

KE tool documentation

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Introduction and Scope

KE (Knowledge Extraction) tool is a set of objects built using different Python libraries but mainly RPy (<http://rpy.sourceforge.net/legacy/>). The current version of KE tool is based on RPy2 (<http://rpy.sourceforge.net/>), which is a redesign and rewrite of RPy.

The scope of the tool is to provide simulation modellers with a collection of objects that can be connected like "black boxes" in order to facilitate both the input and output data process in a simulation model. This collection is desired to be expandable by giving means to developers for:

- customizing existing objects by overriding certain methods
- adding brand new objects to the list

KE tool is product of a research project funded from the European Union Seventh Framework Programme (FP7-2012-NMP-ICT-FoF) under grant agreement n° 314364. The project name is DREAM and stands for "*Simulation based application Decision support in Real-time for Efficient Agile Manufacturing*". More information about the scope of DREAM can be found at <http://dream-simulation.eu/>.

DREAM is a project which kicked off in October of 2012 and finishes in September of 2015. KE tool is an ongoing project and we do not claim that it is complete or bug-free. The platform will be expanded and validated through the industrial pilot cases of DREAM. Nevertheless, it is in a quite mature state to attract the interest of simulation modellers and software developers.

The dream repository contains the following 4 folders:

- **platform**: contains code for a GUI (Graphical User Interface) that is being built for KE tool and ManPy, which stands for "Manufacturing in Python" and it is a layer of Discrete Event Simulation (DES) objects built in SimPy (<http://simpy.sourceforge.net/>). This is a parallel work and it is not always synchronized to KE tool's or ManPy's latest version
- **simulation**: contains all the simulation ManPy code along with some input files and some files from a commercial simulation package that are used for verification
- **KnowledgeExtraction**: contains all the KE tool code along with some input and output files from KE tool's examples
- **test**: contains unit-tests for the project.

This document regards ONLY the KE tool part of the project. Note that KE tool is independent from both the GUI and ManPy and can be used separately as a library of Python objects, which can be used to input data in a simulation model or to conduct output analysis on simulation results. Users can implement alternative methods to be able to customize the objects for their own needs.

The reader of this documentation needs to have basic, yet not deep knowledge of programming in Python (<http://www.python.org/>) and RPy2. Also the reader is expected to have a basic knowledge of statistical analysis and Discrete Event Simulation (DES).

1. How to get started

To be able to run the documentation examples just copy the dream folder to your Python folder. Then you can import ManPy objects as it is written in the examples, e.g.:

- `from dream.KnowledgeExtraction.StatisticalMeasures import BasicStatisticalMeasures`
- `from dream.KnowledgeExtraction.ConfidenceIntervals import Intervals`

KE tool uses the R project (<http://www.r-project.org/>) and the following Python libraries which need to be installed in order to run the examples:

- RPy2 (<https://pypi.python.org/pypi/rpy2>)
- xlrd (<https://pypi.python.org/pypi/xlrd/0.9.3>)
- xlwt (<https://pypi.python.org/pypi/xlwt/0.7.5>)
- json (<https://pypi.python.org/pypi/python-json/3.4>)
- xml.etree (<https://pypi.python.org/pypi/elementtree/>)
- csv (<https://pypi.python.org/pypi/csv/1.0>)
- pyodbc (<https://pypi.python.org/pypi/pyodbc/3.0.7>)

2. Architecture

KE tool objects are written exclusively in Python and they use methods of RPy2 and other aforementioned Python libraries. Figure 1 shows the current state of the generic architecture.

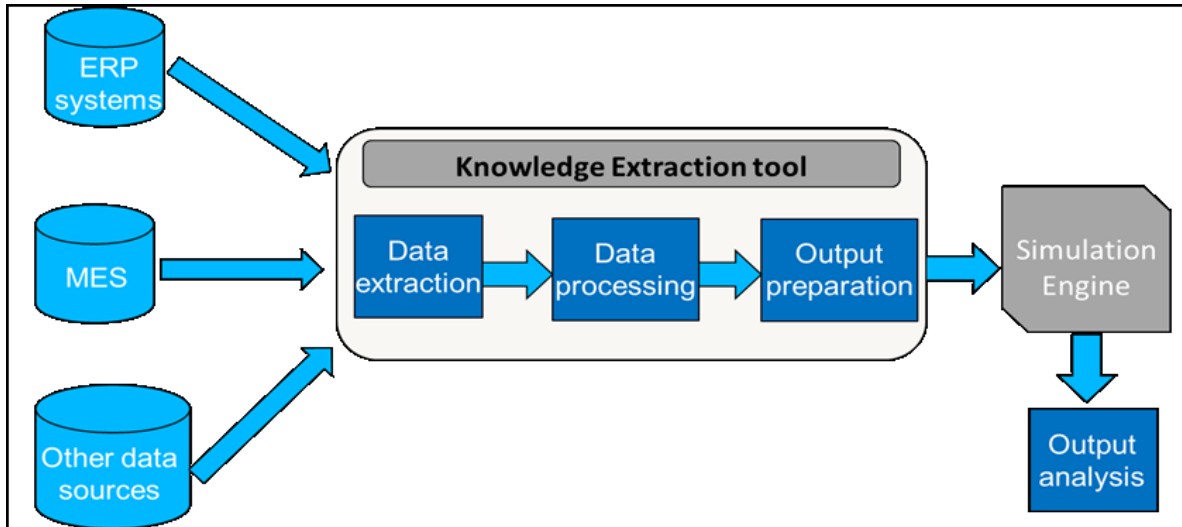


Figure 1: KE tool's architecture

In Figure 1 the four different components of the KE tool are depicted:

- Data extraction
- Data processing
- Output preparation
- Output analysis

Figure 1 illustrates at one hand the route of data to the Simulation Engine (either COTS (Commercial-off-the-self) simulation software or open-source simulation engines like ManPy) and at the other hand the analysis conducted to simulation results.

The import and extraction of data to the tool is the main role of the first component “Data extraction” (see Figure 1). After the initial extraction, some process may be needed to transform the samples into a useful form. For instance, to obtain process time of a station in a production line, the stop time has to be subtracted from the start time. Additionally, after having the actual process time data points, this data should be analysed using statistical methods in order to calculate statistical measures or fit a distribution. The above work is mainly conducted by the second component of the tool called “Data processing” (see Figure 1). The outcome of the “Data processing” component of the tool should be provided in a readable format to ManPy, this is exactly the role of the third component called “Output preparation” (see Figure 1). At the moment, KE tool can export data in three different data formats.

These data formats are the following:

- CMSD standard (http://www.nist.gov/manuscript-publication-search.cfm?pub_id=908209), so Extensible Markup Language (XML) files that follow the CMSD specification,
- JSON format (<http://www.json.org/>),
- MS Excel files, using the xlwt Python library (<https://pypi.python.org/pypi/xlwt>)

The last component of the tool comes after the run of the simulation application called “Output analysis” (see Figure 1). Output simulation analysis is the last modeling stage in a simulation study; it is concerned with the statistical analysis of the output data.

The tool is built in a way that the data input, the processing of this data and the output preparation are conducted by a separate script. We refer to this script as the “main script”. This main script is the only one to be changed in order to read data from different files. Therefore, this main script calls different objects so as to give as an output the actual selected data exchange file format, updated with the new available data. As it is stated in the Introduction, the main script consists of different tool’s objects connected like “black boxes” in order to facilitate both the input and output data process in a simulation model.

2.1 KE tool objects

The set of these objects is the “heart” of KE tool. These give the basic guidelines of how the tool is structured. Note that since this is an ongoing work, the names of the classes may change, since we currently think towards the best abstraction. Also new generic classes might be added in future versions, even though the number should be kept reasonably short. The objects include:

- **StatisticalMeasures:** calculates a variety of basic statistical measures in a given data sample
- **DistributionFitting:** fits statistical distributions in a given data sample.
- **ReplaceMissingValues:** replaces missing values in a given data sample.
- **ImportExcelData:** retrieves data from a MS Excel file and imports this in the tool
- **ImportCSVdata:** retrieves data from a CSV file and imports this in the tool
- **ImportDatabase:** allows the user to connect with a database given that the user has provided the connection data in a .txt file
- **CMSD_Output:** exports the outcomes of the statistical analysis in XML file that follow the CMSD standard specification.
- **JSON_Output:** exports the outcomes of the “Data processing” component into JSON (JavaScript Object Notation) file format.
- **ExcelOutput:** another export offered by the tool is in MS Excel files.
- **Plots:** represents data using graphs, plots and charts or the data points of the sample
- **ConfidenceIntervals:** calculates the confidence intervals of a given data sample. It gives to user the ability to insert the probability that the confidence interval “covers” the true statistic.
- **Transformations:** calculates a variety of transformations in a given data sample

- **DataManipulation:** a series of manipulations in the given data set is conducted applying this object
- **DetectOutliers:** detects and deletes either just extreme outliers or both mild and extreme outliers in a given data sample

In the following subsections details for the methods and the functionality provides in each of the above objects are described.

2.1.1 StatisticalMeasures

This is one of the most important objects of the “Data processing” component of the tool. Applying the method “BasicStatisticalMeasures” of this object, one is able to calculate different useful statistical measures in a data set. An example of this object, with the calculation of the length of a data set is presented below:

```
#The BasicStatisticalMeasures object
class BasicStatisticalMeasures:
# A variety of statistical measures are calculated in this object
    def length(self, data):          #Calculate the length of data sample
        data=objects.FloatVector(data) ##The given list changes into float vector in
                                         order to be handled by RPy2
        rlength = objects.r['Length'] #Call length function-R function
        return rlength(data)[0]
```

Other available statistical measures like mean value, variance, standard deviation, length, summary, quantiles, frequency of each data point, range, interquartile range, min, max, mad and median can be calculated so as to extract useful information from a data sample.

Using this information one can describe a data set and we using the results provide useful information to the simulation software. The above measures called descriptive statistics and provide simple summaries about the sample and about the observations that have been made. The analysis that is conducted to calculate these measures is called Univariate analysis. Univariate analysis involves describing the distribution of a single variable, including its central tendency (including the mean, median, and mode) and dispersion (including the range and quantiles of the data set, and measures of spread such as the variance and standard deviation).

2.1.2 DistributionFitting

DistributionFitting object is the most useful and applied object in the “Data processing” component of the tool. Calling this object one is able to choose between two options, which essentially are the two classes of this object. These classes representing the method that the modeler is able to choose in order to fit a data set in a statistical distribution. Using the first class “Distributions” the modeler is able to conduct distribution fitting with Maximum Likelihood Estimation statistical method (see below). Applying the second class “DistFittest” the modeler based his distribution identification on the Kolmogorov-Smirnov statistical goodness-of-fit test (this test calculates the maximum distance between the empirical and the fitted Cumulative Distribution Functions (CDF), which is applied for automatically selecting the best-fitting distribution (see below).

- Part of Distribution class (Normal distribution)

```
#The Distributions class
class Distributions:

    def Normal_distrfit(self,data):
        data=objects.FloatVector(data)          #The given data sample changes into float
        vector in order to be handled by RPy2
        rFitDistr=objects.r['fitdistr']          #Call FitDistr function - R function
        try:                                     #try..except syntax to test if
            the data sample fits to Normal distribution
            self.Normal= rFitDistr(data,'Normal')  #It fits the normal distribution
            to the given data sample
        except RuntimeError:
            return None                          #If it doesn't fit Return None
        myDict = {'distributionType':'Normal','mean':self.Normal[0][0],'stdev':
self.Normal[0][1],'min':0, 'max':(self.Normal[0][0]+3*self.Normal[0][1])}
        #Create a dictionary with keys distribution's and distribution's parameters names
        and the parameters' values
        return myDict                          #If there is no Error return the
        dictionary with the Normal distribution parameters for the given data sample
```

- Part of DistFittest class (Exponential distribution)

```
#The Distribution Fitting test class
class DistFittest:

    def Exp_kstest(self,data):
        data=objects.FloatVector(data)          #The given data sample changes into
        float vector in order to be handled by RPy2
        rkstest= objects.r['ks.test']            #Call ks.test function - R function
        rFitDistr=objects.r['fitdistr']          #Call FitDistr function - R function
        try:                                     #try..except syntax to test if the
            data sample fits to Exponential distribution
            self.Normal= rFitDistr(data,'Exponential')  #It fits the exponential
            distribution to the given data sample
        except RuntimeError:
            return None                          #If it doesn't fit Return None
        exp=self.Normal
        self.Exptest= rkstest(data,"pexp",exp[0][0])  #It conducts the Kolmogorov-
            Smirnov test for Exponential distribution to the given data sample
        return self.Exptest                    #If there is no error returns the
        outcome of the Kolmogorov-Smirnov test (p-value,D)
```

At the time of writing this documentation the tool using the functions from RPy2 library can identify and fit data using the following distribution functions:

- Normal
- Exponential
- Poisson
- Gamma
- Logistic

- Geometric
- Cauchy
- Log-Normal
- Negative Binomial
- Weibull
- Fixed
- Triangular
- Beta

2.1.3 ReplaceMissingValues

Another useful functionality mostly for pre-processing is provided using the *ReplaceMissingValue* object of the tool. Applying the class *HandleMissingValues* the modeler is able to select the functionality (Python method) that suits him best. It is worth mentioning that this object inherits methods from the *StatisticalMeasures* object. Data preparation and pre-processing is a crucial step before the start of the statistical analysis. The main activity of the data pre-processing step is to handle the missing values in a data set. Using this object the modeler is able to replace the missing data with:

- zero,
- mean value
- median of the non-missing values,
- totally erase the missing data.

2.1.4 DetectOutliers

The *DetectOutliers* object is an additional feature provided by the tool for pre-processing analysis. Applying the class *HandleOutliers* the user is able to select one of the two provided approaches – Python methods. The first one deletes both the mild and extreme outliers while the second approach deletes only the extreme outliers in a given data set. Like in *ReplaceMissingValues* object, *DetectOutliers* inherits methods from the *StatisticalMeasures* object. The detection of outliers is done calculating the inner and outer fence of the data set, a point beyond an inner fence on either side (Lower Inner Fence – LIF and Upper Inner fence – UIF) is considered a mild outlier. A point beyond an outer fence (Lower Outer Fence – LOF and Upper Outer Fence – UOF) is considered an extreme outlier. These borders are calculated using the lower and upper quartiles (defined as the 25th and 75th percentiles). If the lower quartile is Q1 and the upper quartile is Q3, then the difference (Q3 - Q1) is called the interquartile range or IQ, then:

- Lower Inner Fence - LIF: $Q1 - 1.5 \cdot IQ$
- Upper Inner Fence - UIF: $Q3 + 1.5 \cdot IQ$
- Lower Outer Fence - LOF: $Q1 - 3 \cdot IQ$
- Upper Outer Fence - UOF: $Q3 + 3 \cdot IQ$

2.1.5 ImportExceldata

The *ImportExceldata* object retrieves data from MS Excel files and imports this data into KE tool, adjusting this data in a way that can be later handled by the other objects of the tool. The

extraction is achieved using the xlrd Python library (<https://secure.simplistix.co.uk/svn/xlrd/trunk/xlrd/doc/xlrd.html?p=4966>). Applying this object and particularly the `Input_data` method of this object the different data points are inserted in the tool in a form of a Python dictionary. The keys of this dictionary are the specified labels of these data points in the excel worksheet. This method as it is reasonable has as argument the name of the worksheet and the name of the input book. It is one of the “Data Extraction” objects of the KE tool.

2.1.6 ImportCSVdata

Another generic object to extract and import data to the tool is applying the *ImportCSVdata* object. As happens with the *ImportExceldata* object a Python library is used to develop this object, this library called `csv` (<https://docs.python.org/2/library/csv.html#module-csv>). The functionality of this object is similar to the *ImportExceldata* object.

2.1.7 ImportDatabase

One more object in the Data extraction component of the tool is the *ImportDatabase* object. Using the `pyodbc` (<https://code.google.com/p/pyodbc/>) Python library we developed a generic object that allows the users to connect with databases like MySQL, MS Access etc. As a prerequisite to use this object is to download the ODBC driver for your Python and database platform, for example if want to access SQL Server connector for Python in MySQL database you should download the driver from [here](#).

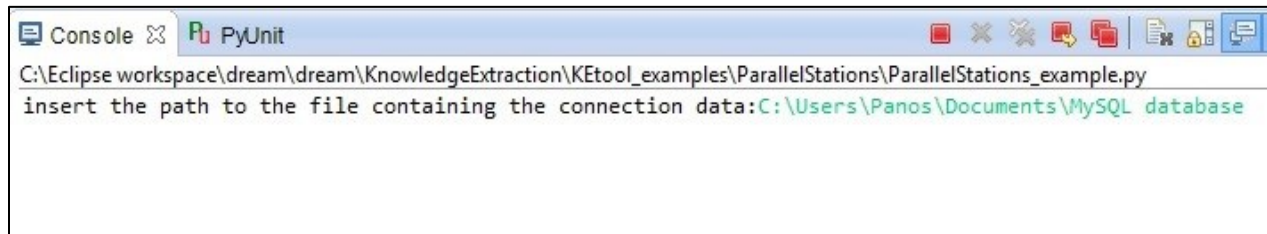
The user in order to apply this object has to create a txt file with his connection information, he should provide info such as the name of the installed driver, the name of the server (which host the database), the port, the name of the database, the username and the password (see below).

```
driver = {MySQL ODBC 3.51 Driver}
server = localhost
port = 3306
data_base = name of the database
user = username
pass_word = xxxxx###
```

Having created the txt file with the above info, the user has to save this file in a directory that he will be able to use it afterwards. Calling the object the user has to specify the name of the txt file, the file extension of this file (for example txt) and the number of cursors need to use (one cursor for each database query). See below the way that the user should call this object:

```
Cnxn = ImportDatabase.ConnectionData(seekName='ServerData', implicitExt='txt',
number_of_cursors=3)
Cursors = cnxn.getCursors()
```

When the user runs the model that contains the *ImportDatabase* object, in his console appears the following message “insert the path to the file containing the connection data:”. The user has to write the connection data file directory. For example in the figure below as you can see we put the file directory as required.



2.1.8 ExcelOutput

The KE tool can export the results from the conducted analysis in the second component of the tool “Data processing” in MS Excel files. The outcomes of the *StatisticalMeasures* and *DistributionFitting* objects are exported in standard templates in Excel files. Applying the Output Python class and especially either the *PrintStatisticlameasures* method (for the results of the *SatatisticlMeasures* object) or the *PrintDistributionFit* (for the results from the *DistributionFitting* object) the model can examine the results of these objects opening an Excel file.

2.1.9 Plots

This object is mainly referring to Output analysis, which is the last component of the KE tool. But the modeler can also apply it during the Data processing component when he wants to present the data points in a data set in a graphical representation. So using this object the modeler can represent data using graphs, plots and charts. So far, we are able to display data in plots, scatterplots, histograms, barplots and pie charts. Each one of the above is separate method of the *Graphs*, which is the class of this object. It is also provided the functionality of the parallel representation of two data sets in a plot.

2.1.10 ConfidenceIntervals

Another object referring to Output analysis component is the *ConfidenceIntervals*. Confidence interval estimation quantifies the confidence (probability) that an interval “covers” the true (but unknown) statistic. The boundaries of the confidence interval are estimated using appropriate point estimates therefore, those boundaries are random variables, and the confidence interval is a random interval which varies across experiments (replications). The modeler predetermines the desired probability that the confidence interval “covers” the true statistic (the larger the probability, the wider the interval).

The *ConfidIntervals* method of the object takes as arguments the data set, in which the modeler wants to estimate the confidence intervals and the desired probability explained above.

2.1.11 Transformations

Another object that mostly refers to the Data processing component of the tool is called Transformations. The modeler applying the methods of this object is able to calculate a variety of really useful sometimes data transformations. The provided functionality include the calculation of the sum, the cumulative sum, the cumulative product, the cumulative min value and the cumulative max value. Also, applying the scale method the modeler can centre the data points of a data set around the mean value and scales by the standard deviation (sd). Finally, using the reverse method, the modeler can reverse the order of values in the data sample.

2.1.12 DataManipulation

DataManipulation object is again close related to the Data processing component of the KE tool. Using the methods of this object, the modeler is able to calculate really helpful measures. The modeler applying these methods gets as results the rounded values of a data sample (*round* method), the smallest integers bigger than the values of the data sample (*ceiling* method), the largest integers smaller than the values of the data sample (*floor*), a list with the absolute values of the data sample (*abs*) and the square root of the values in the data sample (*sqrt*).

2.1.13 CMSD_Output

CMSD_Output is not yet a separate object, but we aspire to develop a generic object to handle all situations in a macro level. Despite that, the tool is able to export the already processed data in XML files that follow the CMSD specification. In the example section the reader can see how we manage to output the processed data to CMSD information model using the xml.etree Python library (<https://docs.python.org/2/library/xml.etree.elementtree.html#>).

2.1.14 JSON_Output

Similar to CMSD_Output the JSON_Output is not yet a separate object but using the json Python library (<https://docs.python.org/2/library/json.html>) the tool is able to export the processed data from the Data processing component of the tool to JSON files. These files follow a specification that has been defined by DREAM project for the sake of communication among the different modules KE tool, GUI, ManPy. Using this specification we have achieved the integration of the different modules of the DREAM platform.

3. Examples

3.1 Two servers model with failures and repairman

We built an example of the KE tool developing a main script of the tool using the above objects in a simple topology. Figure 2 illustrates the graphical representation of the topology modeled in the DREAM platform GUI. In this model we have two Machines and a Queue between them. The Machines are vulnerable to failures and when a failure happens then they need a repairman to get fixed. In this model there is only one repairman available.

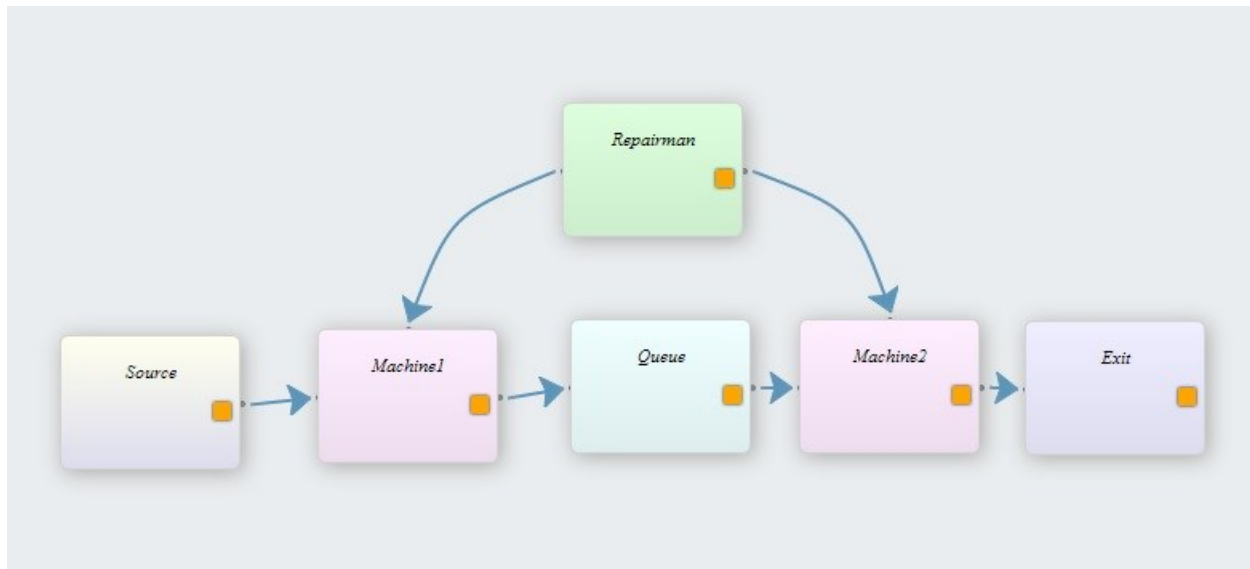


Figure 2: Two servers model with failures and repairman

For the needs of the example we assume that the processing times of the two machines are recorded in a simple Excel file. Having a sample of this data, we use the `ImportExcelData` object to retrieve these data samples with the processing times of the two machines and import them to the tool (“Data extraction” first tool’s component). Then, we make use of the `ReplaceMissingValues` object and we delete the missing values in the data samples in order to continue our process without missing data in the samples. The `DistFittest` object of the `DistributionFitting` script is used so as to perform a Kolmogorov-Smirnov test trying to identify the best fitting statistical distributions for our two data samples. The above two objects complete the operations of the second component “Data processing” for this example. Finally, we export four documents with the updated values coming from the data process, to demonstrate the three available ways to output data from the tool. The four documents are the CMSD information model of the topology, the JSON file based again on the example’s topology and two Excel files with the outcomes of the statistical analysis (calculation of basic statistical measures and distribution fitting results for one data sample). The output of these four ManPy readable documents fulfils the operations of tool’s third component “Output preparation”.

Apart from the main script of the example, in GitHub at there are also available the Excel files with the inputs to the tool (`inputsTwoServers.xls`), the CMSD information model of the topology (`CMSD_TwoServers.xml`) and the JSON file of the topology (`JSON_TwoServers.json`).

Below is the KE tool main script for the topology illustrated in Figure 2.

```

from dream.KnowledgeExtraction.ImportExceldata import Import_Excel
from dream.KnowledgeExtraction.DistributionFitting import DistFittest
from dream.KnowledgeExtraction.ExcelOutput import Output
from dream.KnowledgeExtraction.ReplaceMissingValues import HandleMissingValues
from xml.etree import ElementTree as et
import xlrd
import json

```

```
#===== This script is a simple example of the Knowledge extraction tool =====#
```

```
#The following is the Main script, that calls two Python objects in order to conduct the three main components of the Knowledge extraction tool
```

```
#In the following example the operation times of the topology's two machines are given in an Excel document.
```

```
#Import_Excel object imports data from the Excel document to the tool and DistFittest object fits the data to a statistical distribution using Kolmogorov-Smirnov test
```

```
workbook = xlrd.open_workbook('inputsKEtool.xls')      #Using xlrd library opens the Excel document with the input data
worksheets = workbook.sheet_names()
worksheet_OperationTime = worksheets[0]                #It creates a variable that holds the first Excel worksheet
```

```
X=Import_Excel()                                     #Call the import_Excel object
OperationTimes= X.Input_data(worksheet_OperationTime,workbook)      #It defines a Python dictionary, giving as name OpearationTimes and as value the returned dictionary from the import_Excel object
Machine1_OpearationTimes = OperationTimes.get('Machine1',[])        #Two lists are defined (Machine1_OpearationTimes, Machine2_OpearationTimes) with the operation times data of each machine
Machine2_OpearationTimes = OperationTimes.get('Machine2',[])
```

```
A=HandleMissingValues()                               #Call the HandleMissingValues object
Machine1_OpearationTimes= A.DeleteMissingValue(Machine1_OpearationTimes)      #It deletes the missing values in the lists with the operation times data
Machine2_OpearationTimes= A.DeleteMissingValue(Machine2_OpearationTimes)
```

```
Dict={}
B=DistFittest()                                       #It calls the DistFittest object
Dict['M1']=B.ks_test(Machine1_OpearationTimes)        #It conducts the Kolmogorov-Smirnov test in the list with the operation times data
Dict['M2']=B.ks_test(Machine2_OpearationTimes)
M1=Dict.get('M1')
M2=Dict.get('M2')
```

```
#===== Output preparation: output the updated values in the CMSD information model of Topology10 =====#
```

```
datafile=('CMSD_Topology10.xml')                      #It defines the name or the directory of the XML file that is manually written the CMSD information model
tree = et.parse(datafile)                             #This file will be parsed using the XML.ETREE Python library
```

```
M1Parameters=[]
M1ParameterValue=[]
for index in list(Dict['M1'].keys()):
    if index is not 'distributionType':
        M1Parameters.append(index)
        M1ParameterValue.append(Dict['M1'][index])
if Dict['M1']['distributionType']=='Normal':
```

```

del M1['min']
del M1['max']
elif Dict['M2']['distributionType']=='Normal':
    del M2['min']
    del M2['max']

M2Parameters=[]
M2ParameterValue=[]
for index in list(Dict['M2'].keys()):
    if index is not 'distributionType':
        M2Parameters.append(index)
        M2ParameterValue.append(Dict['M2'][index])

root=tree.getroot()
process=tree.findall('./DataSection/ProcessPlan/Process') #It creates a
new variable and using the 'findall' order in XML.ETREE library, this new variable
holds all the processes defined in the XML file
for process in process:
    process_identifier=process.find('Identifier').text #It creates a
new variable that holds the text of the Identifier element in the XML file
    if process_identifier=='A020': #It checks
using if...elif syntax if the process identifier is 'A020', so the process that uses
the first machine
        OperationTime=process.get('OpeationTime') #It gets the
element attribute OpeationTime inside the Process node
        Distribution=process.get('./OperationTime/Distribution') #It gets the
element attribute Distribution inside the OpeationTime node
        Name=process.find('./OperationTime/Distribution/Name') #It finds the
subelement Name inside the Distribution attribute
        Name.text=Dict['M1']['distributionType']
#It changes the text between the Name element tags, putting the name of the
distribution (e.g. in Normal distribution that will be Normal)

DistributionParameterA=process.get('./OperationTime/Distribution/DistributionParamete
rA')
    Name=process.find('./OperationTime/Distribution/DistributionParameterA/Name')
    Name.text=str(M1Parameters[0]) #It changes the
text between the Name element tags, putting the name of the distribution's first
parameter (e.g. in Normal that will be the mean)

Value=process.find('./OperationTime/Distribution/DistributionParameterA/Value')
    Value.text=str(M1ParameterValue[0]) #It changes the
text between the Value element tags, putting the value of the distribution's first
parameter (e.g. in Normal so for mean value that will be 5.0)

DistributionParameterB=process.get('./OperationTime/Distribution/DistributionParamete
rB')
    Name=process.find('./OperationTime/Distribution/DistributionParameterB/Name')
    Name.text=str(M1Parameters[1]) #It changes the
text between the Name element tags, putting the name of the distribution's second
parameter (e.g. in Normal that will be the standarddeviation)

Value=process.find('./OperationTime/Distribution/DistributionParameterB/Value')

```

```

        Value.text=str(M1ParameterValue[1]) #It changes the
text between the Value element tags, putting the value of the distribution's second
parameter (e.g. in Normal so for standarddeviation value that will be 1.3)
    elif process_idenfifier=='A040': #It checks using
if...elif syntax if the process identifier is 'A040', so the process that uses the
second machine
        OperationTime=process.get('OpeationTime')
        Distribution=process.get('./OperationTime/Distribution')
        Name=process.find('./OperationTime/Distribution/Name')
        Name.text=Dict['M2']['distributionType']

DistributionParameterA=process.get('./OperationTime/Distribution/DistributionParamete
rA')
        Name=process.find('./OperationTime/Distribution/DistributionParameterA/Name')
        Name.text=str(M2Parameters[0])

Value=process.find('./OperationTime/Distribution/DistributionParameterA/Value')
        Value.text=str(M2ParameterValue[0])

DistributionParameterB=process.get('./OperationTime/Distribution/DistributionParamete
rB')
        Name=process.find('./OperationTime/Distribution/DistributionParameterB/Name')
        Name.text=str(M2Parameters[1])

Value=process.find('./OperationTime/Distribution/DistributionParameterB/Value')
        Value.text=str(M2ParameterValue[1])
    else:
        continue
    tree.write('CMSD_Topology10_Output.xml',encoding="utf8")
#It writes the element tree to a specified file, using the 'utf8' output encoding

    #===== Output preparation: output the updated values in the JSON file of
    Topology10 =====#
jsonFile= open('JSON_Topology10.json','r') #It opens the Topology10 JSON file
data = json.load(jsonFile)
#It loads the file
jsonFile.close()
nodes=data.get('coreObject',[])
#It creates a variable that holds the 'coreObject' list

for element in nodes:
    name=element.get('name')
#It creates a variable that gets the element attribute 'name'
    processingTime=element.get('processingTime',{})
#It creates a variable that gets the element attribute 'processingTime'

    if name == 'Machine1':
        element['processingTime']=Dict['M1'] #It checks
using if...elif syntax if the name is 'Machine1', so the first machine in the
Topology10
    elif name=='Machine2':
        element['processingTime']=Dict['M2']
    else:
        continue

```



```

    jsonFile = open('JSON_Topology10_Output.json', "w")           #It opens the JSON file
    jsonFile.write(json.dumps(data, indent=True))
#It writes the updated data to the JSON file
    jsonFile.close()
#It closes the file

#===== Calling the ExcelOutput object, outputs the outcomes of the statistical
#analysis in Excel files =====#
C=Output()
C.PrintDistributionFit(Machine1_OpearationTimes, 'Machine1_DistFitResults.xls')
C.PrintStatisticalMeasures(Machine1_OpearationTimes, 'Machine1_StatResults.xls')
C.PrintDistributionFit(Machine2_OpearationTimes, 'Machine2_DistFitResults.xls')
C.PrintStatisticalMeasures(Machine2_OpearationTimes, 'Machine2_StatResults.xls')

```

The above main script consists of four KE tool objects and it has also parts for CMSD_Output and JSON_Output. The CMSD, JSON and Excel output files can easily be obtained by downloading and running the example. In Appendices the reader can see the above output files.

3.2 Production line

Another example of the KE tool is built developing a main script using the objects in a real production line. Figure 3 illustrates the graphical representation of the production line modeled in the DREAM platform GUI. In this model we have several Machines (P1 - P11) operating in parallel, Queues between them and other simulation objects between them. The Machines are vulnerable to failures so scrap parts are produced. We've got information about the processing times and the scrap quantity in each of the machines in the production line.

In this example separate methods for this specific example were developed for the output of CMSD and JSON files. The *CMSD_Output* object is developed using the xml.etree Python library and writing in a script the whole CMSD information model for this example, so resource, process plan and process definitions of CMSD specification have been developed based on production line's logic. The same happens with *JSON_Output* object, which again is a separate method tailored to the specific example and the only difference with the *CMSD_Output* is that the JSON file is manually developed.

The above described objects along with the main script of this example and the .xls file with the processing times and scrap quantity data are available at GitHub repository in KEtool_examples folder.

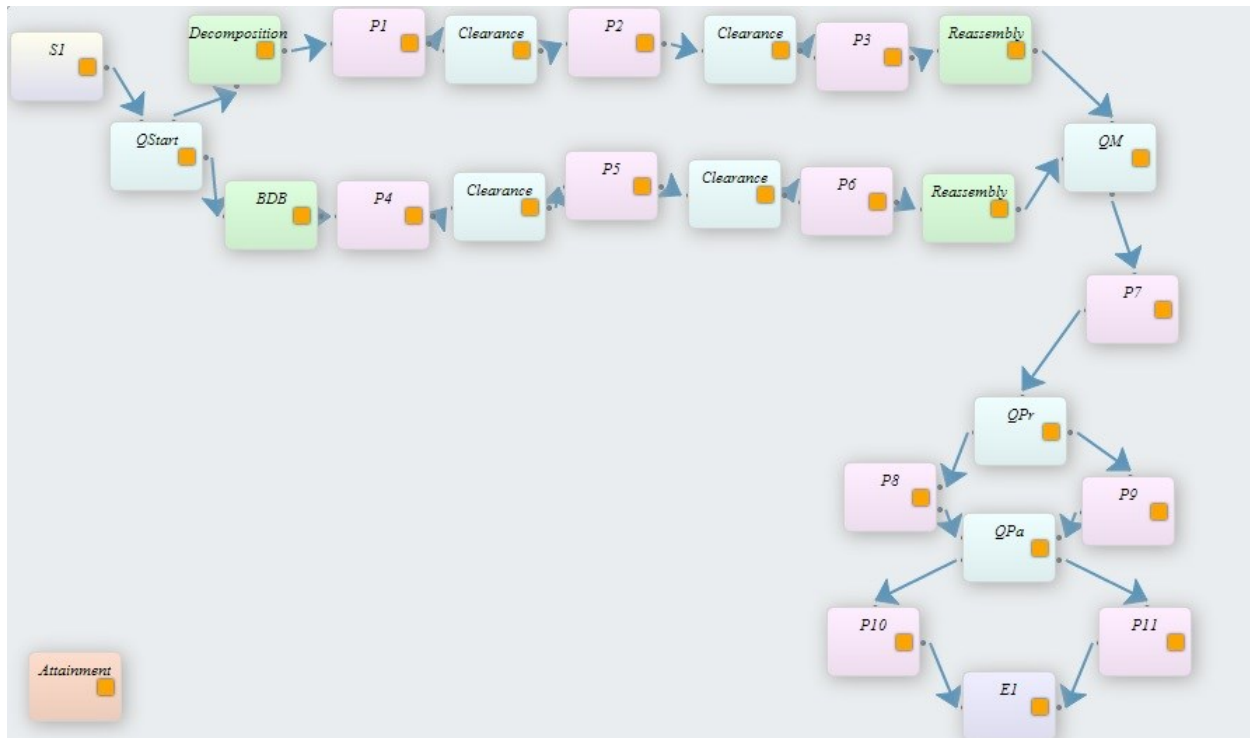


Figure 3: Production line

Below is the KE tool main script for the production line illustrated in Figure 3.

```

from dream.KnowledgeExtraction.StatisticalMeasures import BasicStatisticalMeasures
from dream.KnowledgeExtraction.DataManipulation import DataManagement
from dream.KnowledgeExtraction.DistributionFitting import DistFittest
from dream.KnowledgeExtraction.CMSD_Output import CMSD_example
from dream.KnowledgeExtraction.JSON_Output import JSON_example
from dream.KnowledgeExtraction.ExcelOutput import Output
from dream.KnowledgeExtraction.ReplaceMissingValues import HandleMissingValues
from dream.KnowledgeExtraction.ImportExceldata import Import_Excel
import xlrd

#import ManPy main JSON script
import dream.simulation.LineGenerationJSON as ManPyMain
#===== Main script of KE tool =====#

#Read from the given directory the Excel document with the input data
workbook = xlrd.open_workbook('inputData.xls')
worksheets = workbook.sheet_names()
worksheet_ProcessingTimes = worksheets[1] #Define the worksheet with the
Processing times data
worksheet_ScrapQuantity = worksheets[0] #Define the worksheet with the Scrap
Quantity data

A=Import_Excel() #Call the Python object Import_Excel
ProcessingTimes= A.Input_data(worksheet_ProcessingTimes, workbook) #Create the
Processing Times dictionary with keys the different stations in the line and values
the processing times of different batches in these stations

```

```

ScrapQuantity=A.Input_data(worksheet_ScrapQuantity, workbook)          #Create the
Scrap Quantity dictionary with keys the different stations in the line and values the
scrap quantity data of different batches in these stations

##Get from the Scrap Quantity dictionary the different keys and define the following
lists with the scrap quantity data of the different stations in the topology
P1_Scrap= ScrapQuantity.get('P1',[])
P2_Scrap= ScrapQuantity.get('P2',[])
P3_Scrap= ScrapQuantity.get('P3',[])
P4_Scrap= ScrapQuantity.get('P4',[])
P5_Scrap= ScrapQuantity.get('P5',[])
P6_Scrap= ScrapQuantity.get('P6',[])
P7_Scrap= ScrapQuantity.get('P7',[])
P8_Scrap= ScrapQuantity.get('P8',[])
P9_Scrap= ScrapQuantity.get('P9',[])
P10_Scrap= ScrapQuantity.get('P10',[])
P11_Scrap= ScrapQuantity.get('P11',[])
##Get from the Processing times dictionary the different keys and define the
following lists with the processing times data of the different stations in the
topology
P1_Proc= ProcessingTimes.get('P1',[])
P2_Proc= ProcessingTimes.get('P2',[])
P3_Proc= ProcessingTimes.get('P3',[])
P4_Proc= ProcessingTimes.get('P4',[])
P5_Proc= ProcessingTimes.get('P5',[])
P6_Proc= ProcessingTimes.get('P6',[])
P7_Proc= ProcessingTimes.get('P7',[])
P8_Proc= ProcessingTimes.get('P8',[])
P9_Proc= ProcessingTimes.get('P9',[])
P10_Proc= ProcessingTimes.get('P10',[])
P11_Proc= ProcessingTimes.get('P11',[])
#Call the HandleMissingValues object and replace with zero the missing values in the
lists with the scrap quantity data
B= HandleMissingValues()
P1_Scrap= B.ReplaceWithZero(P1_Scrap)
P2_Scrap= B.ReplaceWithZero(P2_Scrap)
P3_Scrap= B.ReplaceWithZero(P3_Scrap)
P4_Scrap= B.ReplaceWithZero(P4_Scrap)
P5_Scrap= B.ReplaceWithZero(P5_Scrap)
P6_Scrap= B.ReplaceWithZero(P6_Scrap)
P7_Scrap= B.ReplaceWithZero(P7_Scrap)
P8_Scrap= B.ReplaceWithZero(P8_Scrap)
P9_Scrap= B.ReplaceWithZero(P9_Scrap)
P10_Scrap= B.ReplaceWithZero(P10_Scrap)
P11_Scrap= B.ReplaceWithZero(P11_Scrap)
# #Call the BasicStatisticalMeasures object
C= BasicStatisticalMeasures()
#Create a list with values the calculated mean value of scrap quantity on the
different stations in the line
listScrap=[C.mean(P1_Scrap),C.mean(P2_Scrap),C.mean(P3_Scrap),C.mean(P4_Scrap),C.mean
(P5_Scrap),C.mean(P6_Scrap),C.mean(P7_Scrap),C.mean(P8_Scrap),C.mean(P9_Scrap),C.mean
(P10_Scrap), C.mean(P11_Scrap)]

D= DataManagement()

```

```

listScrap=D.round(listScrap)          #Round the mean values of the list so as to get
integers

dictScrap={}
dictScrap['P1']= listScrap[0]
dictScrap['P2']= listScrap[1]
dictScrap['P3']= listScrap[2]
dictScrap['P4']= listScrap[3]
dictScrap['P5']= listScrap[4]
dictScrap['P6']= listScrap[5]
dictScrap['P7']= listScrap[6]
dictScrap['P8']= listScrap[7]
dictScrap['P9']= listScrap[8]
dictScrap['P10']= listScrap[9]
dictScrap['P11']= listScrap[10]

E= DistFittest()          #Call the DistFittest object

dictProc={}
dictProc['P1']= E.ks_test(P1_Proc)
dictProc['P2']= E.ks_test(P2_Proc)
dictProc['P3']= E.ks_test(P3_Proc)
dictProc['P4']= E.ks_test(P4_Proc)
dictProc['P5']= E.ks_test(P5_Proc)
dictProc['P6']= E.ks_test(P6_Proc)
dictProc['P7']= E.ks_test(P7_Proc)
dictProc['P8']= E.ks_test(P8_Proc)
dictProc['P9']= E.ks_test(P9_Proc)
dictProc['P10']= E.ks_test(P10_Proc)
dictProc['P11']= E.ks_test(P11_Proc)

F= Output()
F.PrintDistributionFit(P2_Proc, "DistributionFittingResults_P2Proc.xls")
F.PrintStatisticalMeasures(P2_Proc, "StatisticalMeasuresResults_P2Proc.xls")

CMSD_example(dictProc,dictScrap)      #Print the CMSD document, calling the
CMSD_example method with arguments the dictProc and dictScrap dictionaries
JSON_example(dictProc,dictScrap)      #Print the JSON file, calling the JSON_example
method

#calls ManPy main script with the input
simulationOutput=ManPyMain.main(input_data=str((JSON_example(dictProc,dictScrap))))
# save the simulation output
jsonFile = open('ManPyOutput.json', "w")      #It opens the JSON file
jsonFile.write(simulationOutput)              #It writes the updated data to the JSON file
jsonFile.close()                             #It closes the file

```

The above main script consists of eight KE tool objects (see the comments in the script). The CMSD, JSON and Excel output files can easily be obtained by downloading and running the example. In Appendices one can see the exported CMSD, JSON file and ManPy output JSON file with the simulation results.

In the tables below the simulation results after the 10 times run of the simulation model are presented. The first table shows the results of measures on the Exit station such as throughput etc., while the second table presents the results in one of model's stations, measures such as working ratio, blockage ratio and waiting ratio are illustrated with confidence intervals calculated by ManPy using the *ConfidenceIntervals* object of the KE tool.

Simulation results			
"unitsThroughput"	"throughput"	"takt_time"	"lifespan"
3040	32	43.69950037	761.7374959
3135	33	43.26117961	756.5203249
3230	34	42.16693359	769.0966312
2945	31	45.14615867	768.6464697
3040	32	44.95555252	801.2514402
3040	32	44.78584679	764.5391421
3135	33	43.56360076	792.4484177
3135	33	42.47776569	771.6289614
3040	32	44.60040914	769.6977449
3135	33	43.13267567	771.9918783

Simulation results		
"working_ratio"	"blockage_ratio"	"waiting_ratio"
" <u>avg</u> ": 50.102895148547	" <u>avg</u> ": 48.23664435861	" <u>avg</u> ": 1.660460492836
" <u>lb</u> ": 49.247498682836	" <u>lb</u> ": 47.201622043610	" <u>lb</u> ": 1.1595327223622
" <u>ub</u> ": 50.958291614258	" <u>ub</u> ": 49.27166667362	" <u>ub</u> ": 2.1613882633105

3.3 Parallel stations and Queue model

Another simple example of the KE tool is developed in order to demonstrate the use of the *ImportDatabase* object. Figure 4 illustrates the graphical representation of the model modeled in the DREAM platform GUI. In this model we have two machines Milling1 and Milling2 operating in parallel, one Queue before them, one source and one exit. The machines are vulnerable to failures so when a failure happens then they need a repairman to get fixed. In this model there is only one repairman available.

We've got information about the processing times and the MTTF and MTTR in each of the machines in the production line. For this particular example a simple database is developed that hosts the above information. The database is developed in MySQL; the SQL script of this database is available in the example folder. In order to run the example the user needs to import this SQL script in his local SQL editor and create the database, using their own connection information (see *ImportDatabase* object).

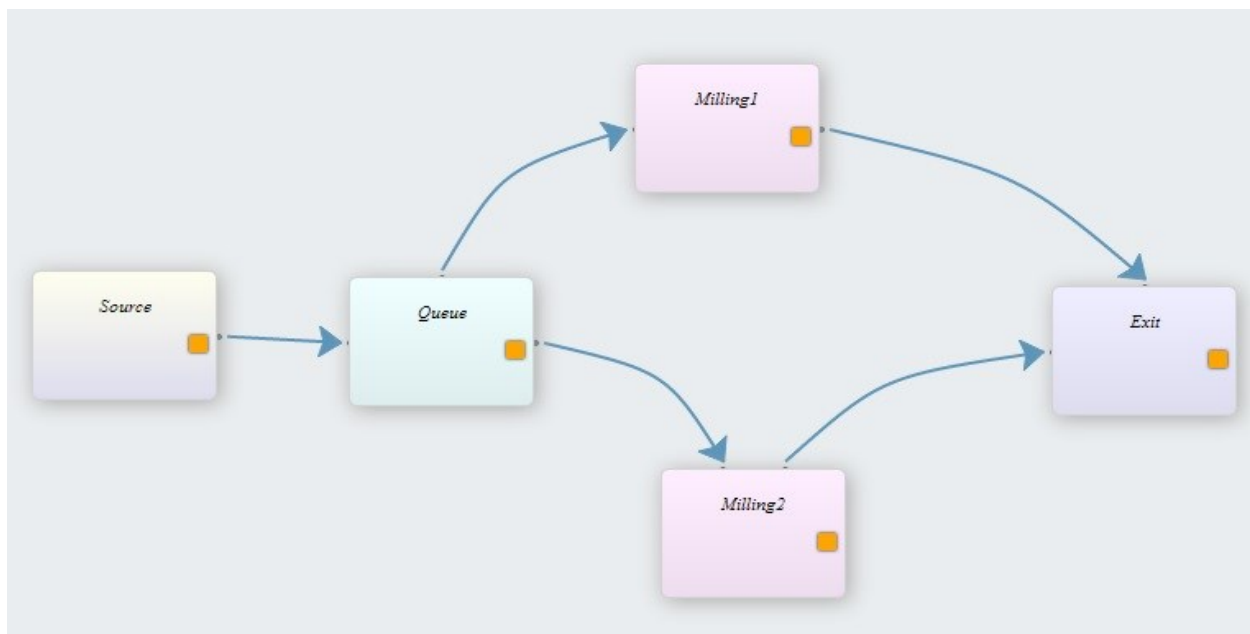


Figure 4: Parallel stations and queue model

Below is the fully commented KE tool main script for the production line illustrated in Figure 4.

```
from dream.KnowledgeExtraction.Transformations import BasicTransformations
from dream.KnowledgeExtraction.DistributionFitting import DistFittest
from dream.KnowledgeExtraction.DistributionFitting import Distributions
from dream.KnowledgeExtraction.ExcelOutput import Output
import dream.KnowledgeExtraction.ImportDatabase
import json

#===== Extract data from the database =====#
cnxn=ImportDatabase.ConnectionData(seekName='ServerData', implicitExt='txt',
number_of_cursors=3)
cursors=cnxn.getCursors()
```

```

a = cursors[0].execute("""
    select prod_code, stat_code, emp_no, TIMEIN, TIMEOUT
    from production_status
    """)
MILL1=[]
MILL2=[]
for j in range(a.rowcount):
    #get the next line
    ind1=a.fetchone()
    if ind1.stat_code == 'MILL1':
        procTime=[]
        procTime.insert(0,ind1.TIMEIN)
        procTime.insert(1,ind1.TIMEOUT)
        MILL1.append(procTime)
    elif ind1.stat_code == 'MILL2':
        procTime=[]
        procTime.insert(0,ind1.TIMEIN)
        procTime.insert(1,ind1.TIMEOUT)
        MILL2.append(procTime)
    else:
        continue

```

Database query to extract the needed data for processing

```

transform = BasicTransformations()
procTime_MILL1=[]
for elem in MILL1:
    t1=[]
    t2=[]
    t1.append(((elem[0].hour)*60)*60 + (elem[0].minute)*60 + elem[0].second)
    t2.append(((elem[1].hour)*60)*60 + (elem[1].minute)*60 + elem[1].second)
    dt=transform.subtraction(t2, t1)
    procTime_MILL1.append(dt[0])

```

```

procTime_MILL2=[]
for elem in MILL2:
    t1=[]
    t2=[]
    t1.append(((elem[0].hour)*60)*60 + (elem[0].minute)*60 + elem[0].second)
    t2.append(((elem[1].hour)*60)*60 + (elem[1].minute)*60 + elem[1].second)
    dt=transform.subtraction(t2, t1)
    procTime_MILL2.append(dt[0])

```

```

b = cursors[1].execute("""
    select stat_code, MTTF_hour
    from failures
    """)

```

```

c = cursors[2].execute("""
    select stat_code, MTTR_hour
    from repairs
    """)

```

```

MTTF_MILL1=[]
MTTF_MILL2=[]
for j in range(b.rowcount):

```

```

#get the next line
ind2=b.fetchone()
if ind2.stat_code == 'MILL1':
    MTTF_MILL1.append(ind2.MTTF_hour)
elif ind2.stat_code == 'MILL2':
    MTTF_MILL2.append(ind2.MTTF_hour)
else:
    continue

MTTR_MILL1=[]
MTTR_MILL2=[]
for j in range(c.rowcount):
    #get the next line
    ind3=c.fetchone()
    if ind3.stat_code == 'MILL1':
        MTTR_MILL1.append(ind3.MTTR_hour)
    elif ind3.stat_code == 'MILL2':
        MTTR_MILL2.append(ind3.MTTR_hour)
    else:
        continue

#===== Fit data to statistical distributions =====#
dist_proctime = DistFittest()
distProcTime_MILL1 = dist_proctime.ks_test(procTime_MILL1)
distProcTime_MILL2 = dist_proctime.ks_test(procTime_MILL2)

dist_MTTF = Distributions()
dist_MTTR = Distributions()
distMTTF_MILL1 = dist_MTTF.Weibull_distrfit(MTTF_MILL1)
distMTTF_MILL2 = dist_MTTF.Weibull_distrfit(MTTF_MILL2)

distMTTR_MILL1 = dist_MTTR.Poisson_distrfit(MTTR_MILL1)
distMTTR_MILL2 = dist_MTTR.Poisson_distrfit(MTTR_MILL2)

#==Output preparation: output the updated values in the JSON file of this example ==#
jsonFile = open('JSON_example.json','r')          #It opens the JSON file
data = json.load(jsonFile)
#It loads the file
jsonFile.close()
nodes = data.get('nodes',[])
#It creates a variable that holds the 'nodes' dictionary

for element in nodes:
    processingTime = nodes[element].get('processingTime',{})          #It creates a
    variable that gets the element attribute 'processingTime'
    MTTF_Nodes = nodes[element].get('MTTF',{})                        #It creates
    a variable that gets the element attribute 'MTTF'
    MTTR_Nodes = nodes[element].get('MTTR',{})                        #It creates
    a variable that gets the element attribute 'MTTR'

    if element == 'M1':
        nodes['M1']['processingTime'] = distProcTime_MILL1          #It checks using
        if syntax if the element is 'M1'
        nodes['M1']['failures']['MTTF'] = distMTTF_MILL1
        nodes['M1']['failures']['MTTR'] = distMTTR_MILL1

```



```

elif element == 'M2':
    nodes['M2']['processingTime'] = distProcTime_MILL2           #It checks using
if syntax if the element is 'M2'
    nodes['M2']['failures']['MTTF'] = distMTTF_MILL2
    nodes['M2']['failures']['MTTR'] = distMTTR_MILL2

    jsonFile = open('JSON_ParallelStations_Output.json','w')     #It opens the JSON
file
    jsonFile.write(json.dumps(data, indent=True))
#It writes the updated data to the JSON file
    jsonFile.close()
#It closes the file

    #= Calling the ExcelOutput object, outputs the outcomes of the statistical analysis
    in xls files ==#
export=Output()

export.PrintStatisticalMeasures(procTime_MILL1,'procTimeMILL1_StatResults.xls')
export.PrintStatisticalMeasures(procTime_MILL2,'procTimeMILL2_StatResults.xls')
export.PrintStatisticalMeasures(MTTF_MILL1,'MTTFMILL1_StatResults.xls')
export.PrintStatisticalMeasures(MTTF_MILL2,'MTTFMILL2_StatResults.xls')
export.PrintStatisticalMeasures(MTTR_MILL1,'MTTRMILL1_StatResults.xls')
export.PrintStatisticalMeasures(MTTR_MILL2,'MTTRMILL2_StatResults.xls')

export.PrintDistributionFit(procTime_MILL1,'procTimeMILL1_DistFitResults.xls')
export.PrintDistributionFit(procTime_MILL2,'procTimeMILL2_DistFitResults.xls')
export.PrintDistributionFit(MTTF_MILL1,'MTTFMILL1_DistFitResults.xls')
export.PrintDistributionFit(MTTF_MILL2,'MTTFMILL2_DistFitResults.xls')
export.PrintDistributionFit(MTTR_MILL1,'MTTRMILL1_DistFitResults.xls')
export.PrintDistributionFit(MTTR_MILL2,'MTTRMILL2_DistFitResults.xls')

```

The above main script consists of five KE tool objects (see the comments in the script). The JSON and Excel output files can easily be obtained by downloading and running the example. In Appendices one can see the exported JSON file.

3.4 Assembly and Dismantle model

The fifth example in the documentation is developed creating the KE tool main script in a model that contains two sources, one assembly station, one machine, one dismantle station and two exits. Figure 5 illustrates the graphical representation of the simulation model modeled in the DREAM platform GUI. The machine in this example is vulnerable to failures and we've got information about the time to failures (TTF) and time to repairs (TTR). Also, we have info about the processing times of the machine. The three categories data are recorded in an xls file.

In this example five objects are used and the input data to simulation is the statistical distribution of the processing times, MTTF and MTTR. The conducted steps in the main script described below:

1. Import the needed objects in order to run the main script
2. Read from the given directory the document with the necessary data
3. Call the *Import_Excel* object in order to input the data to the tool
4. From the imported data (python dictionaries) select the required data and put them in separate lists
5. Call the *ReplaceMissingValues* object and apply its method *ReplaceWithMean*, which replaces the missing values with the mean of the non-missing values in the list
6. Call the *Distributions* (Maximum Likelihood Estimation statistical method) and *DistFittest* (Kolmogorov-Smirnov fitting test) and apply them in my data, it is selected to conduct Kolmogorov-Smirnov test in the processing times data and to fit in Exponential distribution the MTTF and MTTR data
7. Export the processed data (statistical distributions of processing times, MTTF and MTTR) in the developed JSON file of the model
8. Call the *ExcelOutput* object and using its methods we export the statistical analysis and distribution fitting results of the three categories data

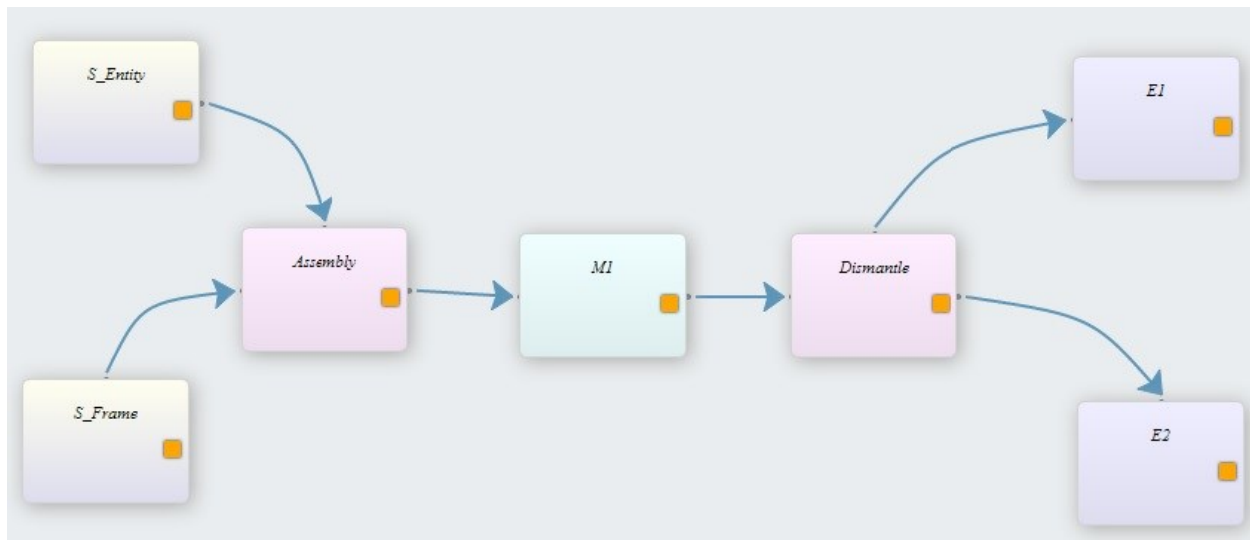


Figure 5: Assembly and dismantle model

Below is the KE tool main script for the model illustrated in Figure 5.

```
from dream.KnowledgeExtraction.ImportExceldata import Import_Excel
from dream.KnowledgeExtraction.ReplaceMissingValues import HandleMissingValues
from dream.KnowledgeExtraction.DistributionFitting import Distributions
from dream.KnowledgeExtraction.DistributionFitting import DistFittest
from dream.KnowledgeExtraction.ExcelOutput import Output
import xlrd
import json
```

```
#Read from the given directory the Excel document with the input data
workbook = xlrd.open_workbook('inputData.xls')
worksheets = workbook.sheet_names()
worksheet_ProcessingTimes = worksheets[0] #Define the worksheet with the
Processing times data
worksheet_MTTF = worksheets[1] #Define the worksheet with Time-to-Failure data
worksheet_MTTR = worksheets[2] #Define the worksheet with Time-to-Repair data
```

```
A = Import_Excel() #Call the Python object Import_Excel
ProcessingTimes = A.Input_data(worksheet_ProcessingTimes, workbook) #Create the
Processing Times dictionary with key the Machine 1 and values the processing time
data
MTTF=A.Input_data(worksheet_MTTF, workbook) #Create the MTTF dictionary with
key the Machine 1 and time-to-failure data
MTTR=A.Input_data(worksheet_MTTR, workbook) #Create the MTTR Quantity
dictionary with key the Machine 1 and time-to-repair data
```

```
##Get from the above dictionaries the M1 key and define the following lists with
data
ProcTime = ProcessingTimes.get('M1',[])
MTTF = MTTF.get('M1',[])
MTTR = MTTR.get('M1',[])
```

```
#Call the HandleMissingValues object and replace the missing values in the
Lists with the mean of the non-missing values
B =HandleMissingValues()
ProcTime = B.ReplaceWithMean(ProcTime)
MTTF = B.ReplaceWithMean(MTTF)
MTTR = B.ReplaceWithMean(MTTR)
```

```
C = Distributions() #Call the Distributions object
D = DistFittest() #Call the DistFittest object

ProcTime_dist = D.ks_test(ProcTime)
MTTF_dist = C.Exponential_distrfit(MTTF)
MTTR_dist = C.Exponential_distrfit(MTTR)
```

```

#== Output preparation: output the updated values in the JSON file of this
example==#
jsonFile = open('JSON_AssembleDismantle.json','r')      #It opens the JSON file
data = json.load(jsonFile)
jsonFile.close()#It loads the file
nodes = data.get('nodes',[]) #It creates a variable that holds the 'nodes' dictionary

for element in nodes:
    processingTime = nodes[element].get('processingTime',{}) #It creates a variable
that gets the element attribute 'processingTime'
    MTTF_Nodes = nodes[element].get('MTTF',{}) #It creates a variable that gets the
element attribute 'MTTF'
    MTTR_Nodes = nodes[element].get('MTTR',{}) #It creates a variable that gets the
element attribute 'MTTR'

    if element == 'M1':
        nodes['M1']['processingTime'] = ProcTime_dist #It checks using if syntax if
the element is 'M1'
        nodes['M1']['failures']['MTTF'] = MTTF_dist
        nodes['M1']['failures']['MTTR'] = MTTR_dist
        continue

    jsonFile = open('JSON_AssembleDismantle_Output.json',"w") #It opens the JSON file
    jsonFile.write(json.dumps(data, indent=True))
#It writes the updated data to the JSON file
    jsonFile.close() #It closes the file

```

7

```

#== Calling the ExcelOutput object, outputs the outcomes of the statistical
analysis in xls files =====#
C=Output()
C.PrintStatisticalMeasures(ProcTime,'ProcTime_StatResults.xls')
C.PrintStatisticalMeasures(MTTR,'MTTR_StatResults.xls')
C.PrintStatisticalMeasures(MTTF,'MTTF_StatResults.xls')
C.PrintDistributionFit(ProcTime,'ProcTime_DistFitResults.xls')
C.PrintDistributionFit(MTTR,'MTTR_DistFitResults.xls')

```

8

As happens with all the examples of the documentation the above main script is available in GitHub. Again the JSON and Excel output files can easily be obtained by downloading and running the example.

3.5 Parallel stations model

Another example in the documentation is developed creating the KE tool main script in a model that contains one source, one Queue, two machines Milling1 and Milling2 operating in parallel and one exit. Figure 6 illustrates the graphical representation of the model modeled in the DREAM platform GUI.

We've got information about the processing times in each of the two machines in the topology (see Figure 6). The processing times data are recorded in a spreadsheet (inputData.xls). In this example as happens with the Production Line example (see 4.2) in the KE tool main script we call the ManPy and we run the simulation model (see the main script below).

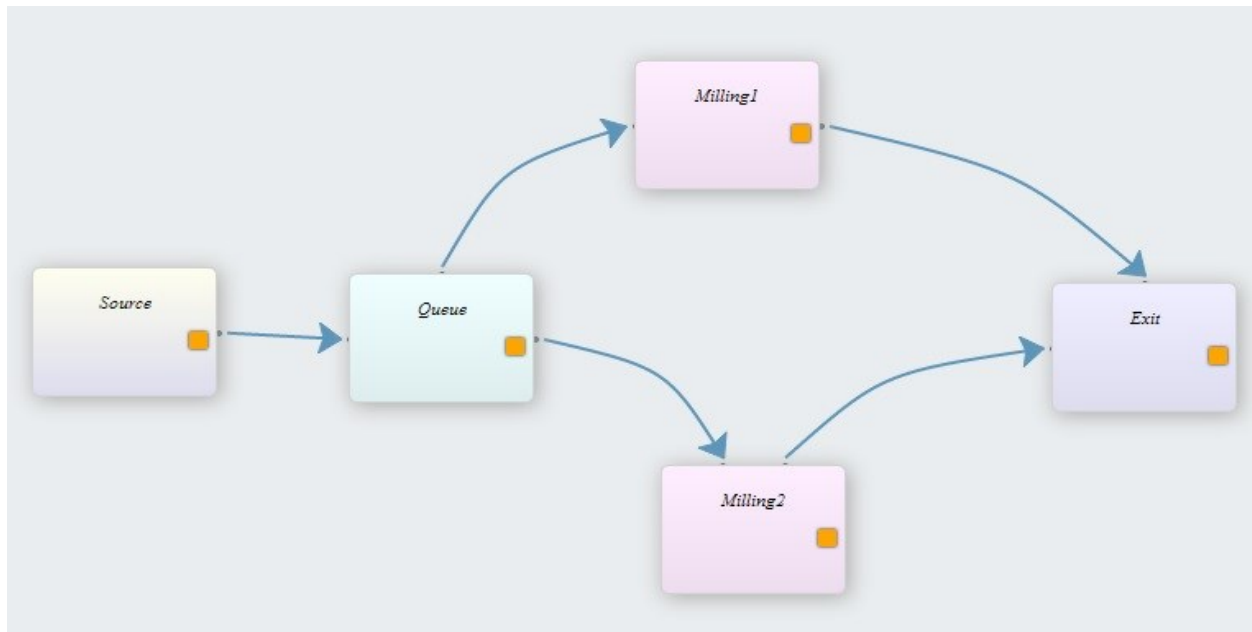


Figure 6: Parallel stations and queue model

Below is the KE tool main script for the model illustrated in Figure 6.

```
from DistributionFitting import DistFittest
from DistributionFitting import Distributions
from ImportExceldata import Import_Excel
from ExcelOutput import Output
from ReplaceMissingValues import HandleMissingValues
import xlrd
import json
#import ManPy main JSON script
import dream.simulation.LineGenerationJSON as ManPyMain

#Read from the given directory the Excel document with the input data
workbook = xlrd.open_workbook('inputData.xls')
worksheets = workbook.sheet_names()
worksheet_ProcessingTimes = worksheets[0] #Define the worksheet with the
Processing times data
```

```

inputData = Import_Excel()                                #Call the Python object
Import_Excel
ProcessingTimes = inputData.Input_data(worksheet_ProcessingTimes, workbook) #Create
the Processing Times dictionary with key Machines 1,2 and values the processing time
data

##Get from the above dictionaries the M1 key and define the following lists with data
M1_ProcTime = ProcessingTimes.get('M1',[])
M2_ProcTime = ProcessingTimes.get('M2',[])

#Call the HandleMissingValues object and replace the missing values in the lists with
the mean of the non-missing values
misValues =HandleMissingValues()
M1_ProcTime = misValues.ReplaceWithMean(M1_ProcTime)
M2_ProcTime = misValues.ReplaceWithMean(M2_ProcTime)

MLE = Distributions()      #Call the Distributions object (Maximum Likelihood
Estimation - MLE)
KS = DistFittest()         #Call the DistFittest object (Kolmogorov-Smirnov test)

M1ProcTime_dist = KS.ks_test(M1_ProcTime)
M2ProcTime_dist = MLE.Normal_distrfit(M2_ProcTime)

#===== Output preparation: output the updated values in the JSON
file of this example =====#
jsonFile = open('JSON_TwoParallelStations.json','r')      #It opens the JSON file
data = json.load(jsonFile)
#It loads the file
jsonFile.close()
nodes = data.get('nodes',[])
#It creates a variable that holds the 'nodes' dictionary

for element in nodes:
    processingTime = nodes[element].get('processingTime',{}) #It creates a
variable that gets the element attribute 'processingTime'

    if element == 'St1':
        nodes['St1']['processingTime'] = M1ProcTime_dist    #It checks using if
syntax if the element is 'M1'
    elif element == 'St2':
        nodes['St2']['processingTime'] = M2ProcTime_dist    #It checks using if
syntax if the element is 'M2'

    jsonFile = open('JSON_ParallelStations_Output.json',"w") #It opens the JSON
file
    jsonFile.write(json.dumps(data, indent=True))
#It writes the updated data to the JSON file
    jsonFile.close()
#It closes the file

#===== Calling the ExcelOutput object, outputs the outcomes of the
statistical analysis in xls files =====#
export=Output()

```

```

export.PrintStatisticalMeasures(M1_ProcTime, 'M1_ProcTime_StatResults.xls')
export.PrintStatisticalMeasures(M2_ProcTime, 'M2_ProcTime_StatResults.xls')

export.PrintDistributionFit(M1_ProcTime, 'M1_ProcTime_DistFitResults.xls')
export.PrintDistributionFit(M2_ProcTime, 'M2_ProcTime_DistFitResults.xls')

#calls ManPy main script with the input
simulationOutput=ManPyMain.main(input_data=json.dumps(data))
# save the simulation output
jsonFile = open('ManPyOutput.json', "w")      #It opens the JSON file
jsonFile.write(simulationOutput)              #It writes the updated data to the JSON file
jsonFile.close()                             #It closes the file

```

The example can easily be found in GitHub repository at the following URL: https://github.com/nexedi/dream/tree/master/dream/KnowledgeExtraction/KEtool_examples.

The folder TwoParallelStations contains the files needed to run the simulation model and get the results applying the KE tool main script (TwoParallelStations_example.py). In the table below, part of the output simulation traces are illustrated. In Figure 7 the differences between stations' simulation input data before and after running the KE tool are illustrated. The exported JSON file from the KE tool is available in the Appendices, as happens with the other examples the rest output files can easily be obtained downloading and running the KE tool main script (TwoParallelStations_example.py).

```

0 Batch0 got into Queue
0 Batch0 got into Milling2
1.0 Batch1 got into Queue
1.0 Batch1 got into Milling1
2.0 Batch2 got into Queue
39.0494038135 Batch0 got into Exit
39.0494038135 Batch2 got into Milling2
39.0494038135 Batch3 got into Queue
98.8013056079 Batch2 got into Exit
98.8013056079 Batch3 got into Milling2
98.8013056079 Batch4 got into Queue
0 Batch0 got into Queue
0 Batch0 got into Milling2
1.0 Batch1 got into Queue
1.0 Batch1 got into Milling1
2.0 Batch2 got into Queue
55.0034334831 Batch0 got into Exit
55.0034334831 Batch2 got into Milling2
55.0034334831 Batch3 got into Queue
58.7717522811 Batch1 got into Exit

```

<pre> "St1": { "_class": "Dream.BatchScrapMachine", "element_id": "DreamNode_3", "failures": { }, "name": "Milling1", "processingTime": { "distributionType": "Fixed", "max": "", "mean": 0.75, "min": "", "stdev": "" } } </pre>	<pre> "St1": { "processingTime": { "shape": 30.69, "rate": 100.14, "distributionType": "Gamma" }, "failures": {}, "element_id": "DreamNode_3", "_class": "Dream.BatchScrapMachine", "name": "Milling1" } </pre>
<pre> "St2": { "_class": "Dream.BatchScrapMachine", "element_id": "DreamNode_4", "failures": { }, "name": "Milling2", "processingTime": { "distributionType": "Fixed", "max": "", "mean": 0.75, "min": "", "stdev": "" } } </pre>	<pre> "St2": { "processingTime": { "max": 1.0094712814384956, "stdev": 0.11040396153317669, "min": 0, "distributionType": "Normal", "mean": 0.6782593968389655 }, "failures": {}, "element_id": "DreamNode_4", "_class": "Dream.BatchScrapMachine", "name": "Milling2" } </pre>

Figure 7: Stations simulation input data before run the KE tool (left), updated simulation input data (right)

3.6 Assembly line

The KE tool main script was created and tested in a real assembly line. Figure 8 illustrates the graphical representation of the assembly line modeled in the DREAM platform GUI. In this model we have several Machines operating in parallel, Queues between them and other simulation objects between them. The Machines are vulnerable to failures so scrap parts produced.

This case study uses different data sources to record operational information. Raw data from the assembly line are recorded in batch level on the local MES platform servers and transferred every 3-6 minutes to a local SAP server. Raw data are extracted in spreadsheet files coming from the local MES server. Figure 9 demonstrates the format of data in the MES database, the columns contain different information about the events, for example start time, stop time, station name, container name, quantity of the container etc.

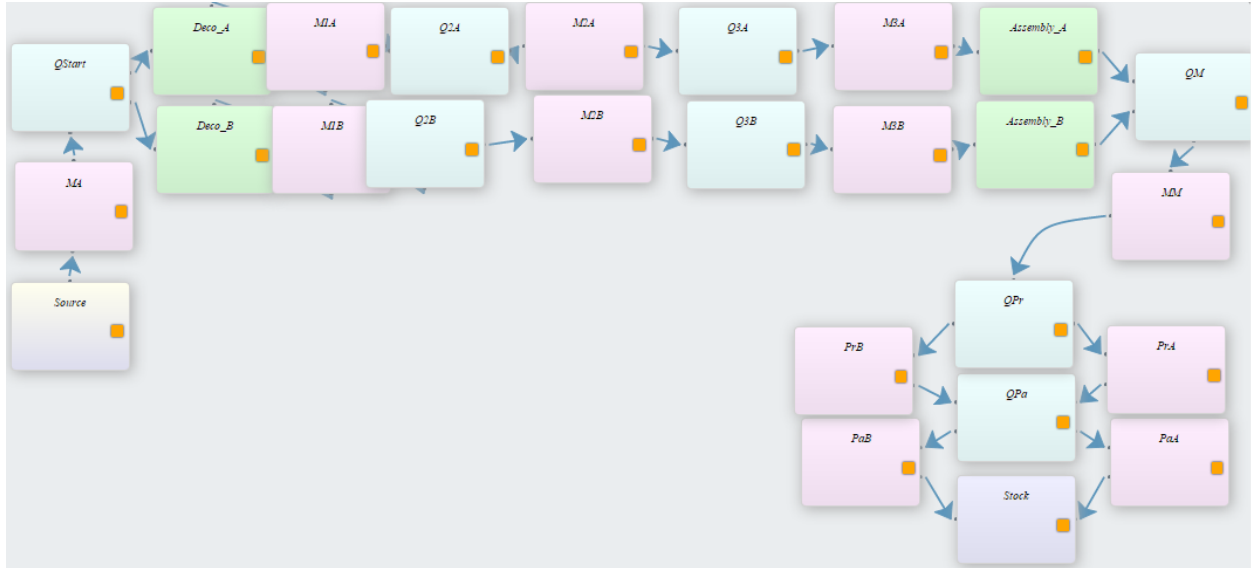


Figure 8: Assembly line modeled in DREAM.GUI

prod_data [Compatibility Mode] - Microsoft Excel								
File Home Insert Page Layout Formulas Data Review View Developer PDF-XChange 2012 Team								
J16 fx								
	A	B	C	D	E	F	G	H
	CONTAINERNAM	PRODUCTNAME	PRODUCTDESCRIPTION	TASKDATE	TASKTYPENAME	STATIONNAME	CONTAINERQTYATTXN	EMPLOYEEENAME
1	16803192-001	Prod3	Prod_desc3	2014-03-18 08:49:29	Start Station	MA		80 kujawskm
2	16803192-001	Prod3	Prod_desc3	2014-03-18 08:49:32	Finish Station	MA		80 kujawskm
3	16803192-001	Prod3	Prod_desc3	2014-03-18 08:53:09	Start Station	M1A		80 kujawskm
4	16803192-001	Prod3	Prod_desc3	2014-03-18 09:02:14	Start Station	M2A		80 coganm
5	16803192-001	Prod3	Prod_desc3	2014-03-18 09:21:13	Start Station	M3A		80 kellehp
6	16803192-001	Prod3	Prod_desc3	2014-03-18 10:35:43	Finish Station	M1A		80 kujawskm
7	16803192-001	Prod3	Prod_desc3	2014-03-18 10:56:24	Finish Station	M2A		80 coganm
8	16803192-001	Prod3	Prod_desc3	2014-03-18 11:11:50	Finish Station	M3A		80 kellehp
9	16803192-001	Prod3	Prod_desc3	2014-03-18 12:00:32	Start Station	MM		80 watersg
10	16803192-001	Prod3	Prod_desc3	2014-03-18 12:50:35	Finish Station	MM		80 watersg
11	16803192-001	Prod3	Prod_desc3	2014-03-18 14:15:40	Start Station	PrA		80 siuchnim
12	16803192-001	Prod3	Prod_desc3	2014-03-18 15:46:47	Finish Station	PrA		80 siuchnim
13	16803192-001	Prod3	Prod_desc3	2014-03-18 19:48:17	Start Station	PaA		80 ahernt1
14	16803192-001	Prod3	Prod_desc3					

Figure 9: Example of the MES database structure in the assembly line

In this example the KE tool interacts with the data file executing the three main components “Data extraction”, “Data processing” and “Output preparation”. The Python objects needed for the three components incorporated that form the KE tool are included in the main script for this example.

Company's requirement was the extraction of the processing times, the scrap quantity and the WIP levels. For the fulfilment of the above requirements a method was developed (that is called by the main script) apart from the KE tool main script in order to identify the WIP levels in the line at the time that the engineer in the line desires to run the simulation model. Executing the KE tool main script a JSON file that follows the JSON schema (data exchange format for DES) is exported with info needed for the simulation model, for example the continuous statistical distributions for the processing times of each station, the discrete statistical distribution (Geometric distribution) for the scrap quantity appeared in each station and the WIP level either in queues (buffers) or stations (machines). In the latter case (WIP in machines) it is also estimated the approximate quantity of units left to be processed, the estimation was conducted

calculating the average processing time in a particular machine, and the quantity of time between the start time in this machine and the stop time (time that the engineer wants to run the simulation model, so the KE tool main script gets executed).

A number of objects were used to form the main script and the outcome is the exported JSON file that contains the required information for the simulation model. The KE tool main script along with the spreadsheet data (see Figure 9) can be found at GitHub repository in KEtool_examples folder. In the Appendices can be found the exported JSON file for this example.

3.7 Example using the Plots object

KE tool offer methods for output analysis of the simulation results. One of the developed objects that mostly referring to Output analysis component of the tool (see Figure 1) is the *Plots* object. Applying *Plots* object in given data sets, we can get plots and charts with the representations of the data points in charts.

A simple example to demonstrate the use of this object is developed. This example as happens with the other examples is in GitHub repository in dream\KnowledgeExtraction\KEtool_examples\ Plots\Plots_example.py, this example retrieves data from a CSV file using the *ImportCSVdata* object and apply the data sets in *Plots*' methods returning the different charts.

- In the beginning the Graphs and the Import_CSV modules are imported:

```
from dream.KnowledgeExtraction.Plots import Graphs
```

```
from dream.KnowledgeExtraction.ImportCSVdata import Import_CSV
```

- Then we call the Import_CSV module and using its method *Input_data* import the data set from the CSV file to the tool

```
filename = ("DataSet.csv")  
A=Import_CSV()  
Data = A.Input_data(filename)
```

- After we get from the returned Python dictionary the two data sets:

```
M1 = Data.get('M1',[])  
M2 = Data.get('M2',[])
```

- Then a Graph object is created and all its methods applied to the data sets (M1,M2)

```
#create a graph object
```

```
B=Graphs()
```

```
B.Plots(M1, 'M1SimplePlot.jpg')
```

B.ScatterPlot(M1, M2, 'Scatterplot.jpg')

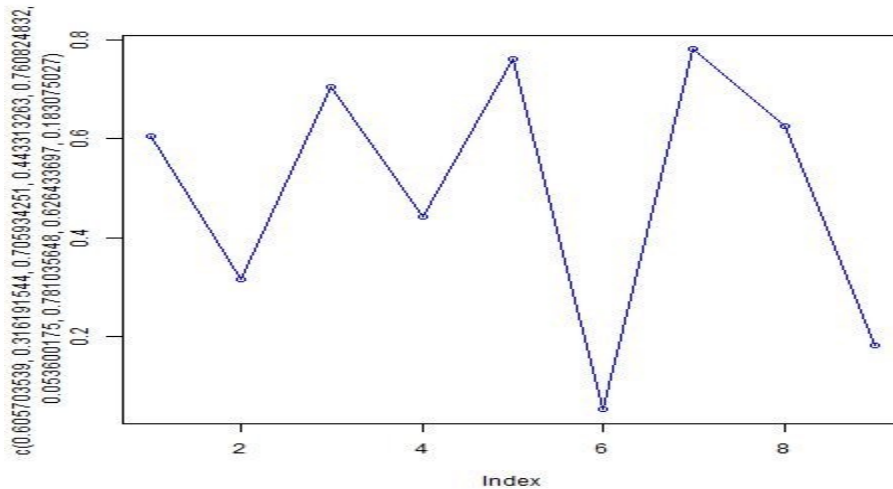
B.Barplot(M2, 'M2Barplot.jpg')

B.Histogram(M1, 'M1Histogram.jpg')

B.TwoSetPlot(M1, M2, 'M1M2Plot.jpg')

B.Pie(M2, 'M2PieChar.jpg')

Below find an example of the obtained .jpg files with the above charts. All the files can be easily obtained running the example.



As another example we present the dream\simulation\Examples\TwoServersPlots.py, this example outputs a pie chart that presents graphically the percentage of time that the repairman is busy or idle.

The new entries on the already existing dream\simulation\Examples\TwoServers.py on the code are:

- In the beginning the Graphs module is imported:

```
from dream.KnowledgeExtraction.Plots import Graphs
```

- After the simulation run the values for the pie are calculated:

```
#calculate the percentages for the pie
```

```
repairmanWorkingRatio=R.totalWorkingTime/G.maxSimTime*100
```

```
repairmanWaitingRatio=R.totalWaitingTime/G.maxSimTime*100
```

- Then a Graph object is created and the *Pie* method is called in order to create the output file

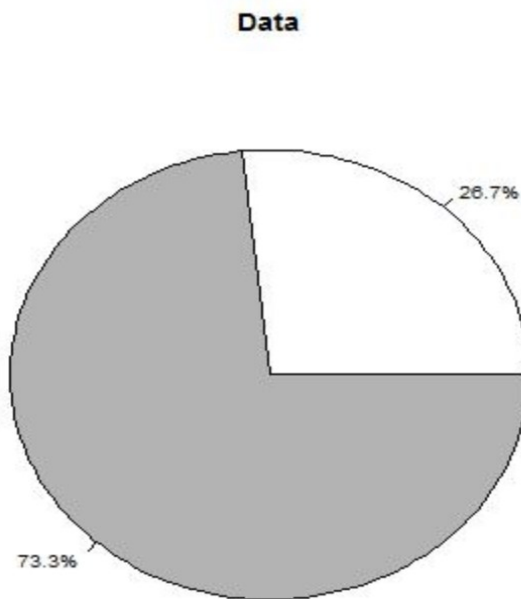
```
#create a graph object
```

```
graph=Graphs()
```

```
#create the pie
```

```
graph.Pie([repairmanWorkingRatio,repairmanWaitingRatio], "repairmanPie.jpg")
```

Running the script the user gets in addition to the console output repairmanPie.jpg that contains the following graph:



3.8 Example using the Confidence Intervals object

A very simple example is developed in order to describe the use of the *ConfidenceIntervals* object of the tool. This object offers the functionality to calculate confidence intervals in given data sets. The calculation of confidence intervals is really crucial in the output analysis of simulation.

This example as happens with the other examples is in GitHub repository in dream\KnowledgeExtraction\KEtool_examples\ConfidenceIntervals\ConfidenceIntervals_example.py, this example retrieves data from a CSV file using the *ImportCSVdata* object and apply the data sets in *ConfidenceInterval*'s method returning the actual lower and upper bound (confidence intervals) of the data sets.

- In the beginning the *ConfidenceInterval* and the *Import_CSV* modules are imported:

```
from dream.KnowledgeExtraction.ConfidenceIntervals import Intervals
```

```
from dream.KnowledgeExtraction.ImportCSVdata import Import_CSV
```

- Then we call the Import_CSV module and using its method *Input_data* import the data set from the CSV file to the tool

```
filename = ("DataSet.csv")
data=Import_CSV()
Data = data.Input_data(filename)
```

- After we get from the returned Python dictionary the three data sets:

#get from the returned Python dictionary the following three data sets

```
ProcTime = Data.get('ProcessingTimes',[])
MTTF = Data.get('MTTF',[])
MTTR = Data.get('MTTR',[])
```

- Then a Intervals object is created and all its method applied to the three data sets

#create a Intervals object

```
CI=Intervals()
```

#print the confidence intervals of the data sets applying either 90% or 95% probability

```
print CI.ConfidIntervals(ProcTime, 0.95)
```

```
print CI.ConfidIntervals(MTTF, 0.90)
```

```
print CI.ConfidIntervals(MTTR, 0.95)
```

Below the returning lists with the calculated upper and lower bound (confidence intervals) of the three data sets.

```
[0.4558596307362209, 0.5351412918337792]
```

```
[0.49255403041288176, 0.5575672826771183]
```

```
[0.4719902587261917, 0.5545222108338084]
```

Appendices

- **Example Two servers model with failures and repairman**

Below the three different output data formats are presented. The highlighted parts reveal the inputs of the KE tool in the processing times of Machine 1 and 2.

CMSD information model of the example

```
<?xml version='1.0' encoding='utf8'?>
<CMSDDocument>

  <DataSection>
    <PartType>
      <Identifier>Part1</Identifier>
    </PartType>
    <PartType>
      <Identifier>UnfinishedPart1</Identifier>
    </PartType>
    <Resource>
      <Identifier>S1</Identifier>
      <Description>The source of the topology</Description>
      <ResourceType>Source</ResourceType>
      <Name>RawMaterial</Name>
    </Resource>
    <Resource>
      <Identifier>M1</Identifier>
      <Description>The lathe of the topology</Description>
      <ResourceType>Machine</ResourceType>
      <Name>Machine1</Name>
    </Resource>
    <Resource>
      <Identifier>M2</Identifier>
      <Description>The moulding machine of the topology</Description>
      <ResourceType>Machine</ResourceType>
      <Name>Machine2</Name>
    </Resource>
    <Resource>
      <Identifier>Queue</Identifier>
      <Description>The queue of the topology</Description>
      <ResourceType>Queue</ResourceType>
      <Name>Queue</Name>
    </Resource>
    <Resource>
      <Identifier>Exit</Identifier>
```

```

        <Description>The exit of the topology</Description>
        <ResourceType>Exit</ResourceType>
        <Name>Stock</Name>
    </Resource>

    <Resource>
        <Identifier>A</Identifier>
        <ResourceType>employee</ResourceType>
    </Resource>
    <Resource>
        <Identifier>B</Identifier>
        <ResourceType>employee</ResourceType>
    </Resource>
    <Resource>
        <Identifier>Repairman</Identifier>
        <Description>This element describes a class of
employees</Description>
        <ResourceType>employee</ResourceType>
        <Name>W1</Name>
    </Resource>
*****Process Plan*****

    <ProcessPlan>
        <Identifier>ProcessPlan:Part1</Identifier>
        <PartsProduced>
            <Description>The part produced the process</Description>
            <PartType>
                <PartTypeIdentifier>Part1</PartTypeIdentifier>
            </PartType>
            <PartQuantity>1</PartQuantity>
        </PartsProduced>
        <PartsConsumed>
            <Description>The part(s) consumed the
process</Description>
            <PartType>
                <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
            </PartType>
            <PartQuantity>1</PartQuantity>
        </PartsConsumed>
        <FirstProcess>
            <ProcessIdentifier>MainProcessSequence</ProcessIdentifier>
        </FirstProcess>
        <Process>
            <Identifier>MainProcessSequence</Identifier>
            <RepetitionCount>1</RepetitionCount>
            <SubProcessGroup>
                <Type>sequence</Type>
                <Process>
                    <ProcessIdentifier>A010</ProcessIdentifier>
                </Process>
                <Process>
                    <ProcessIdentifier>A020</ProcessIdentifier>
                </Process>
            </SubProcessGroup>
        </Process>
    </Process>

```

```

        <ProcessIdentifier>A030</ProcessIdentifier>
    </Process>
    <Process>
        <ProcessIdentifier>A040</ProcessIdentifier>
    </Process>
    <Process>
        <ProcessIdentifier>A050</ProcessIdentifier>
    </Process>
</SubProcessGroup>
</Process>
*****Process*****

```

```

    <Process>
        <Identifier>A010</Identifier>
        <Description>Process 1</Description>
        <ResourcesRequired>
            <Description>Source</Description>
            <Resource>
                <ResourceIdentifier>S1</ResourceIdentifier>
            </Resource>
        </ResourcesRequired>
        <Property>
            <Name>interarrivalTime</Name>
            <Unit>minutes</Unit>
            <Distribution>
                <Name>Fixed</Name>
                <DistributionParameter>
                    <Name>mean</Name>
                    <Value>0.5</Value>
                </DistributionParameter>
            </Distribution>
        </Property>
        <Property>
            <Name>partType</Name>
            <Value>Part</Value>
        </Property>
    </Process>

    <Process>
        <Identifier>A020</Identifier>
        <Description>Process 2</Description>
        <PartsProduced>
            <Description>...</Description>
            <PartType>

<PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
            </PartType>
            <PartQuantity>1</PartQuantity>
        </PartsProduced>
        <PartsConsumed>
            <Description>...</Description>
            <PartType>

<PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
            </PartType>

```



```

        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>A</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>Machine1.</Description>
        <Resource>
            <ResourceIdentifier>M1</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minutes</Unit>
        <Distribution>
            <Name>Weibull</Name>
            <DistributionParameterA>
                <Name>shape</Name>
                <Value>2.6127833842</Value>
            </DistributionParameterA>
            <DistributionParameterB>
                <Name>scale</Name>
                <Value>5.3444350739</Value>
            </DistributionParameterB>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>MeanTimeToFailure</Name>
        <Unit>minutes</Unit>
        <Distribution>
            <Name>Fixed</Name>
            <DistributionParameter>
                <Name>mean</Name>
                <Value>60</Value>
            </DistributionParameter>
        </Distribution>
    </Property>
    <Property>
        <Name>MeanTimeToRepair</Name>
        <Unit>minutes</Unit>
        <Distribution>
            <Name>Fixed</Name>
            <DistributionParameter>
                <Name>mean</Name>
                <Value>5</Value>
            </DistributionParameter>
        </Distribution>
    </Property>
        <Name>RepairmanRequired</Name>
        <ResourcesRequired>
            <Description>The employee performing
the operation.</Description>

```

```

<ResourceIdentifier>W1</ResourceIdentifier>
    </ResourcesRequired>
  </Property>
</Process>

<Process>
  <Identifier>A030</Identifier>
  <Description>Process 3</Description>
  <ResourcesRequired>
    <Description>Queue1.</Description>
    <Resource>
      <ResourceIdentifier>Q1</ResourceIdentifier>
    </Resource>
  </ResourcesRequired>
  <Property>
    <Name>capacity</Name>
    <Value>1</Value>
  </Property>
</Process>

<Process>
  <Identifier>A040</Identifier>
  <Description>Process 4</Description>
  <PartsProduced>
    <Description>...</Description>
    <PartType>

<PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
  </PartType>
  <PartQuantity>1</PartQuantity>
</PartsProduced>
<PartsConsumed>
  <Description>...</Description>
  <PartType>

<PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
  </PartType>
  <PartQuantity>1</PartQuantity>
</PartsConsumed>
<ResourcesRequired>
  <Description>The employee performing the
operation.</Description>
  <Resource>
    <ResourceIdentifier>B</ResourceIdentifier>
  </Resource>
</ResourcesRequired>
<ResourcesRequired>
  <Description>Machine2.</Description>
  <Resource>
    <ResourceIdentifier>M2</ResourceIdentifier>
  </Resource>
</ResourcesRequired>
<OperationTime>

```

```

        <Unit>minutes</Unit>
        <Distribution>
          <Name>Normal</Name>
          <DistributionParameterA>
            <Name>stdev</Name>
            <Value>0.110403961533</Value>
          </DistributionParameterA>
          <DistributionParameterB>
            <Name>mean</Name>
            <Value>0.678259396839</Value>
          </DistributionParameterB>
        </Distribution>
      </OperationTime>
    <Property>
      <Name>MeanTimeToFailure</Name>
      <Unit>minutes</Unit>
      <Distribution>
        <Name>Fixed</Name>
        <DistributionParameter>
          <Name>mean</Name>
          <Value>40</Value>
        </DistributionParameter>
      </Distribution>
    </Property>
    <Property>
      <Name>MeanTimeToRepair</Name>
      <Unit>minutes</Unit>
      <Distribution>
        <Name>Fixed</Name>
        <DistributionParameter>
          <Name>mean</Name>
          <Value>10</Value>
        </DistributionParameter>
      </Distribution>
    <Property>
      <Name>RepairmanRequired</Name>
      <ResourcesRequired>
        <Description>The employee performing
the operation.</Description>
      </ResourcesRequired>
    </Property>
  </Process>

  <Process>
    <Identifier>A050</Identifier>
    <Description>Process 5</Description>
    <ResourcesRequired>
      <Description>Exit.</Description>
      <Resource>
        <ResourceIdentifier>E1</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
  </Process>

```

```
        </Process>
    </ProcessPlan>
</DataSection>
</CMSDDocument>
```

JSON file of the example

```
{
  "modelResource": [
    {
      "_class": "Dream.Repairman",
      "capacity": "1",
      "id": "W1",
      "name": "W1"
    }
  ],
  "_class": "Dream.Simulation",
  "coreObject": [
    {
      "name": "Raw Material",
      "entity": "Part",
      "interarrivalTime": {
        "distributionType": "Fixed",
        "mean": "0.5"
      },
      "successorList": [
        "DummyQ"
      ],
      "_class": "Dream.Source",
      "id": "S1"
    },
    {
      "processingTime": {
        "shape": 2.6127833842030075,
        "scale": 5.344435073902506,
        "distributionType": "Weibull"
      },
      "name": "Machine1",
      "predecessorList": [
        "DummyQ"
      ],
      "successorList": [
        "Q1"
      ],
      "failures": {
        "MTTR": "5",
        "failureDistribution": "Fixed",
        "repairman": "W1",

```

```
    "MTTF": "60"
  },
  "_class": "Dream.Machine",
  "id": "M1"
},
{
  "processingTime": {
    "stdev": 0.11040396153317669,
    "distributionType": "Normal",
    "mean": 0.6782593968389655
  },
  "name": "Machine2",
  "predecessorList": [
    "Q1"
  ],
  "successorList": [
    "E1"
  ],
  "failures": {
    "MTTR": "10",
    "failureDistribution": "Fixed",
    "repairman": "W1",
    "MTTF": "40"
  },
  "_class": "Dream.Machine",
  "id": "M2"
},
{
  "capacity": "1",
  "name": "DummyQ",
  "isDummy": "True",
  "predecessorList": [
    "S1"
  ],
  "successorList": [
    "M1"
  ],
  "_class": "Dream.Queue",
  "id": "DummyQ"
},
{
  "capacity": "1",
  "name": "Q1",
  "isDummy": "False",
  "predecessorList": [
    "M1"
  ],
  "successorList": [
    "M2"
  ],
  "_class": "Dream.Queue",
  "id": "Q1"
},
{
  "predecessorList": [
```

```

    "M2"
  ],
  "_class": "Dream.Exit",
  "id": "E1",
  "name": "Stock"
}
],
"general": {
  "maxSimTime": "1440",
  "_class": "Dream.Configuration",
  "numberOfReplications": "1",
  "trace": "Yes",
  "confidenceLevel": "0.95"
}
}

```

Excel file showing the distribution fitting test in the processing times of Machine 1

DistributionFit												
data points	2.86922	6.686919	8.886369	3.518466	4.324875	4.605777	3.708975	7.383754	8.028705	4.109362	8.023564	2.142588
	Discrete distributions							Kolmogorov-Smirnov test				
	Poisson	lambda				D-statistic		p-value				
		4.755402				0.100034		0.257422				
	Geometric	probability				D-statistic		p-value				
		0.17375				0.375322		4.94E-13				
	Continuous distributions											
	Normal	mean	standard deviation			D-statistic		p-value				
		4.755402	1.961543			0.083622		0.467974				
	Exponential	rate				D-statistic		p-value				
		0.210287				0.298857		2.45E-08				
	Gamma	shape	rate			D-statistic		p-value				
		4.487709	0.943705			0.158721		0.012053				
	Lognormal	log mean	log standard deviation			D-statistic		p-value				
		1.443717	0.546901			0.101007		0.247517				
	Weibull	shape	scale			D-statistic		p-value				
		2.612783	5.344435			0.081239		0.504857				
	Logistic	location	scale			D-statistic		p-value				
		4.727945	1.169962			0.089629		0.381573				
	Cauchy	location	scale			D-statistic		p-value				
		4.519232	1.34031			0.104665		0.212804				

Excel file showing the distribution fitting test in the processing times of Machine 2

DistributionFit												
data points	0.623414	0.618009	0.669085	0.714608	0.728286	0.572689	0.756631	0.633322	0.865086	0.322813	0.516356	0.594359
	Discrete distributions							Kolmogorov-Smirnov test				
	Poisson	lambda				D-statistic		p-value				
		0.678259				0.5075		4.44E-16				
	Geometric	probability				D-statistic		p-value				
		0.595855				0.595855		4.44E-16				
	Continuous distributions											
	Normal	mean	standard deviation			D-statistic		p-value				
		0.678259	0.110404			0.057582		0.882533				
	Exponential	rate				D-statistic		p-value				
		1.474362				0.492123		4.44E-16				
	Gamma	shape	rate			D-statistic		p-value				
		34.3284	50.61251			1		4.44E-16				
	Lognormal	log mean	log standard deviation			D-statistic		p-value				
		-0.40286	0.176532			0.076091		0.594621				
	Weibull	shape	scale			D-statistic		p-value				
		7.112427	0.724066			0.07006		0.695245				
	Logistic	location	scale			D-statistic		p-value				
		0.680653	0.063103			0.076566		0.586776				
	Cauchy	location	scale			D-statistic		p-value				
		0.680082	0.072959			0.097241		0.292919				

- **Example Production line**

Below the CMSD and JSON output data formats are presented. The highlighted parts reveal as example the inputs of the KE tool in the processing times and scrap quantity of stations P6 and P10.

CMSD information model of the example

```
<CMSDDocument xmlns="urn:cmsd:main"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="urn:cmsd:main main.xsd">
<!--<CMSDDocument>-->
  <DataSection>
    <PartType>
      <Identifier>Part1</Identifier>
    </PartType>
    <PartType>
      <Identifier>UnfinishedPart1</Identifier>
    </PartType>
    <Resource>
      <Identifier>resource1</Identifier>
      <Description>This resource describes the first of two parallel
stations in Section PA</Description>
      <ResourceType>station</ResourceType>
      <Name>P1</Name>
    </Resource>
    <Resource>
      <Identifier>resource2</Identifier>
      <Description>This resource describes the second of two parallel
stations in Section PA</Description>
      <ResourceType>station</ResourceType>
      <Name>P4</Name>
    </Resource>
    <Resource>
      <Identifier>resource3</Identifier>
      <Description>This resource describes the first of two parallel
stations in Section PA</Description>
      <ResourceType>station</ResourceType>
      <Name>P2</Name>
    </Resource>
  </Resource>
</DataSection>
```



```

        <Identifier>resource4</Identifier>
        <Description>This resource describes the second of two parallel
stations in Section PA</Description>
        <ResourceType>station</ResourceType>
        <Name>P5</Name>
    </Resource>
    <Resource>
        <Identifier>resource5</Identifier>
        <Description>This resource describes the first of two parallel
stations in Section PA</Description>
        <ResourceType>station</ResourceType>
        <Name>P3</Name>
    </Resource>
    <Resource>
        <Identifier>resource6</Identifier>
        <Description>This resource describes the second of two parallel
stations in Section PA</Description>
        <ResourceType>station</ResourceType>
        <Name>P6</Name>
    </Resource>
    <Resource>
        <Identifier>resource7</Identifier>
        <Description>This resource describes the machine in Section
PB</Description>
        <ResourceType>machine</ResourceType>
        <Name>P7</Name>
    </Resource>
    <Resource>
        <Identifier>resource8</Identifier>
        <Description>This resource describes the first of two parallel
stations in Section PC</Description>
        <ResourceType>station</ResourceType>
        <Name>P8</Name>
    </Resource>
    <Resource>
        <Identifier>resource9</Identifier>
        <Description>This resource describes the second of two parallel
stations in Section PC</Description>
        <ResourceType>station</ResourceType>
        <Name>P9</Name>
    </Resource>
    <Resource>
        <Identifier>resource10</Identifier>
        <Description>This resource describes the first of two parallel
stations in Section PD</Description>
        <ResourceType>station</ResourceType>
        <Name>P10</Name>
    </Resource>
    <Resource>
        <Identifier>resource11</Identifier>
        <Description>This resource describes the second of two parallel
stations in Section PD</Description>
        <ResourceType>station</ResourceType>
        <Name>P11</Name>
    </Resource>

```

```

<Resource>
  <Identifier>A</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>
<Resource>
  <Identifier>B</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>
<Resource>
  <Identifier>C</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>
<Resource>
  <Identifier>D</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>
<Resource>
  <Identifier>E</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>
<Resource>
  <Identifier>F</Identifier>
  <ResourceType>employee</ResourceType>
</Resource>

<ProcessPlan>
  <Identifier>ProcessPlan:PPPlan1</Identifier>
  <PartsProduced>
    <Description>The part produced the process</Description>
    <PartType>
      <PartTypeIdentifier>Part1</PartTypeIdentifier>
    </PartType>
    <PartQuantity>1</PartQuantity>
  </PartsProduced>
  <PartsConsumed>
    <Description>The part(s) consumed the
process</Description>
    <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
    </PartType>
    <PartQuantity>1</PartQuantity>
  </PartsConsumed>
  <FirstProcess>
    <ProcessIdentifier>PFirst</ProcessIdentifier>
  </FirstProcess>

  <Process>
    <Identifier>PFirst</Identifier>
    <RepetitionCount>1</RepetitionCount>
    <SubProcessGroup>
      <Type>sequence</Type>
      <Process>
        <ProcessIdentifier>PA</ProcessIdentifier>

```

```

        </Process>
        <Process>
            <ProcessIdentifier>PB</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>PC</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>PD</ProcessIdentifier>
        </Process>
    </SubProcessGroup>
</Process>

<Process>
    <Identifier>PA</Identifier>
    <SubProcessGroup>
        <Type>decision</Type>
        <Process>
            <ProcessIdentifier>PA1</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>PA2</ProcessIdentifier>
        </Process>
    </SubProcessGroup>
</Process>

<Process>
    <Identifier>PA1</Identifier>
    <SubProcessGroup>
        <Type>sequence</Type>
        <Process>
            <ProcessIdentifier>P1</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>P2</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>P3</ProcessIdentifier>
        </Process>
    </SubProcessGroup>
</Process>

<Process>
    <Identifier>PA2</Identifier>
    <SubProcessGroup>
        <Type>sequence</Type>
        <Process>
            <ProcessIdentifier>P4</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>P5</ProcessIdentifier>
        </Process>
        <Process>
            <ProcessIdentifier>P6</ProcessIdentifier>
        </Process>
    </SubProcessGroup>
</Process>

```

```

        </SubProcessGroup>
    </Process>

    <Process>
        <Identifier>PB</Identifier>
        <SubProcessGroup>
            <Type>sequence</Type>
            <Process>
                <ProcessIdentifier>P7</ProcessIdentifier>
            </Process>
        </SubProcessGroup>
    </Process>

    <Process>
        <Identifier>PC</Identifier>
        <SubProcessGroup>
            <Type>decision</Type>
            <Process>
                <ProcessIdentifier>P8</ProcessIdentifier>
            </Process>
            <Process>
                <ProcessIdentifier>P9</ProcessIdentifier>
            </Process>
        </SubProcessGroup>
    </Process>

    <Process>
        <Identifier>PD</Identifier>
        <SubProcessGroup>
            <Type>decision</Type>
            <Process>
                <ProcessIdentifier>P10</ProcessIdentifier>
            </Process>
            <Process>
                <ProcessIdentifier>P11</ProcessIdentifier>
            </Process>
        </SubProcessGroup>
    </Process>

    <Process>
        <Identifier>P1</Identifier>
        <Description>P1</Description>
        <PartsProduced>
            <Description>...</Description>
            <PartType>

                <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
                </PartType>
                <PartQuantity>1</PartQuantity>
            </PartsProduced>
            <PartsConsumed>
                <Description>The part that is an input to this
process</Description>
                <PartType>

```

```

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
      </PartType>
      <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
      <Description>The employee performing the
operation.</Description>
      <Resource>
        <ResourceIdentifier>A</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
      <Description>The resource where the operation is
being performed.</Description>
      <Resource>

    <ResourceIdentifier>resource1</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
    <OperationTime>
      <Unit>minute</Unit>
      <Distribution>
        <Name>Gamma</Name>
        <DistributionParameter>
          <Name>shape</Name>
          <Value>29.4228251359</Value>
        </DistributionParameter>
        <DistributionParameter>
          <Name>rate</Name>
          <Value>94.5230276629</Value>
        </DistributionParameter>
      </Distribution>
    </OperationTime>
    <Property>
      <Name>ScrapQuantity</Name>
      <Name>mean</Name>
      <Value>0.0</Value>
    </Property>
  </Process>

  <Process>
    <Identifier>P2</Identifier>
    <Description>P2</Description>
    <PartsProduced>
      <Description>...</Description>
      <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
      </PartType>
      <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
      <Description>The part that is an input to this
process</Description>

```

```

        <PartType>
    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>B</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>
        <Resource>
    <ResourceIdentifier>resource3</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Gamma</Name>
            <DistributionParameter>
                <Name>shape</Name>
                <Value>1225.91219908</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>rate</Name>
                <Value>6153.93113526</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>2.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P3</Identifier>
    <Description>P3</Description>
    <PartsProduced>
        <Description>...</Description>
        <PartType>
    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>

```

```

        <Description>The part that is an input to this
process</Description>
        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>C</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>
        <Resource>

        <ResourceIdentifier>resource5</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Normal</Name>
            <DistributionParameter>
                <Name>mean</Name>
                <Value>0.402962037037</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>stdev</Name>
                <Value>0.0960106899098</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>0.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P4</Identifier>
    <Description>P4</Description>
    <PartsProduced>
        <Description>...</Description>
        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>

```

```

        <PartsConsumed>
            <Description>The part that is an input to this
process</Description>
            <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
            </PartType>
            <PartQuantity>1</PartQuantity>
        </PartsConsumed>
        <ResourcesRequired>
            <Description>The employee performing the
operation.</Description>
            <Resource>
                <ResourceIdentifier>A</ResourceIdentifier>
            </Resource>
        </ResourcesRequired>
        <ResourcesRequired>
            <Description>The resource where the operation is
being performed.</Description>
            <Resource>

        <ResourceIdentifier>resource2</ResourceIdentifier>
            </Resource>
        </ResourcesRequired>
        <OperationTime>
            <Unit>minute</Unit>
            <Distribution>
                <Name>Normal</Name>
                <DistributionParameter>
                    <Name>mean</Name>
                    <Value>0.290917148148</Value>
                </DistributionParameter>
                <DistributionParameter>
                    <Name>stdev</Name>
                    <Value>0.0476508792381</Value>
                </DistributionParameter>
            </Distribution>
        </OperationTime>
        <Property>
            <Name>ScrapQuantity</Name>
            <Name>mean</Name>
            <Value>1.0</Value>
        </Property>
    </Process>

    <Process>
        <Identifier>P5</Identifier>
        <Description>P5</Description>
        <PartsProduced>
            <Description>...</Description>
            <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
            </PartType>

```



```

        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
        <Description>The part that is an input to this
process</Description>
        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>B</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>
        <Resource>
            <ResourceIdentifier>resource4</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Gamma</Name>
            <DistributionParameter>
                <Name>shape</Name>
                <Value>47.655</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>rate</Name>
                <Value>95.94111769</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>1.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P6</Identifier>
    <Description>P6</Description>
    <PartsProduced>
        <Description>...</Description>
    <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>

```

```

        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
        <Description>The part that is an input to this
process</Description>
        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>C</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>
        <Resource>

        <ResourceIdentifier>resource6</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Normal</Name>
            <DistributionParameter>
                <Name>mean</Name>
                <Value>0.588020851852</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>stdev</Name>
                <Value>0.107534393532</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>1.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P7</Identifier>
    <Description>P7</Description>
    <PartsProduced>
        <Description>...</Description>
        <PartType>

```

```

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
        <Description>The part that is an input to this
process</Description>

        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>

        <Resource>
            <ResourceIdentifier>D</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>

        <Resource>

        <ResourceIdentifier>resource7</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Normal</Name>
            <DistributionParameter>
                <Name>mean</Name>
                <Value>1.10071188889</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>stdev</Name>
                <Value>0.154492557514</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>2.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P8</Identifier>
    <Description>P8</Description>
    <PartsProduced>
        <Description>...</Description>

```

```

        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
        <Description>The part that is an input to this
process</Description>

        <PartType>

        <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>

        <Resource>
            <ResourceIdentifier>E</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>

        <Resource>

        <ResourceIdentifier>resource8</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Gamma</Name>
            <DistributionParameter>
                <Name>shape</Name>
                <Value>55.0859511268</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>rate</Name>
                <Value>56.1808214867</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>1.0</Value>
    </Property>
</Process>

<Process>
    <Identifier>P9</Identifier>
    <Description>P9</Description>

```

```

        <PartsProduced>
            <Description>...</Description>
            <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
        <Description>The part that is an input to this
process</Description>
        <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
        </PartType>
        <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
        <Description>The employee performing the
operation.</Description>
        <Resource>
            <ResourceIdentifier>E</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
        <Description>The resource where the operation is
being performed.</Description>
        <Resource>

    <ResourceIdentifier>resource9</ResourceIdentifier>
        </Resource>
    </ResourcesRequired>
    <OperationTime>
        <Unit>minute</Unit>
        <Distribution>
            <Name>Gamma</Name>
            <DistributionParameter>
                <Name>shape</Name>
                <Value>36.13</Value>
            </DistributionParameter>
            <DistributionParameter>
                <Name>stdev</Name>
                <Value>123.27</Value>
            </DistributionParameter>
        </Distribution>
    </OperationTime>
    <Property>
        <Name>ScrapQuantity</Name>
        <Name>mean</Name>
        <Value>2.0</Value>
    </Property>
</Process>

<Process>

```

```

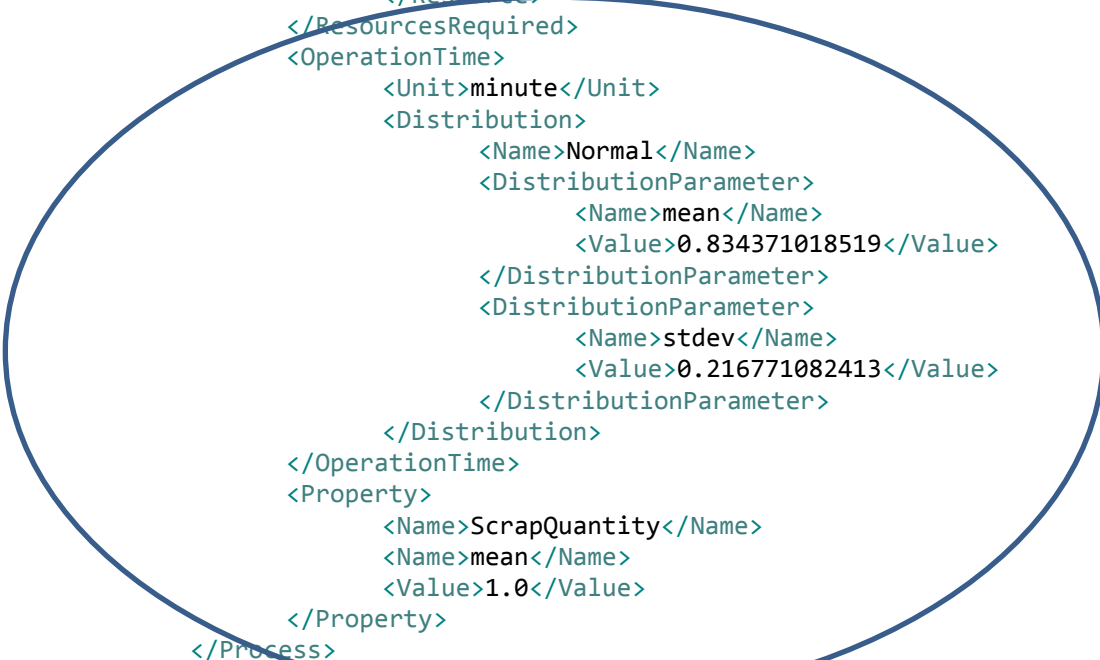
<Identifier>P10</Identifier>
<Description>P10</Description>
<PartsProduced>
  <Description>...</Description>
  <PartType>

  <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
    </PartType>
    <PartQuantity>1</PartQuantity>
  </PartsProduced>
  <PartsConsumed>
    <Description>The part that is an input to this
process</Description>
    <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
      </PartType>
      <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
      <Description>The employee performing the
operation.</Description>
      <Resource>
        <ResourceIdentifier>F</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
      <Description>The resource where the operation is
being performed.</Description>
      <Resource>

        <ResourceIdentifier>resource10</ResourceIdentifier>
          </Resource>
        </ResourcesRequired>
        <OperationTime>
          <Unit>minute</Unit>
          <Distribution>
            <Name>Normal</Name>
            <DistributionParameter>
              <Name>mean</Name>
              <Value>0.834371018519</Value>
            </DistributionParameter>
            <DistributionParameter>
              <Name>stdev</Name>
              <Value>0.216771082413</Value>
            </DistributionParameter>
          </Distribution>
        </OperationTime>
        <Property>
          <Name>ScrapQuantity</Name>
          <Name>mean</Name>
          <Value>1.0</Value>
        </Property>
      </Resource>
    </Process>

```



```

    <Process>
      <Identifier>P11</Identifier>
      <Description>P11</Description>
      <PartsProduced>
        <Description>...</Description>
        <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
      </PartType>
      <PartQuantity>1</PartQuantity>
    </PartsProduced>
    <PartsConsumed>
      <Description>The part that is an input to this
process</Description>
      <PartType>

    <PartTypeIdentifier>UnfinishedPart1</PartTypeIdentifier>
      </PartType>
      <PartQuantity>1</PartQuantity>
    </PartsConsumed>
    <ResourcesRequired>
      <Description>The employee performing the
operation.</Description>
      <Resource>
        <ResourceIdentifier>F</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
    <ResourcesRequired>
      <Description>The resource where the operation is
being performed.</Description>
      <Resource>

    <ResourceIdentifier>resource11</ResourceIdentifier>
      </Resource>
    </ResourcesRequired>
    <OperationTime>
      <Unit>minute</Unit>
      <Distribution>
        <Name>Normal</Name>
        <DistributionParameter>
          <Name>mean</Name>
          <Value>0.887490333333</Value>
        </DistributionParameter>
        <DistributionParameter>
          <Name>stdev</Name>
          <Value>0.12872179624</Value>
        </DistributionParameter>
      </Distribution>
    </OperationTime>
    <Property>
      <Name>ScrapQuantity</Name>
      <Name>mean</Name>
      <Value>1.0</Value>
    </Property>
  </Process>

```

```

        </ProcessPlan>
    </DataSection>
</ CMSDDocument >

```

JSON file of the example

```

{
  "nodes": {
    "Q2A": {
      "top": 0.7727272727272727,
      "_class": "Dream.LineClearance",
      "capacity": "2",
      "name": "Q2A",
      "left": 0.6968085106382979
    },
    "Q2B": {
      "top": 0.7727272727272727,
      "_class": "Dream.LineClearance",
      "capacity": "2",
      "name": "Q2B",
      "left": 0.6968085106382979
    },
    "Q3B": {
      "top": 0.7727272727272727,
      "_class": "Dream.LineClearance",
      "capacity": "2",
      "name": "Q3B",
      "left": 0.6968085106382979
    },
    "S1": {
      "name": "Source",
      "top": 0.9545454545454546,
      "entity": "Dream.Batch",
      "interarrivalTime": {
        "distributionType": "Fixed",
        "mean": 0.5
      },
      "batchNumberOfUnits": 100,
      "_class": "Dream.BatchSource",
      "left": 0.6968085106382979
    },
    "QPa": {
      "top": 0.7727272727272727,
      "_class": "Dream.Queue",

```



```
"capacity": "3",
"name": "QPa",
"left": 0.6968085106382979
},
"QPr": {
"top": 0.7727272727272727,
"_class": "Dream.Queue",
"capacity": "3",
"name": "QPr",
"left": 0.6968085106382979
},
"P6": {
"name": "P6",
"top": 0.5909090909090908,
"scrapQuantity": 1.0,
"processingTime": {
"max": 0.9106240324475632,
"stdev": 0.10753439353190378,
"min": 0,
"distributionType": "Normal",
"mean": 0.5880208518518518
},
"failures": {},
"_class": "Dream.BatchScrapMachine",
"left": 0.4414893617021277
},
"QStart": {
"top": 0.7727272727272727,
"_class": "Dream.Queue",
"capacity": "1",
"name": "StartQueue",
"left": 0.6968085106382979
},
"P5": {
"name": "P5",
"top": 0.5909090909090908,
"scrapQuantity": 1.0,
"processingTime": {
"shape": 47.655,
"rate": 95.94111768995835,
"distributionType": "Gamma"
},
"failures": {},
"_class": "Dream.BatchScrapMachine",
"left": 0.4414893617021277
},
"P10": {
"name": "P10",
"top": 0.5909090909090908,
"scrapQuantity": 1.0,
"processingTime": {
"max": 1.4846842657580035,
"stdev": 0.21677108241316168,
"min": 0,
"distributionType": "Normal",
```

```

    "mean": 0.8343710185185185
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"P11": {
  "name": "P11",
  "top": 0.5909090909090908,
  "scrapQuantity": 1.0,
  "processingTime": {
    "max": 1.2736557220538487,
    "stdev": 0.12872179624017177,
    "min": 0,
    "distributionType": "Normal",
    "mean": 0.8874903333333334
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"E1": {
  "top": 0.045454545454545414,
  "_class": "Dream.Exit",
  "name": "Stock",
  "left": 0.2978723404255319
},
"P2": {
  "name": "P2",
  "top": 0.5909090909090908,
  "scrapQuantity": 2.0,
  "processingTime": {
    "shape": 1225.9121990768035,
    "rate": 6153.9311352581,
    "distributionType": "Gamma"
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"P3": {
  "name": "P3",
  "top": 0.5909090909090908,
  "scrapQuantity": 0.0,
  "processingTime": {
    "max": 0.690994106766528,
    "stdev": 0.09601068990983029,
    "min": 0,
    "distributionType": "Normal",
    "mean": 0.40296203703703704
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},

```

```

"Q3A": {
  "top": 0.7727272727272727,
  "_class": "Dream.LineClearance",
  "capacity": "2",
  "name": "Q3A",
  "left": 0.6968085106382979
},
"P1": {
  "name": "P1",
  "top": 0.5909090909090908,
  "scrapQuantity": 0.0,
  "processingTime": {
    "shape": 29.422825135928104,
    "rate": 94.52302766286348,
    "distributionType": "Gamma"
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"BDA": {
  "name": "Batch_DecompositionA",
  "top": 0.5909090909090908,
  "processingTime": {
    "distributionType": "Fixed",
    "mean": "0"
  },
  "numberOfSubBatches": 4,
  "_class": "Dream.BatchDecomposition",
  "left": 0.4414893617021277
},
"P7": {
  "name": "P7",
  "top": 0.5909090909090908,
  "scrapQuantity": 2.0,
  "processingTime": {
    "max": 1.5641895614304642,
    "stdev": 0.15449255751385838,
    "min": 0,
    "distributionType": "Normal",
    "mean": 1.100711888888889
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"P4": {
  "name": "P4",
  "top": 0.5909090909090908,
  "scrapQuantity": 1.0,
  "processingTime": {
    "max": 0.4338697858624245,
    "stdev": 0.0476508792380921,
    "min": 0,
    "distributionType": "Normal",

```

```

    "mean": 0.2909171481481482
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"BDB": {
  "name": "Batch_DecompositionB",
  "top": 0.5909090909090908,
  "processingTime": {
    "distributionType": "Fixed",
    "mean": "0"
  },
  "numberOfSubBatches": 4,
  "_class": "Dream.BatchDecomposition",
  "left": 0.4414893617021277
},
"P8": {
  "name": "P8",
  "top": 0.5909090909090908,
  "scrapQuantity": 1.0,
  "processingTime": {
    "shape": 55.08595112679275,
    "rate": 56.18082148673797,
    "distributionType": "Gamma"
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"P9": {
  "name": "P9",
  "top": 0.5909090909090908,
  "scrapQuantity": 2.0,
  "processingTime": {
    "shape": 36.13,
    "rate": 123.27,
    "distributionType": "Gamma"
  },
  "failures": {},
  "_class": "Dream.BatchScrapMachine",
  "left": 0.4414893617021277
},
"QM": {
  "top": 0.7727272727272727,
  "_class": "Dream.Queue",
  "capacity": "3",
  "name": "QM",
  "left": 0.6968085106382979
},
"BRB": {
  "name": "Batch_ReassemblyB",
  "top": 0.5909090909090908,
  "processingTime": {
    "distributionType": "Fixed",

```

```

    "mean": "0"
  },
  "numberOfSubBatches": 4,
  "_class": "Dream.BatchReassembly",
  "left": 0.4414893617021277
},
"BRA": {
  "name": "Batch_ReassemblyA",
  "top": 0.5909090909090908,
  "processingTime": {
    "distributionType": "Fixed",
    "mean": "0"
  },
  "numberOfSubBatches": 4,
  "_class": "Dream.BatchReassembly",
  "left": 0.4414893617021277
}
},
"_class": "Dream.Simulation",
"edges": {
  "24": [
    "QPa",
    "P11",
    {}
  ],
  "25": [
    "P10",
    "E1",
    {}
  ],
  "26": [
    "P11",
    "E1",
    {}
  ],
  "20": [
    "QPr",
    "P9",
    {}
  ],
  "21": [
    "P8",
    "QPa",
    {}
  ],
  "22": [
    "P9",
    "QPa",
    {}
  ],
  "23": [
    "QPa",
    "P10",
    {}
  ],
},

```

```
"1": [  
  "QStart",  
  "BDA",  
  {}  
],  
"0": [  
  "S1",  
  "QStart",  
  {}  
],  
"3": [  
  "BDA",  
  "P1",  
  {}  
],  
"2": [  
  "QStart",  
  "BDB",  
  {}  
],  
"5": [  
  "Q2A",  
  "P2",  
  {}  
],  
"4": [  
  "P1",  
  "Q2A",  
  {}  
],  
"7": [  
  "Q3A",  
  "P3",  
  {}  
],  
"6": [  
  "P2",  
  "Q3A",  
  {}  
],  
"9": [  
  "BRA",  
  "QM",  
  {}  
],  
"8": [  
  "P3",  
  "BRA",  
  {}  
],  
"11": [  
  "P4",  
  "Q2B",  
  {}  
],
```

```

"10": [
  "BDB",
  "P4",
  {}
],
"13": [
  "P5",
  "Q3B",
  {}
],
"12": [
  "Q2B",
  "P5",
  {}
],
"15": [
  "P5",
  "BRB",
  {}
],
"14": [
  "Q3B",
  "P6",
  {}
],
"17": [
  "QM",
  "P7",
  {}
],
"16": [
  "BRB",
  "QM",
  {}
],
"19": [
  "QPr",
  "P8",
  {}
],
"18": [
  "P7",
  "QPr",
  {}
]
],
},
"general": {
  "trace": "No",
  "_class": "Dream.Configuration",
  "confidenceLevel": "0.95",
  "maxSimTime": "1440",
  "numberOfReplications": "10"
}

```

ManPy JSON file (simulation results)

```
{
  "elementList": [
    {
      "_class": "Dream.LineClearance",
      "id": "Q2A"
    },
    {
      "_class": "Dream.LineClearance",
      "id": "Q2B"
    },
    {
      "_class": "Dream.Machine",
      "id": "P3",
      "results": {
        "working_ratio": {
          "avg": 99.1232932718127,
          "lb": 99.06288622969795,
          "ub": 99.18370031392745
        },
        "blockage_ratio": {
          "avg": 0.0,
          "lb": 0.0,
          "ub": 0.0
        },
        "waiting_ratio": {
          "avg": 0.8767067281873027,
          "lb": 0.8162996860725587,
          "ub": 0.9371137703020467
        },
        "off_shift_ratio": {
          "avg": 0.0,
          "lb": 0.0,
          "ub": 0.0
        },
        "setup_ratio": {
          "avg": 0.0,
          "lb": 0.0,
          "ub": 0.0
        },
        "failure_ratio": {
          "avg": 0.0,
          "lb": 0.0,
          "ub": 0.0
        },
        "loading_ratio": {
          "avg": 0.0,
          "lb": 0.0,
          "ub": 0.0
        }
      }
    }
  ],
  {
    "_class": "Dream.Queue",
```



```

    "id": "QPa"
  },
  {
    "_class": "Dream.Queue",
    "id": "QPr"
  },
  {
    "_class": "Dream.Queue",
    "id": "QStart"
  },
  {
    "_class": "Dream.Machine",
    "id": "P5",
    "results": {
      "working_ratio": {
        "avg": 3.8484863685556765,
        "lb": 3.835591640224164,
        "ub": 3.861381096887189
      },
      "blockage_ratio": {
        "avg": 94.03753457294879,
        "lb": 93.89318733982336,
        "ub": 94.18188180607422
      },
      "waiting_ratio": {
        "avg": 2.11397905849554,
        "lb": 1.9687688716941143,
        "ub": 2.259189245296966
      },
      "off_shift_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "setup_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "failure_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "loading_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      }
    }
  },
  {
    "_class": "Dream.Machine",
    "id": "P10",
    "results": {

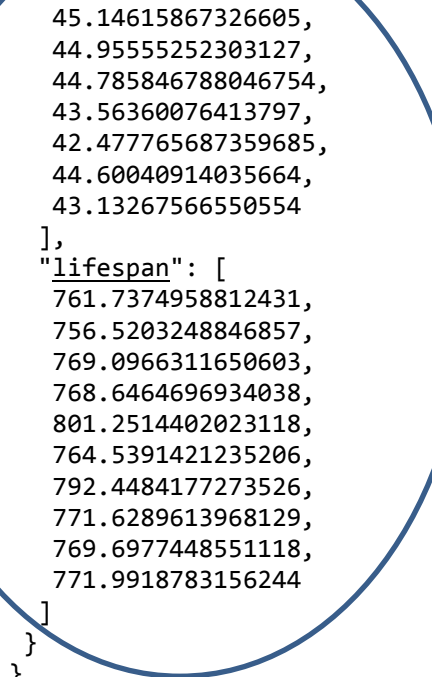
```

```

    "working_ratio": {
      "avg": 33.8643006065708,
      "lb": 33.251018516779276,
      "ub": 34.477582696362326
    },
    "blockage_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "waiting_ratio": {
      "avg": 66.13569939342919,
      "lb": 65.52241730363767,
      "ub": 66.74898148322072
    },
    "off_shift_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "setup_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "failure_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "loading_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    }
  },
  {
    "_class": "Dream.Machine",
    "id": "P11",
    "results": {
      "working_ratio": {
        "avg": 32.80895290519304,
        "lb": 32.20957202613055,
        "ub": 33.408333784255525
      },
      "blockage_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "waiting_ratio": {
        "avg": 67.19104709480696,
        "lb": 66.59166621574448,
        "ub": 67.79042797386944
      }
    }
  }

```

```
},
"off_shift_ratio": {
  "avg": 0.0,
  "lb": 0.0,
  "ub": 0.0
},
"setup_ratio": {
  "avg": 0.0,
  "lb": 0.0,
  "ub": 0.0
},
"failure_ratio": {
  "avg": 0.0,
  "lb": 0.0,
  "ub": 0.0
},
"loading_ratio": {
  "avg": 0.0,
  "lb": 0.0,
  "ub": 0.0
}
},
{
  "_class": "Dream.Exit",
  "id": "E1",
  "results": {
    "unitsThroughput": [
      3040.0,
      3135.0,
      3230.0,
      2945.0,
      3040.0,
      3040.0,
      3135.0,
      3135.0,
      3040.0,
      3135.0
    ],
    "throughput": [
      32,
      33,
      34,
      31,
      32,
      32,
      33,
      33,
      32,
      33
    ],
    "takt_time": [
      43.699500371587746,
      43.26117960529305,
      42.166933591369705,
```



```
45.14615867326605,  
44.95555252303127,  
44.785846788046754,  
43.56360076413797,  
42.477765687359685,  
44.60040914035664,  
43.13267566550554  
],  
"lifespan": [  
761.7374958812431,  
756.5203248846857,  
769.0966311650603,  
768.6464696934038,  
801.2514402023118,  
764.5391421235206,  
792.4484177273526,  
771.6289613968129,  
769.6977448551118,  
771.9918783156244  
]  
}  
},  
{  
  "_class": "Dream.Machine",  
  "id": "P2",  
  "results": {  
    "working_ratio": {  
      "avg": 50.102895148547525,  
      "lb": 49.24749868283626,  
      "ub": 50.95829161425879  
    },  
    "blockage_ratio": {  
      "avg": 48.236644358616054,  
      "lb": 47.201622043610996,  
      "ub": 49.27166667362111  
    },  
    "waiting_ratio": {  
      "avg": 1.6604604928364235,  
      "lb": 1.159532722362285,  
      "ub": 2.161388263310562  
    },  
    "off_shift_ratio": {  
      "avg": 0.0,  
      "lb": 0.0,  
      "ub": 0.0  
    },  
    "setup_ratio": {  
      "avg": 0.0,  
      "lb": 0.0,  
      "ub": 0.0  
    },  
    "failure_ratio": {  
      "avg": 0.0,  
      "lb": 0.0,  
      "ub": 0.0  
    }  
  }  
}
```

```

    },
    "loading_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    }
  }
},
{
  "_class": "Dream.LineClearance",
  "id": "Q3B"
},
{
  "_class": "Dream.LineClearance",
  "id": "Q3A"
},
{
  "_class": "Dream.Machine",
  "id": "P1",
  "results": {
    "working_ratio": {
      "avg": 73.78981870841058,
      "lb": 72.44696726539648,
      "ub": 75.13267015142468
    },
    "blockage_ratio": {
      "avg": 26.175459069367207,
      "lb": 24.83260762635311,
      "ub": 27.518310512381305
    },
    "waiting_ratio": {
      "avg": 0.034722222222218276,
      "lb": 0.034722222222192324,
      "ub": 0.0347222222224423
    },
    "off_shift_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "setup_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "failure_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "loading_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    }
  }
}

```

```

    }
  },
  {
    "_class": "Dream.Machine",
    "id": "P6",
    "results": {
      "working_ratio": {
        "avg": 0.7151499038589795,
        "lb": 0.5631193514563365,
        "ub": 0.8671804562616224
      },
      "blockage_ratio": {
        "avg": 96.37469764512025,
        "lb": 96.17598423856082,
        "ub": 96.57341105167968
      },
      "waiting_ratio": {
        "avg": 2.9101524510207653,
        "lb": 2.783623796389208,
        "ub": 3.0366811056523226
      },
      "off_shift_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "setup_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "failure_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      },
      "loading_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
      }
    }
  }
},
{
  "_class": "Dream.Machine",
  "id": "P7",
  "results": {
    "working_ratio": {
      "avg": 93.16310446225327,
      "lb": 90.46881987070287,
      "ub": 95.85738905380367
    },
    "blockage_ratio": {
      "avg": 0.0,
      "lb": 0.0,

```

```

    "ub": 0.0
  },
  "waiting_ratio": {
    "avg": 6.836895537746727,
    "lb": 4.142610946196325,
    "ub": 9.53118012929713
  },
  "off_shift_ratio": {
    "avg": 0.0,
    "lb": 0.0,
    "ub": 0.0
  },
  "setup_ratio": {
    "avg": 0.0,
    "lb": 0.0,
    "ub": 0.0
  },
  "failure_ratio": {
    "avg": 0.0,
    "lb": 0.0,
    "ub": 0.0
  },
  "loading_ratio": {
    "avg": 0.0,
    "lb": 0.0,
    "ub": 0.0
  }
},
{
  "_class": "Dream.Machine",
  "id": "P4",
  "results": {
    "working_ratio": {
      "avg": 6.666597647254015,
      "lb": 6.468351865246149,
      "ub": 6.864843429261882
    },
    "blockage_ratio": {
      "avg": 93.33340235274599,
      "lb": 93.13515657073812,
      "ub": 93.53164813475387
    },
    "waiting_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "off_shift_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "setup_ratio": {
      "avg": 0.0,

```

```

        "lb": 0.0,
        "ub": 0.0
    },
    "failure_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
    },
    "loading_ratio": {
        "avg": 0.0,
        "lb": 0.0,
        "ub": 0.0
    }
}
},
{
    "_class": "Dream.Machine",
    "id": "P8",
    "results": {
        "working_ratio": {
            "avg": 35.81052909393301,
            "lb": 34.58078555801364,
            "ub": 37.04027262985239
        },
        "blockage_ratio": {
            "avg": 0.0,
            "lb": 0.0,
            "ub": 0.0
        },
        "waiting_ratio": {
            "avg": 64.18947090606699,
            "lb": 62.95972737014761,
            "ub": 65.41921444198636
        },
        "off_shift_ratio": {
            "avg": 0.0,
            "lb": 0.0,
            "ub": 0.0
        },
        "setup_ratio": {
            "avg": 0.0,
            "lb": 0.0,
            "ub": 0.0
        },
        "failure_ratio": {
            "avg": 0.0,
            "lb": 0.0,
            "ub": 0.0
        },
        "loading_ratio": {
            "avg": 0.0,
            "lb": 0.0,
            "ub": 0.0
        }
    }
}
}

```



```

},
{
  "_class": "Dream.Machine",
  "id": "P9",
  "results": {
    "working_ratio": {
      "avg": 35.31986524561169,
      "lb": 34.26751219317828,
      "ub": 36.3722182980451
    },
    "blockage_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "waiting_ratio": {
      "avg": 64.68013475438832,
      "lb": 63.62778170195491,
      "ub": 65.73248780682172
    },
    "off_shift_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "setup_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "failure_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    },
    "loading_ratio": {
      "avg": 0.0,
      "lb": 0.0,
      "ub": 0.0
    }
  }
},
{
  "_class": "Dream.Queue",
  "id": "QM"
}
],
"_class": "Dream.Simulation",
"general": {
  "totalExecutionTime": 12.667999982833862,
  "_class": "Dream.Configuration"
}
}

```

Example Parallel stations and Queue

Exported JSON file

```
{
  "nodes": {
    "Q1": {
      "capacity": 1,
      "name": "Q1",
      "top": 0.5906862745098039,
      "isDummy": "0",
      "_class": "Dream.Queue",
      "left": 0.639751552795031
    },
    "S1": {
      "name": "Raw Material",
      "top": 0.9534313725490196,
      "entity": "Dream.Part",
      "interarrivalTime": {
        "distributionType": "Fixed",
        "mean": 0.5
      },
      "_class": "Dream.Source",
      "left": 0.639751552795031
    },
    "M1": {
      "name": "MILL1",
      "top": 0.40931372549019607,
      "processingTime": {
        "scale": 5.943555041732533,
        "location": 51.57623425532299,
        "distributionType": "Logistic"
      },
      "failures": {
        "MTTR": {
          "distributionType": "Poisson",
          "lambda": 0.1053658536585366
        },
        "repairman": "W1",
        "MTTF": {
          "shape": 3.1671825421393747,
          "scale": 0.7571939493062068,
          "distributionType": "Weibull"
        }
      },
      "_class": "Dream.Machine",
      "left": 0.6335403726708074
    },
    "W1": {
      "top": 0.5906862745098039,
      "_class": "Dream.Repairman",
      "capacity": 1,
      "name": "W1",
      "left": 0.18012422360248448
    },
  },
}
```

```
"M2": {
  "name": "MILL2",
  "top": 0.40931372549019607,
  "processingTime": {
    "scale": 1.7219415441266923,
    "location": 49.732494067271205,
    "distributionType": "Cauchy"
  },
  "failures": {
    "MTTR": {
      "distributionType": "Poisson",
      "lambda": 0.1423076923076923
    },
    "repairman": "W1",
    "MTTF": {
      "shape": 3.1975046230623905,
      "scale": 0.6805471087485552,
      "distributionType": "Weibull"
    }
  },
  "_class": "Dream.Machine",
  "left": 0.1863354037267081
},
"DummyQ": {
  "capacity": 1,
  "name": "DummyQ",
  "top": 0.7720588235294118,
  "isDummy": "1",
  "_class": "Dream.Queue",
  "left": 0.639751552795031
},
"E1": {
  "top": 0.04656862745098034,
  "_class": "Dream.Exit",
  "name": "Stock",
  "left": 0.40993788819875776
}
},
"_class": "Dream.Simulation",
"edges": {
  "1": [
    "W1",
    "M2",
    {}
  ],
  "0": [
    "W1",
    "M1",
    {}
  ],
  "3": [
    "M1",
    "E1",
    {}
  ],
}
```

```
"2": [
  "S1",
  "DummyQ",
  {}
],
"5": [
  "DummyQ",
  "Q1",
  {}
],
"4": [
  "M2",
  "E1",
  {}
],
"7": [
  "Q1",
  "M2",
  {}
],
"6": [
  "Q1",
  "M1",
  {}
]
},
"general": {
  "trace": "No",
  "_class": "Dream.Configuration",
  "confidenceLevel": "0.95",
  "maxSimTime": "1440",
  "numberOfReplications": "1"
}
}
```

- **Example Parallel stations model**

Exported JSON file

```
{
  "general": {
    "numberOfReplications": 5,
    "trace": "No",
    "processTimeout": 10,
    "seed": "",
    "confidenceLevel": 0.95,
    "maxSimTime": 1000,
    "currentDate": "2014/06/16"
  },
  "edges": {
    "con_5": [
      "S1",
      "Q1",
      {}
    ],
    "con_25": [
      "St2",
      "E1",
      {}
    ],
    "con_15": [
      "Q1",
      "St2",
      {}
    ],
    "con_10": [
      "Q1",
      "St1",
      {}
    ],
    "con_20": [
      "St1",
      "E1",
      {}
    ]
  },
  "capacity_by_station_spreadsheet": [
    [
      "Machine",
      "Day 0",
      "Day 1",
      "Day 2",
      "Day 3",
      null
    ],
    [
      null,
      null,
      null,
      null,
      null,
      null
    ]
  ]
}
```

[illegible]

```
"Q1": {
  "element_id": "DreamNode_2",
  "_class": "Dream.Queue",
  "capacity": 1,
  "name": "Queue",
  "schedulingRule": "FIFO"
},
"S1": {
  "name": "Source",
  "entity": "Dream.Batch",
  "interarrivalTime": {
    "distributionType": "Fixed",
    "mean": 1
  },
  "batchNumberOfUnits": 80,
  "element_id": "DreamNode_1",
  "_class": "Dream.BatchSource"
},
"E1": {
  "element_id": "DreamNode_5",
  "_class": "Dream.Exit",
  "name": "Exit"
},
"St1": {
  "processingTime": {
    "shape": 30.69,
    "rate": 100.14,
    "distributionType": "Gamma"
  },
  "failures": {},
  "element_id": "DreamNode_3",
  "_class": "Dream.BatchScrapMachine",
  "name": "Milling1"
},
"St2": {
  "processingTime": {
    "max": 1.0094712814384956,
    "stdev": 0.11040396153317669,
    "min": 0,
    "distributionType": "Normal",
    "mean": 0.6782593968389655
  },
  "failures": {},
  "element_id": "DreamNode_4",
  "_class": "Dream.BatchScrapMachine",
  "name": "Milling2"
},
},
"preference": {
  "coordinates": {
    "Q1": {
      "top": 0.4898081240173095,
      "left": 0.28592454969899506
    },
    "S1": {
```

```

    "top": 0.48224351978538194,
    "left": 0.053083038762682624
  },
  "E1": {
    "top": 0.5011550303652008,
    "left": 0.838470725910555
  },
  "St1": {
    "top": 0.22882927801580868,
    "left": 0.5199724933344594
  },
  "St2": {
    "top": 0.7243108552070638,
    "left": 0.5157499788874278
  }
}
}
}
}

```

- **Example Assembly line**

Below the JSON output data format is presented. The highlighted parts reveal as example the inputs of the KE tool in the processing times and scrap quantity for M1A and MM and the WIP levels in PrB and QPr.

```

{
  "nodes": {
    "M1A": {
      "name": "M1A",
      "shift": {
        "endUnfinished": 0,
        "shiftPattern": [
          [
            360,
            780
          ],
          [
            1800,
            2220
          ]
        ]
      },
      "scrapQuantity": {
        "probability": 0.5,
        "distributionType": "Geometric"
      },
      "processingTime": {
        "shape": 11.29570384628515,
        "rate": 10.206416837150321,
        "distributionType": "Gamma"
      },
      "wip": [],

```



```

    "failures": {},
    "element_id": "DreamNode_6",
    "_class": "Dream.BatchScrapMachine"
  },
  "Q2A": {
    "capacity": "2",
    "name": "Q2A",
    "isDummy": "0",
    "wip": [],
    "element_id": "DreamNode_17",
    "_class": "Dream.LineClearance",
    "schedulingRule": "FIFO"
  },
  "Q2B": {
    "capacity": "2",
    "name": "Q2B",
    "isDummy": "0",
    "wip": [],
    "element_id": "DreamNode_18",
    "_class": "Dream.LineClearance",
    "schedulingRule": "FIFO"
  },
  "M1B": {
    "name": "M1B",
    "shift": {
      "endUnfinished": 0,
      "shiftPattern": [
        [
          360,
          1260
        ],
        [
          1800,
          2700
        ]
      ]
    },
    "scrapQuantity": {
      "probability": 0.5,
      "distributionType": "Geometric"
    },
    "processingTime": {
      "logmean": 0.09892785211508301,
      "logsd": 0.3125963747837659,
      "distributionType": "Lognormal"
    },
    "wip": [],
    "failures": {},
    "element_id": "DreamNode_7",
    "_class": "Dream.BatchScrapMachine"
  },
  "S1": {
    "name": "Source",
    "entity": "Dream.Batch",
    "interarrivalTime": {

```

```
    "distributionType": "Fixed",
    "mean": "0.5"
  },
  "batchNumberOfUnits": 100,
  "element_id": "DreamNode_25",
  "_class": "Dream.BatchSource"
},
"QPa": {
  "capacity": "3",
  "name": "QPa",
  "isDummy": "0",
  "wip": [],
  "element_id": "DreamNode_22",
  "_class": "Dream.Queue",
  "schedulingRule": "FIFO"
},
"QPr": {
  "capacity": "3",
  "name": "QPr",
  "isDummy": "0",
  "wip": [
    {
      "_class": "Dream.Batch",
      "numberOfUnits": "80",
      "name": "Batch",
      "id": "16839092-001"
    }
  ],
  "element_id": "DreamNode_23",
  "_class": "Dream.Queue",
  "schedulingRule": "FIFO"
},
"PrA": {
  "name": "PrA",
  "shift": {
    "endUnfinished": 0,
    "shiftPattern": [
      [
        360,
        780
      ],
      [
        1800,
        2220
      ]
    ]
  },
  "scrapQuantity": {
    "probability": 0.4,
    "distributionType": "Geometric"
  },
  "processingTime": {
    "scale": 0.2176769587098079,
    "location": 1.1936521519564098,
    "distributionType": "Logistic"
  }
}
```

```
    },
    "wip": [],
    "failures": {},
    "element_id": "DreamNode_15",
    "_class": "Dream.BatchScrapMachine"
  },
  "QStart": {
    "capacity": "1",
    "name": "StartQueue",
    "isDummy": "0",
    "wip": [],
    "element_id": "DreamNode_24",
    "_class": "Dream.Queue",
    "schedulingRule": "FIFO"
  },
  "PrB": {
    "name": "PrB",
    "shift": {
      "endUnfinished": 0,
      "shiftPattern": [
        [
          360,
          1260
        ],
        [
          1800,
          2700
        ]
      ]
    },
    "scrapQuantity": {
      "probability": 0.5,
      "distributionType": "Geometric"
    },
    "processingTime": {
      "scale": 0.19146677117107616,
      "location": 1.149889151198035,
      "distributionType": "Logistic"
    },
    "wip": [
      {
        "unitsToProcess": "13.0",
        "_class": "Dream.Batch",
        "numberOfUnits": "80",
        "name": "Batch",
        "id": "16839094-001"
      }
    ],
    "failures": {},
    "element_id": "DreamNode_16",
    "_class": "Dream.BatchScrapMachine"
  },
  "PaA": {
    "name": "PaA",
    "shift": {
```

```

    "endUnfinished": 0,
    "shiftPattern": [
      [
        360,
        780
      ],
      [
        1800,
        2220
      ]
    ],
    },
    "scrapQuantity": null,
    "processingTime": {
      "shape": 4.8004017272798825,
      "scale": 1.4977931476819555,
      "distributionType": "Weibull"
    },
    "wip": [],
    "failures": {},
    "element_id": "DreamNode_13",
    "_class": "Dream.BatchScrapMachine"
  },
  "PaB": {
    "name": "PaB",
    "shift": {
      "endUnfinished": 0,
      "shiftPattern": [
        [
          360,
          1260
        ],
        [
          1800,
          2700
        ]
      ]
    },
    },
    "scrapQuantity": {
      "probability": 0.5,
      "distributionType": "Geometric"
    },
    "processingTime": {
      "shape": 18.715189491869822,
      "rate": 12.84936820932644,
      "distributionType": "Gamma"
    },
    "wip": [],
    "failures": {},
    "element_id": "DreamNode_14",
    "_class": "Dream.BatchScrapMachine"
  },
  "E1": {
    "element_id": "DreamNode_5",
    "_class": "Dream.Exit",

```

```

    "name": "Stock"
  },
  "M2A": {
    "name": "M2A",
    "shift": {
      "endUnfinished": 0,
      "shiftPattern": [
        [
          360,
          780
        ],
        [
          1800,
          2220
        ]
      ]
    },
    "scrapQuantity": {
      "probability": 0.5,
      "distributionType": "Geometric"
    },
    "processingTime": {
      "shape": 3.4463150512174194,
      "scale": 1.342301040240394,
      "distributionType": "Weibull"
    },
    "wip": [],
    "failures": {},
    "element_id": "DreamNode_8",
    "_class": "Dream.BatchScrapMachine"
  },
  "M2B": {
    "name": "M2B",
    "shift": {
      "endUnfinished": 0,
      "shiftPattern": [
        [
          360,
          1260
        ],
        [
          1800,
          2700
        ]
      ]
    },
    "scrapQuantity": {
      "probability": 0.5,
      "distributionType": "Geometric"
    },
    "processingTime": {
      "logmean": 0.2207444731393393,
      "logsd": 0.2793072333110925,
      "distributionType": "Lognormal"
    }
  },

```

```

    "wip": [],
    "failures": {},
    "element_id": "DreamNode_9",
    "_class": "Dream.BatchScrapMachine"
},
"Q3B": {
    "capacity": "2",
    "name": "Q3B",
    "isDummy": "0",
    "wip": [],
    "element_id": "DreamNode_20",
    "_class": "Dream.LineClearance",
    "schedulingRule": "FIFO"
},
"Q3A": {
    "capacity": "2",
    "name": "Q3A",
    "isDummy": "0",
    "wip": [],
    "element_id": "DreamNode_19",
    "_class": "Dream.LineClearance",
    "schedulingRule": "FIFO"
},
"BDA": {
    "processingTime": {
        "distributionType": "Fixed",
        "mean": "0"
    },
    "element_id": "DreamNode_1",
    "_class": "Dream.BatchDecompositionStartTime",
    "numberOfSubBatches": 4,
    "name": "Deco_A"
},
"BDB": {
    "processingTime": {
        "distributionType": "Fixed",
        "mean": "0"
    },
    "element_id": "DreamNode_2",
    "_class": "Dream.BatchDecompositionStartTime",
    "numberOfSubBatches": 4,
    "name": "Deco_B"
},
"EV": {
    "name": "attainment",
    "argumentDict": {},
    "interval": "1440",
    "start": "1440",
    "_class": "Dream.EventGenerator",
    "method": "Dream.Globals.countIntervalThroughput"
},
"MM": {
    "name": "MM",
    "shift": {
        "endUnfinished": 0,

```

```
"shiftPattern": [
  [
    360,
    1260
  ],
  [
    1800,
    2700
  ]
],
},
"scrapQuantity": {
  "probability": 0.5,
  "distributionType": "Geometric"
},
"processingTime": {
  "scale": 0.08886185000322964,
  "location": 0.44185006205738864,
  "distributionType": "Cauchy"
},
"wip": [],
"failures": {},
"element_id": "DreamNode_12",
"_class": "Dream.BatchScrapMachine"
},
"BRB": {
  "processingTime": {
    "distributionType": "Fixed",
    "mean": "0"
  },
  "element_id": "DreamNode_4",
  "_class": "Dream.BatchReassembly",
  "numberOfSubBatches": 4,
  "name": "Assembly_B"
},
"BRA": {
  "processingTime": {
    "distributionType": "Fixed",
    "mean": "0"
  },
  "element_id": "DreamNode_3",
  "_class": "Dream.BatchReassembly",
  "numberOfSubBatches": 4,
  "name": "Assembly_A"
},
"QM": {
  "capacity": "3",
  "name": "QM",
  "isDummy": "0",
  "wip": [],
  "element_id": "DreamNode_21",
  "_class": "Dream.Queue",
  "schedulingRule": "FIFO"
},
"M3B": {
```

```

"name": "M3B",
"shift": {
  "endUnfinished": 0,
  "shiftPattern": [
    [
      360,
      1260
    ],
    [
      1800,
      2700
    ]
  ]
},
"scrapQuantity": {
  "probability": 0.5,
  "distributionType": "Geometric"
},
"processingTime": {
  "shape": 12.679227945840147,
  "rate": 10.380578241576085,
  "distributionType": "Gamma"
},
"wip": [],
"failures": {},
"element_id": "DreamNode_11",
"_class": "Dream.BatchScrapMachine"
},
"M3A": {
  "name": "M3A",
  "shift": {
    "endUnfinished": 0,
    "shiftPattern": [
      [
        360,
        780
      ],
      [
        1800,
        2220
      ]
    ]
  },
  "scrapQuantity": {
    "probability": 0.5,
    "distributionType": "Geometric"
  },
  "processingTime": {
    "scale": 0.2614287816354414,
    "location": 1.1954189574091665,
    "distributionType": "Logistic"
  },
  "wip": [],
  "failures": {},
  "element_id": "DreamNode_10",

```



```
    "_class": "Dream.BatchScrapMachine"
  }
},
"edges": {
  "con_165": [
    "Q2A",
    "M2A",
    {}
  ],
  "con_160": [
    "M1A",
    "Q2A",
    {}
  ],
  "con_205": [
    "M2B",
    "Q3B",
    {}
  ],
  "con_185": [
    "BRA",
    "QM",
    {}
  ],
  "con_200": [
    "Q2B",
    "M2B",
    {}
  ],
  "con_180": [
    "M3A",
    "BRA",
    {}
  ],
  "con_140": [
    "S1",
    "QStart",
    {}
  ],
  "con_145": [
    "QStart",
    "BDA",
    {}
  ],
  "con_250": [
    "PrB",
    "QPa",
    {}
  ],
  "con_255": [
    "QPa",
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