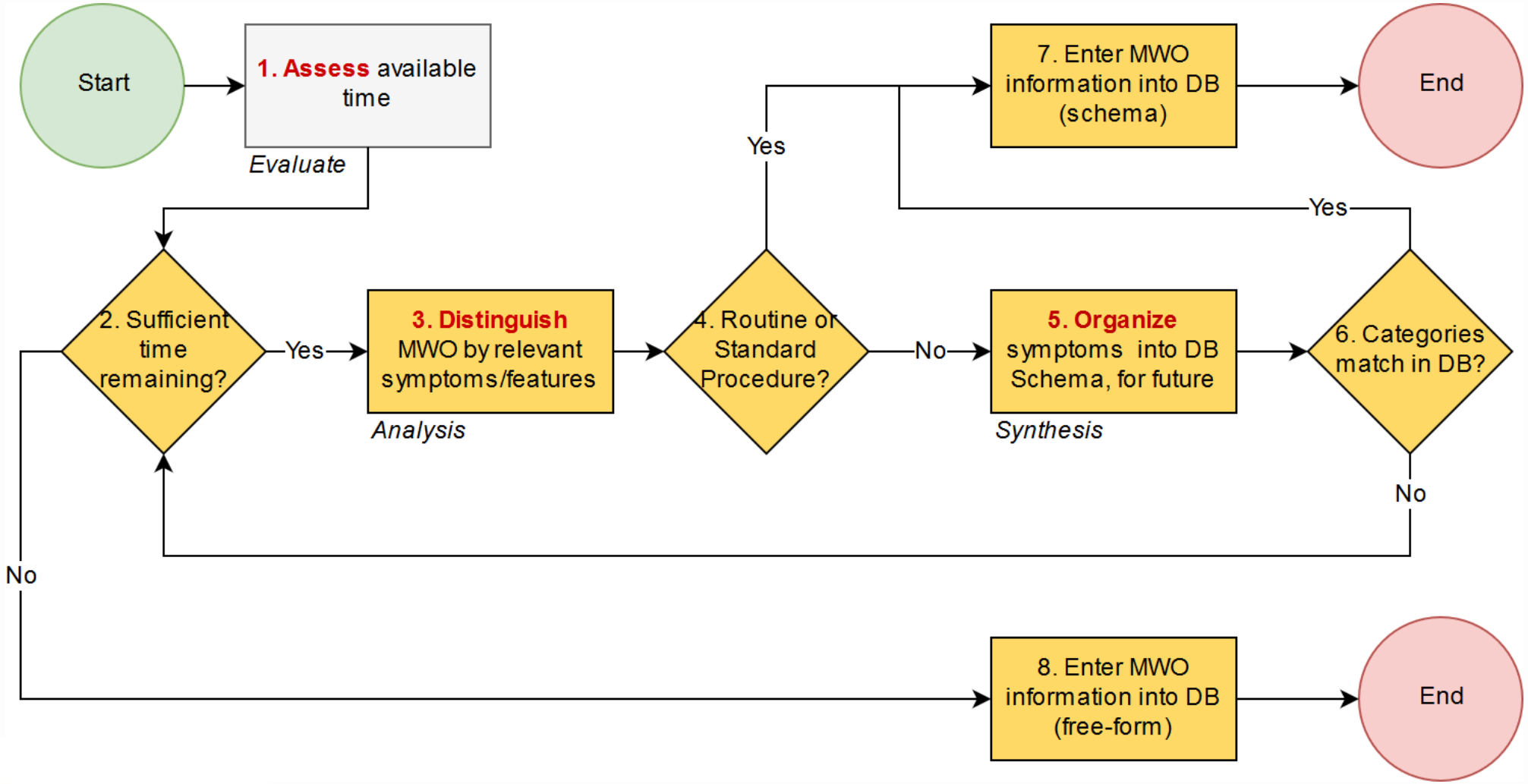
- What are the **TASKS** being performed by the technician?
- What **THEORY** do we have to understand those tasks?
- What social, technological, and organizational **FACTORS** are at play?
- What **ERRORS** are likely, given these?
- What can we do to appropriately **MITIGATE** error rates/impact?

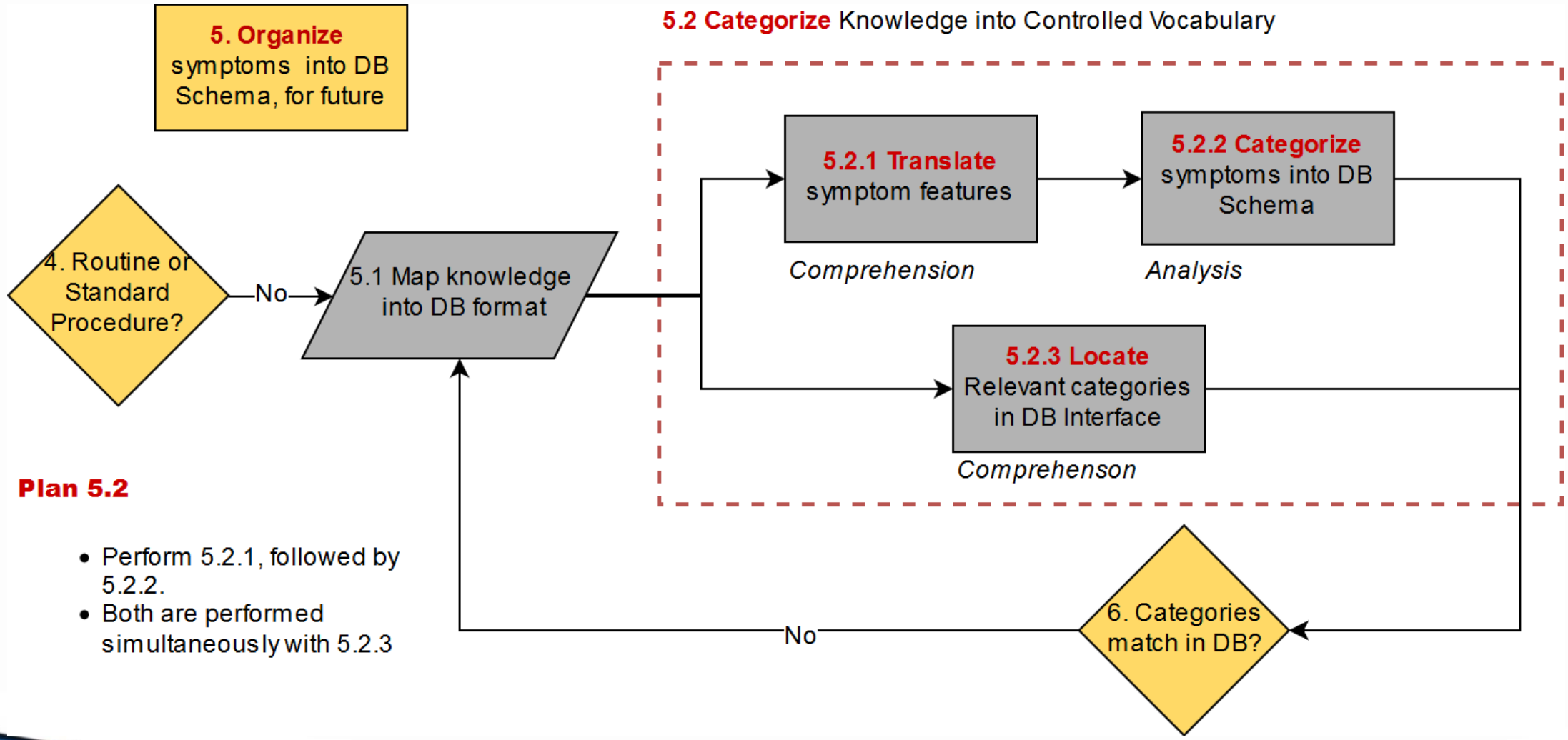
Decision Point	Theory	Reference
1) Relevant causal/functional relationships	Associative Strength	Fazio, Williams, & Powell, 2000
2) Organization/Categorization	Similarity-Choice	Logan, 2004

Task Analysis




3. Distinguish
MWO by relevant symptoms/features
3.1 Recall
symptoms in Issue/MWO
Knowledge
3.2 Identify causal and functional links
Comprehenson
3.3 Collect relevant symptoms/features
3.4 Classify
MWO by relevant symptoms/features
Comprehenson


Start
1. Assess available time
Evaluate
2. Sufficient time remaining?
Yes
3. Distinguish MWO by relevant symptoms/features
Analysis
4. Routine or Standard Procedure?
Yes
7. Enter MWO information into DB (schema)
End
No
5. Organize symptoms into DB Schema, for future
Synthesis
6. Categories match in DB?
Yes
No
No
8. Enter MWO information into DB (free-form)
End


5. Organize symptoms into DB Schema, for future
5.2 Categorize Knowledge into Controlled Vocabulary
5.2.1 Translate symptom features
5.2.2 Categorize symptoms into DB Schema
Comprehension
Analysis
4. Routine or Standard Procedure?
No
5.1 Map knowledge into DB format
5.2.3 Locate Relevant categories in DB Interface
Comprehenson
Plan 5.2
• Perform 5.2.1, followed by 5.2.2.
• Both are performed simultaneously with 5.2.3
6. Categories match in DB?
No

Performance-shaping Factors

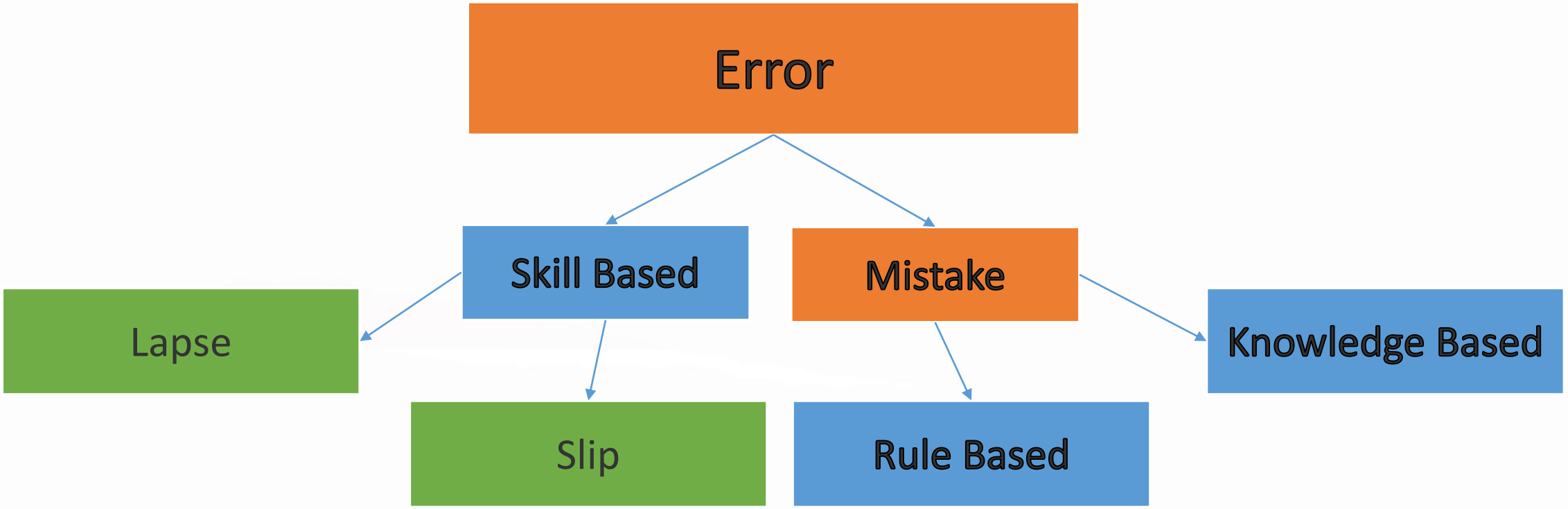
- Many possible factors—overwhelming
- Not merely complications, but ways to address the problems!
- Some things can go a long way
- How do we know which ones?

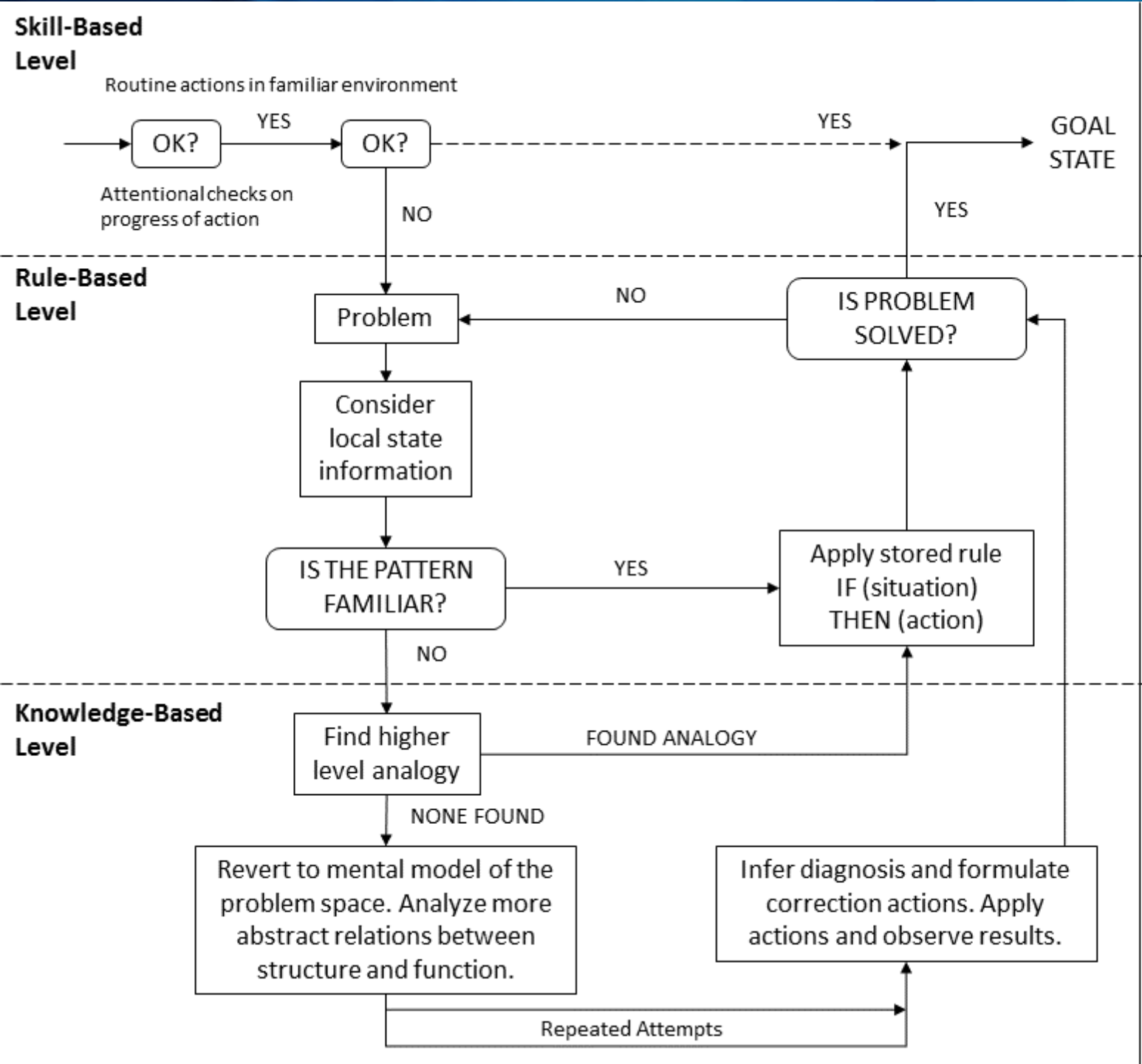
→ Error Analysis

PSF	Category
Communication level of operator/customer to Technician	Social
Visibility and accessibility of system components	Technological
Time passed between investigation and reporting	Organization
Breadth of technician experience across MWO types	Personal
Availability and completeness of standardized procedure	Organization
Training in system functionality	Organization
Depth of technician experience in this MWO type	Technological
Time available for assessment	Organization
Technician problem-solving ability	Personal
Computer literacy of technician	Personal
Communication between management and shop-floor	Social
Human-system interface design	Organization

Skills, Rules, & Knowledge

Reason (1990): Types of “Human Error”





Example Skill-Based Errors

Miscalculate a time estimate for a potential maintenance job

During regular maintenance check, does not notice leaking oil

Technician forgets a screwdriver

Technician overtightens a screw

Example Rule-Based Errors

Machine shows an alarm, maintainer ignores because of a previous false alarm

Technician 1 is assigned a type A-job; Technician 2 was just certified to complete A-jobs and is not being assigned A-jobs.

Technician notices gear pitting – previously replaced gear box when this occurred. Replaces gear box again, when in fact, should have only replaced the one gear.

Maintainer selects Company A for a job, due to previous relationship. However, Company B is better suited for job.

Example Knowledge-Based Errors

A new, unseen work order is submitted – planner creates non optimal SWP

Neural Network trained on steel heat maps predicted a quality drop, but analyst is unable to determine cause of failure mode

Technician attempts to replace motor having never done it before and makes mistake.

Conclusion

- We will be brainstorming to build a Roadmap
- Hearing lots of issues, and potential solutions

Remember

- (Mike) What am I trying to accomplish with this data?
  What problems am I trying to mitigate?

- (Thurston) What might happen in getting it?
  What problems might I encounter?

Questions?

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