Robots, Cobots, and Finance

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Established in 1989, the Equipment Leasing & Finance Foundation is a 501c3 non-profit organization dedicated to inspiring thoughtful innovation and contributing to the betterment of the equipment leasing and finance industry. The Foundation accomplishes its mission through development of future-focused studies and reports identifying critical issues that could impact the industry.

Foundation research is independent, predictive, and peer-reviewed by industry experts. It is funded solely through contributions. Contributions to the Foundation are tax-deductible. Support the Foundation by making a 100% tax-deductible gift today at www.LeaseFoundation.org.

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Preface

The burgeoning reality of autonomous vehicles has captured the attention of not only the public but also the equipment leasing and finance industry, an interest noted by the Equipment Leasing & Finance Foundation (the Foundation). In its role of fostering future-focused research and analyses, the Foundation examined the attendant factors of autonomous vehicles and determined that, while significant, autonomous vehicles represent a subset of a far more pervasive industry – robotics.

The field of robotics also is experiencing rapid growth and change, so it made sense for the Foundation to consider delving more deeply into the impact of robotics on the leasing and finance industry's current and future activities. Of prime concern to the Foundation was determining the technological, societal, and financing aspects of the new frontiers of this broad, but well-established, equipment category. The goal, therefore, was to provide an in-depth examination of the robotics industry and identify any financing opportunities and challenges, as opposed to mapping out potential courses of actions.

Alta's team of professionals that participated in the research and analysis for this project has extensive leasing industry and research experience at both the strategic and tactical level.

John C. Deane
Chief Executive Officer

The Alta Group

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Purpose of the Study

The Alta Group has been commissioned by the Equipment Leasing & Finance Foundation to research and report on the impact of the evolving nature of robotics, including rapidly expanding driverless technology, on the equipment leasing and financing industry. The Foundation's mandate, in this respect, is to identify the opportunities and challenges of automation and robotics rather than lay out a timeline of when these new technologies may be expected to be adopted.

The readers of this study, therefore, will be exposed to numerous robotic applications across various industry segments, along with the elements affecting the provision of financial options to the users of such technology. It is the hope of the study research team that the readers will be exposed to, and become better acquainted with, the technological, societal, and financing aspects of the new frontiers of this broad, but well-established, category of equipment.

Methodology

The principals of The Alta Group approached this study primarily from a research perspective, tempered and enhanced by practical experience and market knowledge, in the following manner:

- **Research**. Alta sought out and used numerous resources across multiple industries and platforms to dimension robotic activity and trends, not only in general terms but also within industry segments of high interest to the equipment leasing and financing industry.
- **Synthesis**. Alta analyzed the data and research indicators and overlaid them with its own knowledge of the equipment leasing and financing industry to frame the study's findings and conclusions. In addition to addressing specific industry segments, Alta's researchers synthesized the data and drew conclusions from the perspective of captive, independent, and bank lessors.

Information sources for this study came from a variety of valuable sources, both qualitative and quantitative. Descriptions and practices are placed in the context of accepted business academic theory and best practices where possible. The information sources include:

- Equipment Leasing and Finance Association-generated data, such as the *2018 Survey of Equipment Finance Activity* (SEFA) report
- Informal interviews with several lessors and other participants
- Various Equipment Leasing & Finance Foundation studies, including *Managed Solutions: Evolutionary or Revolutionary?*
- Multiple trade publications and associations
- Scholarly papers
- Manufacture websites and trade-show information
- Governmental and NGO resources

Executive Summary

Robots generally are viewed as a recent phenomenon, but the first stylized robot appeared in a 1921 theater production, soon followed by a remote-controlled (i.e., driverless) car on the streets of Manhattan in 1925. Now there are robots that perform complex surgery and others that jump and do backflips.

While, everyone has their own perception of what a robot is, the key elements in future financing opportunities are automation and autonomy. Autonomous robots require highly advanced technological components that change the leasing and finance risk-reward calculus, but also create the largest financing opportunities.

IDC's Worldwide Semiannual Commercial Robotics Spending Guide predicts that worldwide purchases of robotics will continue to rise at a compound annual growth rate of 22.8% and reach total spending of $230.7 billion in 2021. The prognoses from various other sources all reflect the same upward trends. Achieving that growth will not be obstacle-free, however, as challenges such as creating new materials and fabrication methods, better power sources and navigating unstructured environments, not to mention ethical issues, must be overcome.

Some sectors, such as farming, forestry, construction, even healthcare, are less susceptible to autonomy because most of the environments in which their activities are performed are unpredictable. Other sectors have less potential for autonomy due to factors unrelated to the unpredictability of the environment, such as knowledge work and complex human interaction. Factors that may create more robotics to be financed include labor shortages and dangerous working conditions.

The flip side of labor shortages is the concern that robots will eliminate jobs, potentially reducing the need for human-operated equipment (not to mention the societal impact). Research shows, however, that when machines do take over some human activities in an occupation, jobs are not necessarily lost in that line of work. On the contrary, their number at times increase as workers that formerly performed repetitive tasks become more valuable, data-enabled decisionmakers.

Adoption of robotics also means that jobs will be created in new occupations and industries that may create additional financing opportunities. More robots mean more opportunities to finance those robots and the assets necessary to build them. The downside of the equation to be considered is the reduction in financing opportunities due to the increased production efficiency (fewer, high-cost machines needed) created by robotics.

New opportunities always create risks, and financing robotics is no exception. Very few of the risks inherent in leasing robotics, however, represent new risks to the industry, as, no matter how elaborate or complex a robot becomes, it still is a piece of equipment with many of the same risks and attributes of other equipment classes currently being financed. As an example, the introduction of robotics into the credit decision does not, by itself, increase the credit risk, although more affordable robots might introduce more small entities into the credit mix.

Similarly, lessors have had to cope with vicarious liability issues for quite some, and there is a substantial amount of case law on the subject. The introduction of human interaction with robots might increase this risk, but documentation standards should remain the same. There also will be additions to the regulatory structure, including national robotic safety and licensing standards or, perhaps, some advancing social policies. The impact to lessors will be tangential and related more to machine production and usage, though.

Residual risks will be key, of course, but they are not materially different than those in other, technologically advanced assets. Rapidly advancing technology, higher soft costs, and software licensing issues will deserve special attention, however, which will favor niche players and asset managers. New technologies also have the potential to disrupt current used equipment markets. A potential offset to these concerns is the monetization of the data collected by advanced robots.

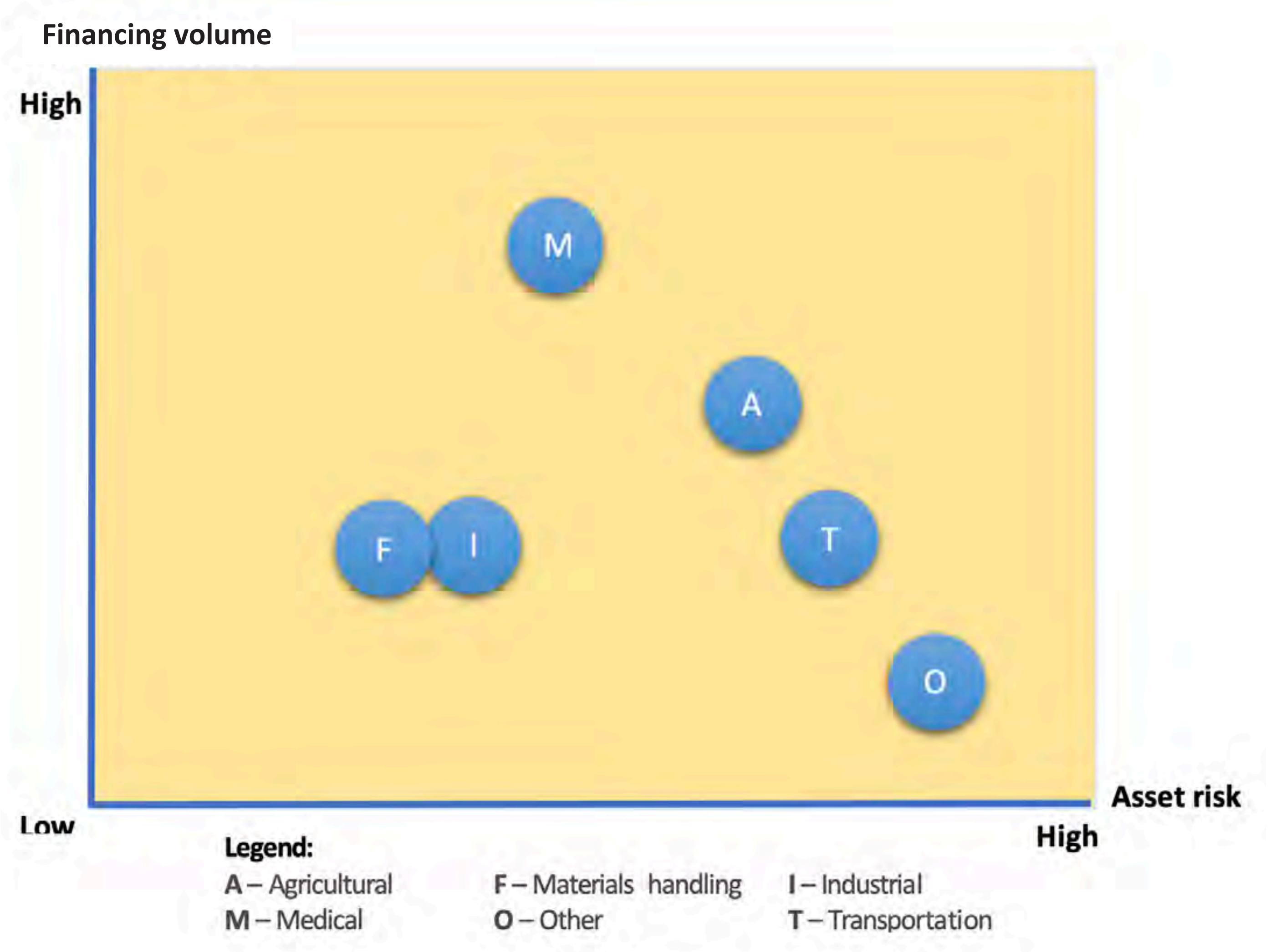
A primary feature of new generation robots is the increasing use of sensors that capture data that can be used to create supplemental revenue sources. This data, along with the many other technology elements of robotics, are creating a perceived link in the industry between robotics and managed solution transactions (MST). A clear distinction should be made between robotics financing and MSTs, however. Although robots can be an element of a managed solution, and there is convergence occurring between them, one does not create the other and vice versa.

The study examined five target industries – agriculture, healthcare, industrial, material handling, and transportation, plus an ‘Other’ category that included exoskeletons, nanobots, military applications and robotic process automation (RPA). The types of robotic assets, their characteristics, and level of autonomy and their impact on the leasing and finance industry were examined.

The primary conclusion drawn from this examination is that there are substantial financing opportunities in each of the primary industry segments analyzed. Several key impacts on the leasing and finance industry in each segment are shown below.

Segment	Impact on the industry
Agriculture	• Significant technology raises residual issues • Robot swarms may replace higher cost equipment • Data is an important element, creating ownership issues • Follow the leader models may increase volumes
Healthcare	• Significant vicarious liability issues • Large market for assistance robots • High capital cost, leading to financing opportunities • Incorporation into managed solution transactions
Industrial	• Significant programming costs raise residual issues • Slowing growth, although spending is expected to continue to rise • Opportunities parallel the machine tool industry
Material handling	• High capital cost, leading to financing opportunities • Continued new investment expected, especially in upgrades • Technology raises residual issues
Transportation	• Opportunities created by labor shortages • Platooning and caravanning create new business models • Full autonomous adoption (maximum opportunities) is decades away • Declining rates of ownership, creating shift to larger customers

The growth potential of each industry segment researched, relative to the asset risk involved, was evaluated, resulting in the following conclusions.



Robotics will be a part of the change in how business is conducted in the future and will create opportunities for those who embrace and understand this asset class. This understanding will be critical if the equipment leasing and finance industry expects to continue to creatively meet the needs of our customers.

Introduction

It has been a long week, and you find yourself busy attending to the weekend chores, so to speak, since you are relaxing in the living room, enjoying a beverage as the Roomba™ tidies up the carpet. Meanwhile, a Dolphin Nautilus™ cleans the pool, and your Miimo™ mows the lawn – all much like a multitasking Rosie the Robot, but without the consciousness. Fiction, meet reality, as consumer robotics have become ubiquitous.

What you may not realize is that the fruit in your refreshing beverage very well could have been planted, tended and harvested by robots – yes, robots. The concept of robots has been around since 1921 when it was first introduced in a science fiction play by Czech writer Karel Čapek.[1] It was not until 1961, however, that commercial robotics became a reality when Unimate went operational on a General Motors assembly line at GM's Inland Fisher Guide Plant in Ewing Township, New Jersey.[2]

The last decade, however, has seen an explosion in robotics business use as advances in technology have enabled new applications. All of which begs the question of how, and to what extent, is this equipment being financed?

Robotics and Automation

Everyone has their own perception of what a robot is. Whether it is Mia in *Humans* or Robot B9 from *Lost in Space*, anthropomorphic or clunky, they all represent some form of automation. Consequently, any discussion of robotics must begin with the concept of automation, a very broad term and, in its simplest form, the backbone of the Industrial Revolutions. But, is there a difference between automation and robotics? Or robotics and a robot?

Moebius Models' Robot B9

Automation is the technology by which a process or procedure is performed without human assistance.[3] A robot, on the other hand, has been described as a machine that senses and acts on the world in which it functions – i.e., it exhibits characteristics of autonomy. Given this definition, one must ask if a robotic welder is a true robot or must a robot be capable of acting autonomously, such as Boston Dynamics' running and jumping Atlas?

Complete autonomy is not a required feature of robotics (think of the robotic welder) nor is artificial intelligence (AI). The definition of autonomy, when it comes to robots, is in the eye of the beholder, although full robotic autonomy is rare. The level of robotic autonomy directly impacts how, and to what extent, these assets may be financed, however, since autonomy, along with a robot's ability to mimic human-like activities, require sophisticated, multiple components such as:

- Hardware – Effectors, sensors, cameras, the robot framework and CPU, enterprise network, server, and storage
- Software - Command and control, network infrastructure software, and specific applications
- Services – Application management, education and training, facility modification, hardware deployment, support, network consulting, management and integration, operations and technology consulting and systems integration

The technology behind many of these components is increasing at a rapid pace.

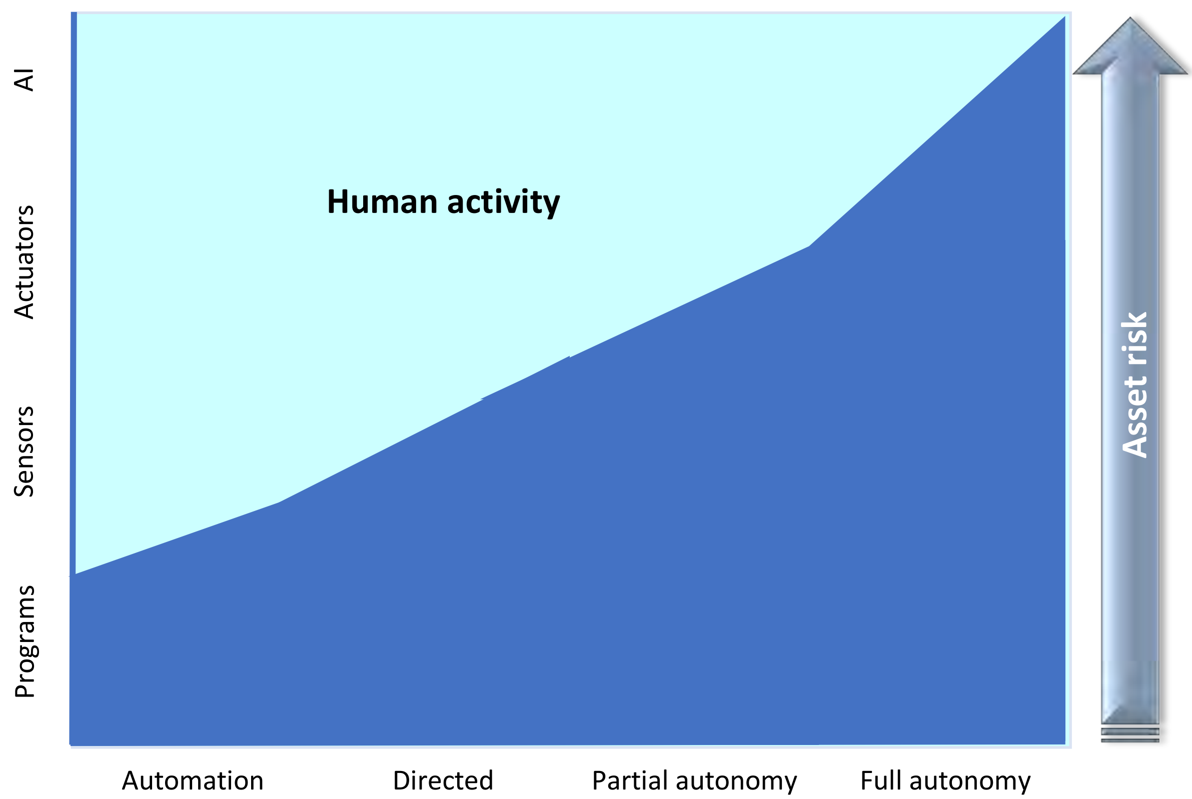
> "The convergence of robotics, artificial intelligence, and machine learning are driving the development of the next generation of intelligent robots for industrial, commercial, and consumer applications," said Jing Bing Zhang, research director of robotics at IDC Manufacturing Insights. "Robots with innovative capabilities such as ease of use, self-diagnosis, zero downtime, learning and adaptation, and cognitive interaction are emerging and driving wider adoption of robotics in the manufacturing and resource industries and enabling new uses in healthcare, insurance, education, and retail."[4]

The more sophisticated/autonomous the robot becomes, the more technology and soft costs play a role in how it functions, both of which are factors that increase the asset risk. Financiers must be cognizant of these factors when choosing to pursue an equipment sector. This correlation is shown in Exhibit I.

As an example of the differences between automation and autonomy and, hence, potential residual risk, consider an oil company that is monitoring the status of its pipeline. Patrol pilots fly at low altitude over the pipeline looking for leaks, damage, vandalism, and other problems. Frequently these flights occur over mountainous, wooded and hazardous terrain. To increase operational safety and reduce monitoring costs, the oil company decides to utilize drone technology to perform this task.

When does the drone, which could be considered a robot, become autonomous? The analysis of this question has many levels, all of which have financing ramifications. The potential autonomy progression of the pipeline drone is shown in Exhibit II.

Exhibit I
Autonomy Curve



Although autonomy, AI and robotics are not necessarily synonymous, machine learning is being incorporated into robotic activities to increase efficiency and reduce wastage. Predictive analytics, used in truck, auto, and forklift fleet financing for some time now, also is being applied in robotics to gather and track data on performance and usage. All these new, additive elements to the basic machine architecture increase the asset risk, as they require significant software and computing capabilities.

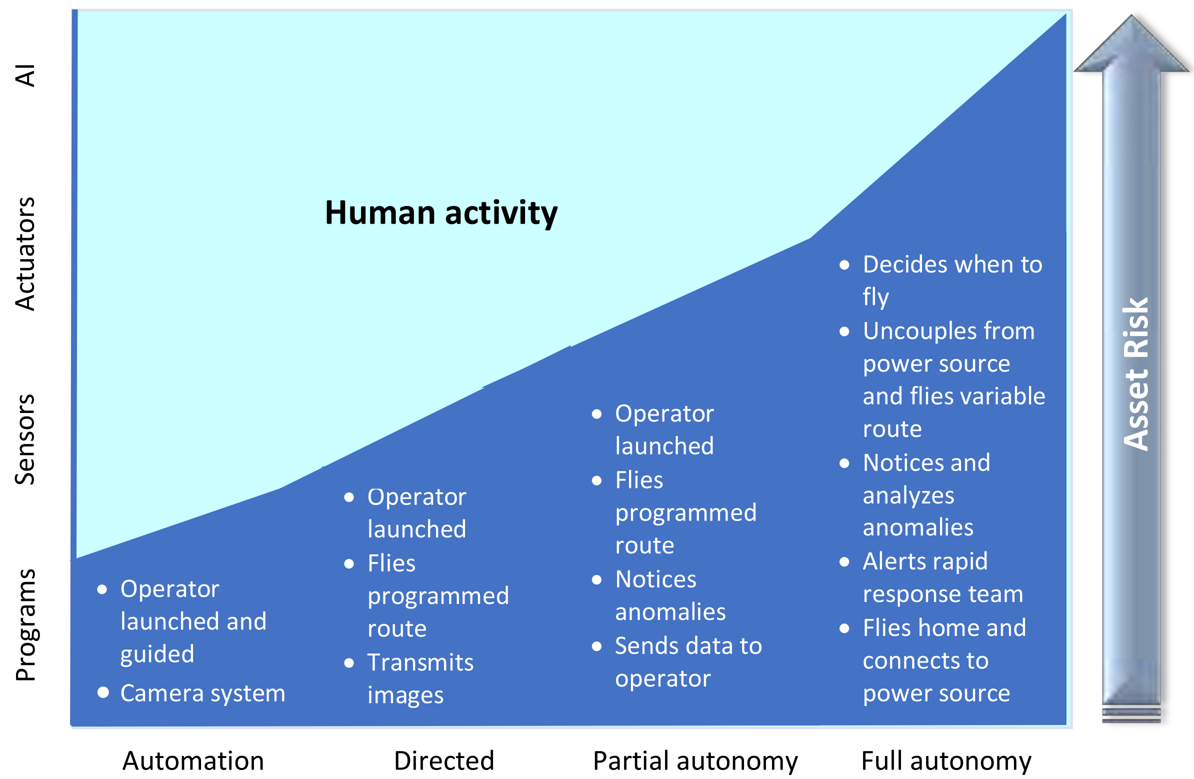
There also are safety and, hence, vicarious liability risks as the interactions between humans and robots continue to increase. These risks are particularly high with the emerging class of robots known as cobots. A cobot (a portmanteau of ‘collaborative’ and ‘robot’) is a robot intended to physically interact with humans in a shared workspace. According to the Robotic Industries Association:

> “Collaborative robots are experiencing rapid market growth in this sector of the robotics industry. The collaborative robots market is expected to reach a value of $4.28 billion by 2023, growing at an astounding 56.94% compound annual growth rate. The primary driving force behind this growth is a consistently decreasing price....”

Human safety always will be an issue, but new techniques are enabling safer and more enhanced physical collaboration between robots and humans in unpredictable environments, such as construction and agriculture.

It is not difficult to draw parallels between the more advanced, autonomous robotics and managed solutions, given the various moving, yet similar, aspects of the arrangements. Many managed services, for example, depend on the Internet of Things (IoT) for data collection, robust analysis of the data and artificial intelligence AI to make the transaction work. The same elements are required for higher forms of autonomous robotics to function.

Exhibit II
Pipeline Drone Autonomy Curve



Market size

There are many questions surrounding the market potential of robotics, including what is the size and scope of any opportunities and the risks attendant to those opportunities. This section analyzes the market regarding current and projected volumes along with future expansion possibilities.

Current state

IDC's Worldwide Semiannual Commercial Robotics Spending Guide predicts that worldwide purchases of robotics – including drones and robotics-related hardware, software, and services – will continue to rise at a compound annual growth rate of 22.8% and reach total spending of $230.7 billion in 2021. Another estimate from ABI Research predicts that the number of industrial robots sold in the U.S. will jump nearly 300% in less than a decade.

The prognoses from various other sources all reflect the same upward trends for the sale and use of robotics. A 2016 report by the International Federation of Robotics predicted that the deployment of industrial robots would swell to around 2.6 million units in 2019, while, closer to home, the Robotics Industries Association says that 40 percent more robots were sold in the US in 2016, compared with four years prior.[5] The Robotics Industries Association also estimates that 250,000 robots are now in use in the United States, the third highest in the world behind Japan and China.

For the first nine months of 2017, 25,936 robots valued at $1.496 billion were shipped in North America, representing growth of 18% in units and 13% in dollars over what was sold in 2016.[6] This strong performance was followed up by shipments of 10,730 robots valued at $507 million in the opening quarter of 2018. The first quarter of 2018 also saw significant growth in shipments to non-automotive related industries such as life sciences (262%), plastics/rubber (130%), and food/consumer goods (64%).[7]

Currently, more than half of all robotics spending is for robotics hardware. Other categories of the robotic spend include applications management, education and training, hardware deployment, systems integration and consulting, network infrastructure, and command and control applications.

According to IDC's research, the discrete manufacturing and process manufacturing industries continue to be the largest purchasers of robotics products and services, accounting for more than half of all robotics spending throughout IDC's five-year forecast.[8] The automated production industries, such as mining and wholesale, will be the second largest sector, followed by the resources industries of mining, oil and gas extraction, and agriculture.

Growth potential

Future growth, such as that which robotics currently is experiencing, is not a given, of course, but the experts' projections of the future are positive. This is not to say that achieving that growth will be obstacle-free, as there are challenges. According to *Science Robotics*, the 10 biggest challenges facing the robotics industry are:

- New materials and fabrication methods
- Creating bio-inspired robots
- Better power sources
- Communication in robot swarms
- Navigating unmapped environments
- AI that can reason

- Brain-computer interfaces
- Social robots for long-term engagement
- Medical robotics with more autonomy
- Ethics

This list of challenges can be viewed as a valuable portent of the future, not just impediments to growth. Take AI that can reason or brain-computer interfaces, for example. The solutions to these challenges will push robotics even further onto the technological edge, thereby increasing investors' risks in these assets even more.

The solutions to these challenges, however, represent future, not current, technologies and capabilities, some of which may or may not occur. When rationalizing future opportunities in robotics, therefore, the potential that automation and/or autonomy can be applied to any given activity has to be assessed in terms of currently demonstrated technologies.

McKinsey rates technical feasibility as a prime factor in determining the likelihood of robotic application to an activity, followed by the cost of developing and deploying the hardware and software for the solution.[9] These aspects relate directly to developing the robotic application. There are other macro and non-solution driven factors that affect the future growth potential of robotics.

McDonald's self-serve kiosks provide an interesting use case for one of these, the cost and supply (or lack thereof) of labor. Societal acceptance is another. Are we ready to have our blood drawn by a robot phlebotomist, even if it could apply a Frozen band aide to the puncture site?

According to the McKinsey study previously cited, almost one-fifth of the time spent in US workplaces involves performing physical activities or operating machinery in predictable environments, where changes are relatively easy to anticipate. Since predictable physical activities figure prominently in sectors such as manufacturing, food service, accommodations and retailing, McKinsey identifies these as the most susceptible to automation. This susceptibility does not extend evenly across all activities in the sector, however, as metal cutting activities are more likely to be automated than a customer service department.

Some sectors, such as farming, forestry, and construction are less susceptible to automation because most of the environments in which their activities are performed are unpredictable. Examples in which the factors comprising the environment keep changing include operating a construction crane or providing emergency care as a first responder.

McKinsey also estimates that one-third of the time spent in the workplace involves collecting and processing data, irrespective of the unpredictability of the operational environment. This number increases to around 50% in the finance and insurance industries, with data collection and processing activities in these sectors having a technical potential for automation exceeding 60 percent.

Other sectors have less potential for automation due to factors unrelated to the unpredictability of the environment. Activities in some of these industries require high levels of knowledge work or complex human interactions, such as the healthcare and education sectors. Although their impact is not as specifically identifiable as labor supply and wages, societal perceptions are factors that also may influence the potential growth of automation, fueled by headlines such as *Job-Stealing Robots are Steadily Taking Over America*. This article referenced National Economic Research Bureau findings that, for every new industrial robot introduced into the workforce, six jobs were eliminated.[10]

Scary stuff, but is this statement true, or does it only reflect one aspect of the picture? Comments posted to this article echo the disparity in social thought on this subject:

- "I, for one, welcome our new robot overlords..."
- "We are so screwed! Why are you guys contributing to the demise of humans?"

The issue of job loss due to advances in technology was addressed at the 2018 Commercial Equipment Marketplace Council Fintech Innovation Summit. According to Pablos Holman of Bill Gates Intellectual Ventures:

> "Many fear the thought of AI replacing workers, but Holman encouraged attendees to adopt a new perspective. "We're good at imagining how a robot is going to take a job and it [the job] will disappear. We're bad at imagining the new kinds of jobs we will create." Our parents could never imagine the type of job experiences we have today."[11]

Even when machines do take over some human activities in an occupation, this does not necessarily spell the end of the jobs in that line of work. On the contrary, their number at times increases in occupations that have been partly automated, because overall demand for their remaining activities has continued to grow. Much of this activity does not represent job loss, but, instead, a shift in the value cycle as people performing repetitive tasks are now becoming data-enabled decisionmakers.

The real question becomes 'What is the net change?', as new jobs will be created in new occupations that may create additional financing opportunities. Furthermore, the equation goes beyond jobs in an equipment ripple effect. More robots mean more opportunities to finance primary equipment (the robot) and secondary equipment (the assets necessary to build the robots), for instance. Another facet of the equation to be considered is the reduction in financing opportunities due to the increased production efficiency (fewer machines needed) created by robotics.

As can be seen, there is growth potential in robotics, which means more equipment will need to be financed in the future. What industries are most likely to present these opportunities? McKinsey has identified those industries most likely to be automated, which by default, will represent more financing opportunities. Exhibit III highlights the wide variation in what McKinsey views as automation potential, both in individual sectors and for different types of activities within those sectors.

Challenges of Financing Robotics

The top 10 challenges of robotic equipment were discussed previously. This section focuses on the challenges and risks in financing robotic equipment and to what degree they differ from those in other financing transactions currently in the marketplace. The typical risks in an equipment financing transaction, and how these risks change, or do not, when robotics is introduced are examined.

Exhibit IV identifies the risks in equipment finance transactions, along with an assessment of robotics' impact on the applicable risk in the transaction. This impact is characterized in a heat map format. A green impact indicates no increase in the particular risk, whereas, a red impact indicates substantial risk. Shades of yellow reflect levels of moderate risk. The causative factors behind any increased risks are examined in the following subsections.

Exhibit III
Potential Robotic Growth Sectors

Credit Risk

Credit risk, of course, remains a central element in any financing transaction and robotics is no different. The question that needs to be answered, however, is whether robotics transactions require a different, or added focus on, customer credit adjudication.

The answer is that, overall, the introduction of robotics into the credit decision does not, by itself, increase the credit risk in the transaction. This is not to say that there will not be changes in credit risk in certain areas, however. As an example, credit risk may change for some transactions if prices drop as technology advances and smaller firms are able to take advantage of newer equipment. Changes in technology also affect residual values and, hence, losses given default numbers but, again, this is the case with any technology assets and is not unique to robots.

Credit issues and underwriting risks also will change if robotics are included in managed solutions. These changes are more a function of the characteristics of managed solution transactions than the robotic equipment embedded in the solution, however, and are similar to those facing leasing and finance companies in other equipment sectors of the economy.

Some, although not all, robotics have significant soft costs in terms of software and other elements. Furthermore, many areas of robotics are built on new or rapidly changing technology.

These factors can impact the credit decision, depending on the organization's risk management perspective.

Some credit professionals believe that, if the customer is going to default, it will default, and the credit decision process should be the same no matter the transaction type. Others argue that the proportion of soft costs and changing technology in a robotics transaction must affect the decision. Their opinion is that, since soft costs are higher, and the underlying value less tangible, the credit of the customer becomes more important, thereby necessitating the application of tighter standards to these transactions.

The customer credit profiles may change as lower equipment costs make it possible for small companies to acquire robotic equipment. An entity that seeks to finance robotics, however, should not need to adjust its credit policies and processes because it is financing robotic equipment. Therefore, a relatively low impact has been assigned to this area in the heat map in Exhibit IV.

Residuals

How will lessors assess residual risk in robotic technology that is heavily dependent on sensors, computing power, software, and data access? The residual valuation and realization aspects of new generation equipment always create angst for the risk and upper management teams and financing robotics is no different. When it comes to setting residual values, though, is robotic equipment any different from other high-technology and software-rich equipment? The fact is, the equipment leasing and financing industry has been addressing changing technology when valuing assets almost since its inception (think positron emission tomography, nuclear cameras, and mainframes, for example).

The importance placed upon asset and residual value risk is dependent upon, at least two factors – the specific underlying assets and the ratio of assets to soft costs. Key, albeit not new, considerations in residual valuation for robotics is the cutting-edge technology and high reliance on the software that is becoming commonplace in many robotic applications.

Exhibit IV
Challenges Heat Map

Risk	Impact	Comments
Credit		Potential expanded credit profile due to lower cost
Residual		
• Valuation		Increased risk due to technology and software
• Realization		Disposition expertise/effect on existing assets
Accounting		Possible friction as deals approach MST models
Income tax		Special-use equipment may be problematic
Legal		
• Vicarious liability		Proximity to humans create potential risks
• Documentation		Will follow standard industry practices
Operational		No new operational challenges introduced
Regulatory		New safety and social issues created
Funding		Will follow standard industry practices
Pricing		Will follow standard industry practices
Investment		No new issues raised

There are other factors that deserve mentioning when discussing robotic asset risk. New technologies always require specialist knowledge to assess and realize residuals, knowledge that may be difficult to obtain on a timely basis. New technologies also have the potential to disrupt current used equipment markets, so residual realization on lessors' current portfolio will be affected, particularly if prices on new, more effective, equipment start to drop.

Emerging robotics also may have longer lifespans that require more servicing and software upgrades or experience increased return levels. Another issue is whether the lessor will have access to diagnostic and repair software or be beholden to using vendor repair facilities.

Compounding all these issues is the growing incorporation of robotics into managed services transactions (MSTs). The assets are integrated into the solution in an MST, which makes it hard to strip out the asset and limits residual plays. Residual performance also becomes more subject to noncontrollable factors brought on by multiple partners. Since MSTs rely heavily on data creation and analytics, interesting questions are raised as to who owns the data, as "…. the value of the data collected can supplement the value of the device by creating diagnostic, customer, market or employee trend reporting."[12]

Although the risks of residual valuation and realization for robotic assets remain important considerations, they not seen as being materially different than traditional equipment, hence, its increased risk has been rated as moderate relative to similar high-technology assets.

Legal

Lessors have had to cope with vicarious liability issues for quite some, and there is a substantial amount of case law on the subject ranging from motor vehicles to aircraft. A federal statute[13] provides that companies that lease or rent vehicles may not be held vicariously liable for the negligence of those to whom their vehicles are leased or rented. The thought of driverless semi-trucks running amok amongst the civilian population certainly raises the unwanted specter of huge vicarious liability claims, though. The bottom line, however, is that the underlying issues remain the same as for other equipment.

Mitigating factors for vicarious liability risk might include more focus on the manufacturers for recompense, as operation of this complex equipment becomes more reliant on embedded robotic performance and controls. Lessors will need to continue to be diligent in their UCC 2-A finance lease efforts, therefore, to avoid any hint of agency between themselves and the suppliers of robotic equipment that might open them up to damage awards targeted to those suppliers.

Elements to the regulatory structure applicable to robotics, such as national standards, also may be introduced. Although most likely anathema to the states, national standards may be the only effective answer, as:

> "For over two centuries, the United States has addressed the legal regulation of, and liability for, risks of physical injury from new technologies with a complex hierarchical system of federal, state, and local governmental entities …"[14]

It can be argued that robotics, particularly autonomous ones such as vehicles, may increase the likelihood of claims against deep-pocketed lessors. Aside from the emotional component of "no one in control," though, if there are adequate regulatory safeguards in place, lessors are likely to protect themselves in the same manner as before, even with the possibility of increased claims. Consequently, the increase in vicarious liability risk has been categorized as moderate.

Regulations

There are continuing state and federal efforts to regulate the financing industry, but any regulations that arise related to financing robotics are more likely to be driven by the robotics themselves, rather than the associated financing. Since simply fencing off a robot to protect humans severely limits its autonomy, and, hence, utility, safety will be front-of-mind with many regulators. This statement becomes even more true as the interactions between humans and robots continue to increase, as with cobots.

Additions to the regulatory structure, as previously mentioned, might include national robotic safety and licensing standards or, perhaps, universal, no-fault insurance. These licensing restrictions, at some point, may have to extend beyond operators to include repair and maintenance providers due to the sophistication and complexity of the equipment.

Regulations intended to advance social policies also are likely, as efforts are made to protect jobs and general feelings of well-being. Many of these policies could be based on the premise behind Asimov's zeroth law that states, in part, that "A robot may not injure humanity, …." Any adverse change to the human condition caused by robots, therefore, may be considered antithetical to this law, however unenforceable.

There will be increased regulation of robotic equipment, and these regulations may impact the growth of robot utilization. Any impediments to equipment growth always affect financing opportunities but, for the various reasons discussed, the increased regulatory risk of financing robotics has been deemed moderate.

Industry Segment Analysis

The following sections of the report examine the current and future state of robotics in several key industries, as well as the financing opportunities and challenges in each industry.

Agriculture

The first development of robotics in agriculture can be dated as early as the 1920s, with research to incorporate automatic vehicle guidance into agriculture beginning to take shape.[15] Other examples of early robotics include the first robot to shear a live sheep in 1979 and John Deere, Inc.'s efforts to create autonomous tractors. Although industrial robots have been in use since the 1960s, agricultural robotics have developed more slowly due to such factors as the unpredictability of terrain and crop variability.

Background

Slow development notwithstanding, the agricultural robotics industry is becoming vibrant and diverse. Since farmers already are embracing technology by digitizing their equipment and using software in crop management, for instance, agricultural robots, or agrobots, represent a logical next step in the technological evolution.

According to a recent report[16], the market for agricultural robots and drones is expected to reach $35 billion within the next five years. Creating the underlying foundation for this growth are the problems facing modern agriculture. These include the struggles of traditional farming methods to achieve and maintain the efficiencies required by the market and the declining workforce in developed countries due to age and immigration policies. The ever-increasing demand for food amidst dwindling resources also looms large, as, by 2050, the world population could boom to almost 10 billion people.[17]

Agricultural robots are helping address these challenges through a variety of methods, including enabling wider use of precision agricultural methods. By applying precision, customized solutions to subplots of land, or even individual plants and animals, farmers are better able to increase productivity and lower overall costs. Examples of precision farming include fertilization, sowing, weeding, irrigation, and thinning.

Spraying chemicals onto fields, for example, is not only wasteful but also can harm the environment. Robots provide a much more efficient method of weed control. By using computer vision technology, the robot can detect weeds and then spray a targeted drop of herbicide onto them. Or, for those farmers seeking a more ecological approach to the task, a weeding robot either can automatically hoe the spaces between plants, punch the weeds into the ground or use lasers to kill them.

As can be seen, the scope for growth in agricultural robot usage is large. The top 10 robotic applications in the agricultural industry[18] are as follows:

- Nursery planting
- Crop seeding
- Crop monitoring and analysis
- Fertilizing and irrigation
- Crop weeding and spraying
- Thinning and pruning
- Autonomous tractors
- Picking and harvesting
- Shepherding and herding
- Milking

Challenges

Development of agricultural robots has its challenges, however, the biggest of which is the unstructured environments of agricultural activities. Farming is not like a typically stable industrial environment – the wind blows, the sun may or may not shine, and the fruits, many of which, like strawberries, are delicate, may be hidden within the trees or plants.

Consequently, agricultural robotics, like many other industries, is bifurcated between fairly straightforward applications like autonomous tractors and complex systems like pepper or strawberry pickers. These more advanced robotics require cutting-edge vision systems and robotic arms capable of navigating unstructured and dynamic environments. As Dan Harburg of Dutch agtech venture capital firm Anterra Capital noted:

> "Traditional robots were designed to perform very specific tasks over and over again. But the robots that will be used in food and agricultural applications will have to be much more flexible than what we've seen in automotive manufacturing plants in order to deal with natural variation in food products or the outdoor environment."[19]

A critical aspect of a successful agricultural robot is its ability to acquire sensory information, process that information and then analyze and interpret that visual input in order to transmit it to the robotic manipulators and end effectors. As researchers in this critical area have pointed out:

> "… the challenges associated with machine vision in severely unconstrained environments like those encountered in agricultural settings are countless: objects of various colours, shapes, sizes, textures, and reflectance properties; highly unstructured scenes with large degree of uncertainty; ever-changing illumination and shadow conditions; severe occlusions; and the sheer complexity of the typical unstructured agricultural scene, are only part of the problems that such a machine vision system must face."[20]

Avital Bechar of Israel's Institute of Agricultural Engineering reinforced the difficulty of this challenge at the SIVAL trade show in January 2018 when he told a symposium that:

> "The unstructured environments of farms mean inherent uncertainty, which makes it difficult for robots, and the same goes for crops themselves. The coefficient of variation is low for most products like nuts and bolts but is an order of magnitude bigger for, say, flower cuttings."[21]

Although agricultural robots are intended to minimize human involvement, developers are tasked with making the robots more human. Farmers definitely use touch to harvest certain crops, rely on multiple senses to drive a tractor, and use observation skills to ‘read’ the land – none of which are easy skills to replicate. One, non-equipment related solution being used to alleviate some of these problems is the corollary development of crops that better facilitate robotic tending and harvesting.

A logical question to ask at this point is how far in the future is totally autonomous farming? It is already here in theory and, in some cases, in application. Researchers in Shropshire, England, for example, sowed and harvested a field of barley in the fall of 2017 using nothing but robots. In the Hands-Free Hectares Project, the land was tilled, planted, monitored, sprayed and harvested autonomously. The process even was checked autonomously by drone, including scooping and carrying soil samples. Although Kit Franklin, the project’s leader, and an agricultural engineer, freely admits that it was “the most expensive hectare of barley ever,”[22] the project did represent a milestone in agricultural robotics development.

Voluntary milking via an automatic milking system (AMS) is another agricultural area that has achieved advanced levels of autonomy. AMS allows a cow to decide her own milking time and interval, which requires complete automation of the milking process. This process includes cow ID sensors, automatic gates, and a control system. A robotic manipulator performs the automatic teat cleaning, milking cup application, milking, and post-milking teat spraying. It is interesting to note that, despite the high-tech nature of the process, it is only made successful by appealing to the self-interest of the cow by providing the incentive of highly desirable feed in the milking box.[23]

Impact on the industry

While the exact breakdown of the anticipated volume of the anticipated $35 billion agricultural robotics market is hard to come by, some data is available. For instance, The IDTechEx Agricultural Robots report found that more than 300,000 tractors with autonomous functionality were sold in 2016.

One way to appreciate the challenges and opportunities for financing agricultural robots is to look at how Fendt, a German manufacturer of agricultural tractors and machines, approaches robot-based precision farming when planting corn. Fendt currently is marketing a robotic solution that consists of multiple parts, the first of which is the logistic unit.

The logistic unit takes care of transport, seed supply, battery charging and precise navigation of a swarm of the robots through satellite-based guidance. Each electric-driven robot in the swarm has its own integrated planting unit. Communication with the logistic unit is done via the Cloud. Specialized software, also in the Cloud, is used to constantly optimize and supervise the planting operation. Meanwhile, task planning, live monitoring and administration of seed data can be done, for example, with a tablet from any location.

What do the characteristics of this robotic solution tell us? First, there is significant technology involved in the process, which raises residual setting and realization issues. Many of the sensors, computer vision systems, actuators, and AI capabilities are relatively new iterations of robotics. This technology goes beyond the equipment as, in many cases, the robot is linked to the world (the logistic unit, other robots and the farmer) via a wireless signal and onboard computers. Software and data analytics also are key components of agrobots.

Another lesson to be drawn from the corn planting example is the concept of robot swarms. The small robots of a swarm collaborate autonomously in a safer, more reliable and productive manner. Because they speed up the task, provide continuous operation, reduce soil compaction, and use a low amount of energy to move, they reduce operating costs.

Robot swarms have the potential to replace larger, high-cost machinery, which has financing connotations. On the one hand, there are more pieces of lower cost equipment to finance, particularly if the lower cost allows farmers to invest in more equipment. Replacing high-cost equipment with more lower cost equipment, however, may drive dollar volume down and increase overall transaction costs. Other financing aspects such as maintenance, storage, and energy costs will be affected, particularly for captives.

Data is an important element of agricultural robotics as it is used to predict yields and used to focus efforts and resources through analysis of vegetative development, water status, plant condition, and other data. Just as data technology solutions are critical for the farmer or rancher, it has relevance for the lessor.

This data has the potential to create direct and indirect revenue streams that can be used to increase profitability and/or mitigate residual risk. Under the direct revenue model, lessors could sell the data being generated by their equipment to seed companies, chemical concerns, and hydrologists, to name but a few examples. A lessor, in an indirect model, also could use the data to fine-tune its managed solutions product and better serve its client, much like fleet managers currently do in the transportation industry.

Key to this data usage will be the resolution of who owns the data and to what extent it can be used. Is it the manufacturer's, the asset user's or the asset owner's data and how can it be used? What is the answer if the lessor adds sensor and data gathering capabilities to equipment it already owns? A corollary to this challenge is the issue of access to the diagnostic and maintenance software supporting the equipment. Lessors that offer full-service leases will be constrained in what they can offer clients if they are unable to repair and refurbish their assets in a cost-effective manner.

Industry members also must be mindful about the liability surrounding autonomous robot activity. Agrobots must get to where they are needed in addition to being capable of detecting what is going on in their surroundings and acting accordingly. As is often the case in robotics, the lack of clear regulation can cause concern, not only for the robotics providers but also for their financing partners. Safety and vicarious liability, as with any equipment, is an issue.

Another model that has the potential to increase financing opportunities is the rising trend for follow-the-leader autonomy, much like the caravanning concept in over-the-road trucking. Under this model, tractors autonomously follow human-driven combines to collect the grain, thereby freeing up valuable (or unavailable) labor for use elsewhere.

New commercial applications for agricultural robotics also are being developed that may represent new opportunities for equipment financiers. As an example, EM3 AgriServices, an India-based company, has launched Farming as a Service. A combination of equipment, information technology, mobile telecom services, agricultural expertise, and financial services, etc., allows the farmer to farm in an efficient and affordable manner through a network of farm centers. Each center is equipped to handle a comprehensive suite of basic and precision farm operations throughout the entire crop production cycle. Managed solutions meld with agriculture!

Healthcare

Whereas the term 'robot' was first used in 1921, the first medical robot did not arrive on the scene until 1983 when the Arthrobot was used in surgery in Vancouver, Canada. The Arthrobot, a voice-activated assistant, manipulated and positioned the limb as the doctor performed the surgery. This robot, similar to its industrial cousins, was more precise and not susceptible to fatigue like a human surgical assistant. Other robotic assistants, such as one that hands the surgeon instruments in response to voice commands, soon followed.

Background

Robots and cobots increasingly are being used today in medical and healthcare applications, although they more commonly are employed in healthcare laboratory settings, rather than clinical medicine. The medical robot market, though, is expected to exceed more than $12.80 billion by 2022 and grow at a compound annual growth rate (CAGR) of 21.1% in the given forecast period.[22] The introduction of new generation robotic systems integrated with advanced data recorders, remote navigation systems, HD microscopic cameras, data analytic systems and 3-D imaging all are expected to boost demand over this period.

Medical robots include an extensive assortment of applications, but the following represent general classes of medical robots.

- Surgical
- Telepresence
- Assistive
- Laboratory

SURGICAL ROBOTS

Surgical robotics are the highest-profile segment of medical robots. The foremost benefits of surgical robots are to allow (1) surgical operations to be carried out with greater precision, (2) minimally invasive surgery and (3) remote surgery in which a human surgeon is not physically present with the patient.

The overall global surgical robotics market is likely to experience a compound annual growth rate of 8.5% from 2017 to 2024.[25] It is estimated that the worldwide surgical robotic market in 2024, including equipment, services, and accessories, will be $98 billion, an 8.4% compound growth rate from the 2017 level.[26]

Intuitive Surgical's daVinci surgical system, a product of Defense Advanced Research Programs Agency (DARPA) research, was used in 1997 to perform a laparoscopic cholecystectomy in Belgium. The original daVinci surgical system consisted of a remote surgeon's console and a three-armed, robotically controlled instrument drive system. In the surgeon's console are two viewers, one for each eye, which provide a three-dimensional view of the operating field. The surgeon's hands rest in control grips which allow for arm, wrist, and pincer movement. The wristed instruments track the surgeon's movements 1,300 times per second and provide for tremor filtration and scaled motion—translating larger movements of the surgeon's hand into the required robotic movements.[27]

Robotic surgery can be divided into three subcategories,[28] based on the degree of surgeon interaction during the procedure. The level of surgeon control drives the level of autonomy which, in turn, affects the asset risk of financing these robots.

- Supervisory-controlled – the procedure is executed solely by the robot acting in accordance with a surgeon-input computer program. The individual programming makes this method extremely expensive.
- Telesurgical (also known as remote surgery) – the surgeon manipulates the robotic arms during the procedure, eliminating the need for a predetermined program. Using real-time image feedback, the surgeon operates from a remote location using sensor data from the robot. The da Vinci system falls in this subcategory.
- Shared-control – the procedure has the most surgeon involvement. The surgeon carries out the procedure with the use of a robot that offers steady-hand manipulations of the instrument.

The robotic surgical systems themselves have been segmented into four types of procedures – neurology, orthopedics, laparoscopy and others. Although laparoscopy accounted for the highest share of growth through 2014, the neurology segment is anticipated to account for the fastest growth in the next four years, with a CAGR of 16.7%, owing to the global increase in neurological disorders such as Alzheimers and depression.[29]

Orthopedics robotic systems are anticipated to be the second fastest growth segment with an expected growth rate of CAGR of 14.2% through 2022. Significant developments in terms of software will trigger increasing demand for minimally invasive robot-assisted surgeries, along with a growing number of musculoskeletal conditions such as rheumatoid arthritis, low back pain, osteoarthritis, and osteoporosis.[30]

It may seem surprising to describe the human body as an unpredictable environment, but it is, in many respects. In surgery, certain internal structures of a patient may not be where the surgeon (human or robot) expects to find them. A large tumor, for example, may displace everything around it, dramatically affecting the predictability of its location.[31]

This unpredictability is a limiting factor in the development and growth of autonomous robotic surgery. Another is the psychological resistance among surgeons and patients to putting significant health processes into the hands of robots. It is one thing, after all, to have our car worked on by a robotic welder but quite another to trust our body to a scalpel-wielding machine.

It likely will be a long time, therefore, before robots will be allowed to operate on humans without human participation, or at least oversight. This will affect financing decisions, as the less autonomy a robot has, the less technology and software needs to be incorporated into the equipment and the less innovation there will be.

TELEPRESENCE

There are several forms of telepresence robotics, one of which is to use robots to perform surgery from a remote location, a la the da Vinci system in the previous discussion. This application could be in the next room, in rural settings or a far-flung battlefield. Another form of telepresence is remote diagnosis and monitoring, a practice that has been referred to as telehealth or telemedicine.

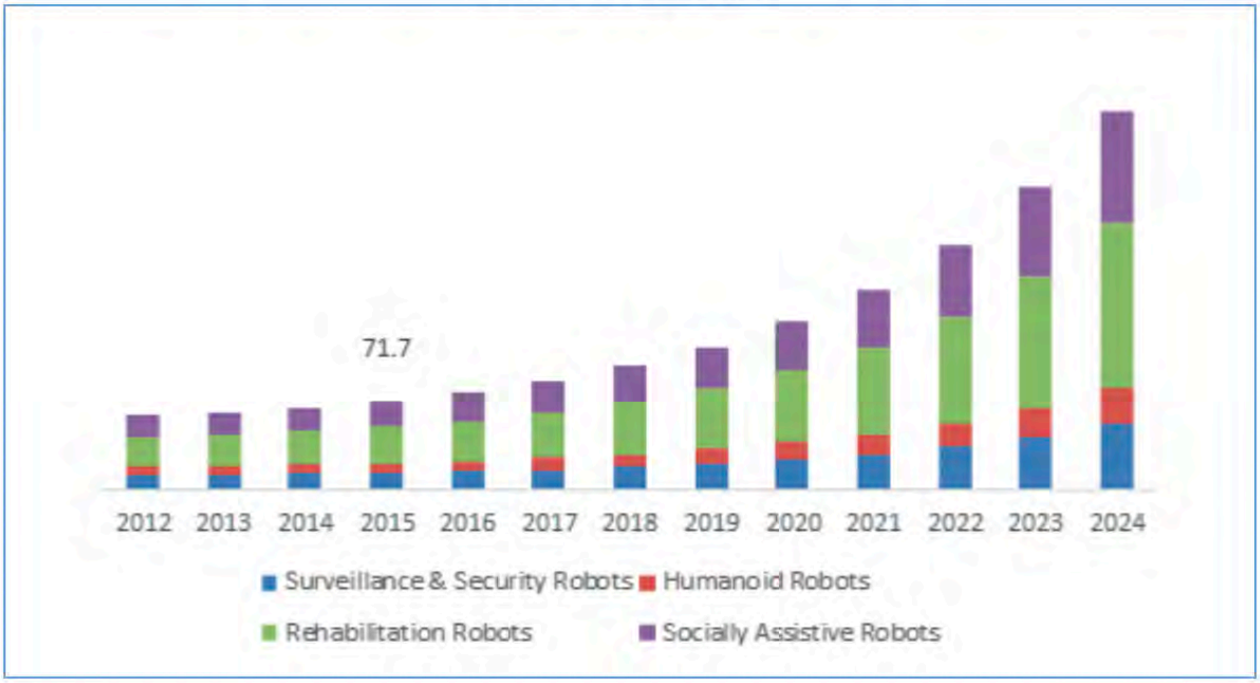
Telehealth allows off-site medical professionals to move, look around, communicate, and participate in diagnostic and monitoring activities from remote locations. An example of this is Robo-doc, a motile robot developed by UCLA Neurosurgery for routine monitoring of patients.[32] Robo-doc is operated by a doctor while allowing her to remain in a fixed location and not spend time moving from patient to patient in a large full-service medical center.

Telehealth also is applied across large distances, as illustrated by University of Utah Health, which has provided telemedicine services for over 10 years. Connected to over 60 facilities throughout a six-state region, it provides clinical and educational resources to rural and underserved areas in nearly 20 clinical specialty fields. Although this form of telehealth relies primarily on video cameras, monitors and internet connectivity, and less on robotics, it does present leasing and financing opportunities.

ASSISTIVE ROBOTS

In addition to enhancing surgical capabilities, robots are increasingly being integrated into routine, non-medical tasks, thus freeing up staff for more skilled and essential work. These tasks include assisting in patient care, physical rehabilitation, and in-patient comfort and care activities. Other applications not directly related to patient care include detecting bacterial, viral, and other harmful environmental matter and autonomously disinfecting hospital and clinical spaces through ultraviolet means. The growth potential for assistive robots is highlighted in Exhibit V.

Exhibit V
US Healthcare Assistive Robots Market, by Product ($ million)
[Global Market Insights]



Many of these applications are service robots that roam freely around hospitals and clinics using limited AI and sensors capable of navigating changing environments, such as the chaos encountered in certain hospital settings. Autonomous service robots such as these, however, function most effectively in a relatively confined, well-known and well-mapped space.

Robots like the Aethon TUG move supplies such as medication, linens, and food from one location to another. The robot moves through hospital corridors, elevators, and departments at any time to make either scheduled or on-demand deliveries. In a caravanning technique similar to those used in transportation and agriculture, users can attach the system to a variety of hospital carts. According to the company, the TUG allows for increased productivity since it “doesn’t get distracted while making a delivery” and can complete the work of three full-time employees while costing less than one.

Autonomous and semi-autonomous robots also are gaining acceptance in such long-term care applications as companions for bed-ridden or house-bound patients and to provide for patient comfort and security.

For example, the aging population in developed countries is growing and is expected to drive growth in eldercare-assistive robotics. According to UN data, the global over-65 population will grow by 181% and will account for nearly 16% of the population by 2050.[33] An expected shortage of medical personnel for this activity will provide additional impetus to growth. Driven primarily by connected communications, robots used in these applications also have wheels and can be remotely controlled by a caregiver using a PC.

There also is a growing market for therapy-aid robots that is used for therapeutic training, evaluation, patient monitoring, physical therapy, occupational therapy, and other hands-on treatments. These treatments and procedures can be taught to semi-autonomous robots and carried out interactively with patients. Many of these care robots may be used by consumers, but the bulk of them will be deployed by commercial care-giving organizations that will need the equipment financed.

LAB ROBOTICS

Robotics is being used in clinical and research laboratories to conduct scientific study and research experiments. Technavio’s market research predicts the global laboratory robotics market will grow steadily at a CAGR of above 8% by 2021, with North America accounting for a significant portion of that growth. One of the overall drivers for this market is human and product safety.

Laboratory experiments involve the use of flammable materials, hazardous chemicals, and substances such as carcinogenic toxins. Consequently, there have been a number of cases in which experiments have caused injuries, or even death, to researchers. As in other industries, laboratory robots are being used to make sure that humans are not directly exposed to these dangers.

Laboratory robotics is one of the few areas in the medical sector in which autonomy and data analytics are playing increasing roles, which presents opportunities for lessors willing to take on the residual risk. Much of this change is being driven by the increasing use of advanced sensors including chemical detectors to measure concentrations of gases, such as methane, and temperature detection sensors to monitor overheating in equipment.

In addition to providing more precise measurements, these sensors also generate a high volume of data that, when analyzed, provide researchers with enhanced diagnostic capabilities. Growth in the pharmaceutical robots market is projected to reach $119.5 million by 2021 from $64.4 million in 2016, at a CAGR of 13.2%, due largely to the growth of use of robotics in pharmaceutical manufacturing.[34]

It is interesting to note that, whereas many segments of robotics are hamstrung by regulation and safety concerns, the opposite is true for laboratory robotics. In this case, regulatory compliance is proving to be a significant impetus to growth.

OTHER APPLICATIONS

Other types of healthcare that will require financing include medical transportation, pharmaceutical robots that provide medications to patients and mix IV solutions, and companion robots that engage emotionally with a user, keep them company and alert the provider if there is a problem with their health.

There are some very high-tech and fascinating robotic applications on the horizon, although their financing potential may be low at this time. One of these is robotic skin technology developed by Yale researchers that enables users to create their own robotic systems on the fly.

> "The skins are made from elastic sheets embedded with sensors and actuators developed in Kramer-Bottiglio's lab. Placed on a deformable object — a stuffed animal or a foam tube, for instance — the skins animate these objects from their surfaces. The makeshift robots can perform different tasks depending on the properties of the soft objects and how the skins are applied."[35]

Exoskeletons also are being developed to reduce the strain on caregivers of lifting and moving patients and aid the disabled through prosthetics that detect bioelectric signals sent from the brain to the muscles. Powered clothing, perhaps leveraging robotic skin technology, that will aid senior citizens with mobility problems currently is in the works. Nanobots that can transport drugs through the bloodstream also are being explored.

In a final note to this industry segment, investment capital is being applied to efforts to monetize the plethora of data created by the sensors so critical to most robotic applications. Some of these include using deep learning image analytics systems to grab data from millions of radiology scans and real-time automated extraction of knowledge from the scientific, regulatory, and commercial body of literature within the life sciences realm.[36]

Challenges

As previously discussed, a significant impediment to medical device autonomy, and, hence, future financing opportunities, is the unstructured environments of hospital activities. The provision of medical care is very people intensive, with everyone doing different things at different times. A hospital ward has nothing in common with the structure of a manufacturing plant, whose robotics thrive on rote repetition.

Another potential obstacle to growth is the acceptance of robotic procedures by surgeons, patients, and healthcare providers. This acceptance most likely relates to differences in experience and comfort with automation and robotics and a preference for receiving human care (both concern and attention). As shown in Exhibit VI, there is an age gap when considering having robotic or traditional surgery.

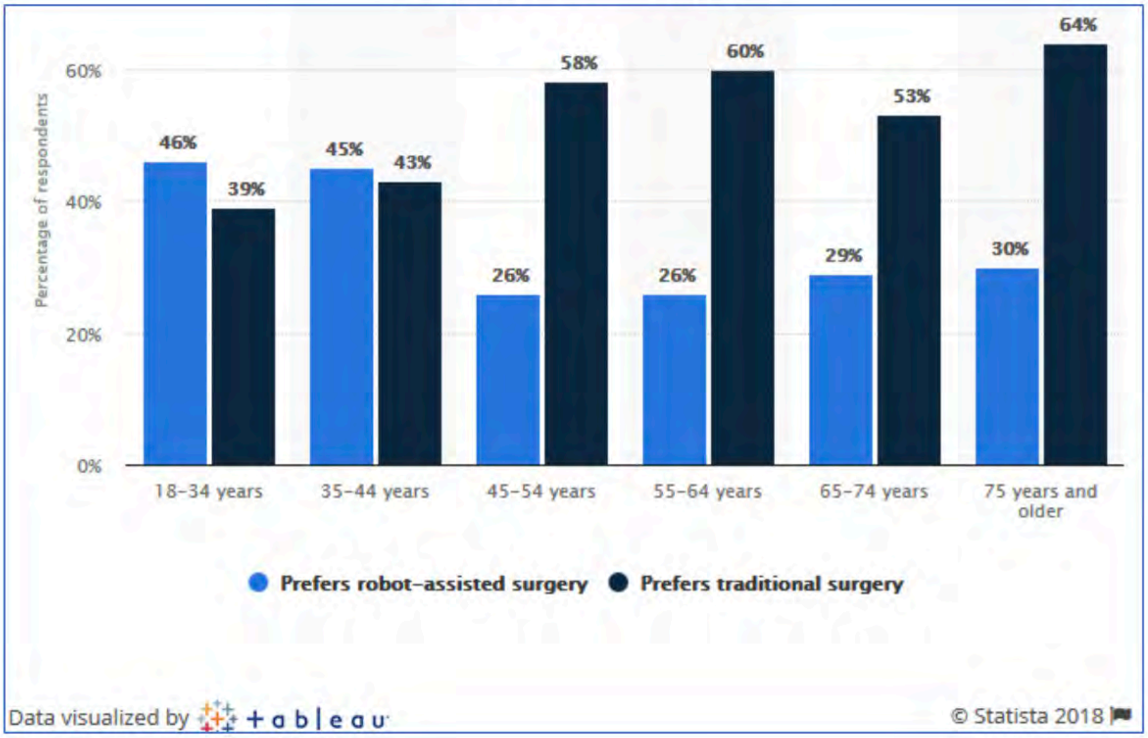
Although one might assume that better results from robotic surgery, for example, might offset the above emotional obstacles, is this, indeed, the case? One of the most-cited studies in this regard, conducted in Australia, compared outcomes for 252 men being treated for prostate cancer. Roughly one-half of the subjects were given robot-assisted laparoscopic prostatectomies, and the others were give open radical prostatectomies in the customary form of surgery.

Outcomes for both groups, using three different criteria, including postoperative complications, were roughly identical. Emotions aside, these kinds of results lead some in the medical profession to suggest that the very large cost differential between using elaborate robotic devices and more traditional procedures in the hands of skilled surgeons, weighs against the further expansion of robotic surgery generally.

Industry members also must be mindful about the liability surrounding autonomous robot activity. The safety and vicarious liability issues found with many equipment classes become even more important in the medical space, given the litigiousness of US society.

There have been a relatively large number of liability claims made against robotic surgery equipment manufacturers, including the industry leader, Intuitive Surgical. The company reported in a 2014 regulatory filing that it was facing 3,000 product liability claims over the use of its da Vinci Surgical System and that it had reserved $67 million to settle an unknown number of such claims.[37] The risk is that lessors may be drawn into these actions.

Exhibit VI
Surgery Preferences by Age



Whether or not such claims could result in exposure of third-party financing companies under vicarious liability or other legal theories remains to be seen, but in any new and emerging technology these kinds of risks must be considered and appropriate precautions, through insurance, contractual indemnities, or other defensive methods, must be taken.

The credit profile of the healthcare industry, of course, is different than other industries due to the number of nonprofit entities in the customer base. Nonprofits, notwithstanding, introduction of robotics into the credit decision does not, by itself increase the credit risk. There may be some added credit risk, though, as prices in the cutting-edge applications drop and smaller firms are able to take advantage of the newer equipment.

There also is an increased residual risk in technology-centric applications. This risk is created by new technology, increased soft costs (the da Vinci system requires significant installation and training costs, for example) and the potential for increased lease breakage due to upgrades or functionality. This residual risk also indirectly affects credit risk.

Impact on the industry

Robotics and cobots will continue to play a growing role in medicine and healthcare, including new modalities yet to be brought to market. Because the capital cost of many of these devices is substantial (e.g., the widely used da Vinci Surgical System may carry an initial cost of $4 million), there will continue to be opportunities for traditional financing and leasing.

In addition, there are growth opportunities for financing managed services in several elements of this segment, as many high technology robotic and automated systems require ongoing services and disposables to operate the equipment. The changing cost structure of healthcare also lends itself to a pay-as-you-go model. As was pointed out in a recent Monitor article, "…usage-based payment structures enable healthcare providers to allocate capital where it will be the most impactful to patients…"[38]

Industrial

The use of robotic technology in the manufacturing sector (often referred to as industrial robotics or industrial technology) has been growing steadily since its earliest days in the 1930s. First devised and utilized for such menial tasks as stacking crates and parcels and moving heavy objects from one part of the factory floor to another, industrial technology came into its own in the 1950s in the automotive manufacturing and assembly industry, with pioneering technical advances created by Kawasaki and General Motors.

Background

Although industrial robots still are very widely used in the automotive industry, their use is continuing to expand into much more diverse applications as technology becomes more adaptable and diversified, incorporating parallel developments in precision mechanics and methods of control using AI.

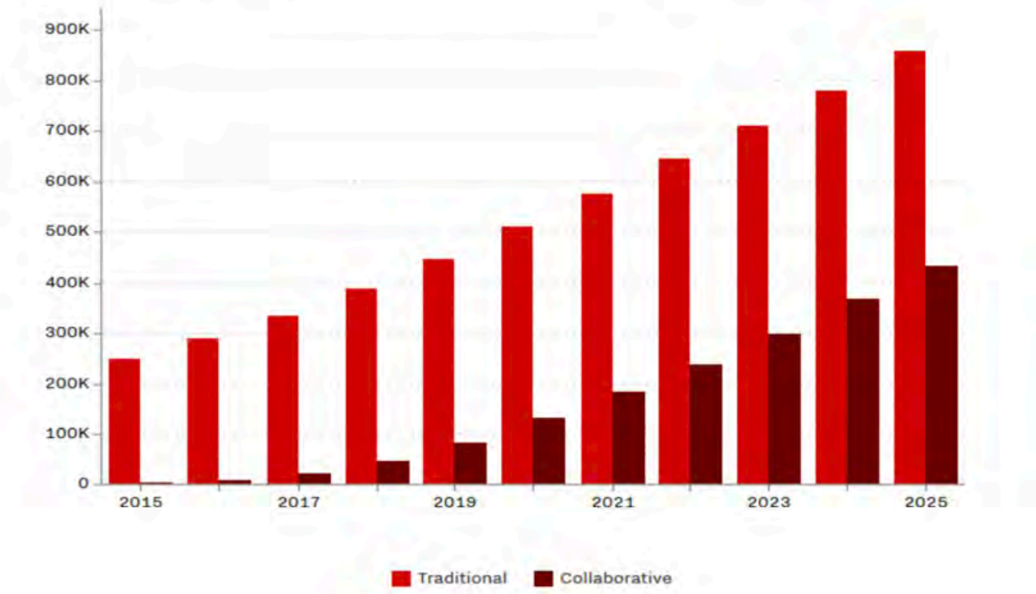
Applications are growing most rapidly in electronics and electrical manufacturing, where robots are utilized for delicate assembly processes requiring precision of movement and positioning; indeed, such uses of industrial robotics are growing at four times the rate of new automotive installations.[39] In many Asian manufacturing markets, total installed units in electrical and electronic assembly applications already exceed those used in automotive manufacturing and assembly.

It is estimated that the worldwide market value of industrial robotics will likely triple over the 10-year period from 2015 through 2025. Although the average selling price of industrial robots is expected to decline over time, from nearly $44,000 to closer to $28,000, the number of units sold is forecast to increase from 250,000 in 2015 to more than 850,000 in 2025 – a 13% compound annual rate of increase in sales.[40]

Growth in sales of cobots in the manufacturing and industrial sector is expected to be even more dramatic over the same period, with the number of units forecast to increase from a mere 3,600 in 2015 to more than 434,000 in 2025 (a CAGR of over 61%).[41] Again, although the average selling price of cobots is anticipated to decrease each year, this volume of robotics (including both robots and cobots in the industrial sector) represents annual sales volume of more than US$33 billion by 2025, up from US$11 billion in 2015. The breakdown between traditional robots and cobots is shown in Exhibit VII.

Perhaps a more interesting metric regarding industrial robots (and industrial automation generally) is the measure of industrial robots in use per capita (the "density" of industrial robots). By far the densest use of industrial automation and robots in the world occurs in South Korea, where, in 2016, there were 631 robots installed per 10,000 employees, primarily due to their accelerating use in electronics and in manufacturing generally.[42]

Exhibit VII
Traditional versus Collaborative Industrial Robots (units sold)



In Singapore, Germany, and Japan, three of the most highly industrialized nations in the world, the density of robots also is significantly higher than in other countries (488 per 10,000 employees for Singapore and about 300 per 10,000 employees in both Germany and Japan). In the US, on the other hand, robot density is somewhat below 189 per 10,000 employees, reflecting a slow pace of development and deployment in a proportionally smaller manufacturing sector.[43]

This level of robotics adoption in US industries would appear to be a sign of opportunity for US manufacturers and the leasing and financing companies that support them, given the relatively greater scope for expansion. This expansion will come as more users become better acquainted, and more comfortable, with robots working side by side with their human counterparts.

Challenges

The trend in the industrial sector of robotics is less toward full robotic autonomy and more toward collaboration between human operators and specially designed cobots. Begun only in 1994 at General Motors, the incorporation of collaborative machines into industrial applications has been growing over the past two decades. In 2015 the first true cobot was commercially introduced by FANUC, a Japanese manufacturer, the world's largest producer of industrial robotics. Since then, worldwide growth in the use of such machines has continued to accelerate.

As noted, autonomy is generally less of an issue than the closeness of cooperation between cobots and their human operators. At Toyota's auto manufacturing plant in Georgetown, KY, for example, humans provide quality assurance, inspection, and testing while their cobot partners do the heavy lifting, assembling, and bolting of parts and structures.[44] In spite of increased use of cobots, the company is not targeting reductions in the labor force. Instead, Toyota views robots and cobots as "merely enablers and handmaidens, helping assemblers do their jobs better, stimulating employee innovation, and, when possible, facilitating cost gains."[45]

Instead of replacing humans in assembly and manufacturing applications, robots and cobots have provided increases in the productivity of existing human operators and workers through the cooperative integration of complementary digital and robotic functions. Over the past 25 years, the Siemens Amberg Electronics facility in Germany has developed into a fully digital plant, yet, over that time the number of workers has remained the same at about 1,200. Being trained in digital technology and manufacturing, however, these workers have increased their productivity – and the productivity of the plant – by more than 1,000% by "assisting" their cobot co-workers on the line and increasing the efficiency of the combined workforce.[46]

Indeed, it has been said that humans are being forced by cobots to become more human and embrace the skills and attributes that robots cannot yet replicate or do better than we can.[47] These results have positive ramifications for the leasing and financing industry, the volume of equipment to be financed will not be artificially constrained over concerns of job losses.

As with CNC machines before them, industrial robots are designed and used largely for repetitive and predictable tasks. They can be programmed to perform these tasks very efficiently and, in situations requiring great strength, agility, or exposure to physical or health risks, without the inherent limitations and dangers presented to human workers. Likewise, even cobots are used in roles that generally are predetermined while still allowing for human intervention and guidance for specific tasks and changes in circumstances. Thus, they do not use or need a high level of artificial intelligence, mobility, or on-board problem solving and responsive skills required in other applications such as medicine or personal services.

Similarly, industrial robots and cobots often are stationary or have a sufficiently limited range of mobility or positioning that they can function without relying fully on telecommunications or Internet connectivity. They can nearly always be hard wired or tethered to power sources and controlling units without the need for potentially intermittent wireless interfaces and access to power or other resources via tethers or internet linkage. Nevertheless, it has been predicted that within the next three years intelligent robotic agents may themselves be used to supervise and coordinate more routine industrial robots. Strides in this regard are estimated to increase the productivity of such combined systems – robots supervising robots – by as much as 30%.[48]

It is predicted that by the year 2020, 45% of newly installed industrial robots will have at least one intelligent feature that is not in common use now.[49] These may include:

- Predictive analytics, providing robots with the ability to foresee failures, improvements, or additional uses based upon analysis of data and information gathered through routine use and operation
- Health condition awareness, including reporting of dangers or exposure of human coworkers to hazardous materials or byproducts or risky operational activities and uses
- Self-diagnosis, providing human maintenance engineers and designers with the ability more quickly and accurately to predict or repair failures or misuse
- Peer-learning, through which robots may observe, sense, or track each other's activities and motions to adapt different or better methods or approaches to common problems and improvements

- Autonomous cognition, allowing robots to learn from their activities, sensors, and feedback to adjust their own behavior and responses to stimuli and inputs, thereby enhancing their efficiency and capabilities (although in a more limited way than employing true artificial intelligence)

Most industrial robots are programmed using Programmable Logic Controllers (PLCs), which allow operators to utilize unique instruction sets for motion control, process control, distributed control systems, networking, and other functions in and among robotic devices. PLC programming may be a significant cost of initially installing an industrial robot and of retooling it when the requirements of a specific product line or factory floor change.

Software and other soft costs, therefore, became a crucial issue when financing these assets, especially when combined with cutting-edge technology. These soft costs create different credit considerations, as well as those associated with traditional asset risk.

As with many forms of technology-based assets, industrial robotics carry a degree of obsolescence risk. This risk may be mitigated, however, by a comprehensive obsolescence plan and by paying continuing attention to technology-based and age-based failures and maintenance issues. An industry study has shown that more than 90% of process manufacturers use automation beyond the OEM's obsolescence date,[50] and a certain element of comfort is found in the fact that reprogramming and repurposing some types of robots and cobots may extend their useful lives.

However, manufacturing plants may be just one breakdown away from a shut down due to the unexpected failure of one crucial part or operation, especially near (or after) the end of a system's useful life. This risk is illustrated in the "bathtub curve" model of failure rates and continuing maintenance costs shown in Exhibit VIII. Underwriting of leases and loans supported or collateralized by such assets must include careful consideration of this phenomenon in determining optimum tenor and pricing for technology assets with appreciable obsolescence risk.

Exhibit VIII
Bathtub Curve Example

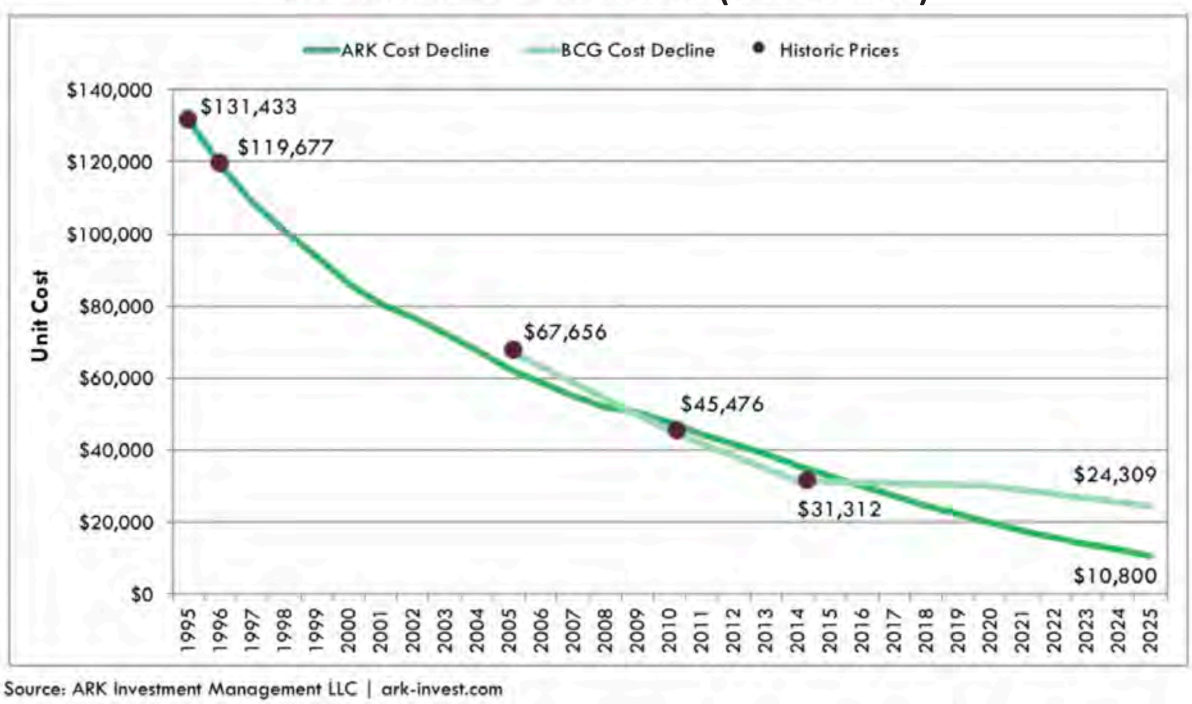
Fig 1. Failure rates and maintenance costs have been shown to increase as equipment reaches the end of its useful life.

Of course, knowledge of these factors and customers' willingness to deal with them at the optimum time during the life of a robotic system may also present opportunities for upgrades, expansions, and even early disposal at still-attractive pricing for both vendors and financing sources who specialize in this equipment segment.

In the long run, any ancillary costs and risks incurred by introducing industrial robots are likely to be offset by reduced labor costs and increased productivity and throughput. When other costs related to human operators (e.g., payroll burden, accidents, time off, illness) are considered, potentially high rates of return for companies investing in (or financing) robots and robotic systems become possible. From the financiers' standpoint, the soft costs and risks involved in industrial applications are not substantially different from those encountered in financing CNC machines or other regularly used automated devices in this segment.

Credit issues and underwriting risks are in many ways similar to those facing leasing and finance companies in other equipment sectors of the economy. As the unit cost of industrial robots continues to decline, as illustrated in Exhibit IX, it is anticipated that they will be become cost-effective and, hence, available for increasingly smaller manufacturers, assemblers, packagers, and other companies.

Exhibit IX
Industrial Robot Cost Decline (2015 dollars)



Accordingly, the customer base for sophisticated industrial robotics is expected to expand into SMEs and smaller-scale enterprises, which in turn may present different credit and underwriting challenges for financing companies than those found in large volume transactions with the likes of Toyota or Siemens. Nevertheless, the factors affecting credit underwriting and pricing of transactions in industrial automation systems and robotics in smaller scale applications are not unique to these assets types, but rather to the marketplace itself – and they may be dealt using methods and practices similar to those in other segments of the SME market, including pricing to anticipated returns in a particular application or use of robotic systems and equipment in their intended setting, regardless of relative size.

Indeed, the ROI for some applications in which relatively small-scale robots and systems are deployed may even be dramatically improved over manual alternatives. For example, Baxter, a cobot sold by Rethinking Robots and used in small company assembly and packing applications, is reported to deliver a break-even ROI is as little as 10 months. This while still allowing the staff of humans who work with it to remain at full strength and concentrate on less repetitive and burdensome tasks.[51] With results like these, even credit-conscious financing sources may see expanded opportunities.

There is always the risk of exposure in selling (or leasing) equipment, especially equipment that has sufficient physical power, characteristics, and opportunities to result in significant harm to humans in the event of failure or design flaws. Robots may be especially susceptible to claims for damages in this regard because of their appearance and reputation in many peoples' minds (and imaginations) as anthropomorphic beings.

To date, the industrial robotics industry, through individual manufacturers and through very robust trade association activity, has focused a great deal of attention on the safety issue. As a result, many installations include safety and risk training as well as physical safeguards, barrier fences, operator intervention and shut-down devices for assuring operator protection and safety. New generations of cobots incorporate force-limiting restrictions, more advanced sensors and electronics, and more user-friendly means of adapting cobot movement and power to their shared environments.

These approaches have been very effective overall for traditional industrial robot installations. In the 30-year span between 1984 and 2013, only 37 robot-related accidents occurred, of which 27 resulted in a worker's death.[52] Compared with 4,585 reported workplace fatalities in 2013 alone,[53] robot-related activities in the workplace represent a statistically very safe environment.

In the manufacturing and industrial context, the likelihood of robots or cobots causing harm to members of the general public is very low, since these machines are most often confined to specific tasks in limited areas of workspace and with limited access by onlookers, customers, or passers-by. However, injury to workers caused by robots or cobots may nevertheless continue to be a risk that must be calculated into any manufacturer's, operator's, or financier's assessment of roboticization.

Such risks may take several forms. They may arise, for example, through the misuse or misapplication of robots in activities for which they were not designed or adequately programmed, leading to liability on the part of owners, operators, or even third-party funding sources. Of greater (or at least more rapidly growing) concern currently is the risk of misbehavior by robots that incorporate elements of artificial intelligence – teaching themselves inappropriate or dangerous behavior or activities which result in harm to human operators or bystanders.

Such cases may result in claims of liability for negligence of the robot manufacturer or even of the owner of the robot under the theory of *respondeat superior* (i.e., that the robot is a servant or agent of the owner, who then bears liability for the acts of the robot).[54] Such a doctrine could theoretically even implicate a third party financier under earlier case law developed with respect to leased equipment and motor vehicles. One way to protect against this risk to provide enacted relief is enacted in the form of exclusions for lessors and finance companies that contractually are uninvolved in the robots' operation, programming, or AI applications.

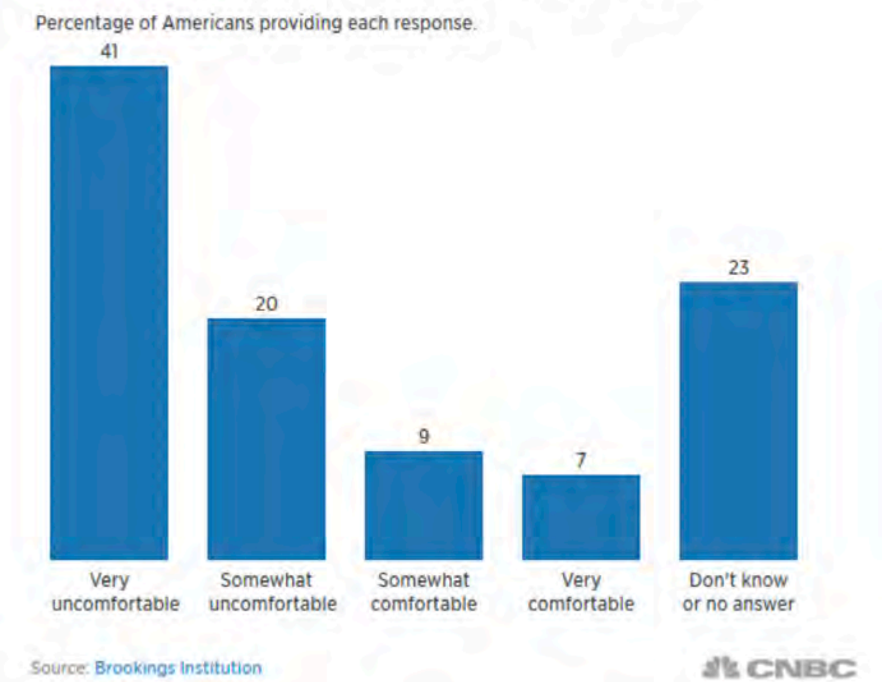
To date, the US law around regulating industrial robots and automation has centered around ensuring worker safety.[55] Beginning in 2014 there has been discussion of a potential Federal Robotics Commission, which would not regulate the use of robots directly but would promulgate rules for the safe use and operation of industrial robots and automated systems. However, some published analysts consider the legal framework surrounding regulation of robots already to be well established, with laws and regulations currently available to deal with incidents of misuse, negligence, failure to supervise, and malfeasance utilizing existing law and regulations.

Much of the effort to create a regulatory framework for the use and management of robots seems to stem from the inherent fear by many people of the power and capabilities of robots which may not be adequately managed or supervised. In a recent CNBC/Brookings Institution poll more than 60% of Americans said they are uncomfortable with robots, and 52% of those polled believed it is somewhat likely or very likely that within 30 years most human activity will be taken over by robots. The results of this poll are shown in Exhibit X.

While these results may reflect more on robots used in everyday life (such as personal or virtual assistants) than industrial robots or cobots, they nevertheless show a state of mind that could at some point lead to more regulation of the industry.

Residual value considerations for the financing of industrial robots are similar in nature to those that apply to financing of machine tools and other production and manufacturing equipment. There are currently no major disruptive technological advances being discussed for these kinds of machines. Rather, the field has grown around the more gradual introduction of improved software capabilities, the addition of AI and advanced self-learning and adaptive technologies, and improved precision, strength, and other physical characteristics resulting from advances in materials science.

Exhibit X
Americans' Comfort with Robots



The only identifiable disruption on the horizon for robots and cobots in manufacturing may be from the continuing growth of additive manufacturing, or so-called 3D printing, which already is taking hold in widely diverse US manufacturing environments. Typically smaller scale (at least for now), additive manufacturing currently is being used mostly for specialized high-value parts and fabrication. It may be combined with robotics, however, to automate the production of an array of specialty products and to enhance the manufacture of relatively smaller or limited volumes of products, thereby achieving economies of labor, raw materials, and throughput. For example, GE Aviation has incorporated additive manufacturing processes into the fabrication of turboprop engines, reducing the need for 855 separate parts to only 12, with more than one-third of an entire engine produced by robotic additive manufacturing.[56]

From an operational standpoint, the financing and leasing of industrial robotics is expected to be very similar in structures and operations to those currently used in financing CNC machines, machine tools, and other traditional industrial equipment. Robots and cobots in this space can be rather readily repossessed and resold. They also will continue to have reasonably strong collateral and residual value because they can readily be reprogrammed and adapted to other uses in the manufacturing process. As an interesting indication of this premise, there are hundreds of industrial robots and cobots for sale on eBay at any given time, and a Google search shows more than 19 million hits for the term “industrial robots for sale.”

Impact on the industry

The growth rate in industrial robotics is slowing somewhat as the market reaches a level of saturation, but new applications still are being explored, and new technologies may create opportunities for replacements and upgrades.

Spending on industrial robots is expected to continue to accelerate as new methodologies and technologies are incorporated into updated models and applications and as new methods of production are created for the integration of cobots and other human-assistive devices in the workplace. Therefore, even with no major breakthroughs forecast for the underlaying technology, there will continue to be opportunity in this segment for providing long-term financing and leasing.

As is the case in many industry sectors, some lessors and lenders may be attracted by the potential volume of growth in robotics and related technology, and the opportunity to become specialized in this equipment at a relatively early time in its lifecycle (at least as to cobots and adoption of AI technologies) may be very attractive. Pricing and structuring will likely remain in their current forms and will change in parallel with machine tool and other industrial machinery trends, with some reductions in purchase pricing over time as newer models of robots and cobots become faster, more accurate, and longer-lived, thus extending their useful economic lives and reducing times to profitability.

Material handling

Examples of automation within the materials handling industry date back to the 1950s with the development of the Unimate, an effort of Joseph F. Engelberger and George C. Devol, Jr.[57] The Unimate was first delivered to General Motors in 1961 and used to unload high-temperature parts from a die casting machine – a very unpopular job for manual labor. While the automobile industry is still a major beneficiary, materials handling, itself, and the continuing developments in automation have become quite ubiquitous throughout the industry.

Material handling is the embodiment of industrial robotics as most robotic applications fall within this category. End-users deploy robots to improve throughput, quality, flexibility, and consistency while decreasing ergonomic hazards for workers, scrap and the need for additional conveyance systems in manufacturing and warehouse distribution centers. Robots are increasingly called on to handle material ranging from blood samples to entire vehicles during the manufacturing process.

Background

While automation in material handling dates back over 60 years, the market has been experiencing dynamic growth of late and, according to one report, mobile robotics in material handling and logistics will become a $75 billion market by 2027 and then more than double by 2038.[58] On the industrial side, this includes automated guided vehicles and carts, autonomous industrial material handling vehicles, autonomous mobile carts, mobile picking robots, and trucks

According to the 2018 MHI Annual Report, in a survey of more than 1,100 manufacturing and supply chain industry leaders across a wide range of industries, implementation of robotics and automation continues to expand as companies look for ways to remain competitive. According to the survey, adoption of these technologies is currently at 34%. However, adoption is predicted to reach 53% over the next two years, and 73% over the next five years.[59]

AUTOMATED GUIDE VEHICLES (AGVs)

The advent of advanced sensors, data analytics, and other technology is enabling a new generation of AGVs for use in the first wave of smart manufacturing and distribution facilities. These advances require new ways of thinking across all aspects of material handling, especially when it comes to functional safety and reducing accidents in the workplace.

The rate of adoption of AGVs in material handling has been slow in the past, but all that is changing with the aforementioned technologies and the rise of the interconnected workplace. AGV's, which represent about 10% of the global market for automated materials handling equipment in factories, industrial facilities, retail outlets, warehouses, etc., can be categorized into four distinct types:

- Forklift trucks
- Pallet lift trucks
- Tow vehicles
- Unit load carriers (to convey heavy goods from conveyor to assembly line)

What distinguishes today's AGV from its predecessors is the rapid development of highly sophisticated sensors and controls that help increase efficiency and cost-effectiveness as well as providing greater safety. These AGVs have been shown to be more efficient and cost-effective than human-controlled materials handling equipment. Today's technology offers navigation and steering controls as well as a wide range of sensors and encoders that provide environmental feedback to the central control system.

There are various types of navigation technologies in the market such as magnetic navigation (using magnetic tape for the guide path) as well as laser-guided navigation. The advantage of laser-guided technology is that it requires no floor work and route changes can be made via software updates. Vision-guided vehicles (VGVs) use optic, speed and/or laser sensors along with software that builds a 3D map of the operating environment to navigate. AGVs based on natural navigation technology do not require reflectors or markers and use LiDAR (Light Detection and Ranging) technology.

There also are a variety of automated steering control set-ups with the three most common being three-wheel, differential and quad configurations. The three-wheel is most common for AGVs while the differential is popular for unit load carriers and tow-vehicle AGVs. The quad-wheel configuration provides the most maneuverability as it permits full-circle movement in any direction, making it the ideal solution for unit load carriers.

MOBILE PICKING ROBOTS

Typically, significant physical labor has been a requirement for the role of warehouse employees. Mobile piece-picking robots are capable of supporting workers by removing both the mundane and the hazardous tasks, allowing workers to spend more of their time on complex and rewarding work, including maintaining and training the robots.

Mobile robotic picking generally has been restricted to stationary robotic arms operating on known objects in controlled environments. However, artificial intelligence technology for robotic grasping is changing the dynamics, and the list of limitations is quickly shrinking. The prospect of robots working alongside human workers is now very much a reality, and this enhanced collaboration better optimizes warehouse processes.

Challenges

The major challenges to future automation within material handling include concerns that are not limited to this industry. These include cost, the availability of an adaptable workforce that can shift to more complex and challenging tasks, and the concern of cyberthreats as the environment becomes more digital, and IoT becomes more prevalent.

Certainly, costs will come down as automation becomes more prevalent, particularly for labor. For example, there has been much discussion about moving to a "lights-out" environment, in which there are no people and all material handling tasks are fully automated. While many companies are on that path, it is still early on, and some experts say that the dark factory or distribution center is many decades away.

That being said, several industry experts peg 80% lights out as a reachable goal towards which companies can strive. Some even believe that 95% may, at some point, be achievable although the last 5% "just isn't financially worth it."[60] With automation far below the 80% threshold, many companies are seeking to justify the investment in automation, knowing that it will increase productivity and efficiency as well as enhance safety.

Certainly, the larger companies can better afford to make these investments, but the smaller companies will be slower to come on board in making such major investments that include not only equipment but systems upgrades to accommodate the new technology and data feedback requirements. One of the best examples of the impact that automation can bring to an organization is the acquisition of Kiva Systems by Amazon in 2012.

Amazon paid $775 million for the start-up material handling company, roughly a 300% premium over the company's last private equity evaluation. At the time, Amazon called Kiva simply "a leading innovator of material handling technology," but the acquisition was revolutionary, radically changing how the e-commerce giant fulfills millions of orders and potentially saving the company, by some estimates, up to $2.5 billion.

Addressing the availability of labor, there is a concern in the industry about the current labor shortage that is being driven by near full-employment in the U.S. and the rapid growth of e-commerce, that by some estimates will create a need for an additional 450,000 warehouse and distribution workers in 2018-2019.[61] While it is recognized that automation in material handling will eliminate some jobs in the longer-term, the reality is that it will also create other more complex and rewarding jobs and achieving the 80% lights-out number will take time and considerable money.

The threat of cyberattacks has been an issue for some time as the world becomes more connected. This greater connectivity is transforming the industry in mostly positive ways, but, as more and more devices talk to each other, keeping data safe has arguably never been more challenging. Manufacturing plants are getting 'smarter' as physical devices become connected, thereby allowing them to talk to each other, become more efficient and trigger actions with minimal human involvement. This connectivity raises risks, however, so companies must also take steps to improve their security. Given the abundance of shared data, it is important that this information generated is protected from outside security risks.

Impact on the Industry

While cost and ROI are primary foci within the industry, companies in the materials handling industry continue to invest heavily in innovation. According to an industry survey, 47% of respondents are planning new technology investments totaling more than $1 million over the next two years, while 20% plan to spend more than $5 million and 10% plan to spend more than $10 million.[62]

The areas in which they intend to invest are numerous and present significant opportunity for equipment lenders and lessors, as shown in Exhibit XI. The automation of this particular industry has the attention of many companies in a multitude of business lines with the potential cost savings, especially human labor, obviously attractive as well as the enhanced safety it provides.

As previously mentioned, the potential of significant upfront costs, in particular, creates a major hurdle for many companies, so lease financing is a strong alternative to consider. That being said, what constitutes a large part of the investment in transitioning to automation involves soft costs and software and raises some issues concerning residual realization and collateral values. However, the ability of the equipment finance lessors and lenders to adapt to these changes and set reasonable expectations for both residuals and collateral values has been a hallmark of the industry for decades. In addition, the presence of high technology devices in material handling and the potential for more frequent upgrades presents opportunities for additional business.

Exhibit XI
Investment in Products and Services over Next Three Years

Transportation

While it seems that the technological state of autonomous vehicles has gone from future fantasy to reality overnight, the history of self-driving vehicles goes back almost 100 years. It was not long after the birth of the automobile that inventors started thinking about autonomous vehicles. For instance, in 1925, Francis Houdina drove his radio-controlled car through the streets of Manhattan without anyone at the steering wheel. According to *The New York Times*, the radio-controlled vehicle could start its engine, shift gears and sound its horn, "as if a phantom hand were at the wheel."[63]

As another example, John McCarthy, one of the founding fathers of artificial intelligence, wrote an essay in 1969 titled "Computer-Controlled Cars" in which he refers to an "automatic chauffer" capable of navigating a public road via a "television camera input that uses the same visual input available to the human driver".[64] McCarthy's vision of the autonomous vehicle is mirrored closely by (at least) one current definition of a driverless car.

This definition states that "A self-driving car (sometimes called an autonomous car or driverless car) is a vehicle that uses a combination of sensors, cameras, radar, and artificial intelligence to travel between destinations without a human operator. To qualify as fully autonomous, a vehicle must be able to navigate without human intervention to a predetermined destination over roads that have not been adapted for its use."[65]

In the 1980s, Carnegie Mellon University in its Navigational Laboratory (Navlab) began building driverless vehicles and has built a series of robot cars, vans, SUVs, and buses. Since that time there have been multiple advances, with the technology accelerating rapidly over the past several years, in particular.

Background

As evidence of this acceleration, over the period from August 2014 to June 2017, approximately $80 billion was invested in the autonomous vehicle (AV) market.[66] While the dollar investment has been significant, the number of units operational is very minimal and consists primarily of test vehicles from automakers and high-tech companies investing in developing self-driving cars and trucks.

The ultimate target of these efforts is the completely autonomous vehicle not requiring a driver under any situation. However, the market is not there yet. Some would claim that we are nowhere near there and could be decades out. However, there is evidence that major auto manufacturers including General Motors and Ford are planning to roll out their own fleet of driverless taxis within the next couple of years. Google's Waymo has announced that it plans to launch a driverless taxi service in Metro Phoenix by the end of this year. Analysts are predicting that self-driving revenue will hit $2.3 trillion by 2030, with Waymo capturing 60% of the market.[67]

SAE International released a document in 2014 titled *Taxonomy and Definition for Terms Related to On-Road Motor Vehicle Automated Driving Systems*, which is the current standard for describing the level of automation in vehicles. This standard is used by the National Highway Traffic Safety Administration and also is directly referenced in proposed legislation to standardize self-driving technology in the US.

SAE established five different levels of automation,[68] as illustrated in Exhibit XII. According to a recent article, Level 2 is the sweet spot for many auto manufacturers, which means the driver still needs to keep their hands on the wheel and pay attention.[69]

Exhibit XII
SAE Levels of Automation

LEVEL	AUTOMATION TYPE	EXAMPLES	WHERE OPERATIONAL	IF AUTOMATION STOPS WORKING
	Driver performs part or all of the dynamic driving task			
0	**No driving automation**	No driving automation anywhere	Not applicable (no automation)	Not applicable (no automation)
1	**Driver assistance**	Adaptive cruise control OR lane centering (driver supervises)	Limited roads or modes	Driver resumes performing all of the dynamic driving task
2	**Partial driving automation**	Adaptive cruise control AND lane centering (driver supervises)	limited roads or modes	Driver resumes performing all of the dynamic driving task
	Automated Driving System (ADS) performs all of the dynamic driving task			
3	**Automated driving** CONDITIONAL	Automated driving in dense freeway traffic (low speeds)	Limited area, roads, and/or modes	Driver takes over after warning
4	**Automated driving** HIGH	Automated driving within a city center (geo-fenced location)	Limited area, roads, and/or modes	ADS brings vehicle to safe stop
5	**Automated driving** FULL	Automated driving everywhere	Everywhere on-road	ADS brings vehicle to safe stop

The automakers and high-tech companies that are spending billions of dollars on developing self-driving cars and trucks tout the idea that AVs will help create a safer, cleaner and more mobile society. Politicians are not far behind in their enthusiasm for the new technology, either. “This is probably the biggest thing to hit the auto industry since the first car came off the assembly line,” Senator Gary Peters (D–MI) told a cheering audience of researchers and executives at a computing conference in Washington, D.C. in late 2017.

“It will not only completely revolutionize the way we get around, but AVs also have the potential to save hundreds of thousands of lives each year.”[70] While developers amass data on the sensors and algorithms that allow cars to drive themselves, research on the social, economic and environmental effects of AV are sparse. According to most transportation experts, truly autonomous driving is still decades away, however, as there has not been enough experience to study satisfactorily.

While the concept of the autonomous vehicle was initiated with the focus on driverless cars on the consumer side, there also has been ensuing progress in developing commercial autonomous vehicles, including trucks, buses, and shuttles. There is significant interest in the truck manufacturing market to address several ongoing and growing needs that impact the industry, as it is believed there would be major cost reductions through the employing autonomous vehicles in the over-the-road hauling of goods and services.

A study by PricewaterhouseCoopers suggests that by 2025, fleet owners could reduce their total costs by 15% compared to 2016 and even 28% beyond that year.[71] While certain other costs would have single digit savings, the highest potential cost savings lies with the cost of the driver. It is estimated that autonomous driving technologies are likely to reduce annual driver costs by a staggering 30 percent by 2025 – an incentive that makes self-driving trucks a hot prospect for freight companies.[72]

Cost, however, is not the only motivation, as the US might need self-driving trucks to avoid a labor shortage crisis. The trucking industry had a shortage of 51,000 truck drivers at the end of 2017, American Trucking Association (ATA) chief economist Bob Costello told *The Washington Post*. That number is on the rise, up from 36,000 at the end of 2016.

The ATA attributes the growth of the sector to a boom in online shopping, with Amazon leading the way. People want things from far away, and they want it now, and it is only going to get worse, as the ATA predicts the trucking industry will need to hire 900,000 more drivers in the next 10 years to keep up with demand."[73] This statistic is no surprise given the estimated 21 million autonomous vehicles expected to be sold globally by 2035.[74] Manufacturers are developing commercial vans with roof-mounted drones and automated cargo areas to assist delivery drivers in this sector.[75]

There have been new transportation models recently introduced into the truck marketplace as the technology moves in the direction of full automation. The concept of platooning – whereby vehicles travel closely together in convoy or caravan while connected by a wireless communications system – has been employed overseas for some time and is gaining more interest in the US. These wirelessly attached rigs accelerate and brake in unison without any driver input in the following vehicles. The claimed benefits of platooning include improved road safety, fuel efficiency, and traffic flow.

As of January 2018, there were sixteen states that were supporting platoon demonstrations and testing. Several trucking companies were conducting truck platoon demonstrations and testing, including:

- Daimler—Freightliner/Western Star
- Peloton
- PACCAR—Kenworth/Peterbilt
- Volvo (Caltrans, UC-Berkley PATH)
- Navistar—International (TxDOT, Texas A&M Trans. Inst.)
- Tesla

Tech developers also have entered the market, aiming to leapfrog Advanced Driver-Assist Systems (ADAS) and jump to full autonomy, these companies include TuSimple, Uber, Waymo, Embark, and others.[76]

In addition to platooning and caravanning, automation is being used to make public transportation and shared rides, such as Uber and Lyft, more efficient. Automated, driverless shuttles have been introduced to solve the first mile/last mile situation in which public transit accommodates riders from station to station but does not get or take them to their final destination. Truly driverless vehicles are currently operating in the US and around the globe, including San Ramon, California as well as local transportation providers in Australia, China, Japan, Sweden, and Switzerland.

LAST-MILE DELIVERY SOLUTIONS

More and more companies are looking to use robots and aerial drones to deliver goods to customers. Whether they are personal assistant delivery robots, mini-vehicle robots, or unmanned aerial vehicles (UAVs/drones), it is clear that the logistics industry is looking towards automation and autonomy to solve the problem of last-mile delivery to the customer.

While the current state of robotics in this environment is such that some delivery robots are semi-autonomous or even use operators, the industry is moving to fully autonomous units. Some industry experts predict that more than 75% of last-mile deliveries will include elements of autonomous operation, with McKinsey predicting that autonomous vehicles will make up 85% of last-mile deliveries by 2025.[77] Well-known current examples of companies experimenting with robots and drones to deliver parcels include Amazon, DHL, and UPS.

The drone logistics and transportation market will exceed $11 billion by 2022, with a $29.06 billion market by 2027, predicted Research and Markets in June. "Increasing demand for faster delivery in the logistics industry is expected to fuel the growth of the drone logistics and drone transportation market," the research firm stated.[78]

Challenges

The path to pure AVs has many current and potential obstacles. While the consensus is that the Level 5 vehicle – true automation- is sure to come, timing is definitely a question, and several potential barriers need to be addressed. Some transportation engineers project that the SAE Level 5 may not be attained until 2075.[79]

On the legal and regulatory front, specific laws will be required as well as regulation around the interaction between conventional vehicles, pedestrians, and AVs. A patchwork of state and local laws and regulations could block AVs from operating in certain markets, limiting economies of scale. As the process of automating cars has moved forward, there has been considerable litigation, yet, despite litigation and recalls, the manufacturers continue to increase the computerization of automobiles and pursue the development of self-driving vehicles.

Thus, it appears that tort litigation has had little impact on the innovation in robotic vehicles.[80] Furthermore, there is a well-established body of law surrounding vicarious liability, the type of which will arise as AVs become more ubiquitous, so it is not anticipated that there will be unique legal challenges arising from driverless technology.

Consumer acceptance and human behavior also will impact the growth of AVs. As some have experienced, the initial growth phase of AVs can lead to more congestion as conventional vehicles need to interact with AVs, which will also likely be regulated conservatively. There also may be calls for dedicated lanes or roadways to separate AVs and driver-operated vehicles.

While AVs ultimately will yield significantly fewer deaths and injuries, public opinion is currently being defined by incidents and casualties during the testing phase. It is an interesting phenomenon that, although society appears to have some tolerance for road accidents and, even, fatalities caused by human drivers, there may be little tolerance for the inevitable road accidents and fatalities caused by AVs albeit they are at lower levels.

In addition, people surveyed in various studies have grappled with how or if the autonomous vehicles will deal with split-second decisions that need to be made to avoid endangering human lives – both inside the vehicle and outside. Should the vehicle swerve to avoid hitting pedestrians and kill the driver or should the opposite take place? What about women and children versus men or doctors versus bank robbers?

Industry experts have acknowledged these dilemmas and have continued to push for the advancement of autonomous vehicles. Mark Rosekind, a former administrator of the National Highway Traffic Safety Administration during the Obama Administration in a recent interview with BBC, addressed these dilemmas.

"Unfortunately, there will be crashes. People are going to get hurt, and there will be some lives lost. All of that I think is going to be, I hope, focused on the service of trying to save lives," he said, adding that a vast majority of fatal accidents today are due to human error, and that the current risks of letting imperfect self-driving cars onto the road are worth the chance of a future without car crashes at all.[81] Still, according to one report, societal and individual expectations of technical perfection in vehicles is rising. Higher demands in vehicle quality and functions also call for corresponding safety measures when rolling out automated vehicles.[82]

There also are questions of how insurance companies will adapt the policies they write to take account of driverless vehicles. There could be an impact on both the consumer and commercial market for the same reason. According to S&P, shifting liability from individuals to auto manufacturers - should it occur - eventually will have a major effect on motor insurers. Because of crash avoidance technology, it expects to see declines in both the frequency and severity of claims, significantly reducing costs to the motor insurers.[83]

As AVs become connected to and, ultimately, controlled by automated systems, designing cyber-security measures to protect against potential hacking of crash prevention systems causing them to fail will be an important factor in customer acceptance and critical in assuring public safety. This concern is particularly evident in the truck fleet industry, as the consequences could be disastrous if the command and control communications system was compromised.

Impact on the industry

According to several sources quoting an Infoholic Research report, the future opportunities in dollar terms are substantial. Global autonomous vehicles market revenue is expected to grow at a CAGR of 39.6% during the forecast period from 2017 – 2027, reaching $126.7 billion by 2027.[84]

At present, there is not a lot of discussion about any added risk to financing during early stage automation in the transportation industry. S&P, for now, does not expect AV developments to play any meaningful role in their ratings and outlooks o automakers and suppliers. This is because they believe any large-scale commercial deployment of AVs is significantly more uncertain than EVs and likely several decades away (2030-2040), given the hurdles mentioned.[85]

That being said, in the longer term, there will be major changes to the landscape. The transportation industry will experience a major transformation with the transition to driverless vehicles. The question has arisen whether people will buy their own AV and some experts predict an end to that relationship, pointing to the declining rates of car ownership among younger, urban dwellers and a smaller percentage of young adults even bothering to get a license.

Ownership also could decline at a faster rate with elderly adults as well, as those giving up their license for safety reasons can look to continued independence through the subscription approach. The Director of the AgeLab at M.I.T. is betting that “we will probably never own an AV,” opting to subscribe to a package that provides the vehicle as a service[86], similar to what we can expect from the likes of Uber and Lyft and other rideshare services in the future.

As manufacturers consider getting into the driverless taxi service in which they will continue to maintain ownership of the vehicles and freight companies operate without drivers, the customer profile could shift and consolidate. For instance, if fleet services become more predominant due to economies of scale associated with driverless technology, there may be fewer owner/operators to finance. It is too soon to tell when and if this will happen, however, since, with the projected time frame for adoption, a lot can change.

Other

An ‘Other’ category, by definition, is eclectic, and the discussions in this section are no exception. The continued progress of robotics seemingly is limited only by the imagination of the developers, so it is worthwhile to examine some non-traditional robotics that may provide financing opportunities. Some of these opportunities may come from direct investment in the equipment itself while others, such as nanorobots, may arise because of the increased need for equipment used to conduct research and create the robots.

Exoskeletons

Robotic exoskeletons, wearable machines that integrate features of robotics and mechanical science, typically
Robotic exoskeletons, wearable machines that integrate features of robotics and mechanical science, typically
incorporate motors that multiply the wearer's strength. As it is wearable, an exoskeleton represents the ultimate cobot. Types of exoskeletons include wearable robotics, or exosuits, and soft exosuits.

Most discussions of exoskeletons evoke thoughts of sleek, powered suits like Tony Stark's Iron Man garb. Some exoskeletons, however, utilize passive mechanisms to achieve results by taking and distributing the load to the hips or feet, for example. These exoskeletons eliminate the need for a power source, which is the biggest constraint of exoskeletons.

The availability and use of exosuits is not yet widespread, but the number of potential applications continues to expand. In addition to the current use of exoskeletons by the disabled and elderly, nurses and caregivers also are benefitting by using exosuits to reduce the strain of lifting and moving patients. The benefits of exosuits also apply to other occupations in which there is extended lifting, bending, squatting, etc.

> "… shipping and industrial workers, loggers and miners would benefit from job-assist exosuits and robotic wearables, perhaps with employers writing off the costs as a safety device. Meanwhile, governments could soon start outfitting fire-fighters, EMS, and disaster personnel, combat troops and logistics specialists with protective exoskeletons."[87]

The US Food and Drug Administration recently approved a lower-body exoskeleton named, in an ironic tribute to Stanley Kubrick, HAL (Hybrid Assistive Limb). HAL involves sensors that attach to the users' legs, which detect bioelectric signals sent from the brain to the muscles, triggering the exoskeleton to move.[88] Exoskeletons like HAL can be distinguished from more traditional wearables through their utilization of the wearer's nervous system to control the exoskeleton, as opposed to some other independent control.

Even as exoskeletons like HAL continue to evolve, companies such as Superflex are working on what it refers to as powered clothing to aid senior citizens with mobility problems. Powered clothing is wearable technology that reacts to the body's natural movements, adding muscle power to naturally complement the user's strength in getting up, sitting down or staying upright.

The soft suits incorporate actuating sensors, motorized muscle bands, and fabrics and textiles to keep the exosuit lightweight and unobtrusive. Some experts in this field are even projecting a possible demand for what are being termed lifestyle soft exosuits in which lower-cost versions are used by runners, skiers, and hikers.

Military applications

The movies provide ample evidence that robotics and drones can, and do, play a role in modern warfare, although technology like the miniature surveillance robots in *Eye in the Sky* is not yet much beyond the proof of concept stage. Each has a basis in recent and ongoing engineering research, though, mostly funded by DARPA for the Pentagon. Much of DARPA's efforts has made its way into civilian applications.

Financing war materiel typically is not front-of-mind, though, when lessors examine new market opportunities, especially given the high likelihood of asset loss. Despite an understandable aversion to this asset class, military hardware is being leased. The British Ministry of Defence, for example, leases warships and air tankers.

Closer to home, under 10 U.S. Code § 2401, "The Secretary of a military department may make a contract for the lease of a vessel, aircraft, or combat vehicle or for the provision of a service through use by a contractor of a vessel, aircraft, or combat vehicle …" One must ask, therefore, how large a concern is asset loss if the casualty loss schedule and language are enforceable and the government is amenable?

The Center for the Study of the Drone at Bard College notes that the US Department of Defense is pushing a plan to maintain the technological superiority of the US military. This plan has a growing emphasis on non-aerial, unmanned vehicles and incorporates new projects such as researching swarming weapons and increased autonomy. As noted in its report:

> "Drones are an important part of this strategy. The military has allocated approximately $4.61 billion for drone-related spending in the FY17 budget proposal."[89]

The military also has been testing mobile micro-robots that, operating in swarms, can map areas and detect a variety of threats. It is apparent, however, if one delves deeper into military spending patterns, that the real opportunities in this sector are in non-combat categories, as new robots are being designed to handle a broader range of tasks such as sentry duty, searching vehicles at checkpoints and logistical capacities and support.

Autonomous supply wagons can now follow platoons, and, for rough terrain, Boston Dynamics-designed walking robots (of both the two- and four-legged variety) can carry gear. These robots will automatically follow a soldier in a manner similar to the caravanning models being explored in trucking and agriculture. (One of Boston Dynamics' two-legged models can do a backflip!)

These applications are in addition to the commercial robotic systems required in operating the logistical leviathan necessary to support the everyday functioning of the military. (North American defense capital expenditures are expected to reach US$245.1 billion by 2026.[90])

Nanorobotics and microbots

Ultra-small machines come in various sizes, including those measured in centimeters, millimeters, micrometers and even nanometers. The larger of them, minirobots and microbots, are fabricated using mass assembly techniques and consist of miniature, non-biological components such as chips and small motors. Nanobots, on the other hand, incorporate structures of molecular components that are powered with chemical energy. These small robots may work individually or be deployed in swarms.

Applications include, in the case of nanobots, transporting drugs through the bloodstream precisely to where they are required or penetrating and killing cancer cells. In experiments involving a simulation of the human esophagus and stomach, researchers at MIT, the University of Sheffield, and the Tokyo Institute of Technology have demonstrated a tiny origami robot that can unfold itself from a swallowed capsule and, steered by external magnetic fields, crawl across the stomach wall to remove a swallowed button battery or patch a wound.[91]

Scientists currently are developing various types of nanomachines, but in what, primarily, is basic research, such as a recent nanorobotic project at the University of Bonn. Researchers there have used DNA structures to construct a tiny vehicle with a rotatory motor that can be directed to move in a specific direction.[92] (For perspective, the tiny machine measures about 30 nanometers, which is 30 millionths of a millimeter.) Consequently, financing opportunities, if any, most likely will come from the ancillary equipment, such as atomic force microscopes, necessary to develop and create the nanorobots.

Robotic Process Automation (RPA)

Companies now are exploring how repetitive tasks, traditionally ascribed to industrial settings, can be automated in the non-industrial workplace through what are, essentially, software robots. This emerging field of automation, known as RPA, has been described as taking “the robot out of the human.”[93]

RPA is software that mimics the activity of a human in a process, just as is done in a manufacturing plant. Instead of automating a physically challenging and, potentially, mind-numbing routine, task, however, RPA performs the non-physically demanding, repetitive tasks in a digital environment. In addition to speeding up the process, the software releases human employees to do those things that humans do best – think, reason, exercise judgment and interact with customers. RPA systems range from highly customized software that will work only with certain types of processes to enterprise software that can be scaled and is reusable.

Unlike some physical robots, RPA is not intended to represent or incorporate AI, but only to deal with simpler tasks, a la a robotic welder. It does not need, nor aspire, to use knowledge, understanding, or insight, but only perform the repetitive task to which it has been assigned and programmed to complete.

In addition to realizing high returns on investment through improved efficiency, companies that embrace RPA also are seeing increased employee satisfaction, as employees no longer performing essential, but mundane, repetitive tasks are freed up to deal with more complex and satisfying issues.

> “In every case, we looked at, people welcomed the technology because they hated the tasks that the machines now do, and it relieved them of the rising pressure of work. Every organization we have studied reports that it is dealing with bigger workloads. I think there will be an exponential amount of work to match the exponential increase in data—50% more each year. There is also a massive increase in audit regulation and bureaucracy. We need automation just to relieve the stress that creates in organizations.”[94]

As previously discussed, around 50% of the time spent in the in the finance and insurance industries workplace involves collecting and processing data. As an example, McKinsey estimates that mortgage brokers spend as much as 90 percent of their time processing applications. This statistic has lessor implications beyond financing opportunities, as lessor’s back offices may be prime candidates for RPA.

Conclusion

The topic of robotics continues to fascinate us, both in terms of the robots themselves and now, how they will be financed. This is particularly true as the breadth and scope of new applications accelerate. Robots have been used and financed commercially for over 50 years, so the industry already is involved in financing this equipment, with the operative word being equipment.

It must be recognized, however, that no matter how elaborate or complex a robot becomes, it still is a piece of equipment with many of the same risks and opportunities of other equipment classes. The real question, therefore, becomes whether new generations of robots will be additive and create new financing opportunities? Will autonomous trucks, for instance, mean more assets on the road, or will the units remain the same but just increase in cost and concomitant risks?

A portion of the growth in robotics financing will come by virtue of general economic expansion, but such expansion does not represent new growth opportunities. The real opportunities, for the most part, will come from financing robots capable of operating in unpredictable environments. These robots will incorporate the advanced technology, sensors, AI, data analytics, and the change in delivery and business models of what is referred to as Industry 4.0.

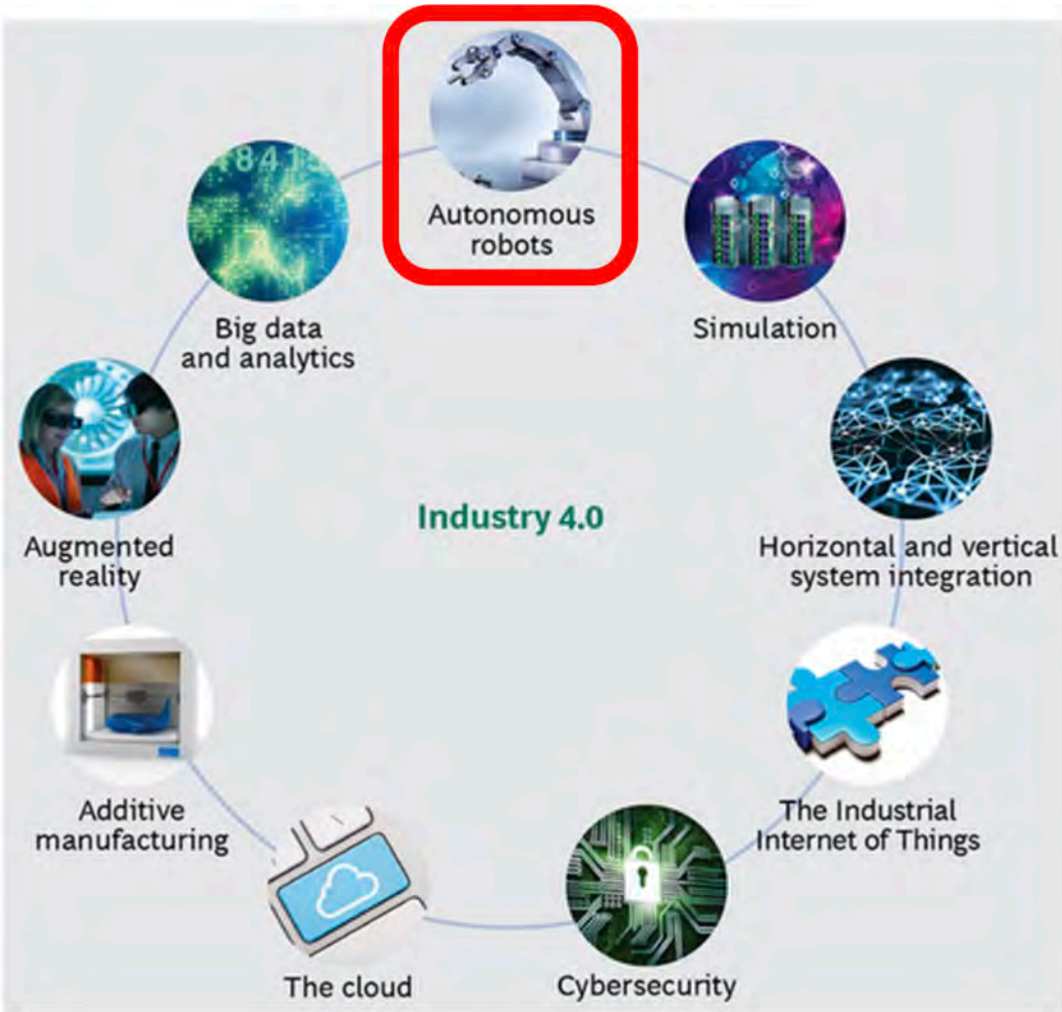
Industry 4.0 is an emerging industrial revolution that encompasses multiple components, including IOT, autonomous robots, the cloud, and big data, as indicated in Exhibit XIII. Autonomous robots are a key piece of Industry 4.0, but it is affecting other equipment classes, also. Another consequence of 4.0 is the creation of new revenue models and industries

A primary feature of new generations of robots, for instance, is the increasing use of sensors, whether it be for navigation, completion of tasks, or internal monitoring. These sensors are capturing a surfeit of data which, in turn, is creating supplemental revenue sources and new business models. This data also is creating a perceived link in the industry between robotics and managed solutions transactions (MSTs), a perception that was confirmed in Alta's discussions with leasing and finance industry practitioners.

It is important, therefore, to make a clear distinction between robotics financing and MSTs – robot financings are not necessarily MSTs.[95] Although robots can be an element of a managed solution, and there is convergence occurring between them, one does not create the other and vice versa, as the critical aspect of MSTs is the underlying subscription pricing model, not the nature of the equipment involved. The convergence occurs when a robotic element in the transaction generates value through its ability to capture and, in some cases, analyze data that is key to successfully generating an MST.

The above comment notwithstanding, increasing growth in opportunities for financing robotics is probable through MSTs. Many high technology robotic and automated systems require on-going services in conjunction with equipment to provide end-users with the depth of training, supplies, upgrades, software, and even on-going management that such technologies will demand in the marketplace. Several well-known industry participants already are offering such forms and structures for end-users in the medical and healthcare fields, both through standalone financing alternatives and program-based vendor relationships and offerings.

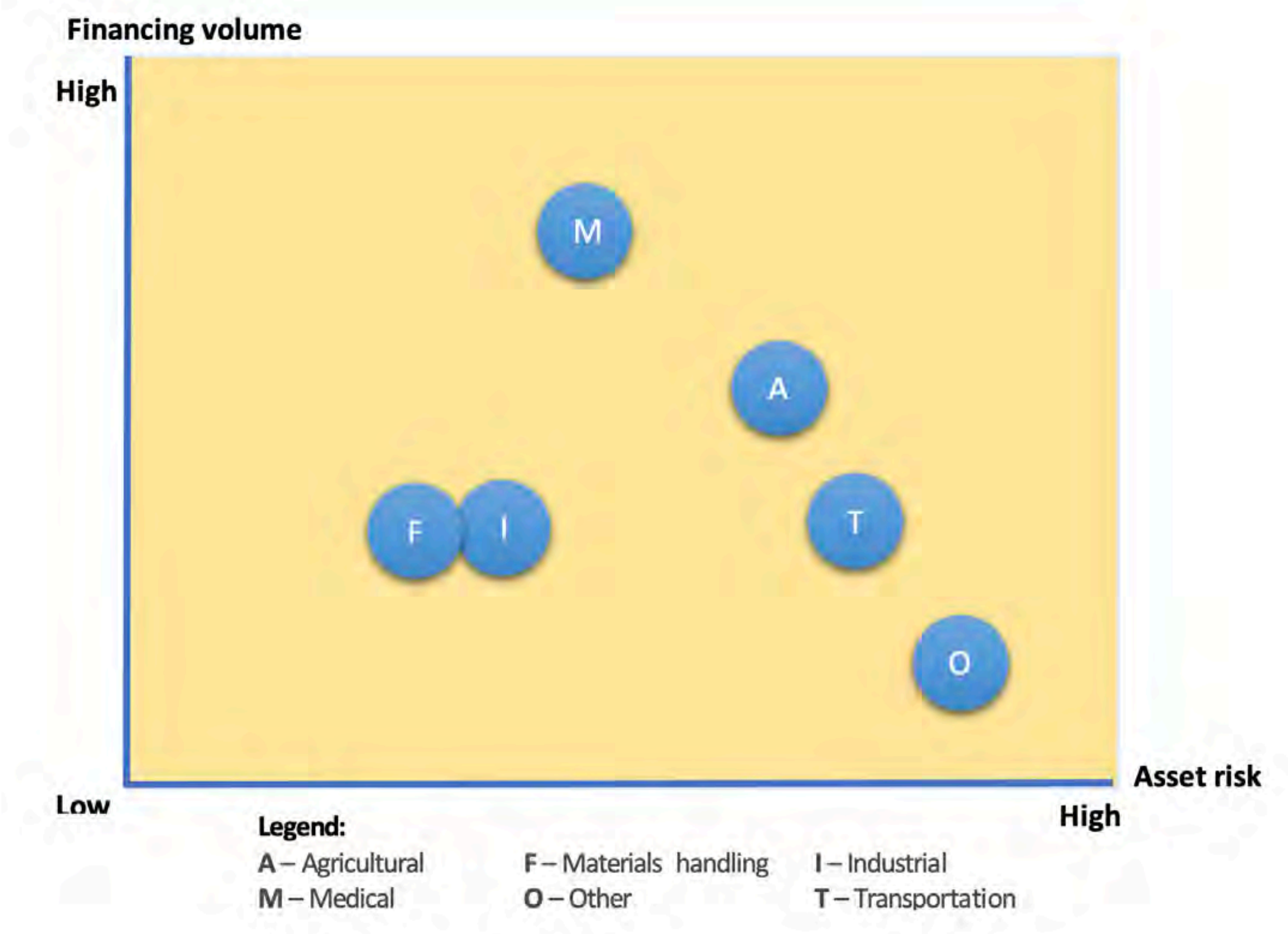
Exhibit XIII
Elements of Industry 4.0



Another growth opportunity is the high cost of many robotic applications, which will push customers to consider financing these assets. The cost trend in several industry segments is downward, however, so financing opportunities will begin to shift. As mentioned earlier, economic expansion will create some volume growth, but Alta anticipates growth potential, relative to the asset risk, in the industry segments it researched is shown in Exhibit XIV.

There are risks in financing robotics, just as there are risks in financing many other types of equipment. Some of these risks are inherent in the transaction, while others are created by the trends occurring within robotics (robot swarms, caravanning, etc.) and convergence with MSTs. Most of these risks, however, are no different than those faced in any technology-driven asset class – managing residual risk and associated soft costs in a fluid environment.

Exhibit XIV
Industry Segment Opportunities



At the end of the day, the real question is whether robotics will increase financing volume, or will these gains be offset elsewhere as robots replace standard equipment operated by human workers? The jury is still out on this issue, but Alta's research indicates that, while changing job demographics, increased robotics utilization will not be dilutive, as the new jobs and businesses being generated through adopting robots will generate more, rather than fewer, financing opportunities.

The overarching take-away from this research is that robotics will create opportunities for those willing to get in front of it. Niche players with asset management skills will lead the pack in this regard. Robotics are going to be a part of the change in how business is conducted in the future. Manufacturers and end-users certainly are being forced to recognize this truth. Consequently, so will the equipment leasing and finance industry if we are to continue to creatively meet the needs of our customers.

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