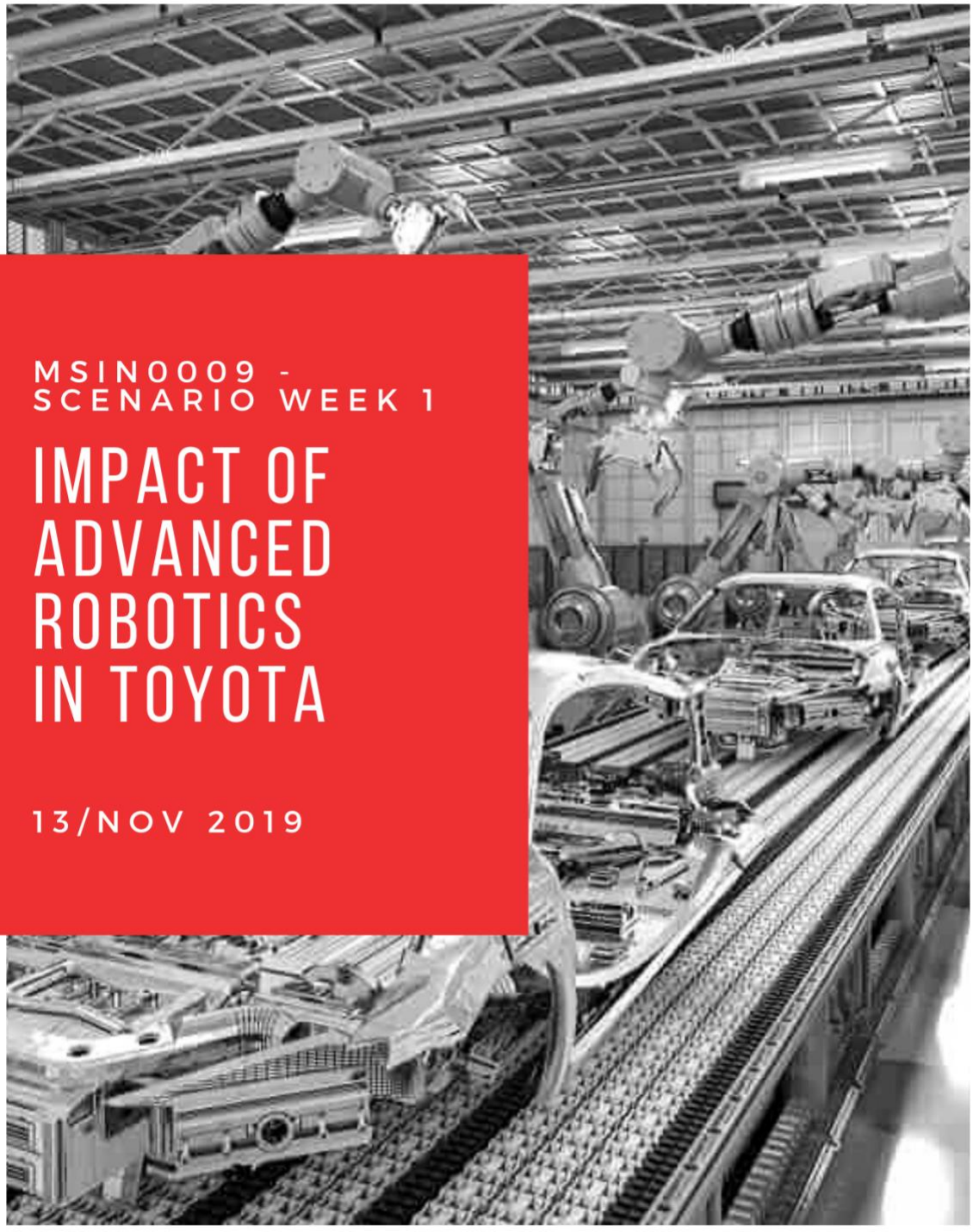

MSIN0009 -
SCENARIO WEEK 1

IMPACT OF ADVANCED ROBOTICS IN TOYOTA

13/NOV 2019

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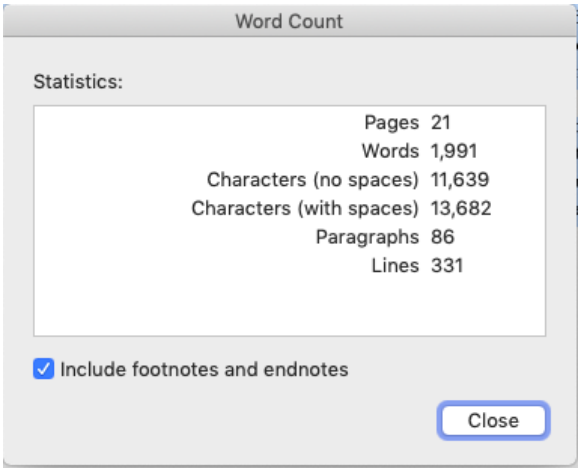
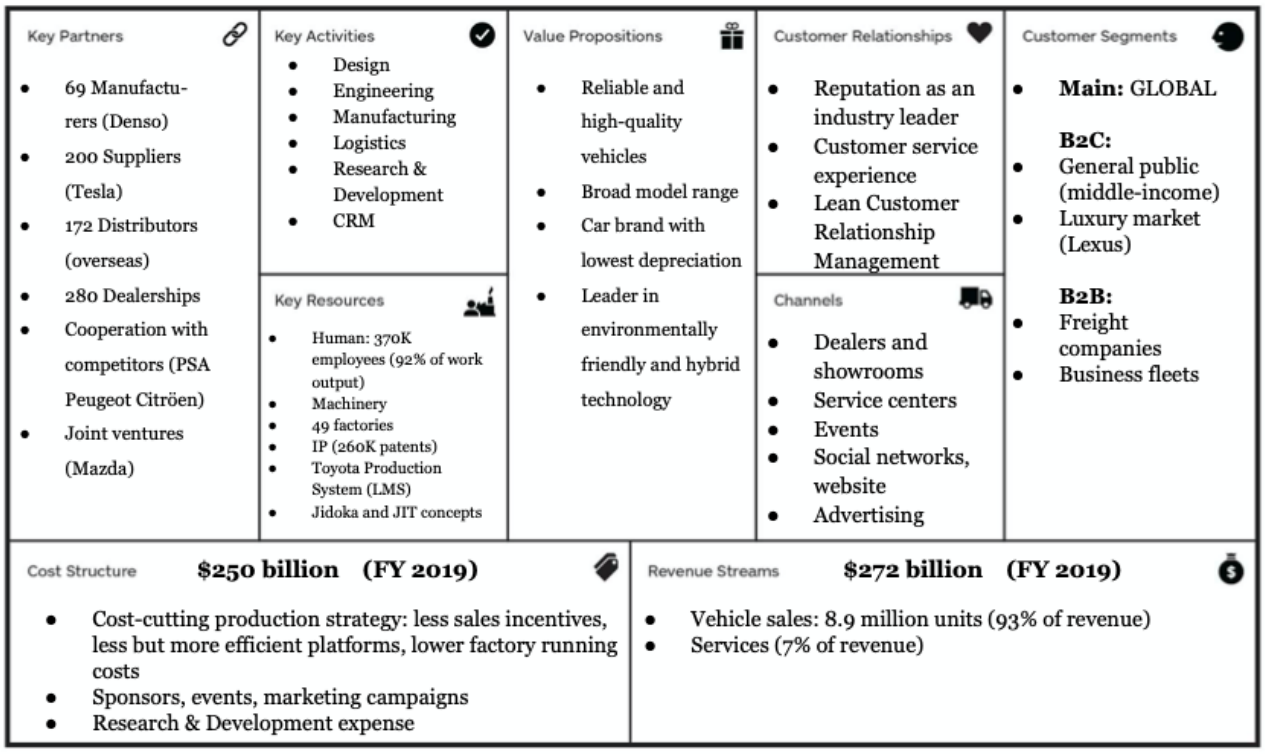
Content



Organisation



Founded in 1937, Toyota Motor Corporation is the largest multinational automotive manufacturer, with a global market share of 9.5% and sales of almost 9 million cars during FY2019 (Statista, 2019; Global.toyota, 2019). The company employs over 370000 people in more than 170 countries and regions (Bloomberg, 2019; TOYOTA CORPORATION, 2019).

The automotive industry is facing numerous challenges, which Toyota needs to address in order to maintain its leadership position in the industry as well as to continue growing. External challenges include geopolitical uncertainty in key markets, the expansion of the sharing economy and automation in manufacturing and driving. But internally, the intense industry competition, its weak presence in emerging markets such as China or India, and the ageing and shrinking workforce (especially in Japan) are important threats to Toyota's operations (Thomsonreuters.com, 2019; MarketLine Company Profile: Toyota Motor Corporation, 2019).

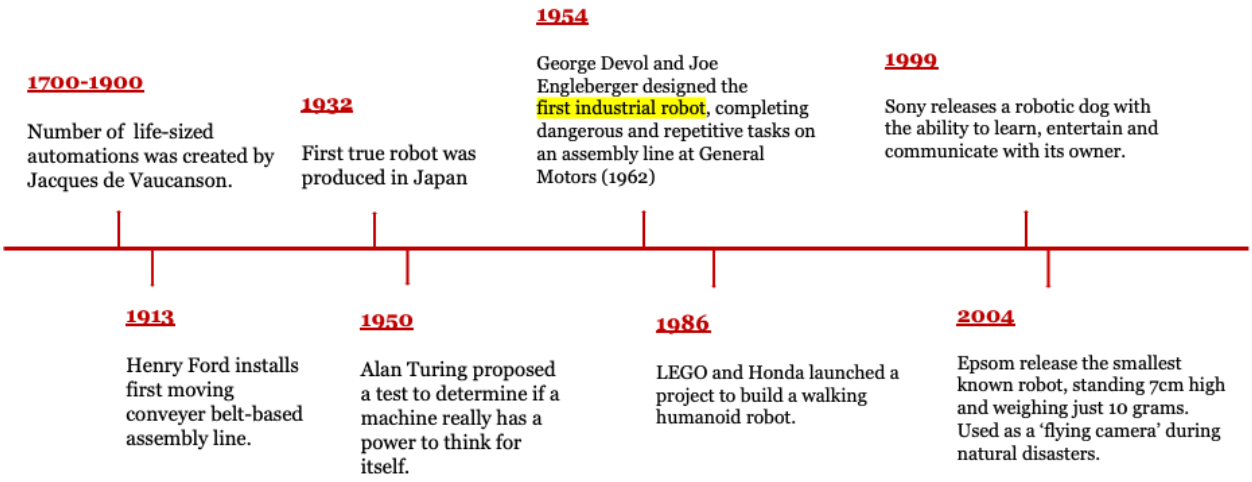
This report will identify the impact of advanced robotics on a world-leading company, Toyota, putting the focus on vehicle production costs reduction and the manufacturing workforce landscape.

Technology and Categorization

What is advanced robotics?

Advanced robotics is defined as devices in sub-categories of traditional robotics that are able to interact with the outside world largely, or partly autonomously with less intervention from humans. They modify their behaviours based on sensor data to enhance problem-solving, resistance, intelligence and adaptability capacities in tougher and less structured environment.

History of Robotics:

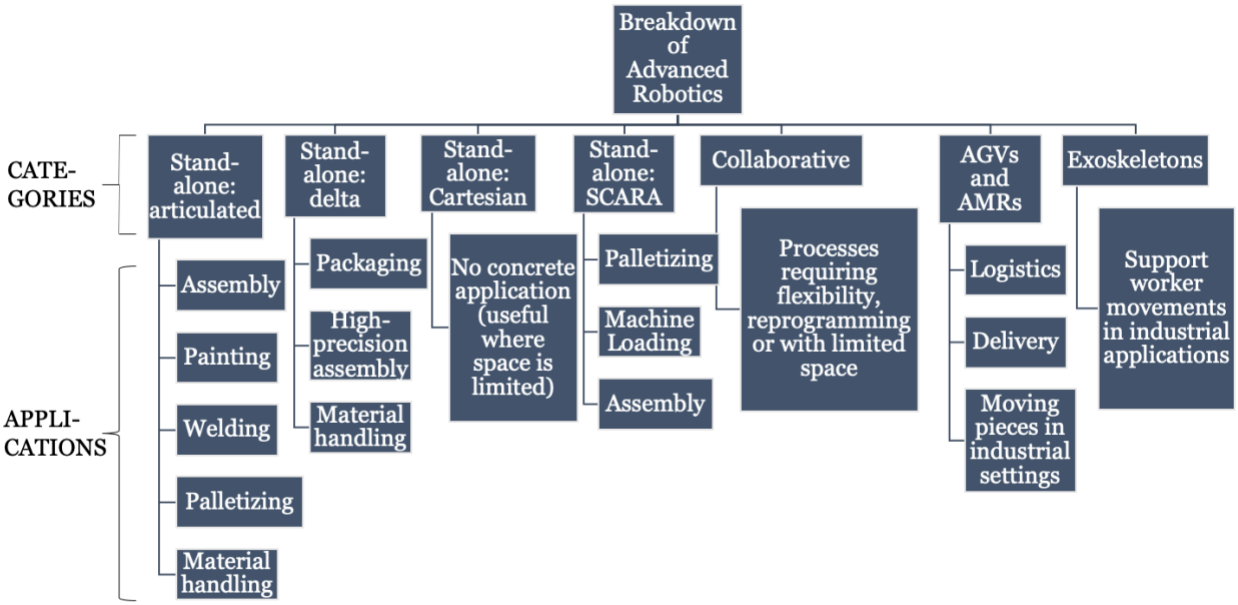


Predictions within Advanced Robotics

The FOME report states that advanced robotics will boost productivity in the industry by 30% in 2025, with an impact on global markets between $1.9 and $6.4 trillion per annum (McKinsey 2019). In the UK, an estimation of 22% of raise productivity in manufacturing by optimizing current RAS technology is carried out by one pan-national survey, with a long-term employment increase of up to 7%. (RAS 2020, 2014, p.9)

With its enhanced system, particularly the high degree of adaptability, advanced robotics have changed the nature of the human-robot relationship. The number of global stock of robots is expected to reach 20 million by 2030 with developing capabilities. 20 million additional manufacturing jobs world-wide will be replaced due to robotization by 2030 (Oxford Economics 2019).

Breakdown of Advanced Robotics

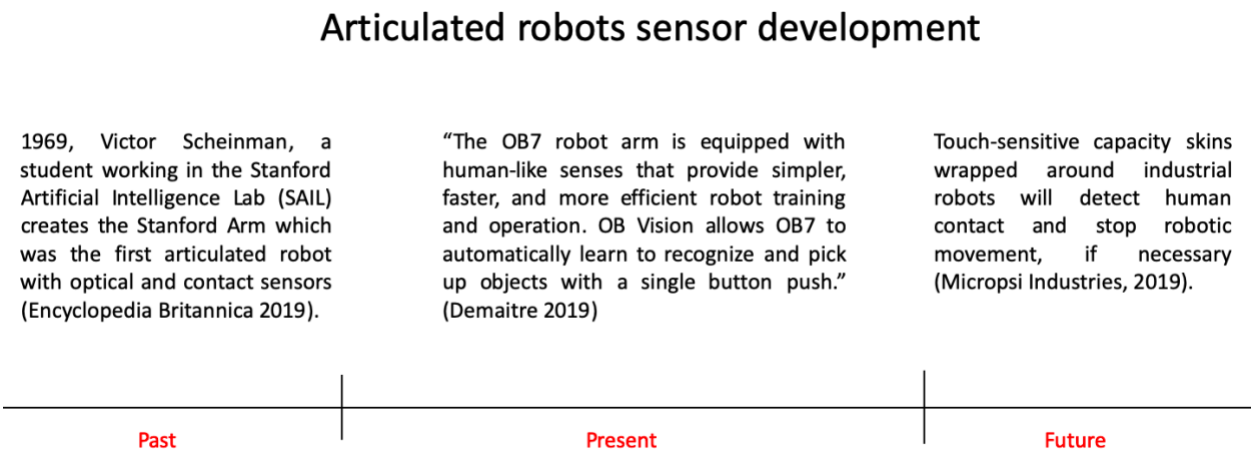


Source: McKinsey Industrial Robotics Report, July 2019

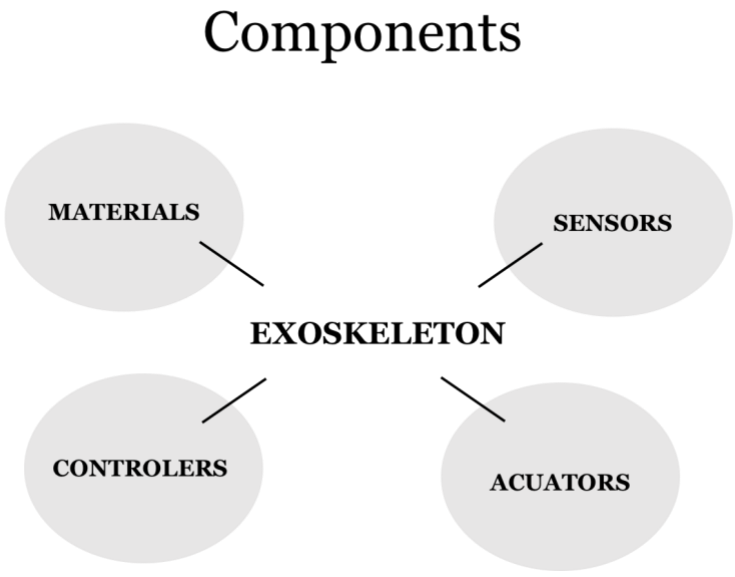
We are going to analyze in more detail the categories from where we obtained the most examples out of articulated and exoskeleton. We will then provide more detail of the impact on Toyota.

Articulated:

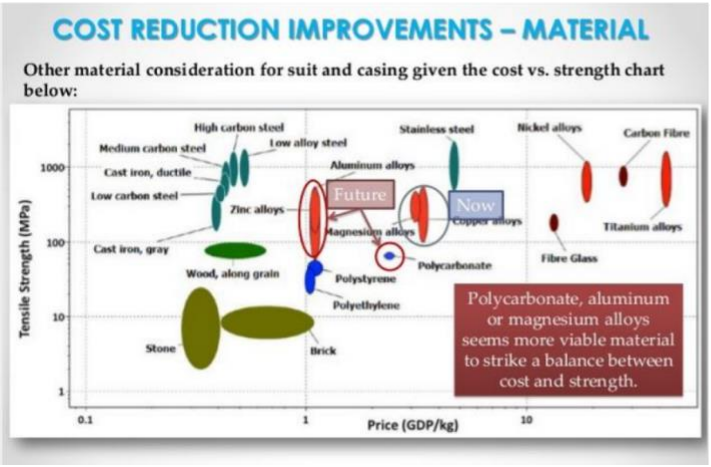
There are different subcategories in articulated: actuators, locomotive components and sensors. We have focused our attention in sensors to explain it in detail through a timeline of its development:



Exoskeleton:



Explanation of timeline



(Gardiner,2016)

A few years ago, metal was used for exoskeletons. A specific example is HAL exoskeleton. Now, the most common material for exoskeleton is aluminium. Given the analyses we have above with material tensile strenght vs. cost comparison, the future of exoskeleton materials should be magnesium and polycarbonate.

Advanced Robotics and the Automotive industry

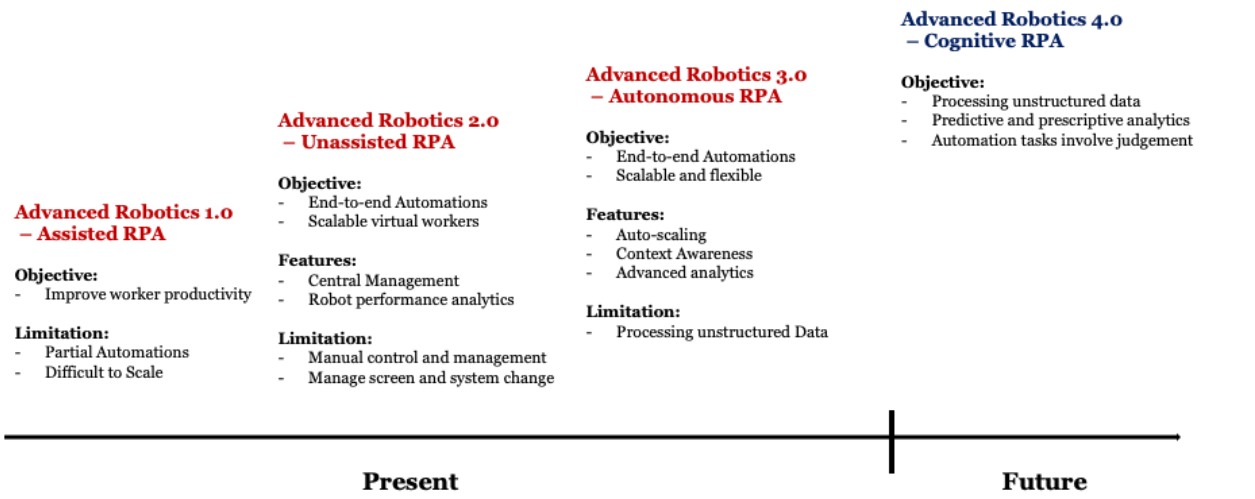
Advanced robotics has a significant impact in the automotive industry. It gives automotive companies a big advantage to improve product quality, protect workers from dangerous jobs and obtain better results in repeated tasks which reduces human errors and warranty costs. It can also detect variance in production processes so it can detect an error rapidly and adapt its program to what is needed. In the end, all of this offers greater flexibility to improve customers' satisfactions.

One of the biggest categories in advanced robotics is the development of collaborative robots which are expected to grow massively (more than 100,000 units shipped in 2020). Installation of collaborative robots ensures that operations alongside human workers are direct and safe, it also provides physical support and assistance to workers thus will improve the process of ergonomics.

Mckinsey stated industrial robotics as "low volume, high complexity" producers such as OEMs, Tier 1s that stand to gain money from the use of robots in the car manufacturing industry. According to MarketsandMarkets™, the Industrial Robotics Market is expected to grow from USD 48.7 billion in 2019 to USD 75.6 billion by 2024, with a growth of 9.2% at a CAGR during the corresponding period.

In this graph we can see how advanced robotics has developed in the present to fulfill the demands of companies and how in the future it will change from Autonomous to Cognitive:

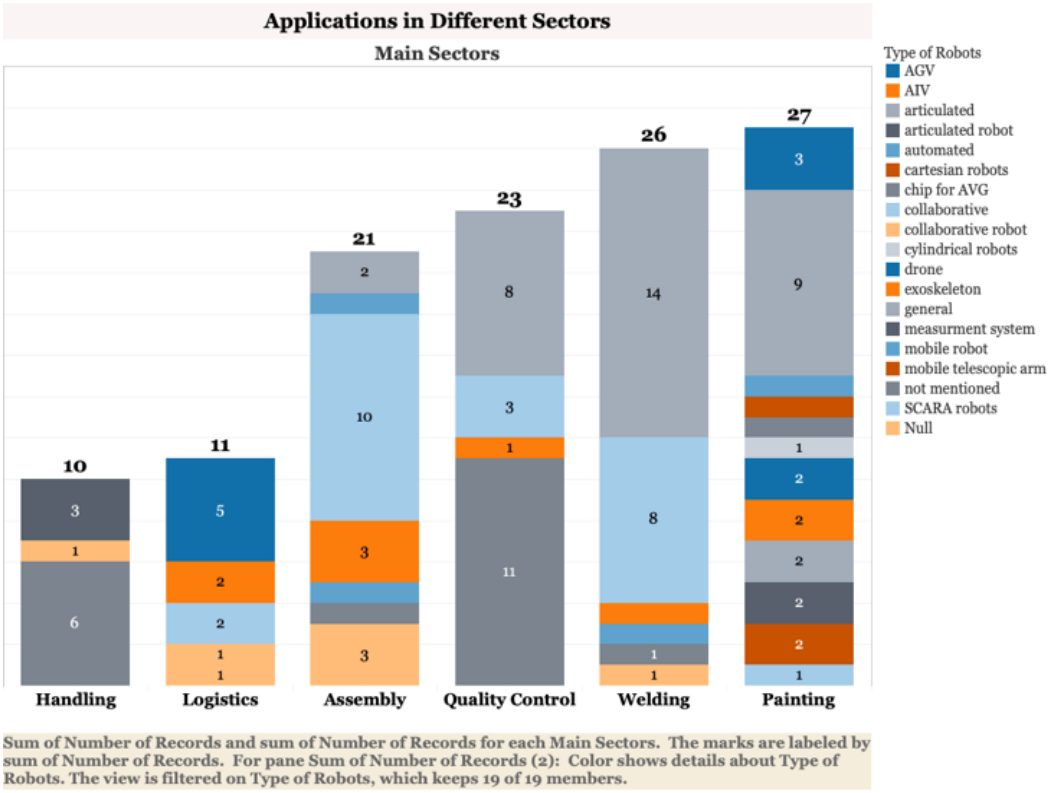
Impact of Advanced Robotics in Toyota

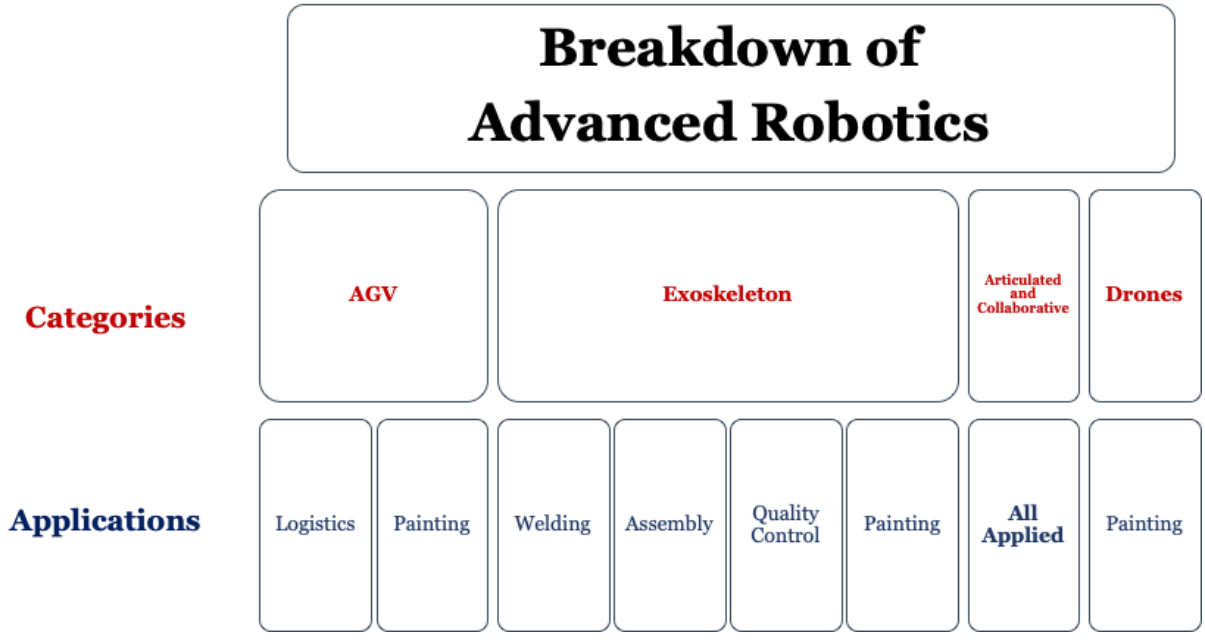


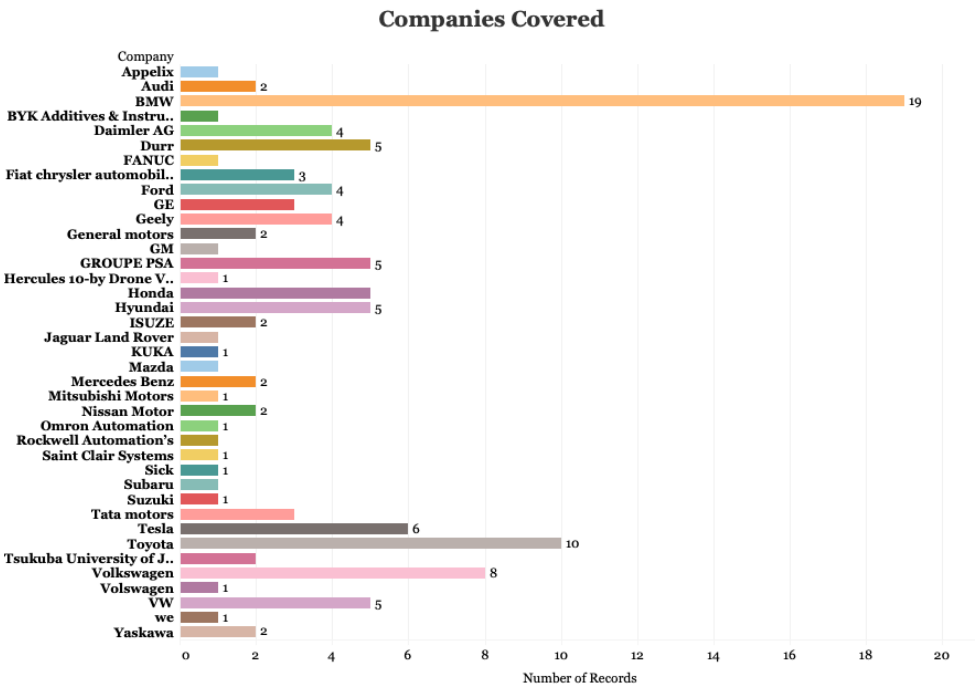
Source: AIMDek Technology 2018

Categories of application in the Automotive industry

Through our detailed research, we concluded 6 main sectors of applications with 118 examples, across 45 different companies.







Sum of Number of Records for each Company. Color shows details about Company. The marks are labeled by sum of Number of Records. The view is filtered on Company, which excludes Null.

Looking at the first Tableau graph we can observe that welding, quality control and painting are the applications that we obtained the most information out of, due to this we are going to explain them in more detail:

Welding

Welding is the permanent joint of two metals using different combinations of temperature, pressure and metallurgical conditions. On average the steel body of a car contains 4500 weld joints. In order to weld all these joints during the production line of a car you need to acknowledge different techniques.

After doing an intense research and finding 26 different examples we decided to base our applications according to the McKinsey graph 2019 (shown before) and our own examples. With this information, we divided the examples of all our applications in the categories. In the case of welding (Devarasiddappa, 2014):

Breakdown of Welding

Articulated	Collaborative	Exoskeleton	Mobile
1. Resistance spot welding 2. Friction welding 3. Pulse welding	1. Resistance seam welding	1. Medium frequency welding	1. Laser beam welding

Quality control

Quality control ensures that all the products leaving the factory are of high quality and without defaults. In the automotive industry the process starts long before the production line of a defined car, it goes all the way back to the first prototypes which are tested to find any weaknesses. Due to being a long process, quality control has different advanced robots to help produce a well designed and strong car. After an intense research we found 23 different examples that we divided into 5 categories depending on the advanced robot that was being used (Garden 2019):

Breakdown of Quality Control

Articulated	Collaborative	Exoskeleton	Drones	Sensor/Wireless
Anchored to the floor and perform repetitive tasks	Hand to hand with workers and increase efficiency	Check integrity of the welds	Perform security checks	Advanced tasks of security and welding

Painting

The painting process starts after the body of the car is assembled and it's functions are to give better appearance to the cars and to provide a layer of protection against corrosion and weathering. There are five steps in the process of painting a car that automotive industries always follow in the same order: pre-treatment and electro-deposition (ED), ED sanding, sealant and PVC line, primer and top coat. Observing the process was very long we indagated and found 27 different examples that we then divided in 12 categories depending on the way painting was being done (Farid Bin M Fathil 2019):

Breakdown of Painting I

AGV (automated guided vehicle)	Exoskeleton	Articulated	Automated paint shop - IoT	Chip for AGV	Drones
Moves the car in faster and safer ways to facilitate painting	Performs repetitive tasks and increases the safety of workers	Better arm reach and cloud connected that allows faster reports if problem	Connects the painting process through the internet	A locator in the AGV to know its exact location	Paints the car in areas due to altitude that anchored machines cannot reach

Breakdown of Painting II

Measurement systems	Mobile telescopic arms	Cartesian Robots	Cylindrical robots	Scara robots	General
Measures the number of layers and the quality	Very large arms to increase efficiency in the production line	It has less axes and performs more specific tasks	Paints in vertical parallel strips, when finished returns to the inicial point	One of the first painting robots with limited movements	Here we included future developments in the painting industry

Timeline of Exoskeleton

Specific Example: Hybrid Assistive Limb (HAL) Suit - Past
Exoskeleton robot that can supplement, expand or improve physical capability.

1993
Mapping out neurons governing leg movement

1996
- Prototype **HAL-1**
- Support only lower half limb

1997
- Prototype **HAL-3**
- **Attach to computer**

1999
- Release **HAL-3**
- Backpack battery and weighted 22kg

2003
- Prototype **HAL-5**
- Attach computer directly to the suit for limb control system

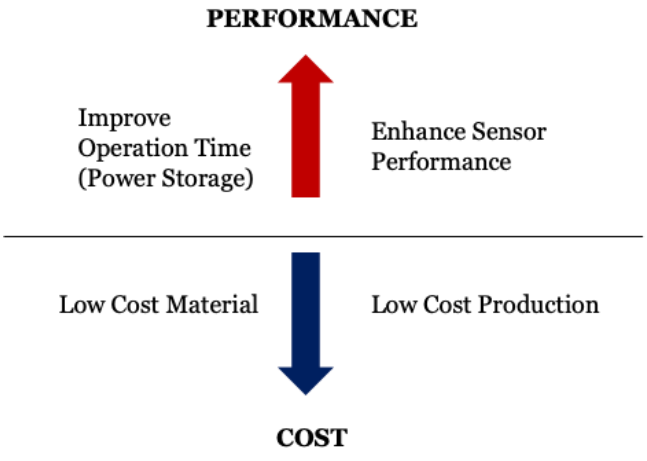
2005
- Released **HAL-5**
- Waist strapped battery and weighted 10kg

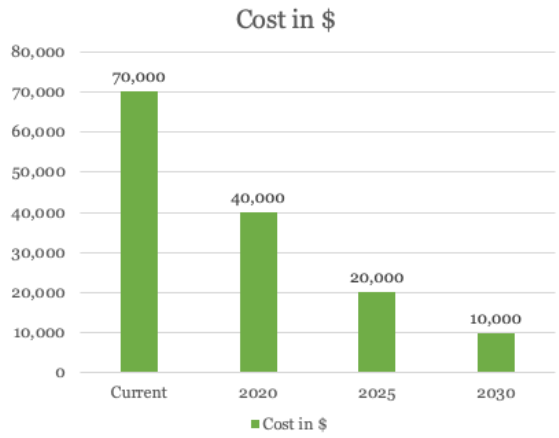
Improvement: Hal-3 to Hal-5A
- 32% weight reduction
- 266% more operating time
- 53% faster response time
- 10% more strength/weight

Improvement: Hal-5A to Hal-5C
- 13% weight reduction
- 166% more operating time
- 16% more ability to lift
- 5% lower lease price

Future Trend of Exoskeleton:

Specific Example: Hybrid Assistive Limb (HAL) Suit - Future
Exoskeleton robot that can supplement, expand or improve physical capability.





Application of Advanced Robotics in Toyota and potential impact

Impact on Painting

Exoskeleton

BEFORE	AFTER

Toyota is currently using robots to apply the primary coat in painting and human workers for hard to reach zones such as the fuel filler surround and parts of the interior that will be visible when the cabin is fitted (Anon, n.d.) We estimate that introducing exoskeletons to help those human workers will have a positive overall impact on Toyota.

Painting exoskeleton is a wearable device with light-weight and strong support capability, which can help painters to reduce shoulder overexertion, improve painting quality and safety. For a painter who needs to hold a paint gun in the painting process, this device can support the arm weight by 50% on average (ASSE, 2016). In this way, using painting exoskeleton is likely to expand the workforce because the disabled, women and smaller men will be able to perform the painting task.(Kardys,2019).

We estimate from an economical point of view, this means that the average wage will become smaller since more workers will be able to work in the paint shop. (Supply of labor increase). Moreover, this device can reduce the cost spent on lost hours and physical injuries(Kardys 2019). ASSE made an experiment and the result was that one painter's productivity improved by 26% and the other by 53% because it helped in performing the repetitive job (ASSE 2016).

Elements of value:

B2B:

- EASE OF DOING BUSINESS VALUE:
    1. **productivity**:time saving, reduce effort
    2. **strategic**: risk reduction

- FUNCTIONAL VALUE:
    1. **economic**: cost reduction

B2C:

- FUNCTIONAL:
    1. Reduce cost

Impact on Quality Control (Articulated)

The following example is an evidence to support our analysis of Advanced Robotics in Toyota's Quality Control. As the body of every vehicle is made up of metal sheet, many Automotive Companies such as Toyota and BMW are currently using automated articulated measuring robots — Metalsa. By implementing Metalsa in production plants, it provides a deeper analysis of the shape and dimension of each sheet metal part, and to report whenever any faults are found before proceeding to the next process. During the inspection, the full-field measuring results are also compared against the CAD data set in order to assure that the metal sheet is aligned within the tolerance range.

Apart from accurate measurements, Metalsa is an easy and intuitive operation due to the measuring machine can be operated even without prior metrological knowledge. It only takes approximately 30 minutes to instruct operators. This helps Toyota to operate the production of vehicles continuously as most workers are working in different shifts.

Elements of Value

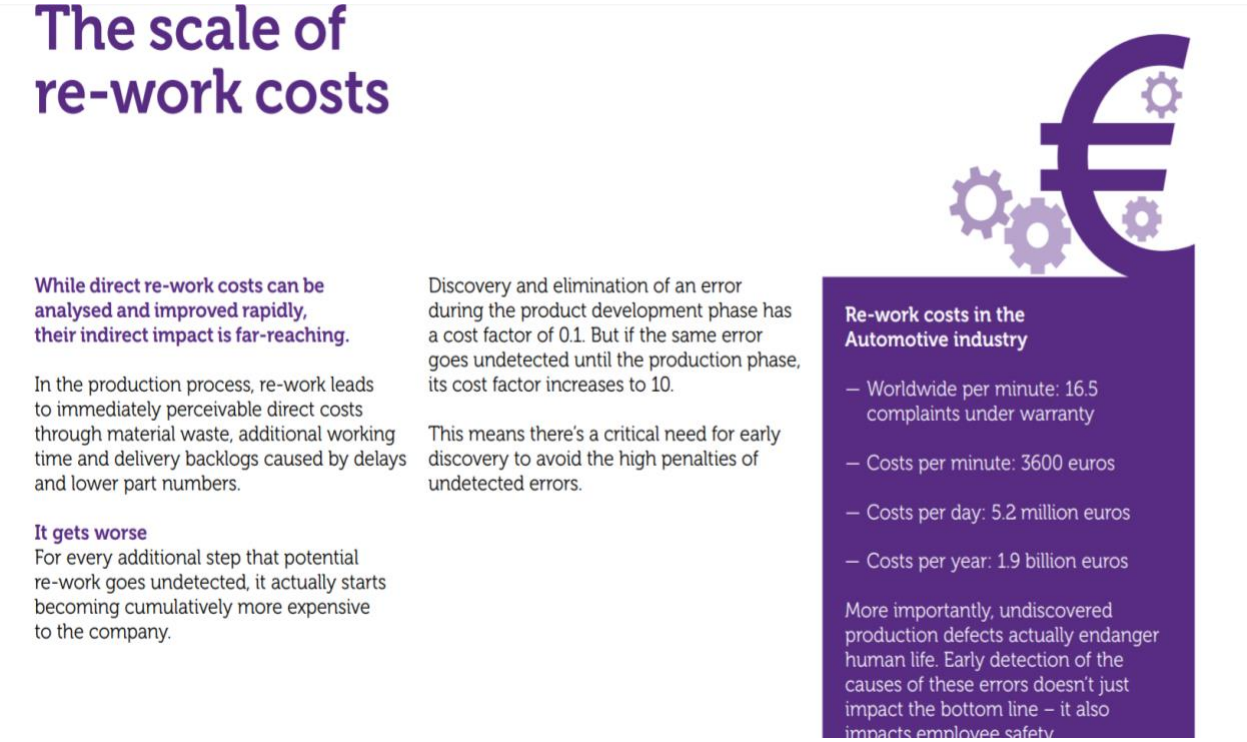
B2B:

- Time savings, reduce effort, Component quality

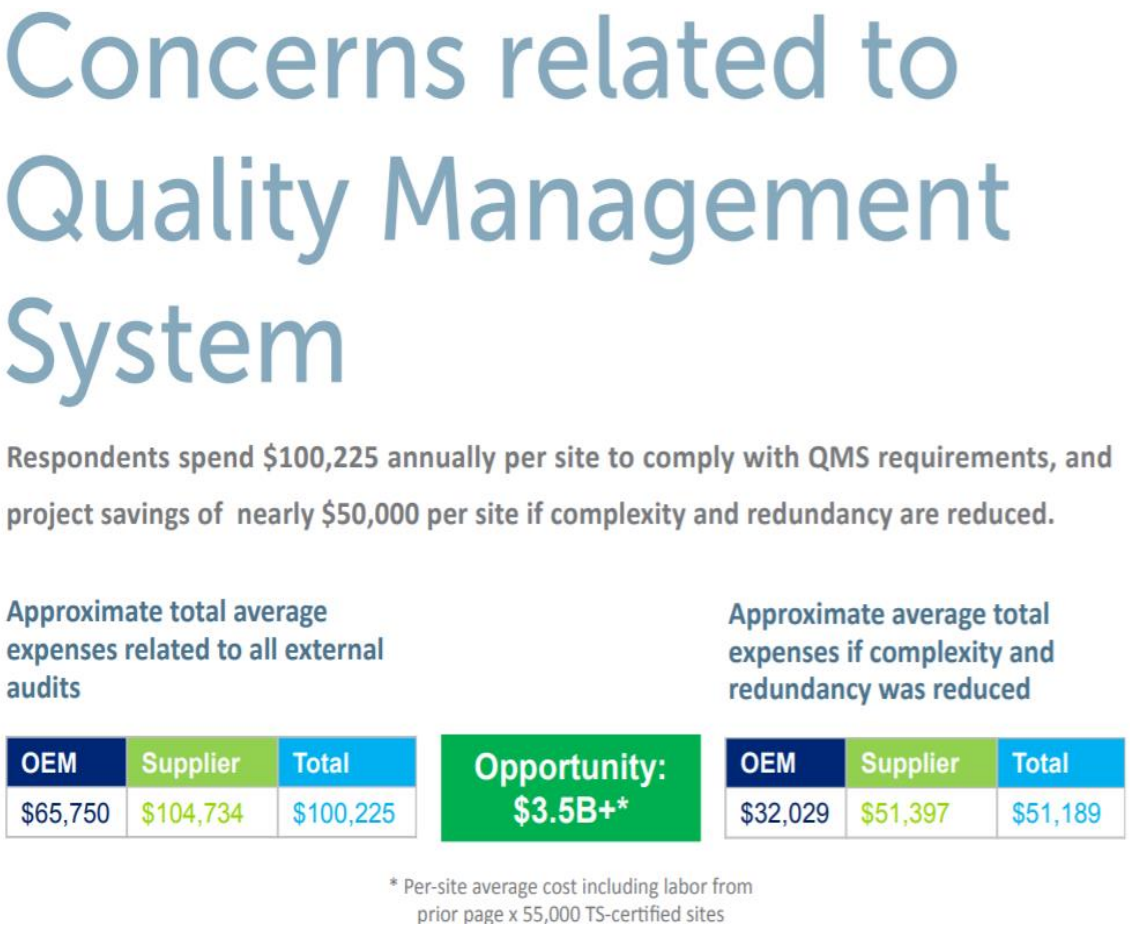
B2C:

- Quality, reduces risk

The "real" impact

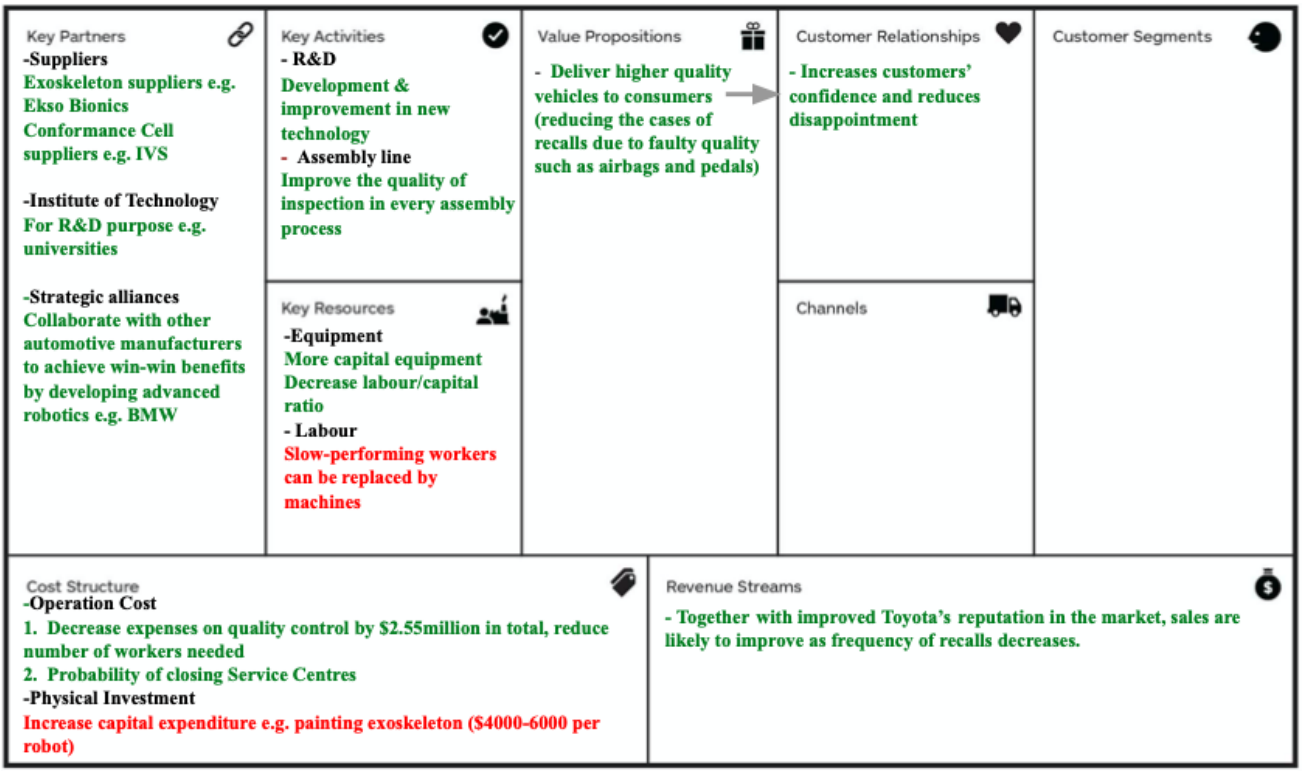


According to a study done by Kimberly-Clark Professional on the re-work costs in the Automotive Industry, the total re-work cost is approaching 2-Billion Euros in 2014 (Clark, K. (n.d.),2014). As Toyota Motor Corporation has 10.4% market share in 2018, it is logical to assume that Toyota is likely to bear approximately 10% of the rework cost, which is nearly 200-Million Euro. In order to support this statement, Toyota Motor Corporation has recalled 1.7million cars in January 2019 due to faulty Takata airbags (Reuters and Benjamin Zhang,2019). Hence, with the implications of Advanced Robotics into the industry, Toyota is extremely likely to improve its vehicles' quality.



This diagram is taken from a research carried out by Deloitte and the Automotive Industry Action Group (AIAG), namely The Deloitte and AIAG Quality 2020. Based on the figures from the diagram, the Automotive Industry is able to reduce the industry's cost with $3.5Billion, where each manufacturing site is able to save up to $50,000. According to the Toyota Motor Corporation 2017 Annual Report, the company has 51 manufacturing plants, which indicates that Toyota Motor Corporation is able to cut $2.55million in total. Hence, the implications of Advanced Robotics would reduce the complexity in Quality Control where Toyota Motor Corporation is able to improve their performance in the coming financial years.

Impact on the Business Model Canvas



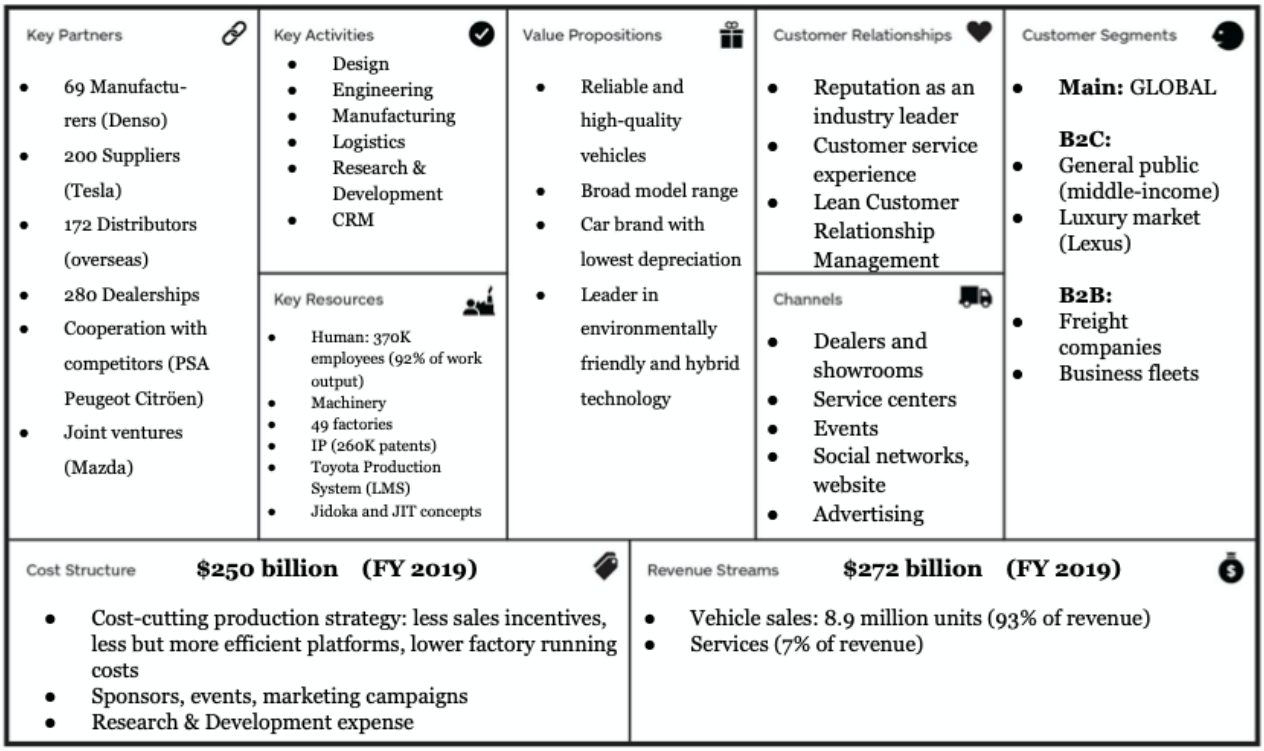
Conclusion

The implementation of different advanced robotics technologies in Toyota Motor Corporation has the potential for greater benefits, both for business and consumers. This can be seen in Toyota's use of Nikon Metrology and Metalsa, which dramatically improves inspection during welding, with only one operator required. Therefore, as inspection processes are sped up, Toyota is able to manufacture more vehicles with assured high-quality. This saves up long-run labour cost, with installation of capital equipment further enhancing stability in the production process. Moreover, introducing novel categories of advanced robotics in the manufacturing process, such as exoskeletons used in paint shops, can eliminate costs spent on lost hours and physical injuries by providing assistance for workers. In this way, the level of safety and productivity can be improved remarkably. Overall, one of the most obvious impacts on Toyota Motor Corporation is saving up to €200,000,000 on rework from vehicles' recall.

However, Toyota's plan to implement higher quantity of Advanced Robotics must come with an enormous capital expenditure. As mentioned, the unit price of painting exoskeleton is approximately $4000-6000. Given Toyota has 51 production sites around the world as per 31 December 2017, Toyota must increase its capital expenditure in worldwide production plants in order to become more capital-intensive.

Appendix 1

Detailed Business Model Canvas



Value Propositions

Toyota is a leading car manufacturer with various value propositions for the consumer. It sells a broad range of models (small city cars, hybrids, SUV's, sedans, sports cars…) designed to fulfill the needs of all customer types. The reliability and high quality of these models are reflected by Toyota's privileged position in a wide number of reliability surveys (Automotive News, 2018). Toyota models retain a big percentage of their original value as time goes by, making it the car brand with the lowest depreciation (KBB, 2019).

Toyota recognized the need to address environmental issues before its competitors, launching the first mass-produced hybrid car in 1997 and selling more than 13 million hybrid vehicles up to date (Toyota Motor Europe, 2019).

Customer Segments

Toyota sells and operates in more than 170 countries around the world. Its cars are aimed at the general, middle-income public, with a broad range of models and prices to satisfy every customer's needs (Coursehero.com, 2019).

Toyota also targets consumers who live a luxurious lifestyle with the Lexus car division, offering high-quality luxury cars at lower prices than similar competitors (Coursehero.com, 2019).

Regarding B2B, Toyota also offers heavy duty trucks for freight companies and provides multiple solutions for business fleet cars (Toyota USA Newsroom, 2019; Toyota UK, 2019).

Customer Relationship

As an industrial manufacturing and production leader, Toyota's reputation is essential when engaging with customers, who see the car manufacturer as successful, fair, trustworthy and responsible (Toyota NZ, 2019).

In terms of customer relationship management, Toyota applies the lean principles: they understand customers' needs through the jobs customers are trying to do and the outcomes they desire from doing them. Afterwards, a value delivery process is mapped and the value is directed to the customers (who are empowered to pull value directly) (Bacon, 2013).

Channels

Toyota's main touchpoint with their customers is its wide global network of dealers and showrooms, where customers can get information about Toyota's vehicles, buy them and stay in contact with sales associates (Toyota-global.com, 2012). Their service centers provide maintenance and car failure support, too.

Toyota regularly showcases its models at the world's most prestigious car shows, such as Frankfurt and Geneva, where it gets the chance of presenting its newest vehicles as well as to release important statements (Automotive News, 2019).

Toyota's network of social media accounts and webpages allows the brand to keep in touch with customers, create and reinforce brand awareness and attract new potential customers through marketing campaigns. Both traditional and digital advertising play important roles within Toyota's marketing strategy (Marketing91.com, 2019).

Key Activities

Toyota's main activity is the design, engineering and manufacturing of cars. Through logistics, Toyota ensures that its resources are coordinated and transported from one location to another as efficiently as possible (Automotive Logistics, 2019).

In order to pursue advanced technological developments that may be key for their manufacturing activities, Toyota spends around $10 billion each year in Research & Development projects (Statista, 2019).

As described before, the Lean CRM is an important part of Toyota's activities, too.

Key Resources

Toyota has a workforce of about 370000 employees, responsible for around 92% of the company's work output. An important part of it focuses on manufacturing their vehicles in 49 factories around the world. Toyota's machinery, including the robots that take care of the other 8% of the industrial output, complements and in some cases even replaces labor work (Rothfeder, 2017).

The established Toyota Production System, based on the Jidoka (automation with a human touch) and Just-In-Time (each process only produces what is needed for the next process) concepts, allows the pursuit of complete waste elimination and efficiency (Leansixsigmadefinition.com, 2019).

Toyota's Intellectual Property, mainly comprised of its granted 260000 patents, contributes heavily to the company's creativity and innovation culture (Patsnap.com, 2019).

Key Partners

Toyota has developed a huge number of partnerships with manufacturers such as Denso and suppliers like Tesla that provide them with car parts, materials, goods and services (Lioudis, 2019; TOYOTA CORPORATION, 2019).

Toyota's wide network of distributors and dealerships serves as main sales channel.

Toyota also works together with some of their competitors so that all of them reap the benefits of development and production cost optimisation. Since 2012, their partnership with PSA Peugeot Citröen has allowed both parties to manufacture mid-size light commercial vehicles with shared technical features, but at the same time distinctive styling (TOYOTA CORPORATION, 2018).

At the same time, Toyota regularly establishes joint ventures with other businesses, such as the one with Mazda, by which both companies will produce vehicles in a newly established manufacturer plant in Alabama (Mazda News Releases, 2018).

Revenue Streams and Cost Structure

(Yen in millions)

	FY2018 (For the year ended March 31, 2018)	FY2019 (For the year ended March 31, 2019)	Increase (Decrease)
Net revenues:			
Sales of products	27,420,276	28,105,338	685,062
Financing operations	1,959,234	2,120,343	161,109
Total net revenues	29,379,510	30,225,681	846,171
Costs and expenses:			
Cost of products sold	22,600,474	23,389,495	789,021
Cost of financing operations	1,288,679	1,392,290	103,611
Selling, general and administrative	3,090,495	2,976,351	(114,144)
Total costs and expenses	26,979,648	27,758,136	778,488
Operating income	2,399,862	2,467,545	67,683

Source: Toyota Motor Corporation FY2019 Financial Summary, 2019

Toyota relies on 2 main revenue streams: the automotive revenue, which includes the vehicles sold and also other secondary revenue from the automotive business, and is accountable for 93% of the total revenue ($253.2 billion); and the financial revenue obtained by the purchase or leasing of vehicles of the company. This revenue stream accounts for 7% of the total revenue ($19.1 billion).

In total, Toyota reported a total revenue of $272.3 billion in FY2019.

In terms of costs, $212 billion were due to the costs of sold products, $12 billion accounted for the financing operations costs and $26 billion were classified as selling, general and administrative costs. In total, this amounts to approximately $250 billion in costs, and allowed Toyota to generate an operating profit of $22 billion in FY2019.

Appendix 2

PESTEL Analysis

Political

- Political instability: the trade war between the United States and China, Japan's cold political relations with China, the uncertainty surrounding Brexit, the Catalan independence debate in Spain… all pose important threats to Toyota's business environment and long-term profitability (Automotiveworld.com, 2018).
- Trade agreements involving Japan, where Toyota owns 16 manufacturing plants, and other regions where Toyota operates, such as the Economic Partnership Agreement signed with the European Union this year, present opportunities for tariffs reduction and improved market penetration (Nadeau, 2019).
- Governmental support for eco-friendly vehicles and stringent emission regulations are presented as an advantage for Toyota over its competitors, profiting from their leading position in the hybrid vehicle market.

Economical

- The trade protectionist policies under the Trump administration affecting car imports could heavily damage Toyota's sales in the firm's second biggest market after Japan (Wallace, 2019).
- With the global automotive market facing stagnating sales, and with mature markets contracting in volume, car manufacturers have to rely heavily on emerging economies (McKinsey.com, 2019). Their high volatility and Toyota's weak position in those markets (4.5% market share in both China and India) represent an important threat to Toyota's operations, but also a chance to adapt to new conditions and end up in a strong market position (Sano, Inoue & Buckland, 2019; Taumar, Nangia & Mishra, 2019).

Social

- The increasing interest in and sales of hybrid and electric cars are good news on one front (Toyota's leadership position in the hybrid market has been undisputed for years), but a reason to worry on the other (the Japanese firm is still reluctant to launch a fully electric vehicle line-up), which may cause them to miss out on of the industry's strongest trends and lose market share (Copeland, 2019; Gassée, 2019).
- The widening income gap within and between countries threatens Toyota's main revenue source: the middle class, caused by a potential reshaping of the demographic landscape (Arends, 2019; Victory, 2016). These social developments may cause the firm to change their demographic segmentation strategies, as well as to prioritize decisive market presence in some countries over others.

Technological

- Toyota's R&D budget for FY2019 reached a company record number of $10 billion, just behind Volkswagen in the automotive industry (Forbes.com, 2018). With 20 R&D centers around the world, the company looks to increase its stance in electrification and automation (TOYOTA CORPORATION, 2019).
- Technology trends such as e-commerce (with an estimated impact on the industry of $12 billion during 2019) can help Toyota in terms of information exchange automation, improved order processing, simplified order search… The growing importance of mobile technology is also a good opportunity to increase customer engagement and loyalty through mobile pages and apps (Jain, 2019).

Environmental

- Environmental matters are crucial priorities for both brands and customers alike. The latter are increasingly looking for environmentally friendly vehicles with low emissions and high fuel efficiency, two areas where Toyota's vehicles excel (Singh, 2019).
- In 2015, Toyota announced the Toyota Environmental Challenge 2050, striving to reduce the environmental costs of automobiles as much as possible, while developing measures such as optimized water usage or the establishment of recycling-based systems, all to seek net positive impacts on the planet and society. Based on Toyota and the industry's current state, more realistic mid-term targets for 2030 were also established (TOYOTA CORPORATION, 2019).

Legal

- The inconsistent and incomplete regulations on autonomous driving are putting this technology at hold. This affects the industry as a whole, which is why Toyota has joined forces with competitors such as GM and Ford to design safety standards for self-driving cars that could eventually help create regulations in the United States (Shepardson, 2019).
- Along with GM and Fiat Chrysler, Toyota sided with the Trump administration against California's fuel economy standards, saying that the federal government's authority should displace the state's when it comes to setting emissions limits. This decision leaves the company in a complicated position in an extremely environmentally active state, and may damage Toyota's image as a leader in clean-car manufacturing (Porterfield, 2019; Hsu, 2019).

Appendix 3

Categorisation and Characterisation of Advanced Robotics

QUID:

Quid has been a very useful tool in our analysis as it helped us find a timeframe for advanced robotics and also helped us identify robot trends for each process of manufacturing in the automotive industry. We started by using the **Companies** database to find which companies are connected to different types of robots.We used the **Patents** database for finding how disruptive technology is developing over time and how fast. Then we used the **News and Blogs** database for finding different types of robots for each manufacturing process, and for this database, we had as timeframe 11/04/2018 to 11/04/2019.

1st Quid search

Firstly, we used the **Companies** database and we used as timeframe 11/10/2014 to 11/10/2019 (the last 5 years).

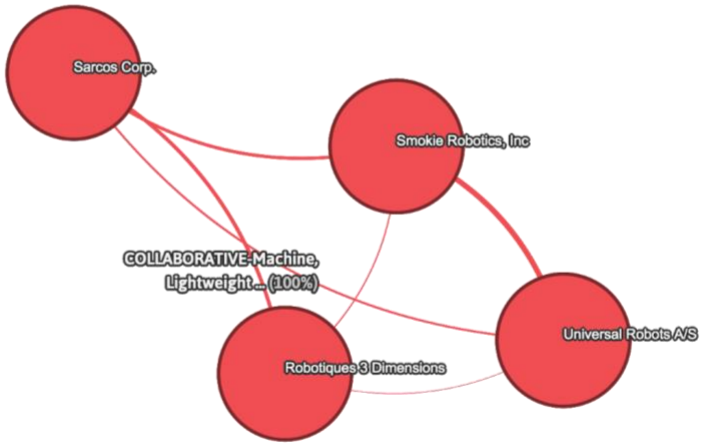
Our query:

“Exoskeleton”OR”articulated robot”OR”collaborative robot”OR”drone”OR”AGV”

The cluster highlighted above helped us identify 5 players in the AGV market.

2nd Quid search

We used the previous Quid search but this time we highlighted another cluster to help us identify key players in the Collaborative robots market.



We identified 4 key players.

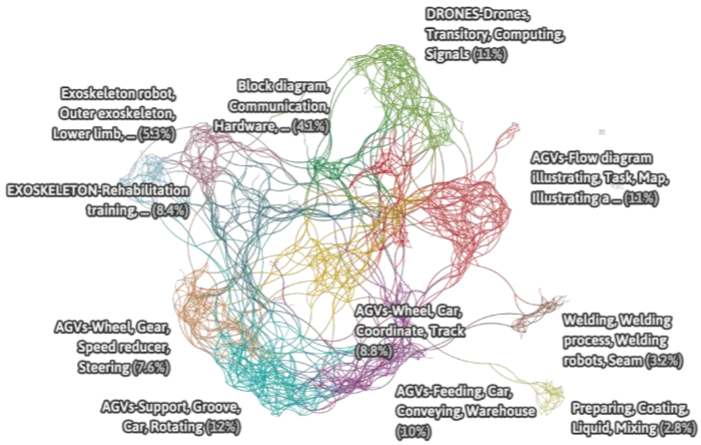
3rd Quid search

We used the **Patents** database to see how advanced robotics are changing over time for more types of robots. We set as timeframe the last 3 years.

Our query:
"Robots" OR "advanced robotics" OR "drones" OR "AGV" OR "AIV" OR "exoskeleton" OR "articulated robot" OR "collaborative robot" OR "robot chip" OR "SCARA" OR "collaborative robot"
We edited this map by deleting the "no cluster" and renaming the top 8 clusters by the type of robot mentioned there. Our top 8 clusters for patents in the last 3 years are, in this order: AGV(9.6%), AGV(9.4%), Exoskeleton(7.5%), AGV(6.5%), Exoskeleton(6.1%), AGV(5.9%), Articulated and Collaborative(5.5%), Drones(5.1%).

4th Quid search

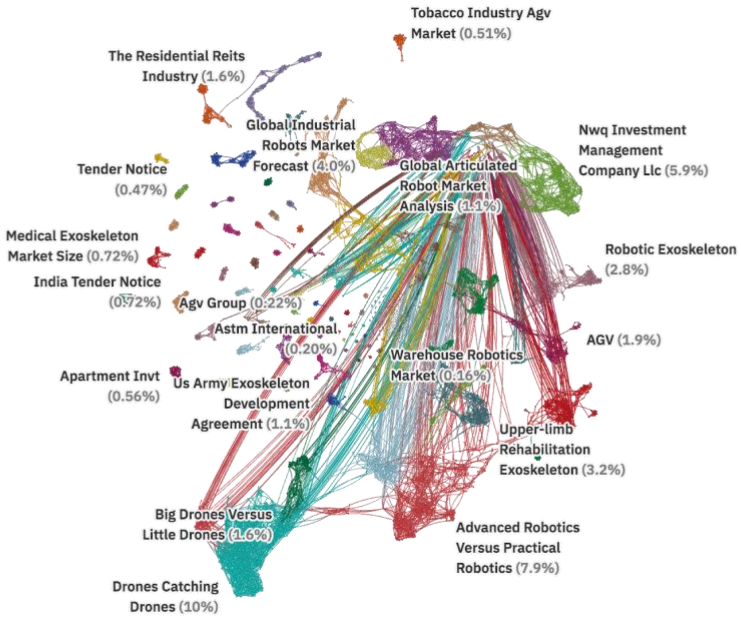
We did the same thing as in our first Quid search, but this time we used as timeframe only the last 1 year. We did this to compare the difference between the patents in the last 3 years and the last 1 year.



This time, our top 8 clusters are, in this order: AGV(12%), AGV(11%), Drones(11%), AGV(10%), AGV(8.8%), Exoskeleton(8.4%), AGV(7.6%), AGV(6.5%).

5th Quid search

Our next step was looking into the **News and Blogs** database to find new trends for advanced robotics, for more types of robots.



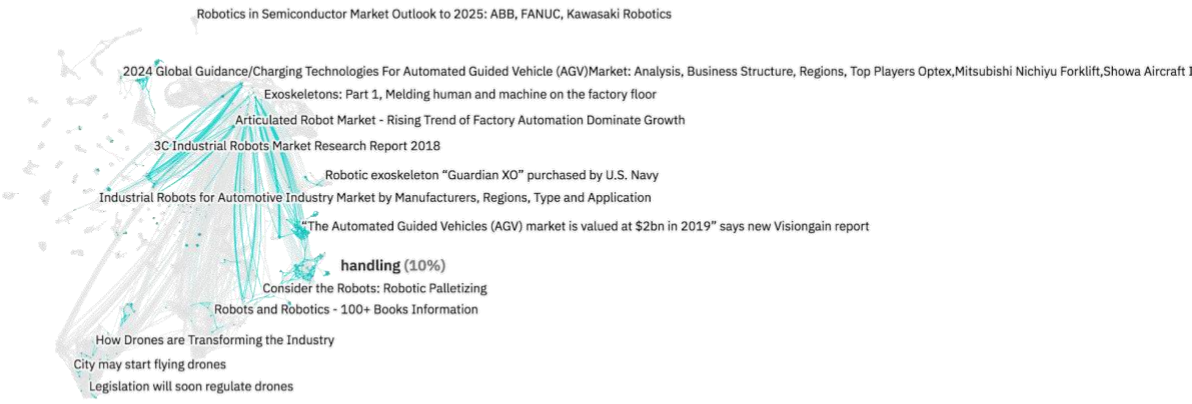
Our query:

"present robots"~10 OR "present robotics"~10 OR "present drones"~10 OR "present exoskeleton"~10 OR "present AGV"~10 OR "present AIV"~10 OR "present robotic arms"~10 OR "present industrial robots"~10 OR "present advanced robotics"~10 OR "present articulated robots"~10 OR "future robots"~10 OR "future robotics"~10 OR "future drones"~10 OR "future exoskeleton"~10 OR "future AGV"~10 OR "future AIV"~10 OR "future robotic arms"~10 OR "future industrial robots"~10 OR "future advanced robotics"~10 OR "future articulated robots"~10 OR "current robots"~10 OR "current robotics"~10 OR "current drones"~10 OR "current exoskeleton"~10 OR "current AGV"~10 OR "current AIV"~10 OR "current robotic arms"~10 OR "current industrial robots"~10 OR "current advanced robotics"~10 OR "current articulated robots"~10 OR " robots"~10 OR " robotics"~10 OR " drones"~10 OR " exoskeleton"~10 OR " AGV"~10 OR " AIV"~10 OR " robotic arms"~10 OR " industrial robots"~10 OR " advanced robotics"~10 OR " articulated robots"~10 OR "trend robots"~10 OR "trend robotics"~10 OR "trend drones"~10 OR "trend exoskeleton"~10 OR "trend AGV"~10 OR "trend AIV"~10 OR "trend robotic arms"~10 OR "trend industrial robots"~10 OR "trend advanced robotics"~10 OR "trend articulated robots"~10

6thQuid search

We wanted to divide our examples of trends into all the processes of manufacturing in the automotive industry and for each process all the types of robots we discovered. To do that, we created tags naming the manufacturing processes for the previous Quid search.

Our first tag was: handling



This map helped us find articles and extract 9 examples of handling applications in 2 robot categories.

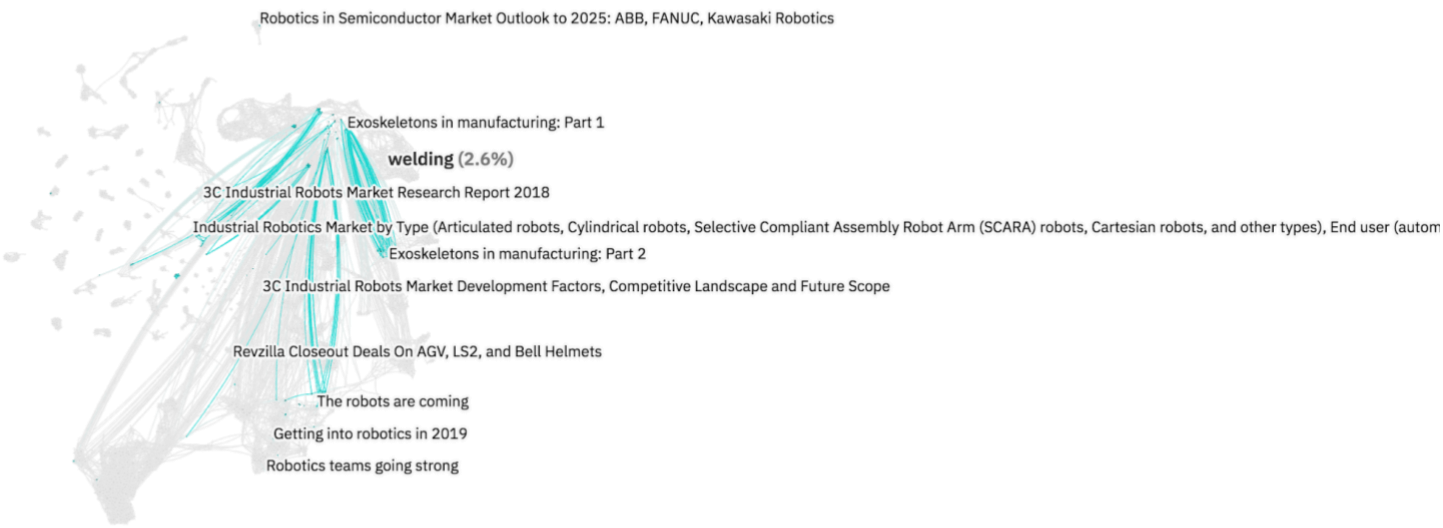
	Handling
	Articulated Robot
1.	Deliver heavy parts with longer reach
2	Take materials from stamping process to the next
3.	Load heavy specs (doors) after welding in order to assemble the cars
4.	Ensure consistent production, maximize process efficiency
5.	Fully automated to ensure a consistent production and quality

	Handling
	Collaborative Robot
1.	Enhanced manipulation
2.	Create safe-working environment, protect workers from repetitive tasks
3.	Achieve automate processes including handling, assembling, packaging, palletizing, labelling, painting, quality control and machine tending
4.	Carrying heavy materials in assembly process

7thQuid search

We used the previous search but this time with another tag in order to identify examples of robots in the welding process.

Our tag: welding



This map helped us find articles and extract 26 examples of welding applications in 4 robot categories.

	Welding
	Articulated
1	Welding body components together with lightning speed and fierce heat
2	Welding which best retains surface appearance with little to no deformation and minimal thermal stress

3	TAL BRABO Robot is a welding high-speed machine
4	Welds aluminum which is a difficult metal
5	The Brabo TRO6-6 is a multitask robot
6	Factory cages between robots and humans in welding tasks
7	With a near faultless weld integrity return of 99.9%
8	Excellent shielding against external environmental conditions.
9	Can weld points that conventional robots cannot reach
10	Maximizes fuel volume and reduces connections to the fuel system.
11	Increase positioning speed and accuracy. Save material and fewer movements.
12	New spot welding method, improve efficiency
13	Dramatically downsized through the use of process integration
14	Cloud-connected welding robots facilitate predictive maintenance
15	New weld workshop to make metal bodies
16	Maximizes fuel volume and reduces connections to the fuel system

	Welding
	Collaborative
1	Higher accuracy (88 laser welds in 40 seconds)
2	A lightweight robot lifts bevel gears and fits them accurately
3	92 advanced robots, 75 percent automated
4	Bodyshell assembly and complex part creation in collaboration with humans
5	New laser system (RWS) to increase efficiency and save up 59% time
6	Controlled by humans using a remote control
7	Increase safety in the workshops by introducing robots in dangerous tasks
8	Enhance production and quality processes

	Welding
	Exoskeleton
1	The number of welded joints increased by 86%

	Welding
	Mobile
1	Mobile manipulation robots

8thQuid search

We used the previous search but this time with another tag in order to identify examples of robots in the assembly process.

Our tag: assembly

This map helped us find articles and extract 21 examples of assembly applications in 4 robot categories.

	Assembly
	Articulated
1	Installs battery packs in the cars, relieving humans of the most labour-intensive operation in the factory and reducing installation time from four to two minutes
2	Reduced gaps between vehicle parts, decreasing wind noise
3	Supports labor cost saving, rationalization and automation

	Assembly
	Collaborative
1	Assembly plastic parts into verification models
2	Improve productivity
3	Driveless Transport System moves equipment in production/assembly lines
4	Identifies engine type, stops when close to human worker
5	Grasp heavy components, improved effectiveness when holding a single screw
6	Collaborative robots help make tasks easier, safer and quicker.
7	Collaborates with workers installing the battery, motor, interior, and miles of cabling and components that form the car
8	Work side-by-side with workers, improving cost effectivity and productivity
9	Provide assistance in the body shop

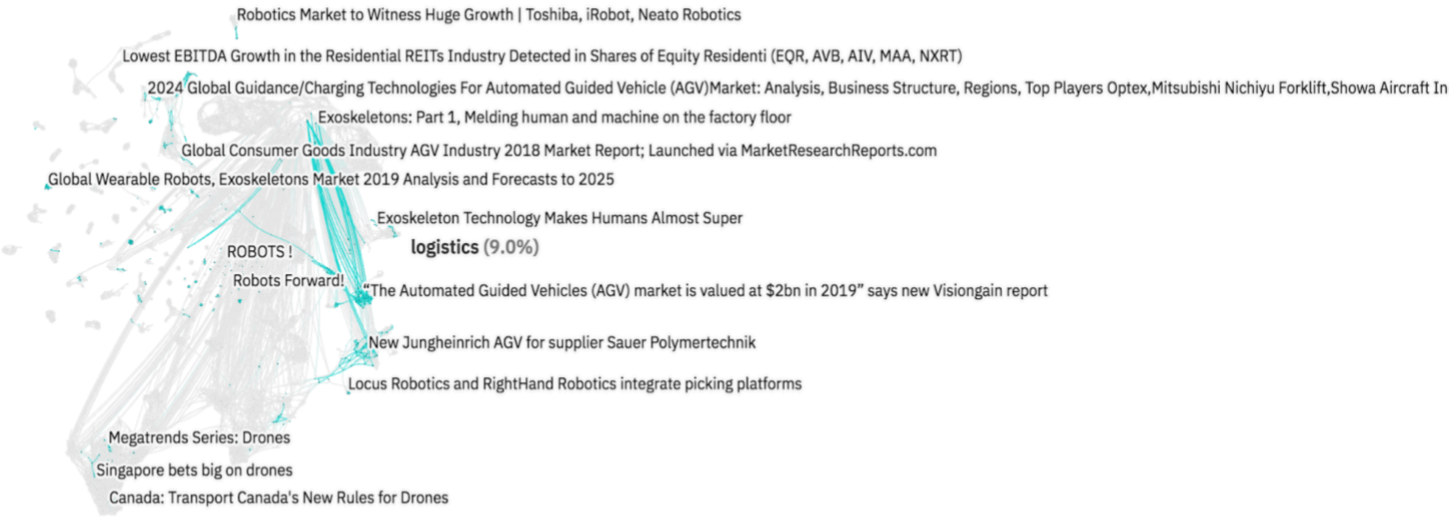
10	High-speed, feed-roller conveyor which uses a skid to carry part of the chassis
11	Apply Virtual Reality to safeguard assembly process for the ergonomic optimisation of the work station
12	Robotic arms equip seats from multiple angles and place glue on window while fitting the window onto cars
13	Analyzed and shared data in real time
14	Lightweight robot is used to calibrate the head-up display

	Assembly
	Exoskeleton
1	Enhance strength and prevent injuries.
2	Ease overhead work strain, prevent injuries.
3	Give load support, mobility and adaptability in overhead environments.

	Assembly
	Mobile
1	Flexibility depending on demand (moved by forklift).

9thQuid search

We used the previous search but this time with another tag in order to identify examples of robots in the logistics process.



Our tag: logistics

This map helped us find articles and extract 11 examples of logistics applications in 4 robot categories.

	Logistics
	AGV
1	Space optimization, fast and efficient process ULTRA Robotic Truck Loading/Unloading Platform
2	Synchronized and optimized loading/unloading operations by Automated guided container transport system
3	Increasingly used to transport goods within production halls. (BMW)
4	Move cars to another process after painting (Tesla)
5	Read the logistics information easily during process, transport goods within production halls (BMW)

	Logistics
	AIV
1	Daimler AG joined forces with torc robotics to created autonomous trucks
2	Intermediate goods transport, trace and verify information of all items (Omron Automation)

	Logistics
	Collaborative
1	Each element is networked and connected to the internet (Daimler AG)
2	Be assisted by logistics robots, more flexible (BMW)

	Logistics
1	High-density storage, space saving robots in Toyota
2	ISUZE has robots that improve productivity

10thQuid search

We used the previous search but this time with another tag in order to identify examples of robots in the quality control process.

Our tag: inspections

This map helped us find articles and extract 21 examples of quality control applications in 5 robot categories.

	Quality Control
	Articulated Robot
1.	Inspect the quality of car door
2	Reduce the Defect Ratio from 5% to 2% in Hyundai's Sriperumbudur near Chennai
3.	automated inspection cells to inspect sheet metal components of various sizes

4.	Atos optical 3D scanner to inspect overall car body
5.	ARAMIS 3D Camera on 6-axis robots in order to carry out deformation analysis
6.	detects and classifies all relevant surface defects on painted and ED-coated surfaces.
7.	detect smallest changes immediately and report them to the control system
8.	Full-field inspection of Body-in-white (BIW) components with ATOS TripleScan
9.	Manufacturing process overview
10.	CarPaintVision surface inspection system detects and classifies all relevant surface defects on the painted surfaces of a car body
11.	Beanmaster 3D with robot for 100% monitoring of glue and sealant beads
12.	PONTOS Live 3D Motion Analysis & Component Positioning helps to examine stiffness and vibration test

	Quality Control
	Collaborative Robot
1.	Inspects the Advanced Driver Assistance System (ADAS) in 85 sec
2.	Speed up the process of quality assurance of crankshaft housings
3.	Test system for autonomous driving in Mercedes Benz

	Quality Control
	Drone Robot
1.	Use drones to inspect sand delivery pipes

	Quality Control
	Exoskeleton Robot
1.	raises workers arms overhead as they move ultrasonic wands over metal to test the integrity of dozens of welds

	Quality Control
	Sensor/Wireless Robot
1.	TRITOP CMM system ensures all the assembly brackets are fully fitted with no distortion
2.	Used in car crash test to examine how likely passengers will be injured
3.	Uses pedal robots, steering-wheel robots and driveless robots to conduct car crash test
4.	Viva, a tailored application packages for fully-automated inspection processes

11th Quid search

We used the previous search but this time with another tag in order to identify examples of robots in the painting process.

Our tag: painting

This map helped us find articles and extract 5 examples of painting applications in 2 robot categories.

	Painting
	AGV
1	Durr designs Ecoprofleet, first AGV's to transport bodies instead of conveyor technology; level 1 functionality: device control for individual AGVs
2	Level 2 functionality: fleet control-route planning
3	Level 3 functionality: order planning-linked via interfaces

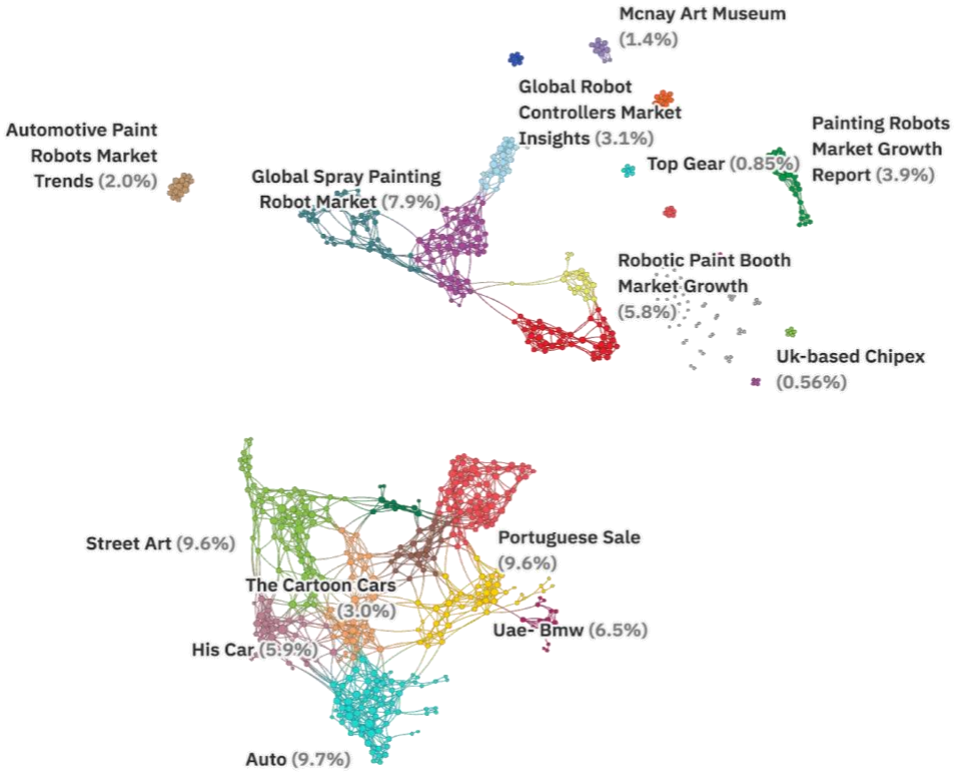
	Painting
	Exoskeleton
1	Robots to assist painters in repetitive task, reduce cost spent on lost hours and physical injury, improve productivity by 86%
2	Expanding the workforce: enable disabled people and women to work

12th Quid search

We wanted to find more examples for painting so we did a tailored Quid search for that in the **News and Blogs** database.

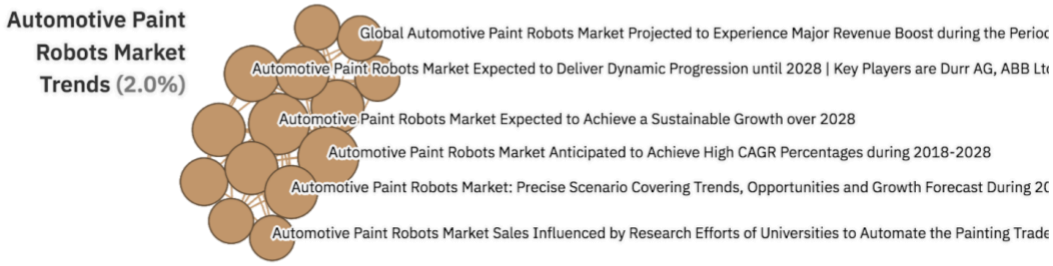
Our query:

"present painting robots" ~ 10 OR "present car painting" ~ 10 OR "future painting robots" ~ 10 OR "future car painting" ~ 10 OR "current painting robots" ~ 10 OR "current car painting" ~ 10 OR "evolution painting robots" ~ 10 OR "evolution car painting" ~ 10 OR "trend painting robots" ~ 10 OR "trend car painting" ~ 10 OR "innovation painting robots" ~ 10 OR "innovation car painting" ~ 10



13thQuid search

We used the previous Quid search but we focused on this specific cluster: Automotive Paint Robots Market Trends.



This map helped us find articles and extract 17 examples of painting applications in 6 robot categories.

	Painting
	Articulated
1	ABB proposed a solution to enable manufacturers to effectively reduce equipment investment and workshop space, improving efficiency and reducing VOC emissions.
2	EcoRP E043, Durr's new 7 axis robot leaves less footprint, no displacement rail, kinematic freedom
3	In Toyota's paint shop, robots cover general areas, human workforce deals with hard-to-reach zones
4	ABB, Durr, KUFA, FANUC, Kawasaki, Yaskawa Motoman are the leaders in today's cloud-connected articulated-arm painting robots which are lighter, speedier and equipped with numerous sensors and activators
5	FANUC's Tier 1 robot can communicate better with other networks and has improved flexibility because of his 6 axis conformation

6	ABB and Durr introduced automative paint robots that enable smart diagnostics and do quality control while they apply paint, not post-completion, to save time
7	Yaskawa introduced robots that require lower interference work envelopes. Level 1 functionality(MPX1150): horizontal reach: 727 mm; vertical reach: 1290 mm
8	Level 2 functionality(MPX2600):horizontal reach: 2000 mm; vertical reach: 3643 mm
9	KUKA introduced KR AGILUS: it has greater arm reach than competitiors, it is waterproof, minimum service cost

	Painting
	Automated paint shop - IOT
1	Durr is working on an automated paint shop that features IOT technology, with dramatic reduction in cost and space

I need space amigo- leave me two papers (mooved yours down

	Painting
	Chip for AGV
1	Sick introduced a chip for AGVs which can locate them and remove the need and cost of reflectors

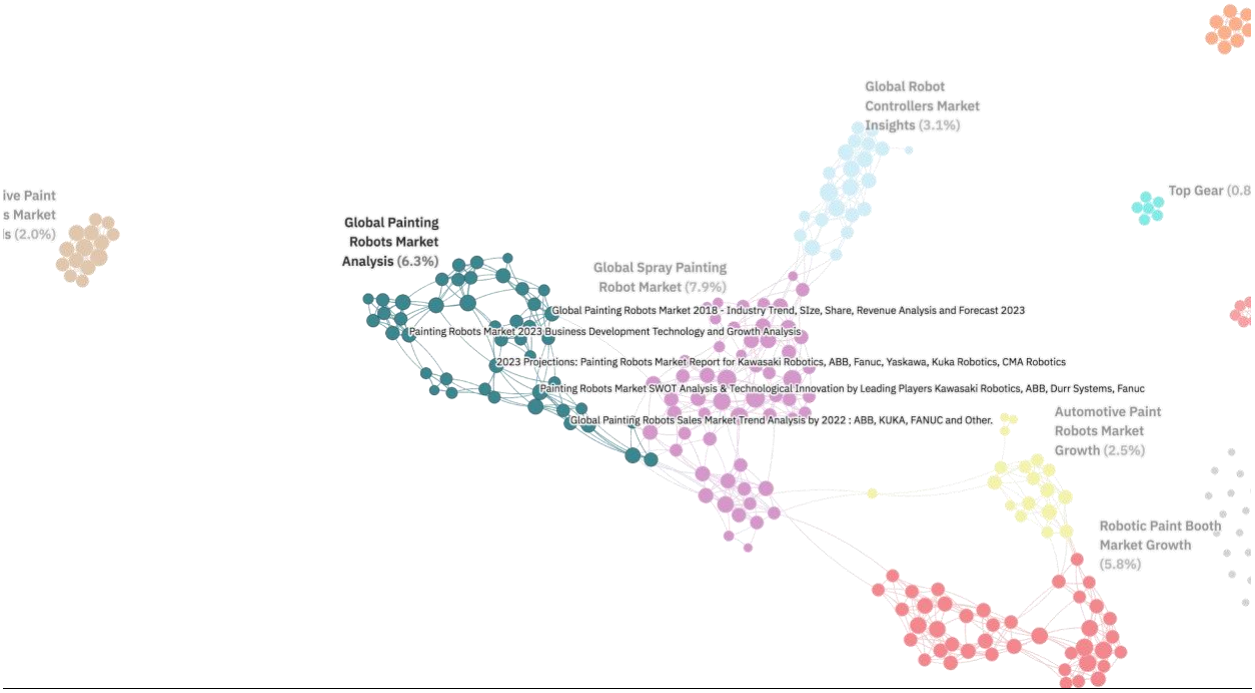
	Painting
	Drones
1	Appelix works on flying automotive paint robots, which combine drones and sprayer systems, and can eliminate challenges associated with altitudes and provide mobility and positioning to surfaces; level 1 functionality-2016
2	Level 2 fucntionality-Drone Volt introduced in 2017the Hercules 10, which can fly faster

	Painting
	Measurement systems
1	BYK Additives & Instruments has introduced an orange peel measurment system-2K paint temperature control system
2	Saint Clair Systems has introduced Wave-Scan, an orange peel measurement technology

	Painting
	Mobile telescopic arms
1	Nanyang Technological University is developing a mobile paint spraying system, with arms up to 10 m
2	A robotic painting system that can coat ships with area output of nearly 1400 square meters per hour is said to become a new trend for painting cars

14thQuid search

We used the previous Quid search but we focused on this specific cluster: Global Painting Robots Market Analysis. We highlighted it in the map below.



This map helped us find articles and extract 5 examples of painting applications in 4 robot categories.

	Painting
	Cartesian Robots
1	Lower number of application compared to articulated robot because it only has 3 axes

	Painting
	Cylindrical robots
1	Lower degree of freedom compared to articulated robots

	Painting
	SCARA robots
1	Lower degree of freedom compared to articulated robots because it was introduced in 1981

	Painting
	General
1	Electricity driven machines- increase the painting speed up 50% compared to conventional machines
2	ABB will produce in 2020 around 300 robots for VW, Audi and Skoda which paint the exterior interior, underbody, cosmetic seam sealing and interior plate wax-spraying for electric vehicles specifically

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FEEDBACK

Feedback received	Improvements made
Unclear graphs visibility	Improved graph from the simple pie chart to the stacked pie chart with detailed information, meanwhile adding a higher variety of graph formats.
Lack of quantitative details in Business Model Canvas	Inclusion of relevant data after researching and analyzing different sources of information, in order to improve the quantitative value of the BMC.
A more clarified categorization is needed	Creation of categories breakdown for the disruptive technology, as well as for each main application category.
No sub-categories	Tables and Quid searches used to present sub-categories such as articulated, exoskeletons, AGV...
No timelines provided for the evolution of the disruptive technology	Inclusion of detailed timelines of the development of advanced robotics in the past, as well as estimated predictions for the future evolution of said technology. In addition, we picked an additional sub-category (exoskeletons) and designed a detailed timeline of the changes in design and cost to illustrate the technology in a more effective and quantitative way.