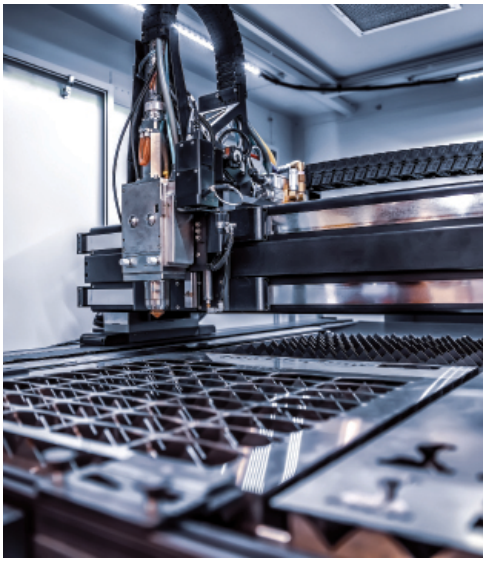
INNOVATIVE MACHINERY DESIGNS DRIVING PRODUCTIVITY, SAFETY AND RELIABILITY

KEY TRENDS AND INSIGHTS TO DESIGN MORE RELIABLE MACHINERY APPLICATIONS



EXECUTIVE SUMMARY

The machines used to manufacture and assemble today's increasingly connected devices, equipment, vehicles, and other items need to be just as advanced and intelligent as the end products themselves. Enhanced connectivity and automation within machinery and equipment is helping increase overall reliability, efficiency, and profitability. We talked to design engineers around the world and have captured their insights on current trends and how integrating connectivity into designs can increase productivity and user safety.

1. The Future of Machinery Design

Design engineers find adopting new technologies and integrating connected solutions into machinery designs as value-add towards increasing efficiency, reliability, and safety. Technologies such as predictive maintenance are becoming critical features in machinery to enable operations managers to proactively plan service and minimize business disruption.

2. Design Considerations

Engineers are evolving machine designs through the use of real-time data intelligence e.g. artifical intelligence (AI), machine learning, and industrial internet of things (IIoT) to automate operations and enable interoperability. These technological advancements are requiring components that will not only stand up to harsh environments but will also reliably transmit critical data from component to component, machine to machine, and machine to enterprise.

3. Product Solutions for Design Requirements

The growing demand for connected machine applications and technologies is recognized by innovative suppliers that have proven engineering expertise in high-performance product solutions. At TE Connectivity (TE), many products, used by engineers to design intelligent applications and connected devices, are suitable for harsh manufacturing environments and offer features such as miniaturization, safety, sealing and reliability, to name a few.

1. The Future of Machinery

We are in the midst of an era of transformative change for manufacturing. In factories around the world, technology is quickly becoming the foundation for productivity and safety.

For example, machine vision systems, which provide imaging-based automatic inspection/analysis, and AI are enabling manufacturers to continually monitor and optimize production. Modular cells, automation, and 3D printing are allowing production lines to be more demand-led, localized, and customizable.

The Journey

Manufacturing in the early 2000s consisted of complex and costly operation processes using machines that functioned on proprietary networks. This required numerous machine software experts and introduced limitations to traditional machine maintenance. An issue that can arise from proprietary networks is when a machine malfunctions and the dedicated on-site software expert is not available. This would result in that machine or even the entire production line being down until the software expert was available and able to discover and repair the malfunction.

In contrast, today's enhanced automation and connectivity network capabilities allow for networked equipment or manufacturing machines to function on a universal open network, requiring only one expert to handle the open network with the ability to manage the machine software remotely through the cloud. This enables predictive maintenance, machine-to-machine communication, and a seamless process with minimal on-site intervention required.

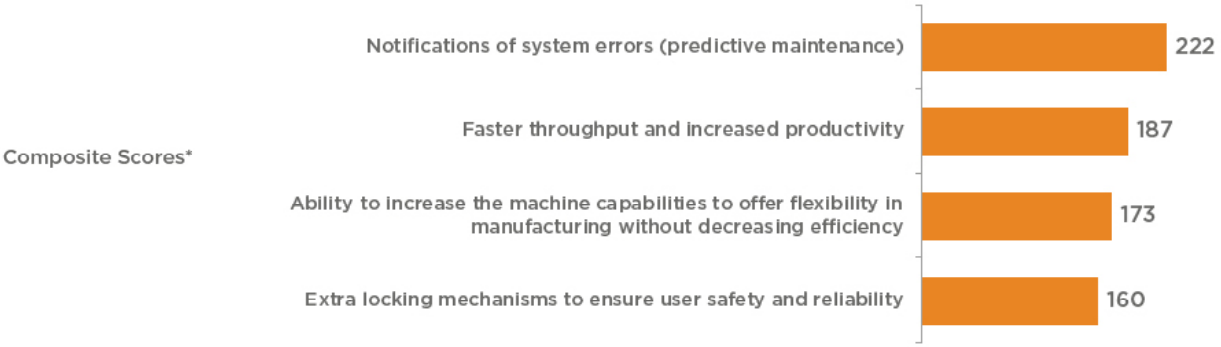
5G for smart manufacturing — Data connectivity built into machines will rely on 5G due to more automation, AI, IIoT, collaborative robots, and virtual and augmented reality being integrated into the production space. 5G offers wireless flexibility, high-bandwidth capabilities, low latency, and high reliability. It enables networked machines and equipment to communicate wirelessly with each other and with back-end systems in ways that were previously not possible. (Learn more about the future of 5G here.)

Predictive maintenance — One of the most critical functions for today's machines is the ability to sense, collect and act on data that can prevent machine breakdowns and limit downtime. Operators or site managers can optimize maintenance tasks in real-time, preventing major failures from occurring, minimizing disruptions to production, and extending the life of the machinery.

As mentioned, predictive maintenance can limit downtime and preserve the life of the machine. The smart machine can report usage analytics that can enhance the productivity and throughput of the machine. By generating a granular level of details in real-time, data connectivity allows workers to continuously monitor the machine analytics and make improvements as needed – getting increased efficiency during production. Workers are automatically notified if there is a system error, odd vibration or noise, enabling management to be notified and predictive maintenance to occur before mass production time is lost.

FIG. 1: **Importance of smart machinery features and requirements**

Notifications of system errors are the features and requirements considered most important to engineers when designing machinery. Increased productivity and more flexibility are also seen as important.



*Composite score is a weighted average based on points given to relative order of choice.

Source: TE Connectivity and IEEE Survey/Analysis 2020.

FUTURE: Post Covid-19 Impact

Virtual and augmented reality (VR & AR) — According to pwc, one in three manufacturers either already uses or plans to use virtual reality (VR) technology within the next three years, and similar usage rates and adoption plans appear for augmented reality (AR) technology. Not only are engineers using VR and AR technologies for product design and development, these technologies are also proving to be useful for safety and manufacturing skills training; maintenance, repair and equipment operations; and remote collaboration.

In a post-COVID world, the VR and AR technologies, along with the IIoT and collaborative robots, may become crucial to manage and sustain social distancing and safety to adapt to uncertainties over the long term.

"AS A RESULT OF THE COVID-19 PANDEMIC, IT IS CRITICAL TO ADDRESS ISSUES OF SOCIAL DISTANCING, SEPARATION OF WORKERS AND REDUCTION OF TOUCH POINT. FOR EXAMPLE, USING HMIs AND OTHER COMPONENTS THAT CAN BE WASHED DOWN BETWEEN SHIFTS, OR USE WIRELESS ACCESS POINTS TO ALLOW FOR SMARTPHONES OR TABLETS TO CONNECT TO THE MACHINE USER INTERFACE."

— Survey Respondent, TE Connectivity and IEEE Survey/Analysis 2020.

As machines are asked to do more and become increasingly connected and complex, design engineers that work on these machines also need to do more to ensure reliability, quality, safety, and cybersecurity. Failure means loss of production, missed customer deadlines, and potentially compromising the safety of workers. Designers are faced with integrating additional software and functionalities into machines—which is in addition to products already included such as signal, power, motor, antenna and relay components. By integrating additional software and functionalities, the machine will be able to communicate with the operator, with other applications and the cloud, and even to another machine. Opportunities for failure are everywhere, so designers must choose high-quality components that are proven reliable and can enhance the safety of the product and assembly process.

"WITHIN THE NEAR FUTURE, I ANTICIPATE THAT COMPUTER PROGRAMS WILL TAKE THE LEAD AND OPERATE THE MACHINES BY LOADING RAW MATERIALS AND PROCESSING THEM THROUGH THE SYSTEM TO THE POINT OF A COMPLETED UNIT THAT IS READY FOR THE CUSTOMER WHO WENT ONLINE AND ORDERED IT. LOADING AND SHIPPING WILL BE ACHIEVED THROUGH SELF-DRIVING TRUCKS THAT WILL DELIVER THE FINISHED UNITS TO A JOB SITE OR THE CUSTOMER."

— Survey Respondent, TE Connectivity and IEEE Survey/Analysis 2020.

2. Design Considerations

From manufacturing machines to heat induction equipment and furnaces to field machinery and equipment used in the oil and gas industry, designers need to source components that will not only stand up to harsh environments but will also reliably transmit tons of critical data from component to component, machine to machine, and machine to enterprise. The cloud stores all data analytics from the machine, but that data needs to be transmitted reliably to provide accurate actionable data to monitor usage, increase operating safety, and enhance productivity (throughput).

As more machines become integrated with other machines and devices and incorporate autonomous functionality, AI, machine learning, and IIoT, there is an increasing need for interoperability. Standards and communication protocols must be considered early in the design stage to ensure reliable data transmission and analysis between sensors, actuators, machines, systems, and platforms. In addition to autonomous equipment, the ideal machine can be programmed to swap out functioning tools without any human interface and at a speed that minimizes downtime.

FIG. 2: **End user safety is top priority.**

MANUFACTURING:

395,300 injuries
IN WORKPLACES ACROSS THE US

621 fatalities
EXPOSURE TO HARMFUL SUBSTANCES OR ENVIRONMENTS

Most Common Safety Violations:
- Unsafe machinery and inadequate machine guarding
- Inadequate eye and face protection
- Failure to control hazardous energy (lockout/tagout violations)

Source: Work Injury Source. https://workinjurysource.com/workplace-injury-statistics-2019/

Designing for Safety — Redundancy is Key

System errors can mean the machine is not operating correctly. By having integrated components that can recognize these errors, the operator's safety is not compromised. The smarter the machine, the less user interaction is needed for operation.

Operational safety is enabled by intelligence, reliability and quality components. It is critical for all functions that require human interaction to have safety protocols matched to it – whether they are implemented mechanically or by software (safety light curtain, safety integrity level (SIL) software, etc.). Although automation and robots can be used for some connector-assembly tasks, many parts are still assembled by hand, so ergonomics is a key safety consideration in machine design. Aim to eliminate or reduce unnecessary motions made by the worker during the assembly process, for example, when mating two connectors. Repetitive motions may cause carpal tunnel syndrome (CTS), strained muscles and other physical injuries that impact workers' productivity, morale and health, as well as increase the tendency to make errors. Designers can try to minimize potential worker injuries by using ergonomically friendly connector designs and integrated solutions that come already assembled.

Mechanical and software redundancy should be incorporated in the machine operations to ensure that the equipment shuts down promptly and properly at crucial times. For example, when the stamping operator attempts to remove a piece of metal from the machine, the machine must stop automatically to prevent the operator's fingers from getting stamped. The human machine interface (HMI) controls need to function properly for optimal performance and safety.

Additional safety mechanisms may include splash guards and safety light curtains to keep operators safe where hot oils or other fluids may be present and where moving machine parts would be in proximity to the operator's fingers, hands or clothing. Designers must measure and understand the SIL of their machine and incorporate the appropriate safety instrumented system (SIS). For example, the SIS may be designed to stop certain machine functions or operations when a certain parameter is reached or exceeded. It may also automatically trigger a safety instrumented function, such as a relay cutting off power to a heater circuit when a specific (potentially hazardous) high temperature is reached, bringing the machine back to a safe state.

Design Engineer Considerations & Machinery Design Requirements

As this increasing push for automation, connectivity and advanced functionality within machinery continues, designers need to choose connectors, sensors and other components that add quality and proven reliability into their designs. The productivity and profitability of their customers and the safety of their workers depend on it, maybe more than ever before.

Design requirements to consider:

- **Durability for Harsh Environments** — Products that can withstand high temperature and high vibration environments.
- **Miniaturization** — High-performance, high reliability miniaturized components that can save space for greater functionality within the machine.
- **Wireless Technology** — Incorporating 5G, Ethernet, IIoT and the cloud along with sensors for better data collection and reporting.
- **Ease of Assembly** — Using simple, fast and secure connection points and insulation displacement contact (IDC) technology for better ergonomics and quicker assembly.
- **Reliable Functionalities** — Choosing products with extra locking mechanisms to ensure safety and reliability (terminal position assurance/TPAs) and ultimately faster throughput.
- **Protection and Safety** — Products with sealed components to protect critical functionalities for increased operating efficiency and safety.
- **Connectivity Options** — Integrated solution offerings to help reduce size and complexity, improve cost-efficiency, optimize performance and increase reliability.
- **Product and Machine Modularity** — The ability to quickly and easily change out lines, tools and capabilities of the machine as well as increase its capabilities to offer flexibility in manufacturing without decreasing efficiency.
- **Certifications** — Such as UL (508), CSA, CuLUS, CE, RoHS, NEC, NFPA, NEMA, IEC, IP and CCC.

"WE WORK IN NUMEROUS AREAS WITH DIVERSE WEATHER AND CONDENSATION. OUR CONCERNS ARE ELECTRICAL AND SMART CONNECTIONS FOR THE SAFETY OF WORKERS. CONDENSATION IS A MAJOR FACTOR AS WELL AS EASE OF USE. A MAJOR SITUATION WILL BE EMPLOYING WORKERS IN SPECIFIC AREAS WITH THE CAPACITY TO OPERATE THE MACHINERY SAFELY. ONE MAY DESIRE THE GREATEST MACHINERY BUT IF IT DOES NOT WORK IN CERTAIN CLIMATES THEY MIGHT AS WELL STICK TO MANUAL FUNCTIONAL EQUIPMENT."

— Survey Respondent, TE Connectivity and IEEE Survey/Analysis 2020.

3. Product Solutions for Design Requirements

Component selection is critical to maximize performance, reliability and efficiencies

The control panel is the heart of the machine with the programmable logic controller (PLC) and HMI located inside. Designers can integrate GPS modules, so owners and operators can identify the location of the machine. Autonomous intelligence software, such as AI, can be designed into the controller or an interface (e.g., Ethernet connectivity) that delivers data to a supervisory control and data acquisition (SCADA) system. This control system architecture comprising hardware and software monitors and controls the machine/equipment and delivers data from the machine or equipment to the cloud. It can be configured to be controlled on-site to directly monitor performance and efficiencies, or to be controlled remotely so the data can be used more broadly to increase optimization and synthesize business strategies, generating data on line-down time, energy or water waste, profitability per minute, and more.

Enabling the data connectivity within machines, from machine to device, and from machine to machine requires the appropriate Ethernet protocols. Designers must choose between three Ethernet architectures for manufacturing the machines:

- **Standard Software/Standard Ethernet** — uses the TCP/IP protocol and has built-in mechanisms to enable real-time communication.
- **Open Software/Standard Ethernet** — uses standard Ethernet layers with new (standard) protocols that manage access to the network and the data being sent from each point or device to ensure the most important data is sent first.
- **Open Software/Modified Ethernet** — uses Ethernet hardware and combines the physical and data link layers with new protocols and additional hardware to enable real-time control and communication.

Because data must transmit with integrity and low latency under the harsh environment applications these machines work in, ethernet architecture requires rugged and robust connectors and cables that often need to be sealed or shielded to protect against dust and fluids or noise, vibration and electromagnetic interferences.

> "I FORESEE WIRELESS COMMUNICATION BEING A REQUIREMENT OF DESIGN ESPECIALLY WITH EQUIPMENT USED IN HARSH ENVIRONMENTS."
>
> — Survey Respondent, TE Connectivity and IEEE Survey/Analysis 2020.

TE Connectivity's Product Solutions Enabling Design

TE offers fully integrated connectors, sensors and tubing products with proven quality and reliability. TE's products are designed with extensive engineering expertise to provide customers with high-performing product solutions. Many of TE's products, used by engineers to design intelligent applications and connected devices, are even suitable for harsh manufacturing environments.

TE Connectors are engineered to reliably transmit data, power, and signal in the harshest environments, under the most extreme use. These connectors are manufactured to reduce application size and power usage while enabling increased performance. We offer IP67 rated sealing options within our Sealed Signal Double Lock connector portfolio, ergonomics-friendly connectors that are glow wire tested and come with optional TPAs and CPAs for extra protection, with operating temperatures up to 110°C.

Sensors to measure pressure, temperature, position, vibration, humidity and fluid property and more. Sensors are vital to the next generation of data-driven technology—including for predictive maintenance, safety, machine learning and remote monitoring. Our engineers can help redefine what's possible using intelligent, efficient and high-performing TE sensors proven in harsh environments.

Relays that are cost-effective, reliable and enhance productivity. Our high-performance relays are designed to withstand extreme shock, vibration and temperature, including products that provide high-inrush capabilities and powerful switching needs. The OJT TV-8 **rated relay features a 117A inrush current capability with a miniature size that enables smaller PCB designs.**

Terminals and splices in a wide array of wire types and sizes. TE's terminals are ergonomic friendly and designed for high retention and low insertion force. The broad portfolio of terminals and splices come in high temperatures up to **105°C within the** FASTON terminals **portfolio** and offer pre-insulated housing options to meet various design needs.

Antennas that provide high-quality transmissions in wireless devices in a wide variety of frequencies. TE's standard and custom antennas can transmit reliably using Bluetooth, WLAN, Cellular, ZigBee bands and more. We operate antenna design and manufacturing facilities worldwide, with testing capabilities in near- and far-field patterns, scattering parameters, specific absorption rate (SAR), vibration, humidity, temperature shock, salt fog, throughput and acoustics.

Heat shrink tubing designed to perform in the most demanding conditions. The heat shrink tubing portfolio offers a wide range of single wall, dual wall and specialty products that seal, protect, insulate, organize and offer strain relief for the components that need it the most. Some of the product benefits include: operating temperatures ranging from 30° up to 150°C, chemical resistant, waterproofing, flame resistant, bundling protection and halogen-free options.

The TE Advantage

150	15K+	78K+	110
COUNTRIES WHERE WE SERVE CUSTOMERS	PATENTS WORLDWIDE	EMPLOYEES	GLOBAL MANUFACTURING AND ENGINEERING CENTERS

For more than 75 years, TE Connectivity has partnered with customers to produce highly engineered connectivity and sensing products. TE understands how components work together and uses this knowledge to optimize performance and create more sophisticated machines that are driving productivity, safety, reliability and profitability.

Finding ways to solve customer design challenges while maintaining or increasing reliability and performance in harsh environments is just one of the ways TE lives up to its purpose of creating a safer, sustainable, productive and connected future.

Learn more about TE today!

APPENDIX

Background on TE Connectivity's Primary Research Survey on the Machines Market 2020

Highlighting Trends, Design Challenges and Product Solutions Through the Eyes of 63 Engineers

To gain customer insights on integrating more connected components into machine application designs, TE conducted extensive primary market research with IEEE through a global industry survey of 63 engineers. The engineers surveyed were from numerous roles including design engineers, research and development engineers, mechanical engineers, production engineers, and application engineers. The survey consisted of a series of 15 questions, which were presented in ways such as open-ended, ranking, and high to lowest importance.

The industries that took part in the survey included industrial machinery and equipment, packaging machinery, HVAC, engineering design, and fabricated metals. This survey was conducted within the countries of the United States, China, Germany, Japan and Sweden.

The key topics that formulated the questions for the survey were focused on machinery trends, design challenges that engineers are facing, and product solutions that are driving the integration of smart machinery.

Key Findings:

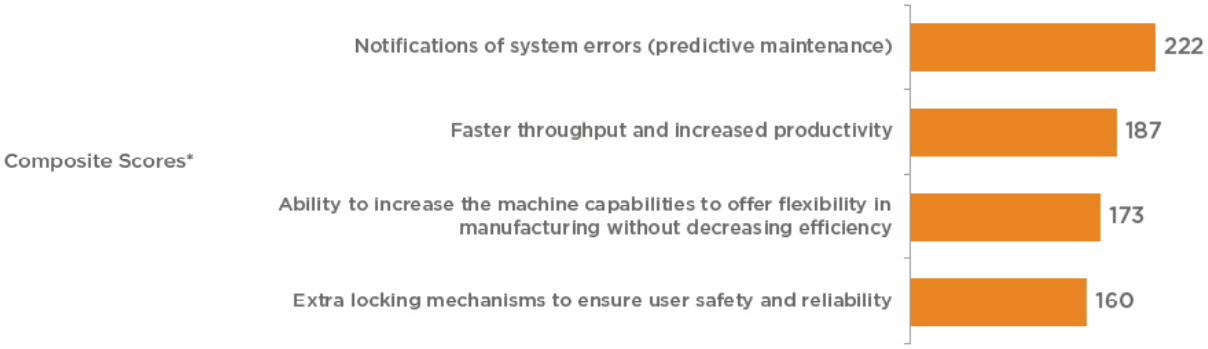
As a result of the survey conducted, notification of system errors, or predictive maintenance, was the feature or requirement that was considered most important to engineers. As more connected components are being integrated into machine designs, the engineers rated increased quality, reliability and safety as the main benefits of smarter machinery and indicated that these are advantages not reliably available within standard machines, along with protection and efficiency. The major challenge that the engineers identified when designing machines is the ability to protect critical components from chemicals and corrosion. Most claim that reliability is more important than cost when designing smart machinery and are willing to pay more upfront to increase reliability in the long run.

Survey Methodology:

Data collection method: Online survey conducted in September 2020
Sample source: Respondents sourced from IEEE member database
Survey length: Approximately 10-15 minutes
Sample size: Total n=63
Accuracy: Overall results are accurate to within ±12.5%, 19/20 times
Notes: Graphs and tables may not always total 100% due to rounding values rather than any error in the data.

FIG. 3: **Importance of Smart Machinery Features and Requirements**

Notifications of system errors (predictive maintenance) is the feature or requirement considered most important to engineers when designing machinery. Increased productivity and more flexibility are also seen as important to the engineers.



*Composite score is a weighted average based on points given to relative order of choice.

Source: TE Connectivity and IEEE survey and analysis 2020.

FIG. 4: **Perceived Benefits of Smart Machinery**

Increased quality, improved reliability and user safety and protection are the key perceived benefits of smart machinery. Nearly 4 in 10 identified safety as their top benefit.

FIG. 5: **Perceived Advantage of Smart Over Standard Machines**

Ensuring user safety and protection, improved reliability, increased efficiency and quality are perceived as a major advantages of smart machines over standard machines by a majority of engineers. Additionally, enhanced intelligence and maximized throughput are also seen as advantages.

FIG. 6: **Smart and Integrated Machinery Design Challenges**

Protecting critical components from chemicals and corrosion is the main challenge engineers face when designing smart machinery. Ensuring machinery can withstand shocks and vibrations is also a notable challenge.

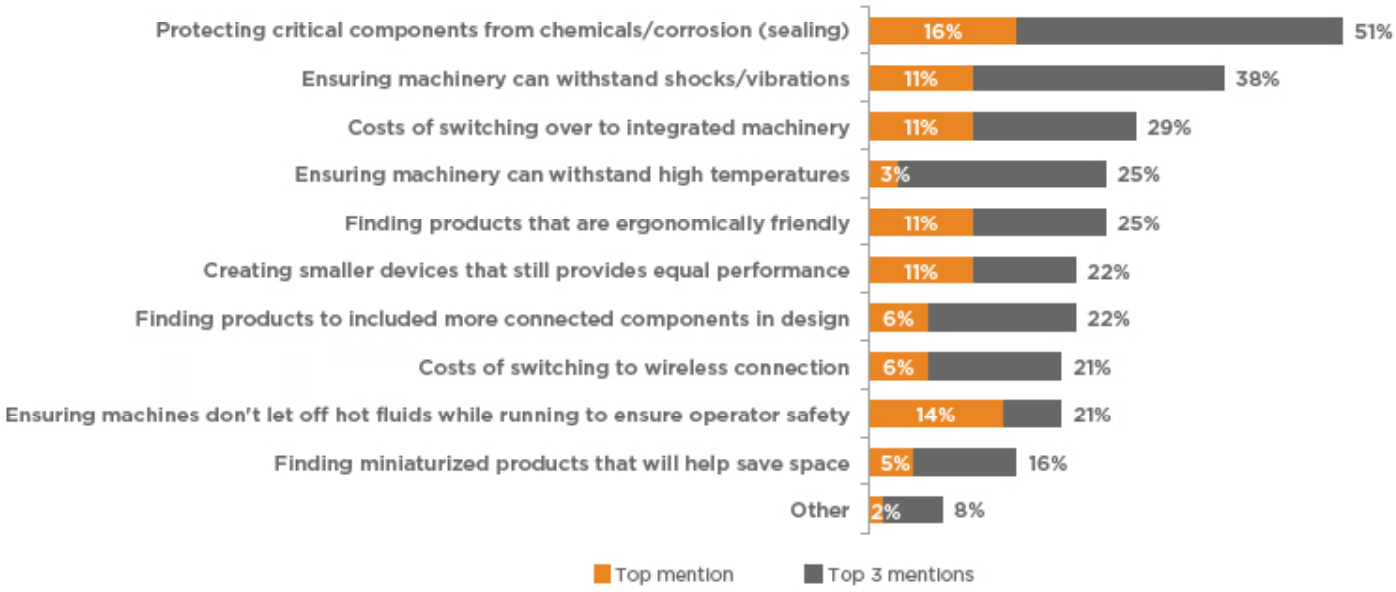


FIG. 7: **Benefit to Cost Trade-Offs**

Ensuring user safety and protection, improved reliability, increased efficiency and quality are perceived as a major advantages of smart machines over standard machines by a majority of engineers. Additionally, enhanced intelligence and maximized throughput are also seen as advantages.

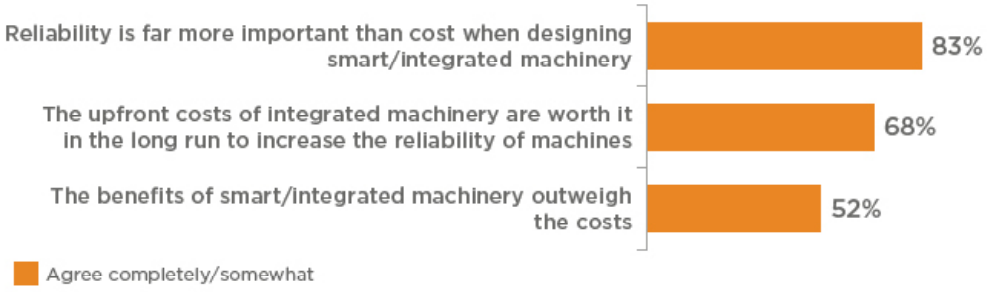


FIG. 8: **Importance and Experience with Products for Smart Machinery Designs**

Most engineers are using a broad selection of products for their smart machinery designs. Connectors and sensors are leading the pack with a majority using these products regularly. Perceived importance is also relatively higher for relays.

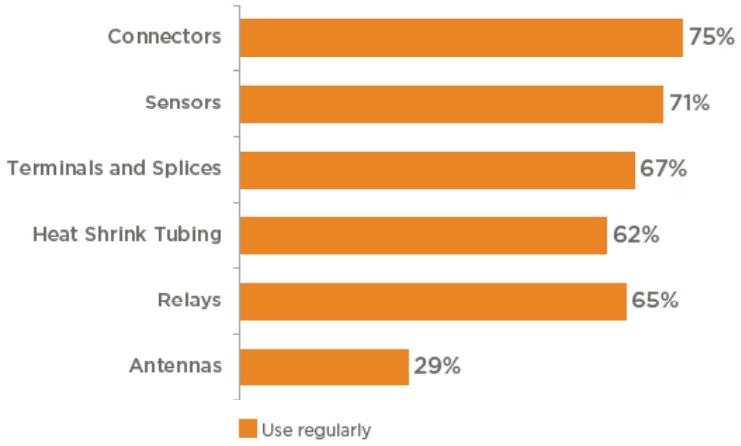
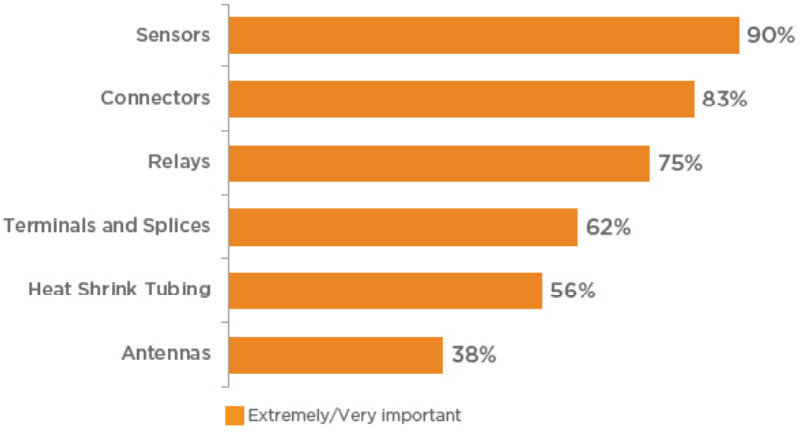


FIG. 9: **Importance of Products for Smart and Integrated Machinery Designs**



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