

DIGITIZATION STRATEGIES

Digitization Strategies for Engineering & Construction in the era of Industry 4.0
Rice Global E&C Forum Roundtable

JUNE 2017



AGENDA

THE FOURTH INDUSTRIAL REVOLUTION & DIGITAL DISRUPTION

DATA SCIENCE & COMPETING ON ANALYTICS

BUILDING A DATA SCIENCE CAPABILITY

NEAR-TERM OPPORTUNITIES FOR E&C COMPANIES

THE FOURTH INDUSTRIAL REVOLUTION

A BRIEF SUMMARY OF INDUSTRIAL EVOLUTION

A BRIEF HISTORY OF INDUSTRIAL PROGRESS

- The First Industrial Revolution used water and **steam power** to mechanize production.
- The Second used **electric power** to create mass production.
- The Third used **electronics** and information technology to automate production.
- A Fourth Industrial Revolution is characterized by a **fusion of technologies** that is blurring the lines between the physical, digital, and biological spheres.
- The velocity, breadth, depth and scale of impact are currently driving an exponential pace of disruption in almost every industry.
 - A key driver is the deluge of data generated by an ever-growing “Internet of Things”
- Incumbent upon us to shape this revolution in a manner that improves the state of the world.

Source: <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/>

WIRED

Data Is the New Oil of the Digital Economy

SUBSCRIBE



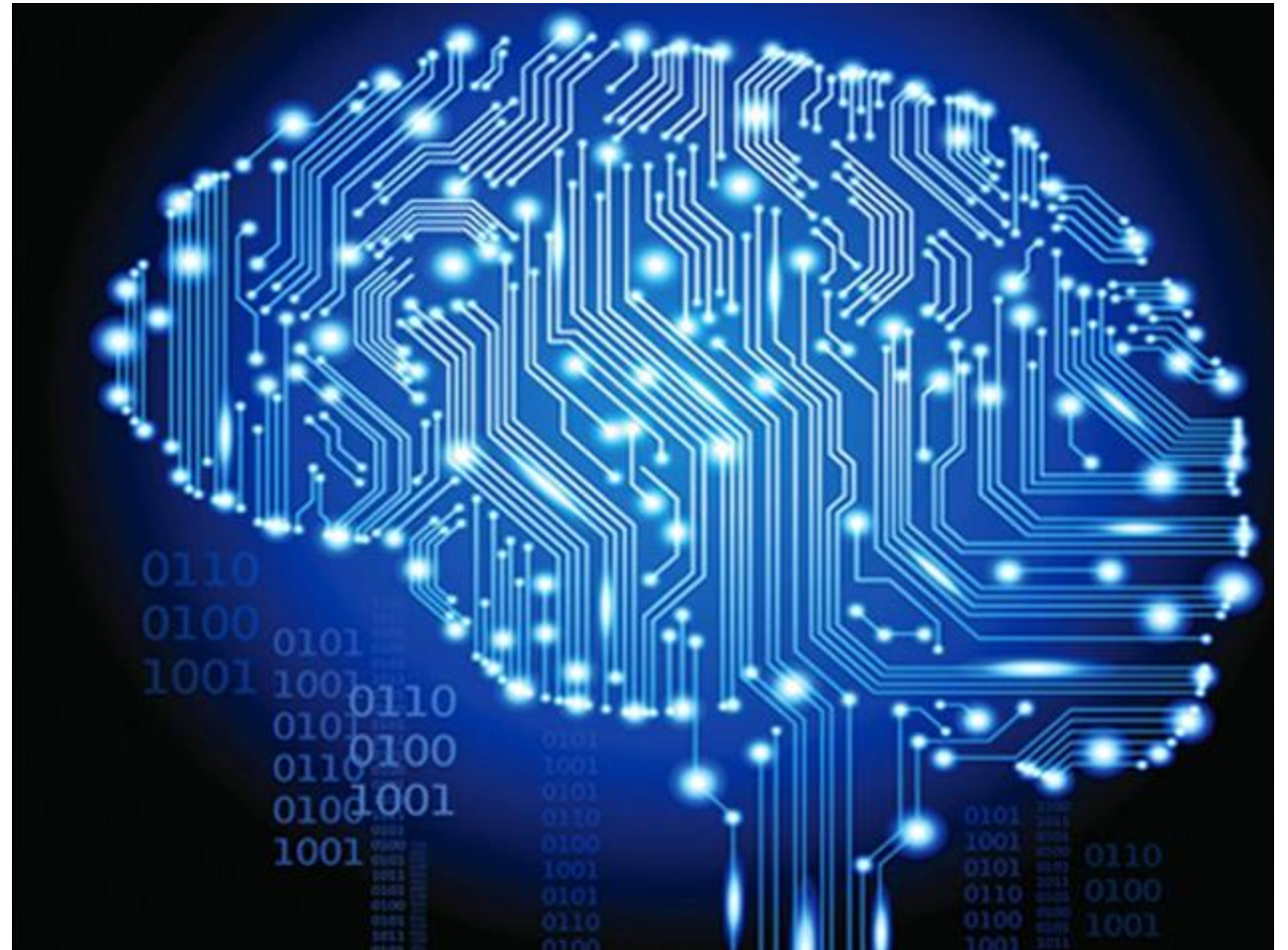
Image: verifex/Flickr

Source: <https://www.wired.com/insights/2014/07/data-new-oil-digital-economy/>

DATA IN THE 21st Century is like Oil in the 18th Century: an immensely, untapped valuable asset. Like oil, for those who see Data's fundamental value and learn to extract and use it there will be huge rewards.

ARTIFICIAL INTELLIGENCE (AI) & MACHINE LEARNING (ML)

- AI concept: building machines that are capable of thinking like humans
 - A crucial lynchpin of the digital transformation
 - AI simulates deductive thought and an ability to learn
- Machine Learning represents the current state-of-the-art in the wider field of AI
 - ML systems learn to work by observing, classifying and learning from mistakes
 - ML promises to unlock the science fiction dream of robots working alongside us and augmenting our own abilities with their speed and flawless logic ... this leads to what many commentators refer to as **Augmented Intelligence** (or Amplified Intelligence)

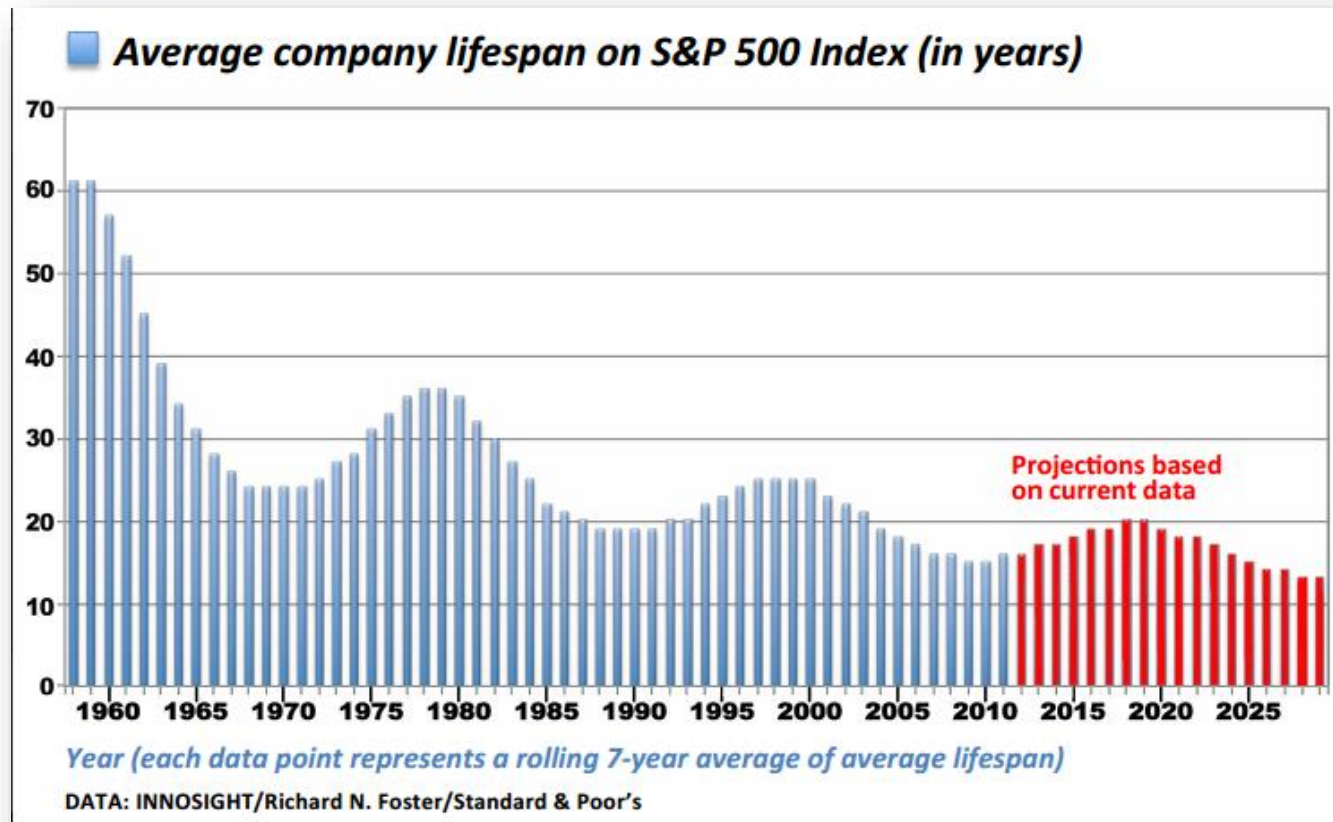


Source: The Complete Beginners' Guide to Artificial Intelligence, Forbes, 2017

DIGITAL DISRUPTION

WHY THE ONLY THING THAT IS CERTAIN IS CHANGE

INCREASING CHURN RATE IN THE S&P 500



The average lifespan of a company on the S&P 500 has decreased from 90 years in 1935 to ~20 years today & ~15 by 2025.

At the current churn rate, 75% of S&P 500 companies will be removed from the index by 2027.

Long-lived companies such as Procter & Gamble that successfully utilize "creative destruction" reinvent themselves and return value to shareholders.

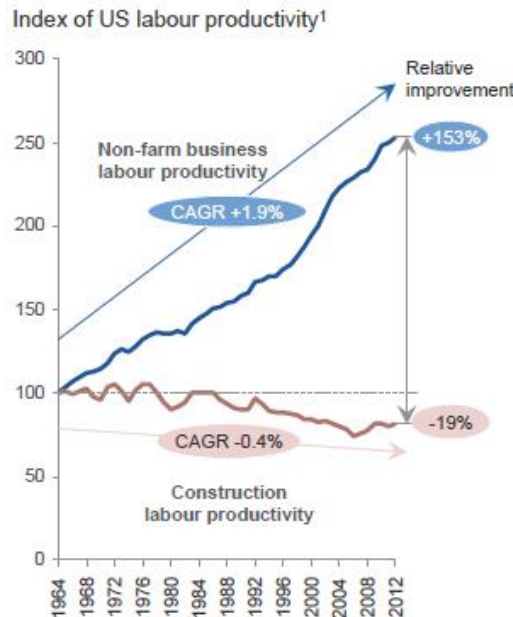
THE CHANGE IMPERATIVE

“Looking at construction projects today, I do not see much difference in the execution of the work in comparison to 50 years ago.”

John M. Beck, Executive Chairman, Aecon Group, Canada



Figure 3: US Industry Productivity and Performance, 1964-2012²⁸



[†] Peer set based on US companies with Engineering, Construction and Services-related Standard Industrial Classification codes. Financials are Inflation-adjusted and Indexed to 1964; output per working hours. CAGR = compound average growth rate
Source: Global Vantage; Compustat; Bloomberg; www.aecbytes.com/viewpoint/2013/Issue_67.html; www.nber.org/papers/w1555.pdf; S&P Capital IQ; BCG ValueScience Center; World Economic Forum

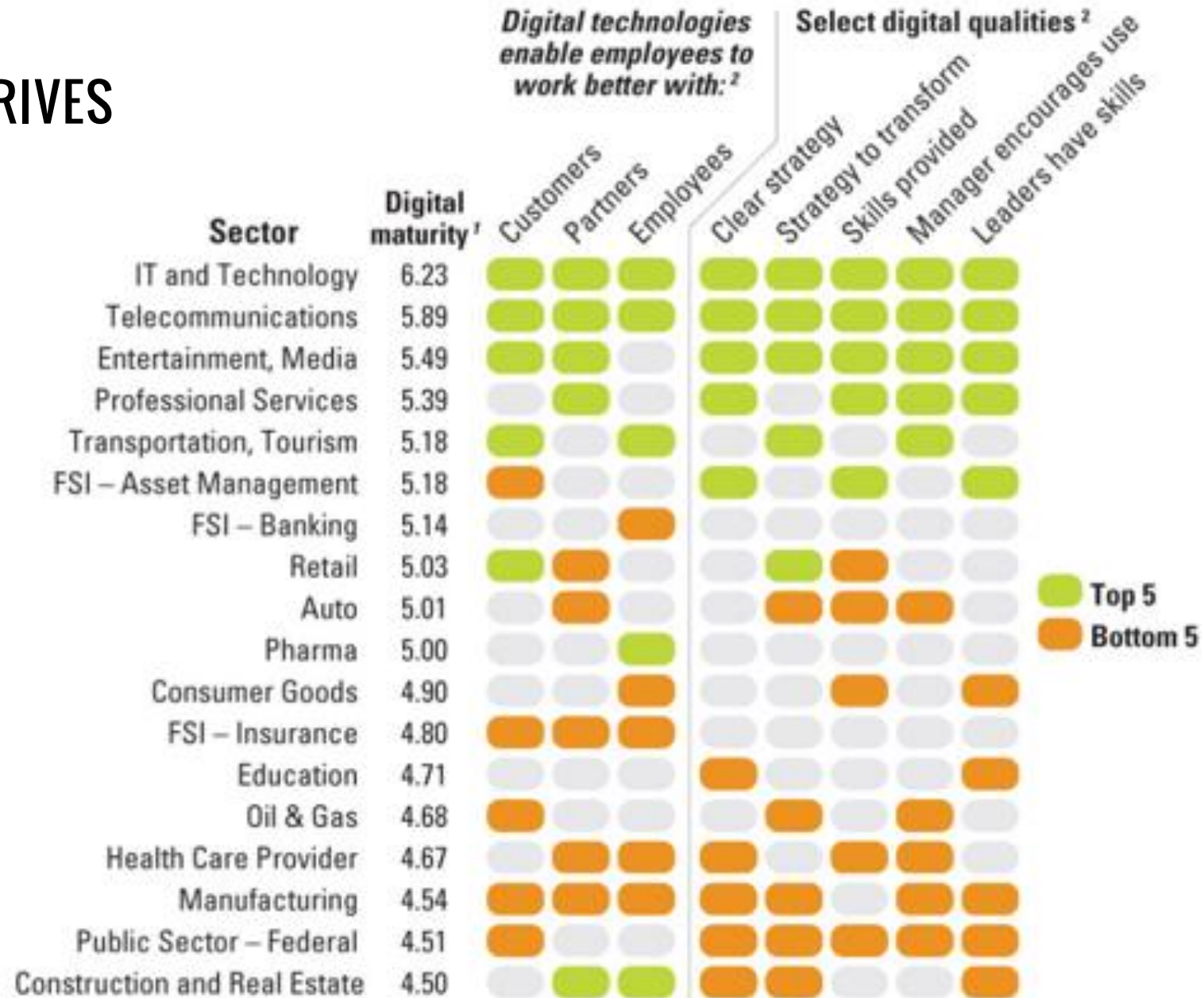
- E&C Industry accounts for 6% of global GDP
- Urbanization is increasing at a rate of 200k people per day
 - \$57tn - estimated value of new infrastructure needed over the next 15 yrs (McKinsey (2015): New Horizons for Infrastructure Investing)
- E&C is largest consumer of raw materials (using ~50% of global steel production)
 - Construction industry has a moral obligation to improve efficiencies in design and delivery
- 1% productivity improvement could save ~\$100bn/yr
- E&C sector traditionally slow to embrace new technology
- Opportunities for E&C:
 - Overcome falling productivity levels
 - Enhance supply chain collaboration
 - Improve project to project knowledge transfer
 - Talent attraction and retention

Source: Shaping the Future of Construction, A Breakthrough in Mindset and Technology, WEF & The Coston Consulting Group, 2016

STRATEGY, NOT TECHNOLOGY, DRIVES DIGITAL TRANSFORMATION

The 2015 Digital Business Global Executive Study and Research Project by MIT Sloan Management Review and Deloitte identified:

- Of the 18 sectors they studied, construction and real estate had the lowest level of digital maturity.
- The power of a digital transformation strategy lies in its scope and objectives.
- Maturing digital organizations build skills to realize the strategy.
- Employees want to work for digital leaders.
- Taking risks becomes a cultural norm.
- The digital agenda is led from the top.



DATA ANALYTICS AND DIGITAL TRUST UNDERPINNING INDUSTRY 4.0

In a 2016 survey conducted by PWC:

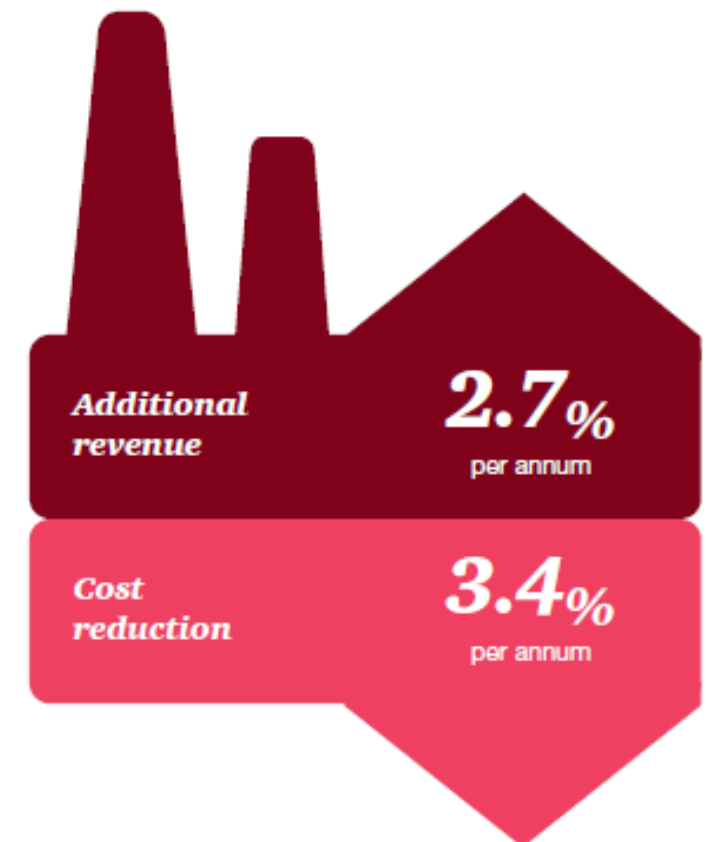
- Only 19% of E&C companies rate the maturity of their data analytics capabilities as advanced
- 59% pinpoint lack of data analytics skills in their own workforce as a challenge.
- 72% cite increasing in-house data analytics technology and skill levels as the single biggest improvement route

Figure 5: *Engineering and construction companies: in five years from now a significant importance will be placed on data analytics*



Figure 2: *High expectations of cost savings, increased revenue and efficiency gains (engineering and construction)*

Expected benefits from digitisation over the next five years



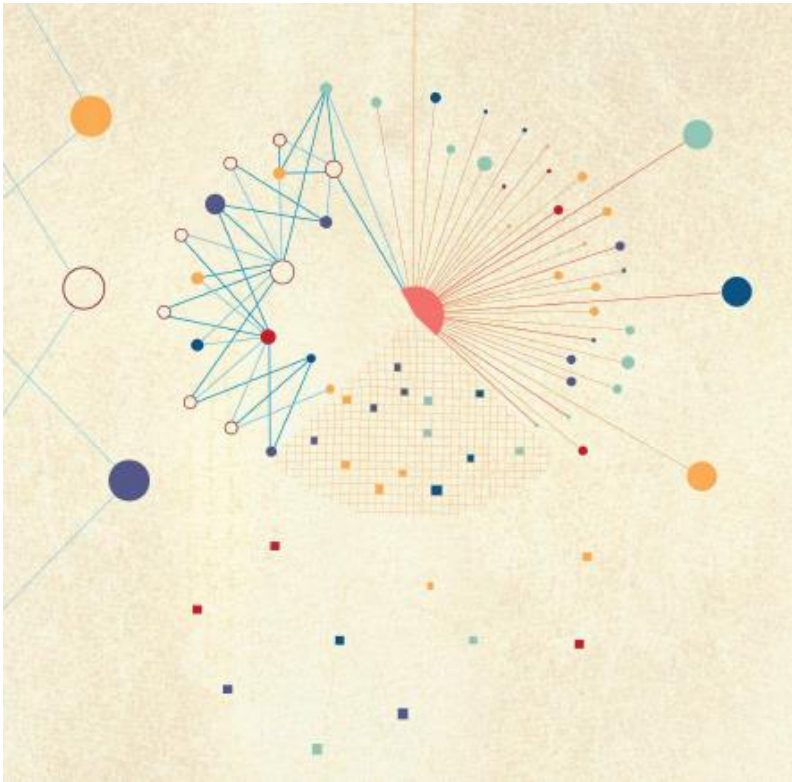
Source: Industry 4.0: Building the digital enterprise, Engineering and construction key findings, PWC 2016

DATA SCIENCE & COMPETING ON ANALYTICS

AN INTRODUCTION TO DATA SCIENCE & THE GROWING USE OF ARTIFICIAL INTELLIGENCE

DATA SCIENCE AS A CATALYST FOR PERFORMANCE IMPROVEMENT

Data Science: “the analysis of data using the scientific method with the primary goal of turning information into action.”



Source: The Field Guide to Data Science, Booz Allen 2015

DATA SCIENCE IS NECESSARY...

17-49%

increase in productivity when organizations increase data usability by 10%

11-42%

return on assets (ROA) when organizations increase data access by 10%

241%

increase in ROI when organizations use big data to improve competitiveness

1000%

increase in ROI when deploying analytics across most of the organization, aligning daily operations with senior management's goals, and incorporating big data

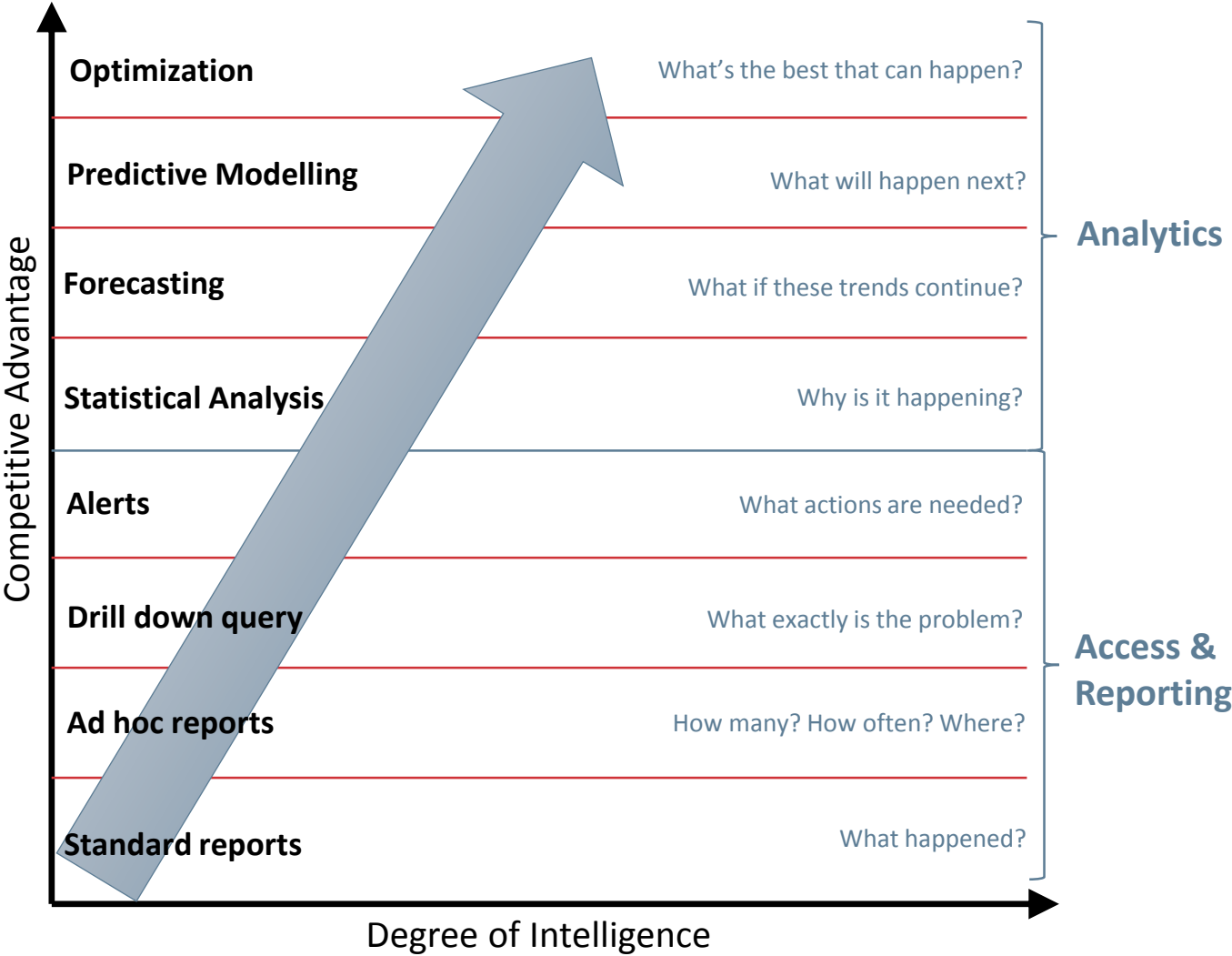
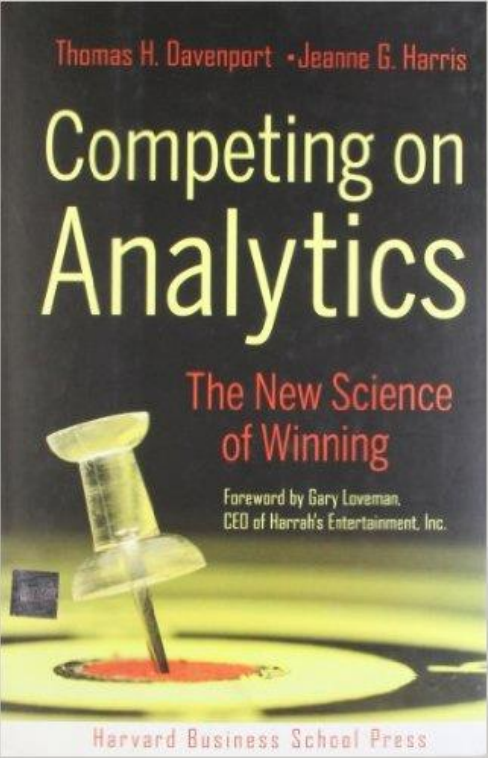
5-6%

performance improvement for organizations making data-driven decisions.

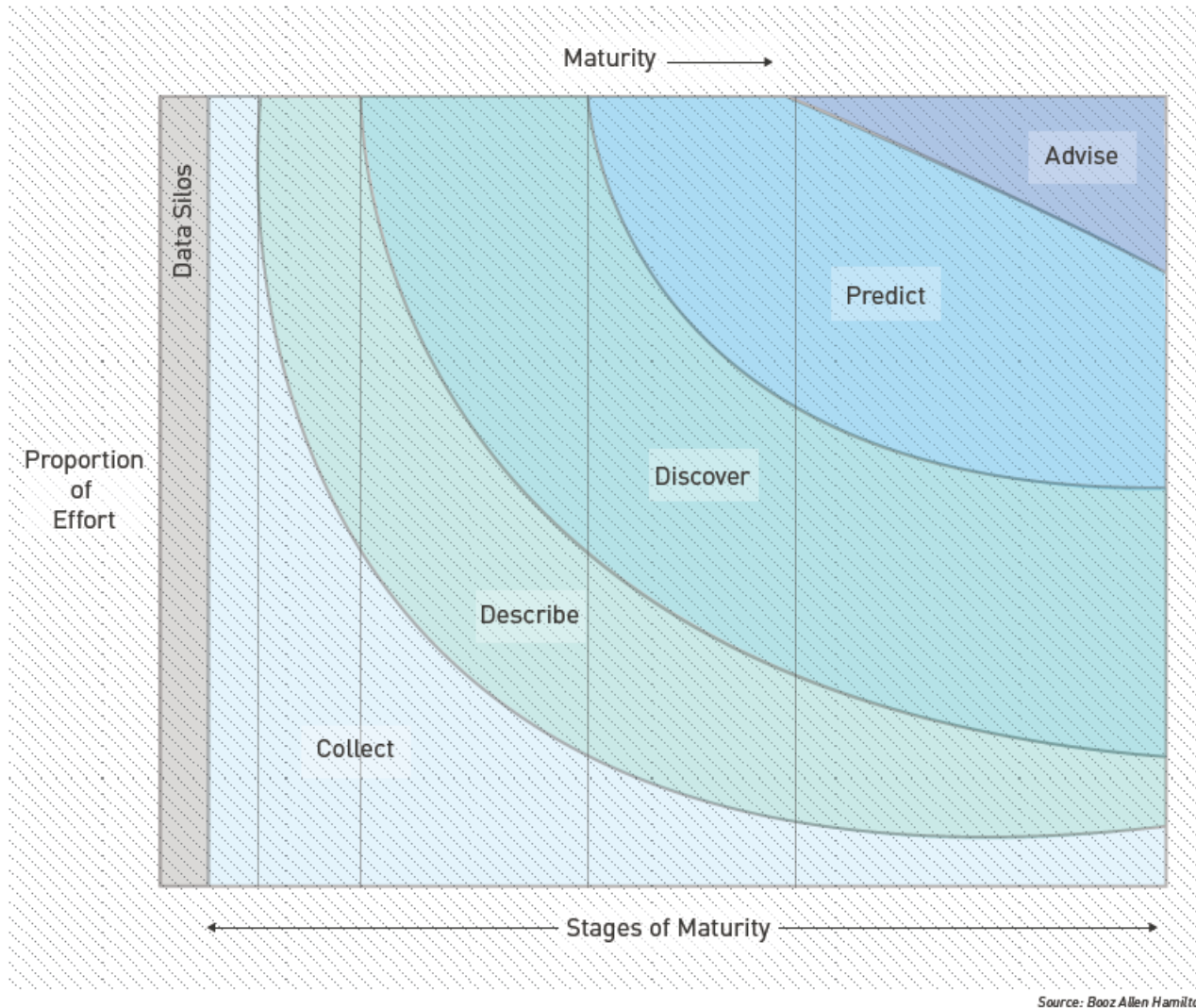
...TO COMPETE IN THE FUTURE

THE NEW SCIENCE OF WINNING

Source:

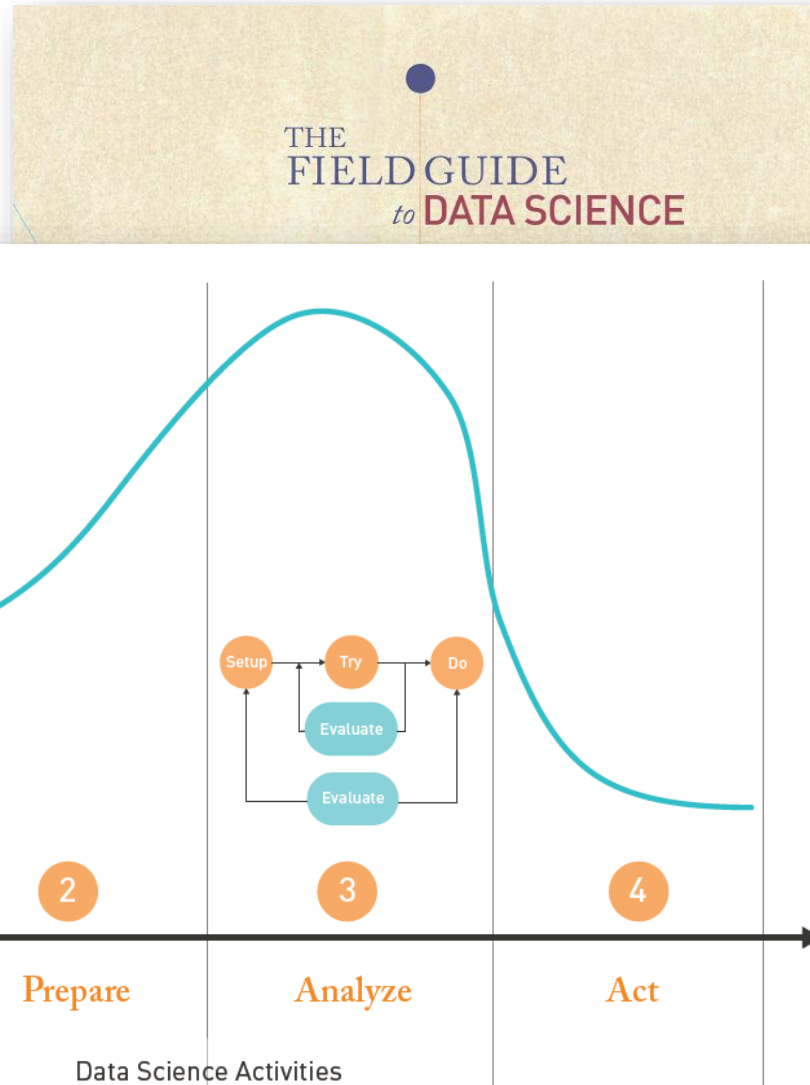


DATA SCIENCE MATURITY MODEL



Stage	Description	Example
Collect	Focusses on collecting internal or external data sets.	Gathering productivity / progress records and corresponding weather data.
Describe	Seeks to enhance or refine raw data as well as leverage basic analytical functions such as counts.	How long after a significant weather event did productivity return to a consistently stable level.
Discover	Identifies hidden relationships or patterns.	Are there causes outside the weather conditions influencing productivity.
Predict	Utilizes past observations to predict future observations.	With resources working on their current assignment, what is the likely completion date?
Advise	Defines your possible decisions, identifies an optimal state and advises on the decision tat gives the best outcome.	On which work fronts should resources be deployed to achieve an optimal completion date?

KEY DATA SCIENCE ACTIVITIES



- Activity 1: ACQUIRE
 - Focus is on obtaining the required data. Diversity is good and complexity is okay. Think beyond structured databases and consider unstructured and semi-structured as viable sources.
- Activity 2: PREPARE
 - Data Lakes offer Data Scientists the best opportunity to prepare data for analysis. By eliminating time-consuming and expensive ETL processes, organization benefit from removing silos and subsequent blind-spots.
- Activity 3: ANALYZE
 - Both an art and science, analytics are applied iteratively to create value from data. Specialized and scalable computational resources enable real-time risk review by evaluating situational, operational and behavioral data. Maturity will determine the extent to which analytic goals achieved.
- Activity 4: ACT
 - The ability to make use of the analysis is critical. Every effort must be made for the decision-maker to meaningfully recognize and interpret patterns, trends and exceptions. Logic supporting findings must be clear, compelling and traceable.

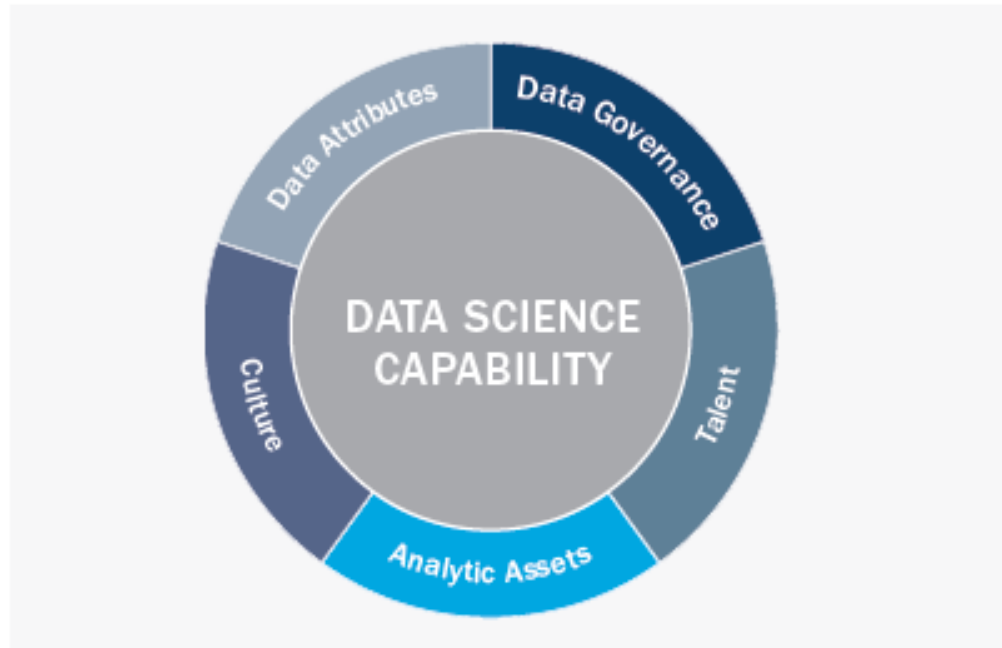
“Knowing is not enough; we must apply.”
- Johann Wolfgang von Goethe

BUILDING A DATA SCIENCE CAPABILITY

STRATEGIES FOR RISK-BASED KAIZEN

LEADING WITH THE RIGHT STRATEGY

After answering key business questions to drive strategy, teams need to work with you through five areas:

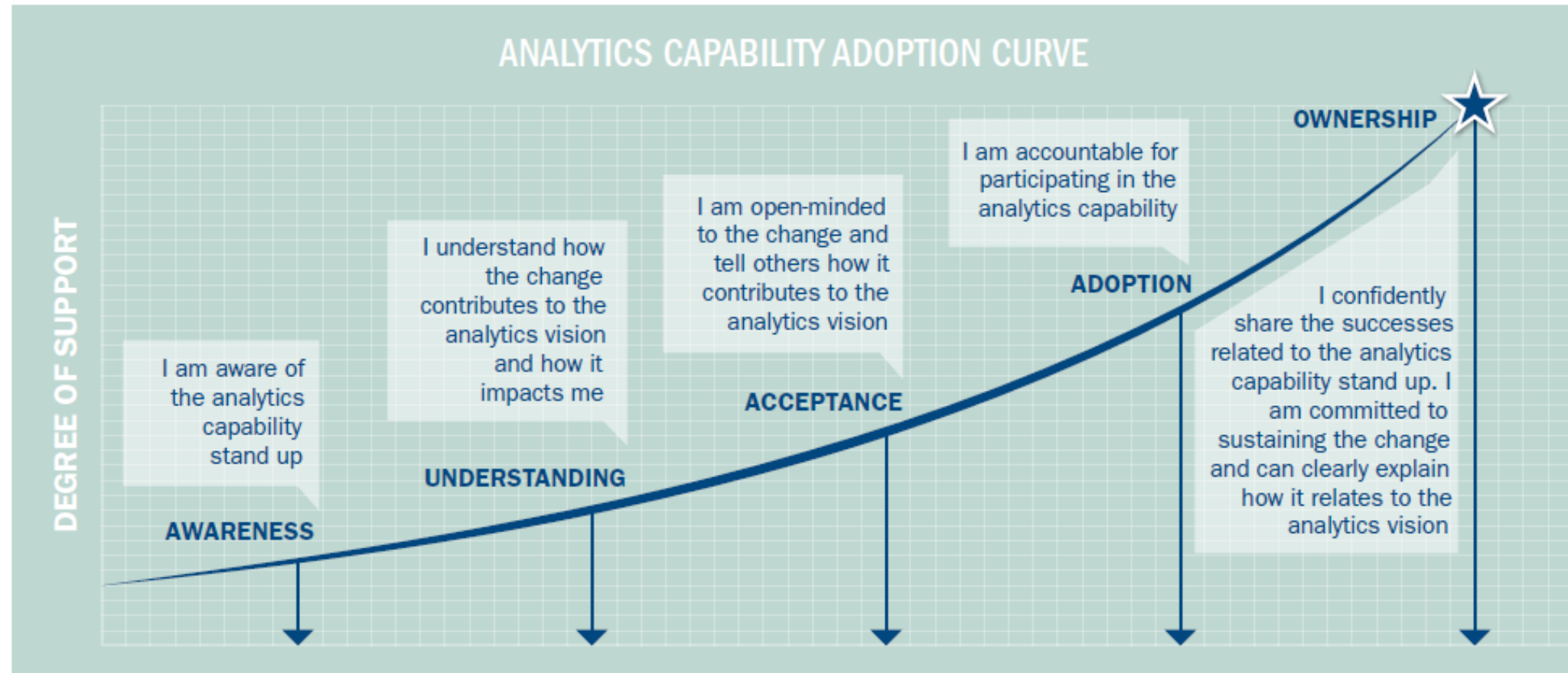


Source: Data Science That Makes a Difference, Booz Allen

- + **Culture** that values transparent decision-making, empowered by analysis
- + **Data's Attributes** to focus analysis on the ability to answer key business questions
- + **Data Governance** to ensure data is accurate, relevant, and current
- + **Data Science Talent**—the people—unlocks Big Data and is the heart of any capability
- + **Analytic Assets** the tools that provide data-driven insights to empower your business

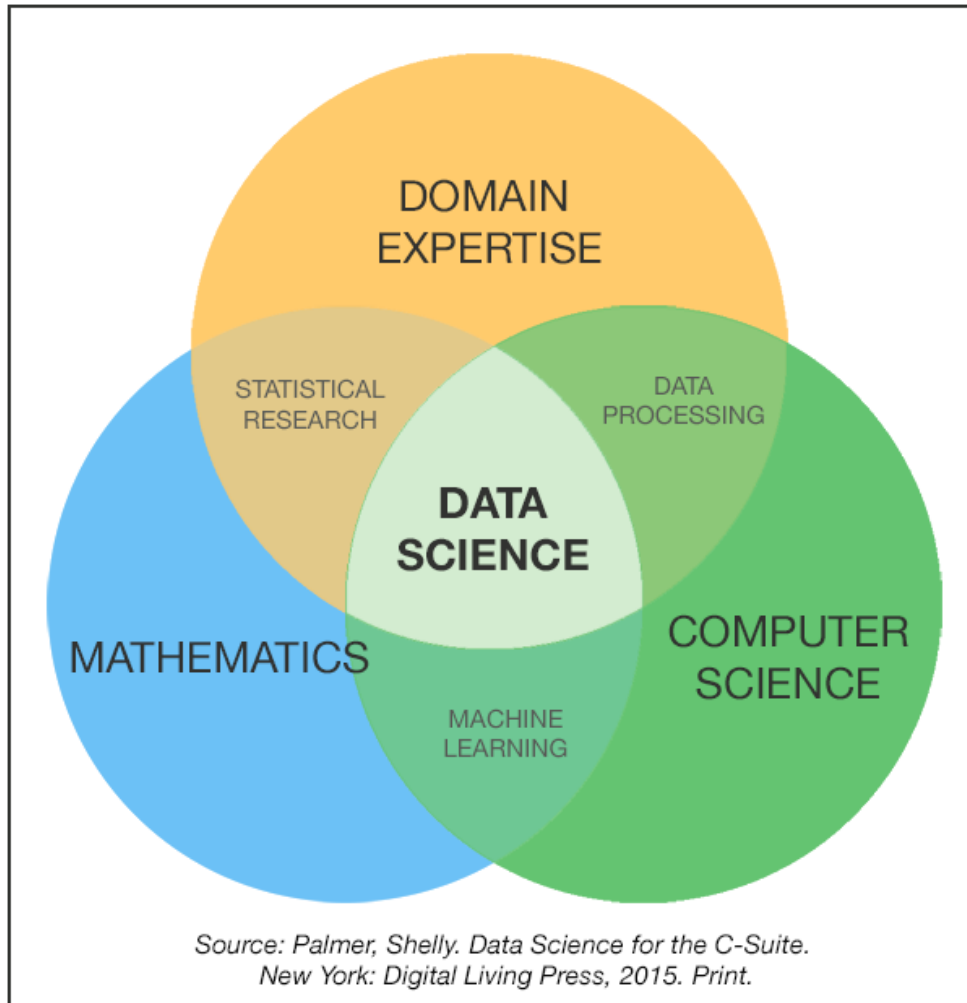
A data science capability must be rooted in the value a company seeks to generate.

BUILDING BUY-IN



- Stakeholder analysis will help understand cross-organizational goals and concerns in order to define a appropriate vision
- Change agents and embedded advocates can facilitate communication among stakeholders to help breakdown silos and encourage data sharing
- Develop an analytics prototype to solve a hard problem that yields a high return

THE ESSENTIAL BLEND OF SKILLS & KNOWLEDGE



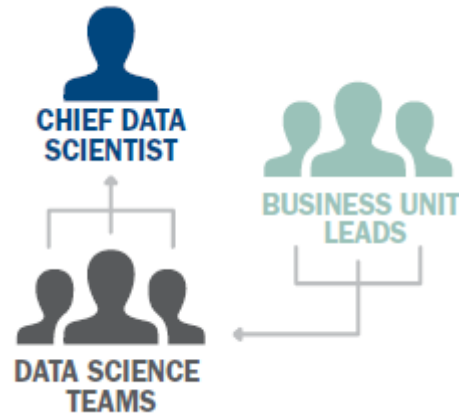
Foundational Skills

- In order to turn information into action, you need a team that is proficient in the three foundational skills:
 - **Domain Expertise** – to define the problem space
 - **Mathematics** – for theoretical structure and problem solving
 - **Computer Science** – to provide the environment where data is manipulated
- Data science exists at the intersection of these three foundational skills. Discounting or overweighting any of them will yield suboptimal results.

Source: Are you ready for Data Science, Huffington Post, http://www.huffingtonpost.com/shelly-palmer/are-you-ready-for-data-sc_b_6844032.html

BUILDING A DATA SCIENCE TEAM

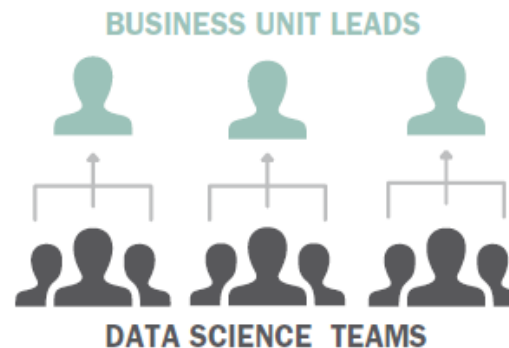
The Centralized Model



Business units (BUs) bring their problems to a centralized data science team, overseen by a chief data scientist

- **Advantages,** efficiency with limited resources, separation from BUs promotes perception of objectivity and Project diversity motivates data science (DS) teams and contributes to strong retention.
- **Challenges,** can be difficult to enlist BUs who've not yet bought-in to Data Science, BUs may feel they have to compete for resources and teams reform for every new problem.

Diffused



Data science teams are fully embedded in business units and report to individual business unit leaders

- **Advantages,** DS teams can quickly react to high-priority needs. DS teams learn the organization's data and its context. DS teams know the right questions to ask and a deepened understanding of business inspires them to ask new, hard questions of the data.
- **Challenges,** DS teams may feel pressure to compromise objectivity. Potential for inhibited collaboration in already siloed BUs. Work for DS teams may become stale driving them to seek new challenges.

Deployed



Data science teams are overseen by a chief data scientist and forward deploy to business units

- **Advantages,** Shares benefits of both the centralized and diffused model, Data Science teams collectively develop knowledge across BUs.
- **Challenges,** Deployed teams are responsible to two bosses and staff are uncertain to whom they are ultimately accountable. Access resources may be competitive and DS units risk alienating BUs whose projects are not selected.

Source: Tips for Building a Data Science Capability, Some Hard-Won Best Practices and (Surprising) Lessons Learned, Booz Allen Hamilton


NEAR-TERM OPPORTUNITIES FOR E&C COMPANIES

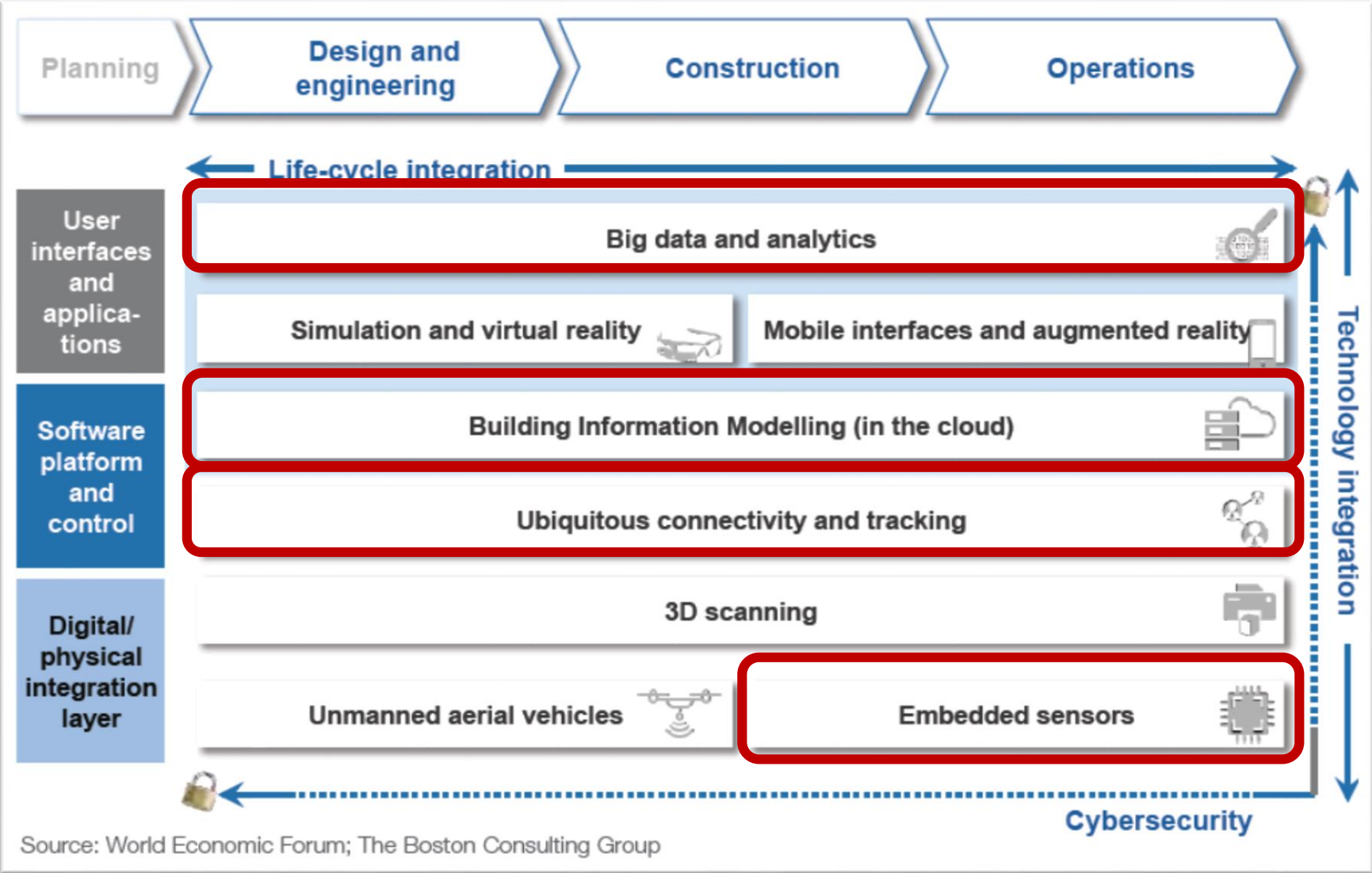
EMPLOYING ADVANCED ANALYTICS IN ENGINEERING AND CONSTRUCTION

DIGITAL TECHNOLOGIES APPLIED IN THE E&C VALUE CHAIN

Digitalization – the development and deployment of digital technologies and processes

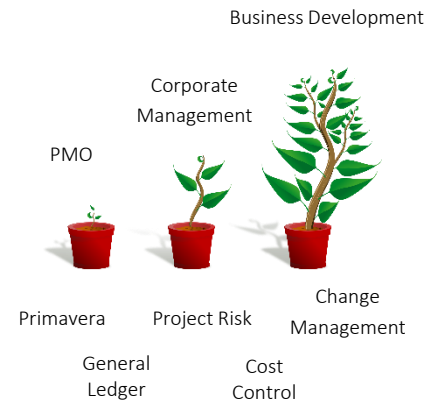
Within 10 years, full-scale digitalization, could deliver annual global cost savings to E&C of \$0.7 – 1.2tn (13-21%)

 = high potential / quick-wins



Source: Shaping the Future of Construction, A Breakthrough in Mindset and Technology, WEF & The Coston Consulting Group, 2016

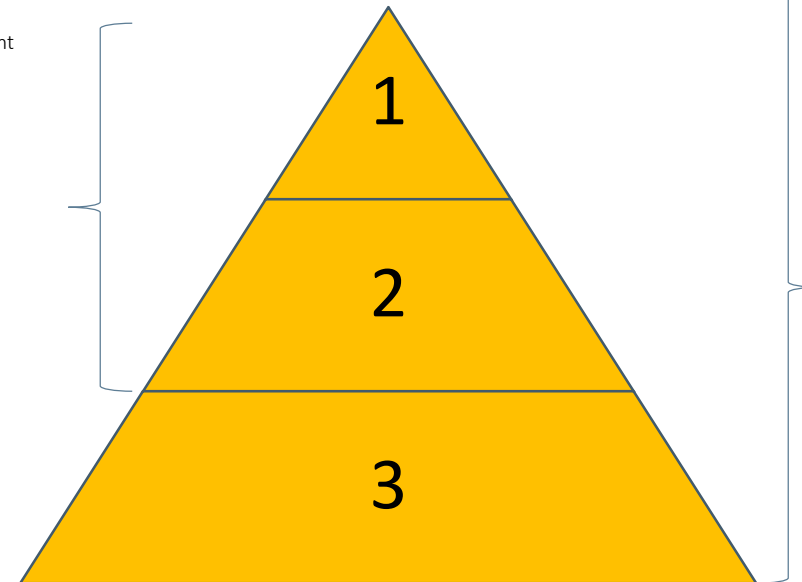
EMPHASIS ON RISK DATA CURATION



Close-out Reporting

At stage gate close-out, are Data Governance processes ensuring all data used by decision-makers is effectively captured?

*Effective data curation will enable enterprises' to unearth and foster an understanding of an **Rewarded & Learnable Risk**.*



Transferable Data Attributes

Level 1 = Universal Reports

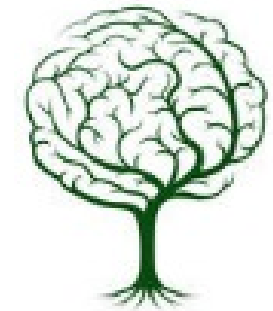
(Strategic / Generic)

Level 2 = Operational Data

(Tactical / Core Data)

Level 3 = Specialized Reports

(Tactical / BU Specific)

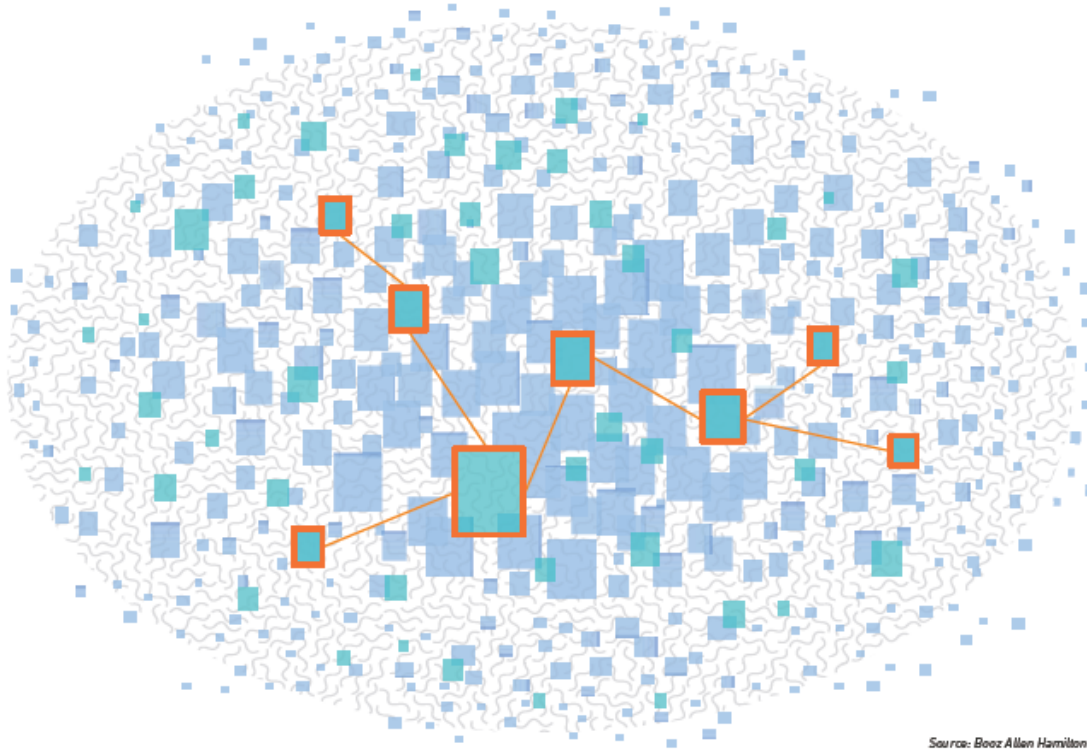


Fostering Data Analytics / Cultivating Knowledge Trees

As Close-out effort expands, the knowledge tree evolves, branching into areas that capture “how & why” and share “lessons observed”.

ANALYTIC CONNECTIONS IN THE DATA LAKE

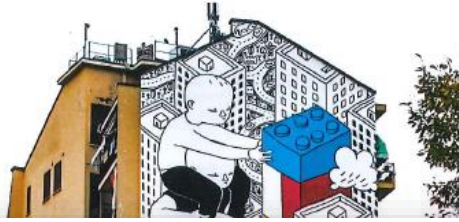
Pouring all relevant risk artifacts into a Data Lake enables organizations to discover new connections and patterns.



- Exploratory findings will illuminate areas of bias or preventable mistakes.
- Impact and benefit will be amplified when critical assets are tagged, tracked and their interplay and affect on overall performance analyzed.

This document is intended solely for the recipient to whom it is addressed.





DECISION MAKING

Leaders as Architects

by John Beshears and Francesca Gino

FROM THE MAY 2015 ISSUE

From Nobel Prize to Project Management: Getting Risks Right

by

Bent Flyvbjerg, Ph.D. & Dr. Techn.
Aalborg University, Denmark

Printed in

Project Management Journal, vol. 37, no. 3, August 2006, pp. 5-15

See in-print version here:

<http://flyvbjerg.plan.aau.dk/Publications2006/Nobel-PMJ2006.pdf>

Electronic copy available at: <http://ssrn.com/abstract=2238013>

DECISION ARCHITECTURE

Decision outcomes can be improved if care is given to the environment in which decisions are made.

DISTILLING RELEVANT DATA STREAMS

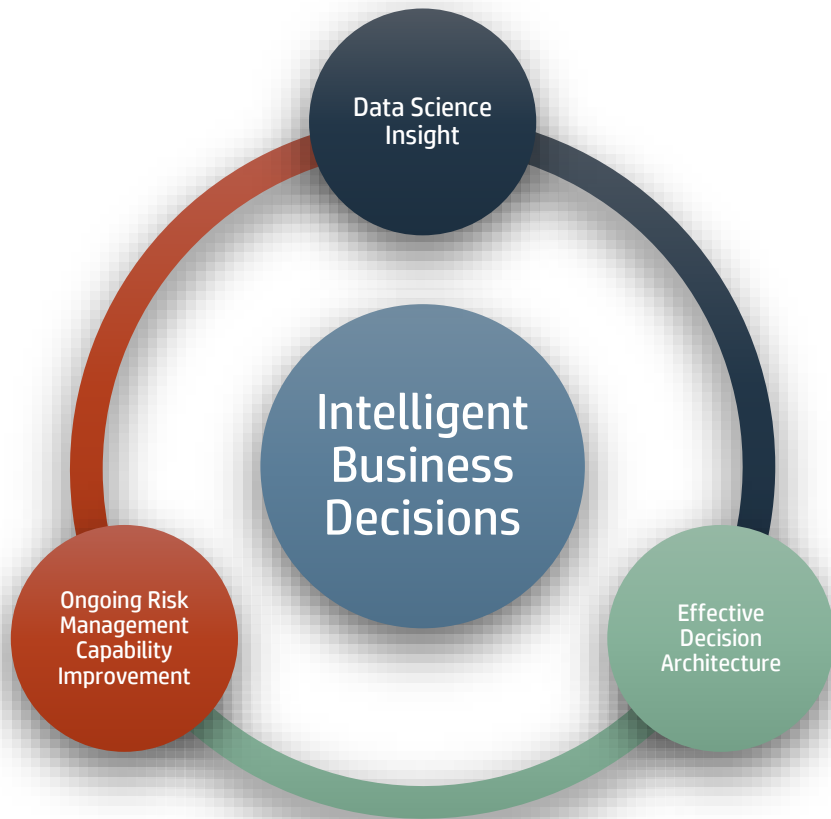
- Decision Architecture is employed to:
 - Deliver the right data at the right time (embedded analytics)
 - Avoid preventable mistakes
 - Minimize bias and systemic risk

CONCLUSION - A FRAMEWORK FOR INTELLIGENT BUSINESS DECISIONS

E&C companies have an opportunity to develop a Risk Framework, underpinned by a Data Science capability, to optimize performance outcomes.

DATA SCIENCE FOR PERFORMANCE OPTIMIZATION

- Data Science can provide a better decision-making environment by:
 - Promoting the importance of Risk Data curation
 - Mapping risk ecosystems via intercompany data exchange
 - Exploiting Knowledge Management synergies:
 - Verifying and corroborating data inputs
 - Disseminating and promoting known paths to success
 - Predicting known and previously unknown causes of failure
 - Minimizing the potential for cognitive bias
 - Promoting empiricism in place of subjectivity





THANK YOU

For more information, contact...



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APPENDIX

*The following content was addressed indirectly but, owing to time constraints,
not covered in detail.*

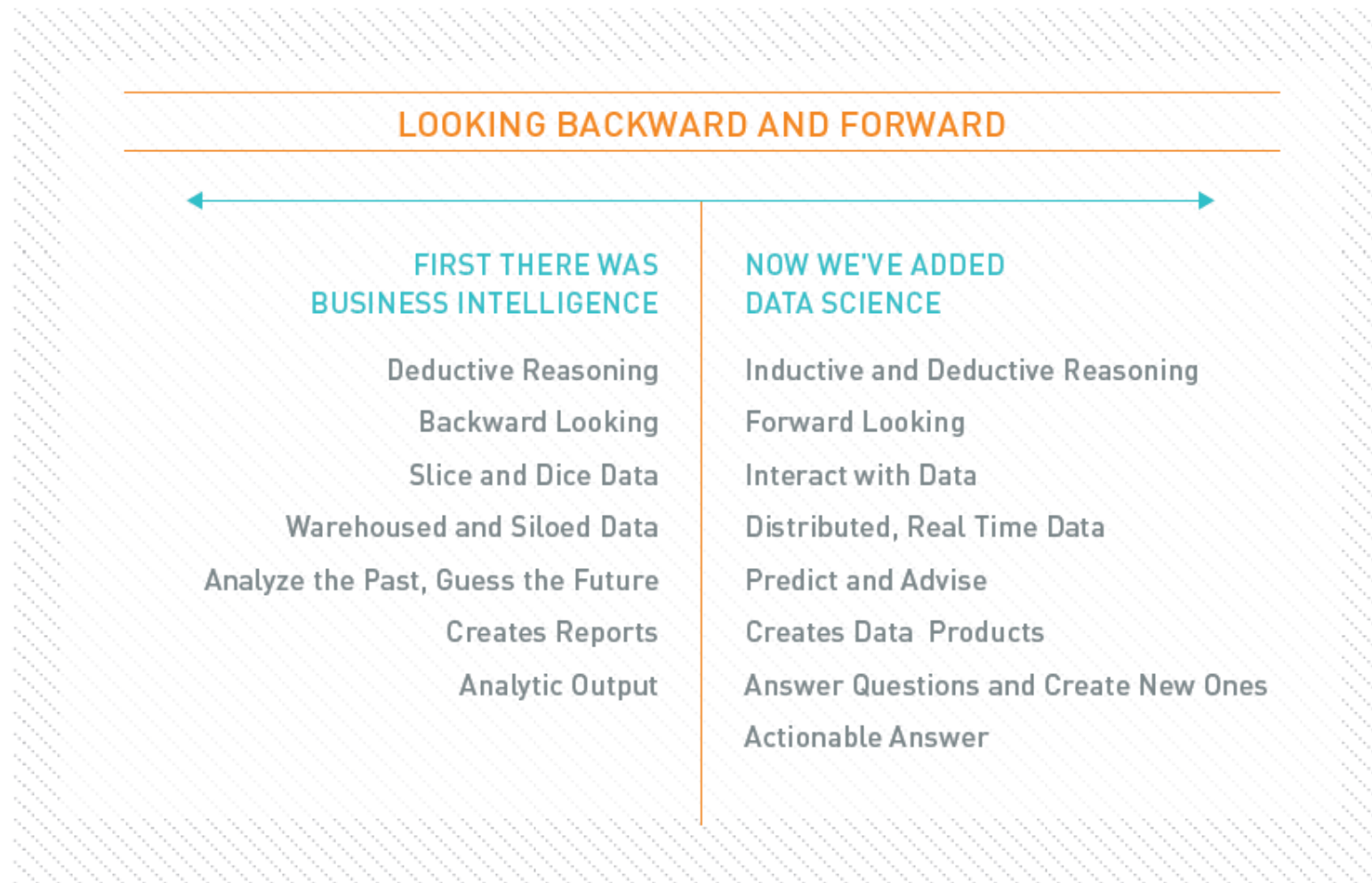
APPENDIX

DATA SCIENCE & COMPETING ON ANALYTICS

AN INTRODUCTION TO DATA SCIENCE & THE GROWING USE OF ARTIFICIAL INTELLIGENCE

BUSINESS INTELLIGENCE & DATA SCIENCE - A COMPARISON

Data Science offers a distinctly different perspective than capabilities by systems orientated toward providing Business Intelligence.

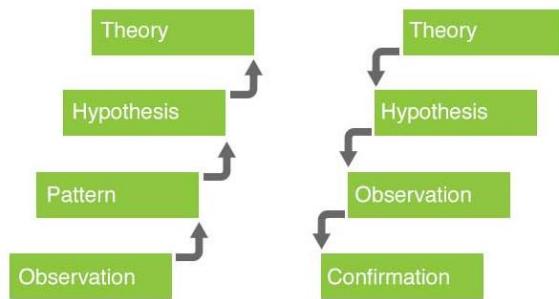


Source: Booz Allen Hamilton

TYPES OF REASON AND THEIR ROLE IN DATA SCIENCE

- Data Science supports and encourages shifting between deductive (hypothesis-based) and inductive (pattern-based) reasoning.

Inductive Reasoning vs Deductive Reasoning



Source: Using Inductive Reasoning in User Experience Research, Designorate.com

- Inductive reasoning and exploratory data analysis provide a means to form or refine hypotheses and discover new analytic paths.
- Data Science creates an environment where models of reality no longer need to be static and empirically based.
- Instead, models are constantly tested, updated and improved until better models are found.

THE TYPES OF REASON...

DEDUCTIVE REASONING:

- › Commonly associated with “*formal logic*.”
- › Involves reasoning from known premises, or premises presumed to be true, to a certain conclusion.
- › The conclusions reached are certain, inevitable, inescapable.

INDUCTIVE REASONING

- › Commonly known as “*informal logic*,” or “everyday argument.”
- › Involves drawing uncertain inferences, based on probabilistic reasoning.
- › The conclusions reached are probable, reasonable, plausible, believable.

...AND THEIR ROLE IN DATA SCIENCE TRADECRAFT.

DEDUCTIVE REASONING:

- › Formulate hypotheses about relationships and underlying models.
- › Carry out experiments with the data to test hypotheses and models.

INDUCTIVE REASONING

- › Exploratory data analysis to discover or refine hypotheses.
- › Discover new relationships, insights and analytic paths from the data.

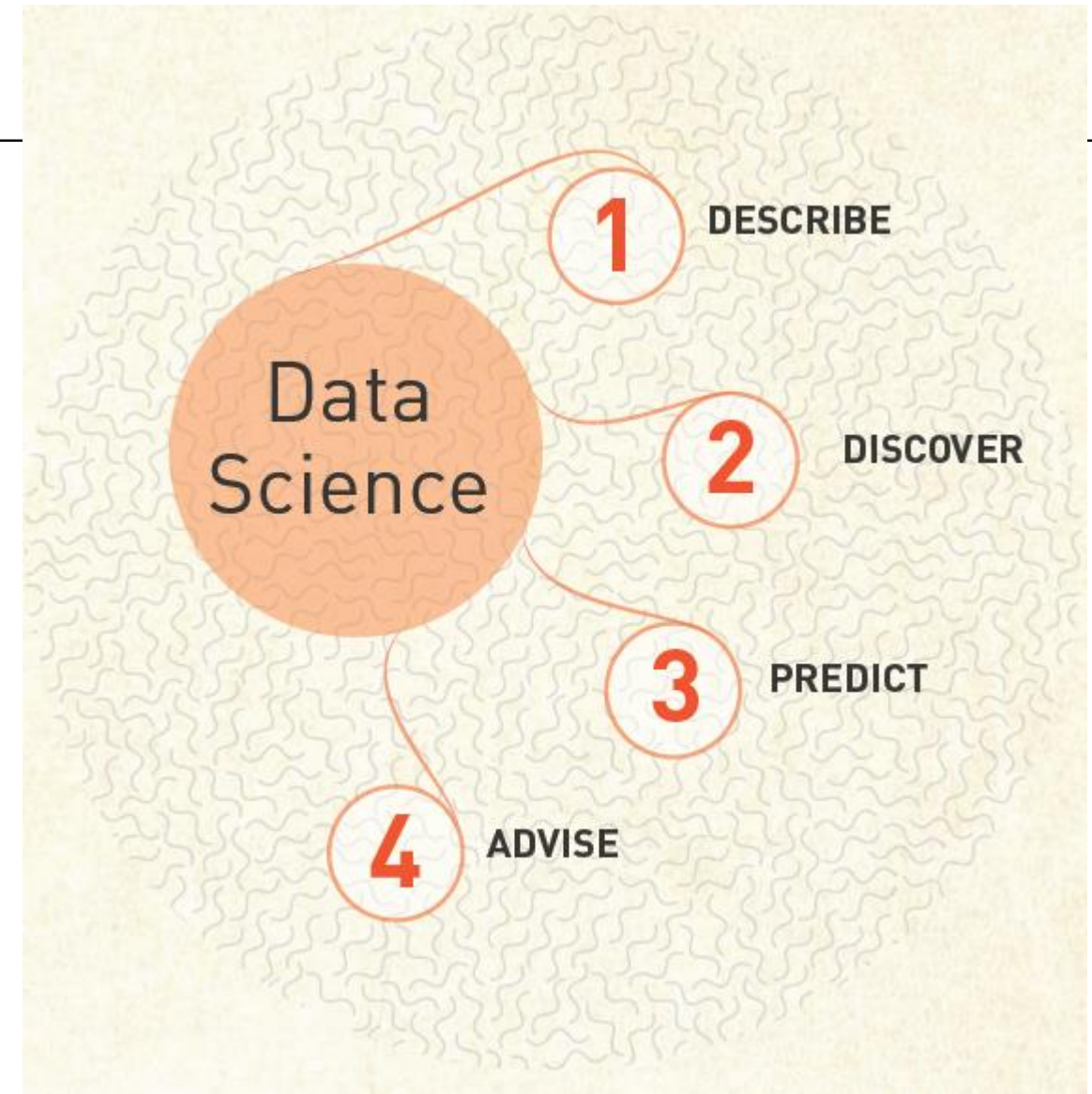
Source: Booz Allen Hamilton

ANALYTIC SELECTION PROCESS

The spectrum of analytic goals helps guide the selection of the appropriate analytic technique:

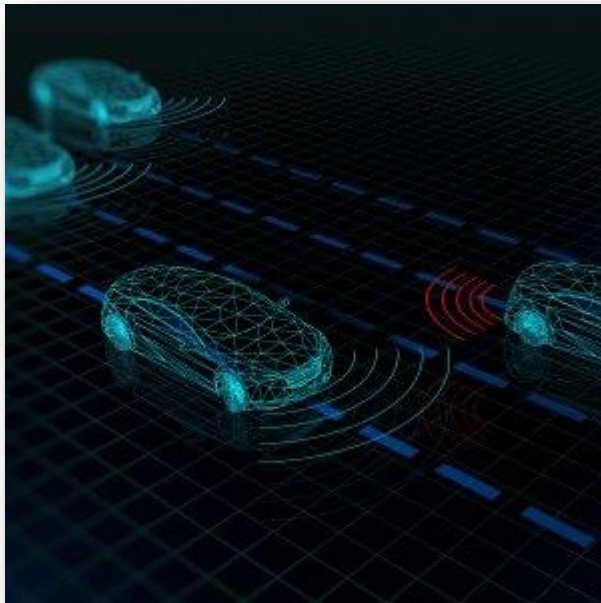
- Step 1: DESCRIBE
 - How do I develop an understanding of the content of my data: Processing, Aggregation and Enrichment.
- Activity 2: DISCOVER
 - What are the key relationships in the data: Clustering, Regression, Hypothesis Testing.
- Activity 3: PREDICT
 - What are the likely future outcomes: Classification, Regression, Recommendation*.
- Activity 4: ADVISE
 - What course of action should I take: Logical Reasoning, Optimization, Simulation.

**Diversity is needed to avoid the phenomena of the “recommendation bubble” i.e. confirmation bias.*

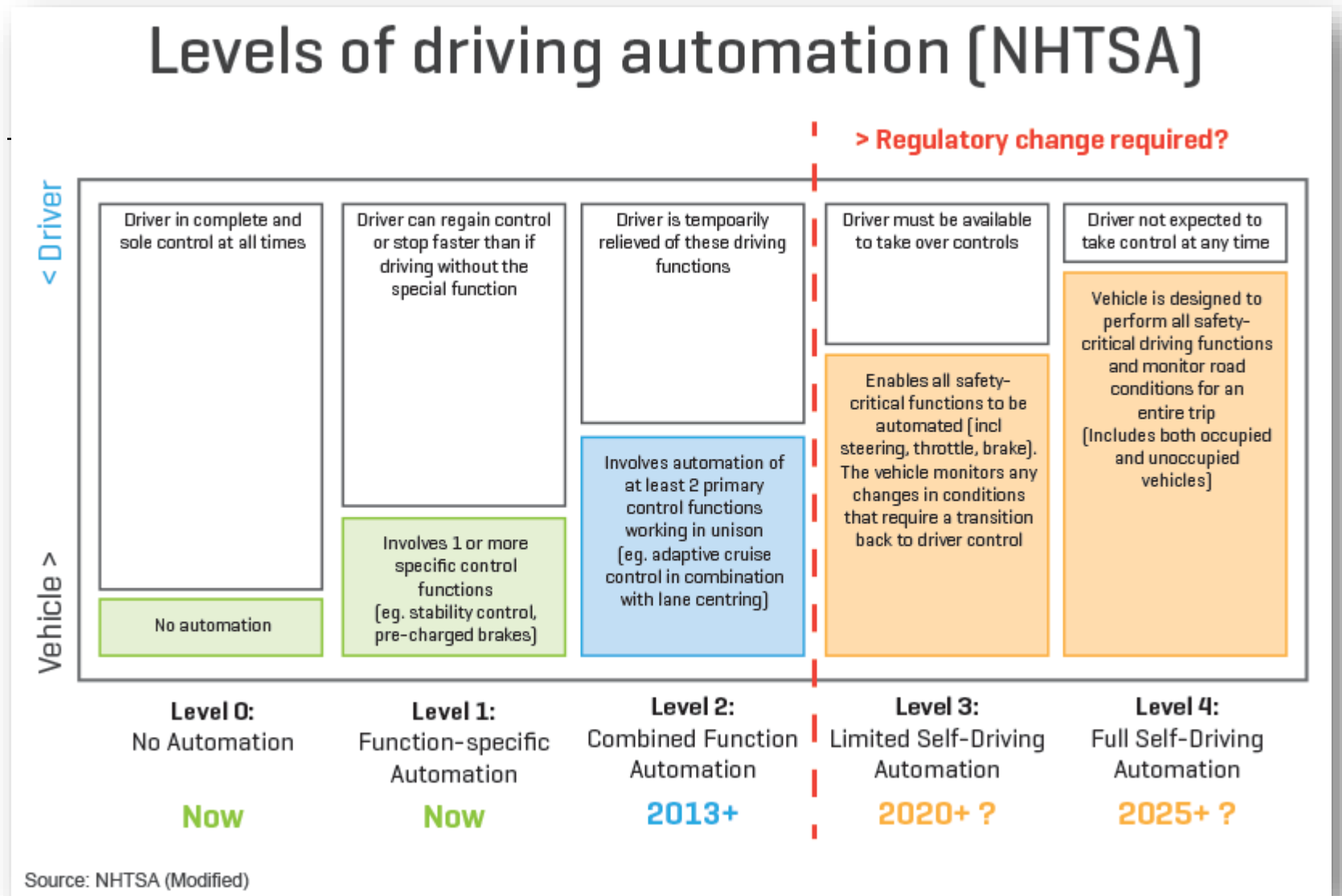


PREDICTED PACE OF AI PROGRESS

Developments in the world of transport provide both a window into the pace of AI progress and useful analogy for us to better appreciate how technological advancements may influence how we could navigate the project world in the coming years.



Source: **Four Management Lessons From Self-Driving Cars**, MIT SMR



Source: <http://www.transport.govt.nz/ourwork/technology/specific-transport-technologies/road-vehicle/autonomous-vehicles/>

APPENDIX

BEYOND THE HYPE

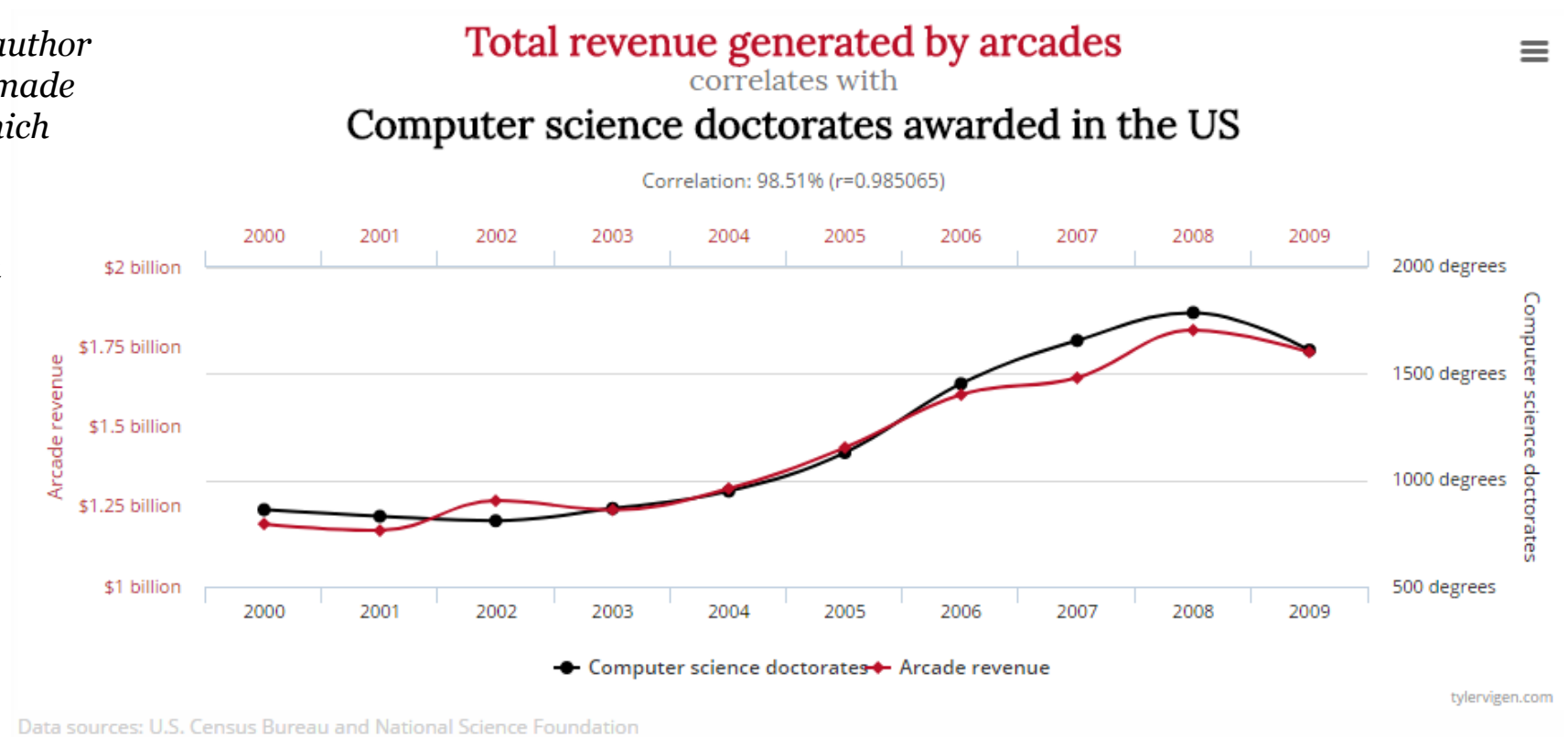
POTENTIAL PITFALLS & A CALL FOR COLLECTIVE ACTION

SPURIOUS CORRELATIONS

“Correlation doesn’t imply causation”

Tyler Vigen, a JD student at Harvard Law School and the author of Spurious Correlations, has made sport of this on his website, which charts farcical correlations

Since falsity grows faster than information, the need for appropriate domain expertise should not be overlooked



RAGE AGAINST THE MACHINES: THE SWING RIOTS (1830 -1832)

Figure 1 Swing riots: Incidents per parish, 1830-1832

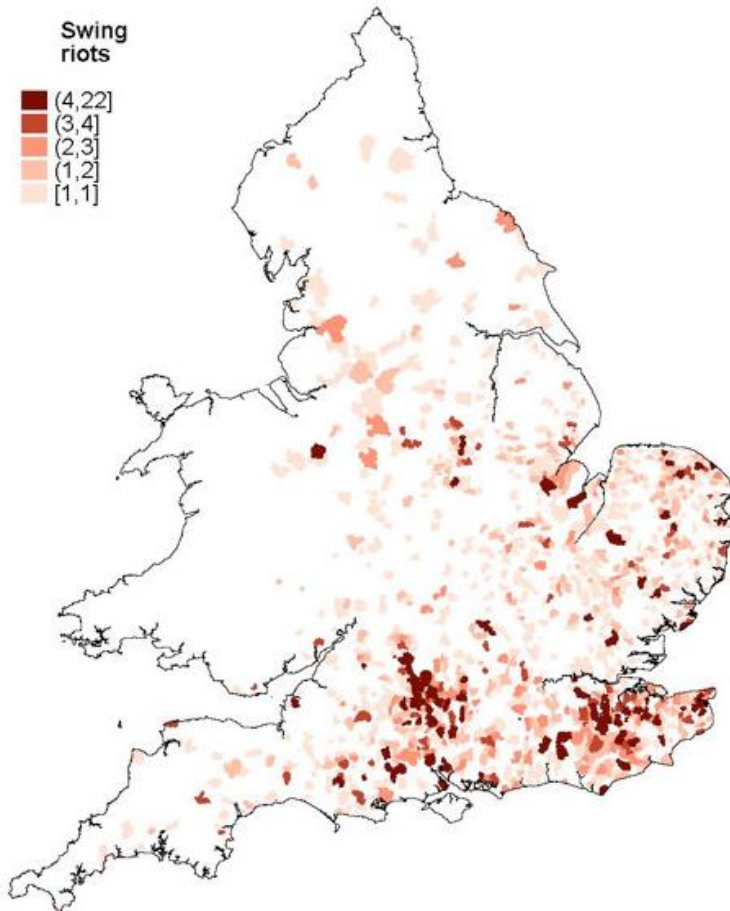
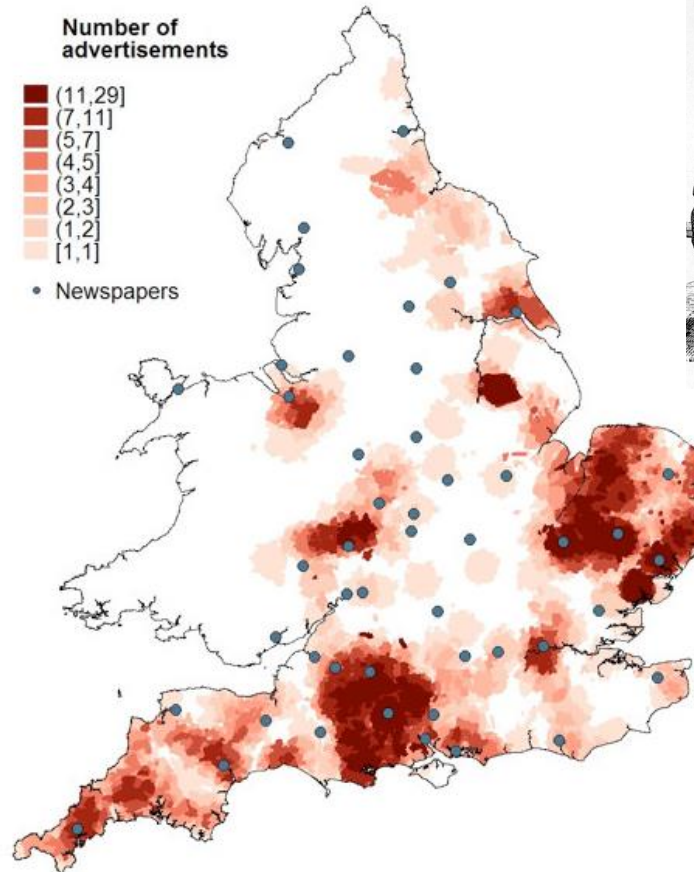
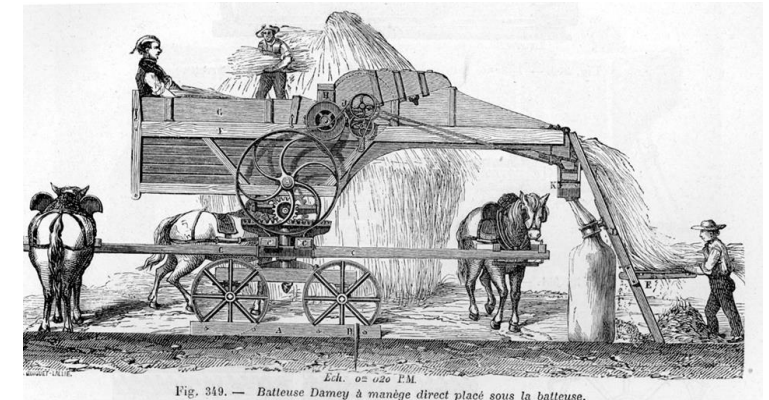


Figure 2 Geographical distribution of threshing machine advertisements



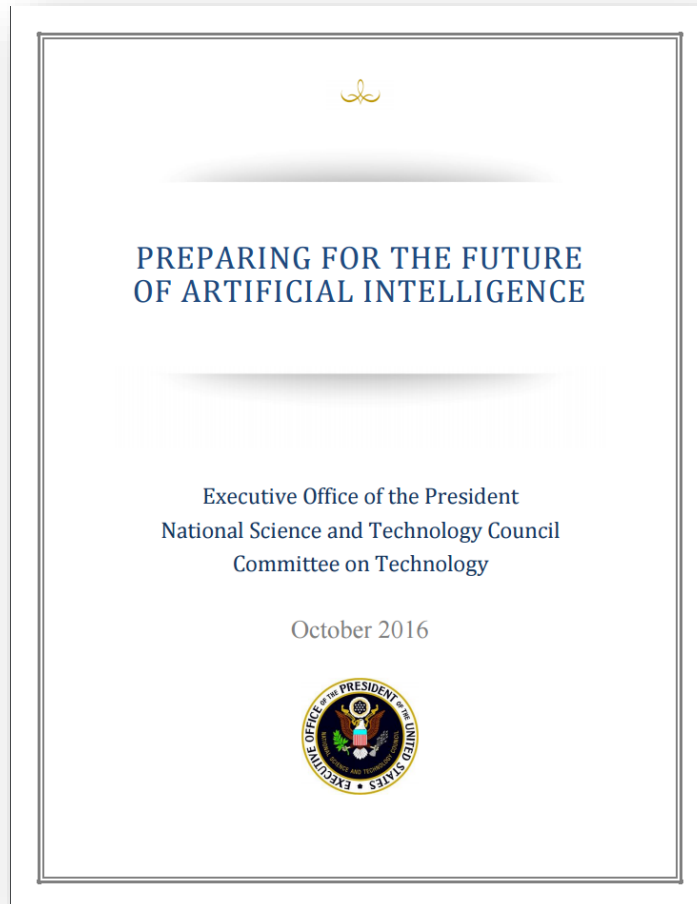
Note: Blue dots show the location of cities that printed at least one of the newspapers we use.



- The advent of threshing machines brought about labor market dislocation and depressed wages
- AI will automate mundane, repetitive white collar jobs

Source: Rage against the machines: New technology and violent unrest in industrializing Britain <http://voxeu.org/print/61692>

PREPARING FOR THE FUTURE OF ARTIFICIAL INTELLIGENCE



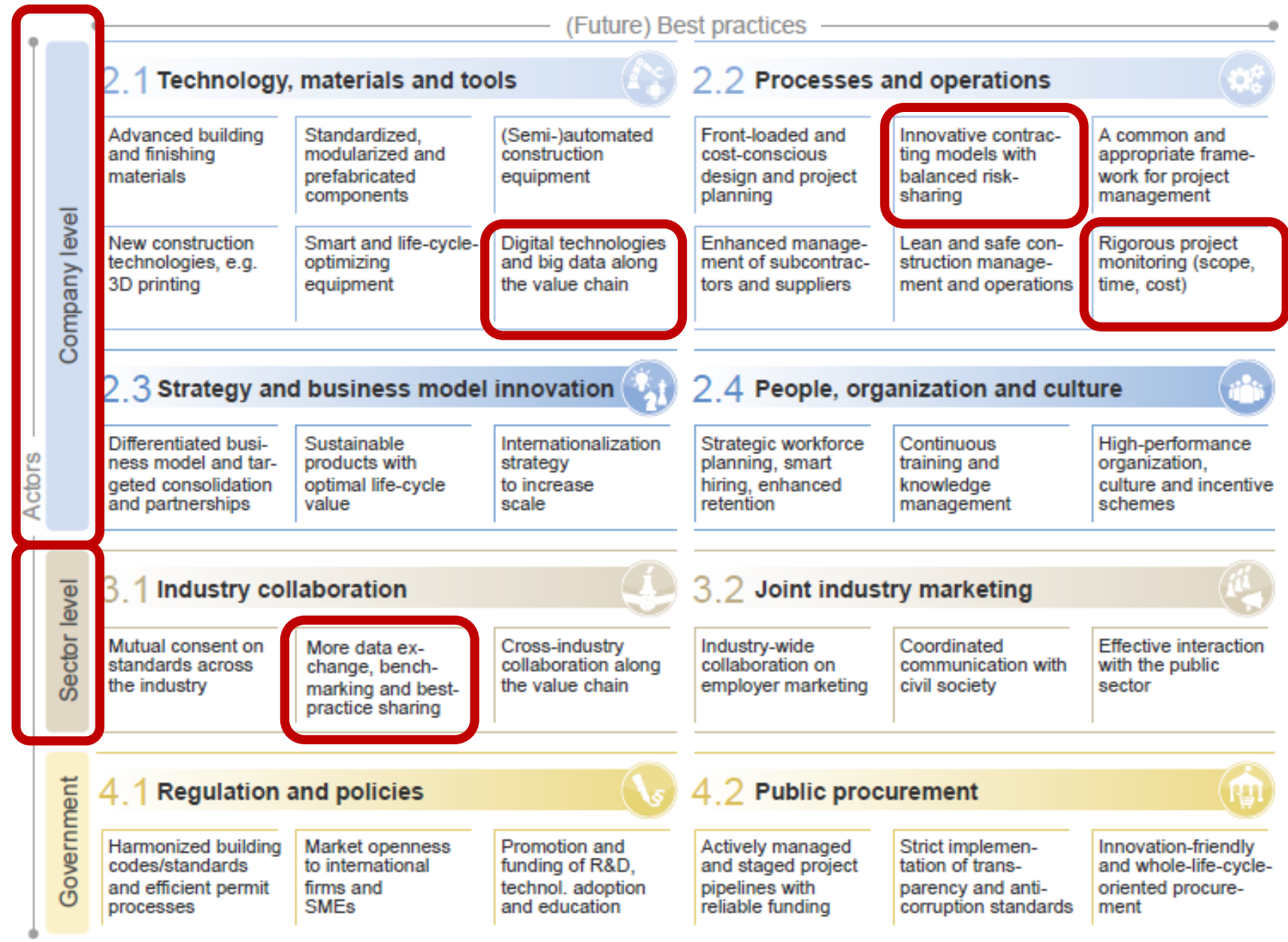
“AI will continue to contribute to economic growth and will be a valuable tool for improving the world, as long as industry, civil society, and government work together to develop the positive aspects of the technology, manage its risks and challenges, and ensure that everyone has the opportunity to help in building an AI-enhanced society and to participate in its benefits.”

Source: https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf

WEF CONSTRUCTION INDUSTRY TRANSFORMATION FRAMEWORK

- Substantial improvements are already within reach for companies.
- Cross-company collaboration is pivotal.
- As both regulator and major client, the government needs to take action too.

 = our focus today



Source: World Economic Forum; The Boston Consulting Group

Source: Shaping the Future of Construction, A Breakthrough in Mindset and Technology, WEF & The Boston Consulting Group, 2016

APPENDIX

BUILDING A DATA SCIENCE CAPABILITY

STRATEGIES FOR RISK-BASED KAIZEN

HOW TO INCUBATE A SUSTAIN AN ANALYTICS DRIVEN CULTURE



Relentlessly ask the right questions and constantly search for the next one.

- True curiosity and experimentation requires an enormous tent of skills, abilities and perspectives.
- An inclusive data science team will include, data scientists, technologists, domain experts, organizational design and strategy practitioners, design thinkers and human capital specialists.

Source: <https://www.boozallen.com/s/insight/thought-leadership/tips-for-building-a-data-science-capability-2.html>

DATA & ANALYTICS CATALYST

4 types of leader commonly play a critical role in advancing data-based decision-making.

ENTERPRISE LEADER



Setting the Vision

Works across the enterprise to set the organization's data and analytics vision and strategy

BUSINESS/ OPERATIONS LEADER



Enabling Actionable Analytics

Advances grassroots use of data and analytics from within a business/operational unit

SERVICE PROVIDER



Demonstrating Value

Provides services that prove the value of data and analytics for internal customers

PRODUCT EXECUTIVE



Pushing the Envelope

Drives product development by applying cutting-edge data science and advanced analytics

Each has a varying degrees of responsibility, oversight and influence in their organization.

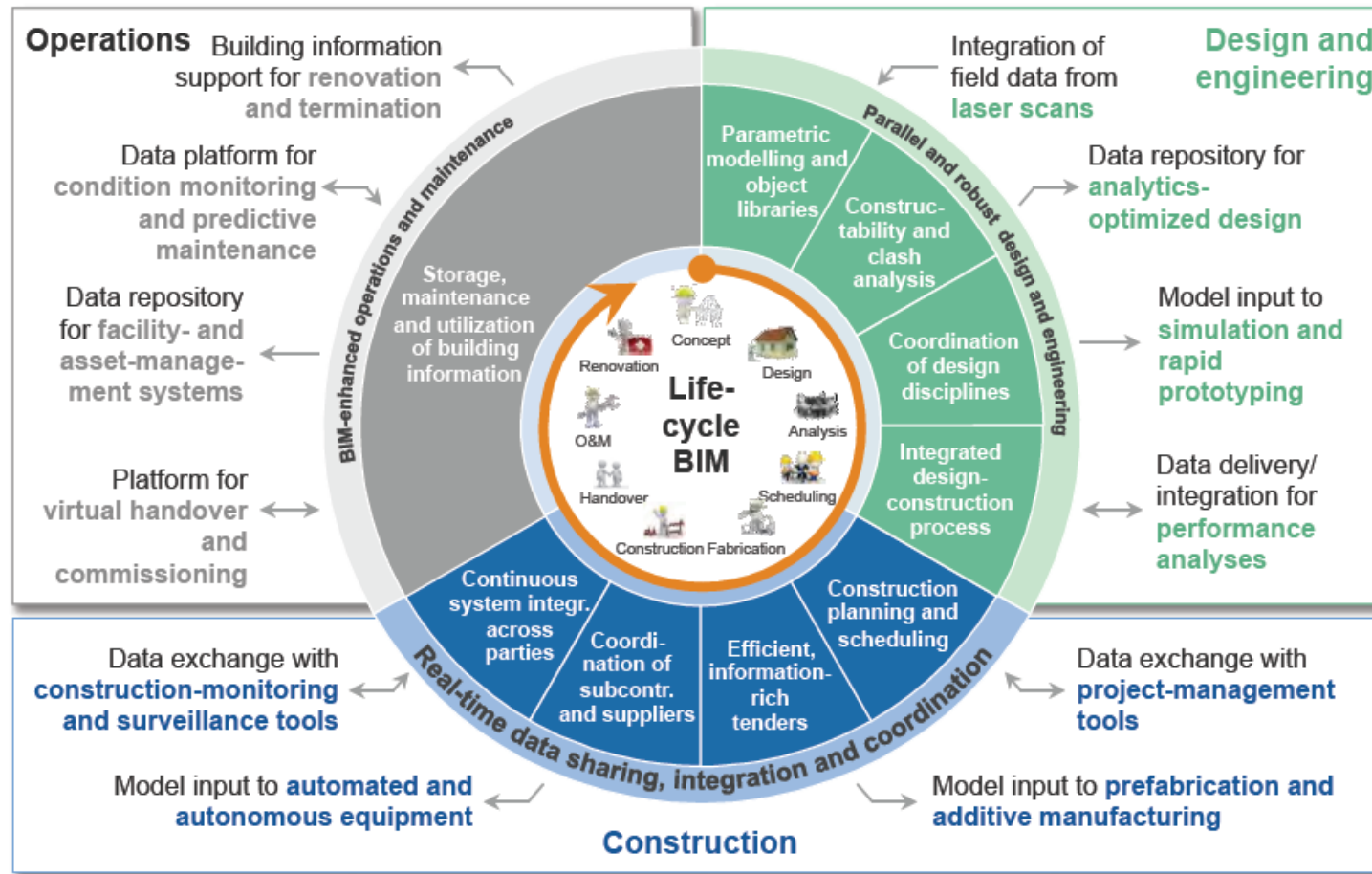
Source: <https://www.boozallen.com/s/insight/thought-leadership/data-and-analytics-catalyst.html>

APPENDIX

NEAR-TERM OPPORTUNITIES FOR E&C COMPANIES

EMPLOYING ADVANCED ANALYTICS IN ENGINEERING AND CONSTRUCTION

BIM APPLICATIONS ALONG THE E&C VALUE CHAIN



At project close-out, enhanced knowledge transfer can support DfMA or Design for Manufacture and Assembly during the front-end of future projects.

Using more information earlier in the process not only reduces the Total Cost of Ownership (TCO) but also make both the TCO and project delivery more predictable.

Source: The Boston Consulting Group

Source: Shaping the Future of Construction, A Breakthrough in Mindset and Technology, WEF & The Boston Consulting Group, 2016