JANUARY/2021

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Packaging and Predictive Maintenance

An in-depth assessment from PMMI

PMMI Business Intelligence

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PMMI is the leading global resource for the packaging and processing industry, and represents over 900 North American companies involved across all levels of the value chain. The membership includes many local subsidiaries of European and Asian corporations.

We see our core purpose as being to unite the industry across the manufacturing supply chain; connecting people, knowledge, and ideas to help our members succeed in a rapidly changing global marketplace. We know that our members can only achieve business growth, and keep up with rapidly evolving consumer demands, by developing innovative manufacturing solutions.

That's why we've recently teamed up with global market intelligence company Interact Analysis to research and author this work. Interact Analysis is a leading authority on industrial markets, and produces a variety of market reports on subjects ranging from predictive maintenance to mobile robots. We think the resultant work is the most in-depth assessment available of what predictive maintenance means for the packaging and processing industries.

We hope you enjoy the read.

Who is Interact Analysis?

Interact Analysis is an international provider of market research for the entire automation value chain from product manufacturing in automated factories, through to product storage in automated warehouses, and finally through distribution via fleets of increasingly electrified and automated commercial vehicles.

Our team of experienced industry analysts is spread across offices in the US, China and the UK. And our client base includes companies such as Siemens, Rockwell Automation and Geek+. During our research, we conduct extensive primary analysis, and we are confident that our information is the most up-to-date and accurate on the market.

To learn more, contact us at info@interactanalysis.com

PMMI Business Intelligence | INTERACT ANALYSIS

Publication Date: January 2021

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ABOUT THIS REPORT

PMMI – The Association for Packaging and Processing Technologies – has conducted a major piece of research into predictive maintenance as it relates to the packaging and processing industries. The purpose of this work is to show how predictive maintenance can be applied to the unique needs of packaging and processing machinery; as well as to educate our colleagues across the industry on how predictive maintenance really works, what it really means, and what it can do for their businesses.

Predictive Maintenance: Why Now?

The term predictive maintenance has been widely used in recent years although there is no agreed industry-wide definition. The result is that some people may have dismissed the concept as a buzzword, thereby missing out on an emerging technology that has the potential to be disruptive. That is why we wanted to use this first section to sketch out what predictive maintenance really is.

Predictive maintenance, our definition: The basic idea behind predictive maintenance is to monitor a machine, or a component on a machine, to determine when it is likely to fail and to take action to stop it, thus avoiding unplanned downtime.

Many veteran engineers may feel that they've been doing such monitoring and maintenance for a long time. Certainly, it is true that the idea of predictive maintenance has a considerable legacy.

For example, consider portable monitoring devices. These handheld devices are designed to read the health of industrial assets – monitoring such outputs as vibration or electrical data – and are widely used across industry. The market for this hardware alone was worth $120m in 2019, with significant growth still forecast for the future. While portable monitoring devices do not provide true predictive maintenance capability, they have been a precursor for this by providing a method for measuring the status of key assets in the field, and will thrive going forward in a supporting role alongside emerging predictive maintenance technologies.

The reason predictive maintenance is being talked about so much at the moment is because it is the lowest hanging fruit that can be harvested from another much-talked about concept in industry – digitalization. Sometimes also referred to as Industry 4.0, digitalization is quite nebulous as its scope is so broad, and it can be challenging to justify from an investment perspective. This is not the case for predictive maintenance. Plant downtimes can incur millions of dollars of lost output, so justifying investments in new technology that demonstrably reduces this represents an easy sell.

Currently, we see implementation of predictive maintenance technologies playing out in two different parts of the plant – both are important, and these trends will merge over time. Developments in predictive maintenance functionality for plant-level software have been taking place the longest. All the major digitalization platforms will offer the ability to perform advanced analytics on data being already collected by existing automation infrastructure; and there are numerous start-ups developing new platforms too. Most commonly we see this taking place in process or hybrid process industries where a DCS is used and a historian is in place.

The second area of implementation is the most important one – on the factory floor. The problem here is that while many assets are connected to historians, many more are not. Also, the measurements being collected by existing plant infrastructure are not necessarily the ones needed to be most effective at performing predictive maintenance. So, you might have the best analytics platform in the world, but if your critical assets are not being tracked properly, what use is it? This is why the emergence of "smart sensors" is disrupting the market. These are typically small MEMS-based devices with integrated wireless communications and microprocessors, designed to be placed on existing infrastructure creating new points of asset measurement. They have emerged in the last 3-4 years largely as a result of MEMS technology dropping substantially in cost thanks to its broad uptake in consumer applications. What was cost prohibitive before is no longer so, and assets can be retrofitted and monitored in a way never previously possible.

Predictive Maintenance: What You are Manufacturing **Matters**

While we haven't researched predictive maintenance in all other industry verticals outside packaging, we feel confident in saying that adoption in the packaging industry is very high.

Why look at predictive maintenance within packaging?

Our bespoke research across the packaging and processing sector showed something very interesting. It showed us that, among consumer packaged goods companies (or end users), of all possible digitalization initiatives we could define (from big data analytics, to cobots, to digital twins) – predictive maintenance is far and away the most likely to be of potential interest to consumer packaged goods companies. In fact, we found that 29.4% of the packaging and processing industry are evaluating the technology; 21.6% are piloting it; and 23.5% *have already implemented it*[1] . Of all possible up-and-coming digitization initiatives, the next largest was collaborative robots – in use by 14% of end users.

Predictive maintenance is far and away the most likely to be of potential interest to consumer packaged goods companies

29.4% **are evaluating it**

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23.5% **have already implemented it**

Of all possible up-and-coming digitization initiatives, the next largest was collaborative robots – in use by

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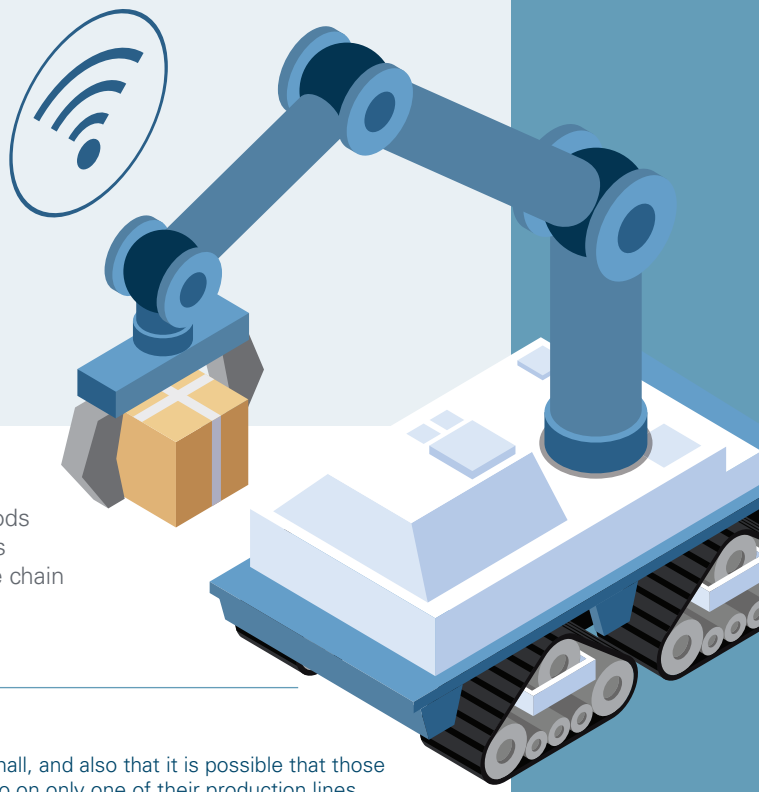


Clearly then, when nearly a quarter of consumer-packaged goods companies say they have adopted predictive maintenance, it is something that the rest of the packaging and processing value chain needs to take seriously and understand.

[1] We caveat this by pointing out that the sample size was relatively small, and also that it is possible that those who have currently implemented predictive maintenance have done so on only one of their production lines, and may only be using historical data that they already possessed from their existing plant automation software – thus still leaving a lot of room for new assets to be connected via sensors. We also believe that there was some confusion amongst survey respondents regarding the term's preventative and predictive maintenance – in particular, a tendency to use the terms interchangeably, as though they were the same thing

Some of the reasons for this are immediately clear. For example, many fast-moving consumer goods (FMCG) companies are heavy users of packaging and processing machinery. These are high velocity industries – margins are low, and volumes are high, meaning downtime can be financially catastrophic. For this reason, we think that FMCG companies in particular will embrace predictive maintenance massively. We also expect predictive maintenance to be adopted more heavily in any factories that manufacture in batch, such as many food & beverage production operations. The reason for this is that equipment failures in batch manufacturing can result in an entire batch loss.

Understanding the Packaging Industry and the Machinery That Drives It

Within the packaging industry we see three distinct types of packaging: primary, secondary, and tertiary. Primary packaging is the packaging that is immediately responsible for protecting the product – for example, a chocolate bar wrapper. Secondary packaging is the packaging used for branding and display – for example, the outer wrapper in a multipack of chocolate bars. Meanwhile, tertiary packaging is the packaging used to hold together multiple products in storage or transit – for example, a box holding 100 multipacks of chocolate bars while in transit to the retailer.

Primary Packaging

Secondary Packaging

Tertiary Packaging

Each of these packaging types has very different requirements. An obvious example of this is the much greater hygiene needed in the primary packaging process compared to the tertiary packaging process. For this reason, these distinct packaging types require distinct types of packaging machines – and OEMs will often tend to specialize in one specific machine type. Broadly speaking, it is machines operating at the primary packaging level that tend to be the most complex, and to have the most demanding requirements made of them by end users – and so it is here that we see the most complicated predictive maintenance solutions being applied. Additionally, unlike with secondary and tertiary packaging, primary packaging can never be done manually if the line does go down – meaning that downtime in primary packaging lines almost always results in heavy financial losses.

PART ONE:
The Packaging Difference

Packaging and processing machinery has many unique characteristics. An important part of our research was isolating and defining these unique characteristics, and relating them to the possibilities for predictive maintenance.

Packaging is Largely About Motion Control

Those who know a little on the topic of predictive maintenance, will probably be aware of some of the more well-known predictive maintenance offerings, such as ABB Ability or Nidec's FORECYTE. Other well-known companies offering predictive maintenance are Siemens, WEG and PetaSense. Most of the solutions currently on the market are designed to monitor critical assets such as AC induction motors, pumps, and gearboxes; and they tend to be based on vibration sensor solutions.

So, it is important to be aware that, while of course packaging machines do employ standard AC motors, their critical functions tend to be under servo control – which does not lend itself to vibration monitoring. Unfortunately, packaging OEMs will find that they cannot usefully apply current industry standard predictive maintenance solutions to servo axis – as none today exist. Therefore, at this time, something more bespoke is tending to be adopted. For example, OEMs we spoke to during this research were using thermal imaging to gather health data on servo systems. We expect this to be a temporary workaround as we anticipate servo motion companies will catch-on to this opportunity and build this capability directly into the servo drive.

Packaging Machinery is Prone to Downtime

The possibility of machinery failures shutting down production lines ranks pretty high on most manufacturing managers' list of worries. Those operating packaging machinery should be particularly mindful of this possibility, because our research shows that manufacturing managers at consumer packaged goods companies consider their packaging machines to be much more prone to downtime than the other types of machines they use. In fact, when asked,

69.3%
of users

told us that their packaging machines were either extremely, moderately, or slightly more likely to experience downtime when compared to other types of machinery. (see Fig. 1).

Even discounting the sizable "slightly likely" chunk, this means that 38.7% of manufacturing professionals at consumer packaged goods companies feel their packaging machines are extremely or moderately likely to experience downtime compared to other types of machines.

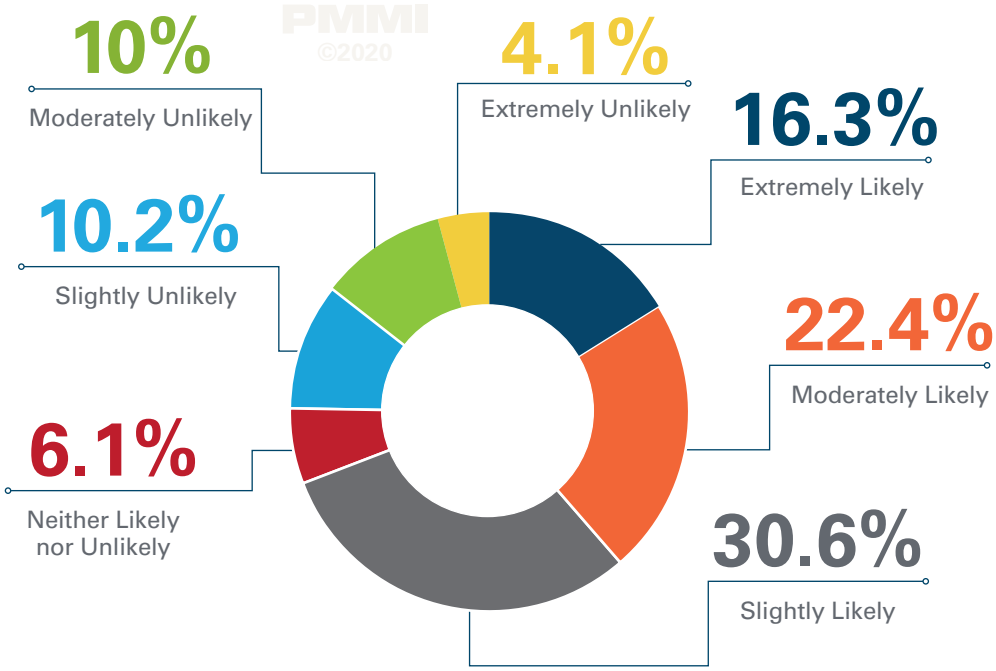


Fig. 1 – how prone consumer packaged goods companies feel that their packaging machinery is to downtime, compared to other types of machinery

Which Types of Packaging Machines Tend to Fail?

It will be no surprise to packaging professionals to learn that some types of packaging machinery are more prone to downtime than others. When we asked consumer packaged goods companies which types of packaging machines were most likely to fail, we got some interesting results. We split machines likely to suffer downtime into three categories: "extremely likely", "moderately likely" and "slightly likely". In the "extremely likely" category, **form, fill & seal** machines are in the lead – with 14.3% of manufacturing managers at consumer packaged goods companies rating them as extremely likely to suffer downtime. Next down the list in the "extremely likely" to fail category are **labelling**, **decorating, and coding** machines – which were placed in this category by 13.3% of respondents. Interestingly though, when the three categories of likely to fail (extremely, moderately, and slightly) are aggregated, labelling, decorating, and coding machines comes out in the lead as the least reliable type of machine; while **form, fill & sea**l machines only make it into third place (see Fig. 2).

Packaging Machine Types Extremely Likely to Suffer Downtime

Form, Fill & Seal **14.3%**

Labelling, Decorating and Coding **13.3%**

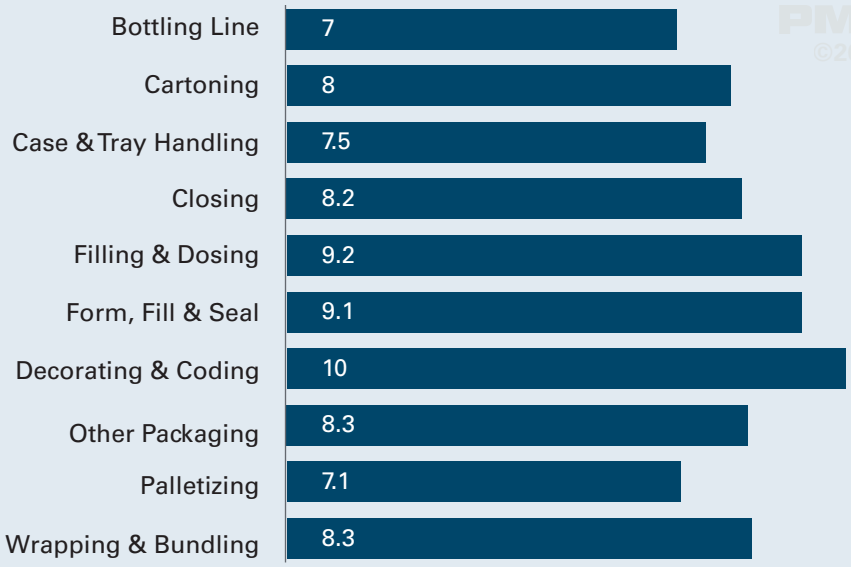


Fig.2 – aggregated results using a weighted index to show which types of packaging machinery are most likely to fail

Which Factors Lead to Downtime in Packaging Machines?

When we looked at the factors that lead to downtime, we found seven causes that were perceived by respondents at consumer packaged goods companies as the most common cause of packaging machine downtime. Within these seven leading types of downtime, three were clearly ahead: general wear and tear (26.3%), operator error (21.1%), and product changeover (22.1%) (see Fig. 3). Of these three, the only one that clearly could not be addressed by predictive maintenance is operator error.

Product changeover was also an issue that came up during our research interviews, and it refers to machines that are used to package multiple types of items. When switching between different items, a changeover of machine parts can be required. Whether this part changeover is manual or automated, it is this that causes the problems.

Most Common Cause of Downtime Survey Results (CPG)

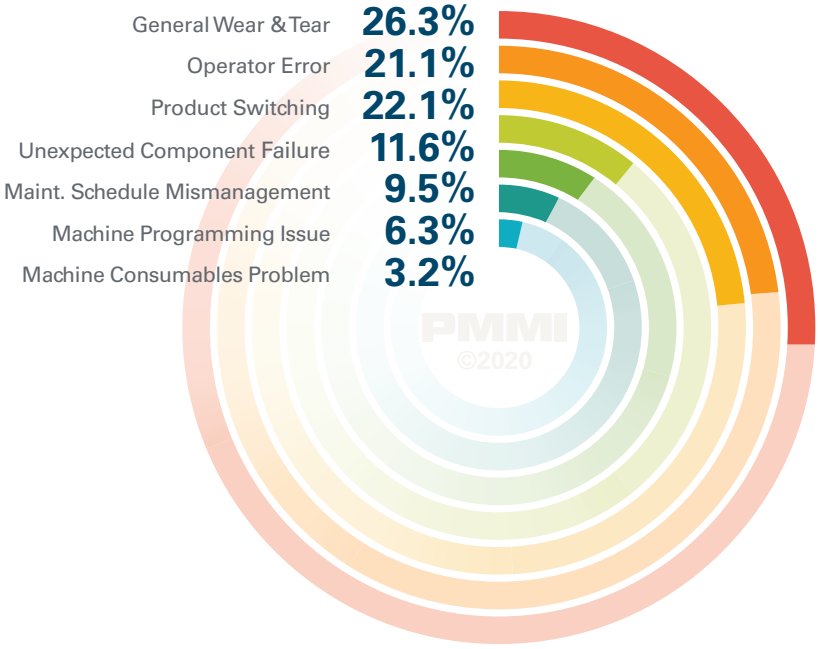


Fig. 3 – most common causes of packaging machine downtime according to consumer packaged goods companies

Our conclusion is that there is a clear and definite need for OEMs to work with predictive maintenance specialists to design bespoke predictive maintenance solutions that can monitor the product changeover process.

Downtime in Packaging Machinery is on a Downward Trend!

Despite finding that packaging machinery as a sector is more prone to downtime than other types of machinery; we were also pleased to discover that overall, the vast majority of consumer packaged goods companies – 71.4% – report that downtime which affects production is decreasing. Another 20.4% report that downtime hasn't changed in the previous three years; while only 8.2% have seen increased downtime. What this tells us is that there is a sustained effort in the consumer packaged goods industry to reduce downtime, but that still the industry is not satisfied with where it has got to. Therefore, any packaging machinery OEM who can show that their machines are less prone to downtime than the competition, is producing excellent added value for their brand.

71.4%

Consumer Packaged Goods Companies

report that downtime which affects production is decreasing

Washdown is a Notable Packaging Industry Need – and It can Cause Problems

The food & beverage sector has a strong need for packaging machinery, as well as for machines that can operate in washdown areas. Where packaging machines are implementing predictive maintenance based on vibration sensing, we found that a common problem is for the sensors to become dislodged by high pressure water washdown processes. This is particularly notable in the meat packing segment. In many ways, this is not surprising. Washdown limits the ability of industrial automation vendors of all types to enter the food & beverage sector (for example, variable speed drives manufacturers). However, it is certainly worth remembering that predictive maintenance is no different.

Companies who want to implement predictive maintenance in washdown areas need to ensure that they find a predictive maintenance partner who understands their specific needs.

PART TWO:
Predictive Maintenance – How It Works and How It is Implemented

In the broadest sense, there are two categories of technology that must be implemented to create a predictive maintenance solution. One of these is the hardware. Increasingly, the key category of hardware in any predictive maintenance solution consists of smart sensors. Such sensors are constantly growing in terms of their capabilities, and we believe that a likely future trend is for processing capacity to be embedded directly on sensors. In some of the more advanced predictive maintenance solutions we've seen, edge computing devices are also used to sift through data before it is transmitted to the cloud.

The key pre-requisite to deciding where to deploy smart sensors for predictive maintenance within a packaging machine is understanding which data is useful. We researched this topic thoroughly among packaging machine OEMs and system integrators. We found that OEMs and integrators believe that run-time, current/ voltage draw, and speed are the three most useful types of data for performing predictive maintenance. However, it is our view that relying on run-time for predictive maintenance may be flawed logic as it assumes that equipment is most likely to fail in the latter part of its life which is not the case. Particularly with motor driven equipment, many failures happen within the first year due to manufacturing defects or installation error. Additionally, we caution that each packaging machine is different. The key thing for OEMs and system integrators to draw from this research is that a very wide range of data is available to harvest from most packaging machines (see Fig. 4). Once an OEM knows what data will be needed to perform predictive maintenance on their machines, then the first priority is to take advantage of any existing smart devices already in their machine to record this data – such as PLCs and variable speed drives. After this, if required, they can proceed with deploying additional sensors in the appropriate places. Once sensors are laid out, it is at this point that edge computing devices could be tied into the system. Edge devices can decide which data is useful, and transmit only that data to the cloud, slashing data transfer and storage costs.

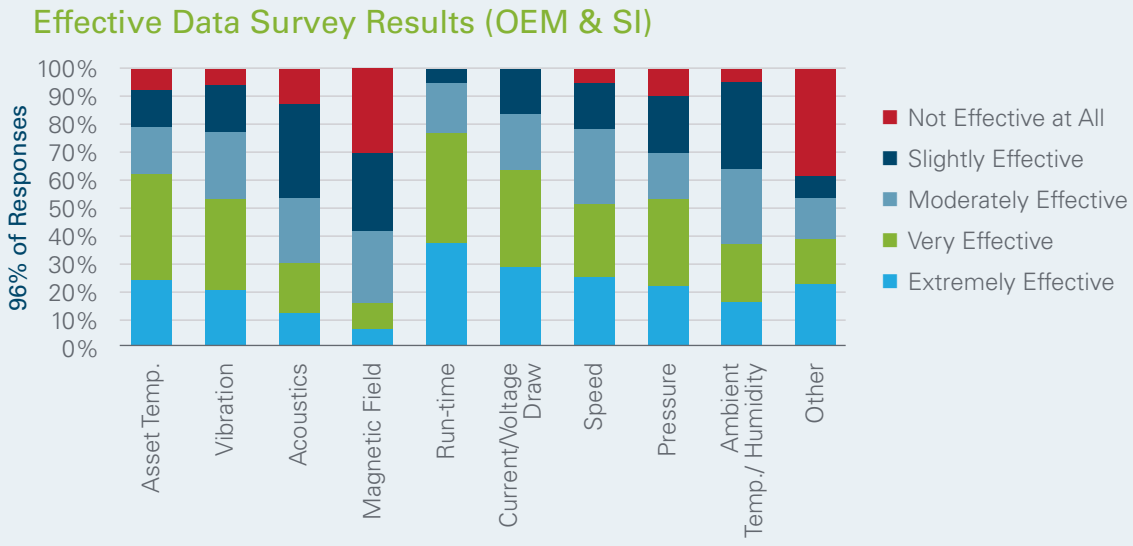


Fig. 4 – which types of data OEMs and integrators feel would be most useful for predictive maintenance

Of course, gathering data is the easy part. And it is here that the second key technology for predictive maintenance steps in: software and analytics (often hosted on the cloud). Without advanced software and analytics to process the data that the sensors gather, no predictive maintenance is possible. Most machine builders will not possess the ability to write this software in-house, and a predictive maintenance specialist will be needed at this stage.

At the moment, predictive maintenance solutions tend to be stitched together in a somewhat piecemeal fashion. One of the biggest challenges for implementing this technology is the architecture that you have to put in place to gather, store and analyze all the data for predictive maintenance. Most predictive maintenance hardware solutions do come with their own dedicated software; but a single software solution that brings all of the data under one umbrella is not yet on the market. In our view, this is a hole in the market that needs to (and will) be filled.

Business Models

When it comes to implementing predictive maintenance, we know the technology is there. So, what's stopping people? In many cases, the question for OEMs is how to make money out of it.

The benefits to predictive maintenance are simple and clear: reduced downtime and increased machine lifetime. For the end user, an improvement in either of these areas promises a significant improvement to the bottom line. But if predictive maintenance is taken to its full potential, then it will radically extend the average lifetime of a machine. This will mean new business models are essential for OEMs to maintain the revenue streams they need to survive.

Which Types of Maintenance Programs are Currently Successfully Monetized?

Our research shows that OEMs and systems integrators currently commonly offer seven types of maintenance programs (see Fig. 5).

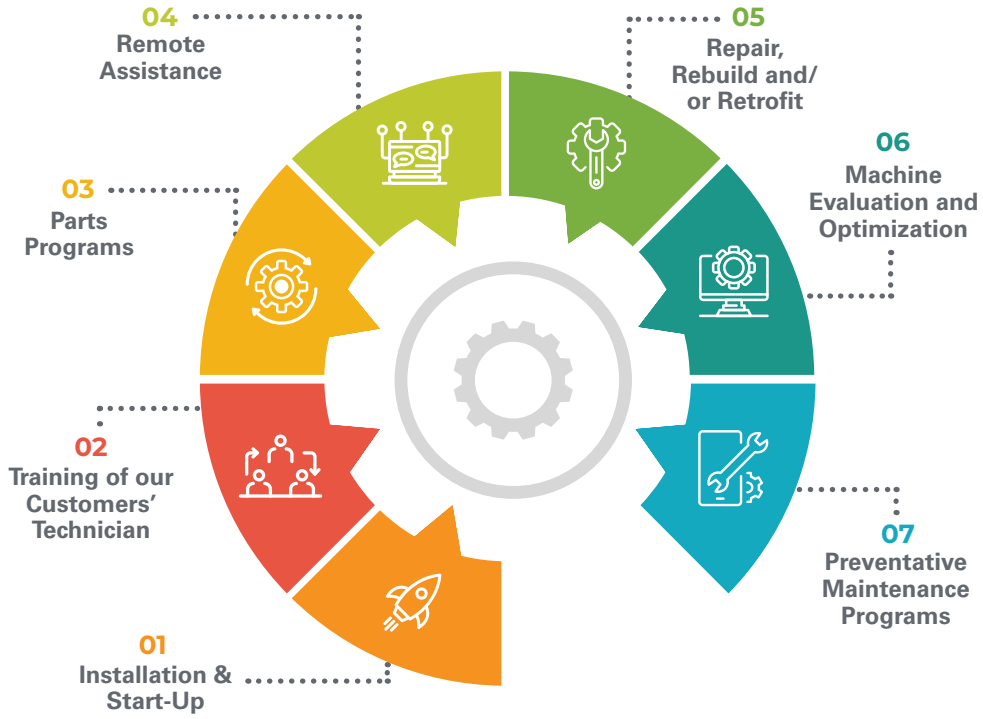


Fig. 5 – the degree to which OEMs and systems integrators are able to monetize preventative maintenance, relative to other types of maintenance programmes

When we look at their future potential, it is interesting to see that systems integrators and OEMs overwhelmingly agree that preventative maintenance programs have the greatest potential for providing new revenues, relative to the other types of revenue programmes. In total, 36.8% of respondents felt preventative maintenance had the greatest potential for new revenues. The next highest score was repair, rebuild and retrofit programmes with 15.8% seeing this area as having the greatest potential for new revenues (see Fig. 6).

36.8%
of Respondents

felt preventative maintenance had the greatest potential for new revenues

It is also important to note that there is a strong tendency among end users to rely on in-house maintenance where they can. Yet our previous research has shown that OEMs increasingly find it hard to recruit skilled maintenance engineers. We therefore see predictive maintenance programs as potentially a ready-made solution that OEMs can adopt to deal with this problem.

Highest Potential Revenues Survey Results (OEM & SI)

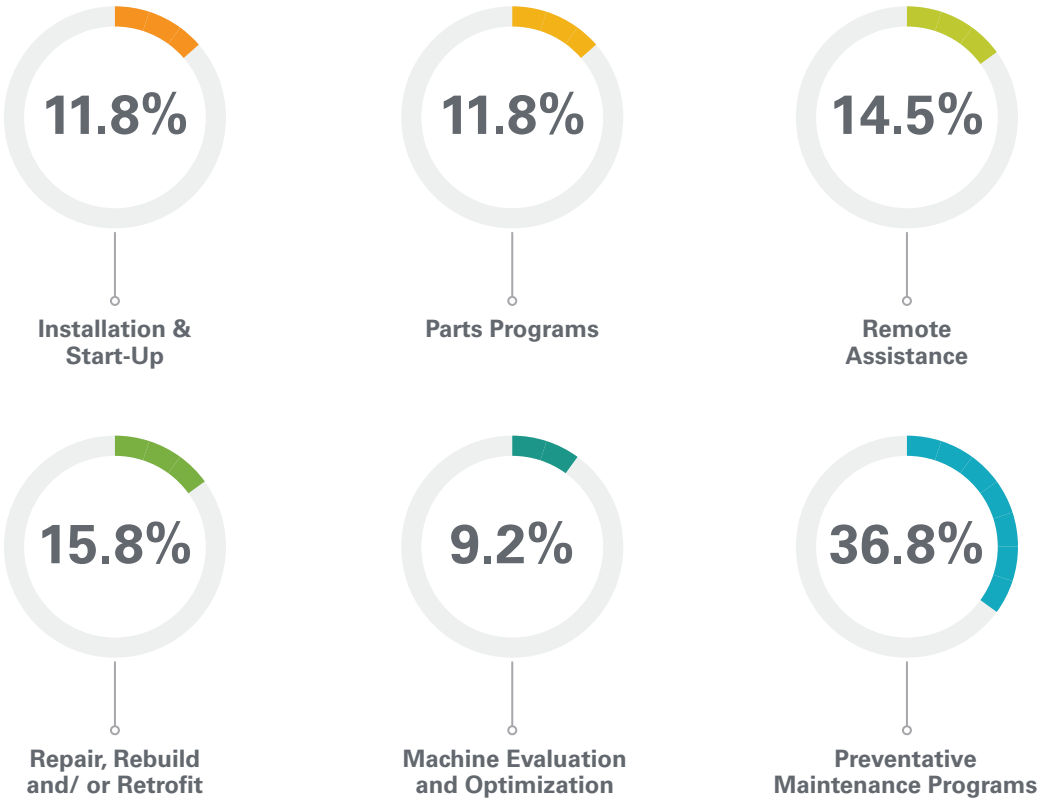
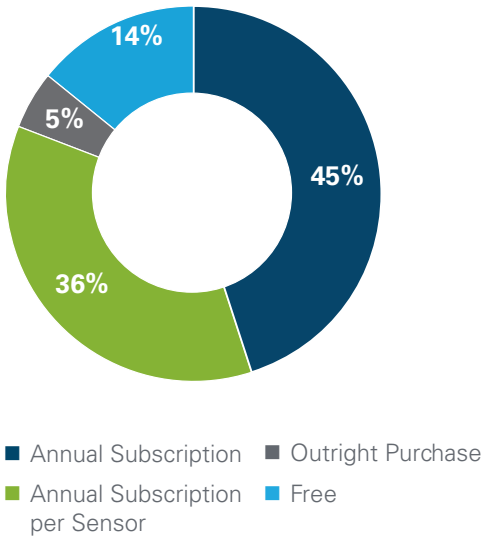


Fig. 6 – Which types of maintenance programs have the highest potential for future revenues

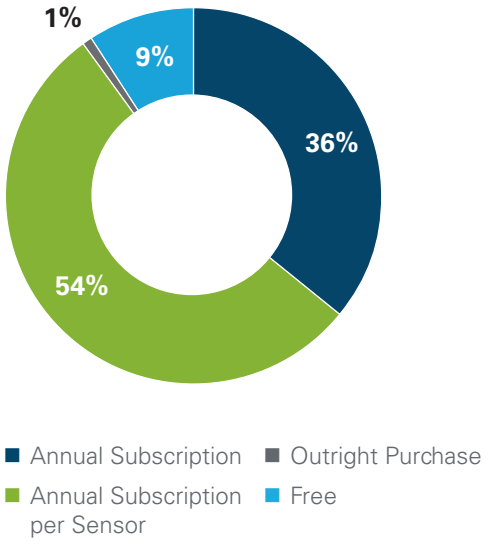
New Business Models

Currently, in the wider market beyond just packaging and processing, most predictive maintenance solutions are sold on a per-unit basis. On this model, suppliers charge an annual or monthly price per sensor which grants the customer access to dedicated software used to perform analysis[2]. We do expect this pricing model to continue to gain market share (see Fig. 7), but it leads to a conflict of interest: if OEMs use predictive maintenance solutions to extend the life of their equipment too much, they lose access to the replacement revenue that is vital to their survival.

Software Licenses by Pricing Model Global – 2018



Software Licenses by Pricing Model Global – 2024



Source: Interact Analysis

Fig. 7 – Current popular predictive maintenance pricing models – this data is from our report on predictive maintenance in motor driven systems, we believe this trend will hold true for the broader market, though.

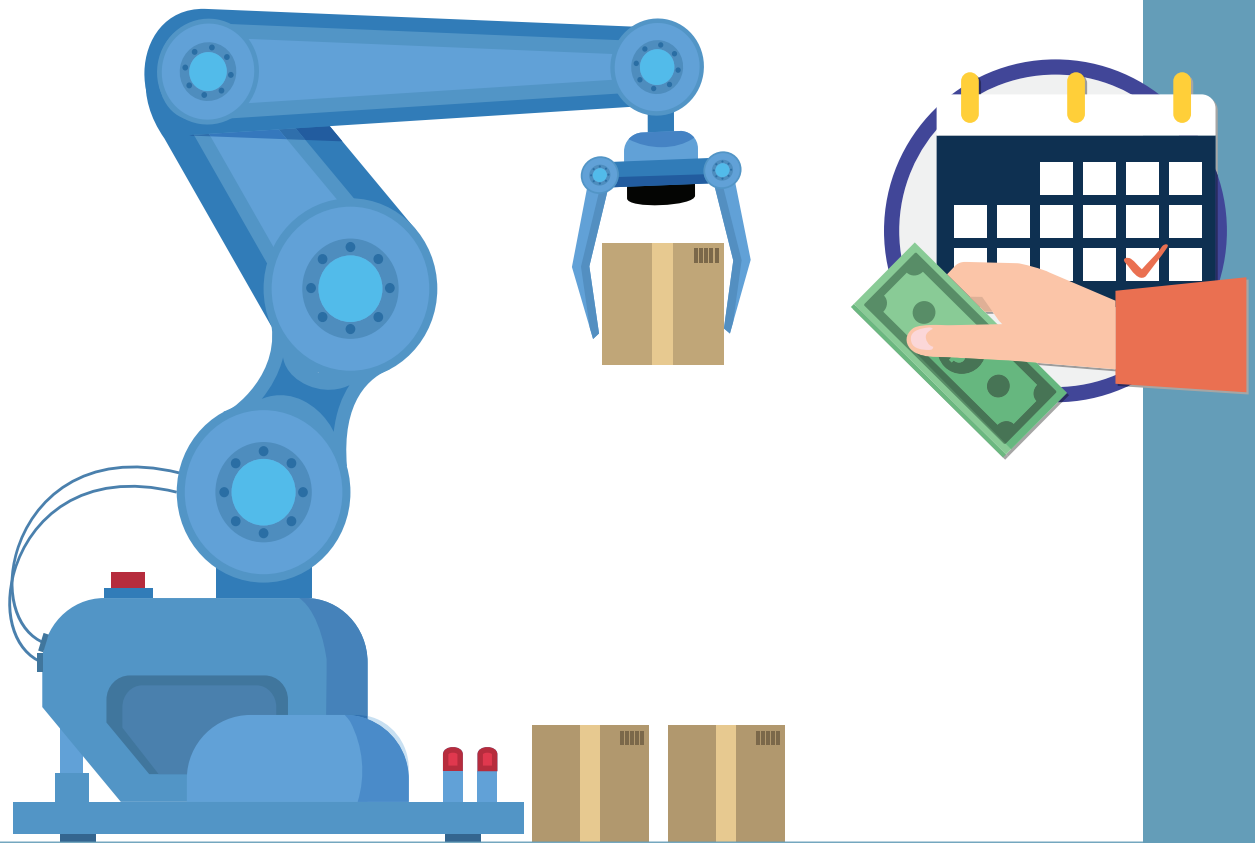
A middle ground is required. What is needed is a solution that reduces downtime for the end user, while also ensuring that the OEMs get the revenue they need to stay in business. The most promising candidate we have found so far is one we have termed Machines as a Service (MaaS). Essentially, it involves pricing based on performance goals set between the OEM and the end user (such as the number of cases palletized). We spoke to several companies who are already selling machines under this model. One example was an OEM whose model involves retaining ownership of packaging machines and charging the customer based on the successful operation of the machine. This incentivises the OEM to minimize downtime and maximize machine lifetime.

[2] We believe that OEMs will be looked at as an important route to market for the smart sensor suppliers that also tend to be responsible for making dedicated predictive maintenance software (for example, Augury). Such companies certainly also sell direct to end-users, but allowing an OEM to integrate the software and then sell it to the end user as part of a complete predictive maintenance solution gives the software provider easy access to a much broader customer base. Additionally, the knowledge that the packaging OEM has can be crucial in tailoring specialist predictive maintenance software to fit the needs of packaging customers. Since few software providers have in-depth knowledge on packaging, this is an interesting niche that will keep OEMs relevant from a software perspective

> The beautiful thing is that those people that take advantage of this, just by definition, we are going to be able to use predictive maintenance to optimize the performance of equipment which is what we have always wanted to do as a company. So, one of the benefits that we are trying to pitch is: 'Hey, you are going to get more uptime. You are actually going to have a different experience then if you don't go down this path' and that is resonating with technical people as well.
>
> — *Senior OEM Representative*

One challenge OEMs reported when selling MaaS solutions is dealing with finance departments at the end users – who need to understand the model because it is new to them too. It means that the OEM has to speak to people from the customer who they would never normally come into contact with, adding another potential barrier to making a sale.

Another common message from OEMs was that for MaaS to take off it really needs to become more commonplace. Once more OEMs offer it and it's well known in the market, and once end users realise it is in their interest, then selling on the MaaS model will be far easier.



Cybersecurity – The Key Barrier to MaaS, and to Predictive Maintenance More Broadly

If there is one single problem that is likely to stop the widespread adoption of an MaaS business model for predictive maintenance, it is the aversion that many end users have to connecting their machines to the cloud, and to allowing remote access. While remote access is vital for an MaaS business model, it is also important for many other predictive maintenance solutions too, so it represents a broader barrier. Our research showed us that 31% of consumer-packaged goods companies agreed that the following statement was "probably" or "definitely" true: "Our cybersecurity concerns are too great to allow OEMs remote access".

Additionally, when we surveyed OEMs and systems integrators, we found that

46.9%

of Respondents

agreed that the statement "Our customers will not allow remote access to their machinery" was "definitely" or "mostly" true

The concerns lie in two specific areas:

1. Security against malicious hackers who may try to remotely access a machine to cause criminal damage
2. Ensuring that their own data and commercial secrets are protected from competitors

The aversion to remote connectivity is changing over time. Two different OEMs told us that Covid has helped in this regard:

"All of a sudden, these IT departments are saying: 'We need to figure this remote access thing out'. They always had the option, but they chose not to".

The truth is that remote connectivity is usually no less secure than on-site connectivity. One OEM pointed out that in most factories anyone can plug a flash drive into a factory floor computer and that this has ten times the potential to cause problems or to be used maliciously. In fact, remote connections and cloud storage are not as insecure as is usually assumed. Such services are supplied by expert third party providers such as Microsoft Azure or Amazon Web Services. These are companies that have huge teams of cybersecurity experts dedicated to protecting their customers. Because of this, unless on-site servers are completely isolated from the internet (which would be unusual), then cloud and remote solutions are often actually more secure than managing IT on site.

To learn more about trends in adoption of remote access within the packaging and processing industries, check out our whitepaper – *Trends in Adoption of Remote Access.*

Conclusion

So, You Want to Implement Predictive Maintenance...

Phase 1: What you can do right now

If you want to implement a predictive maintenance solution right now, you can. Most OEMs, however well they know their own industries, will probably need to find a specialist digitalization partner. Without this, you are unlikely to have the tech and computing skills necessary. A specialist partner can take an unbiased look at your machine and help you figure out what data you can record and use; as well as help design a software solution to do it. They can also help set up remote cloud services to allow the implementation of an MaaS business model.

Phase 2: What you can do in the near future

Once a PdM program has been well established, there are a number of value propositions that come into play. This could include being able to evaluate the performance of assets at the enterprise level; or the ability to optimize your machinery from a purchasing perspective. By this, we mean that machine users can analyze data gathered over the lifetime of their assets to determine which equipment works best and most cost-effectively. For example, if an end user notices that components from one particular brand are failing more frequently, they can switch brand. Without tracking such data, it is hard to make these decisions. Additionally, predictive maintenance makes it possible to more accurately regulate your inventory because less unplanned downtime means a smoother forecasting ability.

In terms of emerging technologies that OEMs can consider implementing over the next few years, we see three that are of particular interest.

DRIVES AS A SENSOR

Our research shows us that, even today, some motor drives have enough onboard intelligence to function as a sensor by reading and recording data such as motor current draw. In the next few years, we believe an increased number of motor drives will have this capability. So, assessing this, and ensuring the full capabilities of motor drives are being used, will be an important process when OEMs start to implement predictive maintenance.

EXPLORE NEW BUSINESS MODELS

Before OEMs can sell predictive maintenance packages, robust and viable business models are essential. Machines as a Service is one such option where the OEM charges for uptime instead of for the machine. MaaS is, we think, the most viable and obvious business model, but there will be others.

INVESTIGATE PRESCRIPTIVE MAINTENANCE

Prescriptive maintenance is the next step again beyond predictive maintenance. As an idea, this is in its infancy, but essentially it means determining not only when an asset will fail, but also how to fix it. At the prescriptive maintenance level, the system does more than simply monitor machine status and make recommendations on when to perform maintenance – it also continues monitoring after the maintenance has been completed, to ensure it helped and to work out the possibilities for future improvements. The difference lies in the use of machine learning technology. It doesn't just tell you to fix something, it tells you how to fix it.

APPENDIX:
Introduction & Methodology

To support the whitepaper development, we conducted a survey whose results are contained in this document. Following the survey, we conducted 14 in-depth interviews with consumer-packaged goods brands (CPGs) and machine builders to provide additional color to the responses.

Several commonalities amongst the interviewees were quickly identified and further backed up by the analysis of the survey results. Throughout this document, which is intended to supplement the white paper, we will explore the key insights developed through our interview process and explain them in the context of the survey. In addition to this commentary, the full survey results are contained in the last two sections of this document.

Methodology

This research was conducted in two parts. The first consisted of a carefully designed survey which was issued to CPGs, original equipment manufacturers (OEMs)/systems integrators (SIs). The majority of respondents conduct business primarily in North America with a significant bias towards the United States. Upon receiving an adequate number of responses, the results were aggregated and analyzed. While the survey results were being analyzed, 14 interviews were conducted with a hand selected group of survey respondents. Both sources helped us formulate this white paper and accompanying survey analysis.

The survey response was solid, with a total of 138 valid responses received. The questionnaire was designed to branch into slightly different lines of questioning depending on whether the respondent was a CPG or an OEM/SI. The largest response came from OEMs, which when combined with SIs represented the largest branching sample size of 86 valid responses or 62.3%. CPGs accounted for 37.7% or 52 valid responses. Survey results start to achieve higher levels of statistical relevance when responses of 100 are received. As such, when considering the data, we have tried to observe statistically significant deviations in responses to derive our observations to minimize the risk of misinterpreting the data due to statistical error.

Note: in this document we may use the terms OEM and machine builder interchangeably. Similarly, we deem CPGs as "end users."

Demographics

Which best describes the type of company you work for?

- OEM (original equipment manufacturer)
- CPG (consumer packaged goods brand)
- SI (systems integrator)

138
Respondents

49.3%
OEM

37.7%
CPG

13.0%
SI

Demographics – 2

What is the primary industry served by the business unit you belong to?

- Foods and food preparation
- Personal care products
- Consumer and commercial durable products, including hardware, plumbing, automotive, industrial
- Beverage
- Household and industrial chemicals and cleaning/finishing products
- Pharmaceuticals and medical devices

52 **Respondents**

Food	63.5%
Personal Care	11.5%
Consumer & Commercial	9.6%
Beverage	7.7%
Chemical	3.8%
Medical	3.8%

Key Observations from Survey Results

Predictive Maintenance Does Not Mean the Same Thing to Everyone

One of the first things we identified in our interviews is that the understanding of predictive maintenance varied greatly. Often, when companies were describing their maintenance strategies as "predictive", it became very apparent that the strategies they were describing would fall closer to the "preventative" side of the spectrum.

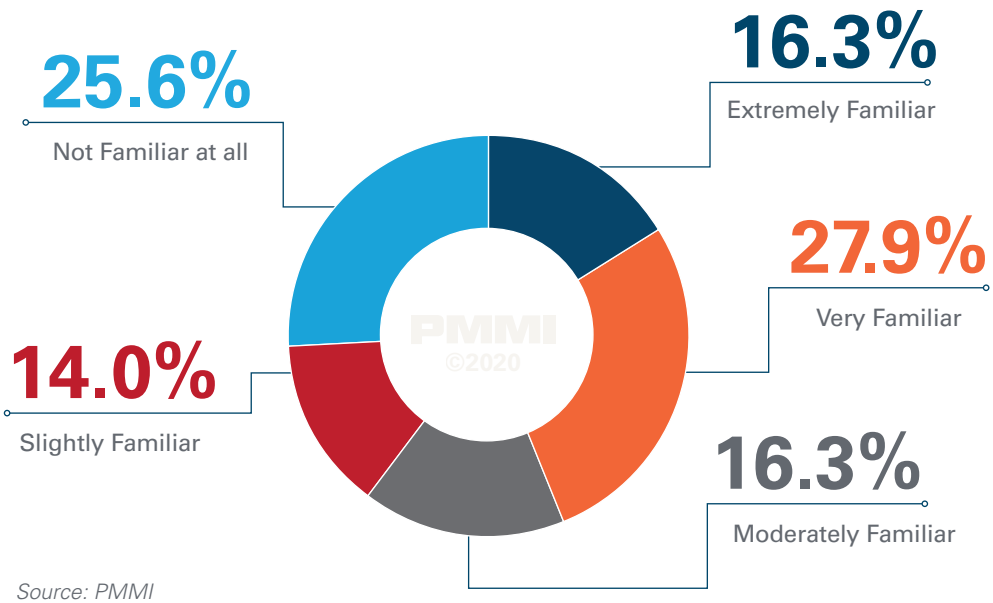
We define predictive maintenance as the following: "The use of technology to gather data on an asset, such as its temperature or vibration levels, and to perform analysis of the data to predict when the asset needs repair to eliminate risk of failure."

This varies greatly from preventative maintenance, which is the scheduled maintenance of assets to prevent or reduce failure (think regular oil changes, etc.). It also goes further than condition-based maintenance, which uses similar technology as predictive maintenance strategies, however, does not try to predict when an asset is going to fail. Many companies we spoke to believed they were engaging in predictive maintenance within their machines/facilities when in fact, they were engaging in a combination of preventative and condition-based maintenance. The next step towards developing a method for predicting the asset behavior had yet to be taken.

The table and graph to the right are the results of two separate survey questions pertaining to the implementation/evaluation of various industrial digitalization initiatives, and the familiarity with our given definition of predictive maintenance, respectively. According to the responses of the top table, 65.8% of respondents perceived they were piloting, evaluating, or had implemented a predictive maintenance program. Compare this with the bottom chart which displayed that only 44.2% of respondents were either very familiar or extremely familiar with the definition of predictive maintenance. In our opinion, if a company were piloting, evaluating, or implementing a predictive maintenance program, that company would be very familiar or extremely familiar with the definition of predictive maintenance. The disparity between these two figures was explored in the follow-up interviews and underscored that companies often believe they are performing predictive maintenance when in fact their program may be more akin to preventative/condition-based monitoring.

Which of the following digitalization initiatives have you evaluated, piloted, or implemented? (CPG)

	Have Not Evaluated	Evaluating	Piloting	Implemented	Evaluated and Rejected	# of Responses
Big Data (on premise)	56.9%	23.5%	3.9%	13.7%	2.0%	51
Big Data (cloud-based)	50.0%	26.0%	12.0%	12.0%	-	50
Digital Twin (simulation)	80.4%	7.8%	5.9%	3.9%	2.0%	51
Predictive Maintenance	25.5%	29.4%	21.6%	23.5%	-	51
Augmented and/ or Virtual Reality	70.6%	13.7%	9.8%	3.9%	2.0%	51
Collaborative Robots	64.0%	14.0%	4.0%	14.0%	4.0%	50
Mobile Robots	68.0%	14.0%	2.0%	12.0%	4.0%	50
Additive Manufacturing	70.6%	19.6%	3.9%	5.9%	-	51



Source: PMMI

CPGs are More Reliant on In-house Maintenance than Perceived

Both CPGs and OEMs/systems integrators were asked similar questions:

CPGs: To what extent are the following statements, describing your company's current maintenance strategy, true or false?

OEMs/systems integrators: To what extent are the following statements, describing your company's current maintenance offering, true or false?

Note: Refer to Question 1 for the CPG and OEM/SI questionnaire branches to understand exactly how this question was posed to the respondent. In the tables below we have condensed the statement to simplify visualization.underscored that companies often believe they are performing predictive maintenance when in fact their program may be more akin to preventative/condition-based monitoring.

To what extent are the following statements, describing your company's current maintenance strategy, true or false. (CPG)

	Definitely True	Mostly True	Neither True nor False	Mostly false	Definitely False	Do not Know	# of Responses
Run to Fail	-	28.8%	15.4%	26.9%	28.8%	-	52
In-House Maintenance	48.1%	36.5%	11.5%	1.9%	1.9%	-	52
Portable Devices	5.8%	30.8%	9.6%	23.1%	28.8%	1.9%	52
Sensors	3.8%	40.4%	17.3%	13.5%	23.1%	1.9%	52
Live Stats	7.7%	25.0%	25.0%	15.4%	26.9%	-	52
Current Strategy Optimized	11.5%	42.3%	15.4%	19.2%	11.5%	-	52
Historian	3.8%	46.2%	13.5%	19.2%	17.3%	-	52

To what extent are the following statements, describing your company's current maintenance offering, true or false. (CPG)						
	Definitely True	Mostly True	Neither True nor False	Mostly false	Definitely False	# of Responses
Run to Fail	8.2%	32.9%	16.5%	18.8%	23.5%	85
Customer Self-Maintenance	25.6%	45.3%	18.6%	7.0%	3.5%	86
Portable Devices	9.4%	20.0%	15.3%	17.6%	37.6%	85
Sensors	18.6%	33.7%	11.6%	14.0%	22.1%	86
Live Data	18.8%	29.4%	9.4%	18.8%	23.5%	85
Current Strategy Optimized	23.3%	39.5%	15.1%	11.6%	10.5%	86
Lack of Resources	14.0%	24.4%	27.9%	17.4%	16.3%	86

53.8%
of CPGs' responses

indicated that it is "mostly" or "definitely true" that "we perceive our current maintenance strategy to be optimized to minimize downtime"

We found this to be indicative that there is more education needed around predictive maintenance among CPGs. An optimized solution would imply a robust predictive maintenance program using leading edge technology. Judging from our interviews, and previous research we have performed on this topic, we believe these robust predictive maintenance programs are few and far between among end-users. It is likely that maintenance teams believe they have optimized their solution when there is a significant amount of savings that can still be achieved through a predictive maintenance program.

Other notable observations follow:

- In-house maintenance is a common maintenance strategy for CPGs, and this was observed in both the CPT and OEM/SI survey branches. Conclusion: in-house maintenance is here to stay, and OEMs/SIs that can offer capabilities that enhance this will likely garner greater success versus those that don't.
- The use of measurement devices among OEM & SI respondents was "definitely" or "probably" true to a greater extent than for CPGs. Conclusion: this may be speculative, but perhaps OEMs & SIs are increasingly incorporating into their newer machinery, and this has not fully penetrated the end-user markets significantly yet.
- It appears CPGs are commonly using historian data to evaluate machine performance. Conclusion: historian data is easily accessible, and there are many software packages that can analyze this data and perform predictive maintenance. The problem here is that historian data analysis is only as good as the assets that are being monitored, so if measurement device usage is low (which it appears to be), assets being monitored will similarly be low. There is room for much improvement.

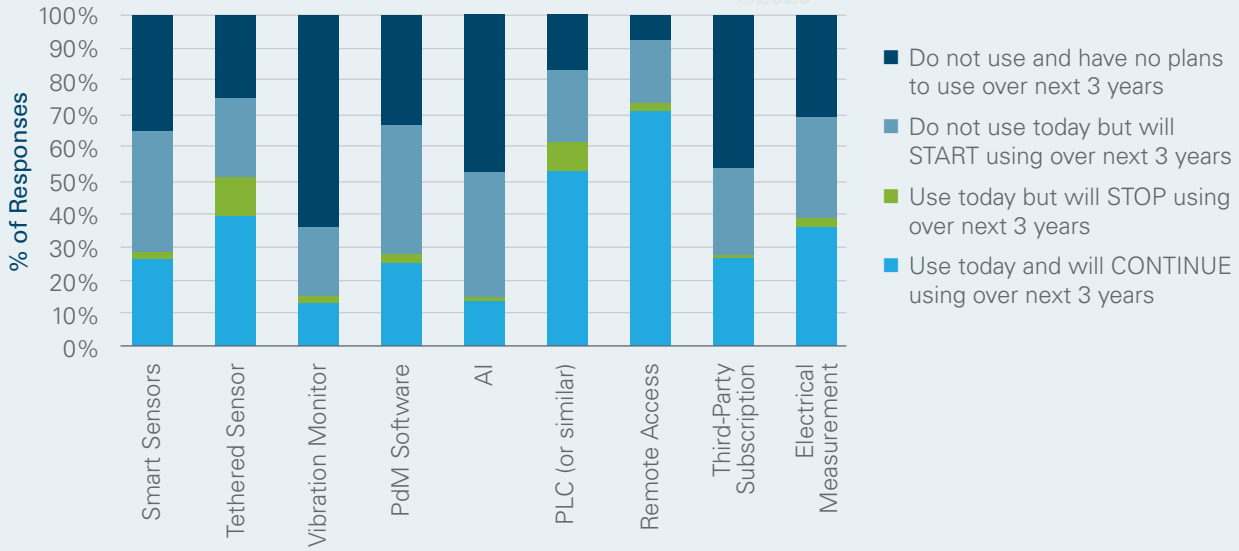
OEMs/SIs are Heavily Relying on PLCs for Predictive Maintenance

In our interviews we found that OEMs were utilizing devices like the PLC to develop insight into the usage of their machine. Since the business models surrounding predictive maintenance offerings are still relatively immature, it would be natural for machine builders to rely on familiar devices like the PLC to develop asset health related date. While we expect the PLC to be utilized as part of predictive maintenance solutions in the future, using the PLC alone is a rudimentary method of performing predictive maintenance. The PLC can provide measurements such as the number of times a device was turned on or off, or the number of safety stops performed. It could also be gathering data from current or voltage sensor relays, which can be used to monitor variations in the voltage/current draw on a connected device. But usually these devices are used as an alarm, rather than a source of continuous measurement, limiting their usefulness in a predictive maintenance setting. All these metrics can be analyzed to get a picture of asset health, but a limited one. Additional metrics such as vibration and temperature are necessary to get the full picture of the health status of assets, as is the ability to constantly store and analyze this data. We do expect the PLC to be an important part of predictive maintenance infrastructure in the future, due to it being well placed to collect and analyze that data. However, right now we do not believe it is being deployed optimally by most end users.

The data below backs up this assertion. 52.6% of respondents indicated that they currently use and plan to continue using the PLC (or similar) programmed to measure usage of key assets. We believe that the PLC (or similar) and other devices like smart sensors will be utilized in conjunction with analytical tools (such as artificial intelligence [AI] & more general-purpose predictive maintenance [PdM] software) to a greater extent in the future. This combination of tools will represent the modern predictive maintenance offering. Data below pertaining to which tools OEMs and SIs will use in the future backs this assertion. Smart sensors, PdM software, and AI all recorded a high number of responses within this category with 37.7%, 39.5%, and 38.2%, respectively.

Remote access scored the highest number of responses pertaining to current use and future use by OEMs & SIs. This was an interesting finding as we perceive remote access to be a topic of much concern for end users. The concern is twofold: (i) there is potential for a malicious attack on operations, and (ii) there is a fear that confidential operational data will get into the outside world undermining competitiveness due to the loss of critical intellectual property (such as a particular recipe for a popular product).

Company Utilization (OEM & SI)



Current/Voltage Draw is a Useful Datapoint and Currently Underserved

Effective Data (OEM & SI)						
	Extremely Effective	Very Effective	Moderately Effective	Slightly Effective	Not Effective at all	# of Responses
Asset temp.	23.4%	39.0%	16.9%	13.0%	7.8%	77
Vibration	20.8%	32.5%	24.7%	16.9%	5.2%	77
Acoustics	11.7%	18.2%	23.4%	35.1%	11.7%	77
Magnetic field	5.2%	10.4%	26.0%	28.6%	29.9%	77
Run-time	36.8%	39.5%	18.4%	5.3%	-	76
Current/voltage draw	28.6%	35.1%	20.8%	15.6%	-	77
Speed	24.7%	27.3%	27.3%	16.9%	3.9%	77
Pressure	22.1%	31.2%	16.9%	20.8%	9.1%	77
Ambient temp./ humidity	15.8%	21.1%	27.6%	31.6%	3.9%	76
Other (please specify)	23.1%	15.4%	15.4%	7.7%	38.5%	13

Note: "Other" responses received were:

Charge voltage

Lubricant health

Cycle count

Load

Gearbox or compressor oil temperature

The data above is in reference to the question "which types of data do you think would be most effective at helping you measure the status of assets on your machine?" Current/voltage received a high number of responses indicating it was either extremely effective or very effective at helping to monitor the status of an asset. This is an important consideration when thinking about ways in which to deploy predictive maintenance in a facility. While smart sensors appear to be the core piece of hardware that will be most broadly used in the future, these devices rarely ever can measure current/voltage draw.

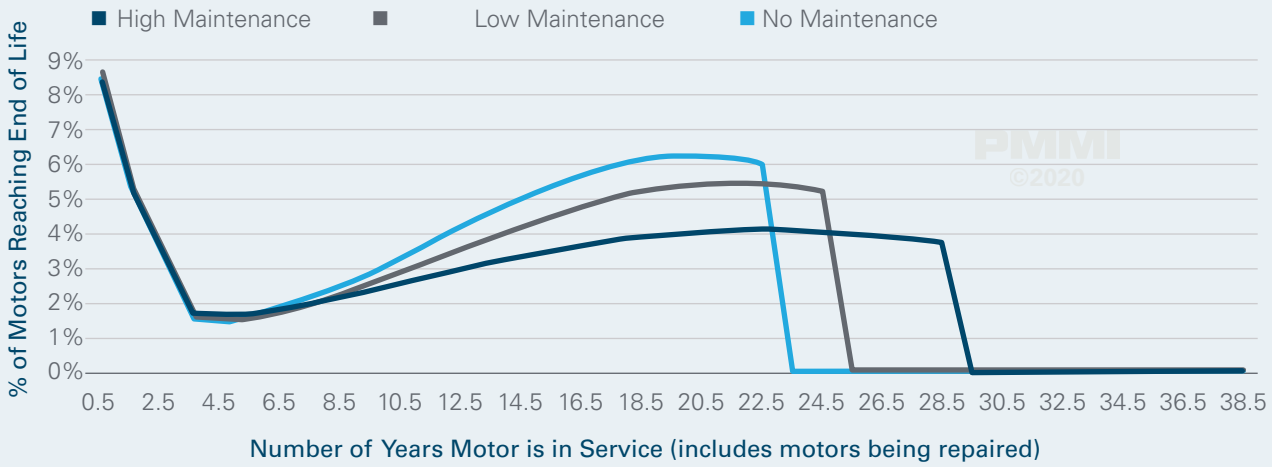
It is worth noting that the importance of this point can be observed in the recent behavior of motor drive companies – they are increasingly offering this capability in their products, although we would consider this trend to be in its infancy. Essentially, motor drives are being utilized as a sensor of motor health through measuring the changes in electrical demand from the motor. As this becomes more commonplace, it will be a low hanging fruit for those wanting to implement predictive maintenance functionality within their facilities. Given these devices are commonplace within manufacturing facilities, it stands to reason that they are more well understood from a technical standpoint and would require less of a learning curve in terms of accessing device data. To date this trend has been observed more among drives vendors targeting induction motors as opposed to servo motors. We expect servo drive vendors to catch-up.

Run Time is Useful…. but Often Misunderstood

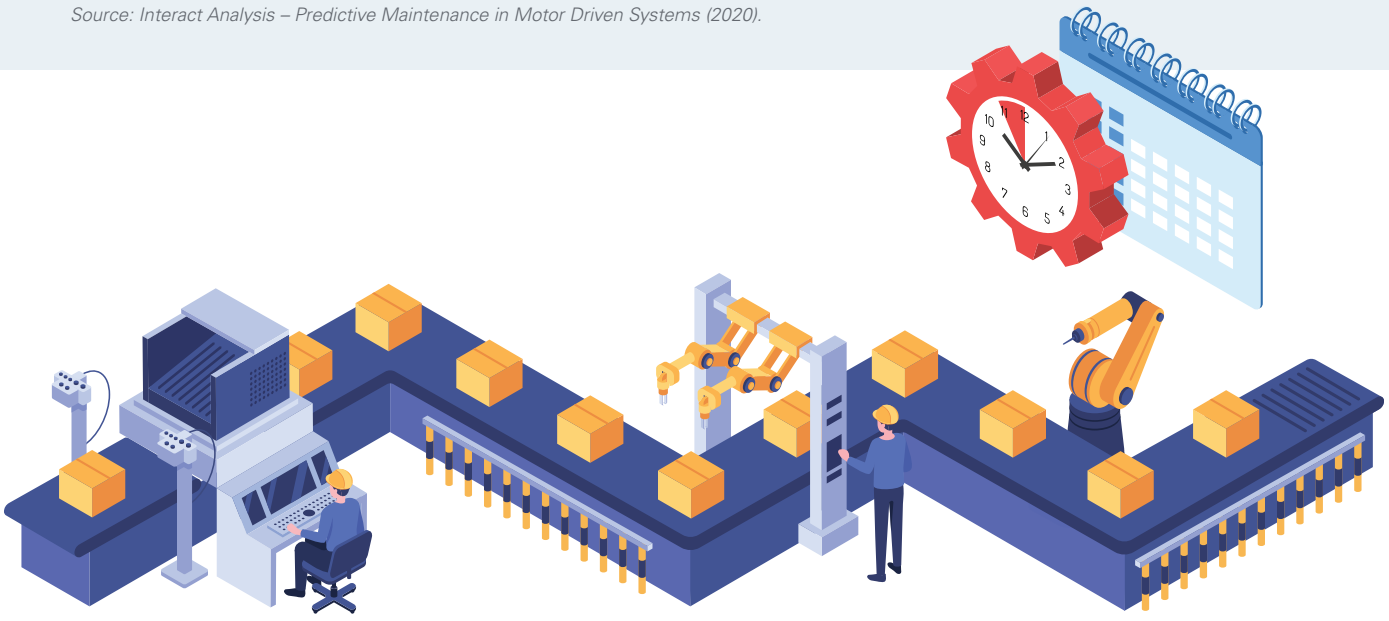
In reference to the question "which types of data do you think would be most effective at helping you measure the status of assets on your machine?", run time garnered the highest percentage of responses indicating this to be "extremely effective". While run time is certainly an important determinant of the life of an asset, often the highest failure rates occur within the first year of installation. This can be due to improper use/installation of a manufacturer defect. In these scenarios, other metrics must be utilized in order to prevent failure.

Shown in the graph below is our modeled projection for the lifespan of a motor given different maintenance strategies. While a motor is not analogous to every machine, it certainly can be used as an example for the nature of failure. Utilizing metrics like vibration and temperature can be critical in identifying these early life failures before they occur.

Life Span of Motor Under Different Maintenance Strategies – Multi-Phase AC Motors > 37kW but <=75kW



Source: Interact Analysis – Predictive Maintenance in Motor Driven Systems (2020).



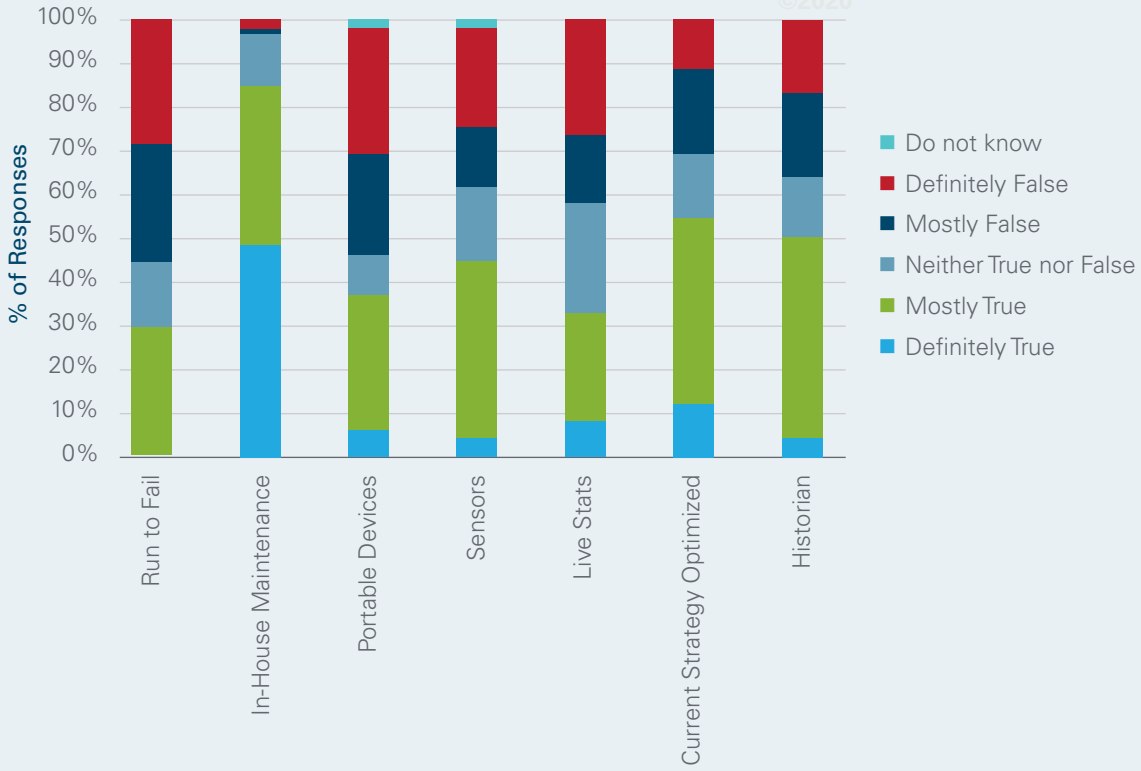
CPG Responses

CPG: Question 1

To what extent are the following statements, describing your company's current maintenance strategy, true or false.

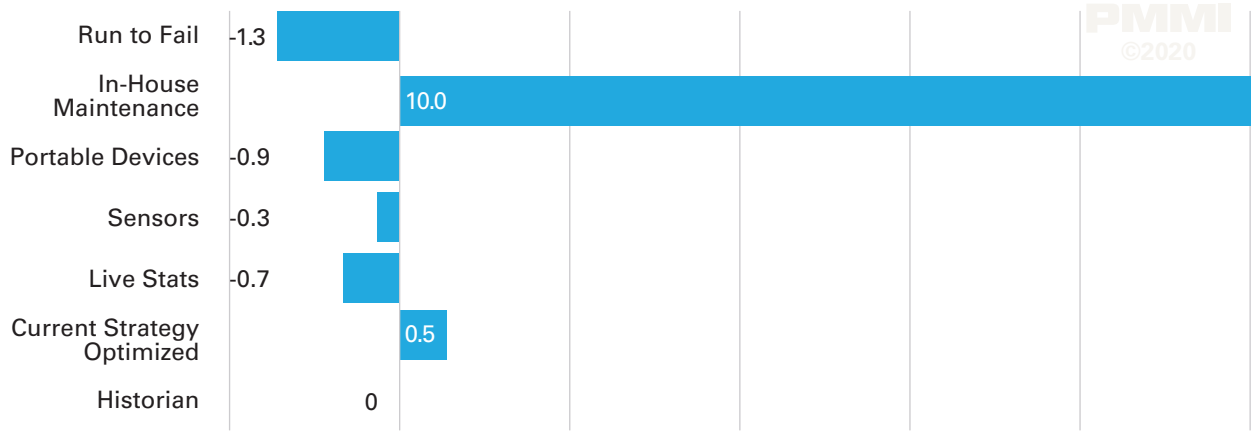
- We tend to "run to fail," and only fix problems as they arise.
- We conduct most of the maintenance of our production lines ourselves (i.e. in-house team).
- We use portable monitoring devices to evaluate which assets are in need of maintenance.
- We use measurement devices on the machinery to monitor equipment status.
- We are able to view live statistics showing the current health of our key assets.
- We perceive our current maintenance strategy to be optimized to minimize downtime.
- We analyze the data from our historian to evaluate machine performance

Maintenance Strategy Survey Results (CPG)



To what extent are the following statements, describing your company's current maintenance strategy, true or false. (CPG)							
	Definitely True	Mostly True	Neither True nor False	Mostly false	Definitely False	Do not Know	# of Responses
Run to Fail	-	28.8%	15.4%	26.9%	28.8%	-	52
In-House Maintenance	48.1%	36.5%	11.5%	1.9%	1.9%	-	52
Portable Devices	5.8%	30.8%	9.6%	23.1%	28.8%	1.9%	52
Sensors	3.8%	40.4%	17.3%	13.5%	23.1%	1.9%	52
Live Stats	7.7%	25.0%	25.0%	15.4%	26.9%	-	52
Current Strategy Optimized	11.5%	42.3%	15.4%	19.2%	11.5%	-	52
Historian	3.8%	46.2%	13.5%	19.2%	17.3%	-	52

Source: PMMI



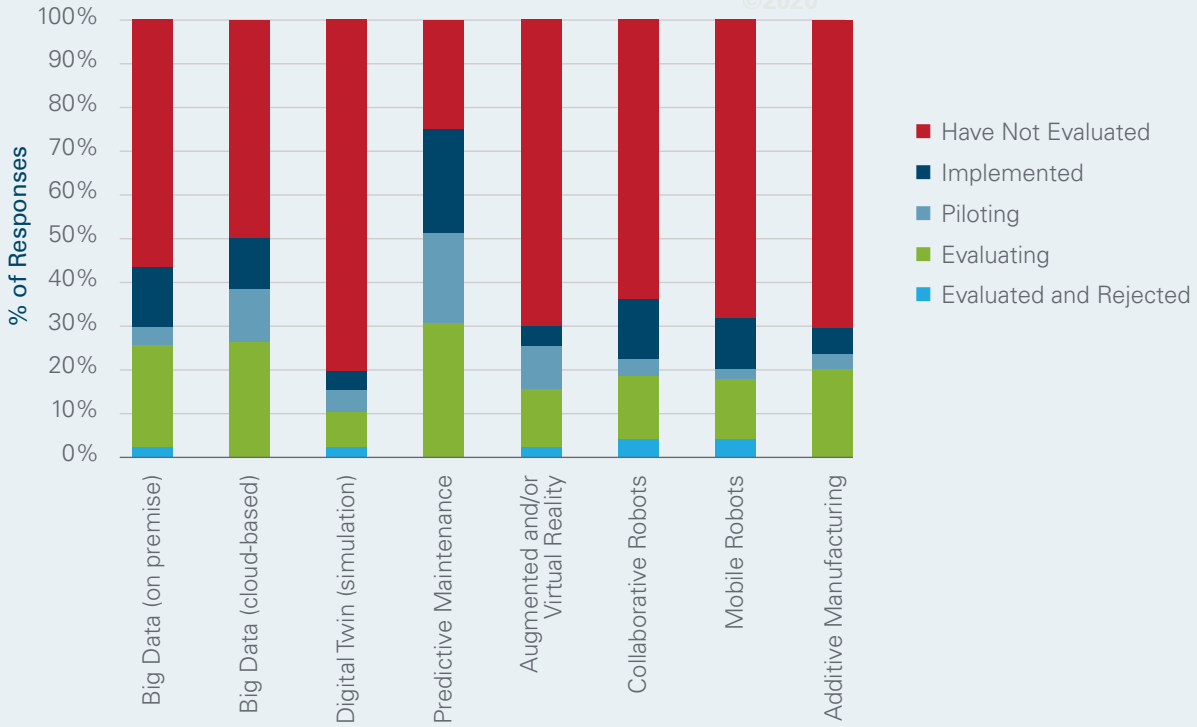
Source: PMMI

CPG: Question 2

Which of the following digitalization (i.e. industrial IOT or Industry 4.0) initiatives have you evaluated, piloted, or implemented?

- Big data analytics (on premise storage)
- Big data analytics (cloud-based storage)
- Digital twin (simulation) of production line or plant
- Predictive maintenance
- Augmented and/or virtual reality
- Collaborative robots
- Mobile robots (AMRs and/or AGVs)
- Additive manufacturing

Digitalization Initiative Survey Results (CPG)



Which of the following digitalization initiatives have you evaluated, piloted, or implemented? (CPG)						
	Have Not Evaluated	Evaluating	Piloting	Implemented	Evaluated and Rejected	# of Responses
Big Data (on premise)	56.9%	23.5%	3.9%	13.7%	2.0%	51
Big Data (cloud-based)	50.0%	26.0%	12.0%	12.0%	-	50
Digital Twin (simulation)	80.4%	7.8%	5.9%	3.9%	2.0%	51
Predictive Maintenance	25.5%	29.4%	21.6%	23.5%	-	51
Augmented and/or Virtual Reality	70.6%	13.7%	9.8%	3.9%	2.0%	51
Collaborative Robots	64.0%	14.0%	4.0%	14.0%	4.0%	50
Mobile Robots	68.0%	14.0%	2.0%	12.0%	4.0%	50
Additive Manufacturing	70.6%	19.6%	3.9%	5.9%	-	51

Source: PMMI

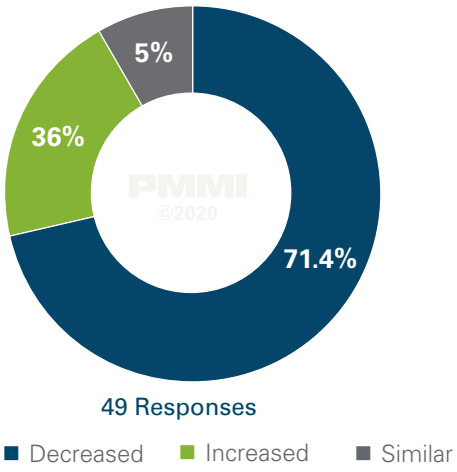
Source: PMMI

CPG: Question 3

Which of the following statements best describes your company's overall downtime and its impact on production? (Pick one only)

- Over the last three years, downtime affecting production has decreased.
- Our downtime this year is similar to levels three years ago.
- Over the last three years, downtime affecting production has increased.

Production Impact Survey Results (CPG)



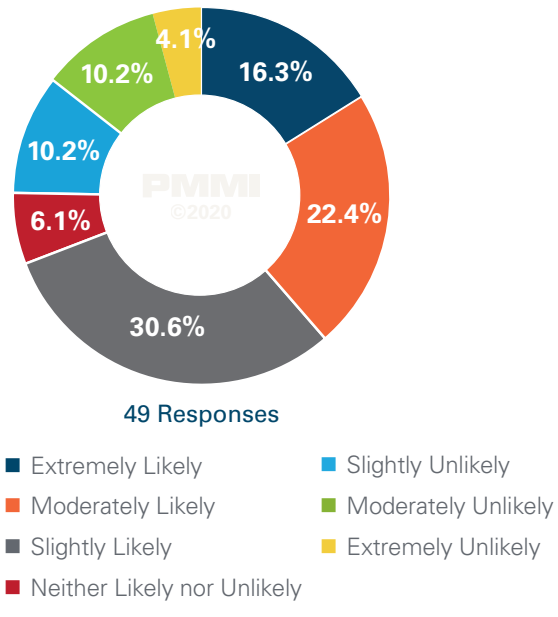
Source: PMMI

CPG: Question 4

Relative to other machinery and equipment (e.g. machine tools, food processing machinery, textile machinery, etc.), how prone to downtime is the packaging machinery you use?

- Extremely likely
- Moderately likely
- Slightly likely
- Neither likely nor unlikely
- Slightly unlikely
- Moderately unlikely
- Extremely unlikely

Prone to Downtime Survey Results (CPG)



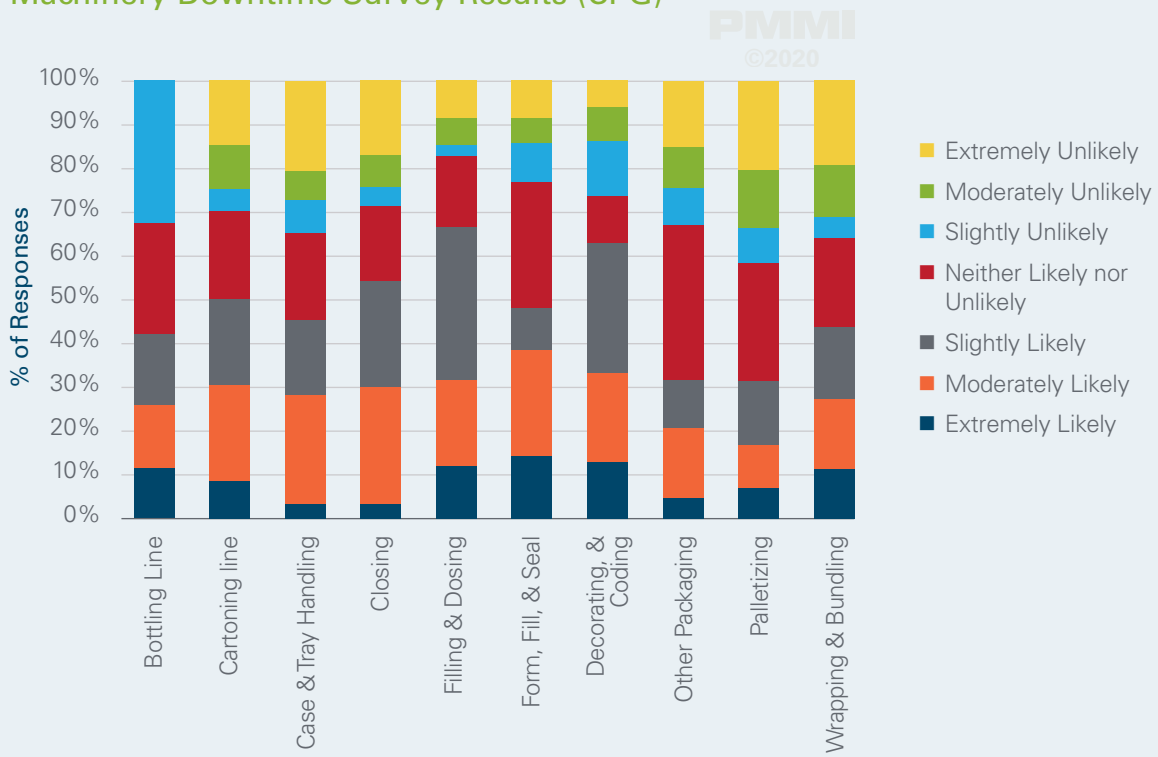
Source: PMMI

CPG: Question 5

For each of the different types of packaging machinery you use, please indicate which types are of a higher or lower risk of downtime.

- Bottling line machinery
- Cartoning line machinery
- Case & tray handling machinery
- Closing Machinery
- Filling & Dosing machinery
- Form, Fill, & Seal machinery
- Decorating, & Coding machinery
- Other packaging machinery
- Palletizing machinery
- Wrapping & bundling machinery

Machinery Downtime Survey Results (CPG)



Source: PMMI

For each of the different types of packaging machinery you use, please indicate which types are of a higher or lower risk of downtime (CPG)								
	Extremely Likely	Moderately Likely	Slightly Likely	Neither Likely nor Unlikely	Slightly Unlikely	Moderately Unlikely	Extremely Unlikely	# of Responses
Bottling Line	11.1%	13.9%	16.7%	25.0%	11.1%	5.6%	16.7%	36
Cartoning Line	7.5%	22.5%	20.0%	20.0%	5.0%	10.0%	15.0%	40
Case & Tray Handling	2.5%	25.0%	17.5%	20.0%	7.5%	7.5%	20.0%	40
Closing	2.4%	26.8%	24.4%	17.1%	4.9%	9.8%	14.6%	41
Filling & Dosing	12.2%	19.5%	34.1%	17.1%	2.4%	7.3%	7.3%	41
Form, Fill & Seal	14.3%	23.8%	9.5%	28.6%	9.5%	7.1%	7.1%	42
Labelling, Decorating & Coding	13.3%	20.0%	28.9%	11.1%	13.3%	8.9%	4.4%	45
Other Packaging	4.4%	15.6%	11.1%	35.6%	8.9%	11.1%	13.3%	45
Palletizing	7.3%	9.8%	14.6%	26.8%	7.3%	14.6%	19.5%	41
Wrapping & Bundling	11.4%	15.9%	15.9%	20.5%	4.5%	13.6%	18.2%	44

Source: PMMI

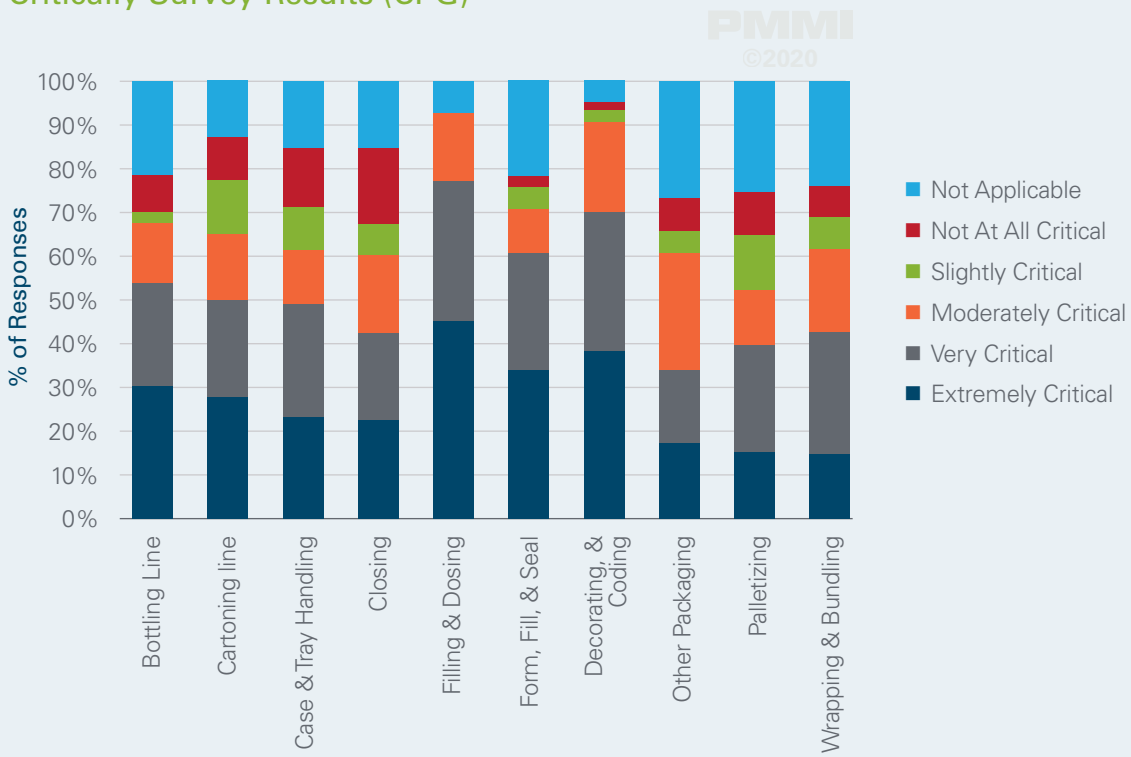
Source: PMMI

CPG: Question 6

Please rate the level of criticality when each of the following machine types are out of service.

- Bottling line machinery
- Cartoning line machinery
- Case & tray handling machinery
- Closing Machinery
- Filling & Dosing machinery
- Form, Fill, & Seal machinery
- Decorating, & Coding machinery
- Other packaging machinery
- Palletizing machinery
- Wrapping & bundling machinery

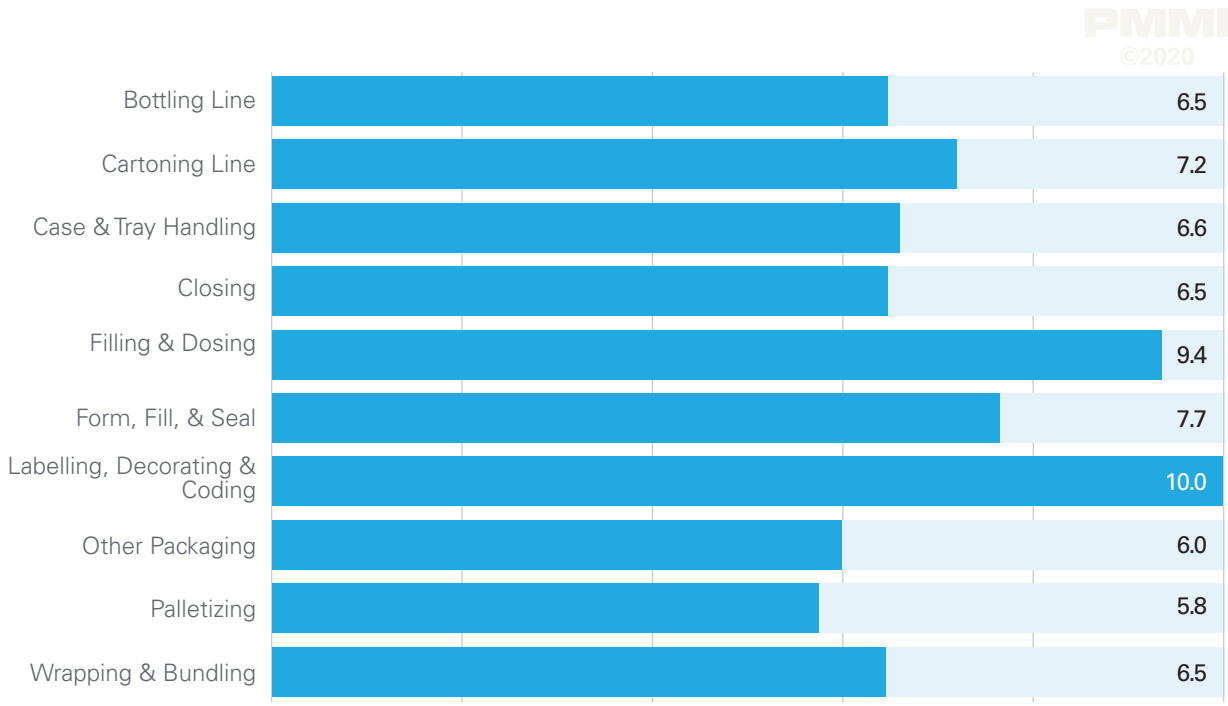
Critically Survey Results (CPG)



Source: PMMI

Please rate the level of criticality when each of the following machine types are out of service (CPG)							
	Extremely Critical	Very Critical	Moderately Critical	Slightly Critical	Not At All Critical	Not Applicable	# of Responses
Bottling Line	29.7%	24.3%	13.5%	2.7%	8.1%	21.6%	37
Cartoning Line	27.5%	22.5%	15.0%	12.5%	10.0%	12.5%	40
Case & Tray Handling	23.1%	25.6%	12.8%	10.3%	12.8%	15.4%	39
Closing	22.5%	20.0%	17.5%	7.5%	17.5%	15.0%	40
Filling & Dosing	45.0%	32.5%	15.0%	-	-	7.5%	40
Form, Fill & Seal	34.1%	26.8%	9.8%	4.9%	2.4%	22.0%	41
Labelling, Decorating & Coding	38.6%	31.8%	20.5%	2.3%	2.3%	4.5%	44
Other Packaging	17.1%	17.1%	26.8%	4.9%	7.3%	26.8%	41
Palletizing	15.0%	25.0%	12.5%	12.5%	10.0%	25.0%	40
Wrapping & Bundling	14.3%	28.6%	19.0%	7.1%	7.1%	23.8%	42

Source: PMMI



Source: PMMI

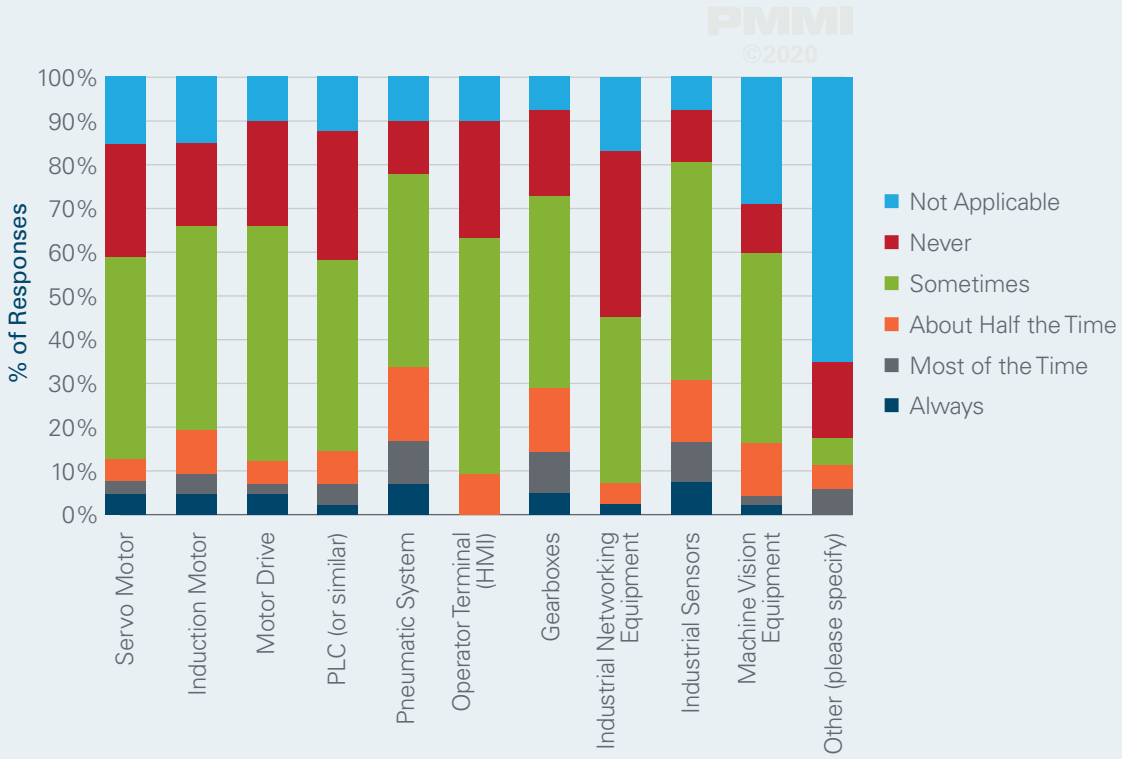
CPG: Question 7

Which of the following automation components most commonly cause downtime through failure?

- Servo motor
- Induction motor
- Motor drive (servo or VFD)
- PLC (or similar)
- Pneumatic system
- Operator terminal (HMI)
- Gearboxes
- Industrial networking equipment
- Industrial sensors
- Machine vision equipment
- Other (please specify)

  • Sealing jaws, bars, heaters
  • Encoders

Common Downtime Survey Results (CPG)

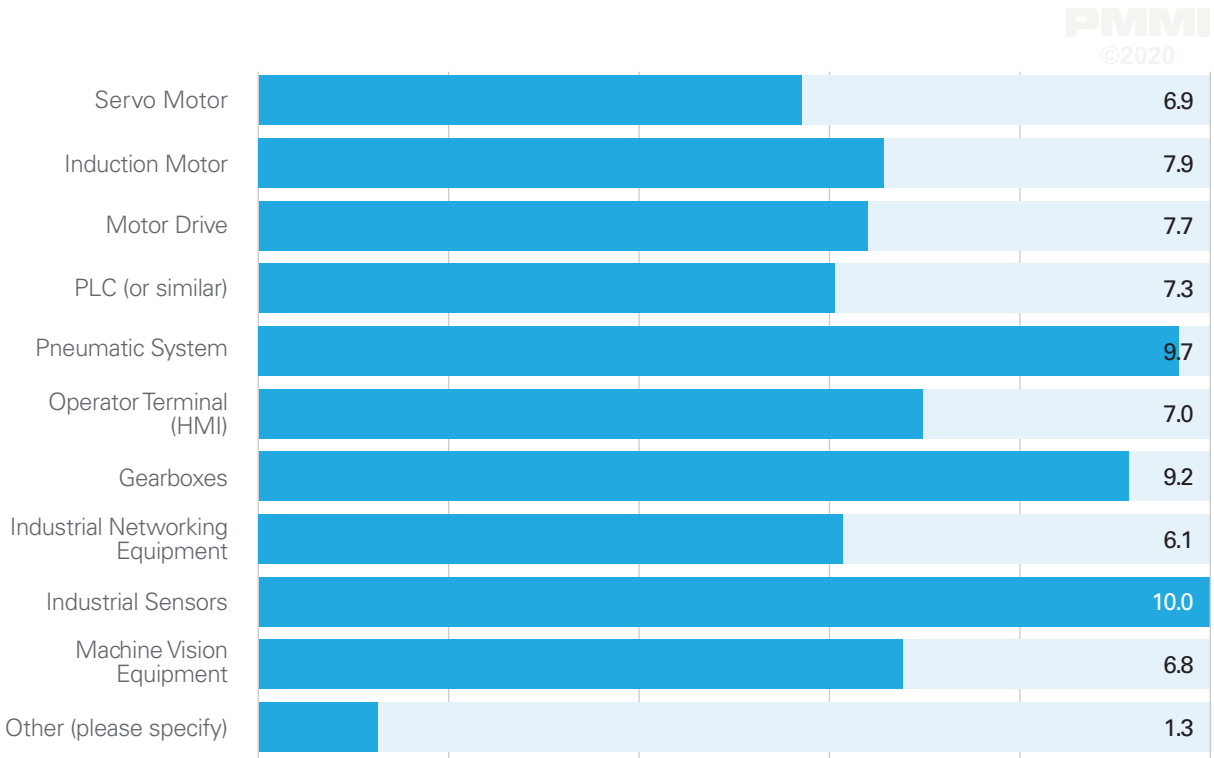


Source: PMMI

Which of the following automation components most commonly cause downtime through failure? (CPG)

	Always	Most of the time	About half the time	Sometimes	Never	Not applicable	# of Responses
Servo Motor	5.1%	2.6%	5.1%	46.2%	25.6%	15.4%	39
Induction Motor	4.9%	4.9%	9.8%	46.3%	19.5%	14.6%	41
Motor Drive	4.9%	2.4%	4.9%	53.7%	24.4%	9.8%	41
PLC (or similar)	2.4%	4.9%	7.3%	43.9%	29.3%	12.2%	41
Pneumatic System	7.3%	9.8%	17.1%	43.9%	12.2%	9.8%	41
Operator Terminal (HMI)	-	-	9.8%	53.7%	26.8%	9.8%	41
Gearboxes	4.9%	9.8%	14.6%	43.9%	19.5%	7.3%	41
Industrial Networking Equip.	2.4%	-	4.8%	38.1%	38.1%	16.7%	42
Industrial Sensors	7.1%	9.5%	14.3%	50.0%	11.9%	7.1%	42
Machine Vision Equip,	2.4%	2.4%	11.9%	42.9%	11.9%	28.6%	42
Other (please specify)	-	5.9%	5.9%	5.9%	17.6%	64.7%	17

Source: PMMI



Other responses: Sealing jaws, bars, heaters • Encoders

Source: PMMI

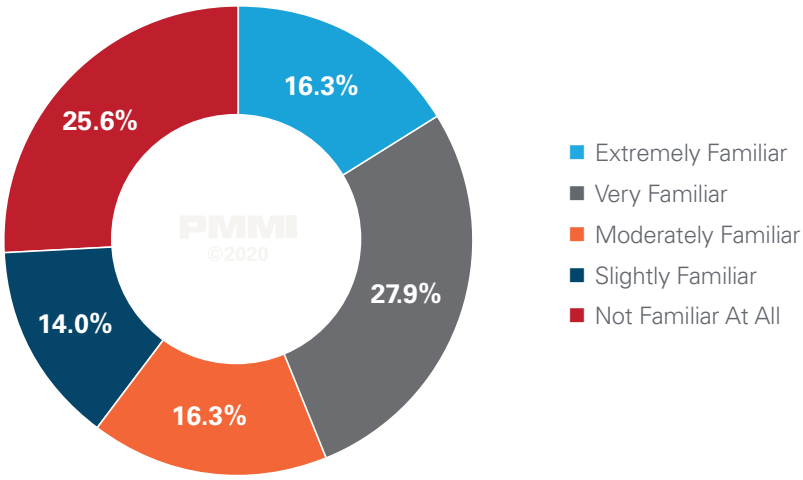
CPG: Question 7

Predictive maintenance is the use of technology to gather data on an asset, such as its temperature or vibration levels, and to perform analysis of the data to predict when the asset needs repairs to eliminate risk of failure.

Using the definition above, please indicate how familiar you are with Predictive Maintenance technology.

- Extremely familiar
- Very familiar
- Moderately familiar
- Slightly familiar
- Not familiar at all

Familiarity with PdM Definition (CPG)



43 Responses

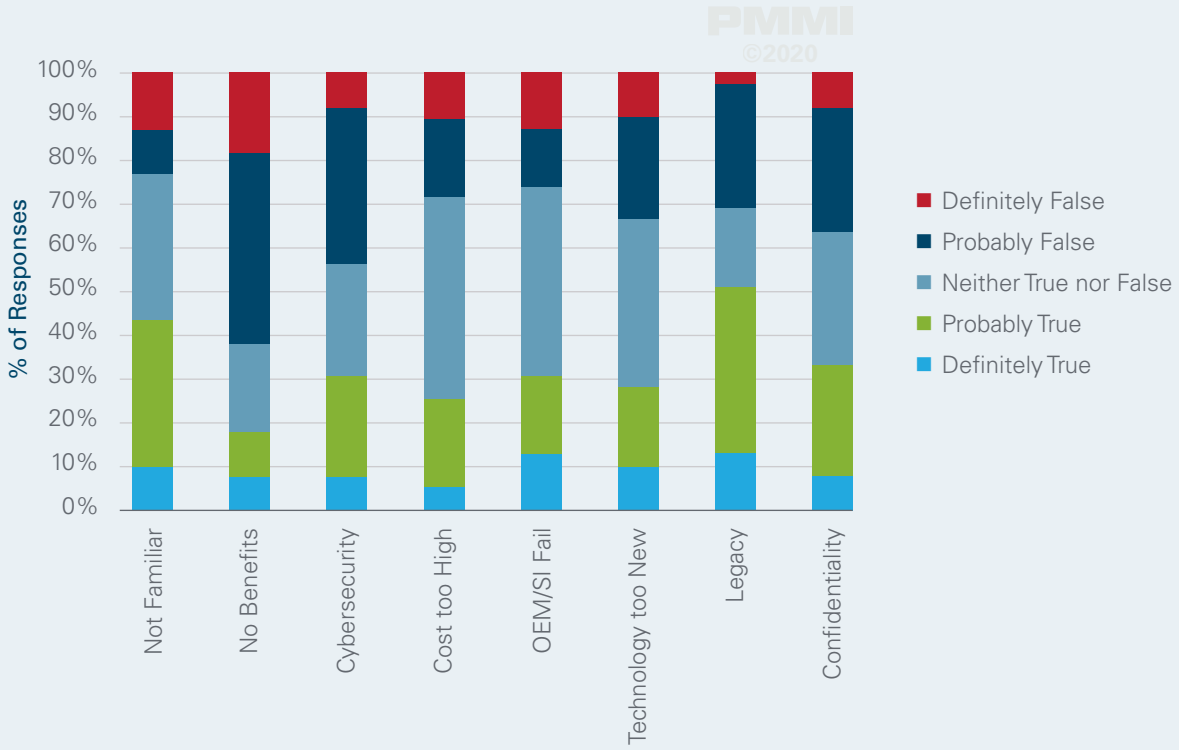
Source: PMMI

CPG: Question 9

To what extent are the following statements describing the adoption of predictive maintenance (PdM) technologies at your company, true or false?

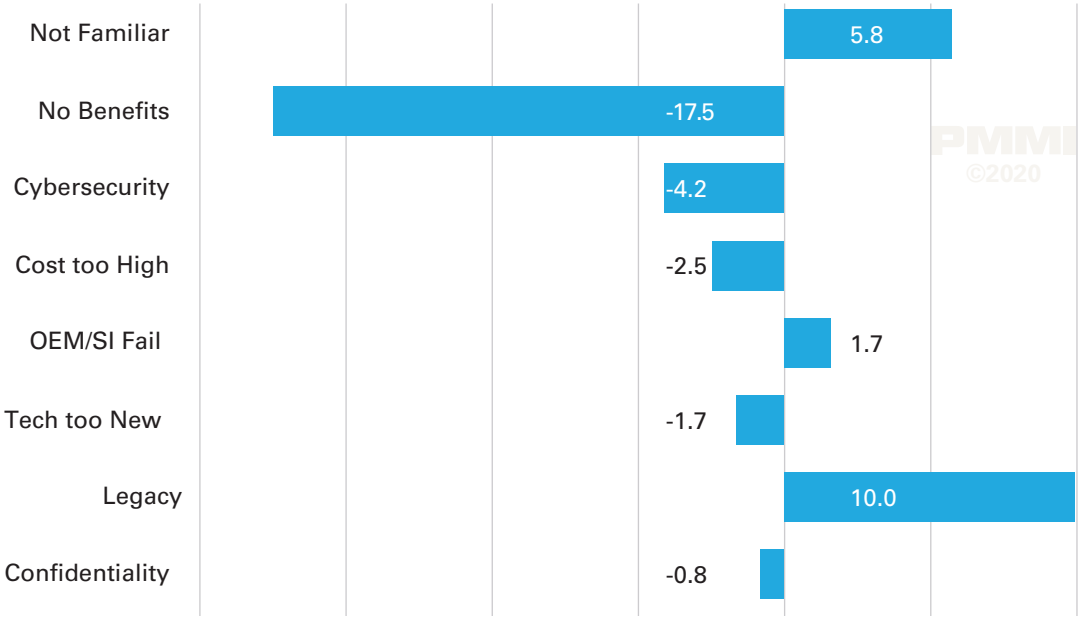
- We are not familiar with PdM technology
- Our management does not perceive any benefits from PdM.
- Our cybersecurity concerns are too great to allow OEMs remote access.
- The added cost of PdM is too high to justify.
- Our OEMs and/or system integrators do not offer this capability.
- The technology is too new.
- We do not know how to implement for old/ legacy equipment
- Our production data is too confidential to allow access to a third party.

PdM Adoption Barriers Survey Results (CPG)



To what extent are the following statements describing the adoption of predictive maintenance (PdM) technologies at your company, true or false? (CPG)						
	Definitely True	Probably True	Neither True nor False	Probably False	Definitely False	# of Responses
Not Familiar	10.3%	33.3%	33.3%	10.3%	12.8%	39
No Benefits	7.7%	10.3%	20.5%	43.6%	17.9%	39
Cybersecurity	7.7%	23.1%	25.6%	35.9%	7.7%	39
Cost too High	5.1%	20.5%	46.2%	17.9%	10.3%	39
OEM/SI Fail	12.8%	17.9%	43.6%	12.8%	12.8%	39
Tech too New	10.3%	17.9%	38.5%	23.1%	10.3%	39
Legacy	12.8%	38.5%	17.9%	28.2%	2.6%	39
Confidentiality	7.7%	25.6%	30.8%	28.2%	7.7%	39

Source: PMMI

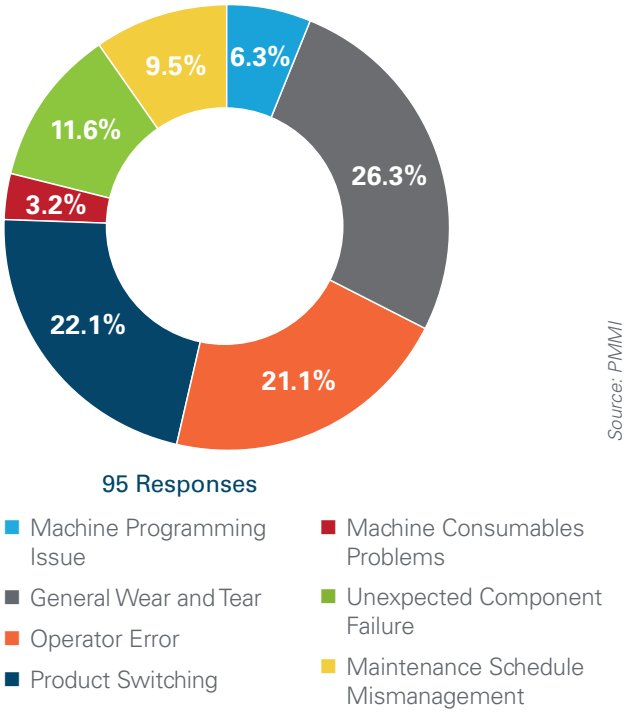


CPG: Question 10

Which of these factors do you perceive to be the most common cause of machine downtime? (Please highlight top 3)

- Machine programming issue
- General wear and tear of components
- Operator error (e.g. overuse of E-stop)
- Switching from one product type to another (e.g. to accommodate different size products)
- Machine consumables problem (e.g. glue)
- Unexpected component failure
- Maintenance schedule not properly adhered to

Most Common Cause of Downtime Survey Results (CPG)



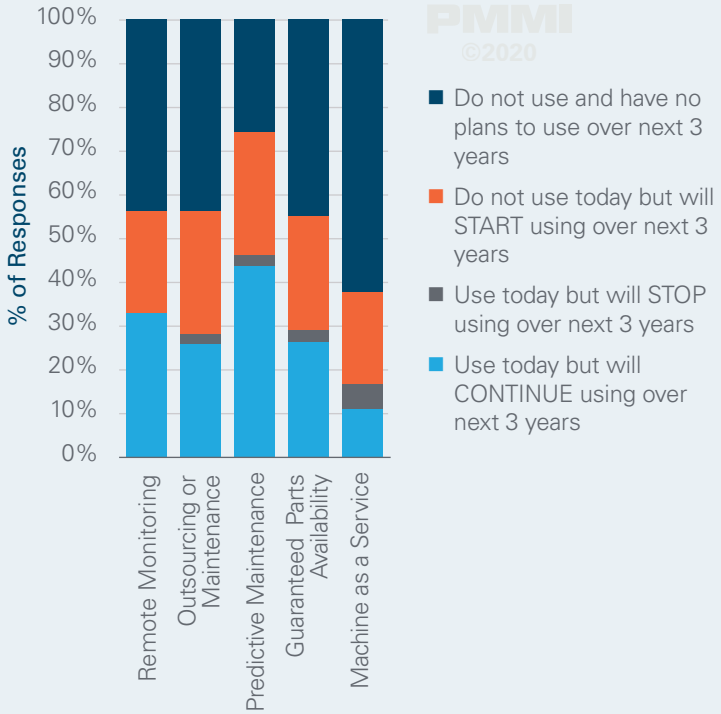
Source: PMMI

CPG: Question 11

Which of the following services are used, in the factory where you personally work?

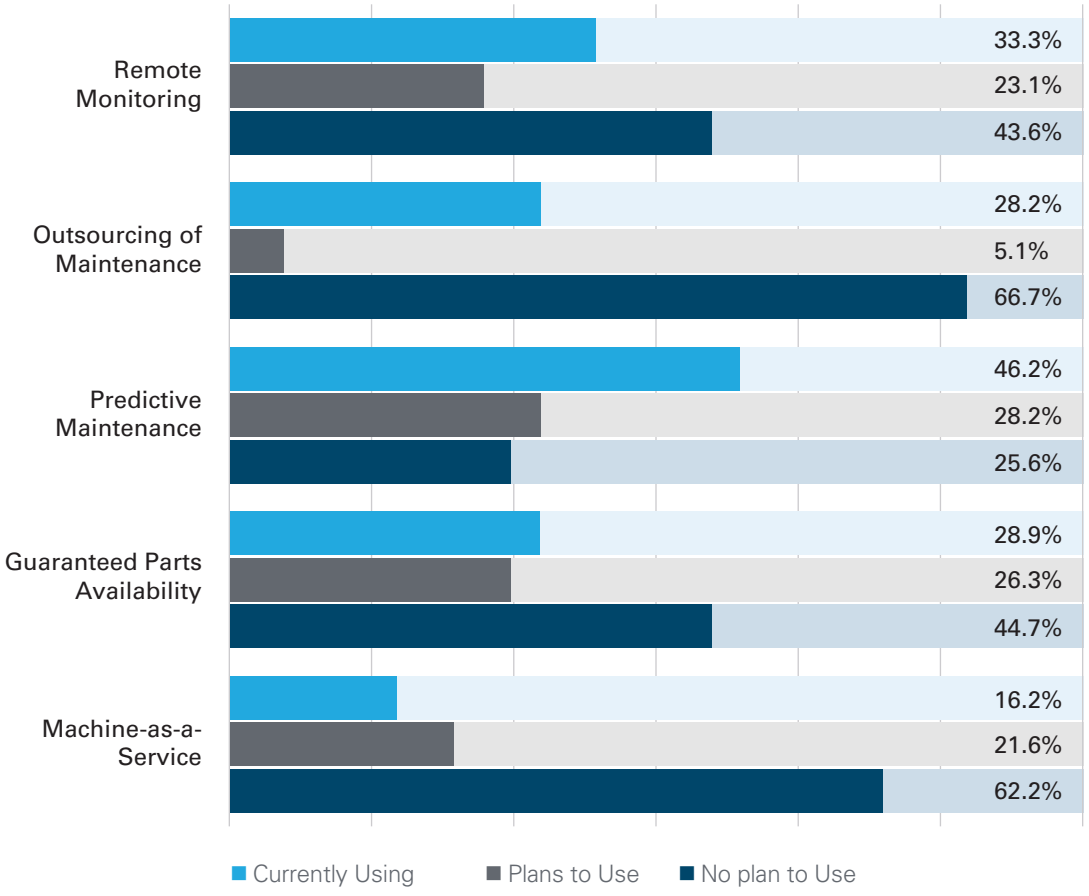
- Remote monitoring
- Outsourcing of maintenance
- Predictive maintenance
- Guaranteed parts availability
- Machine-as-a-service

Factory Services Survey Results (CPG)



Which of the following services are used, in the factory where you personally work? (CPG)					
	Use today and will CONTINUE using over next 3 years	Use today but will STOP using over next 3 years	Do not use today but will START using over next 3 years	Do not use and have no plans to use over next 3 years	# of Responses
Remote Monitoring	33.3%	-	23.1%	43.6%	39
Outsourcing of Maintenance	25.6%	2.6%	5.1%	66.7%	39
Predictive Maintenance	43.6%	2.6%	28.2%	25.6%	39
Guaranteed Parts Availability	26.3%	2.6%	26.3%	44.7%	38
Machine-as-a-Service	10.8%	5.4%	21.6%	62.2%	37

Source: PMMI



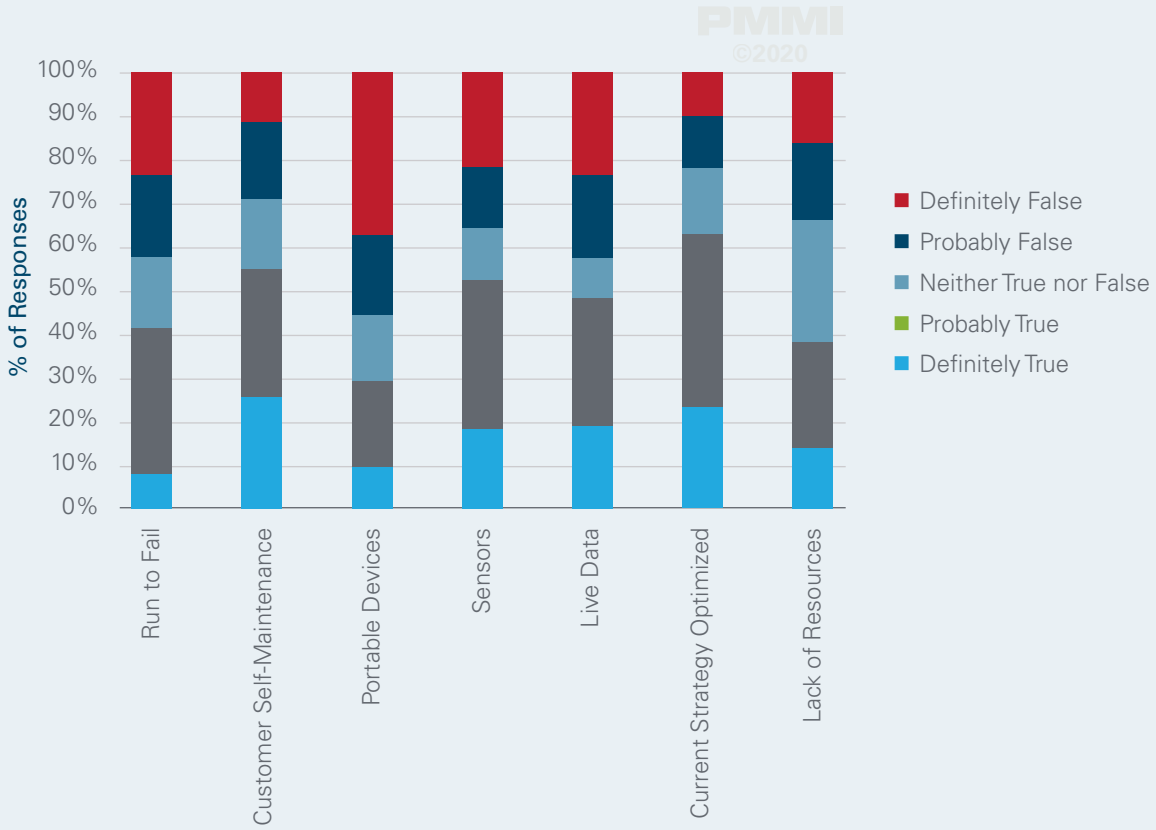
OEM and System Integrator Responses

OEM & System Integrators: Question 1

To what extent are the following statements, describing your company's current maintenance offering, true or false?

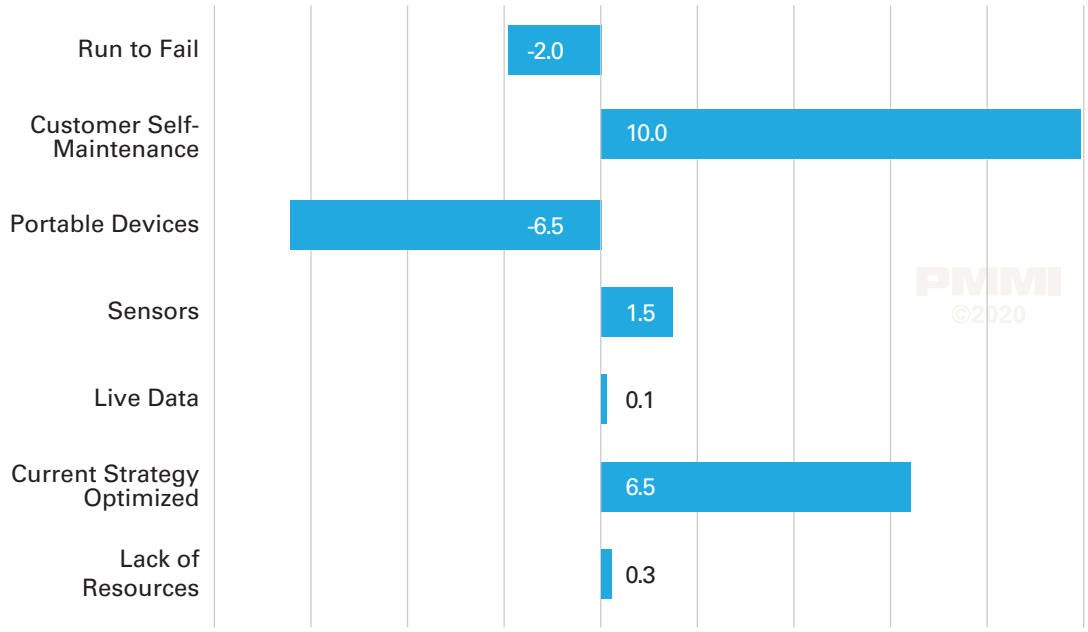
- We tend to "run to fail," and only fix problems as they arise
- Our customers conduct most of the maintenance on their production lines
- We use portable monitoring devices to evaluate which assets are in need of maintenance
- We use measurement devices on the machinery to monitor equipment status
- We are able to provide live data as to the current health of machines during operation
- We perceive our current maintenance strategy to be optimized to minimize downtime for our customers
- We lack the resources to effectively provide best in class maintenance offerings to our customers

Current Maintenance Offering Survey Results (OEM & SI)



To what extent are the following statements, describing your company's current maintenance offering, true or false? (OEM & SI)							
	Definitely True	Mostly True	Neither True nor False	Mostly false	Definitely False	Do not Know	# of Responses
Run to Fail	8.2%	32.9%	16.5%	18.8%	23.5%	85	52
Customer Self-Maintenance	25.6%	45.3%	18.6%	7.0%	3.5%	86	52
Portable Devices	9.4%	20.0%	15.3%	17.6%	37.6%	85	52
Sensors	18.6%	33.7%	11.6%	14.0%	22.1%	86	52
Live Data	18.8%	29.4%	9.4%	18.8%	23.5%	85	52
Current Strategy Optimized	23.3%	39.5%	15.1%	11.6%	10.5%	86	52
Lack of Resources	14.0%	24.4%	27.9%	17.4%	16.3%	86	52

Source: PMMI



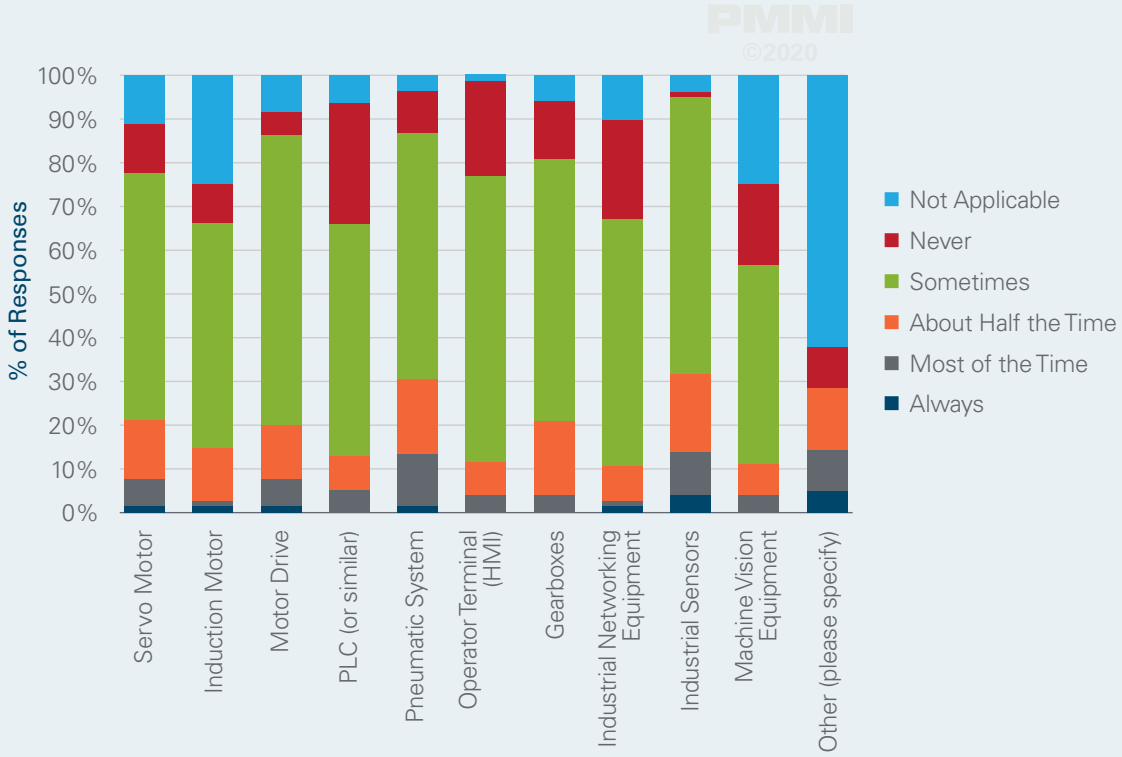
OEM & System Integrators: Question 2

Which of the following automation components most commonly cause downtime through failure?

- Servo motor
- Induction motor
- Motor drive (servo or VFD)
- PLC (or similar)
- Pneumatic system
- Operator terminal (HMI)
- Gearboxes
- Industrial networking equipment
- Industrial sensors
- Machine vision equipment
- Other (please specify)

  - Industrial Pumps
  - Bearings
  - Safety Equipment
  - Changes in programming and cables
  - Belts, bearings and couplings
  - Refrigeration compressors and related equipment

Downtime Through Failure Survey Results (OEM & SI)



Source: PMMI

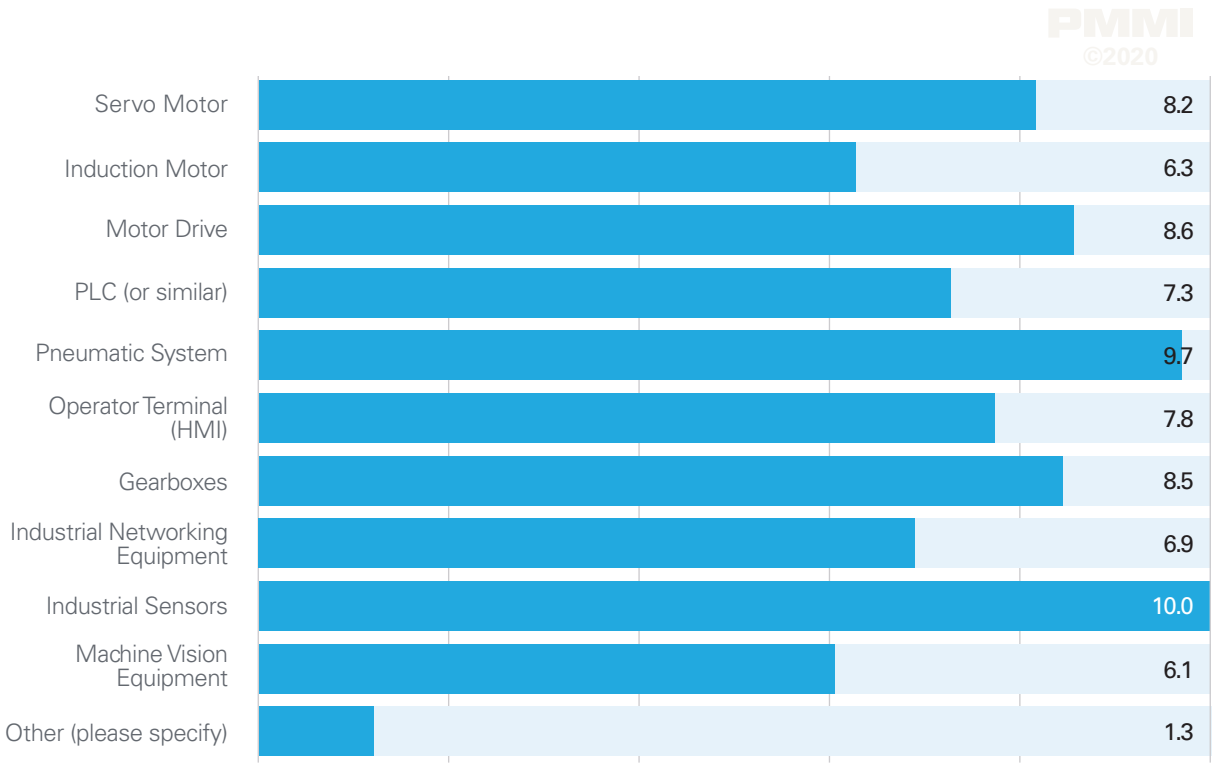
Which of the following automation components most commonly cause downtime through failure? (OEM & SI)

	Always	Most of the time	About half the time	Sometimes	Never	Not applicable	# of Responses
Servo Motor	1.3%	6.3%	13.8%	56.3%	11.3%	11.3%	80
Induction Motor	1.3%	1.3%	11.8%	51.3%	9.2%	25.0%	76
Motor Drive	1.3%	6.3%	12.5%	66.3%	5.0%	8.8%	80
PLC (or similar)	0.0%	5.1%	7.6%	53.2%	27.8%	6.3%	79
Pneumatic System	1.2%	12.2%	17.1%	56.1%	9.8%	3.7%	82
Operator Terminal (HMI)	0.0%	3.8%	7.7%	65.4%	21.8%	1.3%	78
Gearboxes	0.0%	3.7%	17.1%	59.8%	13.4%	6.1%	82
Industrial Networking Equip.	1.3%	1.3%	7.7%	56.4%	23.1%	10.3%	78
Industrial Sensors	3.8%	10.0%	17.5%	63.8%	1.3%	3.8%	80
Machine Vision Equip.	0.0%	3.8%	7.5%	45.0%	18.8%	25.0%	80
Other (please specify)	4.8%	9.5%	14.3%	0.0%	9.5%	61.9%	21

Note "Other" responses received were:

- *Industrial pumps*
- *Bearings*
- *Safety equipment*
- *Changes in programming and cables*
- *Belts, bearings, and couplings*
- *Refrigeration compressors and related equipment*

Source: PMMI

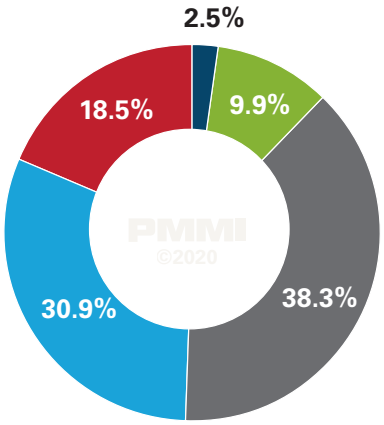


OEM & System Integrators: Question 3

What approach do you use to measure when a machine component needs replacing? (Pick one)

- We currently do not have a strategy for calculating component replacement.
- We have estimated the run-time for each component, with a large margin of error.
- We have found a way to calculate the typical lifecycle of components and use this to time replacements.
- We are able to measure the status of an asset.
- Other - write in

Approach to Measurement (OEM & SI)



81 Responses

Source: PMMI

Other Responses:

- For some components estimated run-time for some others we measure the status on asset
- Relevant to runtime, and specific customer's maintenance plan or lack thereof.

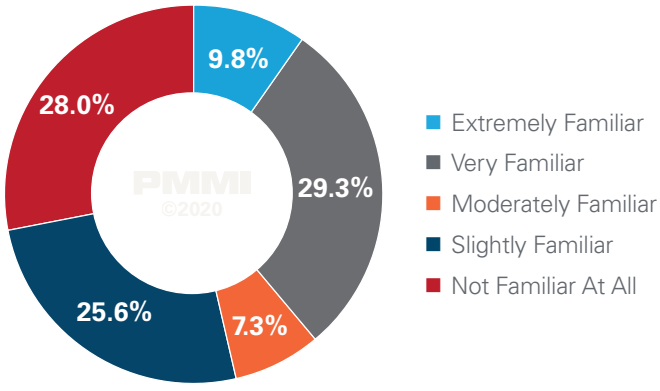
OEM & System Integrators: Question 4

"Predictive maintenance is the use of technology to gather data on an asset, such as its temperature or vibration levels, and to perform analysis of the data to predict when the asset needs repairs to eliminate risk of failure."

Please indicate how familiar you are with this type of technology.

- Extremely familiar
- Very familiar
- Moderately familiar
- Slightly familiar
- Not familiar at all

Familiarity Survey Results (OEM & SI)



82 Responses

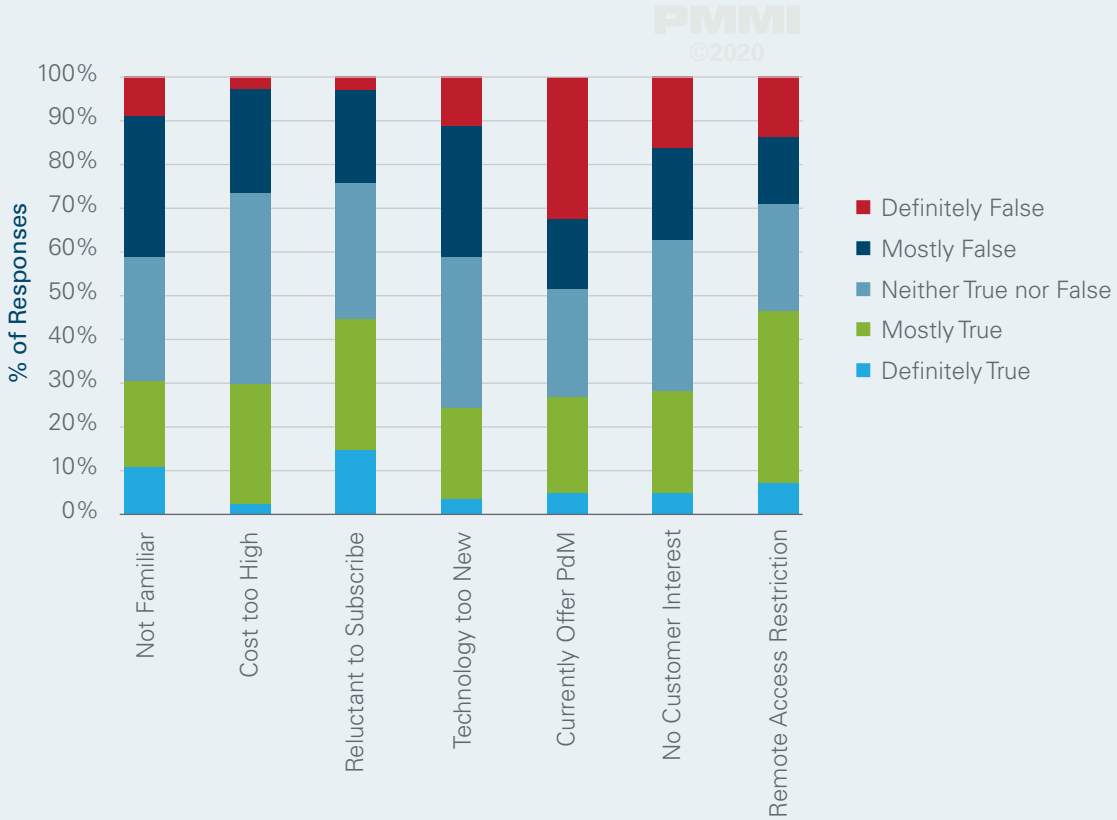
Source: PMMI

OEM & System Integrators: Question 5

To what extent are the following statements describing the adoption of predictive maintenance (PdM) technologies at your company, true or false?

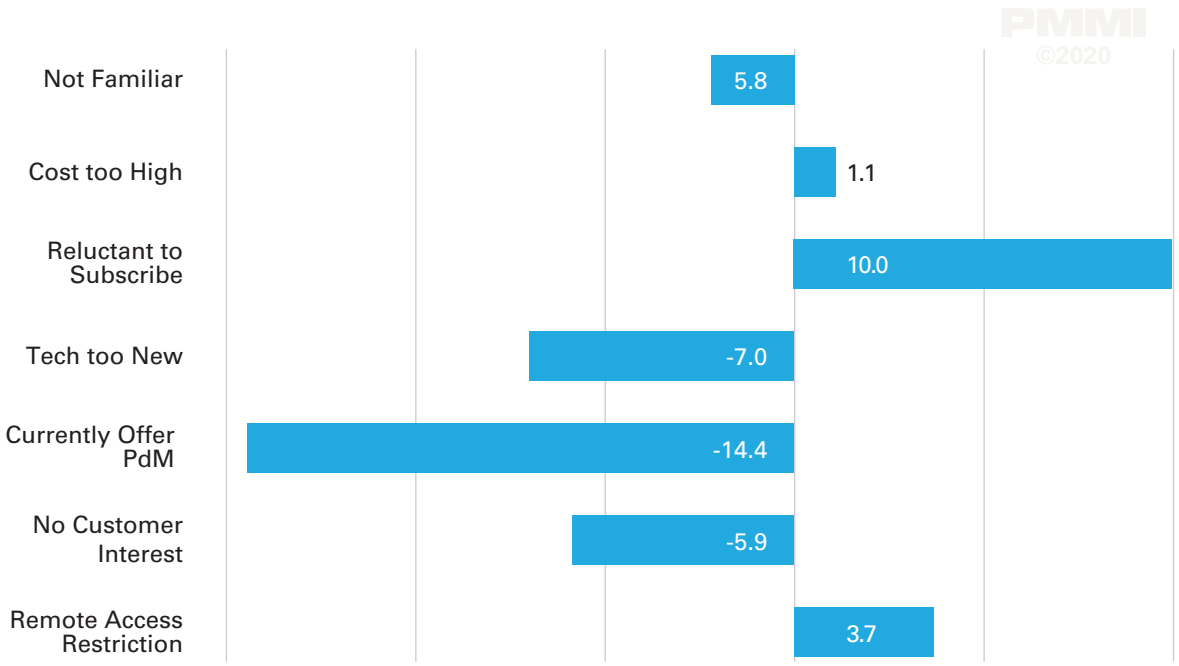
- We are not familiar with PdM technology
- The added cost of PdM technology is too high to justify.
- We do not want to have to pay for an ongoing subscription to access sensor data from an automation vendor.
- The technology is too new
- We currently offer machines with PdM technology
- None of our customers have expressed interest in PdM technology
- Our customers will not allow remote access to their machinery

PdM Adoption Survey Results (OEM & SI)



To what extent are the following statements describing the adoption of predictive maintenance (PdM) technologies at your company, true or false? (OEM & SI)						
	Definitely True	Mostly True	Neither True nor False	Mostly False	Definitely False	# of Responses
Not Familiar	11.1%	19.8%	28.4%	32.1%	8.6%	81
Cost too High	2.5%	27.5%	43.8%	23.8%	2.5%	80
Reluctant to Subscribe	15.0%	30.0%	31.3%	21.3%	2.5%	80
Tech too New	3.7%	21.0%	34.6%	29.6%	11.1%	81
Currently Offer PdM	4.9%	22.2%	24.7%	16.0%	32.1%	81
No Customer Interest	4.9%	23.5%	34.6%	21.0%	16.0%	81
Remote Access Restriction	7.4%	39.5%	24.7%	14.8%	13.6%	81

Source: PMMI

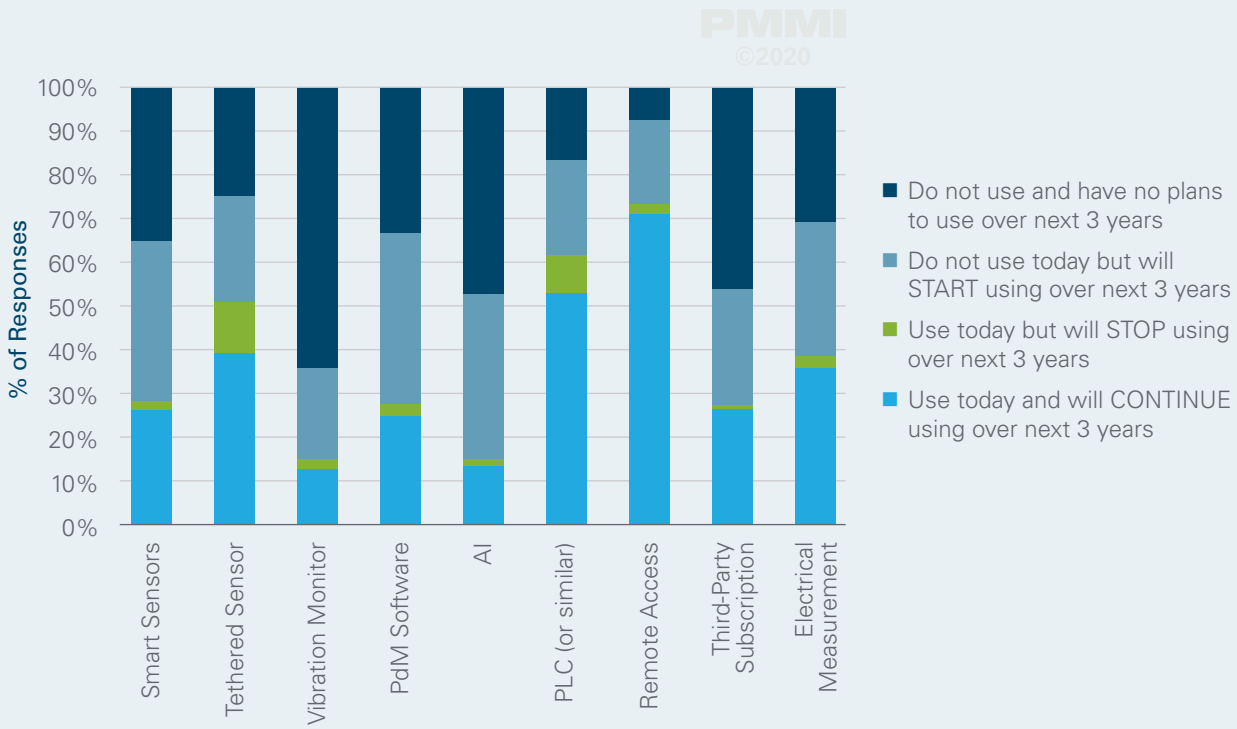


OEM & System Integrators: Question 6

Which of the following maintenance technologies is your company currently using?

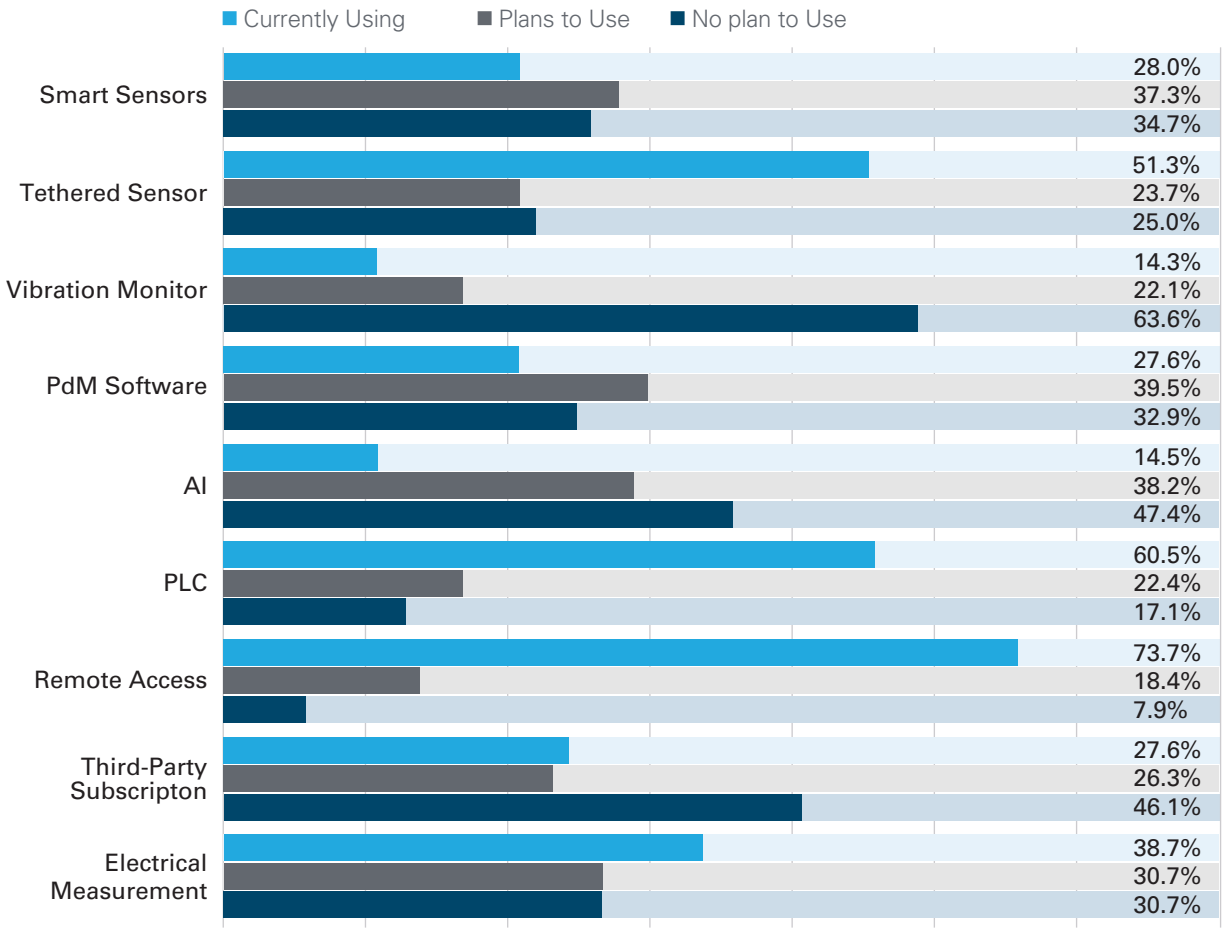
- Smart sensors (wireless sensors with on-board compute)
- Conventional sensor connected via a cable to measure device health.
- Handheld vibration monitor
- Predictive maintenance software (analytics + dashboard)
- Artificial intelligence to analyze maintenance data
- PLC (or similar) programmed to measure usage of key assets
- Remote access to client machinery
- Subscription to a third-party cloud-based analytics platform
- Measurement of the electrical behavior of the machine and/or assets

Company Utilization Survey Results(OEM & SI)



Which of the following maintenance technologies is your company currently using? (OEM & SI)					
	Use today and will CONTINUE using over next 3 years	Use today but will STOP using over next 3 years	Do not use today but will START using over next 3 years	Do not use and have no plans to use over next 3 years	# of Responses
Smart Sensors	26.7%	1.3%	37.3%	34.7%	75
Tethered Sensor	39.5%	11.8%	23.7%	25.0%	76
Vibration Monitor	13.0%	1.3%	22.1%	63.6%	77
PdM Software	25.0%	2.6%	39.5%	32.9%	76
AI	13.2%	1.3%	38.2%	47.4%	76
PLC (or similar)	52.6%	7.9%	22.4%	17.1%	76
Remote Access	71.1%	2.6%	18.4%	7.9%	76
Third-Party Subscription	26.3%	1.3%	26.3%	46.1%	76
Electrical Measurement	36.0%	2.7%	30.7%	30.7%	75

Source: PMMI



OEM & System Integrators: Question 7

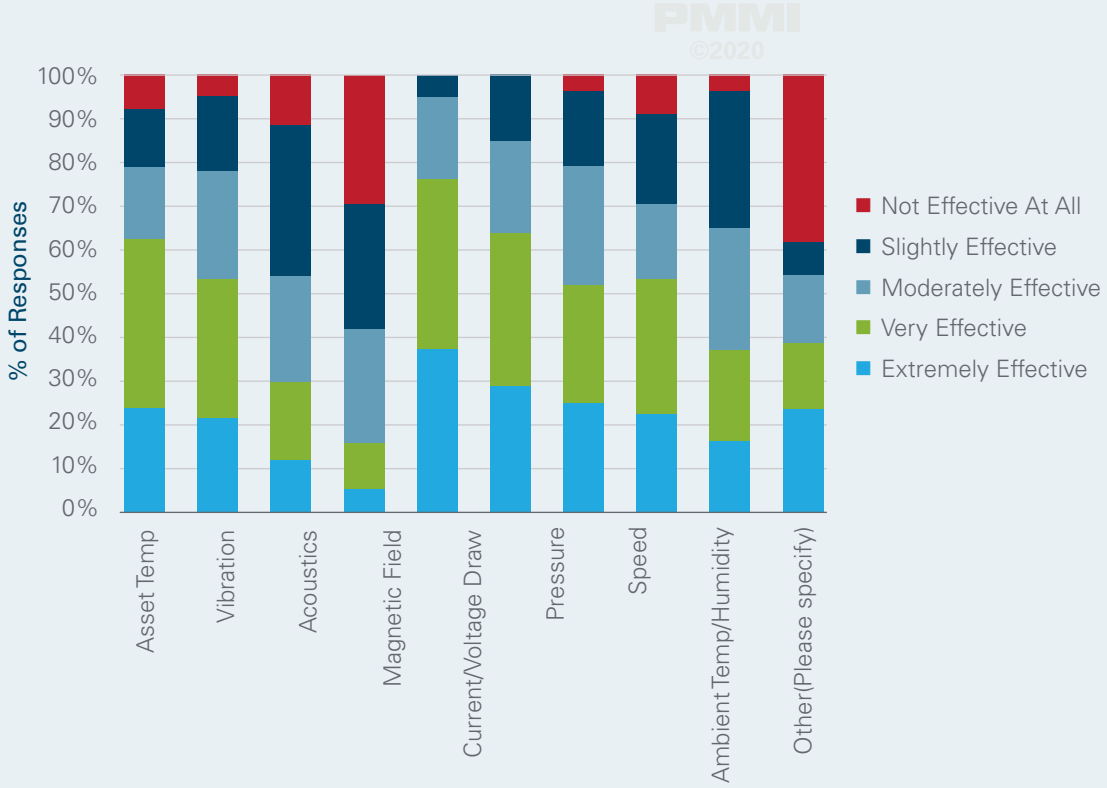
To what extent are the following statements describing the adoption of predictive maintenance (PdM) technologies at your company, true or false?

- Asset temperature
- Vibration
- Acoustic (noise)
- Magnetic field
- Run-time
- Current/voltage draw
- Speed
- Pressure
- Ambient temperature/humidity
- Other (please specify)

  _____

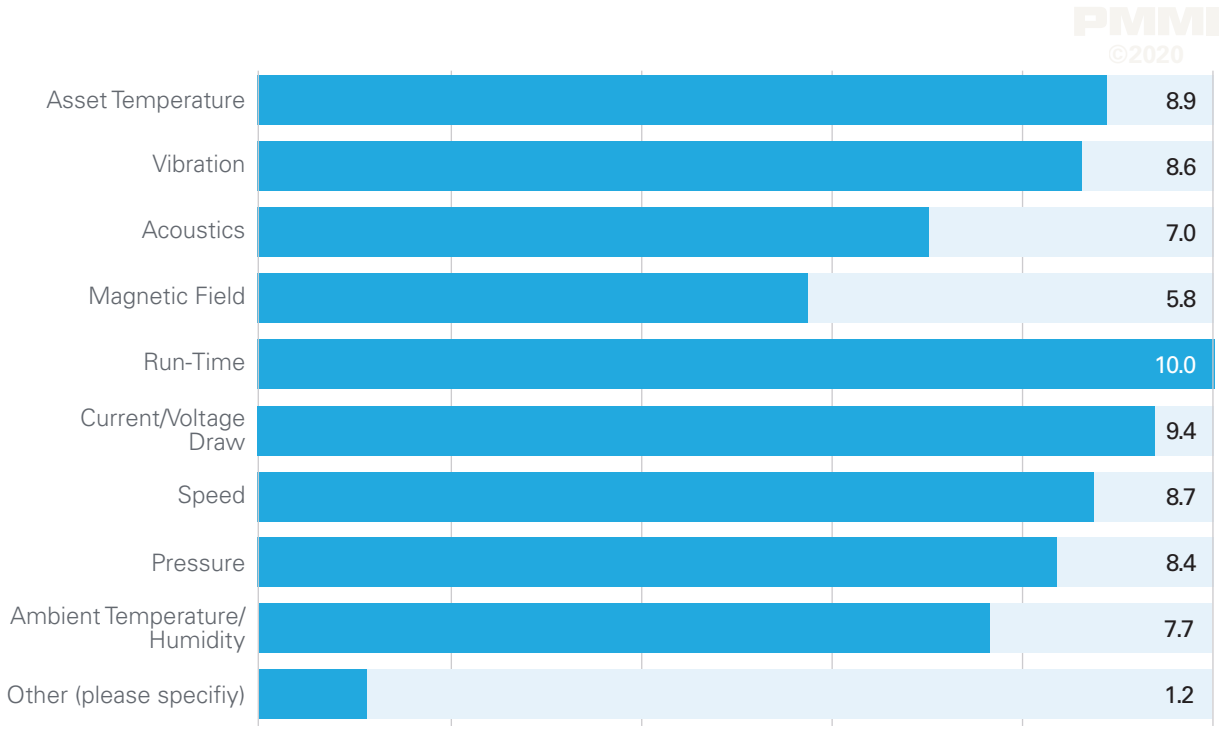
  - Load Charge voltage
  - Lubricant health
  - Cycle count
  - Load
  - Gearbox or compressor oil temperature

Effective Data Survey Results (OEM & SI)



Effective Data (OEM & SI)						
	Extremely Effective	Very Effective	Moderately Effective	Slightly Effective	Not Effective at all	# of Responses
Asset Temp.	23.4%	39.0%	16.9%	13.0%	7.8%	77
Vibration	20.8%	32.5%	24.7%	16.9%	5.2%	77
Acoustics	11.7%	18.2%	23.4%	35.1%	11.7%	77
Magnetic Field	5.2%	10.4%	26.0%	28.6%	29.9%	77
Run-time	36.8%	39.5%	18.4%	5.3%	-	76
Current/Voltage Draw	28.6%	35.1%	20.8%	15.6%	-	77
Speed	24.7%	27.3%	27.3%	16.9%	3.9%	77
Pressure	22.1%	31.2%	16.9%	20.8%	9.1%	77
Ambient Temp./ Humidity	15.8%	21.1%	27.6%	31.6%	3.9%	76
Other (please specify)	23.1%	15.4%	15.4%	7.7%	38.5%	13

Note: "Other" responses received were:
Charge voltage
Lubricant health
Cycle count
Load
Gearbox or compressor oil temperature



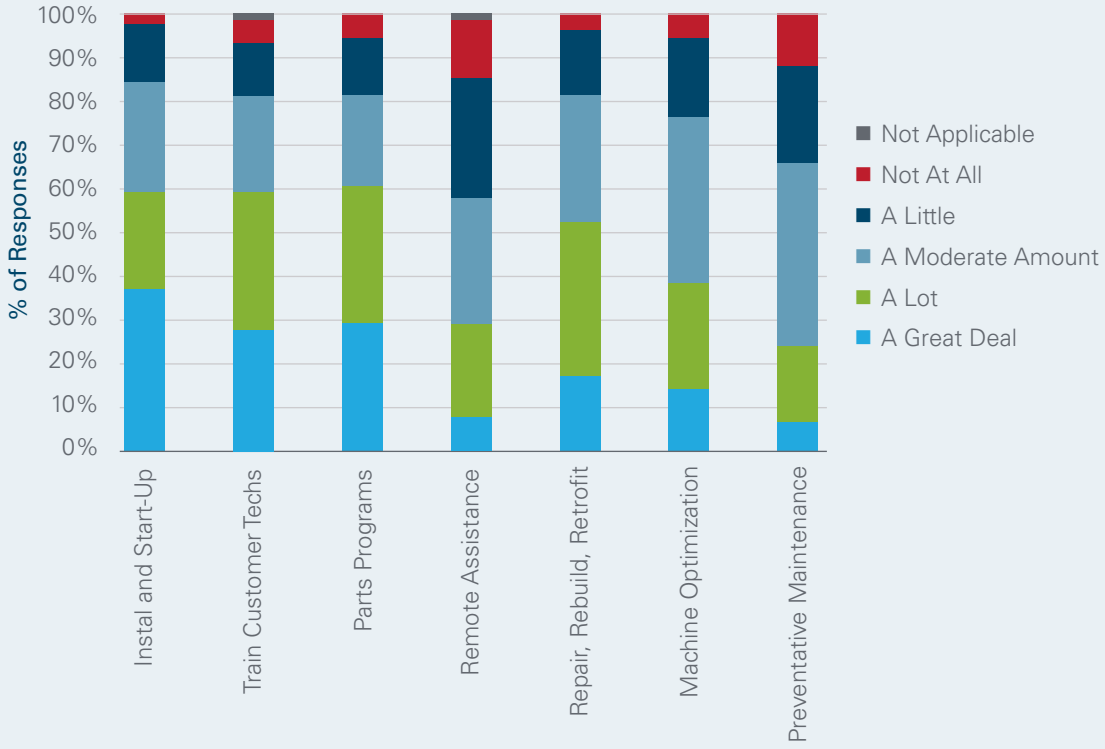
Source: PMMI

OEM & System Integrators: Question 8

For each of the following types of maintenance programs your company offers, please indicate the degree to which you have been able to monetize these programs.

- Installation and start-up
- Training of our customers' technicians
- Parts programs
- Remote assistance
- Repair, rebuild and/or retrofit
- Machine evaluation and optimization
- Preventative maintenance programs

Monetization Survey Results (OEM & SI)



For each of the following types of maintenance programs your company offers, please indicate the degree to which you have been able to monetize these programs. (OEM & SI)							
	A Great Deal	A Lot	A Moderate Amount	A Little	Not At All	Not Applicable	# of Responses
Install and Start-up	28	17	19	10	2	-	76
Train Customer Techs	21	24	17	9	4	1	76
Parts Programs	22	24	16	10	4	-	76
Remote Assistance	6	16	22	21	10	1	76
Repair, Rebuild or Retrofit	13	27	22	11	3	-	76
Machine Optimization	11	18	29	14	4	-	76
Preventative Maintenance	5	13	32	17	9	-	76

Source: PMMI

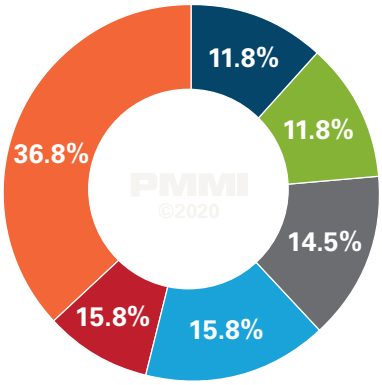
Source: PMMI

OEM & System Integrators: Question 9

In your opinion, which of these maintenance programs has the potential for the greatest amount of new revenues? Pick one

- Installation and Start-up
- Parts Programs
- Remote Assistance
- Repair, Rebuild and/or Retrofit
- Machine Evaluation and Optimization
- Preventative Maintenance Programs

Highest Potential Revenues (OEM & SI)



76 Respondents

Source: PMMI

PMMI Business Intelligence

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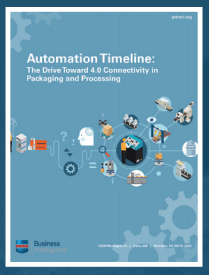

Automation Timeline

Industrial IoT Readiness