

Automated Generation of Datasets from Fishbone Diagrams

Brian Sal, Diego García-Saiz, and **Pablo Sánchez**

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Universidad de Cantabria
Santander (Cantabria, España)



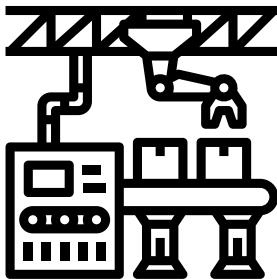
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- 3 Ishikawa Diagrams
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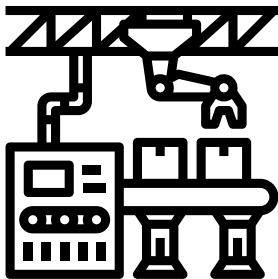
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 - Running Example: Drive Half-Shaft Assembly
 - Data Mining and the Data Reshaping Problem
- 2 Lavoisier
- 3 Ishikawa Diagrams
- 4 Generation of Datasets from Fishbone Diagrams
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Industry 4.0



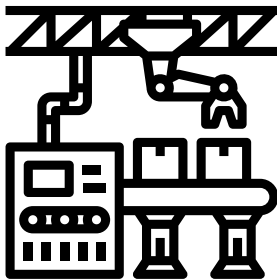
- 1 Gather data produced by machines of production environments.
- 2 Analyze these data to improve both products and processes.

Industry 4.0



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Industry 4.0



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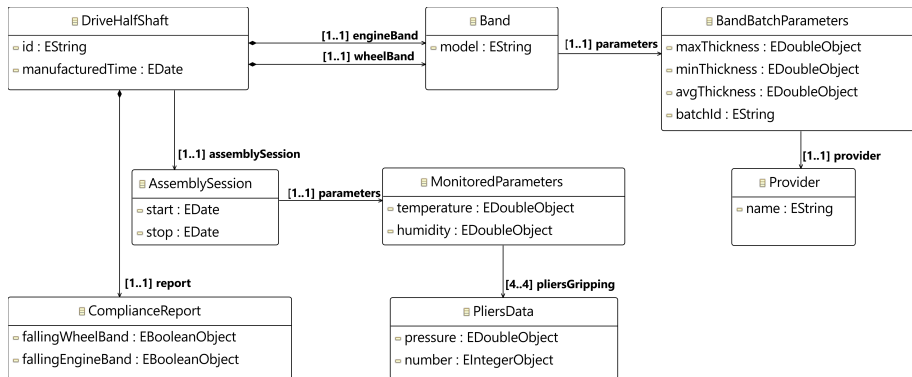
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Drive Half-Shaft



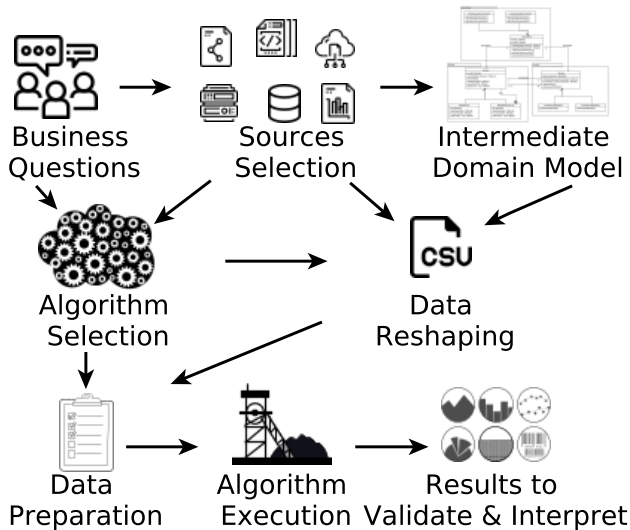
Domain Data



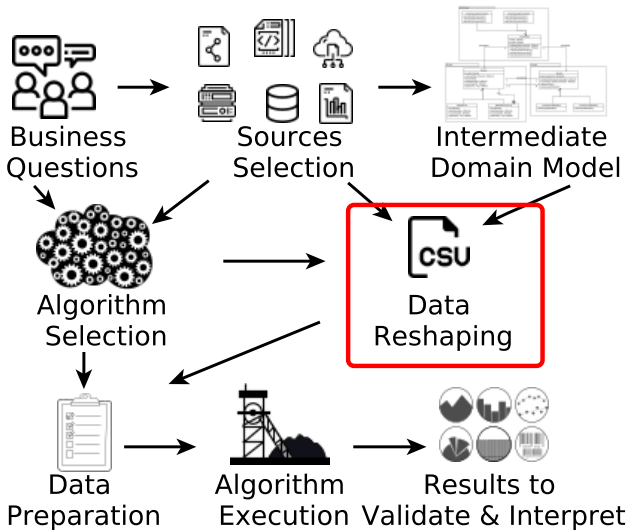
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Data Mining Process



Data Mining Process



Tabular Data for Datasets

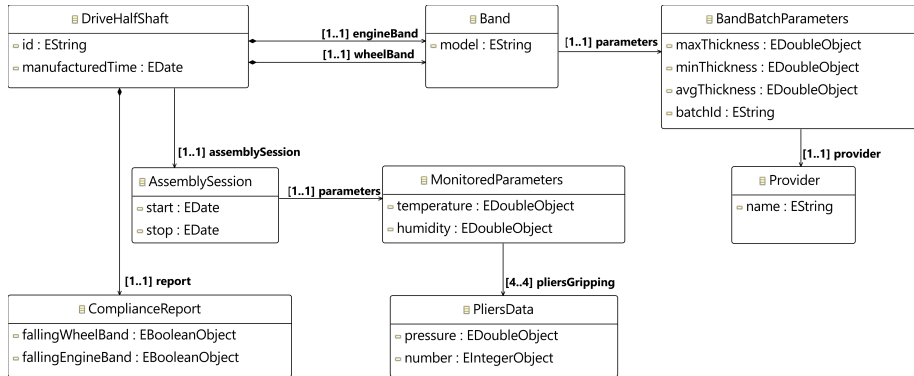
id	temperature	humidity	gripPress00	gripPress01	gripPress02	gripPress03
75689	19.5	56.8	600	603	602	598
75690	19.5	56.8	602	602	602	602
75691	19.6	56.7	601	600	598	600
75692	19.6	56.6	603	603	602	603
...	...	...	...	...	...	...

Tabular Data for Datasets

id	temperature	humidity	gripPress00	gripPress01	gripPress02	gripPress03
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75691	19.6	56.7	601	600	598	600
75692	19.6	56.6	603	603	602	603
...	...	...	...	...	...	...

One entity - one row constraint

Domain Data is Not Tabular



Lavoisier

- ① We develop *Lavoisier*¹, a language for improving the data reshaping stage.

¹A. de la Vega, D. García-Saiz, M. Zorrilla, P. Sánchez. *Lavoisier: A DSL for increasing the level of abstraction of data selection and formatting in data mining*. Journal of Computer Languages (60). 2020.

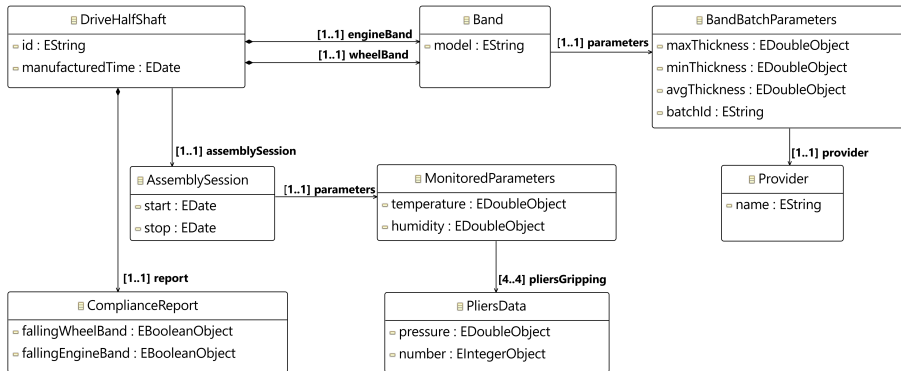
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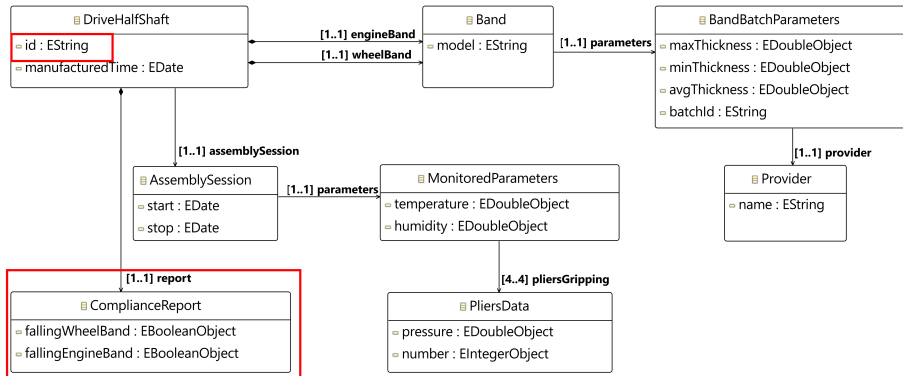
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Lavoisier: Attributes and Single-Bounded References



Lavoisier: Attributes and Single-Bounded References



Lavoisier: Attributes and Single-Bounded References

```
dataset driveHalfShaft_AssemblyParameters {  
  mainClass DriveHalfShaft [id] {  
    include report  
  }  
}
```

Lavoisier: Attributes and Single-Bounded References

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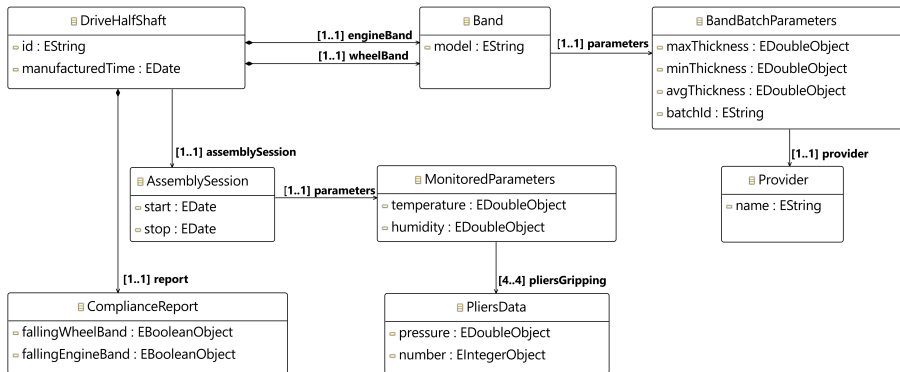


id	fallingWheelBand	fallingEngineBand
75689	false	true
...	...	...

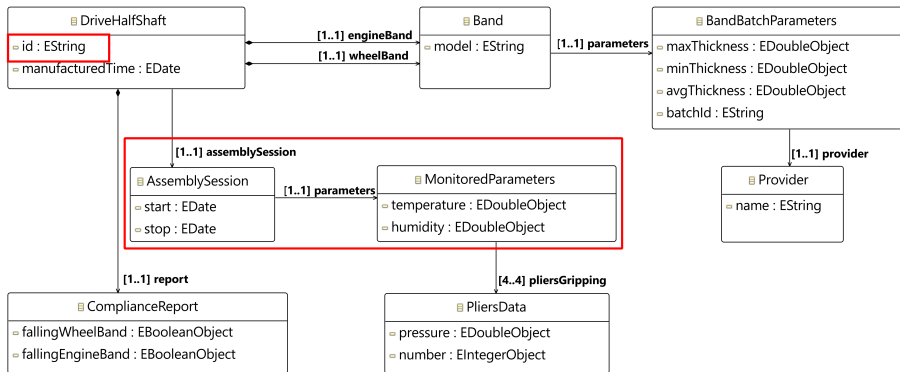
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Lavoisier: Multi and Unbounded References



Lavoisier: Multi and Unbounded References

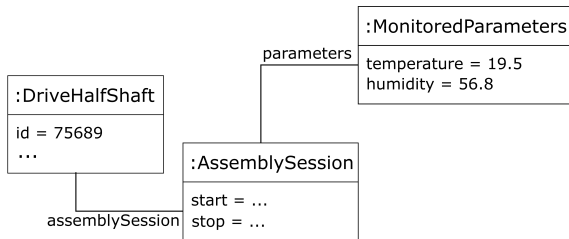


Lavoisier: Multi and Unbounded References

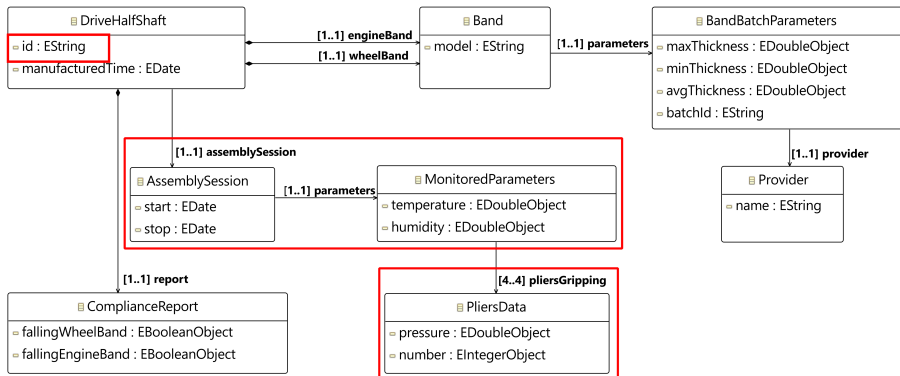
```
dataset driveHalfShaft_AssemblyParameters {  
  mainClass DriveHalfShaft [id] {  
    include assemblySession {  
      include parameters {  
        include pliersGrippings by number}  
      }  
    }  
  }  
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Lavoisier: Multi and Unbounded References

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dataset driveHalfShaft_AssemblyParameters {  
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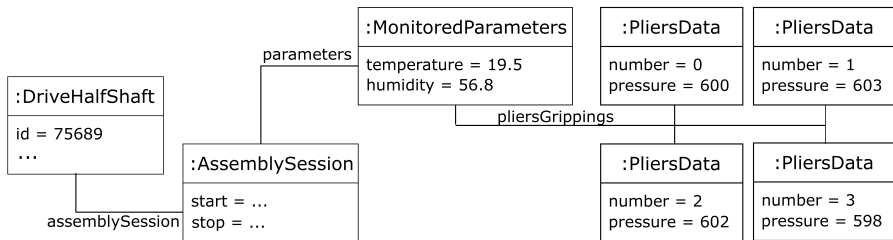


Lavoisier: Multi and Unbounded References



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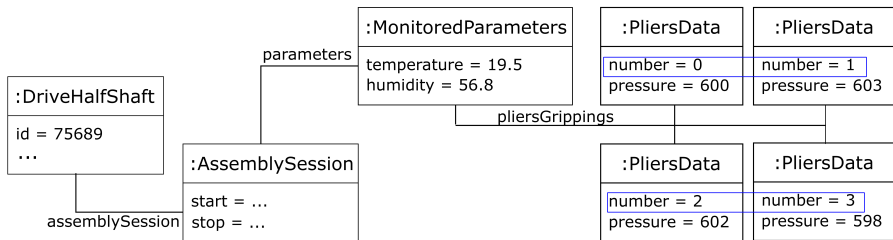
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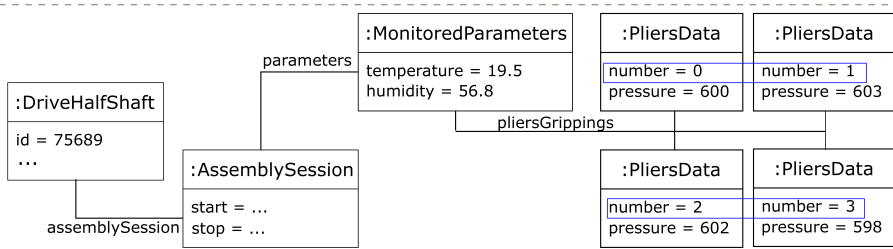


Lavoisier: Multi and Unbounded References

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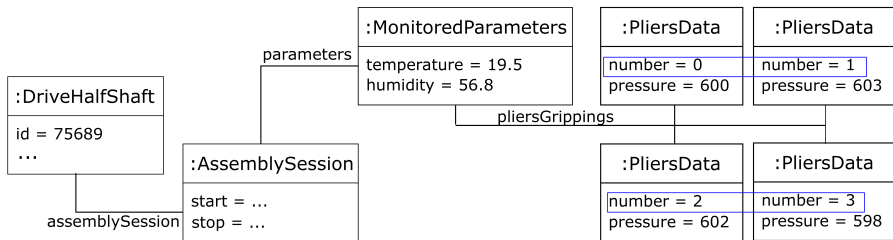
id	...	pliersGripping_0	pliersGripping_1	pliersGripping_2	pliersGripping_4

Lavoisier: Multi and Unbounded References

```

dataset driveHalfShaft_AssemblyParameters {
  mainClass DriveHalfShaft [id] {
    include assemblySession {
      include parameters {
        include pliersGrippings by number}
      }
    }
  }
}

```



id	...	pliersGripping_0	pliersGripping_1	pliersGripping_2	pliersGripping_4
75689	...	600	603	602	598
...	...	...	...	...	...

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Lavoisier in Industry 4.0

- 1 Using *Lavoisier*, complexity of data reshaping scripts decreases by $\sim 60\%$.
- 2 *Lavoisier* relies on **object-oriented models** to describe domain-data...
- 3 but **industrial engineers** are not used to deal with these models;
- 4 but they are used to **Ishikawa diagrams**.

Lavoisier in Industry 4.0

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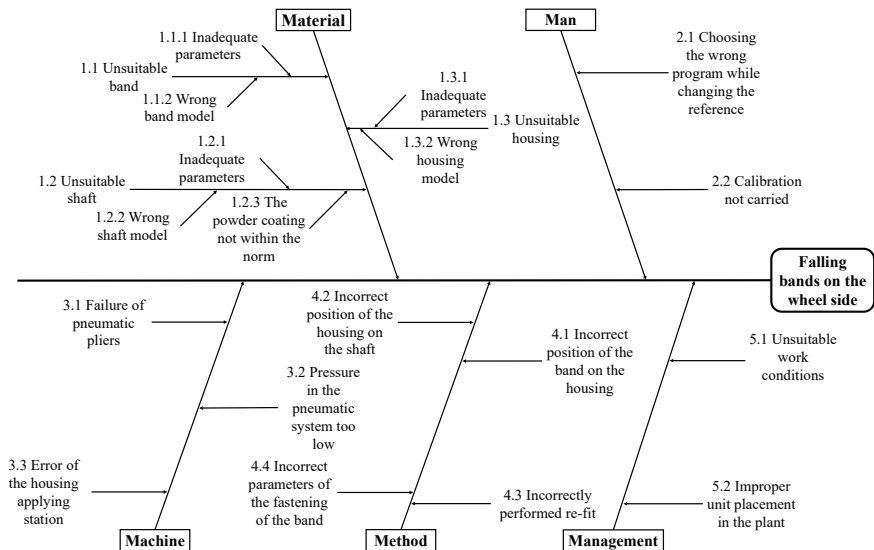
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Ishikawa Diagrams



Paper Contribution

Paper Contribution

To adapt *Lavoisier* to make it compatible with Ishikawa diagrams, which would be more suitable in an Industry 4.0 context.

Challenges

- 1 Modify Ishikawa diagrams so that they can represent data.
- 2 Connect Ishikawa diagrams with domain data.
- 3 Create a Lavoisier-like language to select causes instead of classes.

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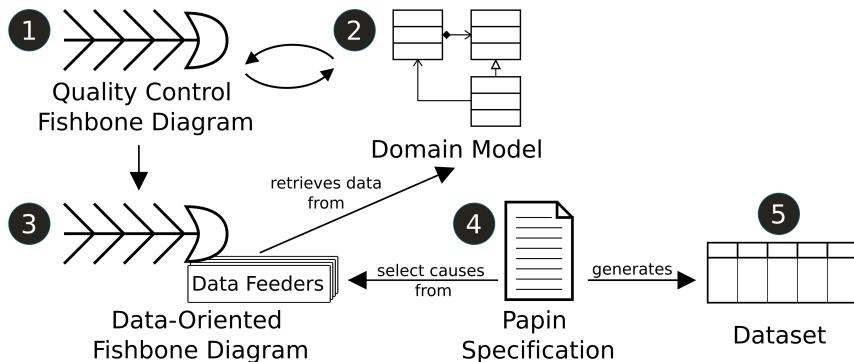
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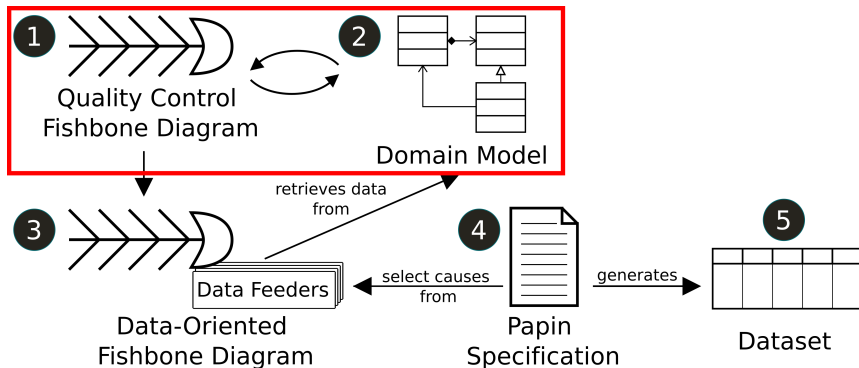
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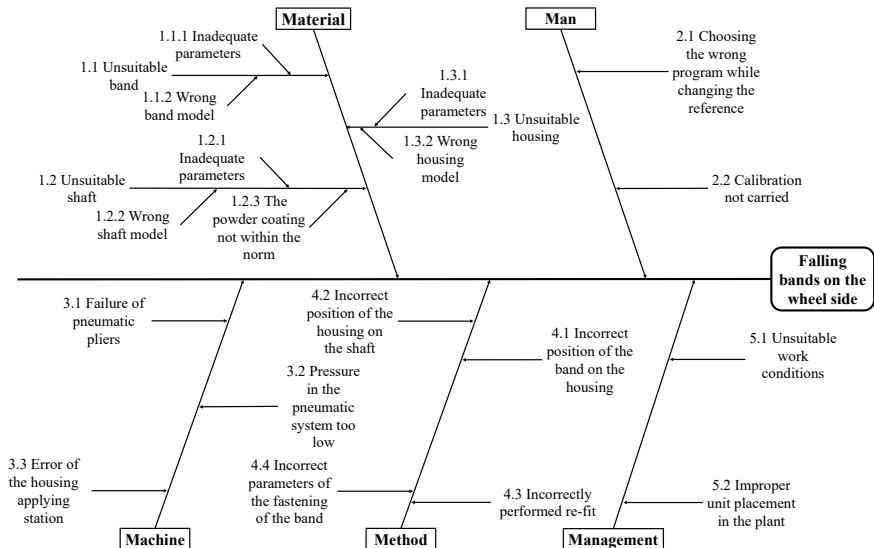
Process Overview



Process Overview



Quality-Control Fishbone diagram (QCF)



Quality-Control Fishbone diagram (QCF)

runtime-EclipseTest - FallingBandProject\FallingBand.qcf - Eclipse Platform

File Edit Navigate Search Project Run Window Help

Model Explorer

type filter text

- DomainModels
 - dummy.model
 - FallingBand.model
 - FallingBand.xml
- FallingBandProject

Outline

- FallingQCF
 - FallingBand
 - Material
 - Unsuitable band
 - Inadequate parameter
 - Wrong band model
 - Unsuitable shaft
 - Inadequate parameters
 - Wrong shaft model
 - The powder coating not within the norm
 - Unsuitable housing
 - Inadequate parameters
 - Wrong housing model
 - Unsuitable housing
 - Man
 - Choosing the wrong program while changing the reference
 - Calibration not carried

FallingBand.xml - DomainModels

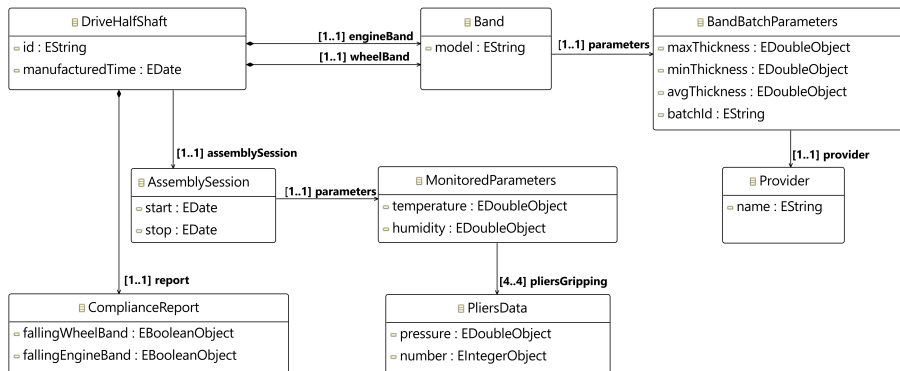
```

qcf FallingQCF
  effect FallingBand description "Falling bands on the wheel side"
  category Material description "Materials used during manufacturing process"
    cause "Unsuitable band" contains {
      cause "Inadequate parameter"
      cause "Wrong band model"
    }
    cause "Unsuitable shaft" contains {
      cause "Inadequate parameters"
      cause "Wrong shaft model"
      cause "The powder coating not within the norm"
    }
    cause "Unsuitable housing" contains {
      cause "Inadequate parameters"
      cause "Wrong housing model"
      cause "Unsuitable housing"
    }
  }
  category Man description "People participating in the process"
    cause "Choosing the wrong program while changing the reference"
    cause "Calibration not carried"
  category Machine description "Elements of the machines and tools used in the process"
    cause "Failure of pneumatic pliers"
    cause "Pressure in the pneumatic system too low"
    cause "Error of the housing applying station"
  category Method description "Procedure used to manufacture an item"
    cause "Incorrect position of the band on the housing"
    cause "Incorrect position of the housing on the shaft"
    cause "Incorrectly performed re-fit"
    cause "Incorrect parameters of the fastening of the band"
  category Management description "General aspects of the process"
    cause "Unsuitable work conditions"
    cause "Improper unit placement in the plant"
  
```

Problems Properties Error Log Console EClass Information

No consoles to display at this time.

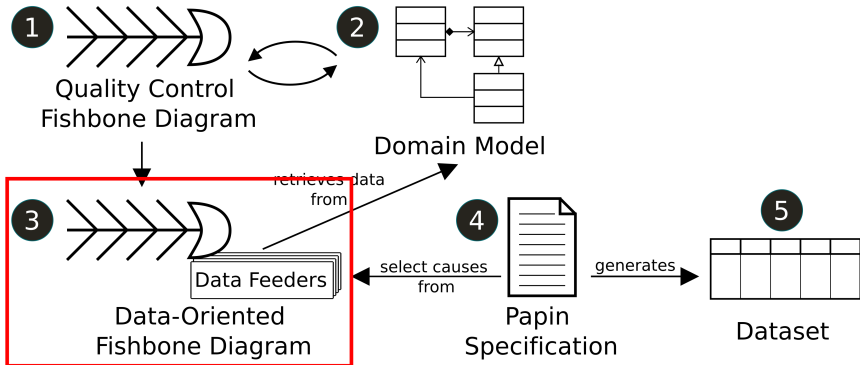
Object-Oriented Domain Model



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Data-Oriented Fishbone Diagrams (DOFs)



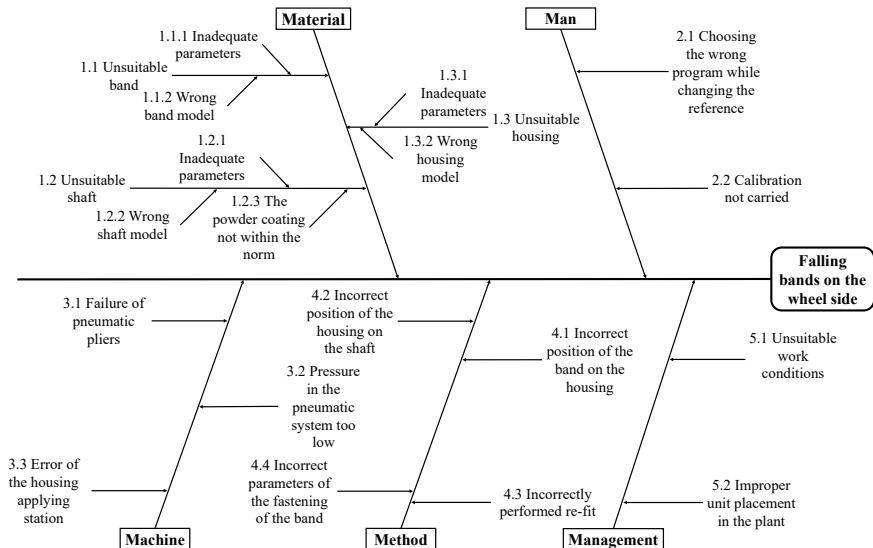
Data-Oriented Fishbone Diagrams (DOFs)

```

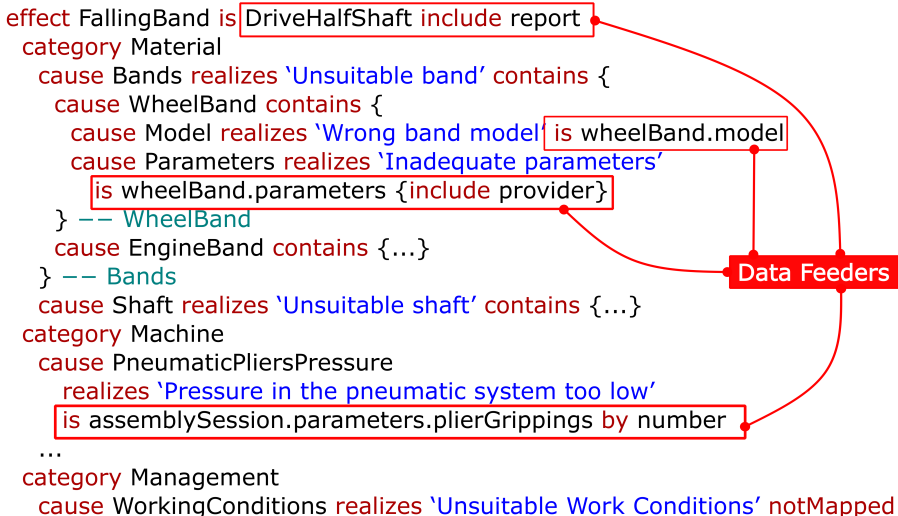
effect FallingBand is DriveHalfShaft include report
category Material
  cause Bands realizes 'Unsuitable band' contains {
    cause WheelBand contains {
      cause Model realizes 'Wrong band model' is wheelBand.model
      cause Parameters realizes 'Inadequate parameters'
        is wheelBand.parameters {include provider}
    } -- WheelBand
    cause EngineBand contains {...}
  } -- Bands
  cause Shaft realizes 'Unsuitable shaft' contains {...}
category Machine
  cause PneumaticPliersPressure
    realizes 'Pressure in the pneumatic system too low'
    is assemblySession.parameters.plierGrippings by number
  ...
category Management
  cause WorkingConditions realizes 'Unsuitable Work Conditions' notMapped

```

Data-Oriented Fishbone Diagrams (DOFs)



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Data-Oriented Fishbone Diagrams (DOFs)

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Data-Oriented Fishbone Diagrams (DOFs)

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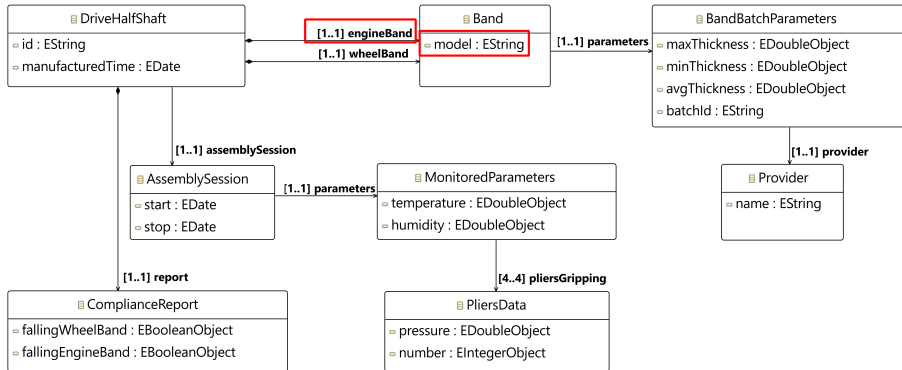
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Data-linked Causes

Data-Oriented Fishbone Diagrams (DOFs)



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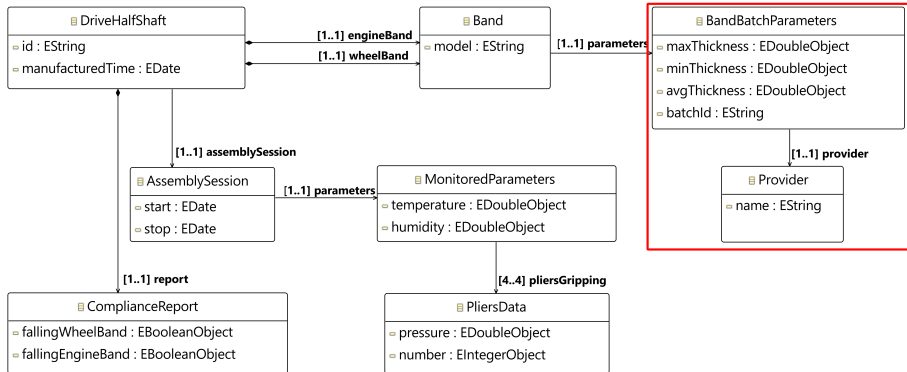
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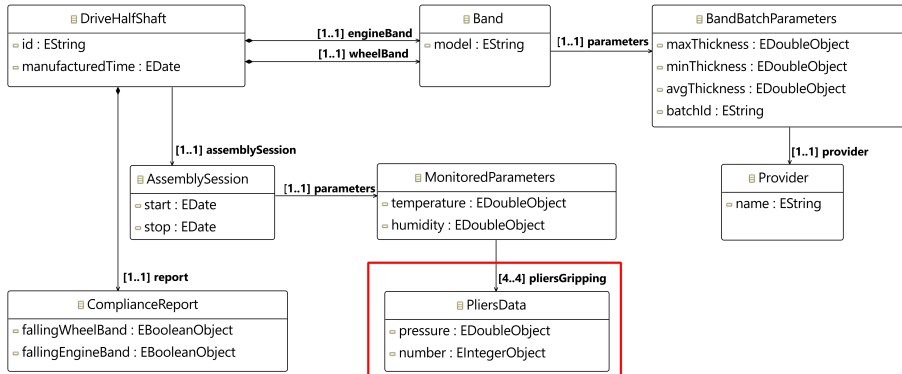
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  } -- WheelBand
  cause EngineBand contains {...}
} -- Bands
```

Compound Cause

cause Shaft realizes 'Unsuitable shaft' contains {...}
category Machine

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cause PneumaticPliersPressure
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Data-Oriented Fishbone Diagrams (DOFs)

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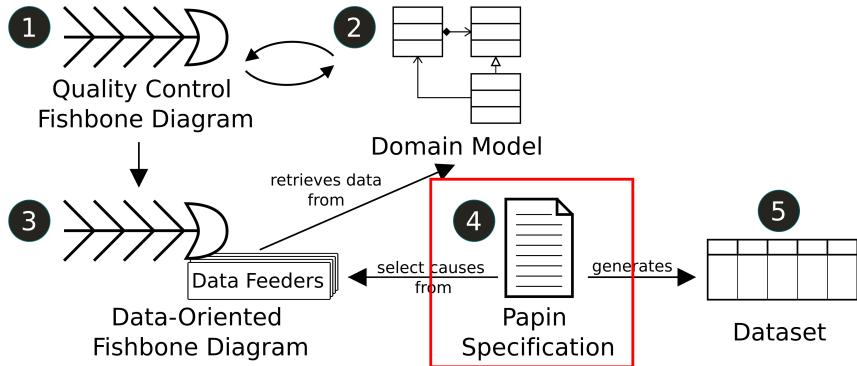
```

Not-Mapped Cause

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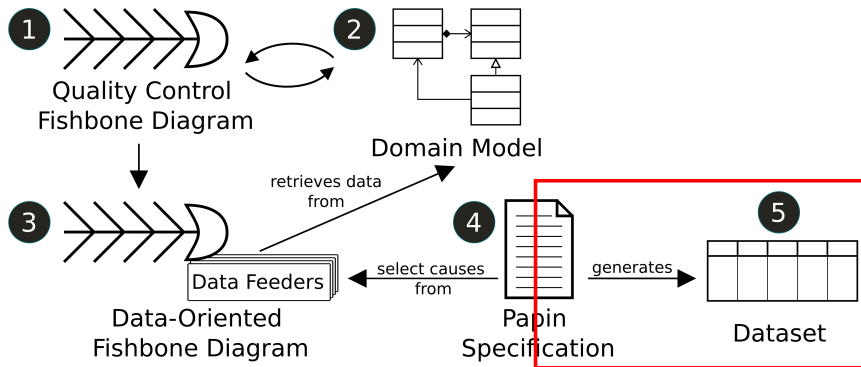
Papin Syntax



Papin Syntax

```
dataset FallingBand_MaterialsAndPressures  
  using FallingBand {  
    include Material  
    include Machine {  
      include PneumaticPliersPressure  
    }  
  }
```

Papin Interpreter



Papin Interpreter

```

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Papin Interpreter

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cause Bands realizes 'Unsuitable band' contains {

cause WheelBand contains {

cause Model realizes 'Wrong band model' is wheelBand.model

cause Parameters realizes 'Inadequate parameters'

is wheelBand.parameters {include provider}

} -- WheelBand

cause EngineBand contains {...}

} -- Bands

cause Shaft realizes 'Unsuitable shaft' contains {...}

category Machine

cause PneumaticPliersPressure

realizes 'Pressure in the pneumatic system too low'

is assemblySession.parameters.plierGrippings by number

...

category Management

cause WorkingConditions realizes 'Un



id	wheelBand_Model
75689	567256C
...	...



id	maxThickness	minThickness	avgThickness	batchId	provider
75689	1.27	1.24	1.26	202156-FGT	Williamson Inc.
...	...	...	...	...	...



id	pliersGripping_0	pliersGripping_1	pliersGripping_2	pliersGripping_4
75689	600	603	602	598
...	...	...	...	...

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- 1 We have adapted Lavoisier for working with Ishikawa diagrams, which might be more suitable in Industry 4.0 contexts.
- 2 DOFs expressiveness has been evaluated using 4 case studies.
- 3 Complexity reduction has not been measured yet.
- 4 Results similar to Lavoisier are expected.
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Thanks for your attention.



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