

# DATA SCIENCE IN MANUFACTURING

## WEEK 1

ANDREW SHERLOCK, JONATHAN CORNEY, DANAI KORRE



## CODE OF CONDUCT

- Use welcoming and inclusive language
- Be respectful of different viewpoints and experiences
- Gracefully accept constructive criticism
- Focus on what is best for the community
- Show courtesy and respect towards other community members
- Be kind
- Be responsive and keep your cameras on if possible

# TAKE THE SURVEY

Please answer the pre-course survey: <https://edinburgh.onlinesurveys.ac.uk/pre-course-survey-ds4m-22-231>



# LECTURE: WEEK 1

## Introduction to the course and manufacturing context



## BY THE END OF THIS LECTURE YOU SHOULD:



Understand how the course will work



Know what learning resources are available



Understand what you need to do and how you will be assessed



Develop an understanding on how data science can be applied to manufacturing

# INTRODUCTION

- **About this course**
- **General Information**
- **Learning Objectives**
- **Syllabus**
- **Assessment**



# INTRODUCTION

- **About this course**

Support to develop a computational mindset, learning the tools of software carpentry, and developing a competence in writing and managing software in a manufacturing context.

- General Information

- Learning Objectives

Introduction to the importance of data in contemporary manufacturing throughout the product lifecycle and current paradigms of data management.

- Syllabus

Develop an understanding of data, from microformats to large datasets, including: simple descriptive statistics, exploratory visual analysis, finding, combining and relating datasets (data wrangling), drawing inferences from data.

- Assessment



# INTRODUCTION

- **About this course**

The course delivered via hybrid teaching, comprising of a series of lectures, discussions and workshop sessions to encourage student-centred learning.

- General Information

- Learning Objectives

A combination of technical lectures, guest speakers from industry and practical manufacturing experience will be used to allow students to make informed decisions on the selection and effective implementation of such approaches in manufacturing .

- Syllabus

- Assessment





# INTRODUCTION

- About this course

Usual timetable:

- **General Information**

**Friday a.m.**

- Learning Objectives

**09:00** Discussion on previous week's topic.  
May also include guest speakers.

- Syllabus

**09:30** Lecture on week's topic.

- Assessment

**10:30** Break

**10:50** Workshop (continued in own time)



# INTRODUCTION

- About this course

- **General Information**

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## Rest of week

Complete workshop

If there is demand we can hold evening surgeries  
(Thursday)



# INTRODUCTION

- About this course
- **General Information**
- Learning Objectives
- Syllabus
- Assessment

## Location

Online via Teams link

*or*

MSA POD, NMIS, 3 Netherton Sq, Paisley, Renfrew  
PA3 2EF

*or*

Class Room 2, Sanderson Building, King's  
Building, Edinburgh, EH9 3FB



# INTRODUCTION

- About this course

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## Rest of week

Complete workshop

If there is demand we can hold evening surgeries  
(Thursday)



# INTRODUCTION

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Upon successful completion of this course, you should:

6. Be familiar with collaborative practices around data collection, analysis and presentation.
7. Understand the manufacturing context:
  - Data types found in manufacturing
  - Strategic use of that data
  - How data can be used to optimise processes and operations



# INTRODUCTION

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Upon successful completion of this course, you should:

8. Have some understanding of particular data science topics:
  - Data Carpentry
  - Data visualisation
  - Machine Learning/AI



# INTRODUCTION

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**LO1 - Program** : Identify and deploy strategies for writing, understanding and managing computer programs using Python and version control.

**LO2 - Data** : The ability to handle, analyse, learn from and visualise a range of data, in a way that demonstrates its relevance to digital manufacturing and create data-driven solutions for various business use-cases.

**LO3 - Communicate** : Communicate around manufacture relevant issues, supported by the use of multiple data sources and appropriate analysis.



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**LO4 - Professionalism** : Working in collaborative, interdisciplinary data science teams to a professional standard.

**LO5 - Data Ecosystem** : Understanding the data ecosystem of manufacturing companies





# INTRODUCTION

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- Assessment

Week	Lecture	Workshop/ Tutorial
1	Introduction and Foundations	Intro to Python programming and Jupyter Notebooks
2	Data Carpentry	Intro to Python and Data carpentry
3	Product Lifecycle / Material Flow	Data cleaning and data carpentry
4	Data visualization and Exploratory Data Analysis	Data visualisation Exploratory Data Analysis
5	Current Manufacturing Software / PLM / ERP /MES	Data Representation / Relational databases

# INTRODUCTION

- About this course
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- **Syllabus**
- Assessment

Week	Lecture	Workshop/ Tutorial
6	Guest Lecture	Project feedback and resources
7	ML / AI	Machine Learning & prediction analytics (Supervised Learning)
8	Asset Management / IoT	Machine Learning & prediction analytics (Unsupervised Learning and cross validation)
9	EBoM / MBoM / Geometry / Time Series	Machine Learning & Visual Exercise (Data mining factory data)
10	Data for Industry 4 / New Business Models / Digital Twin / Digital Thread	Presenting Information



# INTRODUCTION

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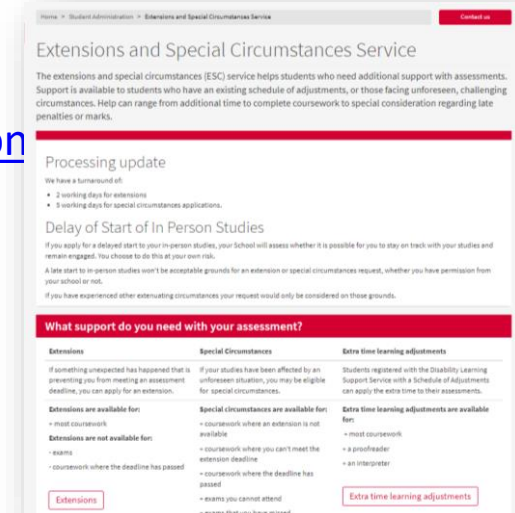
**Weekly Quiz (10%):** sent out every Wednesday and will be active until Saturday 23:59

**Assignment 1 (20%):** given out Friday 13th of October (week 4)  
Submitted 12 noon Tuesday 31st of October (week 7)

**Assignment 2 (70%):** given out Friday 3rd of November (week 7)  
Submitted on Tuesday 5th of December (week 12)

Please read this:

<https://www.ed.ac.uk/student-administration/special-circumstances>



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- **Assessment**

**Please set up a call with me via:**

<https://doodle.com/bp/andrewsherlock/data-science-in-manuf---project-discussion>

**to discuss potential assignment projects**



# CHATGPT: *HTTPS://OPENAI.COM/*

## AI Guidance for Staff and Students

The University strategy is to embrace curiosity and to pursue knowledge. As one of the first to teach and research in the field of Artificial Intelligence over 60 years ago we have set an ambition to be a global leader in Artificial Intelligence (AI) with integrity.

See below information for University of Edinburgh Students and staff on AI and the guidelines in its use in your studies, research and work.

Visit the University's AI site to learn more about our AI strategy



### AI Guidance for Staff

Explore the University's guidance on generative AI for staff.



### AI Guidance for Students

Discover the University's guidance on generative AI for students.



### AI Guidance FAQ

Find answers and examples of prompts to use generative AI tools effectively.

<https://www.ed.ac.uk/bayes/ai-guidance-for-staff-and-students>



THE UNIVERSITY of EDINBURGH  
School of Engineering

J Please write a python program for calculating the area of a circle



Certainly! To calculate the area of a circle, you can use the following formula:

$$A = \pi r^2$$

where:

- $A$  is the area
- $\pi$  is a mathematical constant (~3.14159)
- $r$  is the radius of the circle

Here is a Python program that takes the radius as an input and calculates the area of the circle:

```
python
import math

def calculate_circle_area(radius):
    """Calculate the area of a circle given its radius."""
    if radius < 0:
        raise ValueError("Radius cannot be negative")

    area = math.pi * radius ** 2
    return area
```

Regene

Some or all the class, might be asked to attend interviews and provide verbal explanations of coursework



# VOLUNTEER

**AS A PROGRAMME REPRESENTATIVE TO:**

Gain transferable skills

Meet new people

Give a voice to students like you

School of Engineering Programme Representative nomination form



<https://edin.ac/3eJZhTT>

# Who's who

## Lecturers

- Professor Andrew Sherlock: a.sherlock@strath.ac.uk
- Dr Danai Korre: d.korre@ed.ac.uk
- Professor Jonathan Corney: j.r.corney@ed.ac.uk (**Course Organiser**)

## Tutors

- Sydney (Li Shuang): sli63@exseed.ed.ac.uk
- Abbas Rizvi: abbas.rizvi@ed.ac.uk
- Anushanth Karalasingam: a.karalasingam@sms.ed.ac.uk
- Haleema Sadia

## Course Secretary

Lucy Davie (lucy.davie@ed.ac.uk), upskilling@ed.ac.uk

# ABOUT ME

1995-1998. **PhD in 3D shape optimisation**, University of Edinburgh



1998-2000. **Research Engineer**, Mathématiques Appliquées S.A.



2000-2005. **Lecturer at University of Edinburgh:** *Search algorithms in 3D CAD, numerical simulation of electrochemical machining of titanium aluminide*



2006-present. **CEO ShapeSpace:** *Spin-out for 3D shape search technology and engineering analytics projects*



2012-2015. **VP Engineering Actify Inc:** *CAD software development. Ran development teams in San Francisco, CA, Edinburgh, UK and Minsk, Belarus.*





# ABOUT ME

2016-2019. **Royal Academy of Engineering Visiting Professor at Uni of Edinburgh**



2019-2020. **Secondment at Babcock Rosyth.**



2019-2020. **Senior Lecturer (part-time) at Uni of Edinburgh.**



2020-2021. **Industrial Chair of Data-driven Manufacturing (part-time) at Uni of Edinburgh.**

Aug 2021 - **Director of Data-driven Manufacturing (part-time) at NMIS.**



## JONATHAN CORNEY



**Jonathan Corney, Prof,** Professor Jonathan Corney, School of Engineering, University of Edinburgh: Is Professor of Digital Manufacturing and has been PI on over £1.8 Million of EPSRC funded research. He has published two books and over 80 papers on various aspects of CAD/CAM and advanced manufacturing. His career started at Heriot-Watt University where he worked on geometric modelling, feature recognition and shape search systems. In 2007 he moved to Strathclyde as Professor of Design and Manufacture where he investigated manufacturing applications of crowdsourcing; Internet cloud interfaces for manufacturing and systems for interactive search of digital media.

## DANAI KORRE

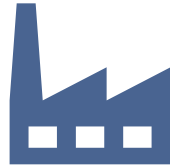


**Danai Korre, PhD**, is a Research Associate at the University of Edinburgh, School of Engineering, in immersive technologies. She has a BSc in Informatics, an MSc in digital media and holds a PhD in Data Science and Human-Oriented Artificial Intelligence from the University of Edinburgh. She has more than 10 years of experience in working with data.



**Shuang Li, PhD**, is a Research Associate in digital manufacturing at the University of Edinburgh, School of Engineering. She has a BSc in Mechanics, a MSc and PhD in Aerospace Engineering. Her main research interests focus on artificial intelligence and digital manufacturing. Her experiences involve Production Control and Management using AI algorithms (Genetic Algorithms, etc.) and simulation methods (Discrete Event Simulation, etc.). Her recent works involve Convolutional Neural Networks (CNN) and Graph Neural Networks (GNN) developments and applications for classification and recognition tasks in manufacturing scenarios.

# LECTURES



## **Week 1**

Introduction and  
Foundations



## **Week 2**

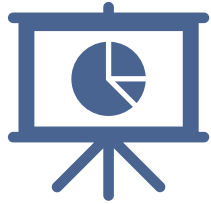
Data Carpentry



## **Week 3**

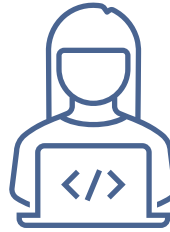
Product Lifecycle/  
Material Flow

# LECTURES



## **Week 4**

Data Visualisation and EDA



## **Week 5**

Current Manufacturing  
Software / PLM / ERP /MES



## **Week 6**

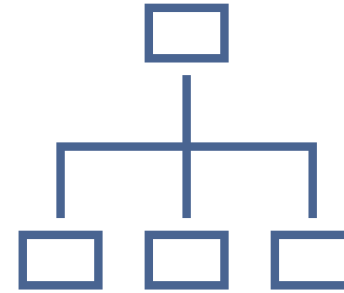
Guest lecture

# LECTURES



## Week 7

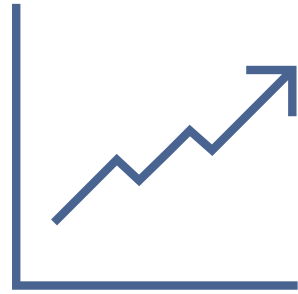
Machine Learning and  
Artificial Intelligence (ML/AI)



## Week 8

Asset Management / IoT

# LECTURES



## Week 9

EBoM / MBoM / Geometry / Time Series



## Week 10

Data for Industry 4 / New Business  
Models/Digital Twin / Digital Thread



# WORKSHOPS

Intro to Python  
programming and  
Notebooks

More Python and  
intro to Data  
carpentry

Data carpentry and  
data cleaning

Data visualisation  
and Exploratory  
Data Analysis (EDA)

Data Representation  
/ Relational  
databases

Assignment 1  
feedback and  
assignment 2 prep

Machine Learning &  
prediction analytics  
(Supervised  
Learning)

Machine Learning &  
prediction analytics  
(Unsupervised  
Learning)

Machine Learning &  
visual exercise (Data  
mining factory data)

Presenting  
Information



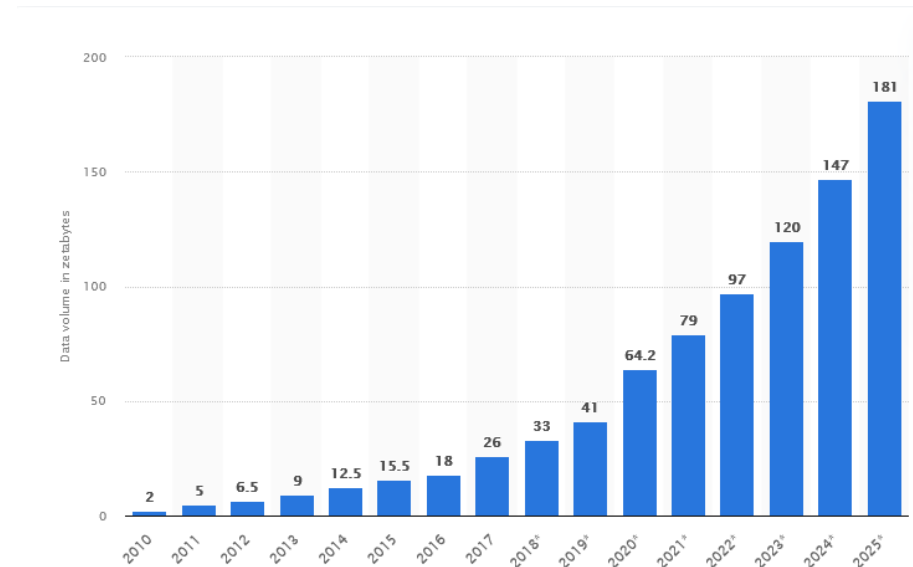
# WHAT IS DATA SCIENCE?

Data science implies a focus involving **data** and, by extension, **statistics**, or the systematic study of the **organization**, **properties**, and **analysis** of data and its role in **inference**, including our **confidence** in the inference [1].

# WHAT IS DATA SCIENCE?

Data science differs from statistics and other disciplines in several important ways:

- the 'data' part of data science is increasingly heterogeneous: unstructured text, images, video often emanating from networks with complex relationships between their entities [1].



Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2025 (in zettabytes).

Source: Statista

# WHAT IS DATA SCIENCE?

Data science differs from statistics and other disciplines in several important ways:

- Analysis, including the combination of the two types of data, requires **integration**, interpretation, and **sense making** that is increasingly derived through tools from multiple fields. Most data generated by humans and computers today is for consumption by computers [1].

# WHAT IS DATA SCIENCE?

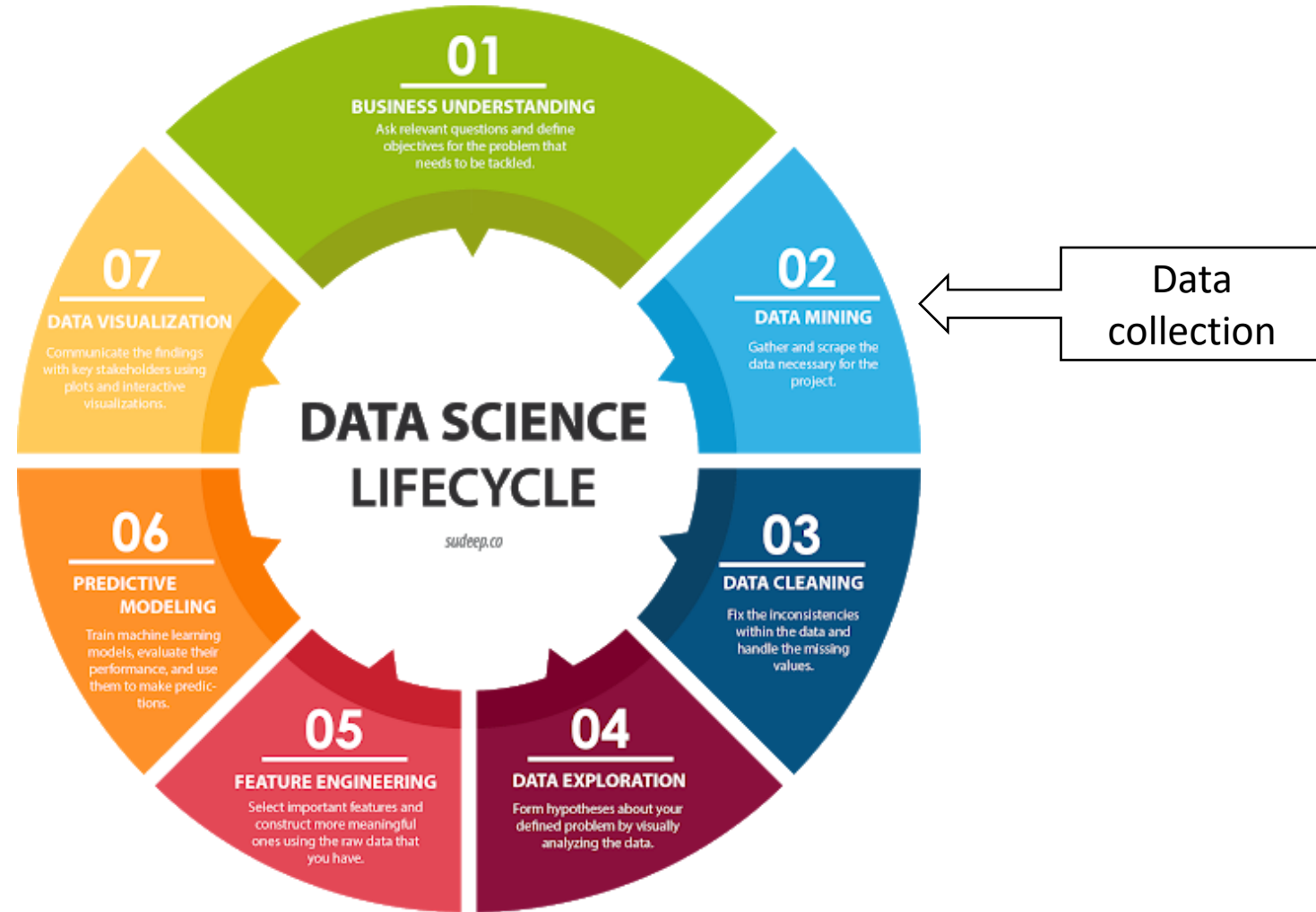
**Scalability:** big data helps in decision making providing lots of raw material for the creation of new knowledge.

**Scale matters:** traditional database models are not particularly suited for knowledge discovery.

They are optimized for fast access and summarization of data, given a user who knows what query they want to ask.

Knowledge discovery searches for patterns in data when users lack a well-formulated query [1].

# DATA SCIENCE LIFECYCLE



# Data Science Tools

## 1 Languages



## 2 Data Analysis



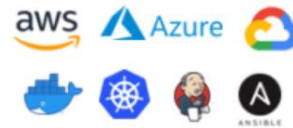
## 3 Data Engineering



## 4 Web Development



## 5 Cloud DevOps



## 6 Machine Learning

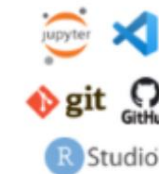


## 7 Business Intelligence



## 8 Other

Development and version control, repositories, integrated development environments (IDE)



(Min, 2020)

# Data Science stack for this course

**1** Languages



**2** Data  
Analysis



**3** Data  
Engineering



**4** Web  
Development



**5** Cloud  
DevOps



**6** Machine  
Learning



**7** Business  
Intelligence



**8** Other  
Development and version  
control, repositories,  
integrated development  
environments (IDE)



(Korre, 2021)



# Data Science stack for this course

python™



PostgreSQL



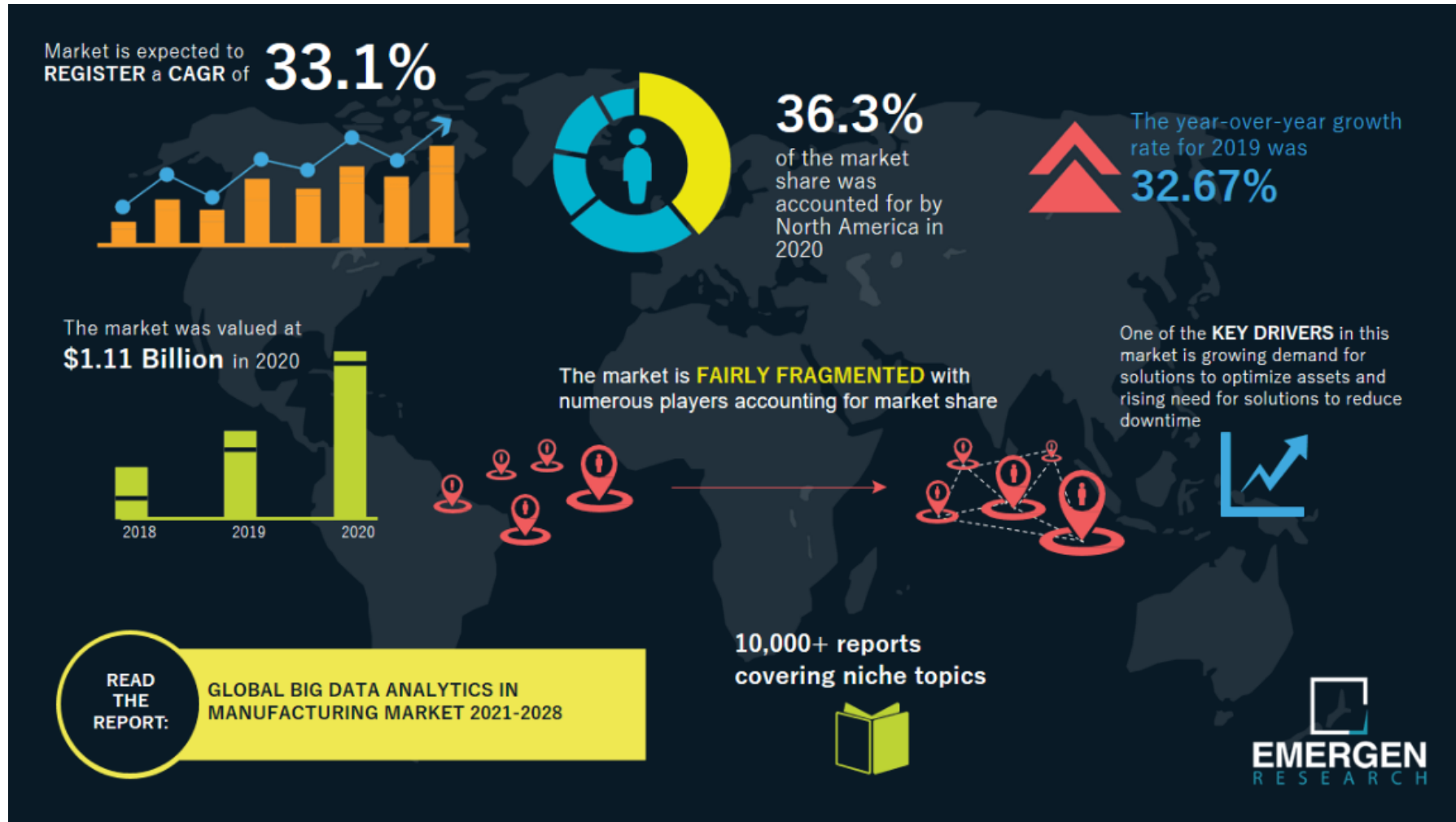
MySQL



PyTorch



# HOW BIG IS DATA SCIENCE IN MANUFACTURING?



## NOTES: HOW BIG IS DATA SCIENCE IN MANUFACTURING?

According to one estimate by Emergen Research, **“The Big Data Analytics in Manufacturing Industry Market was valued at USD 1.11 billion in 2020 and is expected to reach USD 6.79 billion by 2027, at a CAGR of 33.1% over the forecast period 2021 - 2027. ”** [2]

## NOTES: HOW BIG IS DATA SCIENCE IN MANUFACTURING?

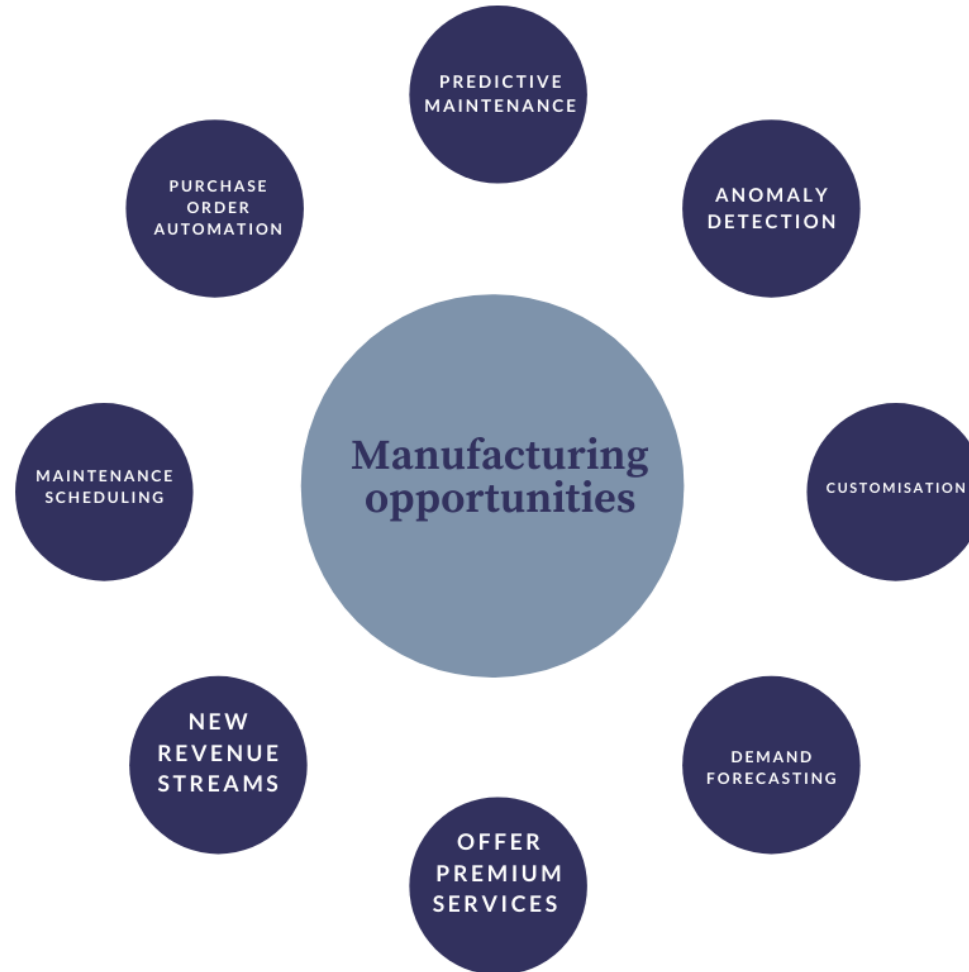
In another estimation, “TrendForce forecasts that the size of the global market for smart manufacturing solutions will surpass US\$320 billion by 2020.” In another report it was stated that “The global smart manufacturing market size is estimated to reach USD 395.24 billion by 2025, registering a CAGR of 10.7% according to a new study by Grand View Research, Inc.”[3]

## NOTES: HOW BIG IS DATA SCIENCE IN MANUFACTURING?

Big data analytics is a framework of gathering large volume of data for data mining, trend analysis. Over the years, industrialization is taking place at a fast pace and the volume of manufacturing is increasing day by day.

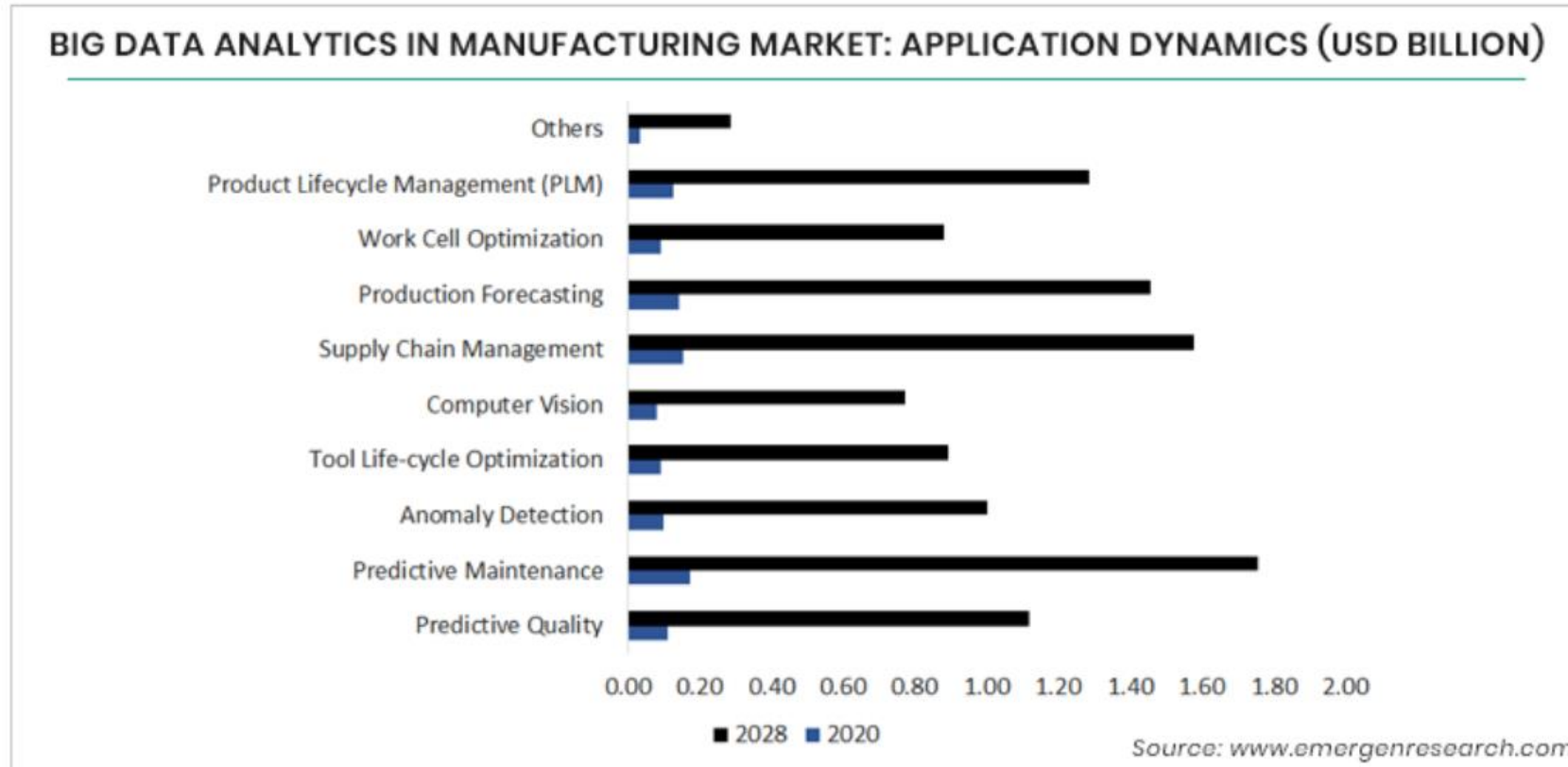
Therefore, the massive shift in data generation by manufacturing industry is pushing the global big data analytics in manufacturing industry market. [4]

# HOW IS DATA SCIENCE USED IN MANUFACTURING

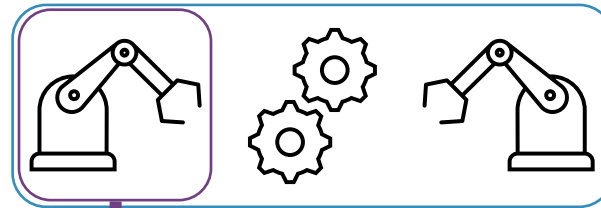
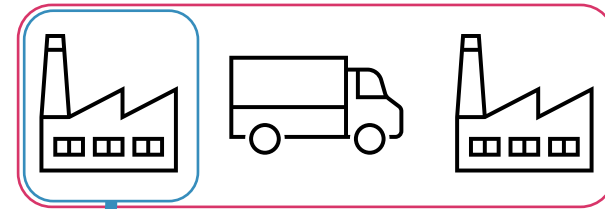


Data science opportunities in manufacturing [5]

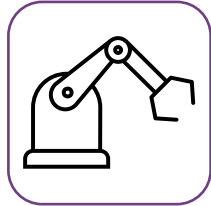
# HOW BIG IS DATA SCIENCE IN MANUFACTURING? APPLICATIONS AND PREDICTIONS



**Smart Business:** Data-driven manufacturing analytics for value chain



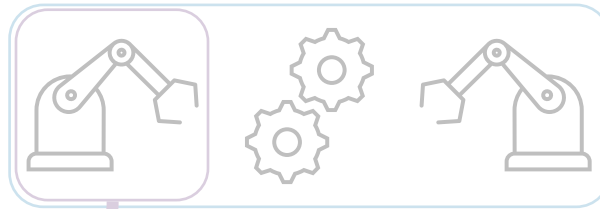
**Smart Factory:** Enablement of coordinated manufacturing operations



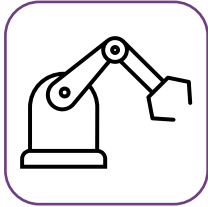
**Smart Processes:** Enhancement of individual manufacturing processes



**Smart Business:** Data-driven manufacturing analytics for value chain



**Smart Factory:** Enablement of coordinated manufacturing operations

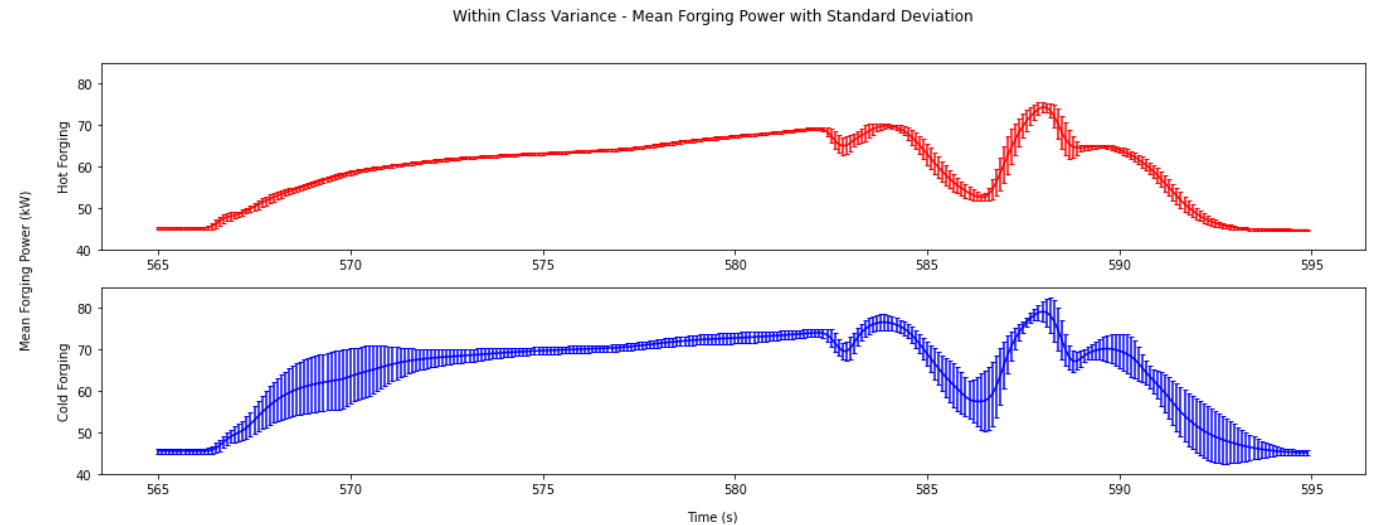
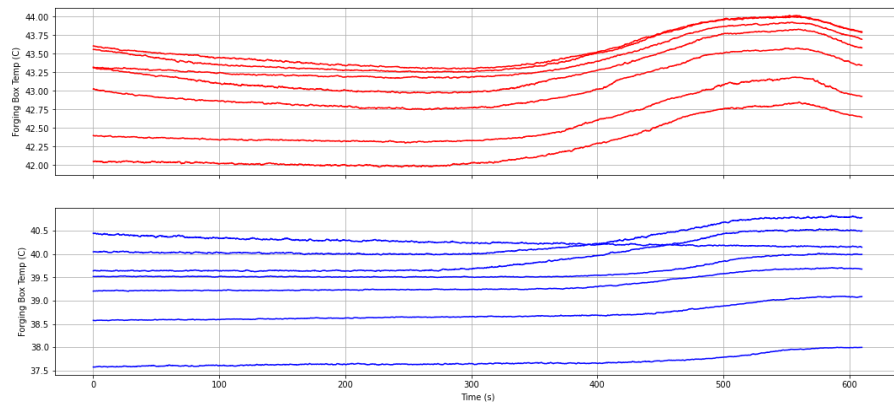


**Smart Processes:** Enhancement of individual manufacturing processes

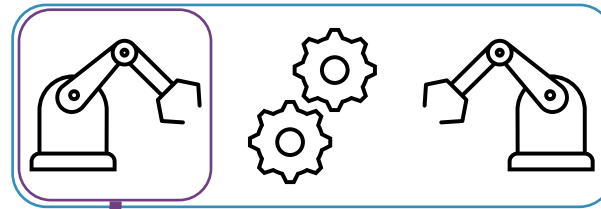


## CASE STUDY: DIGITAL THREAD

- External project led by AFRC technical teams with support of Data Analytics Theme
- Objective - explore data engineering/analytics for digital threads of parts manufactured by AFRC Radial Forge and then subsequently machined
- Identified machining chatter and currently exploring the relationship with initial radial forging conditions



**Smart Business:** Data-driven manufacturing analytics for value chain



**Smart Factory:** Enablement of coordinated manufacturing operations



**Smart Processes:** Enhancement of individual manufacturing processes

# EXAMPLE OF ANALYTICS PROJECT : VALVE BUSINESS

Investigate component variety at valve business on possibility to drive operational improvements.

In particular, the project was in two distinct areas:

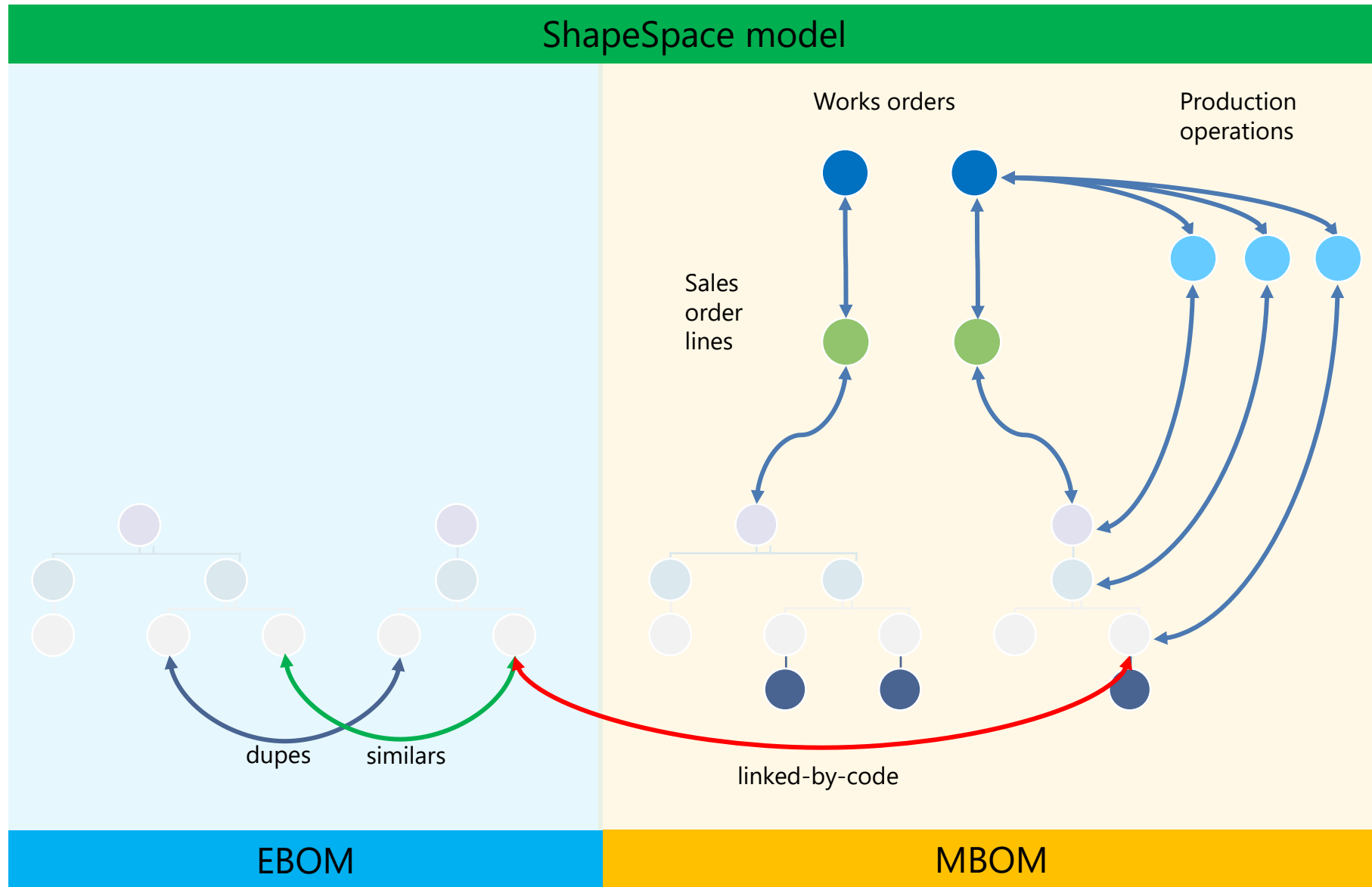
## **A. Component Similarity.**

Determine the degree of component variety and similarity in designs of paddles and valve bodies.

## **B. Production Schedules.**

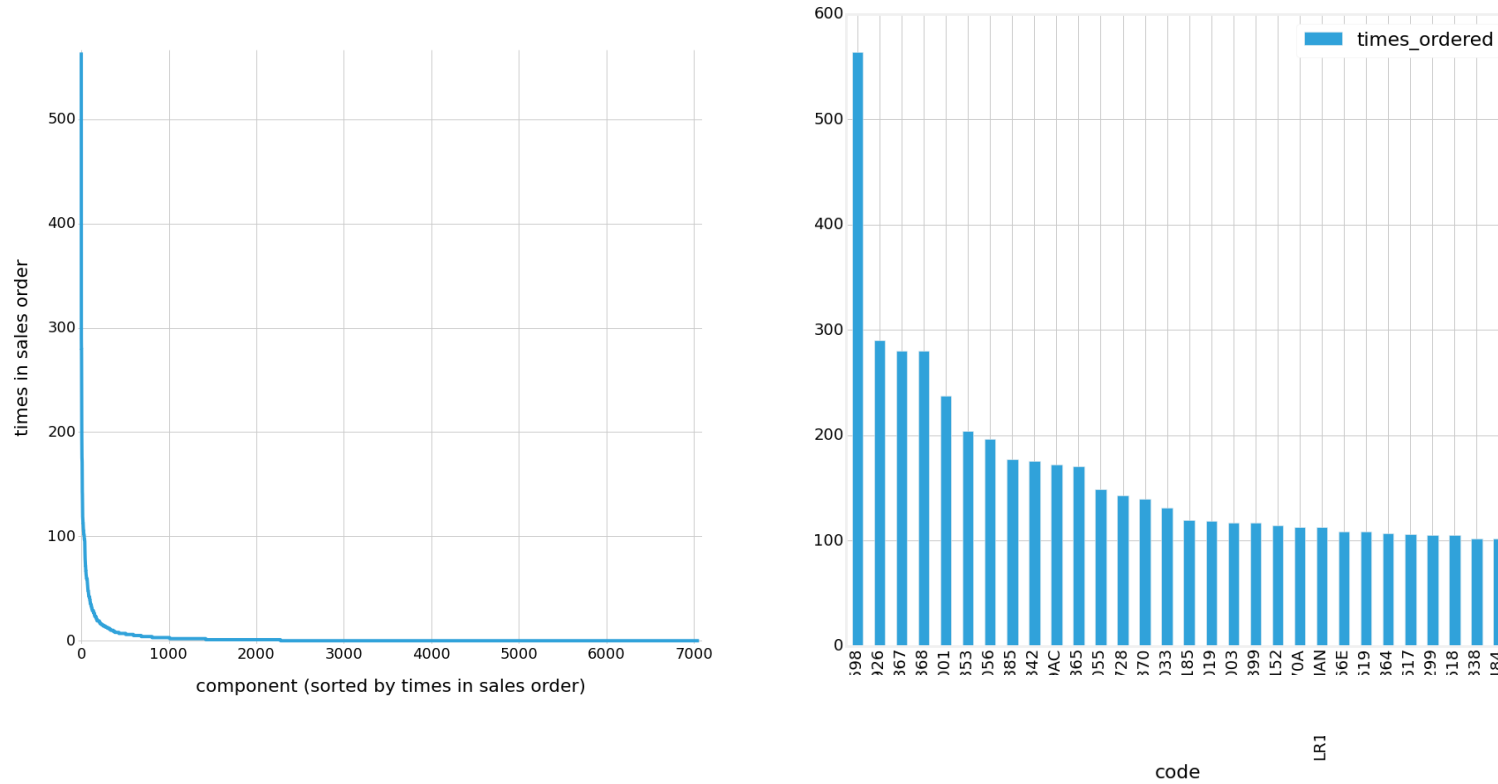
Investigate how much schedules can be optimised by taking account of component and feature similarity to reduce overall setup times without compromising on-time delivery.

Extracted from Autodesk Vault / Inventor



Extracted from ERP

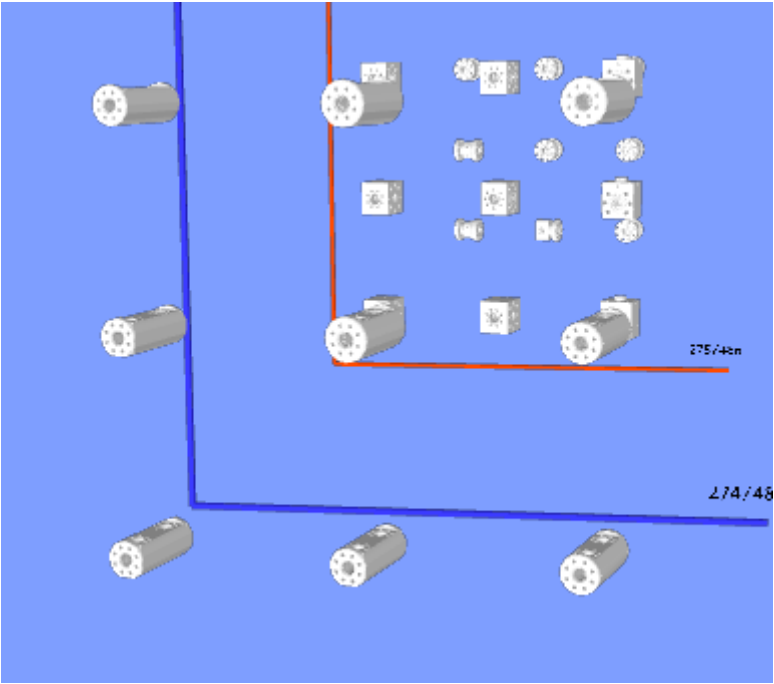
# PROCUREMENT SAVINGS BY ANALYSING SIMILAR COMPONENTS



Identified frequently used components with high price variance to similar items.

**£XXk** per year of confirmed cost savings identified.

# MACHINING SAVINGS BY ANALYSING SIMILAR COMPONENTS

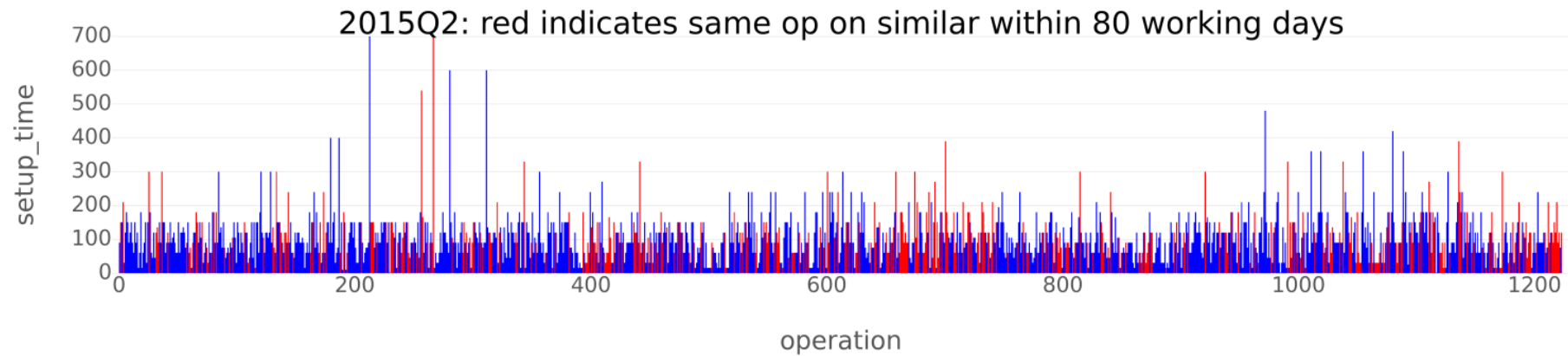
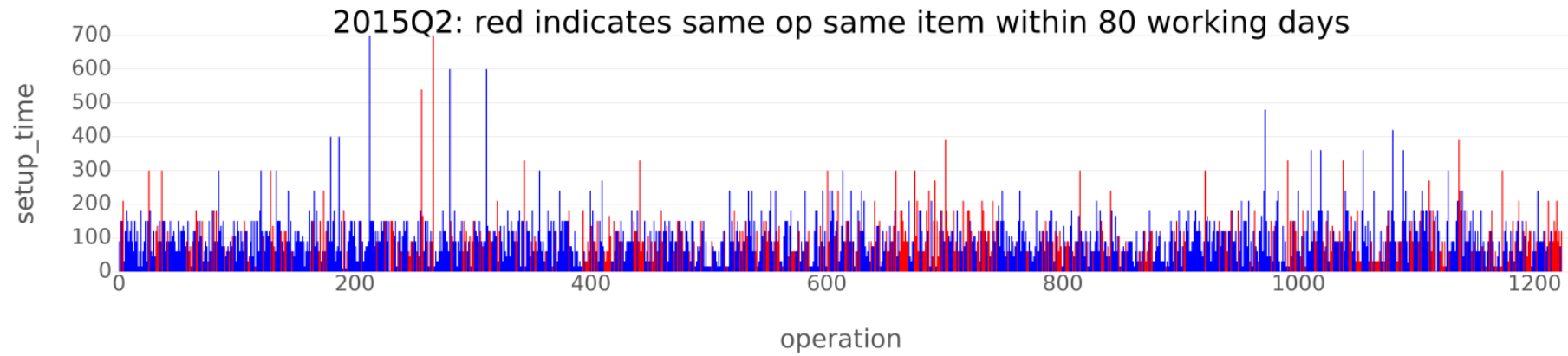


Identified groups of similar items. Analysed variance of setup times and machining times within groups.

This cluster has the largest potential run time saving of £20,314 (assuming machining rate of £50/hr) if all members of the cluster had the same run time.

Item	Description	Run time (mins)	Sales quantity	Total runtime (mins)	Total run time cost (£ at £50/hr)	Potential runtime (mins)	Potential run time cost (£ at £50/hr)
		1,019	3	3,057	2,547	1,956	1,630
		652	0	0	0	0	0
		1,158	46	53,268	44,390	29,992	24,993
		652	0	0	0	0	0
Total				56,325	£46,937	31,948	£26,623
Potential Saving							£20,314

# 80 WORKING DAY WINDOW





# PRODUCTION OPERATION ANALYSIS

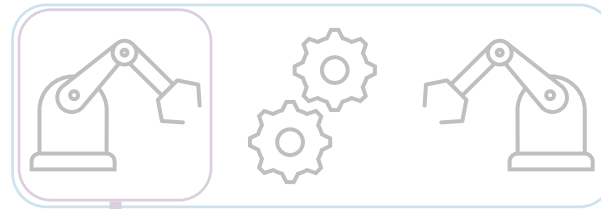
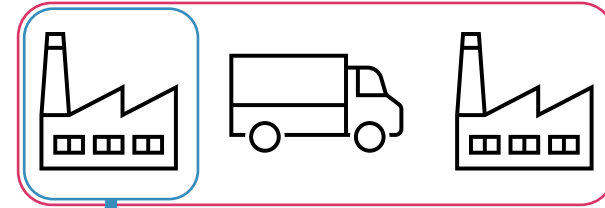
Analysed how often the same machining operation on the same or similar component was repeated in 4 month planning period.

Around 40% of machining time in set-ups.

Opportunity to reduce set-up times by 33% by batching similar jobs.

Re-engineering process underway to standardise frequently used components to enable larger batch sizes.

**Smart Business:** Data-driven manufacturing analytics for value chain



**Smart Factory:** Enablement of coordinated manufacturing operations



**Smart Processes:** Enhancement of individual manufacturing processes

# Xometry

Manufacturing on demand

# REFERENCES

1. Dhar, V. (2013). "Data science and prediction". Communications of the ACM. 56 (12): 64–73. doi:10.1145/2500499. S2CID 6107147
2. Emergen Research, h., 2021. Big Data Analytics in Manufacturing Industry Growth 33.1% CAGR During 2020- 2028 | Market Size, Share & Trend. [online] Emergenresearch.com. Available at: <<https://www.emergenresearch.com/industry-report/big-data-analytics-in-manufacturing-market>> [Accessed 18 October 2021].
3. Amruthnath, Nagdev. (2020). Data Science in Manufacturing: An Overview.
4. Big Data Analytics in Manufacturing Industry Market - Global Analysis, Size, Share, Growth, Trends, and Forecast 2019 – 2027 IT & Telecom TMRGL69903 Ongoing Dec 2021
5. IIoT World, "iiot-world.com," [Online]. Available: <https://iiot-world.com/connected-industry/what-data-science-actually-means-to-manufacturing/>.
6. Trapp, R., 2014. Why Businesses Need To Shift Data Analysis From The Center To The Front Line. [online] Forbes. Available at: <<https://www.forbes.com/sites/rogertrapp/2014/09/29/why-businesses-need-to-shift-data-analysis-from-the-centre-to-the-front-line/?sh=6c533314773c>>