

EXECUTIVE SUMMARY

The Path to Lights-Out Manufacturing

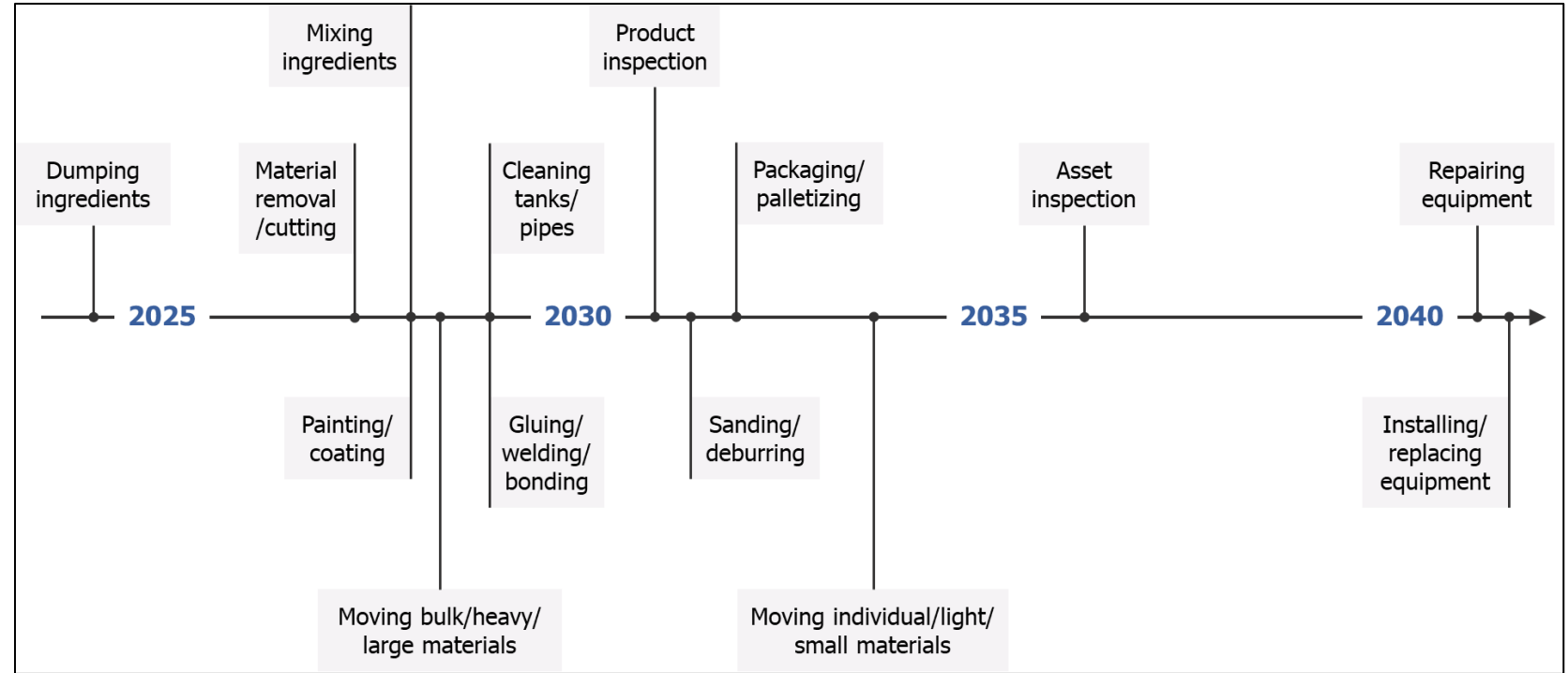
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Executive Summary

Lights-out manufacturing timeline for different manufacturing tasks



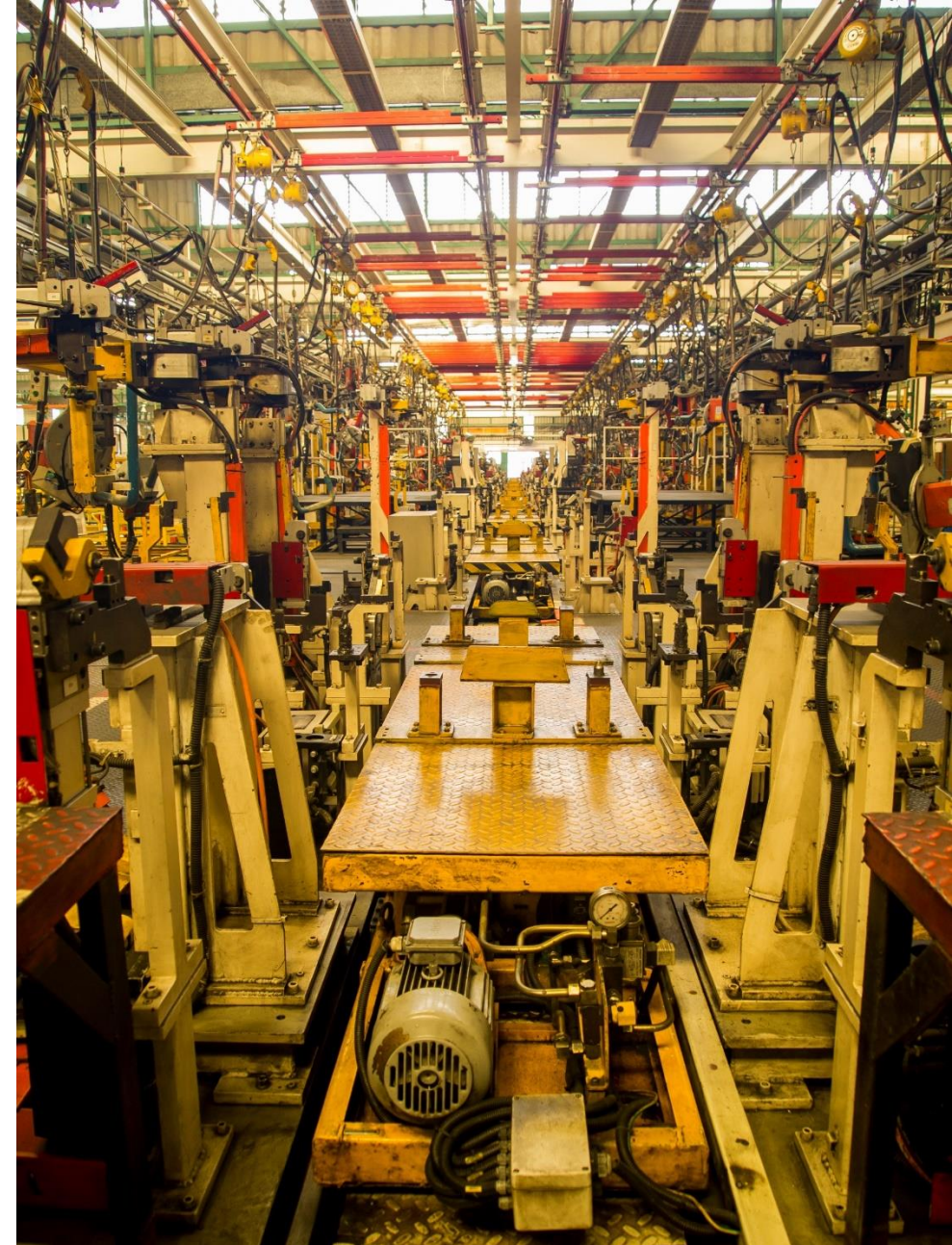
- In this report, we demonstrate a framework that analyzes different drivers and barriers for automation for various manufacturing tasks and predicts the timeline for reaching complete automation.
- We identified operational efficiency, human labor issues, and product customization as the drivers for automation. On the other hand, we identified technology bottlenecks, financial feasibility, and regulatory and cultural pushback as the barriers.
- Based on our findings, most manufacturing tasks that require one or two highly mature robots will be automated between late 2020 and early 2030. However, highly unstructured tasks like equipment repair and installation will probably always require some human intervention and never be fully automated. While achieving lights-out manufacturing is the ultimate goal for many manufacturing companies, it might not be realistic because of the many challenges involved and the lengthy timeline, as seen in the chart above. Therefore, clients should incorporate a hybrid approach of manual and automated work environments in the short term.

Lights-out manufacturing isn't a new concept, and several organizations have tried it

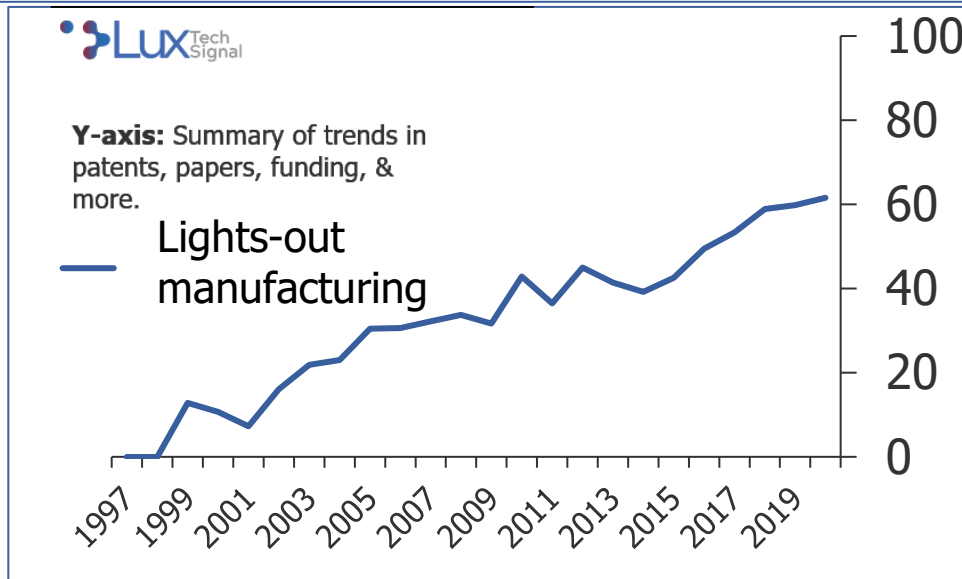
Lights-out manufacturing is a methodology in which manufacturing is fully automated and requires no human presence so that the lights and even ventilation can be shut off, hence the term lights-out.

While lights-out manufacturing sounds futuristic, the concept has been circulating around for a couple of decades now. In fact, many organizations have operated several forms of lights-out factories:

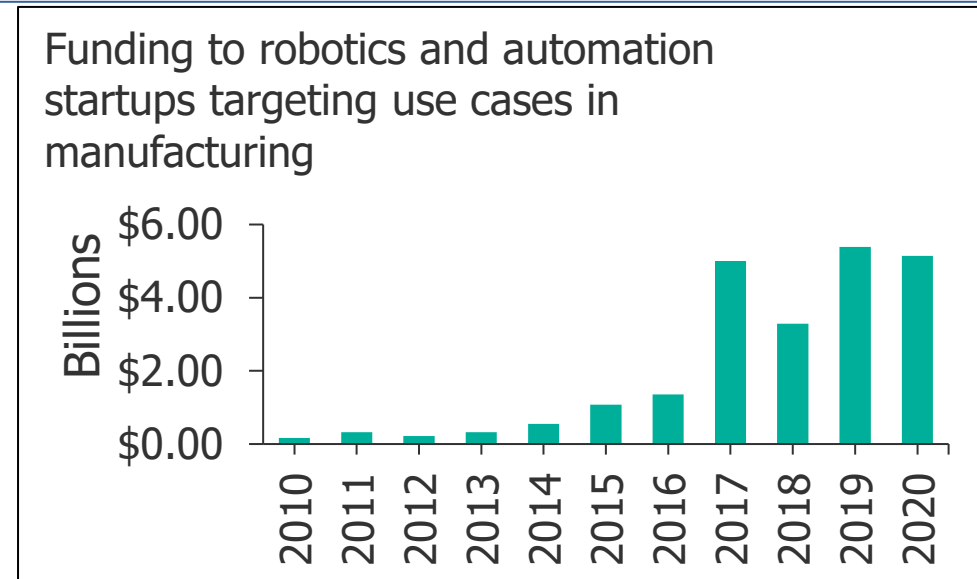
- IBM built a lights-out plant in Texas in 1980 to assemble computer keyboards. However, the project was shut down due to fixed tooling, which made the plant inflexible to adapt to product variations.
- GE operated a light bulb factory in Virginia from the early 1990s to 2010 that produced more than 10,000 units per hour with only a few human workers assigned to perform maintenance on equipment.
- Fanuc has been running 22 lights-out factories since the early 2000s that use robots to manufacture CNC machines. The robots can go unsupervised and without maintenance for as long as a month at a time.
- Phillips has been running lights-out manufacturing plants to produce electric razors with a team of 128 robots and nine quality assurance (QA) workers.



There has been a steady rise in activity and interest from investors in lights-out manufacturing in the past five years



Using the [Lux Tech Signal](#), we can see that there is increasing activity in lights-out manufacturing. Ideas developed in the late 20th century are now seeing a resurgence because of modern technologies like advanced robotics, [computer vision](#), [industrial IoT](#), [machine learning algorithms](#), and improved computing (cloud and [edge](#)).



Similarly, funding in robotics and automation in manufacturing has also increased significantly since 2015. While most of the funding is in the form of VC investments in emerging startups, public companies have also raised millions in post-IPO funding. North America and Asia are the two biggest investors in robotics and automation for manufacturing.

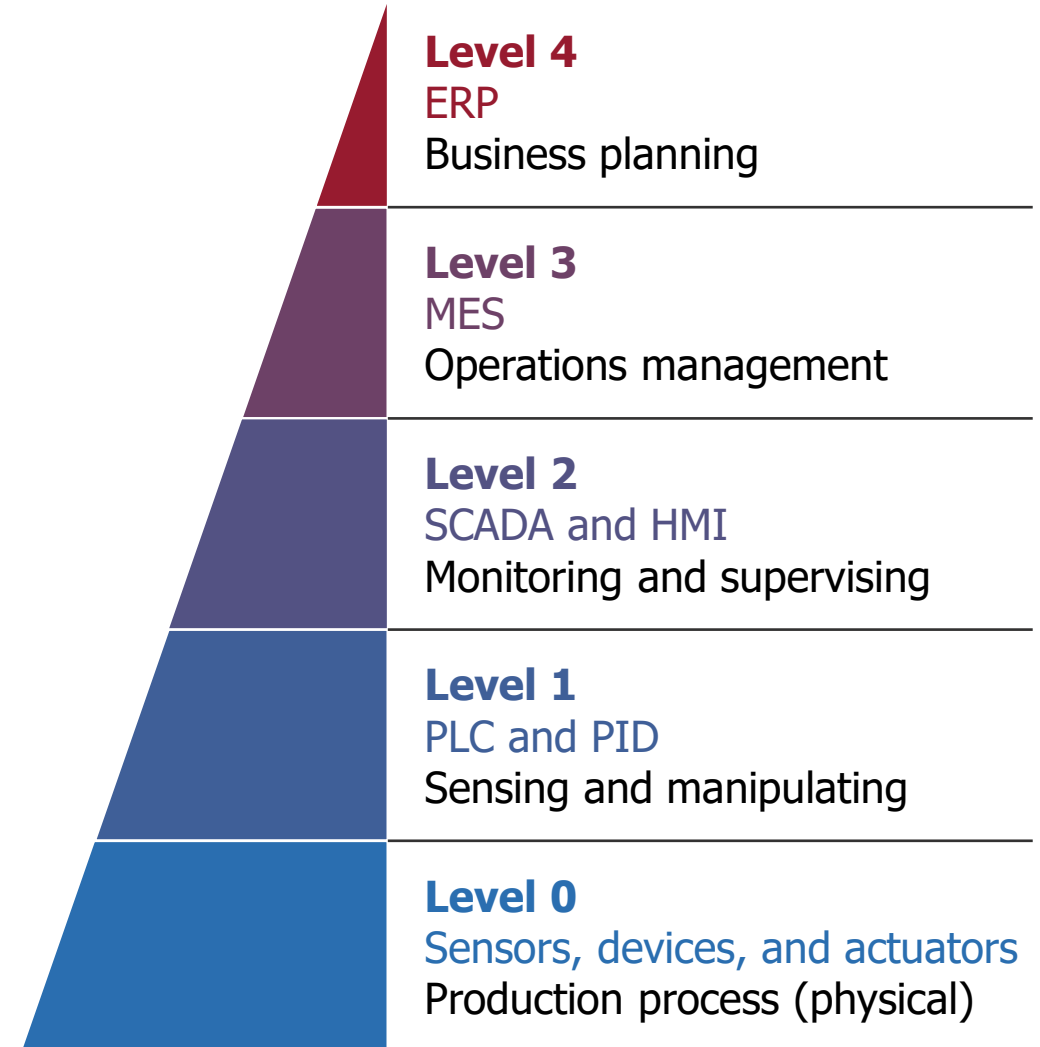
Building lights-out manufacturing will require automation of physical tasks with industrial robots

Factory automation tools like programmable logic controllers (PLCs) have been in use in manufacturing facilities for a long time to automate higher-level processes (as seen in the automation pyramid) like relay control, machine functions, motion control, and process control.

We interviewed several industry leaders, who shared their front-row-seat perspective of automating manufacturing tasks. Most of our interviewees mentioned that their organization still focuses on automating such higher-level manufacturing processes.

Achieving lights-out manufacturing will require automation of production processes at lower levels, such as moving materials, cleaning tanks, and inspecting products and assets, alongside automation of higher levels.

While there are dozens of robotics technologies that can automate lower-level tasks, we have identified the most important ones and used the findings from the interviews in addition to our other research (e.g., company profiles) in the space to assign their individual average technology maturity in the following section.



Technology: Autonomous Mobile Robots (AMRs)

Introduction

- AMRs are great tools to transport raw materials, products, packages, and boxes around a manufacturing facility.
- Assembly lines are increasingly replacing rigid conveyor lines and automated guided vehicles (AGVs) with omnidirectional AMRs to increase flexibility.

Challenges

- **Navigation:** Although AMRs are trained to drive autonomously, they have difficulties navigating through unusual circumstances like wet or highly reflective surfaces.
- **Charging:** AMRs are battery-operated and need to charge. While most AMRs charge autonomously, this reduces the operating time of the robots.



Source: [Forbes](#)

Technology: Autonomous Mobile Robots (AMRs)

Key innovation areas

- **Increased precision in positioning:** Companies are using sensor fusion from sensors like lasers, gyroscopes, and odometers to increase precision to the submillimeter level.
- **AI-based routing algorithm:** Machine learning algorithms have been in increasing use for obstacle avoidance and for orchestrating the movement of AMRs in a fleet to achieve maximum efficiency and minimize collisions.
- **High-capacity batteries and faster charging:** Technologies like high-density batteries and faster contact charging are being adopted into AMRs.

Lux Take

Overall technology maturity level: ■ ■ ■ ■ □

For most manufacturing facilities, AMRs are probably the first step toward lights-out. The technology is quite mature, and the ROI is reasonable considering the manual tasks (moving heavy loads and setting up environmental markers for AGVs) it can replace.

Key players



Technology: Robotic Arms

Introduction

- Robotic arms replace human arms for tasks that require precise dexterity, such as picking, sorting, packing, palletizing, and depalletizing objects.
- Most other robotic systems, such as AMRs, cobots, grippers, and teleoperated robots, tend to work in conjunction with robotic arms.

Challenges

- **Programming:** Because programming and reprogramming robotic arms is still difficult and time-consuming, it makes manufacturing processes more inflexible to changes.
- **Repairs:** Robotic arms contain several moving parts and joints that require periodic maintenance and repairs. Automation of the maintenance of robotic arms is required for lights-out, which is even more challenging.



Source: [Bloomberg News](#)

Technology: Robotic Arms

Key innovation areas

- **Low-code programming:** New robot programming interfaces enable robotic arms to be trained for new tasks by dragging and dropping instructions instead of writing complex codes.
- **Transfer learning:** Transfer learning reuses machine learning models developed for one use case as the starting point for another use case. This speeds up the training process to teach robotic arms new tasks, thereby reducing the time to market.

Lux Take

Overall technology maturity level: ■ ■ ■ ■ □

Robotic arms are essential automation tools for many manufacturing tasks. However, in addition to the high upfront costs, companies should also allocate significant resources for the maintenance and repair of robotic arms.

Key players



Besides technical enablement, there are other nontechnical factors responsible for the growing demand for lights-out manufacturing (1/2)

1. Operational efficiencies

- a) **Minimizing operational costs:** While robots have high upfront costs, they can be less expensive than human labor over time. The push to increase minimum wages and benefits for factory workers is also driving large corporates toward increased levels of automation.
- b) **Achieving higher efficiency:** Unlike human workers, a robustly built robotic system can run 24/7 without the need for breaks, vacations, or shift changes.
- c) **Reducing downtime:** Human error accounts for an [estimated 23%](#) of unplanned downtime in manufacturing, which can lead to millions of dollars in lost revenue. In addition to the unplanned downtime, the lack of flexible production systems and the need for manual inspection, maintenance, and repair (IMR) are reasons for planned downtime in manufacturing.
- d) **Minimizing wastage for sustainability reasons:** In addition to operational and maintenance costs, inefficiency and downtime caused by workers and inflexible manufacturing systems also lead to increased material wastage and carbon footprint.

Besides technical enablement, there are other nontechnical factors responsible for the growing demand for lights-out manufacturing (2/2)

2. Human labor demands

- a) **Rising worker safety concerns and costs:** Adopting [worker safety](#) measures to create a safe workplace for factory workers has several advantages, but it comes at an increased cost. While replacing some workers with robots can help save operational costs, the use of [collaborative robots \(cobots\)](#) requires further worker safety measures for the remaining workers. Therefore, companies are interested in full automation.
- b) **Labor shortages:** Some industries, such as oil and gas, have been [suffering](#) from significant labor shortages caused by both an aging workforce and the lack of fresh graduates interested in working in the field. Even for other industries, knowledge transfer and worker training for new hires are difficult and expensive.
- c) **COVID-19:** The COVID-19 pandemic has been an unprecedented driver for several tech innovations ([see our report](#)), including automation. Companies like [Hitachi](#), [Mitutoyo](#), and [Omron](#) (see respective news commentaries) have claimed COVID-19 as the motivation for their investments and M&A initiatives in automation since 2020.

3. Product customization

Meeting the growing demand for customized products is difficult using workers and even for companies that use robots to manufacture parts in siloed environments. The optimal use of resources and flexible processes required to manufacture custom products based on demand can be achieved using complete automation or lights-out manufacturing.

At the same time, there are several barriers to lights-out manufacturing

1. Technology bottlenecks

- a) **Lack of technology maturity:** While there have been ongoing developments in smart manufacturing, the technologies required for full automation or lights-out still lag behind the demand.
- b) **Skill gaps:** While lights-out could put tens of thousands of factory workers out of work, it will also create demand for a new type of workforce that designs and develops the necessary hardware and software for these systems, which will add to the already existing talent shortage in the skilled workforce in areas like data analytics.

2. Financial feasibility

Although robots might be less expensive in the long run, their excessively high cost often becomes a barrier to adoption, especially for small manufacturing companies. Using robots is still more expensive for countries with low human labor costs and lax worker safety regulations. However, newer business models like renting and [leasing](#) robots are making it easier for companies to avoid large upfront fees and adopt robotic systems.

3. Regulatory hurdles and cultural pushback

Automation is often a topic of criticism, as it can take away jobs and poses the threat of causing widespread unemployment, which is creating rising demand for regulations against such large-scale automation.

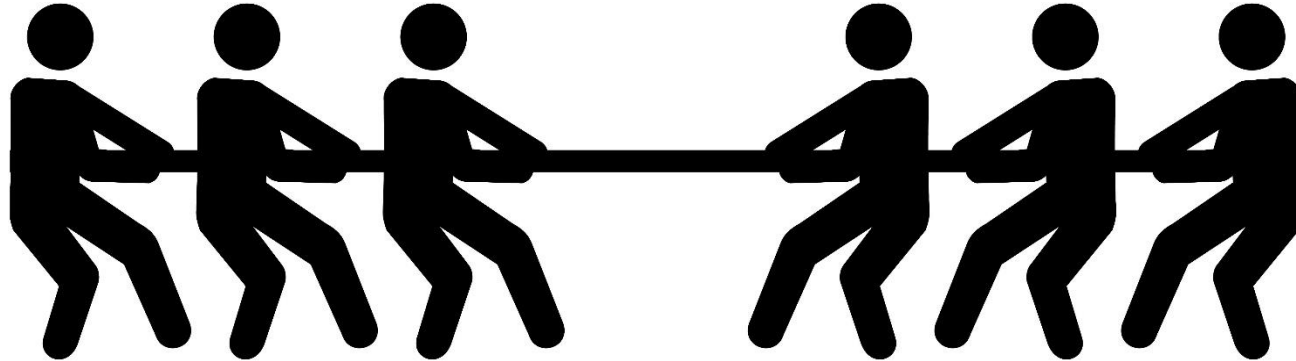
The significance of drivers and barriers determines the timeline for lights-out manufacturing

Barriers

Technology Bottlenecks

Financial Feasibility

Regulatory/Cultural



Drivers

Operational Efficiencies

Human Labor Demands

Product Customization

After identifying the drivers and barriers to lights-out manufacturing, it is important to understand how significant they are. However, **different manufacturing tasks are differently affected by these factors.** For example, worker safety is a bigger concern for tasks like cleaning tanks compared to product inspection.

Similarly, while we have assigned an overall technology maturity to different robots based on their capabilities and challenges, the actual performance will depend on several factors, such as the type and complexity of tasks, the operating environment, and the requirement for integration with other robotic systems. **Adopting a robotic system based on its success in one task might not yield a similar result for another.** For example, an inspection robot that detects anomalies in manufactured products on an assembly line might not have similar performance when used for inspection of industrial machines.

Therefore, **the prediction of the timeline of lights-out manufacturing will require more detailed and case-by-case analysis that accounts for all factors.** In the next section, we present a framework to quantify the timeline for lights-out manufacturing for different manufacturing tasks.

Applying the automation framework

Example task 1: Mixing ingredients

- Mixing ingredients in a process manufacturing plant requires repetitive tasks like picking ingredients and dumping them into the mixing tanks. Achieving higher operational efficiency is the biggest driver for automation for this task, as workers are required to work long hours in multiple shifts to mix ingredients. Similarly, human errors in mixing the wrong type and amount of ingredients can lead to the whole batch being wasted. Finally, customization of products requires different types and amounts of ingredients, which is difficult and more error-prone for human workers.
- The upfront cost of such a robotic setup is somewhat of a barrier, especially for small manufacturing companies. However, the operating and maintenance costs for these robots are not significant, as they do not include very complex design and setup.
- These types of tasks can be automated using robotic arms and grippers. The picking, dumping, and mixing procedures do not have many variations and do not require a high degree of dexterity. Therefore, such robotics systems are relatively mature for this task.

Drivers/Barriers	Significance
Operational Efficiencies	High
Human Labor	Low
Product Customizations	Medium
Technology Bottlenecks	Medium
Financial Feasibility	Medium
Regulatory/Cultural	Low

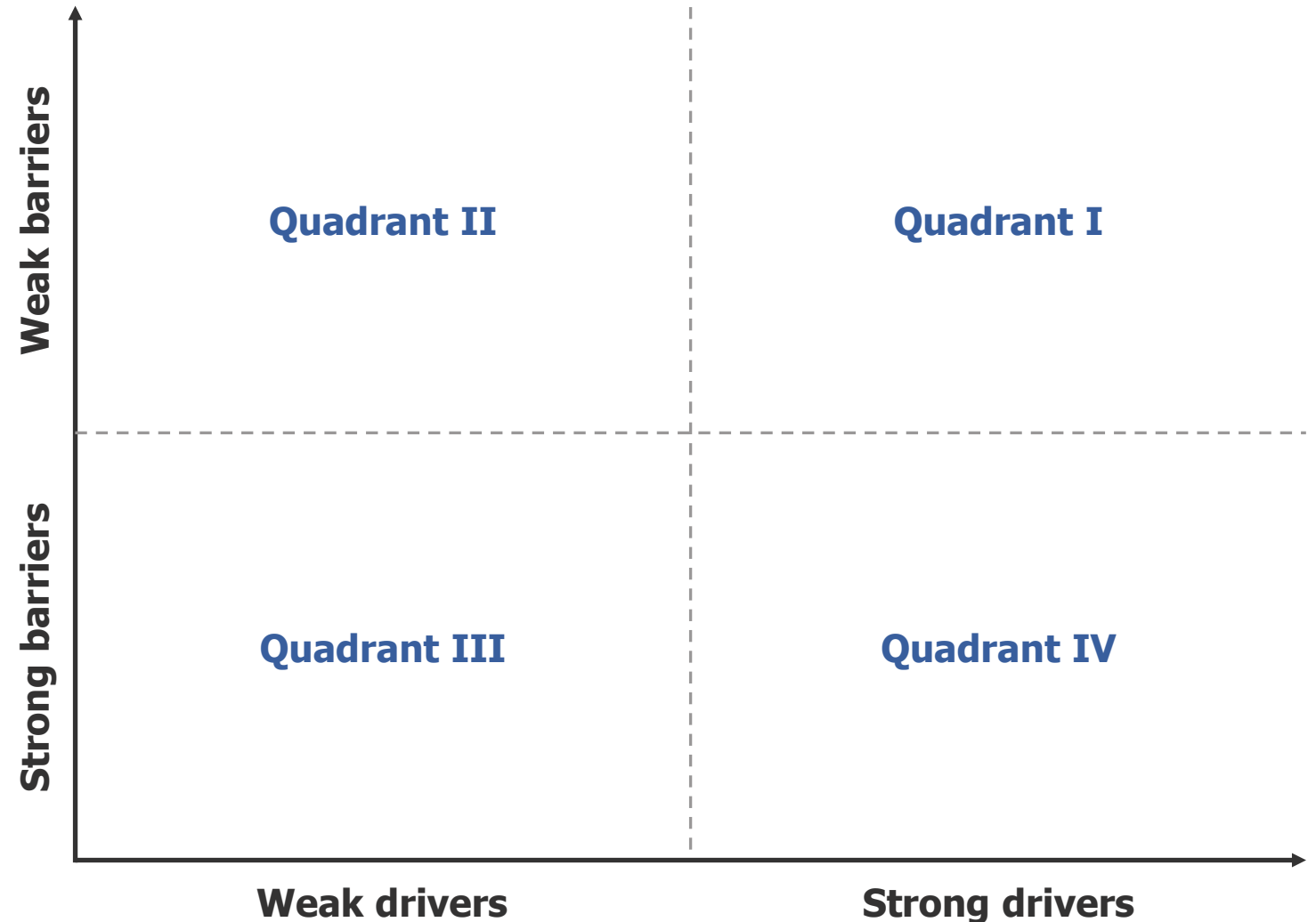
Robots	Technology Maturity
Robotic Arm	■ ■ ■ ■ □
End Effector	■ ■ ■ □ □

Calculation:

Net Driver	2.2
Net Barrier	1.5
Automation Index	0.7

Building a scatter diagram that visualizes manufacturing tasks in four quadrants with distinct characteristics

- The first quadrant contains low-hanging fruit – these are tasks that have strong drivers and low barriers for automation.
- The second quadrant contains tasks that have both weak drivers and weak barriers. These tasks can be automated soon but will not make huge improvements to the manufacturing systems.
- The third quadrant includes tasks with low drivers and strong barriers. These tasks will probably always require some human intervention and never be fully automated.
- The fourth quadrant represents tasks that have both strong drivers and strong barriers. These tasks are worth investing in but with a clear understanding that they will take several years, if not decades, to be fully automated.

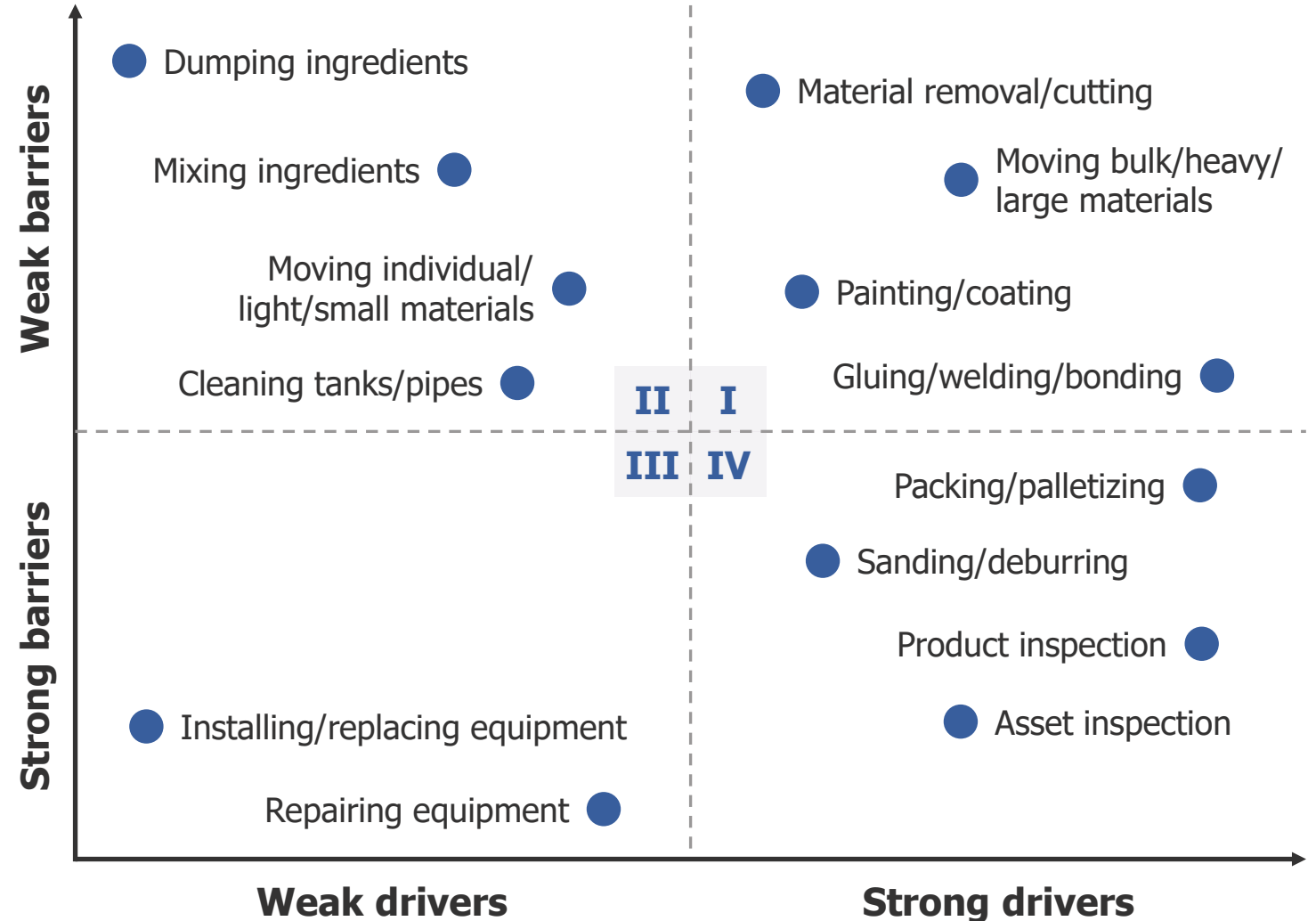


The scatter diagram shows different feasibility levels and requirements for the automation of key manufacturing tasks

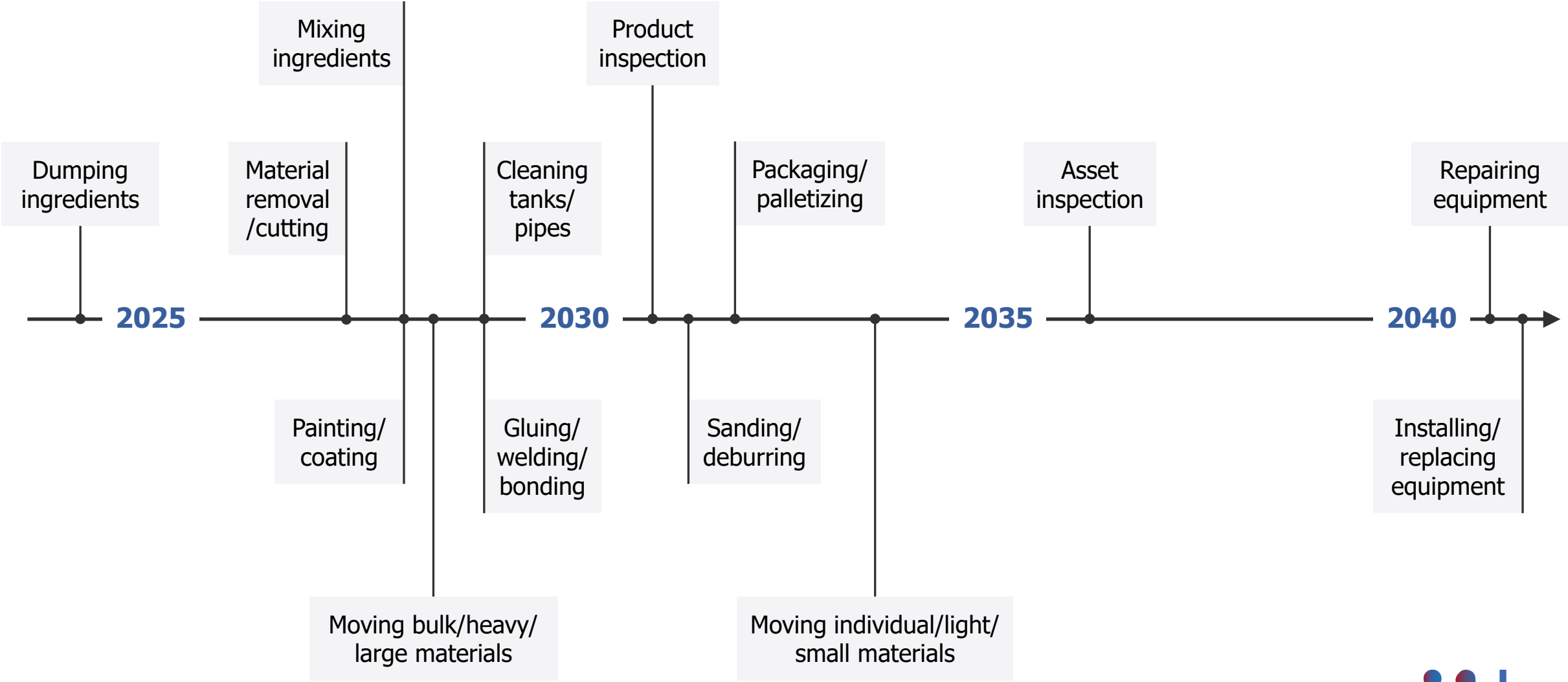
We have used the framework described earlier to visualize the significance of drivers and barriers for several manufacturing tasks in this scatter diagram.

As can be seen from the diagram, common manufacturing tasks fall all over the framework, with significantly different drivers and barriers to automation.

We will elaborate on each quadrant and task in more detail on the following slides.



Lights-out manufacturing for most manufacturing tasks will be feasible between the late 2020s and early 2030s



Recommendations

1

Analyze the drivers and barriers of automation

Perform comprehensive analysis of the drivers and barriers of automation, which are specific to your industry, organization, and tasks, before investing in any automation technology.

2

Use the scatter plot diagram to identify automation opportunities

For a quick start, use our scatter plot diagram to identify types of manufacturing tasks that are worth investing in. In addition, use the timeline of automation in this report to build short-term and long-term projects.

3

Customize the framework to visualize the timeline of lights-out manufacturing

In this report, we have presented a generic framework that can be used across all industry verticals to visualize the timeline of lights-out manufacturing. It is a plug-and-play framework that allows adding new tasks for automation along with personalized factors and different robotic systems. Reach out if you need to build an automation timeline for your factory.



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