

APPLIED INSIGHT SERIES

What businesses can learn from big data and high performance analytics in the manufacturing industry

An independent report conducted by Big Data Insight Group, commissioned by EMC Greenplum and Bull











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Big Data Insight Group is the UK's first independent business and IT focussed big data and advanced analytics community.

Our members are typically senior stakeholders and key influencers from SME to blue chip enterprises, incorporating both the public and private sectors. Our remit is to assist them in overcoming the challenges and realising the true potential of big data.

We do this through a number of channels, including forums, executive dinners, masterclasses, independent research reports and online editorial. Our activities feature a mixture of peer-based learning, insight from best practice leaders, networking and sourcing solutions.

Big Data Insight Group is a sister community of The Cloud Circle (cloud computing) and Obis Omni (business intelligence and performance management).

To become a member of Big Data Insight Group and receive the latest research plus invitations to events, please contact:

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Big data is transforming the manufacturing industry and there is much that other organisations, regardless of their sector, can learn from the tools, techniques and approaches it has applied.

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THIS IS AN INDEPENDENT REPORT, AUTONOMOUSLY RESEARCHED AND WRITTEN BY BIG DATA INSIGHT GROUP.

THE RESEARCH
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Foreword

elcome to
Big Data
Insight
Group's
Applied
Insight report on the
manufacturing industry.
This is the first in a series
of reports examining
how different sectors are
applying big data analytics
for competitive advantage
and, crucially, what every
business can learn
from them.

A minority have been doing what we now consider to be 'big data' for some time; others are only just starting out with projects of their own. The majority though, have little notion of big data and have not attempted to apply it. Therefore, the aim of this series is to help organisations of any size or sector to understand the great potential that big data has to offer.

With insight gathered first-hand from innovative companies in Britain and beyond, these reports will offer examples of how big data can transform a business across a wide array of operations and departments.

We will also explore: the areas where each industry is well placed to take advantage of big data; the unique challenges that those in the industry face; and the practices they have developed which can be appropriated by other industries.

Data is exploding in all areas of modern life. New tools – such as scalable compute power, parallel computing, in-memory

analytics, non-relational databases and advanced visualisation techniques – have been developed

to unlock the insight

that these vast collections of data contain.

We view 'big data' as any data which goes beyond the holding organisation's ability to manage it and gain insight from it using standard database tools. This is due to its volume (the size of the data set), its variety (unstructured and semi-structured) and its velocity (the speed at which it is created, captured and analysed, often now real-time). These are the so-called 'three Vs of big data'.

So using these definitions as our benchmark, we move onto manufacturing – the sector that has been a forerunner of data driven decision-making for decades. The study features insight from end-users, analysts and academic groups, including the likes of McLaren F1, Volvo, Procter & Gamble, Rolls-Royce, the Institute for Manufacturing at the University of Cambridge, Xerox and Ovum. It therefore offers a varied and balanced examination of how big data is used within the industry and what those in other sectors can take away from it.

If you'd like to get in contact with us regarding your big data initiative, whatever industry you work in, we'd love to hear from you.

Many thanks,

Mark Young and Dominic Pollard, Editors



MANUFACTURING WAS ONCE A CORNERSTONE OF THE UK ECONOMY. THE NATION WAS AT THE CUTTING EDGE OF NEW DEVELOPMENTS AND LED THE WORLD IN INNOVATIVE PRODUCT DESIGN AND BUILD.

owever, as manufacturing became an increasingly global industry, thanks to lower freight costs and superior communication networks, problems arose. Competition from emerging economies like China, India and Malaysia, which could offer far lower production costs, has meant that the UK's dominance over the marketplace has been heavily diminished. Manufacturing's contribution to the UK economy fell from 22 per cent in 1990, to 11 per cent in 2010.

When the low cost production began to move east, manufacturers in developed economies responded by using advanced computing and data to concentrate on automation, design, and high value products. But despite cutting large swathes of costs and streamlining operations, the UK

industry never regained its position at the forefront of the market.

As a McKinsey Global Institute report states: "Despite early advances, manufacturing, arguably more than most other sectors, faces the challenge of generating significant productivity improvement in industries that have already become relatively efficient."

ENTER BIG DATA

The advent of big data analytics offers manufacturers the opportunity to take a giant stride forward in the journey that they have been making over the last few years. It allows them to make radical improvements in potentially any area of their value chain – from innovative design to efficient production to superior product lifecycle management.

As McKinsey writes: "Big data provides a means to achieve dramatic improvements in the management of the complex, global, extended value chains that are becoming prevalent in manufacturing and to meet customers' needs in innovative and more precise ways."

To put the amount of data that manufacturers have at their disposal into perspective, General Electric's report,



'The Rise of Industrial Big Data', offers the following example from a leading consumer packaged goods company: when producing a personal care product, the company generates 5,000 data samples every 33 milliseconds. This results in 152,000 samples per second, 13 billion samples per day or 4 trillion samples per year.

And it's not just about size either. As the report explains: "The challenge of managing big data for the industry goes beyond the sheer volume of information; there is the diversity and complexity of data, which comes in various formats and from disparate sources."

Yet manufacturers may be better placed than many to deal with these multiple challenges. For one, they primarily deal with data about materials which is bound by the laws of physics. Although the analysis might be extremely complex, they do not need to account for uncertain variables such as human behaviour.

And they are also simply better versed in the use of data and analytics through their adoption of 'lean' efficiency systems, which have been applied holistically throughout the industry in a bid to cut costs and remain competitive. These rely heavily on recording and analysing performance metrics, as do the 'Enterprise Resource Big data provides a means to achieve dramatic improvements in the management of the complex, global, extended value chains that are becoming prevalent in manufacturing and to meet customers' needs in innovative and more precise ways

McKinsey Global Institute

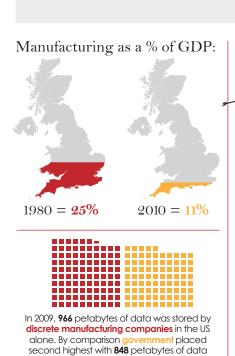
Planning' systems which orchestrate most large manufacturers' operations through insight-based, automated decision-making.

But manufacturers face unique challenges too. Dealing with physical products may offer benefits by limiting possibilities, but conversely it might prove restrictive from a mindset perspective. Manufacturers operate by dividing, combining and distributing physical resources. Intellectual property protection is also high on the agenda. However, as Dr Graham Oakes, a business efficiency expert who has worked with some of the world's leading

organisations, points out, data is most valuable as a shared, collaborative resource. Contradictions to the established paradigms may ensue.

Other challenges that manufacturers face and which are explored in this study could include costs, the need to integrate legacy systems, and more of the globalisation issues that they have already faced.

However, the potential gains available to manufacturers through the effective application of big data cannot be disputed. As is evident from the practical case studies in this report - including insight from the likes of McLaren Group, Xerox, Procter & Gamble, Conair, Volvo and more - there are opportunities to significantly enhance almost any area of the business, whether that's in the design process, on the production lines, in the supply chain or in the marketplace. The changes could result simply in the exchange of a single component, or they could lead to vastly improved maintenance schedules, or even the entire realigning of a company's business model, all of which we'll see over the course of this report.



With big data Toyota claims to have eliminated

of defects prior to building the first physical prototype

During the average cross-country flight, a Boeing 737 generates 240 terabytes of data

It is typical for a large automobile original equipment manufacturer (OEM) assembly plant to be supplied by up to:

In terms of quantity alone, each two hour

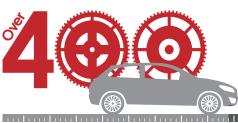
F1 race produces enough data to fill some

books

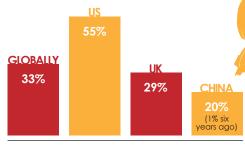
traditional telephone





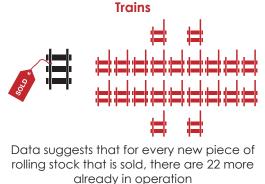


discrete measurements captured from a Volvo car



Estimates of manufacturing companies offering services

Manufacturing stores more data than any other sector – close to 2 exabytes of new data stored in 2010



One personal care product:

5,000

data samples every 33 milliseconds

This results in:

152,000 samples per second

9 million

samples per minute

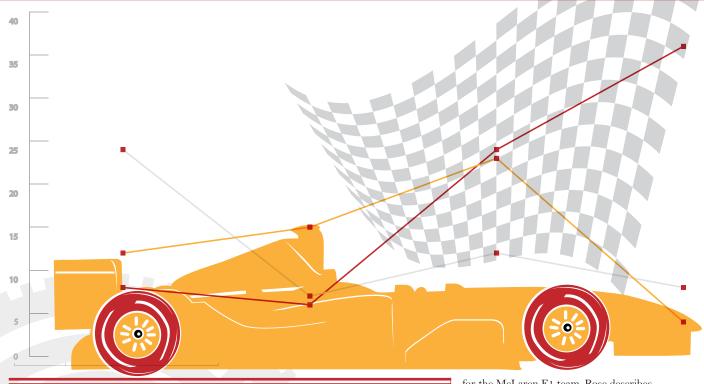
545 million samples per hour

4 | samples per shift

13 billion

4 trillion

samples per year



Simulations and real-time data feeds

otorsport, specifically Formula 1, is undoubtedly among the industries at the very pinnacle of advanced engineering. It's an industry where the ultimate aim of its competitors is to be at the very front of the pack – and it's an industry which is fundamentally driven by big data.

The manufacture of F1 cars is a very specialist discipline. However, although it might seem far removed from the practices of 'normal' organisations, in reality the sector is driving innovation among massmarket product development. In fact, one of the sport's oldest and most successful teams, McLaren, runs a dedicated company, McLaren Applied Technologies (MAT), which is focussed on taking the group's technology, processes and expertise and applying it to uses outside of F1.

Steve Rose has been a solutions architect at MAT since 2008. Prior to that, he spent five years working as a software engineer

for the McLaren F1 team. Rose describes McLaren F1 as "essentially a company that is in continuous research and development (R&D)". Two types of data have been critical in this process: historical and realtime. Both certainly fall inside the bracket of 'big data'. In terms of quantity alone, each two hour race produces enough data to fill some 6,000 traditional telephone books. In addition, since the data collation is recorded at a rate of anything up to a thousand samples per second across the hundreds of sensors on the car, "there is no real way of processing it inside traditional relational databases," Rose says. This is a defining characteristic of what is considered 'big data'.

During a race, data is recorded on all manner of metrics including the temperature, flexing, load levels and wear of all of the car's different components. Collectively, these paint a real-time picture of the performance of the whole car. The engineering team in the track-side base can understand whether everything is running as it should and attempt to predict what the outcome of the race will be based on the current performance levels, directing its race strategy accordingly.

TURNING GUESSWORK INTO A SCIENCE

The biggest innovation involved with the McLaren F1 team's data operations, and the area that other types of business can take most inspiration from, is the ability to

carry out simulations using this real data. For instance, the team can take all of the race data from the last outing and simulate what would have happened had it altered a component in the car. The ability to perform simulations based on archived data allows the team to accurately predict the outcomes and consequences of changes to its cars, eliminating the risk of the unknown.

Rose says F1's niche expertise when it comes to data - something it has had to build up itself over the last decade or so, before commercial big data solutions were available - is abstracting away from the type of data and the source of the data. This allows them to easily contrast and compare data that has come from a virtual environment - a simulation - to data from a real-world environment - the race track. "We can look through data from our complete R&D cycle, from the virtual world to initial tests, to in the car, to a race. This allows us to ensure that any changes we have made are having the effect that we were expecting - that's where we're quite unique."

Through McLaren Applied Technologies, a wide range of other industries have already benefited from the data processes that the McLaren Group has developed. The most high profile of these is being realised through a long-term strategic partnership with the British pharmaceutical giant GlaxoSmithKline (GSK). Four key benefits of this partnership have been touted for the drug maker: improved efficiency in planning processes; strategic decision—making through data modelling; better real-time monitoring, scenario-planning and forecasting; and the development of agile and adaptive management personnel.

GSK will develop a 'Mission Control' centre at its London headquarters which mirrors the one McLaren uses track-side during F1 races. The aim is to drive faster decision-making in wholesaler stocking, inventory management, pricing, responding to retailer requests, competitor activity, market and customer needs, and longer-term investment allocation for new product development and innovations.

In today's challenging economic conditions, we firmly believe that innovative associations such as ours will play an increasingly significant role in ensuring that the UK remains globally competitive in the field of scientific innovation

Ron Dennis, executive chairman, McLaren Group

When the deal was signed, GSK chief executive Andrew Witty said: "McLaren has an unparalleled reputation for innovation, built on rigorous analytics and fast decision-making.

"This partnership is another example of GSK looking outside its sector for inspiration and fresh perspectives on how we can achieve our strategic goals in an ever more challenging and fast-changing business environment."

Ron Dennis, McLaren Group executive chairman, added: "In today's challenging economic conditions, we firmly believe that innovative associations such as ours will play an increasingly significant role in ensuring that the UK remains globally competitive in the field of scientific innovation."

Elsewhere in the health market, McLaren technology has been used to implement remote patient monitoring systems. These combine medical sensors and compact electronics which allow patients to travel or remain in their own homes and still receive the medical observation they require. In sport, the coaches of Team GB Cycling use the telemetry and data management systems to get real-time feedback during practices or races and can identify areas for improvement based on marginal gains.



Product development and fault monitoring

With our old system, it was a standard joke that when you finally got a response to your database inquiry you had forgotten what your question was

Bertil Angtorp, senior business analyst, Volvo

hile specialist car manufacturers might be racing full speed ahead with big data, the commercial, massmarket side of the industry is also making impressive progress. One company that is now using big data to intelligently guide almost every facet of its business is the motorcar division of Volvo, now separated from the rest of the Swedish Volvo group and owned by the Chinese car maker Geely Automobile.

Each new Volvo car is laden with microprocessors and sensors. These generate diagnostic codes when a component within the car experiences a deviation from its usual operational conditions. These include simple binary codes which merely register when a fault has occurred and more detailed information from advanced sensors, including variable metrics which allow fault thresholds and tolerances to be understood. Stored in the engine control units, these codes can be analysed when the car goes into a dealership for maintenance, with over 400 discrete measurements captured in all.

But after introducing this system Volvo's traditional data warehouse was struggling to cope with all of the extra data it was collecting, both from storage and compute perspectives. Specifically, it was painfully inefficient to try and cross-analyse two different types of data, such as the diagnostic data and the information on warranty claims, where a clear correlation for process efficiency had been identified.

"Our old system could only handle about 20 jobs at a time," said Bertil Angtorp, senior business analyst at Volvo, in a case study circulated by the technology vendor. "It was a standard joke that when you finally got a response to your database inquiry you'd have forgotten what your question was."

Dealing with response times is a critical issue for any organisation getting to grips with big data. For Volvo the introduction of a two-node data warehouse yielded instant results. The raw data capacity that analysts could work with increased five-fold to 1.7 terabytes. More impressively, the time it took to compile a comprehensive report of the diagnostic failure codes by model and year fell from two weeks to just 15 minutes. With investigative analysis limited previously to just a handful of users, the new system had the performance capacity to stretch to 300 analysts using the system simultaneously.

DATA DRIVEN DESIGN IMPROVEMENTS

The ability to perform analysis on this scale has had positive effects for Volvo's product improvement operations. Two applications stand out in particular. The first is modelling failures over time. Analysts are able to access information on how many of their cars above a certain age are currently in operation and see which faults they have experienced. Over time they can build an understanding of cumulative hazards and are then able to ascertain which other vehicles are likely to develop the same issue. By cross-

referencing this with sales and warranty data, they are able to accurately predict what the strain on cost and manpower of future warranty claims will be, or whether it makes sense to issue callbacks.

The second application is mapping failure rates by geographical location. A car driven in the rural snow of Scandinavia will face different ecological conditions than one driven within an urban environment in Asia. By comparing diagnostic readout data with operational log data, Volvo can build an understanding of driving patterns and environmental influence. It can then plan location-specific amendments to future models.

Åke Bengtsson, Volvo's vice president of quality and customer satisfaction, is ardent in his backing of big data as a platform to base business decisions upon. "I would say that today we have only scratched the surface; I don't think we understand yet, from a business point of view, this tool's true potential," he added within the vendor case study. "I believe that we can better use data to provide early indications. In today's competitive environment we must be able to act quickly, to reduce the number of steps to an accurate, proactive response.

"Every car we produce with a fault costs the company money. And every minute, hour, and day by which we can expedite a solution saves money for the company. The earlier we can resolve an issue the better it is for the customer and the company. So I think our direction is clear.

"We've recently implemented a hardware and software upgrade that should take us several years ahead, with the performance and capacity we need to really utilise the data we have, and to continue developing new solutions and business opportunities."

RIGHT FOR SOME, NOT FOR ALL

Essentially, any organisation that is able to implement sensors into their products will be able to follow Volvo's lead. However,



took Volvo to compile failure code reports with new big data infrastructure

not all types of product naturally come back into contact with the manufacturer or its representatives in the same way as a car does when it goes in for servicing at a dealership. The 'Internet of Things' - where everyday devices contain radio tags which connect to the Internet - helps resolve this issue though. The tags provide feedback on status and performance metrics, aiding product development by offering a more in-depth, holistic view of the product in the real world. As we'll explore later, this has been used to exceptional effect by organisations including Xerox. However, it could work out to be too expensive for lower value items.

Indeed, Tony Baer, an analyst at the London-based, technology-focussed intelligence firm Ovum, says that many companies will not have any need to introduce big data into product reengineering for reliability purposes. In fact, for many it would be in contravention of their business models.

"Modern consumer electronics have optimised reliability – at least to the level that it makes sense for their business models," he says. "It's different from where we were 30 years ago - the point now isn't to make a TV last for decades - these days if you get more than six or seven years out of something you're doing very well."

Baer says companies "that bend metal or have motion" have the most to gain out of sensor-based big data, essentially because they suffer the most from wear and tear. Other companies will be more focussed on analytics for consumer insight, mirroring retailers by using social media data in order to build products to market demand and exploit consumer trends.

Dr Graham Oakes says the Volvo example demonstrates that "effective use of big data is dependent on technical infrastructure". He explains: "A cycle time of weeks simply doesn't allow for exploratory 'what if' analysis. A cycle time of minutes does. It goes beyond this, however; the most effective users of big data have the right infrastructure in place, but they also have the skills to break

their problems down appropriately and to choose good approaches and algorithms." Clearly this is something that the car manufacturer profits from as a result of its years of commitment to analytical product improvements. If other manufacturers have to build their skills base from scratch, they may struggle to find readily available resources in the talent pool.

APPROPRIATION

Dr Graham Oakes says that although the above examples have mostly been concerned with improving the performance and economics of manufactured products, the same principles can be applied to the ecological impact of products. "Part of this is driven by corporate social responsibility concerns," says Oakes, "but it's also driven by business benefit – redesigning components to, say, reduce weight and hence fuel consumption, saves operating costs as well as giving environmental benefits."

Indeed, the latest versions of computer -aided design software which manufacturers (as well as film and game makers) use to model new products include the ability to swap components for others and instantly see the effects on durability, production costs, carbon emissions, end-of-life procedures and so on.

Ovum's Tony Baer says semi-conductor manufacturers, for one, will be delighted with the advent of big data as they seek to develop new products. He says: "These guys are always looking to implement state of the art systems and big data could present a real opportunity to do so. Right now we are reaching the physical limits of circuitry but the industry is still focusing on how small it can make components; to how many millionths of a human hair."

It is clear that sensory-based data and the simulations that can be run on it will have a dramatic impact on R&D cycles. Cost effective and time efficient experimentation can now be performed on products, improving their quality, performance and longevity.



ora Cecere is widely regarded as one of the world's leading supply chain experts. Now founder and CEO of the research firm Supply Chain Insights, Cecere had previously spent 20 years working as a supply chain practitioner for the likes of Procter & Gamble, Kraft and Dreyers Grand Ice Cream (now a division of Nestlé), and a further 15 years building supply chain software solutions.

Cecere says the supply chain is an area which could be vastly improved with big data. One tool manufacturers are beginning to use is 'health checking' of their suppliers or creditors. These IT systems have entered the market over the last few years and are able to keep track of the usual behaviour of partnering companies, monitoring metrics such as delivery periods, payment times and so on. It also factors in data from the industry sector and wider economy and since much of this is unstructured or is automatically generated from live sources, it requires the unconventional data warehousing tools which are associated with big data. Based on all of these factors, it can flag up a company which exhibits tell-tale signs of being in financial distress which could mean that it may soon be unable to fulfil a contract.



TRACKING MOVING GOALPOSTS

The US-headquartered global beauty and care products manufacturer Conair Corporation – best known in the UK for its BaByliss range – is an excellent example of how big data can be used within supply chains. So much so the company has won awards for it

One of the key problems for Conair was that it found that it could not keep up with the compliance conditions imposed by its retail partners. These change regularly with little in the way of effective reporting. This caused Conair to incur an increasingly large level of charge-back fines from retailers for non-compliance. The fines usually cost an average of 2.7 per cent of revenues, as industry standard for consumer durable manufacturers.

Cecere says many in the manufacturing industry accept these losses as a cost of doing business. Conair, though, sought to eradicate the cost instead. The company utilised screen scraping technology and unstructured data monitoring tools which could flag up changes to its retail partners' rules from their websites. This allowed it to predict which shipments would be at risk of flouting the regulations should they be late in delivery or if there were last minute changes that needed to be made to shipping orders. Interventions could then be made appropriately.

Taking inspiration from the success of this project, Conair has also set up central repositories for sorting purchase orders and delivery data - an essential act since most of its production is outsourced to partners in China where the company is unable to install its own IT systems. Some 90 per cent of the company's goods are made in China and are then distributed to retailers throughout North America, Latin America, Europe and Asia Pacific. By embracing the ability to deal with large volumes of unstructured data from disparate sources which big data has delivered, Conair has dramatically improved visibility and control over all areas of its supply chain.



By abandoning the paper system, prone to duplication and incomplete datasets, and instead creating this central repository where all data is stored and accessed, suppliers and vendors can set up automated inventory-stocking systems. Another benefit is that the system automatically flags changes in purchase orders which have been re-sent to the company. Duplicate versions of these are regularly sent, and hence rekeyed, due to the paper-based system. As such, small changes can often go unnoticed. The new system is able to immediately flag up which purchase orders have new elements and which are copies, saving the company time and money.

Using big data to aid supplier visibility can also be applied to improve corporate responsibility, adds Cecere. Here, manufacturers can look to retailers and marketers for inspiration: the techniques these industries use in analysing the unstructured data streams from social media can be repurposed by manufacturers to check on the social responsibility of their suppliers. Cecere says the computer giant Apple and its well reported controversies with a Chinese supplier is a prime example. "Apple should not have taken eight weeks to resolve the Foxconn issue," she says. "They could have nailed it much quicker with big data."

CHAIN REACTION

While big data helps to identify problems in the supply chain, Dr Graham Oakes is keen to emphasise that it does not represent any kind of 'silver bullet' solution. "It's not enough just to analyse the data and generate insight into what's happening," he says. "You need to be able to act on that insight – move to a less vulnerable supplier, reroute the wayward delivery, cancel the duplicate purchase order."

However, the supply chain work is the area that Oakes feels could have the most to teach other industry sectors. Though supply chains are most often associated with manufacturing owing to the passing-on of physical items, all businesses have them in one form or another. "I can see this monitoring and optimisation of the supply chain as being an area where big data is going to have a huge impact across industries, and probably a place where new service-oriented organisations are going to arise," says Oakes.

Oakes urges regulators to be among the first to take inspiration from the work that manufacturers are doing in supply chains. "Events of the last few years have shown that we have no real handle on just how all of the banks and other intermediaries are really connected and where the vulnerabilities are in that network," he says. "There's plenty of scope for regulators and other similar parties to build more insight into the system via big data."



rocter & Gamble (P&G) is the world's largest manufacturer of consumer goods. The global company has annual revenues of \$80bn and hundreds of household brands, including Duracell, Gillette, Pampers, Pringles and Tampax. The company uses big data in what it calls 'business spheres', of which it has 50 around the world. These business spheres offer senior executives insight into all elements of the company's value chain, from design to production through to sales and supplies. It is an example of how vast combinations of real-time big data analytics can deliver better informed decision-making for all areas of the business.

Importantly, this analysis is then visualised in a clear and engaging manner so time can be spent making business critical decisions, not number crunching. This is now possible thanks to advanced visualisation techniques which can powerfully process large amounts of data and present it dynamically. Whether the business sphere is used to illustrate production numbers, product faults or market trends, P&G can use this insight to adjust elements of its manufacturing process accordingly.

Business spheres help
us make fast, informed
decisions by combining
expert analysis of realtime information and data
visualisation within an
immersive environment

Filippo Passerini, CIO, Procter & Gamble

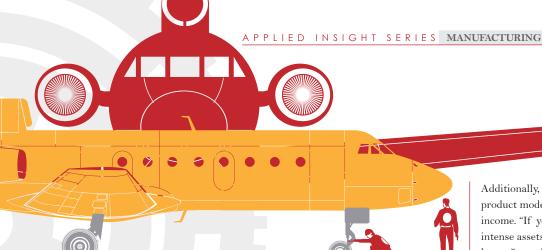
The company's CIO Filippo Passerini says: "[The business spheres] help us make fast, informed decisions by combining expert analysis of real-time information and data visualisation within an immersive environment. This system is being deployed in various formats throughout P&G's network of sites. The system utilises a set of business intelligence capabilities that integrate complex, real-time global data, analytic models, advanced visualisation and IT-analyst facilitation."

This is just part of the vision of Robert McDonald, Procter & Gamble's CEO, for better innovation, higher productivity, lower costs, and faster growth through

more intelligent use of data. McDonald has said that he wants to start using iPads in the manufacturing plants to download data from the production line as part of an enhanced operational programme which will help to reduce inventory across the whole supply chain – a key constituent of the 'lean manufacturing' ideology that the industry strives towards.

In essence, P&G's big data analytics is focussed on delivering a more effective system of manufacturing and distributing its products. From spotting inefficiencies on the production line to simplifying the task of managing the import of raw materials and export of manufactured goods, big data offers this manufacturing conglomerate the chance for organisation-wide improvements. McDonald states: "To be successful we've got to continue to improve productivity and being digitally enabled allows for that. So we're digitising our operations everywhere - from our manufacturing plants to the stores where consumers purchase our products. We believe digitisation represents a source of competitive advantage."

The idea of business spheres have already been used to great effect in other industries, notably at the record label EMI, where their introduction has played a major part in the reversal of the company's fortunes in recent years. Now, decisions are informed by the trend-spotting of data scientists, rather than the gut feeling of record label executives.



Servitisation

he most forward-thinking manufacturing companies are looking to restructure their business models to provide services as well as production. Indeed, analysts regard this to be one of the best ways that the industry can increase its contribution to economic growth. Aerospace company Rolls-Royce is one of the most high profile to have adopted this strategy, with more than half of its revenues now accounted for by services. The company rents engines to many of its customers, rather than selling them, and then provides maintenance for a contracted fee.

Professor Andy Neely of the Institute for Manufacturing (IfM) at the University of Cambridge has been working with the likes of BAE Systems (defence), Caterpillar (construction equipment) and IBM (technology) to create models for this so-called 'servitisation'. Big data, he says, is at the very heart of the development since a service model is reliant on communication, collaboration and efficiency.

There are compelling reasons for introducing services as well as product manufacture, according to Professor Neely. The first is cost. Manufacturers in developed economies such as the UK struggle immensely now to compete with low cost economies like China in process manufacturing. Therefore, manufacturers here need to add value to their customers' operations or make them more efficient in some way, rather than simply selling them a product.

Additionally, a 'low volume, high value' product model provides inconsistent income. "If you are selling lots of capital intense assets the revenue can be very lumpy," says Professor Neely. "A sale provides a chunk of money but a service contract – particularly where the asset lasts for a long time – provides a more stable revenue flow."

The market for services can be far bigger than point-of-sale. In the rail industry, for every new piece of 'rolling stock' sold, there are 22 already in operation; train carriages last, on average, 30 years. "To ignore maintenance here is to ignore a massive market," says Professor Neely.

Another factor is environmental sustainability. A service-based business model inherently reduces resource consumption, whereas a replacement model does the opposite. Professor Neely explains: "It is in some original equipment manufacturers' interests for their products to fail as they can then either sell another product or supply spare parts, with good margins. But consumers want reliability.

"Service models align the incentives between the two parties, with the consequence that fewer resources are used, to the benefit of the environment."

The logic has certainly struck a chord. Around a third of manufacturing firms globally now offer services as well as production. In the US this rises to 55 per cent while the UK lags slightly in the high 20s.

MAINTENANCE, CONSUMERABLES AND INSIGHT

The global office supplies provider Xerox has 'servitised' its business model to great effect. The company's name is synonymous worldwide with document printing and photocopying, with a rich history of selling machinery to offices large and small. However, like Rolls-Royce, over half of its revenues now come from services – renting

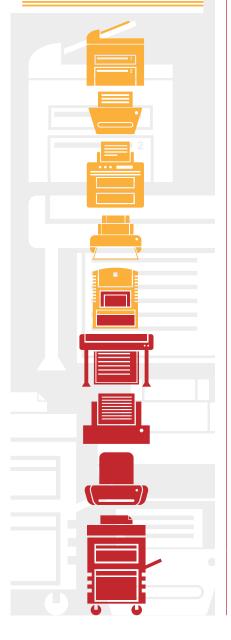
The key to making it all work was to effectively connect all of the devices in the field to a control system so we could monitor the situation and proactively take action around it

Andy Jones, director of European outsourcing operations, Xerox





The number of devices Xerox maintains by service contract worldwide, almost half of which are made by rivals



and maintaining machines by contract, supplying consumerables (toner, paper etc), and now providing business efficiency insight across a range of its customers operations. The company's turnover of \$22.6bn (£14.6bn) in 2011, of which \$1.3bn (£800m) was profit, reflects an eight per cent rise in services and a five per cent reduction in production.

As Andy Jones, director of European outsourcing operations, explains: "What we now sell is the impact that the customer sought from the product, rather than the product itself. The physical product is merely a means to an end where the customer is concerned."

When introducing the new model 10 years ago, the company quickly found that telemetric data collection and advanced analytics were essential in bringing down costs and providing a higher level of service.

"The key to making it all work was to effectively connect all of the devices in the field to a control system so we could monitor the situation and proactively take action around it, rather than relying on customers to feed back to us or us paying people to go around and make assessments," adds Jones.

The company designed software to sit within the customer's site and collate data from the built-in networking and telemetry components within the devices. A commercial data warehouse was positioned within Xerox where all of the data would be consolidated, and bespoke interrogation applications were built to allow Xerox to first analyse the data and then take automated actions, such as ordering or intelligently booking in maintenance.

Now, Xerox has 1.75 million products in the world under service, all transmitting data back to the company every time they experience an 'event'. This can be any number of different indicators, including operation fault codes, low levels of toner or paper, network changes, or user behaviour patterns.

FUTURE PROOFING

Jones describes the move as "an enormous culture change" for Xerox and says buy-in from all factions within the company was one of the most difficult elements. For one, the move would actively reduce the number of machines that Xerox's clients had within their businesses. According to Jones, the company regularly removes up to 30 per cent of a customer's machines, with some of the largest among them having 20,000 within their businesses in total. Of course, in a service-based environment where the machines are provided at reduced or no cost and maintenance is required on each machine, this makes sense. However, for a company that had previously based its success on volume unit sales, this was a difficult transition.

Even more contentious was that not only would the company focus on servicing machines, as well as manufacturing products, but it would also service machines made by its competitors. Again, despite the incongruity with the protectionist ideologies of traditional business models, this provided Xerox the opportunity to flourish in a service-based environment. By monitoring all machines where possible, Xerox could provide its customers with a more complete picture of their business habits and suggest more far-reaching and effective reforms, leading to direct cost, process and environmental efficiencies. As the service contracts tend to be long-term arrangements, the company is able to analyse data over periods of time to learn about trends within one client and the differences in performance across other companies of a similar operation or size. Proactive actions can then be advised or implemented autonomously.

In effect, by introducing services, Xerox was actually future proofing itself more than it may have realised. Since then, office computing habits have shifted significantly with the development of global interconnectivity and mobility through ultra-fast broadband, cloud computing and the popularity of tablet devices. Printing

and copying, while still huge markets, are decreasing in popularity. 'Business-insight-as-a-service', including strategy and analysis, HR and transportation systems, will now be a key part of the company's future growth.

Dr Graham Oakes says retailers should take note of Xerox's work – they could also make informed decisions about what products their customers might require in the future. For example, "the idea of a 'smart fridge' that orders food when stocks are low is about as old as the Internet," says Oakes. "Retailers could turn that on its head and offer a service to keep your fridge stocked for you, just as their suppliers will keep their shelves stocked for them. This is all a question of understanding what the customer really wants, and it's almost certainly not the specific product so much as the underlying need which matters."

SENSORY-BASED PREDICTIONS

The standard way of fulfilling maintenance contracts was to send engineers around to inspect each machine, identifying which, if any, needed to be serviced and then taking the necessary steps to action it. If a part was required which the engineer didn't have, or the nature of the repair meant that it could not be performed on-site, delays would occur.

Now, though, the engineers can monitor their machines remotely and schedule maintenance visits only when needed, ensuring the right tools and parts are in-hand. They ascertain where and when a machine will soon develop faults which means they can book in maintenance before it breaks, scheduling disruption when it is convenient to do so and avoiding the disaster that is unplanned downtime – something that causes curtailed production runs or defective output. Xerox uses telemetry to monitor its machines in the field. Other predictive maintenance models use sensors instead.

One such sensory-based system was developed by Dr David Brown and his team at the Institute of Industrial



Research at the University of Portsmouth. The 'Virtual Engineer' takes readings of the vibrations on machines, as well as noise, temperature and electrical signals. It then transfers these to a remote database where an intelligent understanding is built over which patterns in the data are normal – and therefore acceptable – for the machine. When the indicators digress from normal levels, an alarm is triggered to engineers and automated shutdowns or maintenance can be instigated if necessary.

Before big data analytic capability, noise monitors would be set next to an entire machine and would raise an alarm when decibels reached a certain level. This didn't allow for subtle changes though, and false alarms would be common, causing unnecessary downtime. It also did not identify which of the potential many thousand parts in the machine were failing. More commonly, maintenance supervisors simply install counters to rack up how many hours the machine has been running for and estimate when it will need to be serviced.



The **cost per day** (\mathcal{L}) of its customers' **downtime**

Thus, the Virtual Engineer turns what was a hugely inefficient system, prone to failure, into a precise science.

Stork Food and Dairy Systems (SFDS), a supplier of industrial equipment used by food and drink producers, can attest to its value. In one instance, a defective gear had not been identified by the standard warning system as the noise it produced was so low in frequency that it couldn't be differentiated from the rest of the machine. But the Virtual Engineer's high speed sampling identified the fault. The cost of replacing the entire gearbox - which would have malfunctioned had the fault not been detected – would have been £15,000. That's expensive enough in itself, but the real saving for SFDS was its reputation - its customers need machines they can rely on or they face downtime worth up to £20,000 per day. If that happens SFDS might lose a customer.

Dr Brown and his team envisage many uses for the technology across a wide array of sectors. One such application could be the monitoring of offshore wind turbines.

As with the supply chain earlier in this report, Dr Graham Oakes says the physicality of manufacturers' products has allowed the industry to lead in using big data for servitisation and predictive maintenance. "It makes many of the issues clearer, such as parts wearing out or products weighing too much," he says. "With less tangible products, the issues are less visible, so the value of associated services is hidden. But intangible products also decay over time - once you've watched a movie once or twice you are no longer interested in it, but the desire to be entertained still remains. So other industries have a lot to learn from manufacturers here."

Oakes says predictive maintenance is just part of a more general paradigm of predictive responses to events. This is something that has been widely adopted across many industries, long preceding the latest technology trends. However, big data vastly increases the efficiency and accuracy of doing so.

Challenges

THE COSTS OF BIG DATA AND THE LACK OF SKILLS ARE COMMON TO ALL INDUSTRY SECTORS. BUT MANUFACTURERS FACE SPECIFIC CHALLENGES AS THEY SEEK TO REALISE ITS FULL POTENTIAL.

COLLABORATION

In a survey of 3,000 executives, managers and analysts conducted by the MIT Sloan Management Review, 'data visualisation' and 'simulations and scenario development' were tipped to become the most important big data tools; more important, in fact, than trends analysis and forecasting.

Professor Neely of the IfM certainly sees visual tracking tools such as GPS-navigation devices, and their ability to superimpose accurate, realtime traffic patterns on top of digital maps, as something of great interest to manufacturers. He offers the example of large scale manufacturing plants or shipbuilding yards, where the ability to quickly and easily stock check the whereabouts of machinery and vehicles is not universally available at present. Similarly, live logs of logistics data, such as the expected arrival times of parts or automatic check in and out of goods, are already being used by some to good effect, but not by others.

New developments along these lines present challenges, mostly in collaboration. In the start-up technology industry, partnerships between different companies to share their insight and proprietary functionality are commonplace. But according to Professor Neely, manufacturers are yet to display similar tendencies and this threatens their adoption of some big data tools and technologies.

"This is one of the main things we are focussing on at the Cambridge Service Alliance," he says. "We call it 'complex services'. Networks of companies are starting to come together in order to combine their capabilities to allow service innovation to happen.

"Manufacturers of construction equipment aren't necessarily experts in GPS systems. Therefore they have to partner with organisations that have complimentary capabilities. Between them they can offer complex services. This certainly raises a new challenge. Often you'll find four companies need to partner in order to deliver data enabled services. Though it is in their best interests to collaborate, each will want to maximise the contract for their own company. This level of collaboration is not a mature business model for manufacturers and it is one that could create tension."

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as a common resource...
By sharing it and
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data that other groups
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Dr Graham Oakes, independent business efficiency expert

EVOLUTION

A change in mindset is needed elsewhere, too. As alluded to already in this report, the physicality of manufacturers' products helps them spot opportunities to fix machines or to rework supply chains. However, Dr Graham Oakes suggests that, conversely, the physical aspect also present problems.

"Only one person or group can handle a physical asset at any one time, so manufacturers are used to dividing up resources," he says. "However, data isn't like that. It is most valuable as a common resource – you can share it without creating the same sort of conflicts that you have with physical assets. And by sharing it, and hence combining it with the data that other groups hold, you increase its overall value."

Some will also need to overcome "a latent fear of data". This isn't a problem for engineers, as they come from a mathematical background. However, the biggest potential gains from big data require business-based management.

"Talking about data takes executives back to maths and statistics and a lot of bad memories from school," says Oakes. "It can be very hard for them to help other groups adopt data driven approaches."

Manufacturers must also avoid beginning data projects simply because they have the data at their disposal; they must clarify the business objective first.

Lora Cecere adds: "Big data for the sake of big data is a dead end. It isn't about the data, it's what you do with it.

"The main issue for manufacturers is sorting out processes. We are limited by our imagination by thinking about problems too narrowly. As well as the potential to solve old problems, there are new opportunities with big data. Think outside the box, rather than being limited by traditional paradigms, but make sure it is aligned with the business."

LEGACY SYSTEMS

Cost is an inevitable challenge in any sector; for manufacturers it can be a huge stumbling block. A single piece of machinery can cost millions, meaning that in challenging economic times infrastructure refresh is not an option. Companies must instead bleed their assets. While this theoretically enhances the case for service-based machine maintenance, fitting the necessary sensors and related monitoring software to legacy infrastructure can be problematic and expensive. The physical components need to be bought and fitted and skilled system integrators are required to piece all of the data flows from various disparate machines and systems into one central data repository. From here you must have the analysis software and present the information in a suitable format to where it is needed.

Manufacturers will therefore need to supplement existing systems with new ones. Interoperability between the two becomes the challenge. Enterprise Resource Planning systems – a staple part of the IT for most mid-to-large manufacturers – will need to be factored into the equation as these often form the central hub of data collation and dissemination.

Xerox's Andy Jones advises that careful consideration must be given to how the solution is acquired and deployed: proprietary built, bought off-the-shelf, or outsourced. "There is an inbuilt gene within technical people and engineers that makes us want to sort problems out ourselves. It's a natural thing when you're creative and you understand what you're dealing with," he says. "However, sometimes you have to rein yourself in and concede that it is more effective to buy it in or send the task elsewhere. Ultimately, the 'make or buy' decision will rest on how important the intellectual property is to the business and the needs of data within the context of the business problem you are trying to understand or solve.

"A lot of our big data is directly connected to our technology.

The data sourcing part, which is integral, is unique to us and therefore we needed our own proprietary systems. However, we do use a whole variety of standard tools for presenting the data and subsequent analysis to the service desk and our clients."

COMPETITION

One of the biggest threats that western manufacturers face in servitisation is one they are now uncomfortably familiar with — the threat that someone else will to do it cheaper. Where only one per cent of Chinese companies offered services six years ago, 20 per cent do so now. "It is a global race," says IfM's Professor Neely. "China and others in developing economies won't be happy to just stick to the low cost stuff. If the UK wants to use services as our point of differentiation then we need to act fast."

Chinese manufacturers that offered services six years ago

Chinese manufacturers that offer services today

Natural affinities

WHILE THESE
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Most manufacturing companies can adapt to big data extremely quickly...
There has been an appetite for data for a long time.
Now affordable solutions are emerging that meet that need

Andy Jones, director of European outsourcing operations, Xerox

vum analyst Tony Baer – a software lifecycle and big data expert – says many manufacturers will be well placed to implement big data systems as they can build on existing capabilities in business intelligence and 'lean' operating models. 'Lean' refers to multiple operational efficiency disciplines. It was developed by the Japanese car maker Toyota, whose 'Toyota Production System' is imitated on a mass scale in factories all over the globe. Many elements are greatly dependent on data monitoring and analytics, including the introduction of robotics and automation, flexible line calibration and 'lights out manufacturing', as well as ERP systems. This means most manufacturers will have some complimentary skills and IT systems for big data.

Andy Jones of Xerox agrees. "Most manufacturing companies can adapt to big data extremely quickly," he asserts. "The solution is appearing for problems they have been looking to solve for years. Technology companies are fairly analytical in the way that they go about their work. A lot of the business process improvement systems like lean and six sigma are about collecting data on how the company is running today, finding the gaps and making improvements for the future. There has been an appetite for data for a long time. Now there are affordable solutions emerging that meet that need."

Finally, as discussed previously in this report, the physicality of manufacturers' products could disadvantage their data distribution, but for supply chain and maintenance it throws up distinct benefits.

TAKING INSPIRATION

Xerox made the decision to apply its services to other manufacturers' equipment as well as its own. This has not been without its logistical issues, including the problems with collaboration described earlier. However, the work of Xerox *et al* could be extremely valuable in providing a roadmap to others.

"Each manufacturer has different degrees to which they make information available," says Andy Jones. "Some manufacturers only allow basic information to be taken from their products, others nothing at all. But the fact that there are almost as many non-Xerox machines as Xerox ones within our service fleet suggests that industrial secrecy is lessening."

Rolls-Royce and Xerox are among the first of the 'old guard' to have taken inspiration from the likes of Google, Amazon and Facebook. The Internet giants have all now monetised the infrastructure they use to perform their primary businesses, in some cases to add significantly to their turnover. Amazon started by selling books and found that it needed to keep huge amounts of compute power in reserve to handle peak traffic. When it began to rent out this spare capacity, Amazon Web Services - and the public cloud as many people know it – was born. When Google built up the world's best algorithms for search and retrieval of information, it packaged its knowledge up as its Google Apps for Business suite and its MapReduce big data tool. What begins as a sideline to utilise your knowledge base or spare capacity can quickly rival your main business focus.

Lora Cecere of Supply Chain Insights notes that there is still much to be learned from high growth start-ups. She says: "Amazon didn't worry about the traditional definition of master data. They look at it as a dissociated format and they keep it for when they need it in a semi-structured format. That kind of thinking is very different to that of an enterprise application where we believe that all data needs to be hardwired in fixed code. It's not about relational forms anymore."



Conclusion

ltimately, big data is heavily reliant on paradigms. We've read within this report that it offers an opportunity to solve new problems. We've also explored how it has the potential to provide new solutions to old problems. In reality, it does both.

Clearly the manufacturing industry has much to teach the wider business world about the use of data for advanced analytics. And indeed, as we have explored, the most forward-thinking are already benefiting from the two-decade head start that manufacturing has over other industries in the data analytics market.

But what has been made abundantly clear from this study is that a lot of the truly innovative and most significant benefits can only be realised through a collaborative approach. Whether it's the car manufacturer and the dealership, the machine end-user and the servicer, the construction equipment maker and GPS specialist, or even simply linking together employees within a huge corporation, data enables mutually profitable partnerships to be built.

If UK manufacturing is to recapture its position as a global leader in

the industry, big data could be one of its greatest tools. The apparent glass ceiling that manufacturers had reached in improving their products and creating efficiencies has been shattered with the new sources of data and our ability to analyse it. Furthermore, the ability to move from simply producing physical goods to introducing services into business models has enabled some companies to flourish, despite radically altered business and economic conditions. Big data has allowed companies to evolve as necessary.

Indeed, at a time when traditional revenue streams are under threat, the trend-setting companies have been able to use advanced analytics to significantly improve one or a number of elements throughout their value chain. This has been illustrated in product design, in operational efficiency, in supply chains, in performance visibility, in corporate social responsibility, environmental sustainability, and in the fundamental way that manufacturers are able to make money.

As we have also seen, big data is not and will never be as valuable to some as it is to others. Indeed, there are those in the manufacturing space that have a vested interest in not implementing it into certain areas of their operations – especially production if they are not in the consumer durables sector. But big data's applications within manufacturing are so varied and farreaching that even these businesses

will be able to find at least some suitable areas of their operations which can be improved by it.

If widespread

adoption of big data takes place, the rewards could be extensive and rich. Xerox is evidence of this in itself but Andy Jones thinks the car industry provides a more succinct and influential example. "If you look at the quality improvements in cars over the last 10 to 20 years it's staggering. We now have unbelievably efficient and complex cars at ridiculously low prices. For as little as £10,000 you can get something that is extremely reliable, intuitive and powerful. Big data should take a large portion of the praise for this.".





Greenplum, a division of EMC, is driving the future of Big Data analytics with breakthrough products that harness the skills of data science teams to help global organizations realize the full promise of business agility and become data-driven, predictive enterprises. The division's products include Greenplum Unified Analytics Platform, Greenplum Data Computing Appliance, Greenplum Analytics Lab, Greenplum Database, Greenplum HD and Greenplum Chorus. They embody the power of open systems, cloud computing, virtualization and social collaboration—enabling global organizations to gain greater insight and value from their data than ever before possible.

Greenplum was acquired by EMC in July 2010, becoming the foundation of EMC's Big Data Division. With technical and business leaders from large-scale computing companies like Amazon and Yahoo!, and database companies including Oracle, Informix, Teradata, Netezza, Microsoft and Vertica, Greenplum is tapping the best minds in the business of big data to deliver the next-generation of data warehousing and analytics. www.emc.com.



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