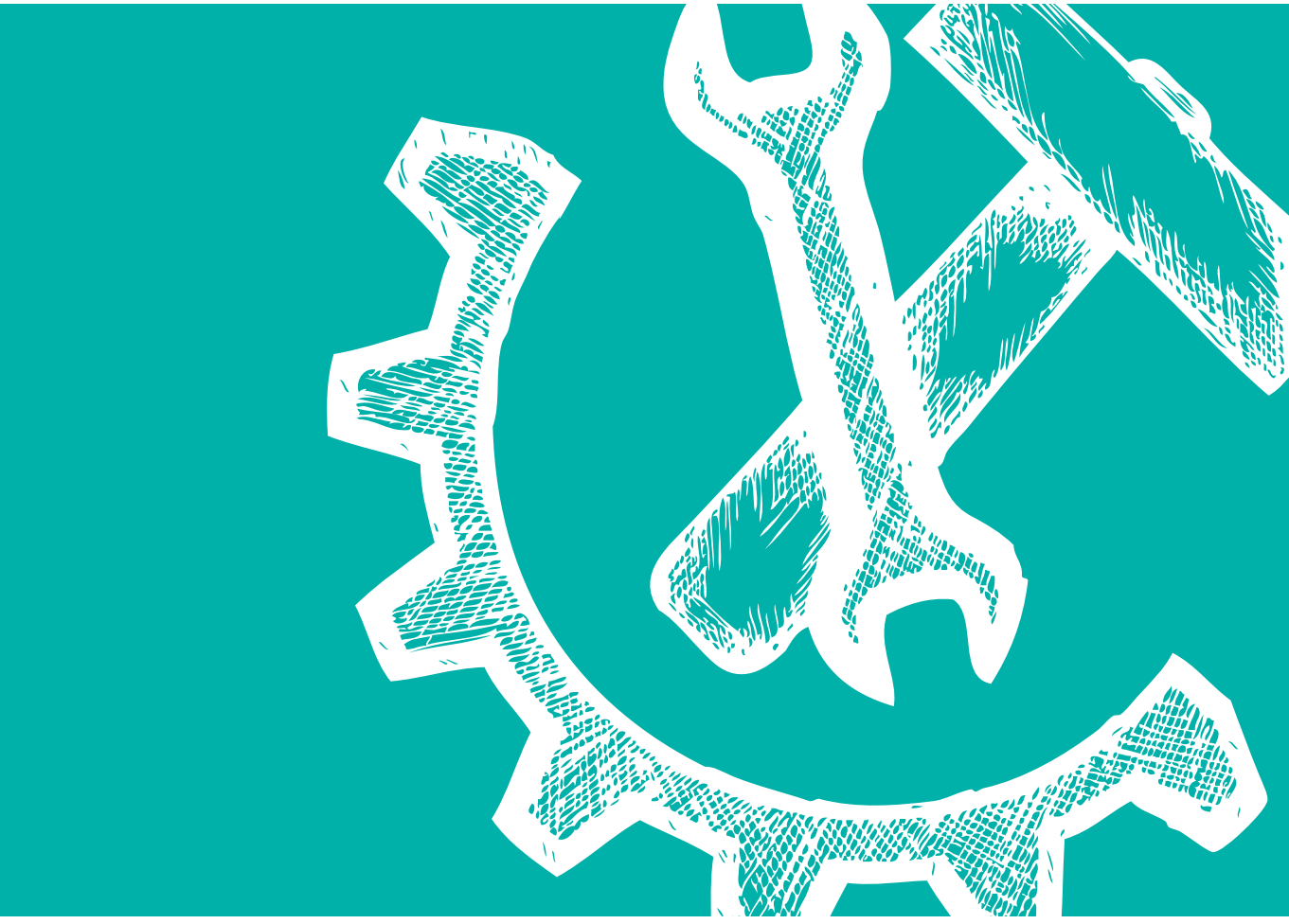
THINK ACT

BEYOND MAINSTREAM



PREDICTIVE MAINTENANCE

Is the timing right for predictive maintenance in the manufacturing sector?

NOVEMBER 2014

Roland Berger
Strategy Consultants

THE BIG 3

1 USD 9/hp p.a.

The average maintenance cost for plants operating a predictive maintenance program on their pumps – comparatively the average reactive maintenance cost is 18 USD/hp p.a and the average preventative cost is 13 USD/hp p.a.
p. 5

2 75%

The average number of breakdowns eliminated by energy companies that have implemented predictive maintenance programs
p. 6

3 15%

The average amount of maintenance time currently spent on predictive maintenance activities in the manufacturing sector. Manufacturers would like to spend 33% of their time on predictive maintenance, and reduce the time spent on reactive and preventative maintenance
p. 11

 # Case studies p. 6-7

Manufacturers' attitudes towards maintenance are changing. Maintenance is increasingly seen as a strategic business function as opposed to a necessary evil.

Manufacturers are increasingly seeing maintenance as a strategic business function as they seek to reduce both maintenance costs and downtime, and increase asset lifecycles. Gone are the days where maintenance was seen as a "necessary evil"; manufacturers now have more alternatives than ever to employ a costly "run until it breaks" reactive maintenance strategy, or an inefficient "fix it regardless" preventative maintenance approach.

Together with Castrol, Roland Berger has been exploring the use of predictive maintenance technologies by manufacturers in order to co-write this thoughtpiece. Our findings reveal that there are now emerging predictive maintenance solutions available that allow manufacturers to streamline maintenance operations by using asset condition data to predict impending failures and therefore schedule maintenance only when it is needed. Best-in-class manufacturing companies that have adopted these solutions to predict when equipment fail may have seen a reduction of unscheduled downtime to c. 5% lower than the industry average and an increase in overall equipment effectiveness (OEE) of more than 8%[1)].

Predictive technologies are evolving, and we are exploring this evolution and the benefits predictive maintenance could bring to today's manufacturers. As part of this we have looked at the practical barriers and challenges that need to be overcome to increase adoption in the manufacturing sector.

What are manufacturers using today to monitor their assets?

Today's manufacturing facilities commonly make use of condition monitoring solutions for their critical assets. Condition monitoring solutions work by monitoring either one or several parameters of asset condition, such as vibration, used oil, thermograph or ultrasound. They use these readings to identify potential problems of which parameter readings are known to be indicative. Vibration analysis, for example, can be used to detect several common mechanical faults such as shaft misalignment, component wear or loose bearings.

However, because many condition monitoring solutions typically focus on only one or two discrete data types, their ability to detect a comprehensive range of potential faults is limited. Furthermore, condition monitoring systems are often neither able to offer diagnosis of the identified issue, nor insight into how urgent the impending problem may be. Instead, the systems merely flag the fact that data readings have gone outside of the specified normal range.

1) Aberdeen Group, November 2012

In manufacturing facilities, an alert to a potential mechnical problem in a critical piece of machinery is not particularly helpful if engineers are not alerted to the severity or cause of the problem. Far more helpful is functionality that points engineers towards both the root cause of that issue and the timeframe in which it is likely to develop. For example, for a grinding machine failure, by specifying that a bearing in the spindle motor has worn and there is a 90% probability of machine failure if it not replaced with a week. This is precisely where predictive maintenance software solutions have the potential to add value.

How do more advanced predictive solutions differ?

In recent years advanced predictive, diagnostic software solutions have been developed and widely adopted in industries such as oil & gas, wind, power generation and aerospace. The latest predictive maintenance software brings multiple benefits over traditional condition monitoring based approaches. Advanced predictive solutions take data inputs from multiple sources and use analytic modelling techniques to make predictions. This enables them to flag issues earlier than those solutions employing simpler techniques, as well as offering diagnostic insight, prioritise issues by severity and suggest actionable measures that can be taken to prevent impending failures. For maintenance teams this makes the job of detecting potential fault and attending to the root cause of an issue before the problem escalates to a full-blown failure far more manageable.

How does predictive maintenance software work?

Predictive maintenance solutions work by employing one, or more, of three broad modelling approaches: empirical, physics-based, or experience-based. All of these approaches build a model of "normality" (i.e. expected output) of how, for each of the data inputs, an asset should behave under certain conditions, and then detect deviations from these "norms". Any deviations from the norm are indicative of deteriorating asset condition.

Solutions vary in how this model of normality is built. Solutions that take the empirical approach use historical data from the asset in question to build the model, whilst experience-based solutions build the model from aggregated group data that has been collected from multiple, similar assets. Physics-based solutions take an entirely different approach and build the model by applying knowledge of the first principles of engineering to understand how an asset ought to theoretically perform under given operating conditions. Each of these approaches has different advantages and disadvantages, so the most advanced solutions employ a combination of these approaches. Common to all advanced predictive maintenance solutions however is the ability to offer early prediction, high diagnostic accuracy, and consequently a high level of value-add to the customer.

What benefits have predictive maintenance technologies brought to other industries?

Advanced predictive maintenance software solutions have already been effectively employed in a wide range of industries including oil and gas, power generation, and aerospace. Across these industries they have brought measurable customer benefits on a wide range of metrics, from return on investment to increased production revenue. A common thread across these industries is that they employ large rotating assets, which are less complex and more homogeneous than the mix of assets found in manufacturing environments.

MAINTENANCE COST IN POWER GENERATION[1)]

REACTIVE	18 USD/hp p.a.
PREVENTATIVE	13 USD/hp p.a.
1 PREDICTIVE	9 USD/hp p.a.
RCM	6 USD/hp p.a.

Predictive maintenance has been shown to be significantly more cost effective in the power generation industry than reactive or time-based preventative maintenance. It is particularly effective as part of a hybrid 'Reliability Centred Maintenance' program, whereby an optimal mix of all three maintenance approaches is applied to assets based on the degree of asset criticality – predictive is applied to the most critical and reactive the least – for maximum cost efficiency.

1) US Department of Energy's O&M Best Practise Guide, 2010 - cost of maintenance plans for pumps

Failure of critical assets was rated as the most significant risk to operational performance in a recent survey. 40% of executives named it as having the greatest impact on operations.

Case study

Oil and gas – Reducing breakdowns and increasing production of highly critical assets

The high cost, criticality, and inaccessibility of assets in the oil and gas industry makes them ideally suited to adoption of predictive maintenance software. If unexpected failures occur, the financial, environmental and safety concerns can be catastrophic. Maintaining assets efficiently, whilst ensuring reliable and safe production, is therefore essential. Consequently, the oil and gas industry has been one of the first to deploy predictive maintenance software with measurable results.

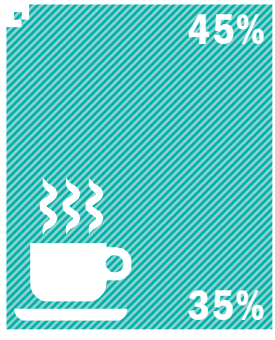
Based on findings from the US Department of Energy[2)], the implementation of a functional predictive maintenance programs in the oil and gas industry has been shown, on average, to have measurable customer benefits, which include:

- Return on investment 10 times
- Reduction in maintenance costs 25% to 30%
- Elimination of breakdowns 70% to 75%
- Reduction in downtime 35% to 45%
- Increase in production 20% to 25%

These findings reveal the extent to which predictive maintenance technology has had a positive impact on adopters in the oil and gas industry.

2) US Department of Energy's O&M Best Practise Guide, 2010

Elimination of breakdowns



Reduction in downtime

Reduction in maintenance costs

Increase in production

Predictive maintenance has provided tangible benefits to wind farm owners, which include reduced operation and maintenance costs and increased production revenues resulting in ROIs in as little as 6 months.

Case study

Wind Power – Reducing maintenance costs and improving uptime in a challenging operational environment

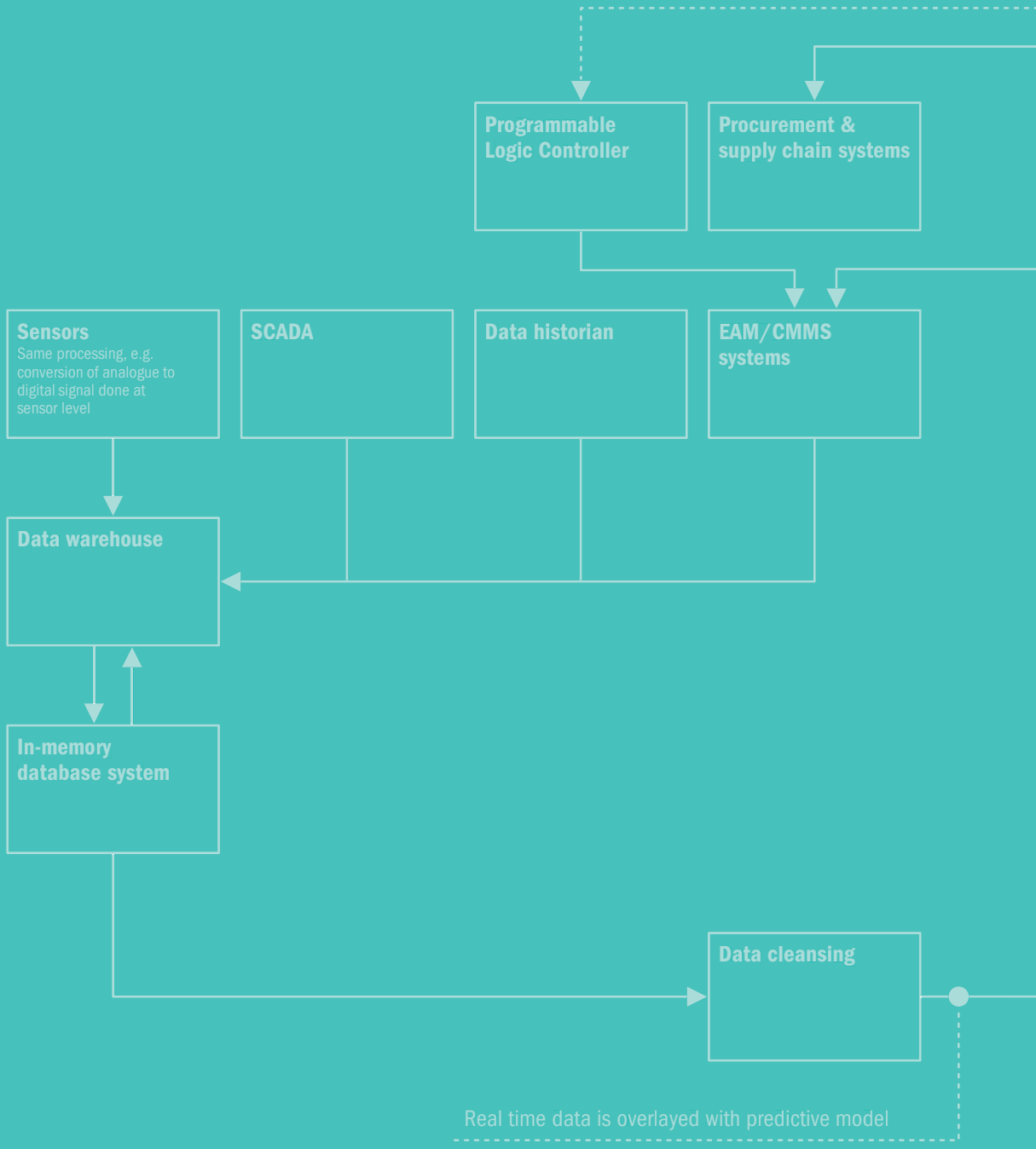
Predictive maintenance has recently been shown to be effective in the monitoring of wind turbines. The remote location and inaccessibility of wind turbines, combined with the challenging environmental conditions in which they operate, leads to high operation and maintenance costs – these are estimated to reach over twenty percent of total production costs in the next few years.

Driven in many instances by he end of turbine's OEM warranty period predictive maintenance technology has been reported by wind operators to have helped both reduce operation and maintenance costs and increase production revenues. In some cases this has produced an ROI within six months.

One global wind operator found that for a medium sized wind farm they were able to save around a quarter of a million dollars in operation and maintenance costs through adopting a predictive software system.

Another operator revealed that whilst using predictive maintenance software to track asset health, they noticed that one of their turbines was significantly under performing in terms of power generation. They were able to identity that this was because an un-intentional limit had been imposed on the turbine. In resolving this, they were able to capture additional revenue they would not have received without installing their predictive maintenance solution.

Again, these examples from wind operators provide insight into some of the tangible benefits realised by implementing predictive maintenance software in sectors with complex mechanical systems.


Programmable Logic Controller
Procurement & supply chain systems
Sensors
Same processing, e.g. conversion of analogue to digital signal done at sensor level
SCADA
Data historian
EAM/CMMS systems
Data warehouse
In-memory database system
Data cleansing
Real time data is overlayed with predictive model

Future: Intelligent intervention – recommendations generated alter operating controls

Automatic notification sent to supply chain systems (e.g POs for spare parts raised)

Alerts generated to maintenance schedule systems

Anomaly detection

Diagnostic analysis

Predictive model
including "fingerprints"
(records of maintenance)

Algorithmic modelling and/or machine learning

Damage propagation models (First principles)

Recommendation & decision support
Describes action needed to be taken

Diagnostic prioritisation
Categorises fault by level of severity

Evaluated impact
e.g. remaining useful life & other operating metrics

What makes advanced predictive maintenance technologies interesting for the manufacturing sector?

Manufacturing shares many characteristics with the industries featured in the above case studies; it is capital intensive, there is significant pressure to reduce both downtime and cost, and production stoppages can be catastrophic. The manufacturing sector also faces additional pressures from a pronounced shortage of skilled personnel - existing experienced workers are beginning to enter retirement whilst new recruits are in decline - and the increasing need to continue to improve returns from existing assets rather than replace them as they start to deteriorate.

As a result, many of the benefits experienced in other industries from the adoption of predictive maintenance software technologies are equally attractive to manufacturers. These include:

> Elimination of unnecessary maintenance tasks
> Reduction in component replacement costs
> Reductions in unplanned downtime
> Extension of asset lifecycles

Combined, these benefits can increase a manufacturing facility's overall productivity and profitability, making predictive maintenance solutions attractive to both management and maintenance teams alike.

What are the challenges to widespread adoption of predictive maintenance solutions in manufacturing?

As we have seen, manufacturers stand to gain from the implementation of predictive maintenance software solutions adapted for the manufacturing environment. However, as yet the adoption of advanced predictive maintenance software has largely evaded the manufacturing industry. We believe there are currently some barriers to be overcome in order for widespread predictive maintenance software adoption to become possible. These are unique to the manufacturing sector and fall under two main headings:

> Difficulties in developing functional solutions applicable to manufacturing
> Readiness of the manufacturing sector

DIFFICULTIES IN DEVELOPING FUNCTIONAL PREDICTIVE MAINTENANCE SOLUTIONS APPLICABLE TO MANUFACTURING

There are a number of technical challenges which make providing a comprehensive predictive solution to the manufacturing industry a challenge for providers:

ABILITY TO SUPPORT A MIX OF LARGE-SCALE, HETEROGENEOUS ASSETS

Unlike industries where predictive maintenance software is commonplace, most manufacturing companies employ a wide and complex range of equipment. Compared to, for example, wind power generation, where criticality is focused predominantly on three main component sets of the turbine, a typical manufacturing plant employs multiple types of equipment which are regarded as critical for production. As a result successful predictive solutions must be applicable to a broad, complex and heterogeneous set of assets; this is technically challenging for existing solution providers.

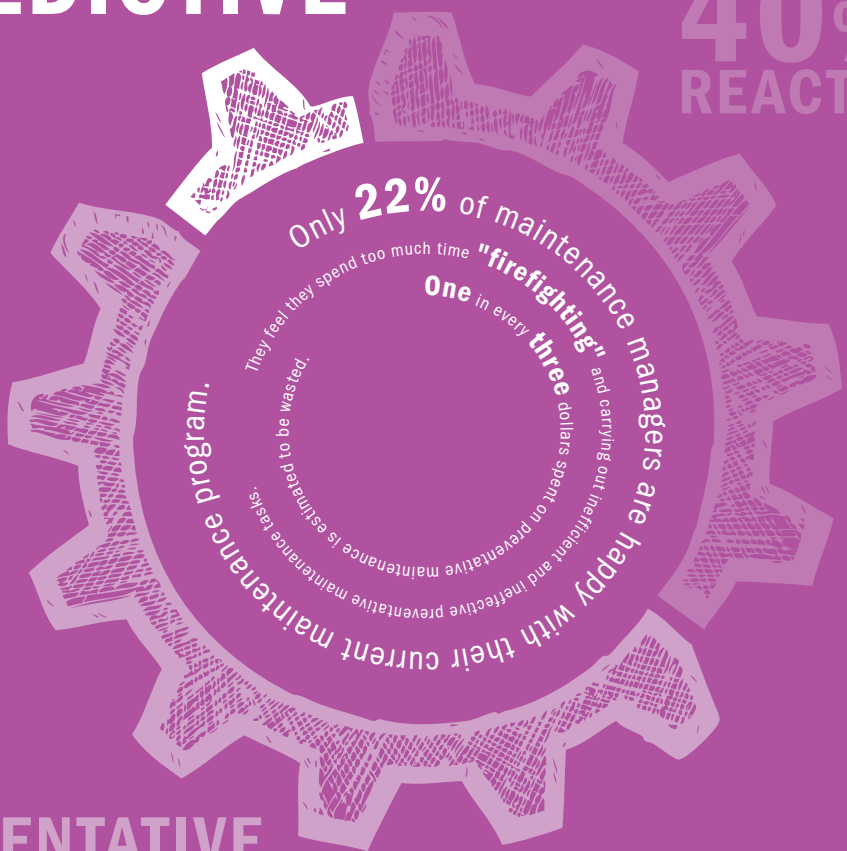
ABILITY TO FUNCTION UNDER DYNAMIC OPERATING CONDITIONS

Similarly, whilst other industries may have a narrower asset range and less variable tendencies in terms of operating conditions, manufacturing assets typically function in highly dynamic conditions. This is due to the higher levels of human interaction, the range of materials processed, the multiple operations performed by a single asset and the changing end products produced. This variability in operating conditions poses additional complexity for predictive maintenance software providers and existing providers are yet to fully resolve this issue.

AVERAGE TIME SPENT ON MAINTENANCE ACTIVITIES

*[3] **15%**
PREDICTIVE

40%
REACTIVE



PREVENTATIVE
45%

INTEROPERABILITY WITH A WIDE RANGE OF OEM MACHINERY

Furthermore, potential predictive solutions for manufacturing need to be applicable to, and interoperable with, machinery from a wide range of manufacturers. This again poses a technical challenge since the method measuring the internal machine state can vary by machine manufacturer.

READINESS OF THE MANUFACTURING SECTOR

We believe there are a number of **key enablers**, or factors, which would need to be in place in order for adoption rates of predictive maintenance software in manufacturing to increase significantly and we believe some of these are yet to be fulfilled.

ASSET DATA AVAILABILITY

In manufacturing today the data that is commonly used in condition monitoring to track asset health is increasingly available, as many 'smart machines' now come with built-in sensors and data capture functionality. When considering the possibility of retrofitting this in older machines the cost and the burden rate of fitting it must be balanced against the criticality of the machine in question.

Additionally new standards of data collection, such as MT Connect, and increased instrumentation in critical assets should make the challenge of obtaining the requisite data for predictive solutions less of an issue going forward.

TIME CRITICALITY OF FAILURES

In manufacturing plants equipment failure can mean significant losses of productivity. As part of our research we spoke to a former maintenance engineer at a leading automotive manufacturer who recounted the seriousness with which any incident involving a machine failure that was not resolved within three minutes and which subsequently lead to a production stoppage, was regarded.

TRUST IN PDM TECHNOLOGY

Discussions with manufacturing maintenance engineers reveals a high degree of scepticism regarding the capability of predictive maintenance technology in comparison to traditional maintenance methods. In the majority of manufacturing facilities there is still a high reliance on maintenance personnel. These personnel often do not believe that technologies are able to identify machine failures as accurately or reliably as they can, and are dis-incen-

"In my role as a maintenance engineer if a failure such as a blown motor wasn't fixed within three minutes it was considered a major incident because of the implications of the lost production time."

MAINTENANCE ENGINEER, TOYOTA

tivised to encourage the adoption of new technology due to concerns regarding their job security. As a result, cultural acceptance of new maintenance technologies is low in most manufacturing plants.

We believe this is one of the key factors which explains why the manufacturing sector is not at the same level of maturity in terms of its general understanding and its trust of predictive techniques as many other analogous industries.

OPENNESS TO LONG TERM INVESTMENTS

The cost pressures in the manufacturing sector and resulting impact on maintenance budgets are well known. Given these budgetary pressures, there is often little appetite amongst manufacturers to make investments in implementing new software programmes.

We see this cautious attitude to long term investments and projects as another key enabler of the widespread adopion of predictive maintenance solutions that is as yet unfulfilled.

"The largest challenge by far has been cultural inertia in what has traditionally been a highly reactive approach."

MANUFACTURING MANAGER,
GLOBAL RELIABILITY ENGINEERING

Conclusion

Faced with mounting pressures caused by the shortage of skilled workers, budget cuts and ageing assets, predictive maintenance software represents a powerful tool to aid manufacturers in easing their maintenance burdens, by reducing costs and improving the productivity of their production processes.

With a wealth of case studies and proof points available in many other analogous industries, there are positive indications that attractive potential benefits await the manufacturing sector should it embrace the latest trend in maintenance strategy.

In our view it is only a matter of time before an accessible predictive maintenance solution is developed for the manufacturing sector which would allow manufacturers to finally have the trust and confidence to harness the power of emerging predictive technologies.

ABOUT CASTROL

Castrol

Castrol is one of the world's leading manufacturers and marketers of premium lubricating oils, greases, metal working fluids, control fluids and related services to automotive, manufacturing, mining, marine, and oil exploration and production customers across the world. Castrol couples high quality lubricant engineering with an expert technical support network and supply capability to deliver quality solutions wherever customers need them. Castrol employs over 7,500 people, it operates directly in more than 80 countries, and is represented by over 2,000 third party distributors. Part of the BP group, the company is headquartered in the UK. At the forefront of pioneering technology with its 13 R&D centres globally, Castrol invests every year in research and development of lubricants. Castrol's global teams of specialists have a deep understanding of what customers need and advise on solutions designed to optimize performance and help improve quality, productivity and the environmental, health and safety profiles of their customers. The brand represents over 100 years' experience in 'liquid engineering': producing advanced lubricants for a wide range of applications, from manufacturing processes and metalworking to mining, shipping and marine activities and energy production. Castrol's products and services play a critical role in lubricating the global economy through what is mined, made and moved around the world.

Castrol innoVentures

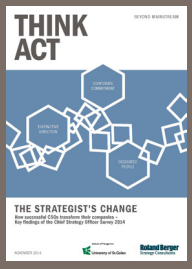
Castrol innoVentures is based in the UK with a global remit. It seeks out and invests in new business opportunities to support Castrol's core lubricants business and to develop options beyond lubricants. The Castrol innoVentures group is focused on investing in and building businesses that significantly improve customer growth and competitiveness in manufacturing, among other sectors. The group makes strategic investments in technology start-ups that help its customers improve operations.

ABOUT US

Roland Berger Strategy Consultants

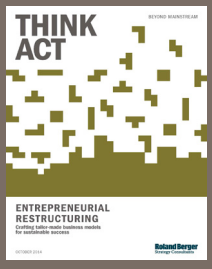
Roland Berger Strategy Consultants, founded in 1967, is a leading global consultancy. With 2,400 employees working from 36 countries, we have successful operations in all major international markets. Our 50 offices are located in the key global business hubs. The consultancy is an independent partnership owned exclusively by 220 Partners. **WWW.ROLANDBERGER.COM**

Further reading



THE STRATEGIST'S CHANGE

In a world of permanent change where geopolitical factors strongly impact the economic context, companies need to be in a position to review and adapt their strategy and business model. For two thirds of firms, transformation is therefore the normal state of affairs as they endeavor to do business successfully; 90 percent of companies have an in-house strategy department these days.



ENTREPRENEURIAL RESTRUCTURING

To do a good job of restructuring a company these days, you need to look at more than just costs and the headcount. Successful restructuring means quickly coming up with a new business model that is convincing and sustainable. Roland Berger Strategy Consultants approaches the task from a strictly entrepreneurial perspective. On behalf of our clients, we moderate what are often conflicting demands. We also manage the transformation process as though we were handling our own business. Responsible, energetic and rigorous decision-making is at the heart of this "entrepreneurial restructuring" approach.

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Publisher

ROLAND BERGER
STRATEGY CONSULTANTS
55 Baker Street
London W1U 8EW
United Kingdom
+44 20 3075 1100
www.rolandberger.com

The authors welcome your questions, comments and suggestions

ROBERT THOMSON
Partner
+44 20 3075 1100
robert.thomson@rolandberger.com

MADELAINE EDWARDS
Senior Consultant
+44 20 3075 1100
madelaine.edwards@rolandberger.com

EMMA BRITTON
Consultant
+44 20 3075 1100
emma.britton@rolandberger.com

BRYAN RABENAU
Castrol innoVentures Territory Leader
+44 7798 655 127
bryan.rabenau@bp.com