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

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

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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.
09:30	Lecture on week's topic.
10:30	Break
10:50	Workshop (continued in own time)

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Rest of week

Complete workshop

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

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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. Understand the ramifications of data collection and use in a manufacturing setting.
5. Able to criticise data use and practices.

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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

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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

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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

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- **Syllabus**

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

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- **Syllabus**

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

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, 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

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

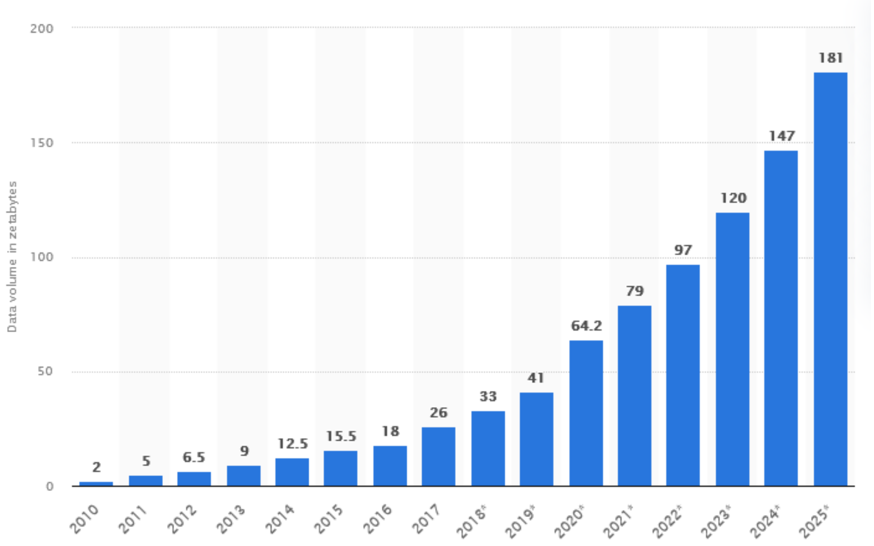
WHAT IS DATA SCIENCE?

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?

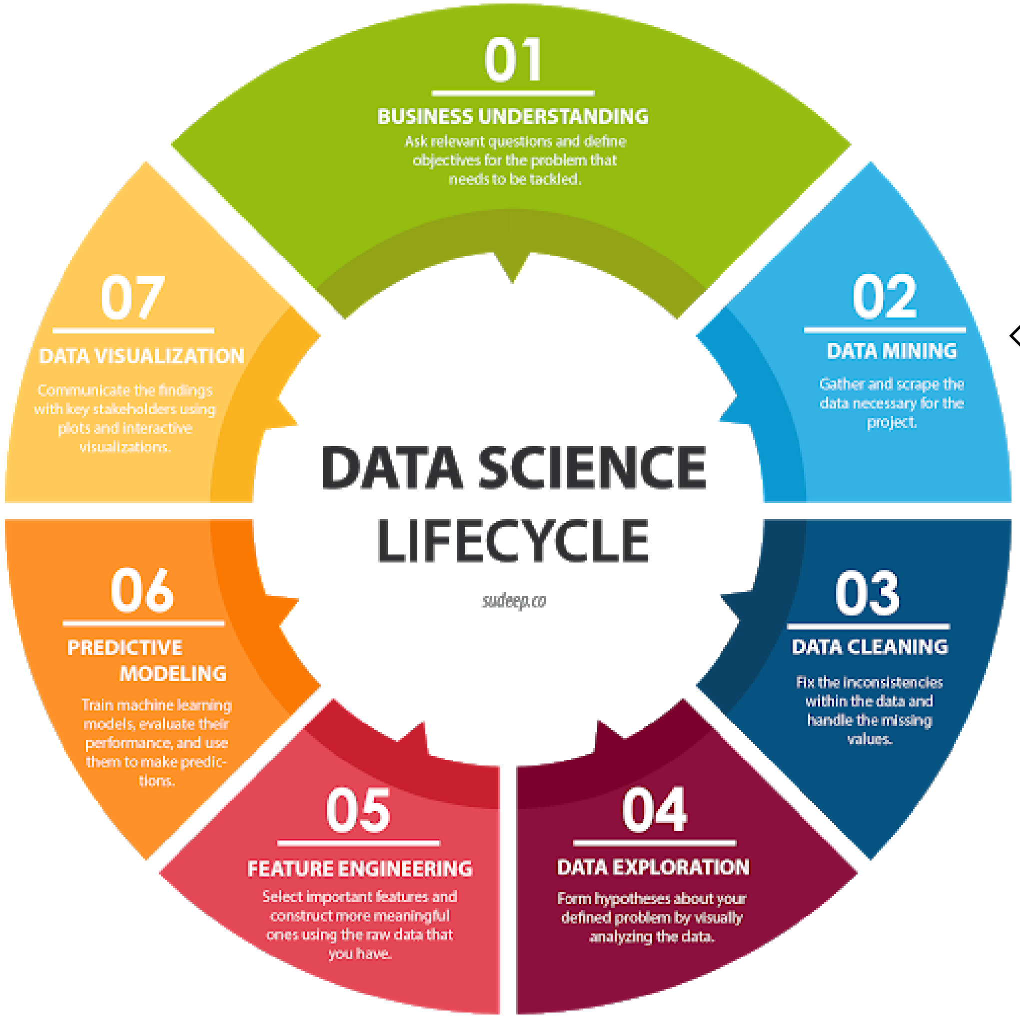
Scalability: big data helps in decision making providing lots of raw material for the creation of new knowledge.

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 collection

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)

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

python

SQL

pandas

matplotlib

NumPy

Seaborn

plotly

SciPy

statsmodels

PostgreSQL

MySQL

PyTorch

jupyter

git

GitHub

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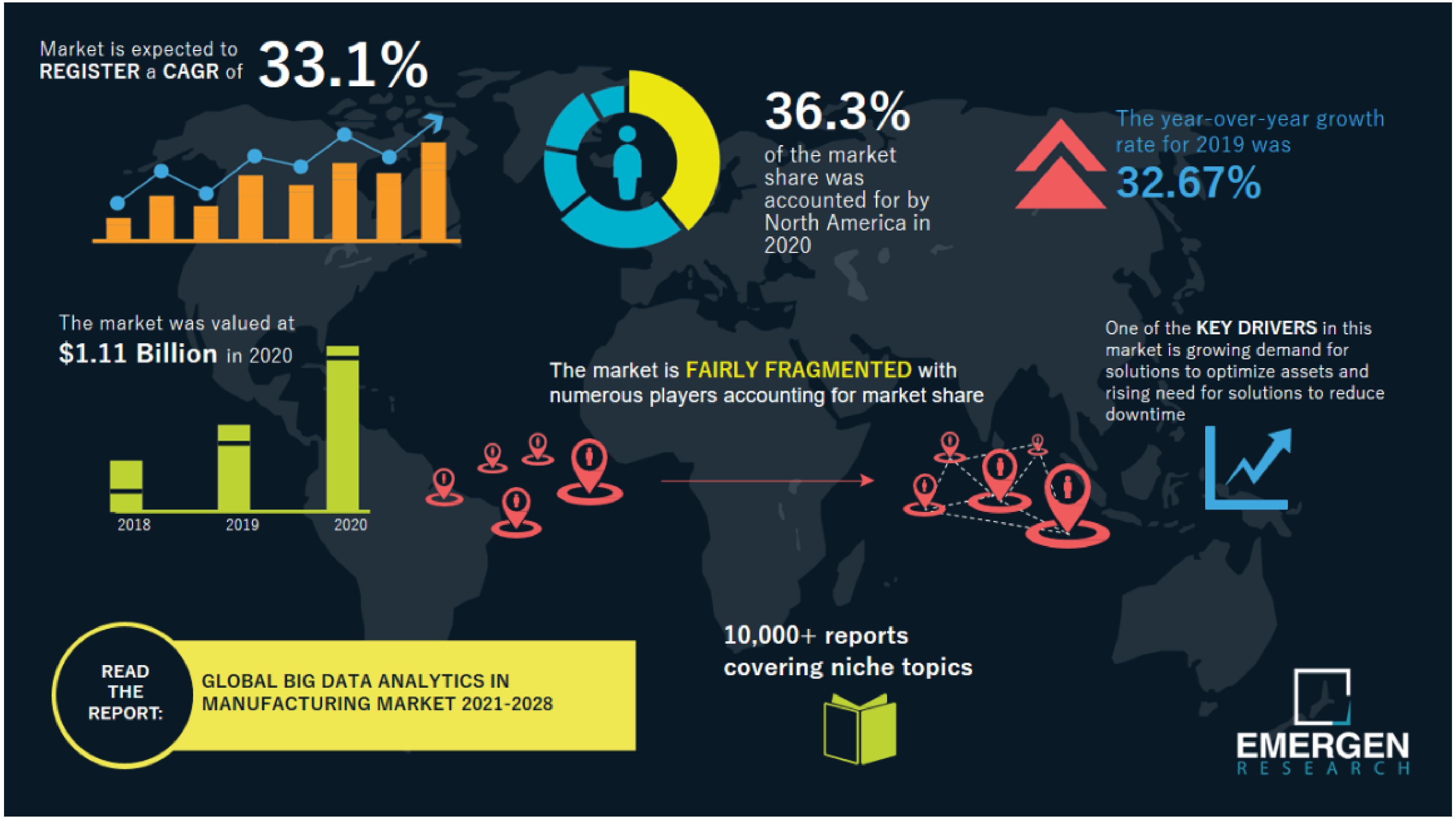
HOW BIG IS DATA SCIENCE IN MANUFACTURING?



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]

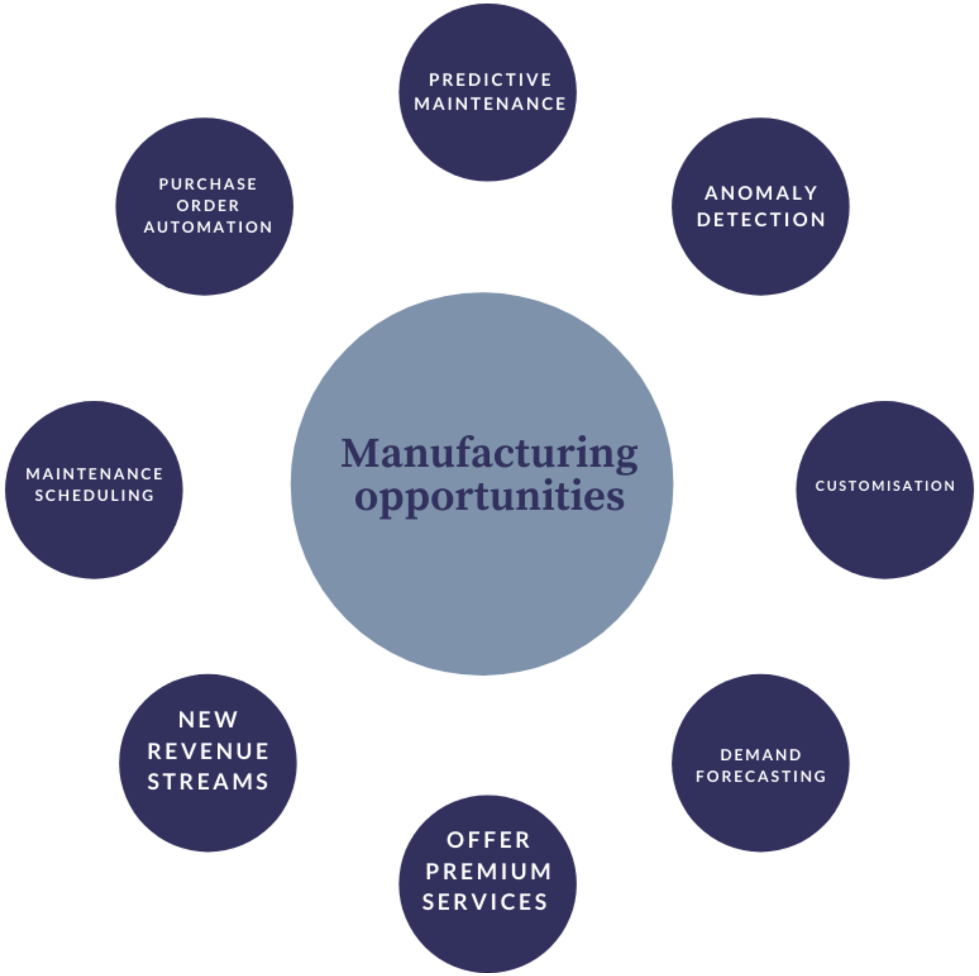
NOTES: HOW BIG IS DATA SCIENCE IN MANUFACTURING?

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?

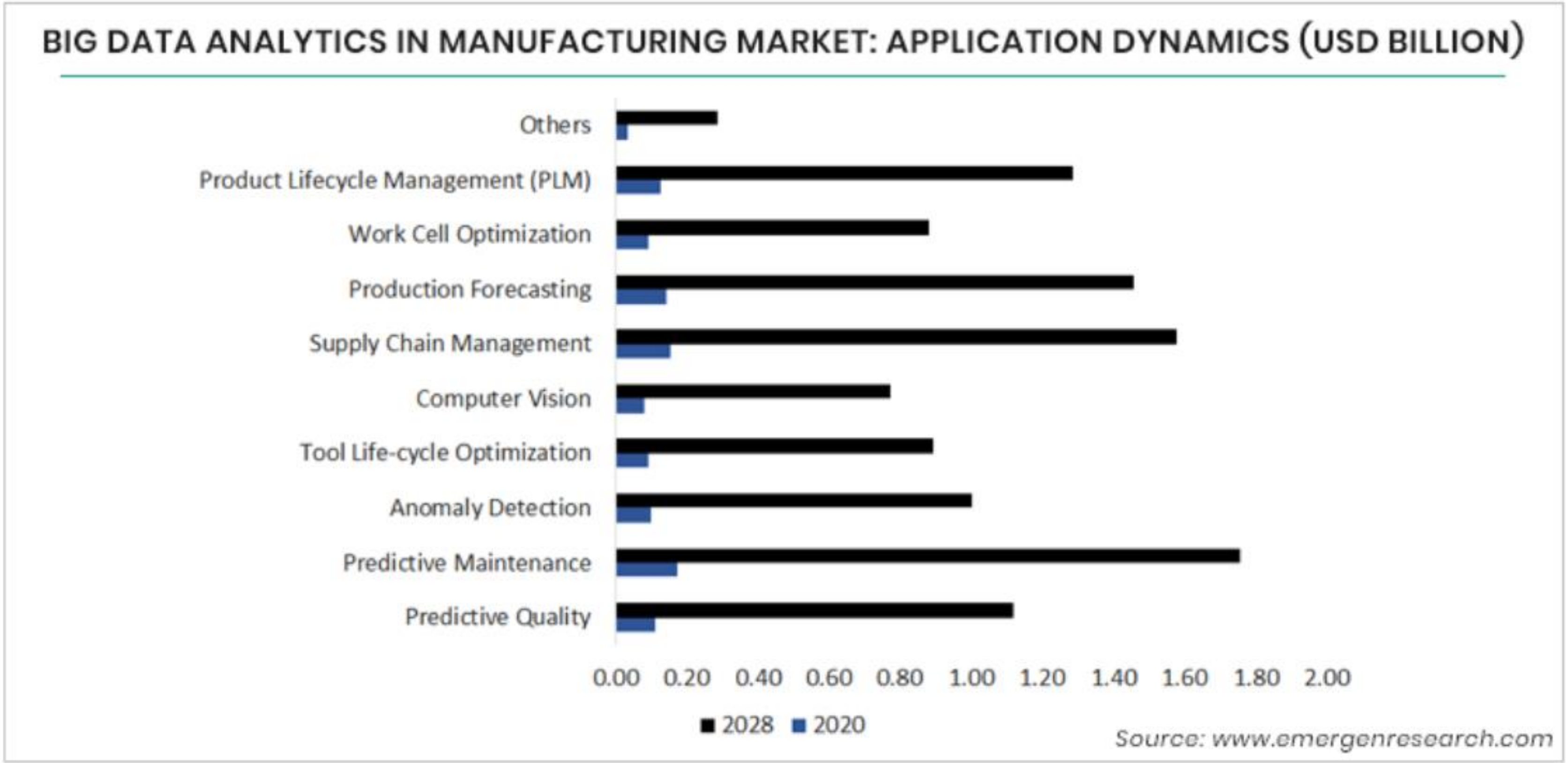
Big data analytics is a framework of gathering large volume of data for data mining, trend analysis. Over the years, industrialization is taking place at a fast pace and the volume of manufacturing is increasing day by day. Therefore, the massive shift in data generation by manufacturing industry is pushing the global big data analytics in manufacturing industry market. [4]

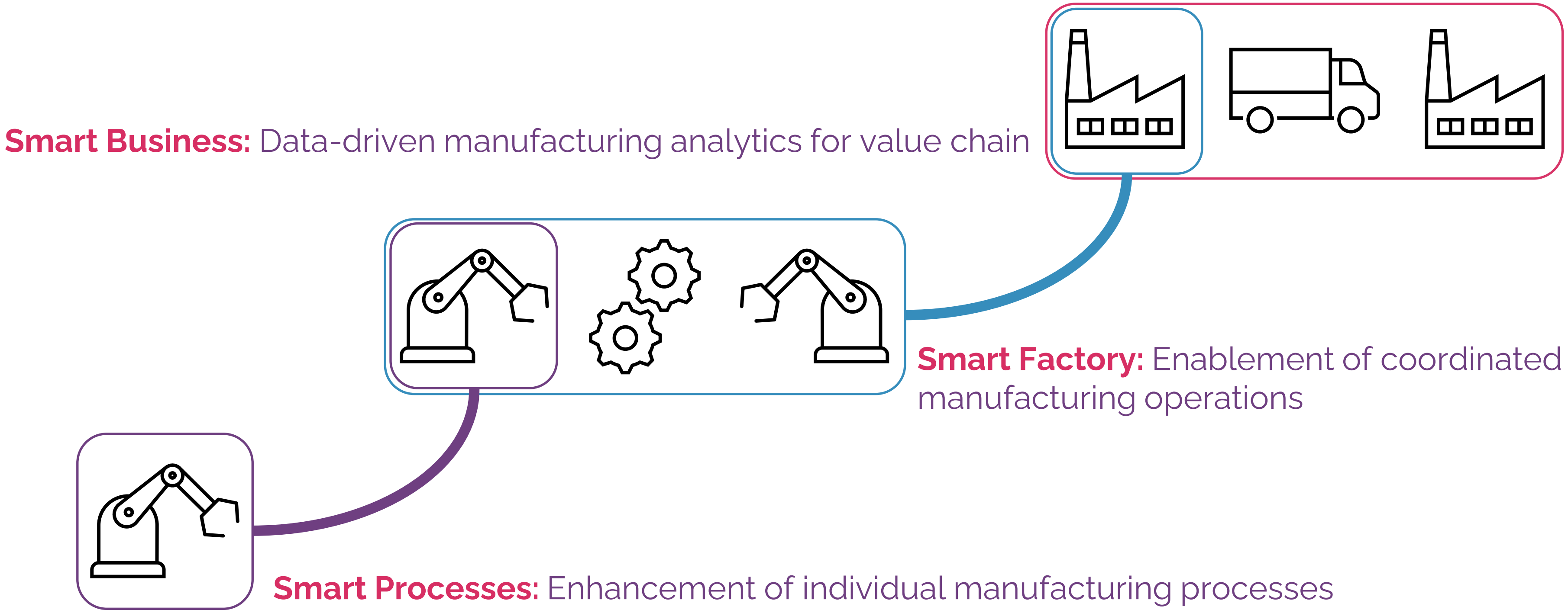
HOW IS DATA SCIENCE USED IN MANUFACTURING

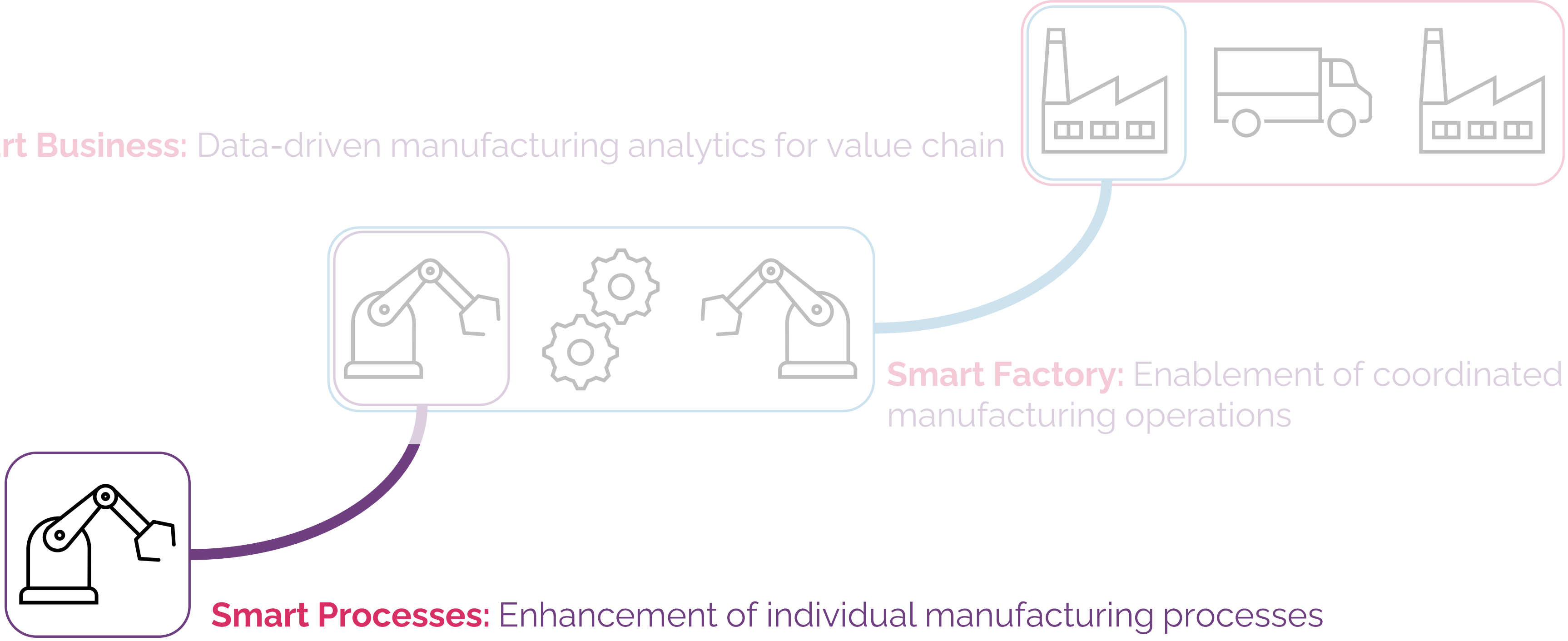


Data science opportunities in manufacturing [5]

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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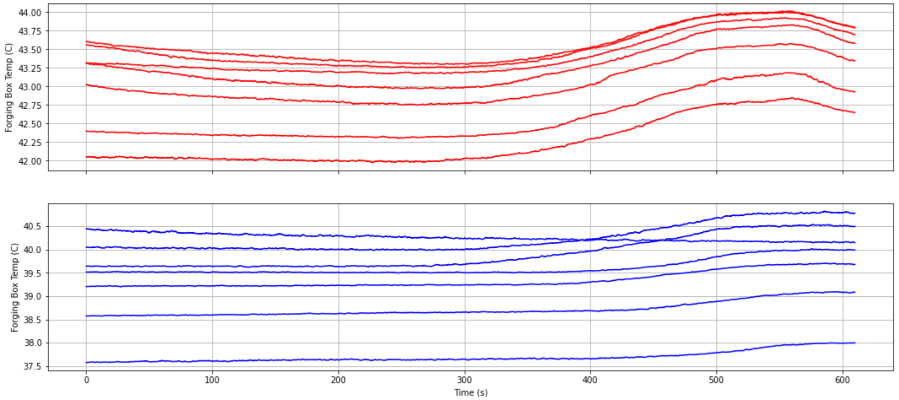
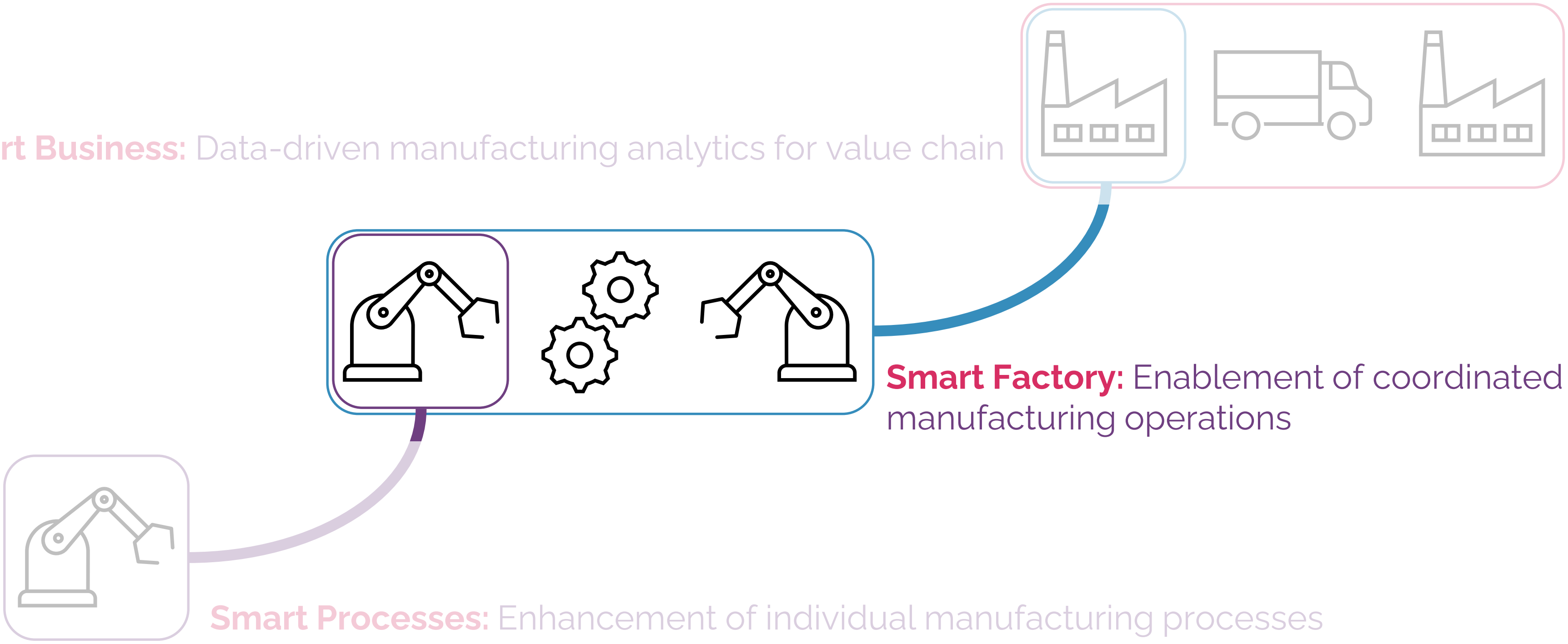
CASE STUDY: DIGITAL THREAD

- 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

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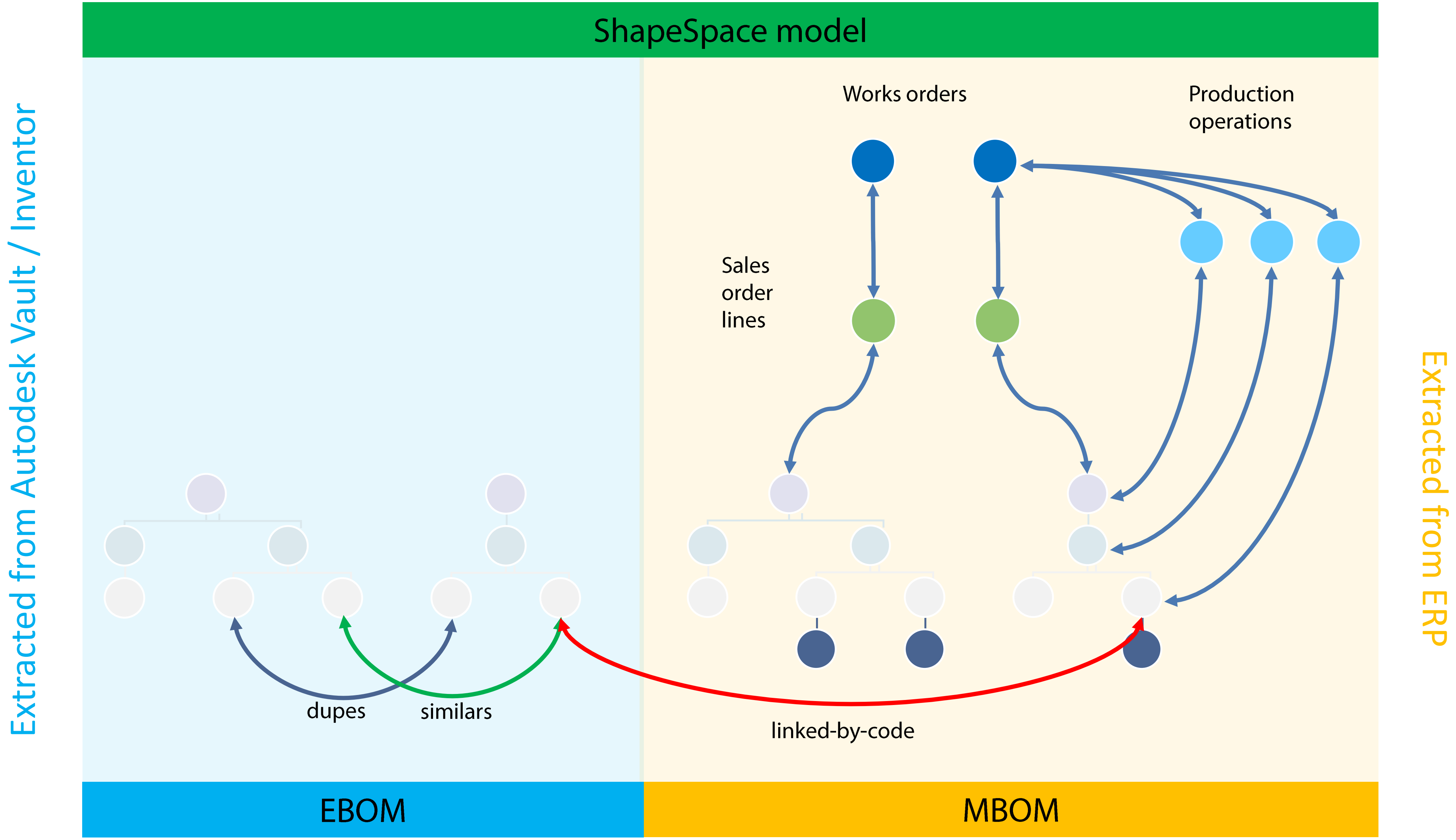
EXAMPLE OF ANALYTICS PROJECT : VALVE BUSINESS

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.



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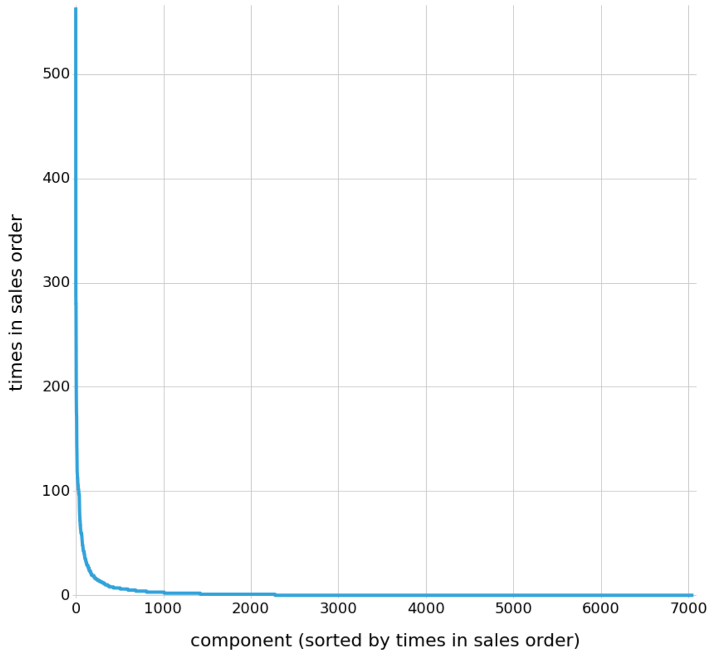
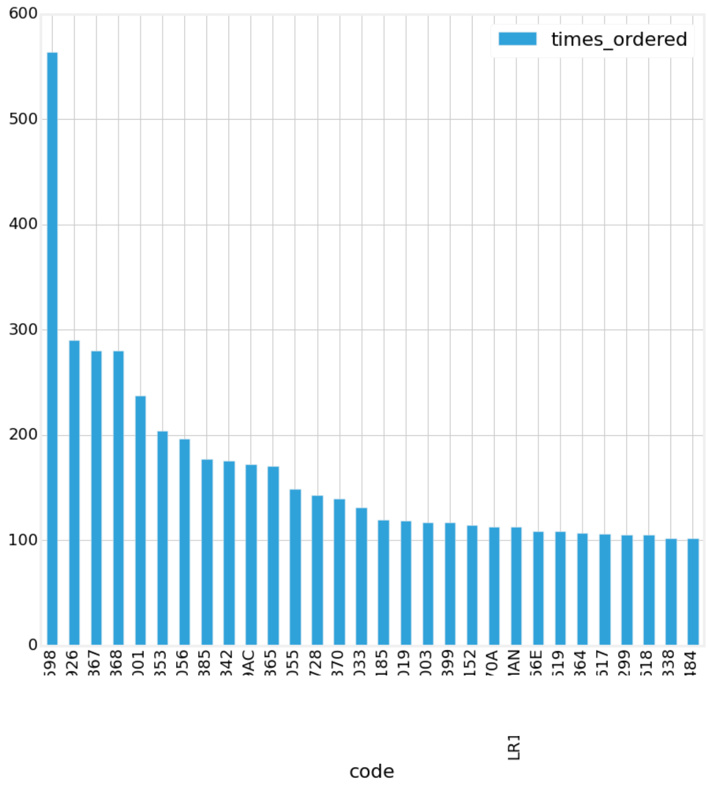
PROCUREMENT SAVINGS BY ANALYSING SIMILAR COMPONENTS

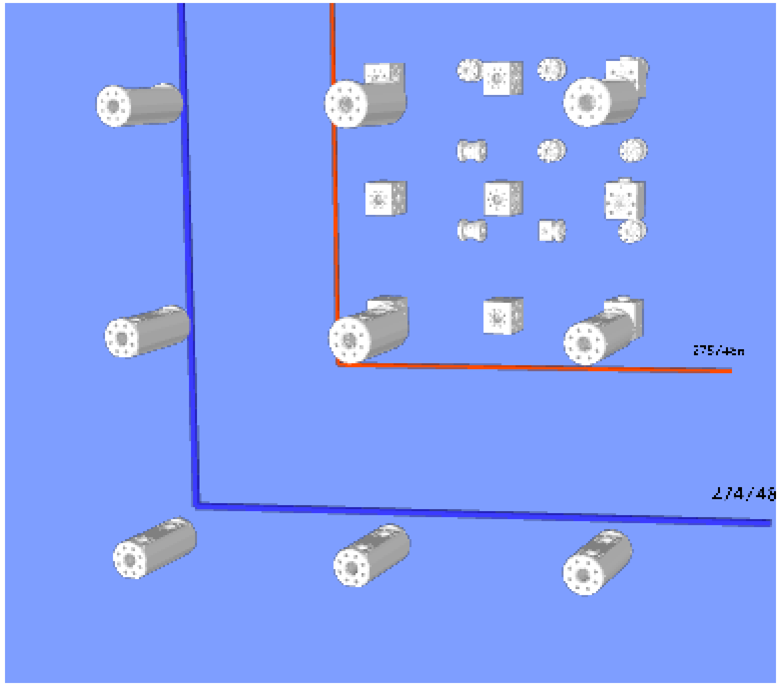




Identified frequently used components with high price variance to similar items.

£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**

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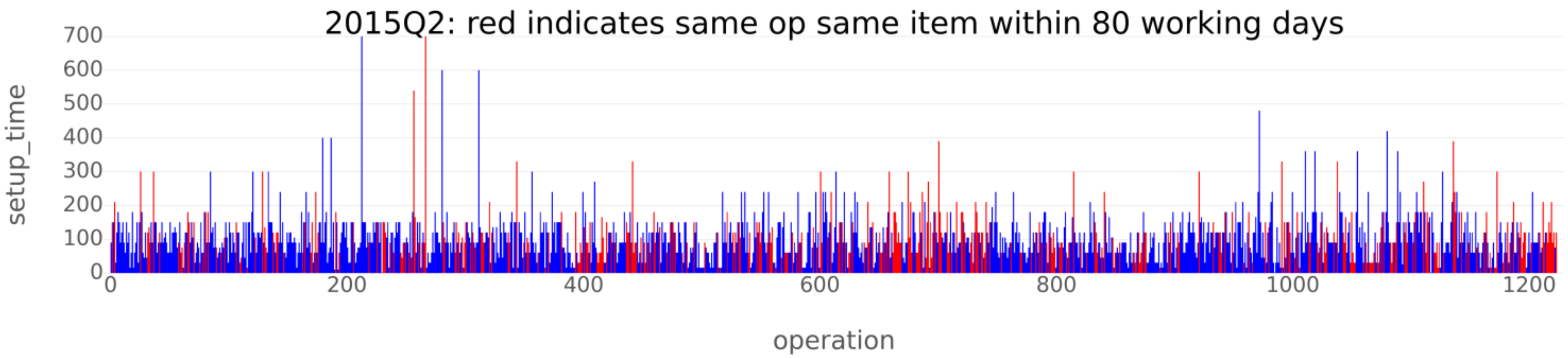
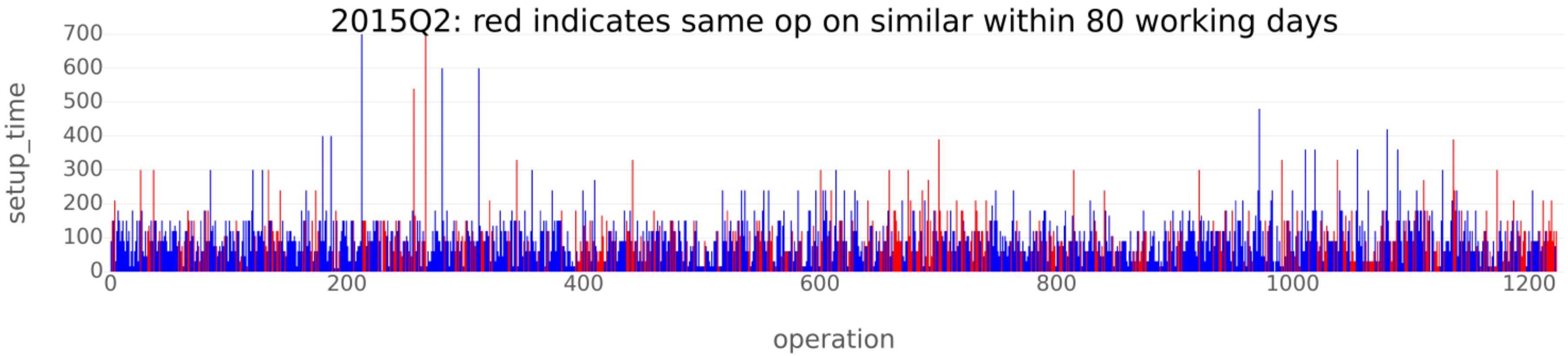
80 WORKING DAY WINDOW





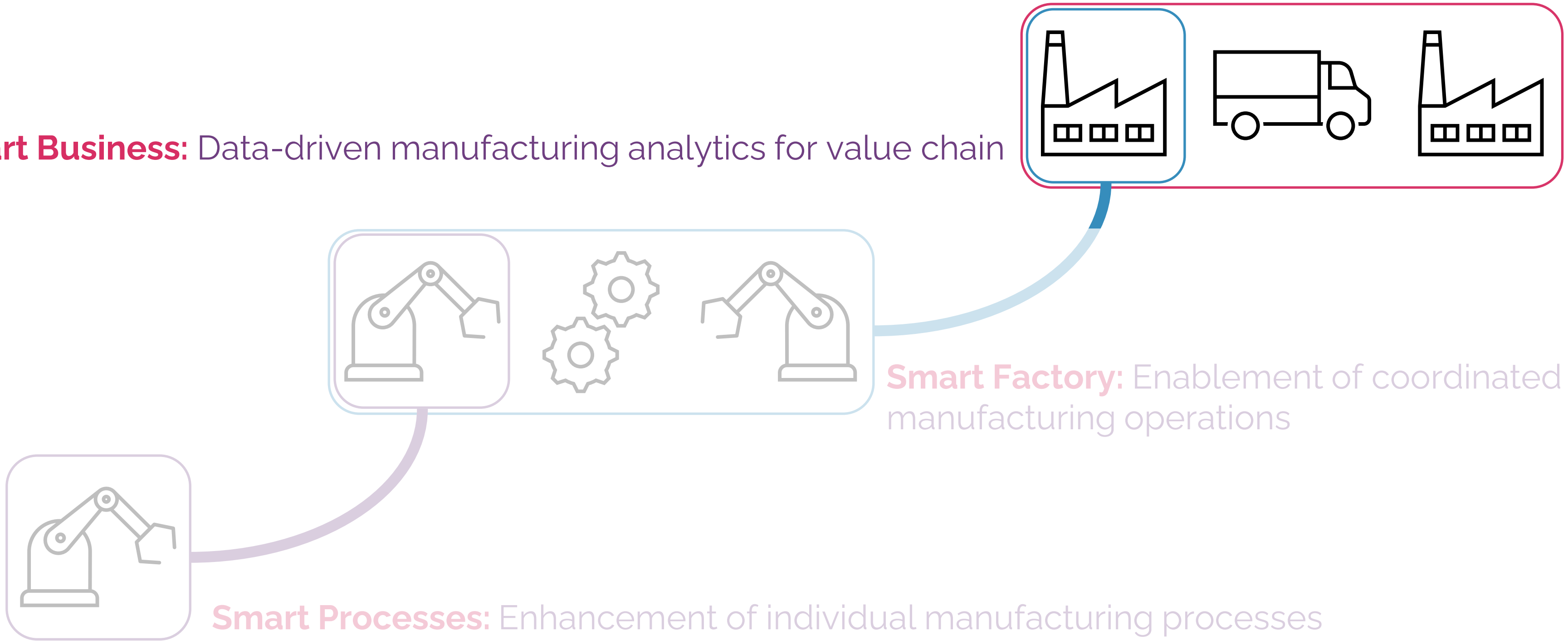
PRODUCTION OPERATION ANALYSIS

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.



Xometry

Manufacturing on demand

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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].
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