Knowledge Base and Taxonomy/Ontology

Group B - Topic 1

Simone Marzeddu (Document Author), Giacomo Aru - 12/11/2024

Introduction

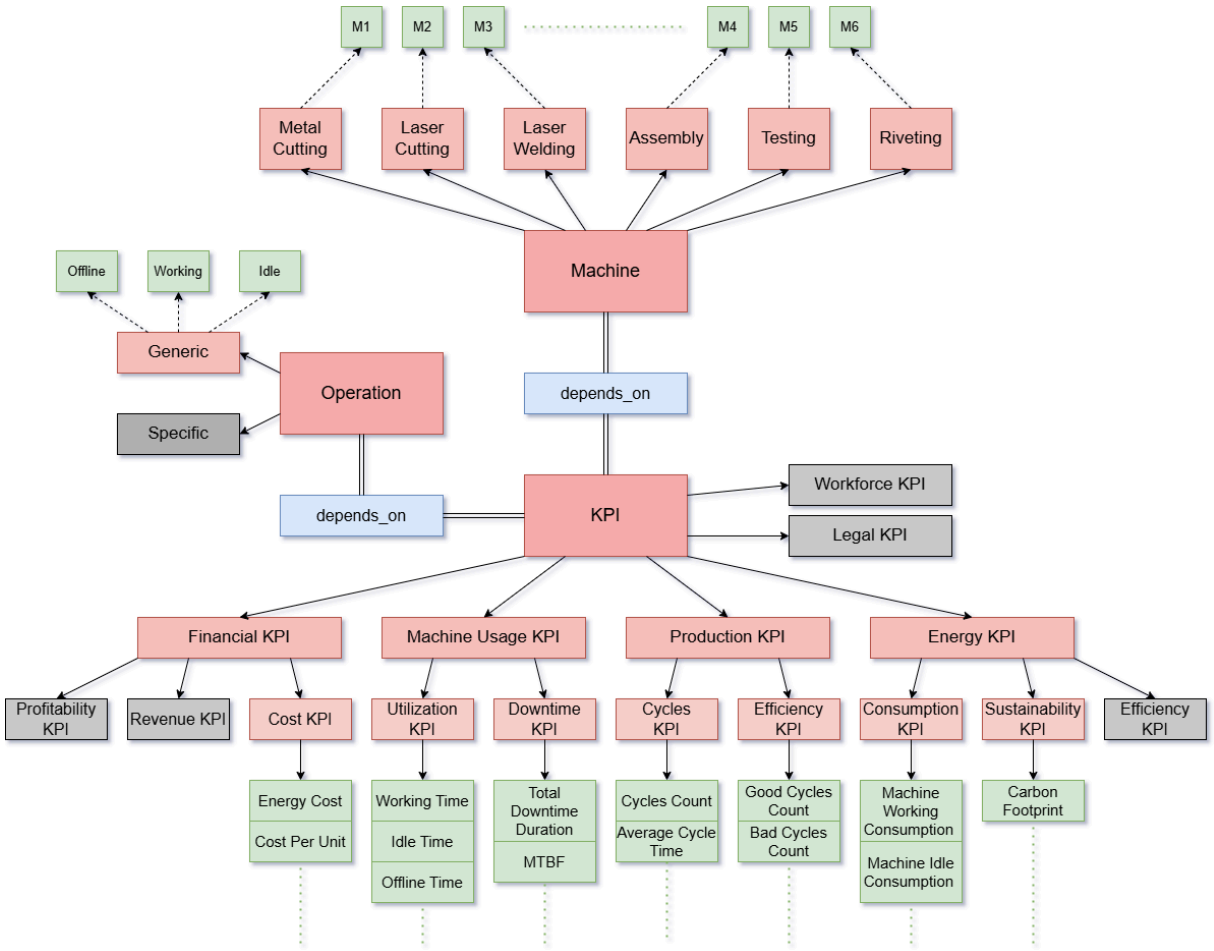
This document provides the description and analysis of the KPIs Taxonomy and Machines and Operations Ontology identified by Group B during the Smart Application Master Course, edition 2024-2025, University of Pisa.

The knowledge base structure described in the following chapters has been designed to offer modularity, extensibility and flexibility in our system. This allows for the inclusion of machine and operations attributes or KPIs that may not be found in the dataset under consideration. With this in mind, this design aims to permit the addition of any other relevant KPIs that may become relevant if the system is used in real contexts that are similar to those studied in the academic environment.

KPIs Ontology

The taxonomy of KPIs that we have identified comprises six principal classes of KPIs. Four of these (***Machine Usage KPIs***, ***Energy KPIs***, ***Production KPIs***, ***Financial KPIs***) will be directly calculable from the dataset that has been provided for the project, while the remaining two (***Workforce KPIs*** and ***Legal KPIs***) will still be taken into account for theoretical completeness and extendibility of our system, despite the fact that they will not be supported by real instantiation in the final product at the end of the course.

This section analyses each of the six classes in detail, highlighting the ramifications of the sub-classes we have identified and giving some examples of KPIs that would be part of these categories.



Machine Usage KPIs

Machine Usage KPIs are metrics used to monitor and evaluate the effectiveness, efficiency, and productivity of **machinery** in a production or manufacturing environment. These KPIs help organizations understand how well their machines are performing and identify areas for improvement to reduce downtime, optimize usage, and enhance overall productivity.

In our ontology, this class of KPIs branches into two subclasses: ***Utilization KPIs*** (e.g. *working_time*, *idle_time*, *offline_time*, *utilization_rate*, *availability, …*) and ***Downtime KPIs*** (e.g. *total_downtime*, *mean_time_between_failure, …*).

Energy KPIs

Energy KPIs are metrics used to assess and optimize an organization’s energy consumption, efficiency, and sustainability. These indicators help companies monitor their energy usage, identify areas to reduce waste, lower costs, and minimize their environmental impact.

In our ontology, this class of KPIs branches into three subclasses: ***Consumption KPIs*** (e.g. *consumption*, *power*, *consumption_working*, *consumption_idle, …*), ***Efficiency KPIs*** (e.g. *energy_efficiency_ratio*, *energy_consumption_per_unit, …*) and ***Sustainability KPIs*** (e.g. *carabon_footprint*, *renewable_energy_usage_percentage, …*).

Production KPIs

Production KPIs (Key Performance Indicators) are metrics used to monitor, assess, and improve the efficiency, quality, and overall effectiveness of **production processes** within manufacturing or production facilities. These KPIs enable companies to track performance, identify bottlenecks, and drive productivity improvements.

In our ontology, this class of KPIs branches into two subclasses: ***Cycles KPIs*** (e.g. *cycles_count*, *average_cycle_time, …*), ***Efficiency KPIs*** (e.g. *good_cycles_count*, *bad_cycles_count, overall_equipment_effectiveness, defect_density, failure_rate, success_rate…*).

Financial KPIs

Financial KPIs are metrics used to evaluate an organization's financial performance, stability, and overall economic health. These KPIs help companies track profitability, manage expenses, optimize cash flow, and assess return on investment.

In our ontology, this class of KPIs branches into three subclasses: ***Cost KPIs*** (e.g. *energy_cost*, *cost_per_unit*, *cost_per_cycle*, *total_energy_cost, total_operational_cost …*), ***ProfitabilityKPIs*** (e.g. *gross_margin_percentage, return_on_investment, …*) and ***Revenue KPIs*** (e.g. *revenue_per_employee*, *sales_growth_rate, …*).

Workforce KPIs

Workforce KPIs are metrics used to evaluate employee performance, productivity, engagement, and overall workforce effectiveness. These KPIs help organizations manage their talent more effectively, optimize workforce performance, and improve employee satisfaction. (e.g. *turnover_rate*, *absenteism_rate*, *employee_satisfaction_score*, *training_hours_per_employee …*)

Since this class is meant to represent a theoretical expansion of our ontology, this will not branch into more specific subclasses.

Legal KPIs

Legal KPIs are metrics used to evaluate the effectiveness, efficiency, and risk management of an organization's legal function. These KPIs help legal departments measure their performance, manage compliance, mitigate risks, and align their work with business objectives. (e.g. *compliance_rate*, *incident_rate*, *contract_compliance_rates*, *litigation_costs*…)

Since this class is meant to represent a theoretical expansion of our ontology, this will not branch into more specific subclasses.

Machines Ontology

As previously stated, our ontology also encompasses machine-related data and hierarchies. This section presents the six classes identified based exclusively on the specific case of the dataset provided for the project (***Metal Cutting Machine***, ***Laser Cutting Machine***, ***Laser Welding Machine***, ***Assembly Machine***, ***Testing Machine*** and ***Riveting Machine***).

Metal Cutting Machine

Metal-cutting machines are employed to shape material from metal workpieces through a variety of cutting techniques, including milling, turning, drilling, and grinding. Such machinery frequently employs cutting tools crafted from hard materials, thereby ensuring precision and accuracy. These tools are used to create specific shapes, dimensions, or finishes for manufacturing parts.

Laser Cutting Machine

Laser cutting machines employ high-powered lasers to cut materials, typically metals, by focusing a laser beam that melts, burns, or vaporises the material along a defined path. These machines are renowned for their precision, speed and capacity to cut complex shapes, and are utilised in industries that require intricate cutting, including automotive, aerospace and electronics.

Laser Welding Machine

Laser welding machines employ focused laser beams to fuse materials together, typically metals or thermoplastics, at high speeds and with precise control. The process results in the formation of robust and precise welds, rendering it particularly advantageous in applications where minimal thermal distortion is desired, including those in the automotive, medical device, and high-tech industries.

Assembly Machine

An assembly machine is an automated system designed to combine different components into finished products or sub-assemblies. Such machinery facilitates the streamlining of

production processes by performing repetitive tasks, including the insertion, fastening, and joining of components, thereby enhancing consistency and reducing the necessity for manual labour. Such machinery is frequently utilised in the production of electronic devices, automotive components and consumer goods.

Testing Machine

Testing machines are employed for the assessment of the quality, durability, and performance of materials or finished products. Such apparatus can be utilised to conduct a plethora of tests, including tensile, fatigue, and pressure testing, with the objective of ensuring that products comply with the requisite industry standards and specifications. Testing machines are indispensable in industrial sectors such as manufacturing, construction and quality assurance.

Riveting Machine

Riveting machines are designed for the purpose of joining materials, typically metals, through the insertion and deformation of rivets, thereby creating secure and permanent joints. These machines apply a force to the rivets, causing them to expand and thereby hold the components together. They are commonly used in industries such as aerospace, automotive, and metalworking, where strong and stable joints are required.

Operations Ontology

As previously stated, our ontology also encompasses operation-related data and hierarchies. This section presents two fundamental classes (***Generic*** and ***Specific***).

Generic Operations

Generic Operations are processes that are common to every type of machine and lack specificity. Instances of this category are in fact the operations *Offline*, *Working* and *Idle*, which can be associated with any existing machine type.

Specific Operations

Although the reference dataset does not contain references to processes or operations, this class is intended to be the main extension point for the application of the software to many and varied business realities. The operations instantiated from this class will be useful for modeling specific and characteristic processes of targeted production pipelines.

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Entities and Attributes

The fundamental classes within the ontology describe three entity types: ***KPI***, ***Operations*** and ***Machine***. Follows a list of the attributes identified for the three classes of entities:

KPIs:

Annotations Properties:

- **Name**: common name of the KPI (human readable)
- **Description**: a textual description of the KPI (human readable)
- **Human Readable Formula**: descriptive textual informations about the formula to compute the KPI value
- **Unit of Measure**: unit of measure of the KPI

Datatype Properties:

- **Database ID**: ID associated with the KPI in the database
- **Parsable Computation Formula**: computation formula reduced to minimal pure terms, stored in a format parsable by the KPI Engine

Objects Properties:

- **depends_on**: Dependency relationship between the KPI and a macro class of the ontology. A KPI can be dependent on machines, operations or both.

Operations:

Annotations Properties:

- **Name**: common name of the operation (human readable)
- **Description**: textual description of the operation (human readable)

Datatype Properties:

- **Database ID**: ID associated with the operation in the database

Machines:

Annotations Properties:

- **Name**: common name of the machine (human readable)
- **Description**: textual description of the machine (human readable)

Datatype Properties:

- **Database ID**: ID associated with the machine in the database
- **Capacity**: acceptable size of the machined material (Large-Low-Medium)
- **Location**: physical location in which the machine is installed