DATA SCIENCE IN MANUFACTURING
WEEK 1

ANDREW SHERLOCK, JONATHAN CORNEY, DANAI KORRE

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

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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.

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

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.

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

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 .

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Usual timetable:

Friday a.m.

09:00	Discussion on previous week's topic. May also include guest speakers.
10:00	Lecture on week's topic.
10:50	Break
11:10	Workshop (continued in own time)

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Rest of week

Complete workshop

Update learning journal

If there is demand we can hold evening surgeries (Tues or Weds?)

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Upon successful completion of this course, you should:

1. Be familiar with programming with Python, version control with Git and other key software practices.
2. Have an understanding of data formats, their wrangling and management, relational databases (SQL), CAD formats.
3. Have developed skills to analyse and visualise a range of data using descriptive statistics and exploratory data analysis.
4. Introduce you to the ramifications of data collection and use in a manufacturing setting.
5. Criticise data use and practises

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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 optimize processes and operations

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Upon successful completion of this course, you should:

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

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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 - Understanding the data ecosystem of manufacturing companies

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- **Syllabus**

Week	Lecture	Workshop/ Tutorial
1	Introduction and Foundations	Intro to Python programming and Jupyter Notebooks
2	Data Carpentry	Git and data carpentry introduction
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

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- **Syllabus**

Week	Lecture	Workshop/ Tutorial
6	ML/AI	Jupyter Notebooks and Machine Learning (ML)
7	Asset Management / IoT	ML and visual Exercise (Time series)
8	EBoM / MBoM / Geometry / Time Series	ML and vis Exercise
9	Data for Industry 4 / New Business Models/Digital Twin / Thread	Presenting Information
10		Assessment

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 and Assistant Lecturer at the University of Edinburgh, School of Engineering, in immersive technologies and data science. She has a BSc in Informatics, an MSc in design informatics and holds a PhD in Data Science, Human-Oriented Artificial Intelligence and User Experience (UX) research from the University of Edinburgh. She has more than 8 years of experience in EdTech, UX and working with data. She is also a review editor in mobile and ubiquitous computing.

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

Machine Learning and Artificial Intelligence (ML/AI)

LECTURES

Week 7

Asset Management / IoT

Week 8

EBoM / MBoM / Geometry / Time Series

Week 9

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

WORKSHOPS

Intro to Python programming and Notebooks	Git and data carpentry introduction	Data carpentry and data cleaning	Data visualisation and Exploratory Data Analysis (EDA)
Data Representation / Relational databases	Notebooks and ML	ML and visual based exercise (Time series)	ML and visualisation exercise (Data mining factory data)
	Presenting Information	Assessment (support)	

KEEPING A LEARNING JOURNAL

Students are expected to reflect upon their learning on a week by week basis.

The reflective learning journal is intended to consolidate learning and to help students consciously and intentionally develop Data Science skills.

As Engineers, reflective writing might be new and a little bit confusing but there is a purpose for using it. Reflection has been shown to be a highly effective way of learning.

Your learning journal will be the basis on which we hold the discussion and Q&A each week.

More details and a video are on the website.

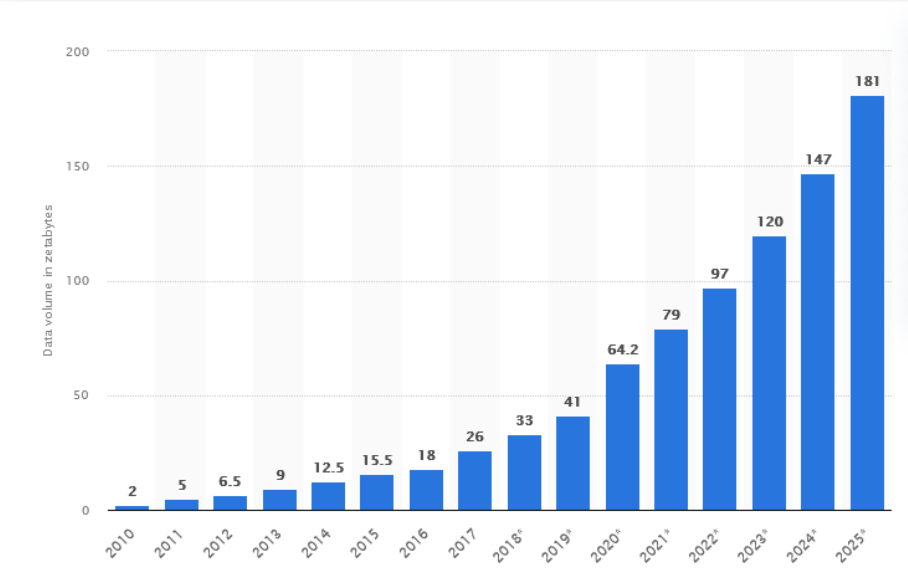
WHAT IS DATA SCIENCE?

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?

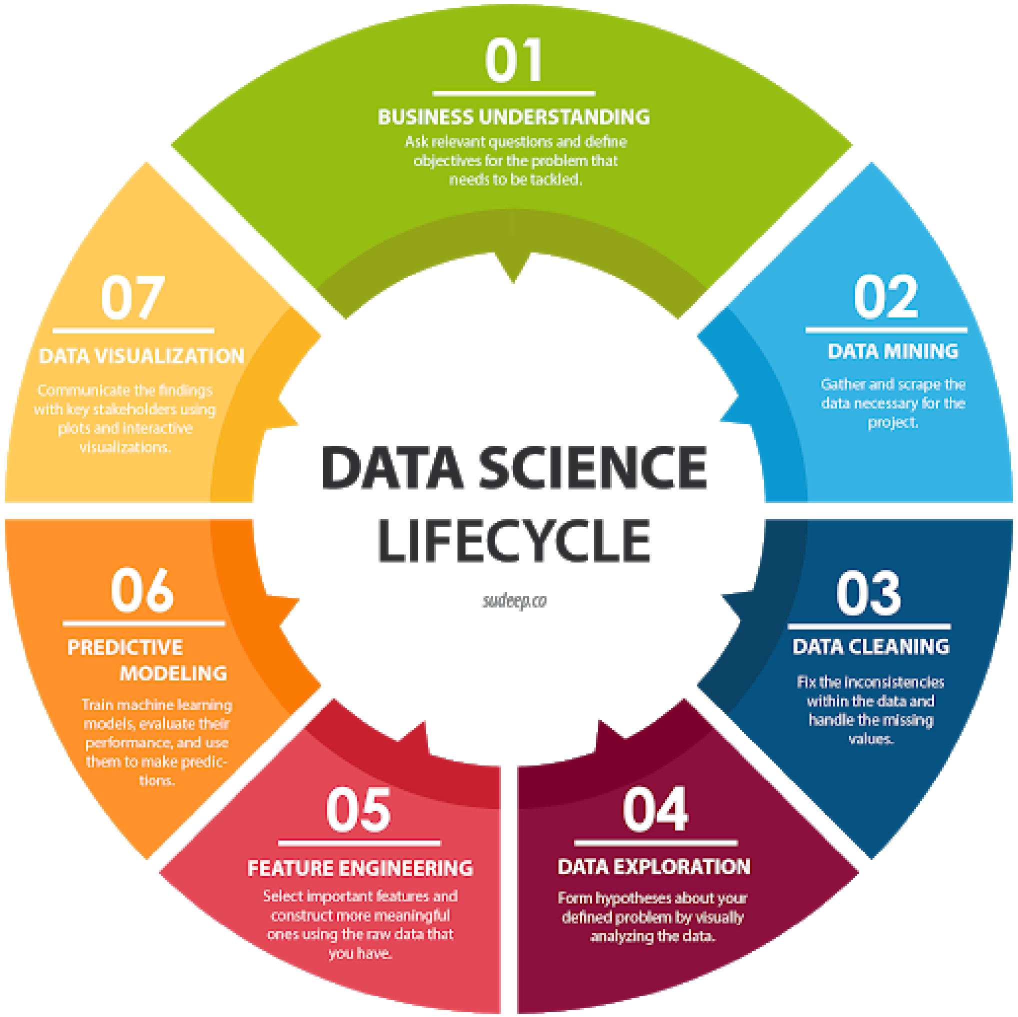
Scalability: big data helps in decision making providing lots of raw material for the creation of new knowledge.

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

(Min, 2020)

Source: Min

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

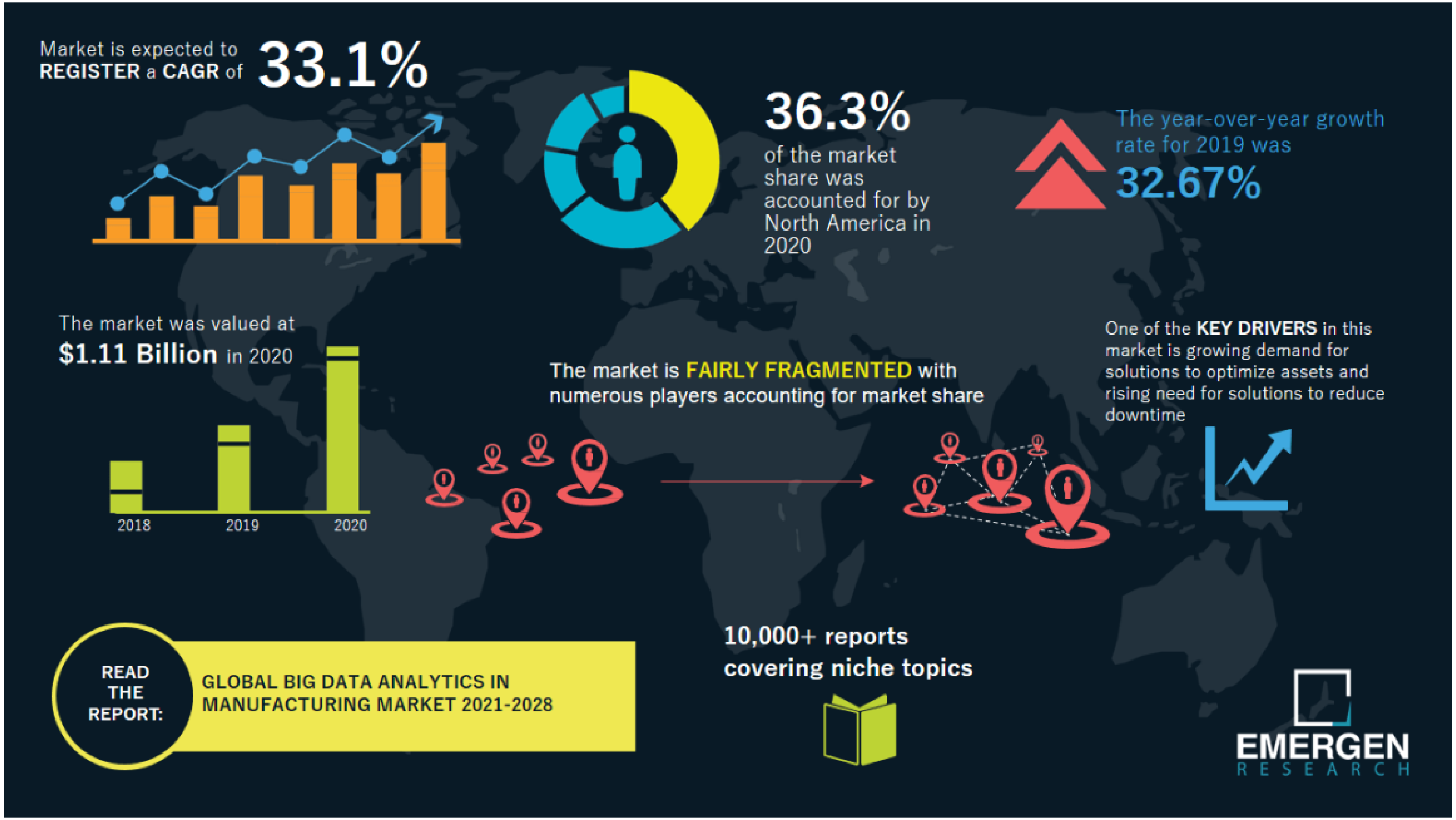
8 Other

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

(Korre, 2021)

Data Science stack for this course

HOW BIG IS DATA SCIENCE IN MANUFACTURING?



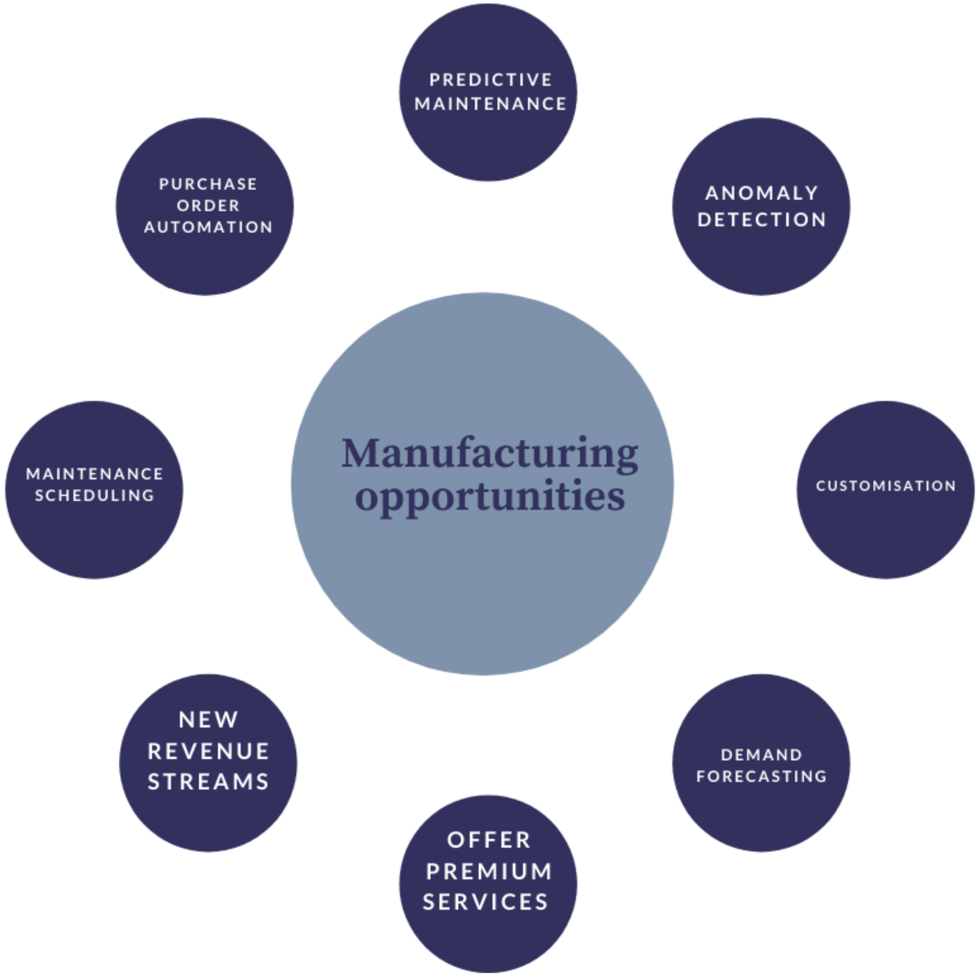
NOTES: HOW BIG IS DATA SCIENCE IN MANUFACTURING?

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]

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]

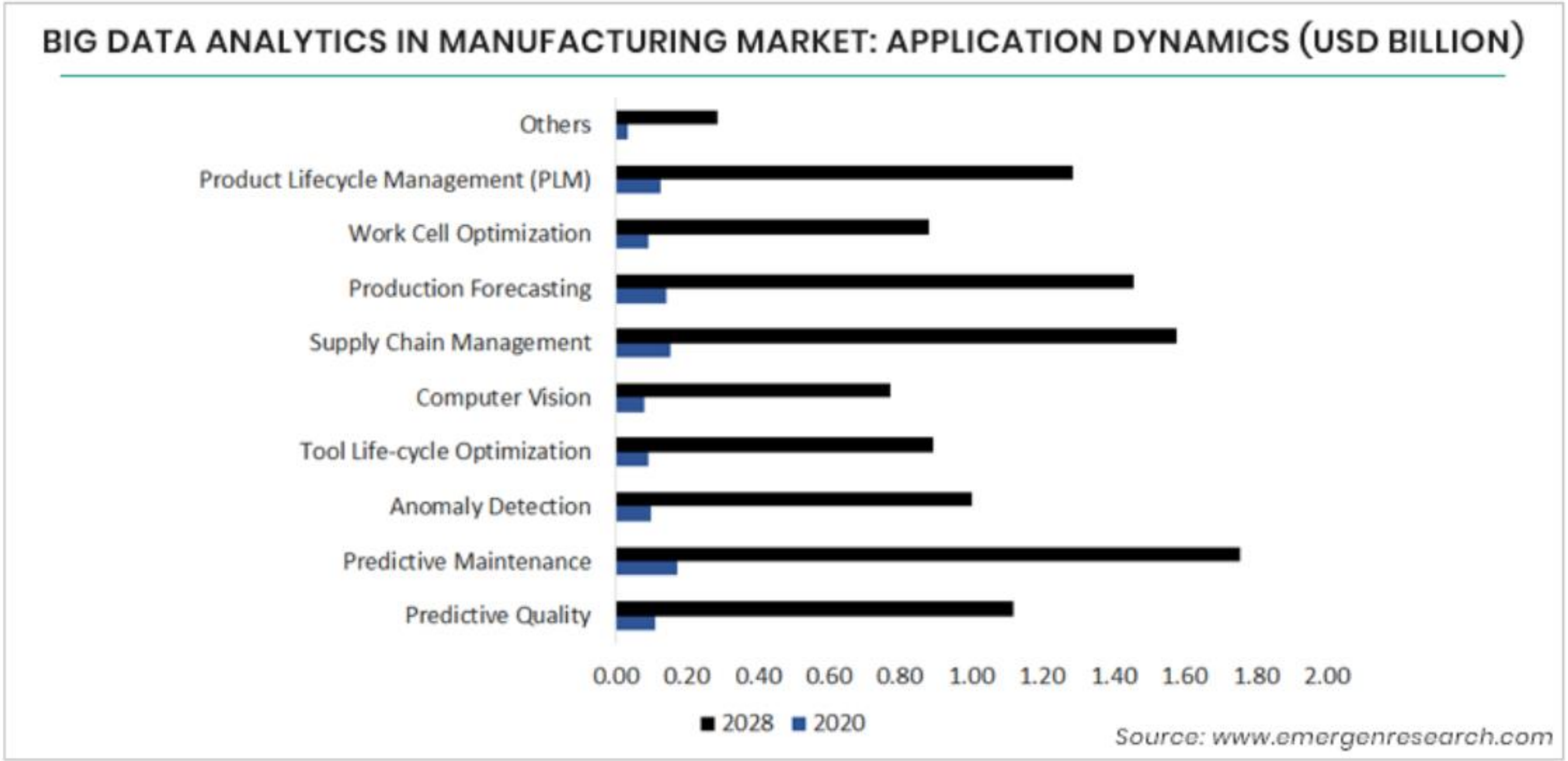
Big data analytics is a framework of gathering large volume of data for data mining, trend analysis. Over the years, industrialization is taking place at a fast pace and the volume of manufacturing is increasing day by day. Therefore, the massive shift in data generation by manufacturing industry is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



MY PERSONAL TAKE ON DATA SCIENCE IN MANUFACTURING

Three areas where data can enhance manufacturing:

- Data-driven Manufacturing and Value-chain
- Digital coordination of manufacturing
- Digital enhancement of manufacturing process

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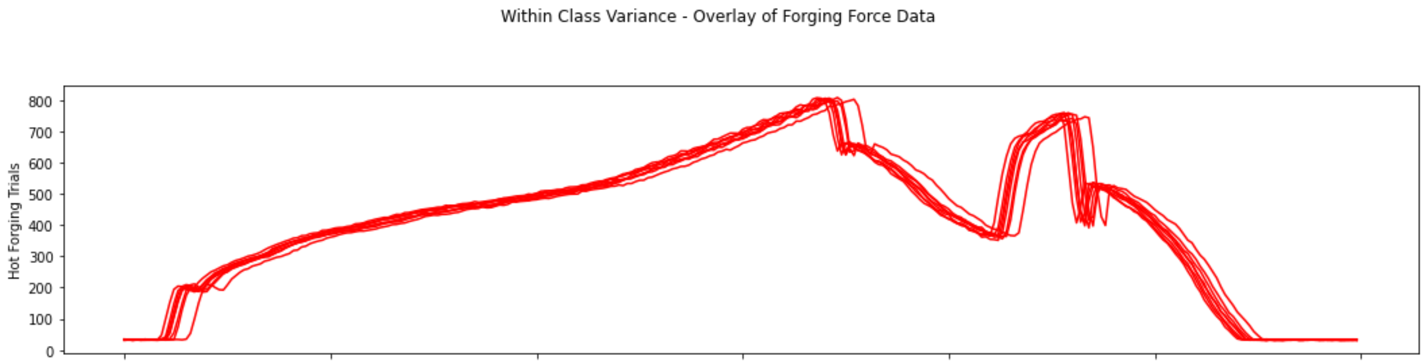


THE UNIVERSITY of EDINBURGH
School of Engineering

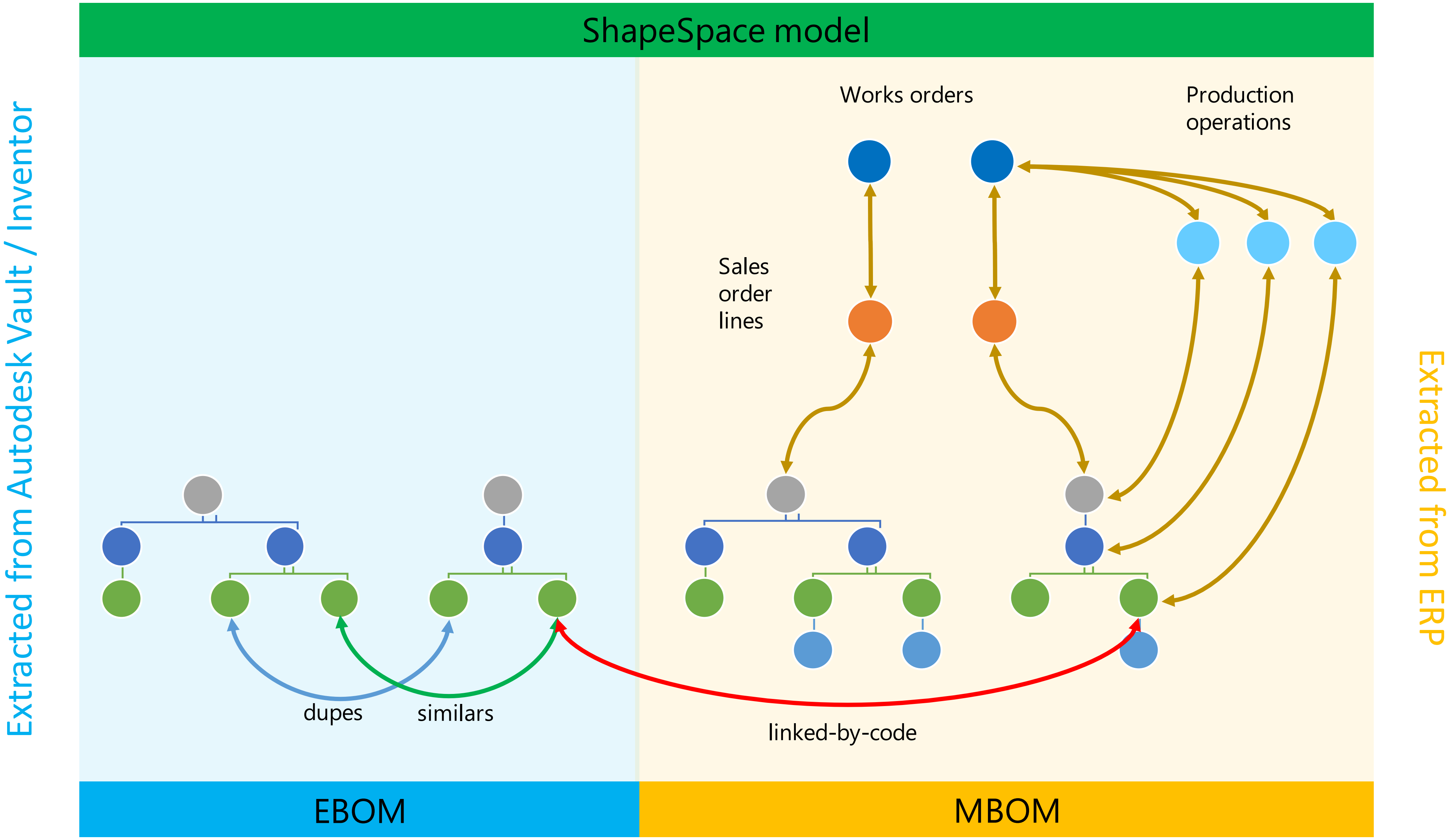
EXAMPLE OF ANALYTICS PROJECT : VALVE BUSINESS

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

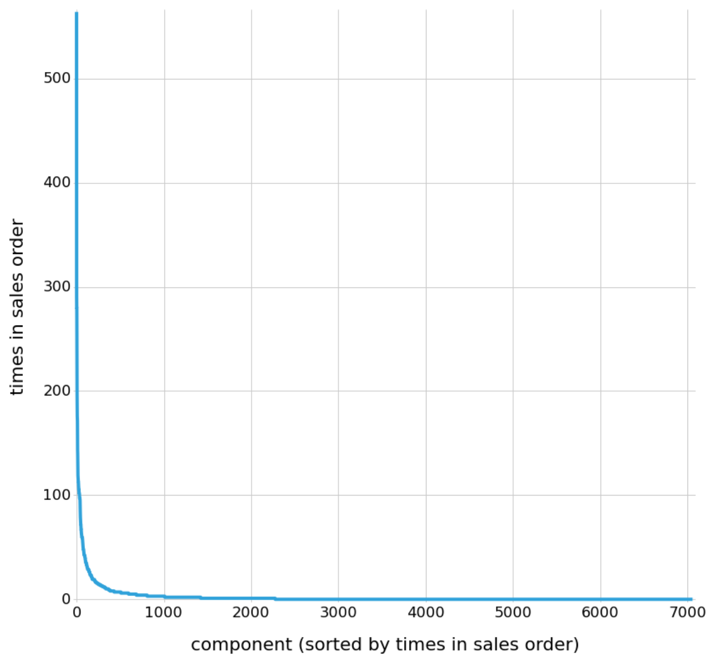
In particular, the project was in two distinct areas:

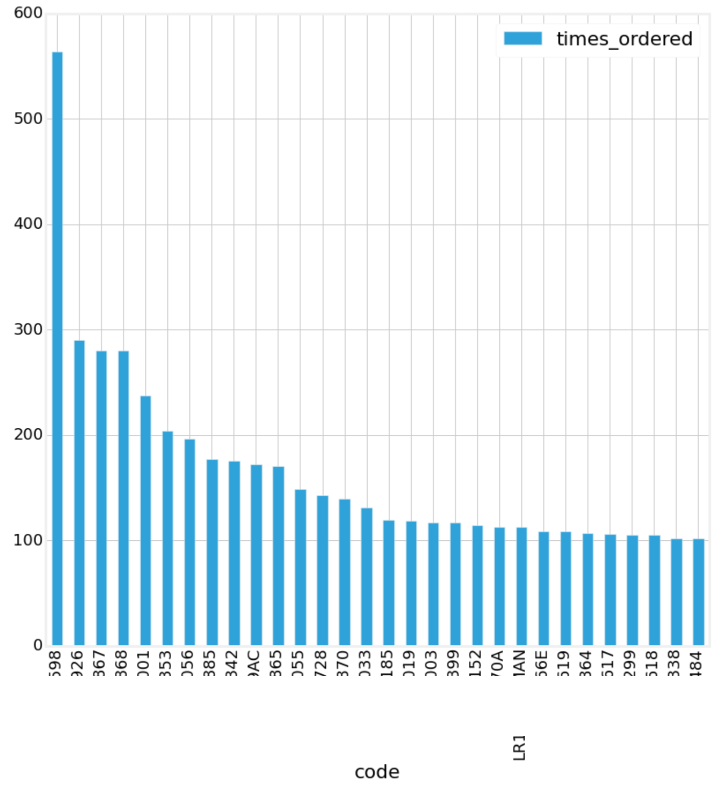
A. Component Similarity.
Determine the degree of component variety and similarity in designs of paddles and valve bodies.

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.


ShapeSpace model
Works orders
Production
operations
Sales
order
lines
Extracted from Autodesk Vault / Inventor
Extracted from ERP
dupes
similars
linked-by-code
EBOM
MBOM

PROCUREMENT SAVINGS BY ANALYSING SIMILAR COMPONENTS

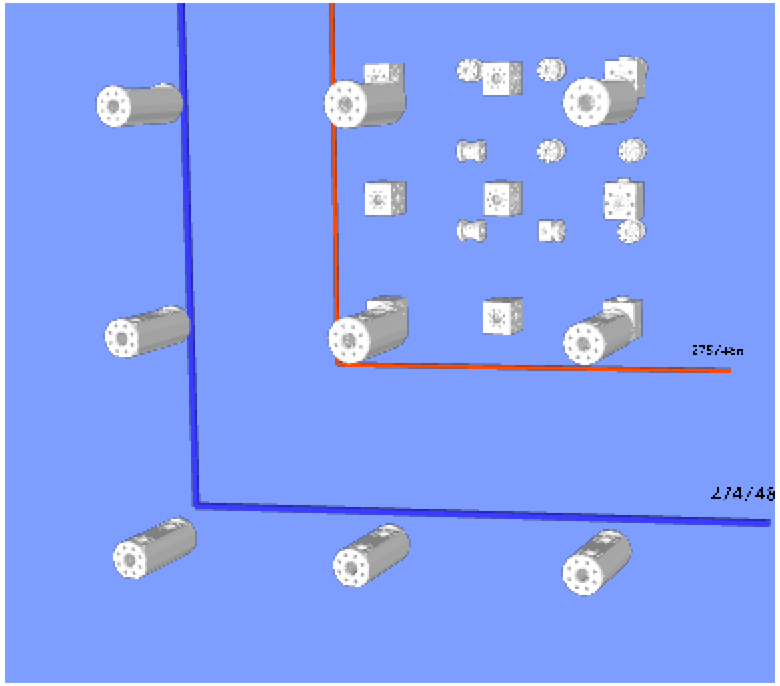




Identified frequently used components with high price variance to similar items.

£XXk per year of confirmed cost savings identified.

MACHINING SAVINGS BY ANALYSING SIMILAR COMPONENTS

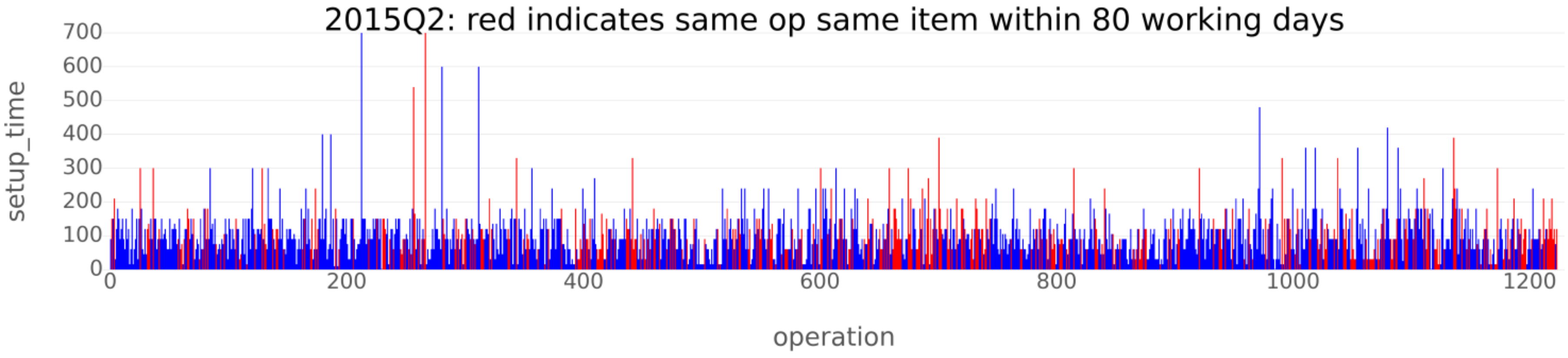


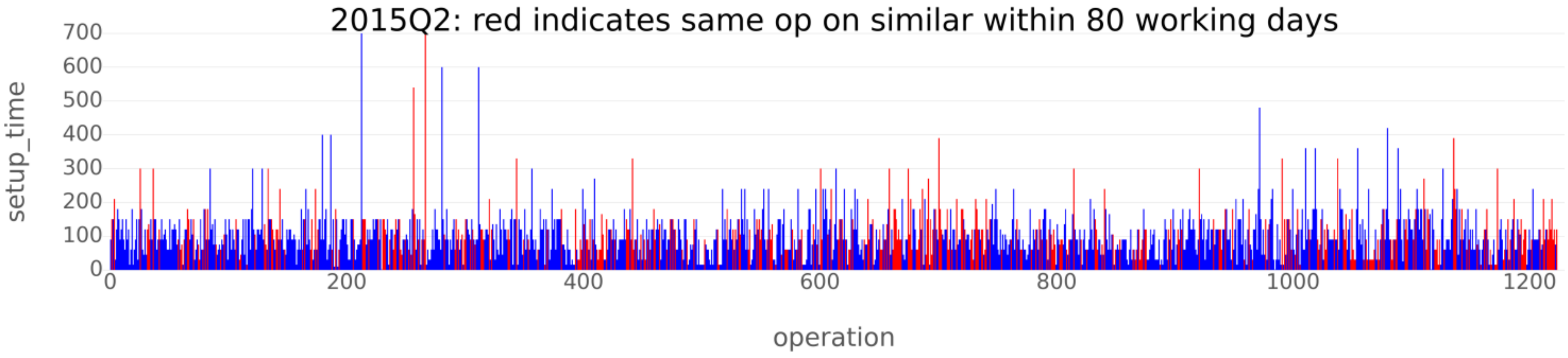
Identified groups of similar items. Analysed variance of setup times and machining times within groups.

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.

Change to a postponement machining strategy – machining some components to a common part-finished state for stock. Then finishing particular operations as demand requires.

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Another valve company

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
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4. Big Data Analytics in Manufacturing Industry Market - Global Analysis, Size, Share, Growth, Trends, and Forecast 2019 – 2027 IT & Telecom TMRGL69903 Ongoing Dec 2021
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