

Industry Survey, Market Study, Recommendations for Action

Automation on Two Legs? Humanoid Robots in Logistics

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Preface

Logistics is reaching a turning point. Global supply chains, demographic change, geopolitical uncertainties, and a persistent shortage of skilled workers are increasing the pressure on companies to make their processes more efficient, resilient, and flexible. As a result, automation is becoming a strategic necessity more than ever.

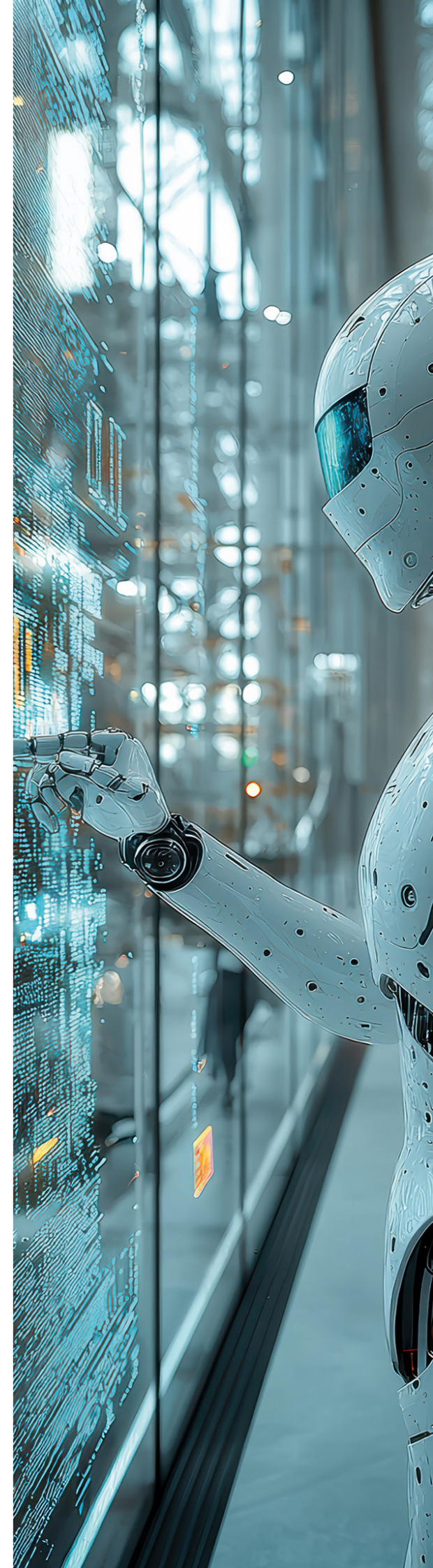
With rapid advances in robotics and artificial intelligence, the focus is shifting to a technology with the potential to push the boundaries of automation: humanoid robots. These promise to be used where traditional automation reaches its structural, economic, or technical limits – in existing work environments designed for humans.

This study by Fraunhofer IML aims to classify the current state of humanoid robotics for logistics applications from an industry perspective. It combines technological analysis with a systematic survey of the logistics industry and derives concrete recommendations for action for industry, research, and politics.

Humanoid robotics is not a short-term trend, but a long-term field of transformation. This study aims to provide guidance, ground expectations, and, at the same time, open perspectives – for logistics that sensibly combines technological innovation and human labor.

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Management Summary

In a nutshell: How humanoid robots can truly transform logistics

Objective of the study

The goal of this study is to systematically evaluate the potential of humanoid robots for logistics. It focuses on the questions of whether and under what conditions humanoid robotics offers added value over existing automation solutions, what requirements the logistics industry places on such systems, and how far the market and the state of the art have actually progressed today. These findings lead to recommendations for action in politics, research, and industry.

Key questions

- How does the logistics industry assess the potential and risks of humanoid robotics?
- What is the state of the art and market readiness of humanoid robots?
- Is a human-like form factor functionally useful for logistics applications?
- What technical, economic, and regulatory hurdles exist?
- What steps are necessary for successful implementation in practice?

Approach

This study is based on three methodological components:

1. Qualitative and quantitative industry survey,
2. Structured market study on currently available humanoid robot systems,
3. Techno-economic classification with recommendations for action derived from this.

Key results

- The logistics industry is showing a high level of interest in humanoid robotics, particularly for automating tasks that have been difficult to automate until now.
- Humanoid robots are seen less as human-like “jack-of-all-trades” and more as flexible, multi-purpose robots for existing work environments.
- The level of technological maturity is not yet sufficient for widespread productive use, with pilot projects dominating.
- The biggest gap between ambitious expectations of industrial maturity lies in handling capabilities, robustness, safety, and integration into existing processes.
- The market is highly fragmented and is currently dominated by non-European suppliers.

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Introduction and Motivation

Image: Golden Boy - stock.adobe.com

Introduction and Motivation

Rethinking automation: Between skills shortages, pressure for efficiency, and the need for innovation

»Humanoid robots embody the ideal of logistical automation.«

Logistics forms the backbone of industry, trade, and society. The performance of logistics systems shapes competitiveness, security of supply, and economic resilience. At the same time, the industry is under unprecedented pressure to change. Global supply chains have become more volatile, customers expect shorter delivery times and greater transparency, while geopolitical crises, economic uncertainties, and regulatory requirements are increasingly limiting predictability. At the same time, demographic change is reducing the availability of manual labor, especially in operational, physically demanding jobs.

In this context, automation is a strategic issue for the future, as well as an operational necessity. For decades, the logistics industry has been investing in technical solutions to increase efficiency, quality, and throughput. Nevertheless, it is becoming apparent that established automation concepts cannot meet all the requirements of modern logistics systems. Many tasks and processes are varied, spatially distributed, and strongly influenced by existing infrastructures. It is precisely in these areas that humans remain the central service providers to this day.

Given this tension, humanoid robotics is gaining attention as a new class of automation technology. It represents the vision of flexible, multipurpose robotics that can operate in existing work environments

designed for humans. At the same time, the topic is heavily influenced by media hype and sometimes exaggerated expectations. There is still a considerable gap between visionary representations and industrial reality.

Multiple studies have already addressed humanoid robotics, especially in the production environment. Particularly noteworthy is the study by Fraunhofer IPA¹⁾, which systematically analyzes the industry's expectations and challenges. Our study focuses on the logistics sector for the first time and combines an industry survey, market study, and recommendations for action to assess the current state of development, specific requirements, and logistical application potential for humanoid robotics.

The goal of this study is therefore to classify humanoid robotics for logistics in a fact-based and practical manner. The focus is on the added functional value of this new technology: What role can humanoid or humanoid-inspired robots play in logistics in the future? What are the requirements of the industry, and to what extent do technology and the market meet them?



Automation as Imperative for Logistical Progress?

»Automation has become an essential factor for competitiveness and scalability.«

Logistics connects markets, industries, and societies. It has been and continues to be a key driver of technological progress – from mechanization and mass production to highly automated cyber-physical systems. Automation has significantly increased the productivity of logistics systems and is a key factor in competitiveness and scalability.

In the logistics industry seemingly contradictory developments can be observed: despite steadily increasing automation, employment figures continue to rise^{2,3}. This illustrates that the increasing performance requirements have not yet been fully compensated for by technological solutions. A key reason for this is that many logistics activities – especially those with high variance, unstructured environments, and complex handling – cannot yet be satisfactorily automated.

Today's modern logistics centers are characterized by specialized automation solutions: conveyor technology, high-bay warehouses, packaging machines, and stationary industrial robots. These systems are designed for maximum efficiency in clearly defined tasks. Their strengths lie in high throughput, stable process conditions, and reproducible quality. At the same time, they involve high planning, integration, and investment costs and offer only limited flexibility in response to changing requirements.

Figure 1 illustrates this trade-off by comparing humans and machines as providers of logistics services. While humans impress with their high flexibility, adaptability, and learning ability, classic automation solutions are severely limited in these dimensions but are highly efficient in standardized processes. Mobile transport robots represent an important intermediate step, as they increase flexibility and location independence, but they have not yet achieved the situational adaptability of humans.

In existing facilities in particular – so-called brownfield environments – traditional automation concepts reach their structural limits. Conversions are costly, scalability is limited, and adaptations to new products or processes often require significant changes to the infrastructure. Against the backdrop of demographic developments and the ongoing shortage of skilled workers, a return to humans as the sole service providers is not a realistic option. Automation, therefore, remains the imperative of logistics development – but it needs to be rethought.

The demand for flexible and resilient automation solutions is reflected in the logistics industry's keen interest in robots. According to the International Federation of Robotics (IFR), the total number of industrial robots worldwide reached over 4.6 million units by the end of 2024, following a doubling of installations in a decade^{4,5}.

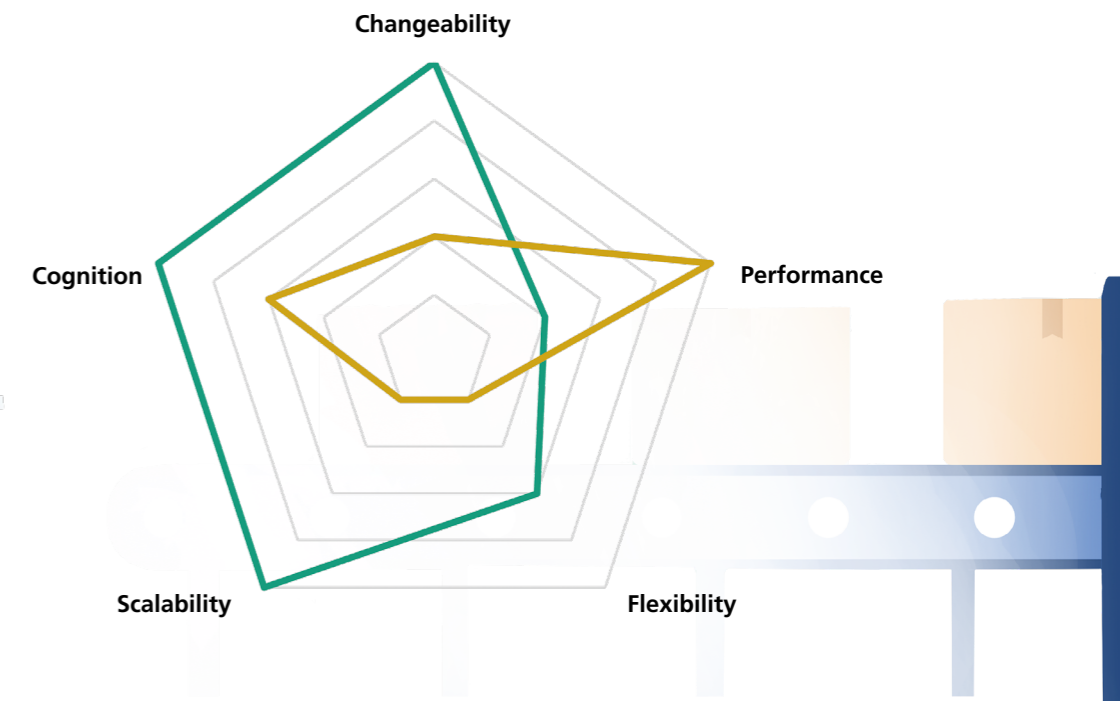


Figure 1: Humans (green) and machines (orange) as providers of logistics services

The use of transport robots alone is growing at double-digit annual rates. Most forecasts agree that this trend will continue for the foreseeable future and that the global robotics market will reach new record levels of over € 200 billion by 2030.

The logistics industry requires a form of automation that combines the advantages of humans and machines, i.e., high performance even in tasks that require flexibility, intuition, and learning ability. This line of thinking leads to so-called multi-purpose robotics, a new generation of robots that can be used for all relevant tasks. They would meet all the criteria in Figure 1 equally.

Humanoid robots particularly embody the ideal of logistical automation. A robot that can be used in the same environments and perform the same manual tasks as a human solves the dilemma between maximizing performance on the one hand and flexibility on the other. Such robots can be deployed as needed where their performance is currently required, reducing the need for investment

in the robots themselves and, in particular, in adapting the working environments. Modern artificial intelligence enables robots to learn and adapt to their environment. The result is a logistics system that is both powerful and resilient.

² Logistikweise / Fraunhofer SCS - Top 100 in Logistik & SCM (2024)

³ Fachkräftesicherung, Kompetenzzentrum (2024). Fahrer:innen gesucht – Die Fachkräftesituation in Verkehrs- und Logistikberufen.

⁴ <https://ifr.org/worldrobotics/>, accessed on March 9, 2026.

⁵ <https://robotikverband.de/world-robotics-report-2025/>, accessed on March 9, 2026.

Target Vision for Humanoid Robotics in Logistics

This trade-off between flexibility and performance has given rise to the vision of a new generation of robotics: the demand is no longer for purely specialized machines, but rather for generalist, adaptable systems that can adjust to logistical realities – especially in areas where human labor has been indispensable up to now. Humanoid robotics especially embodies this vision.

The focus here is less on creating the most perfect replica of the human body and more on the functional ability to perform logistical tasks in existing working environments. Logistics is characterized by a multitude of manual activities that are characterized by high process variance, different objects, and changing requirements. Activities such as picking, packing, sorting, or transporting require a combination of mobility, sensory perception, manipulative dexterity, and digital integration. Classic automation can often only partially meet these requirements, as it relies on stable and standardized process conditions.

The target vision for humanoid robotics in logistics is therefore shaped by a functional perspective: a humanoid robot should be able to orient itself in complex, changing environments and perform tasks with a flexibility comparable to that of humans. The sequence of typical logistics-related activities – such as detecting objects, grasping and placing different items, navigating through busy spaces, and seamless human-machine interaction – makes it clear that a robot needs a broad and integrated range of capabilities to do this.

Figure 2 shows an example of the steps involved in a manual picking process. This illustrates why logistics activities are particularly difficult to automate: the sequence of moving, grabbing, placing, opening, packing, and confirming is highly variable, context-dependent, and requires constant adaptation to changing objects, locations, and process states in a dynamic environment. Traditional automation solutions often reach their limits here, as they either only cover individual sub-steps or place high demands on standardization. The



Figure 2: Exemplary work steps of a manual picking process

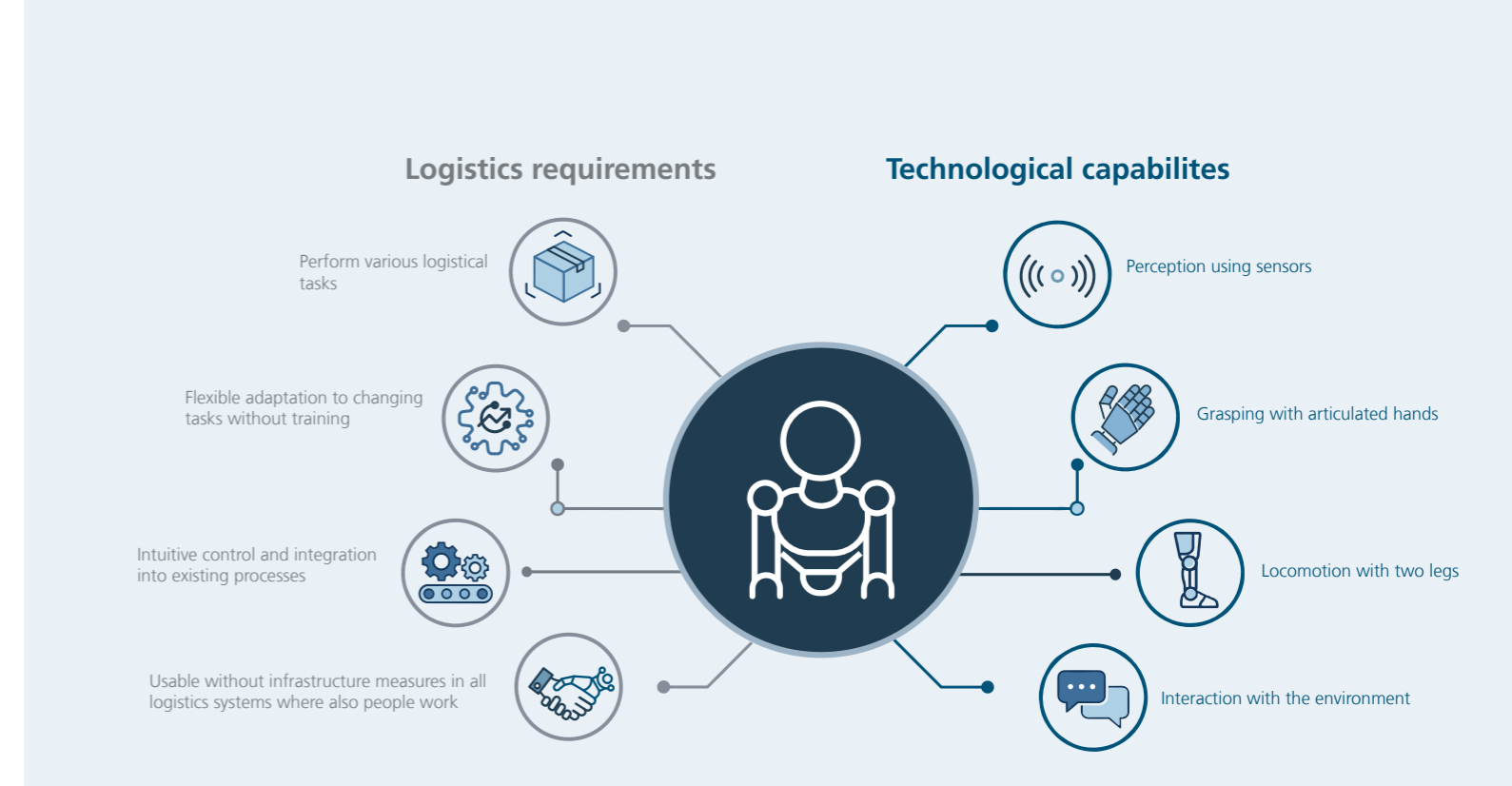


Figure 3: Target vision for humanoid robotics from an industry and technological perspective

example is representative of a multitude of conceivable types of picking systems⁶, which in turn only represent a part of logistics.

A robot designed to holistically support or take over such processes, therefore, requires a broad and integrated range of capabilities. Key technological capabilities include:

- **Perception using sensors** to detect the environment, relevant objects, and people
- **Grasping with articulated hands** for versatile handling of heterogeneous objects
- **Locomotion with two legs** for mobility in human-centered work environments
- **Interaction with the environment** for adaptable collaboration with humans

Figure 3 systematically summarizes the target vision for humanoid robotics in logistics. It links key logistics activities with the respective required skills and possible technical characteristics. The illustration highlights that the spectrum of humanoid robotics extends far beyond the image of a human-like robot. Depending on the application, alternative technical concepts – such as mobile platforms instead of bipedal locomotion or specialized grippers instead of complex hands – can offer greater practicality and cost-effectiveness.

The technical implementation of humanoid robotics in logistics should therefore be understood as a continuum: on the

one hand, there are systems with human-like anatomy that enable maximum flexibility and versatility. On the other hand, modular robots that are specifically optimized for certain logistics tasks can offer just as much added value. The choice of technical design depends largely on the requirements of the respective application, the operational conditions, and the economic objectives.

The target vision for humanoid robotics is therefore not a rigid product promise, but rather a functional guideline for the further development and integration of flexible automation solutions in logistics. It provides orientation for research, industry, and users by describing the essential capabilities that logistics robot systems will need to master in the future. At the same time, it remains open to different technical implementations, each specifically tailored to the requirements and challenges of logistics practice.

Finally, this target vision forms the basis for the subsequent chapters of this study. It structures the analysis of requirements from the industry's perspective, the comparison of current market offerings, and the derivation of practical recommendations for action. Humanoid robotics thus exemplifies the transition from specialized machines to a new generation of generalist, adaptive, and integrative automation in logistics⁷.

6 Schlögl, D., & Zsifkovits, H. (2016). Manuelle Kommissioniersysteme und die Rolle des Menschen; in Berg Huettenmaenn Monatshefte (Springer).

7 ten Hompel, M., Kirchheim, A., Roidl, M. (2026). Wenn KI die Lieferketten führt: Logistik im posthumanen Zeitalter; in VDI-Z 3|2026



Industry Survey



Image: sebra- stock.adobe.com

Industry Survey

Between hype and reality: What the logistics industry truly expects of humanoid robotics

»A humanoid robot resembles humans in its abilities or even its appearance.«

The first publicly visible prototypes of humanoid robots have raised far-reaching expectations. While media presentations often focus on technical innovations, the crucial question remains to what extent they can meet logistical requirements. To systematically capture this perspective, Fraunhofer IML conducted a comprehensive industry survey. This survey aims to obtain a reliable picture of the current mood, degree of maturity, and state of development from the perspective of logistics practitioners.

The study is based on two methodological pillars: On the one hand, qualitative expert interviews were conducted with leading representatives from industry and system providers; on the other hand, a broad-based quantitative survey was conducted among specialists and managers in the logistics industry. This combination allows individual assessments to be deepened while at the same time obtaining a statistically reliable evaluation across company and role boundaries.

A total of eleven expert interviews were conducted, including six representatives from intralogistics system providers and five potential operators of humanoid robotics. Four of the providers already have autonomous mobile robots in their portfolios, but not yet humanoid robots. On the operator side, autonomous mobile robots are in productive use in three companies, while humanoid robots are currently only being evaluated in isolated early tests.

The quantitative survey yielded almost 100 complete responses, predominantly from employees of large companies with various roles – from operational staff to management. Around two-thirds already use robotics productively, with stationary industrial robots and automated guided vehicles dominating. Among the respondents, humanoid robots are exclusively used in pilot projects.

The interviews show that humanoid robotics is currently mainly being observed in the innovation and strategy departments of companies. Operational use, if any, is only taking place within the framework of pilot projects. Current market penetration is correspondingly low: 65 % of the companies surveyed already rely on robot solutions today, but none of the respondents are fully utilizing humanoid robots in production.

Opportunities and Risks as Seen by Companies

Across all participants, the humanoid robot is understood as a system that is modeled on humans in terms of its capabilities and flexibility and can be seamlessly integrated into existing working environments. Aspects such as facial expressions or social interaction play a subordinate role in an industrial context. The decisive factor is its functional suitability for performing manual tasks. Mobility is seen as a key feature, although bipedal locomotion is not considered a prerequisite. Alternative concepts with mobile platforms and manipulative capabilities are considered useful and practical.

»Great potential wherever we reach the limits of conventional automation solutions.«

Three aspects stand out among the opportunities identified (see Figure 4): the automation of previously manual process steps, efficiency gains along existing processes, and the mitigation of the shortage of skilled workers.

Emphasis is placed on the potential in environments that are designed for humans or that exhibit a high degree of variance. One interviewee sums it up succinctly: "Humanoid robotics has great potential wherever we reach the limits of

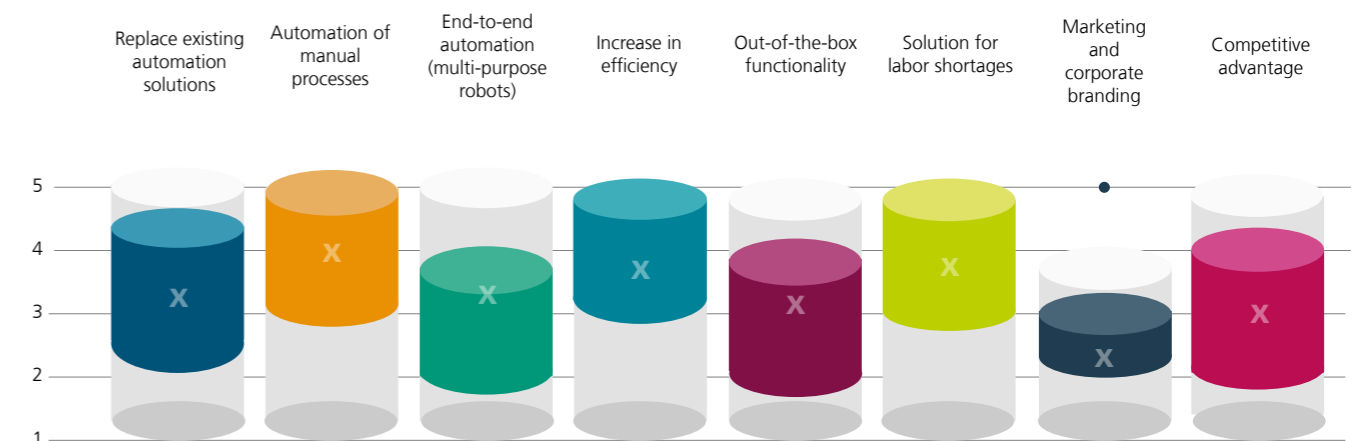


Figure 4: Opportunities for humanoid robotics as seen by respondents



Identified Use Cases and Requirements

Many companies are currently evaluating suitable applications for humanoid robotics. A total of 18 potential application scenarios were identified in the interviews. Figure 6 shows the most relevant applications, weighted according to their priority over time.

Order picking is cited as the most important use case, as it accounts for a significant proportion of operational working hours in logistics. Loading and sorting activities are also given high priority. These activities have in common that they require flexible handling of heterogeneous items and a high degree of adaptability – areas in which today’s automation solutions often reach their limits.

Lower-priority use cases are described by respondents as part of a long-term vision or as a final stage of development to be achieved through several intermediate technological steps. Prioritization thus reflects less fundamental rejection and more an assessment of technological development paths.

Multi-purpose use appears to be particularly relevant: the focus is not on solving a single, complex task, but on the ability to flexibly perform different activities.

One interviewee sums up this expectation: “It’s not about automating one particularly difficult task, but about having a

robot that can flexibly perform various activities – especially in times of staff shortages or seasonal peaks.”

For widespread use in logistics, humanoid robots must meet a variety of requirements. Due to their wide range of content, they are classified into three categories: capabilities, technical characteristics, and framework conditions.

When it comes to capabilities (see Figure 7), handling is of central importance. Logistics is characterized by a broad and heterogeneous range of items. A robot must be able to safely grasp and move both delicate and heavy objects. The experts surveyed estimate the required load capacity to be at least 5 kg (32 %) or 20 kg (36 %). The long-term goal is to achieve a level of flexibility comparable to that of humans. At the same time, there is agreement that this goal is still well beyond the current technological capabilities.

In terms of technical characteristics (see Figure 8), robustness and integrability are cited as prerequisites. Logistical facilities are often regarded as critical infrastructure, where any failures have an immediate impact on operations. In addition, humanoid robots will predominantly be used in existing facilities, making smooth integration into existing IT and processing landscapes essential.

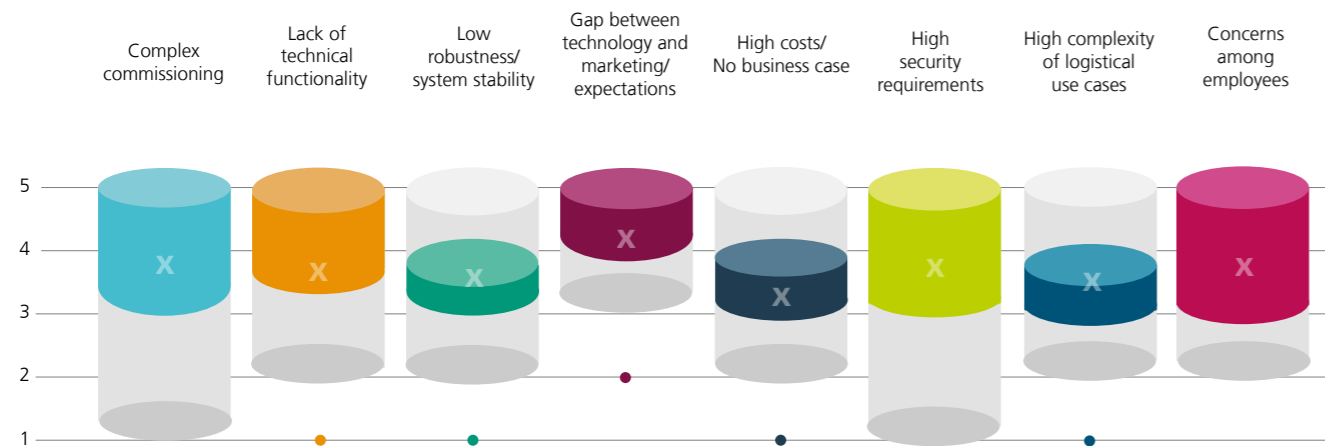


Figure 5: Potential risks associated with humanoid robotics as seen by respondents

conventional automation solutions, because the conditions on site are designed for humans.”

The discrepancy between technological maturity and public perception is seen as a key risk (see Figure 5). Several experts point out the difference between marketing promises and actual performance in everyday business operations. In this context, reference is made to the “valley of tears” in Fenn’s hype cycle (1995)⁸, which threatens to emerge when expectations and reality diverge. One participant puts it this way: “There is a great danger that we will overestimate the

technology and later be disappointed because the systems do not yet deliver what is promised in advertising videos in everyday use.”

8 Fenn, J. (1995). When to leap on the hype cycle. Gartner Group.

Image: Fraunhofer IML/Vinzenz Neugebauer

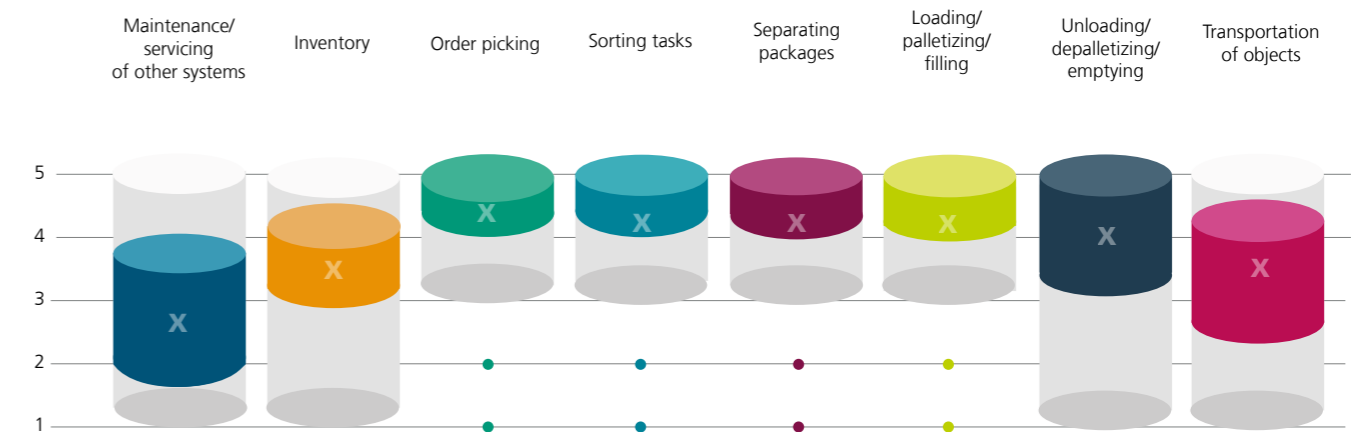


Figure 6: Relevant use cases for humanoid robots in logistics as seen by respondents

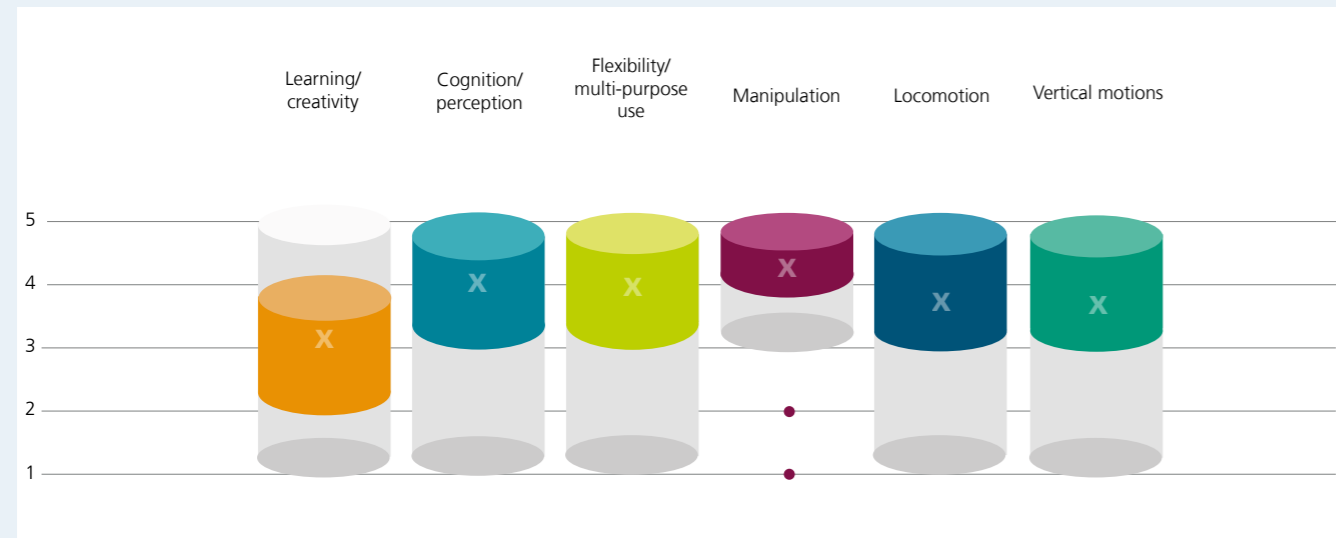


Figure 7: Required skills of humanoid robots as seen by respondents

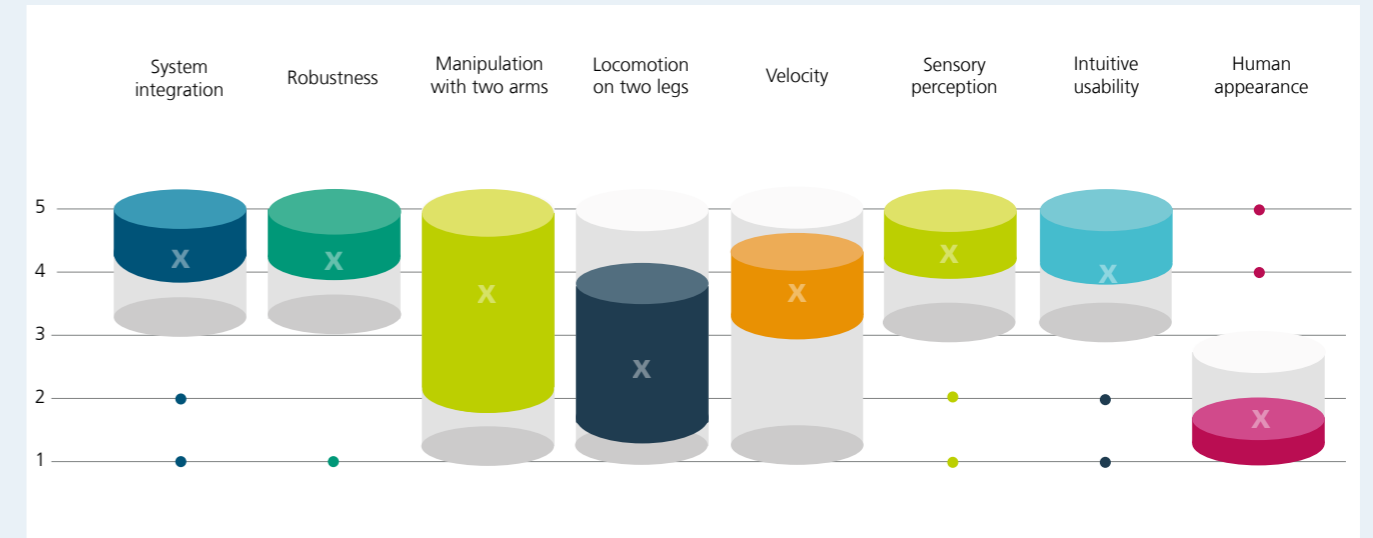


Figure 8: Necessary technical characteristics of humanoid robots as seen by respondents

»For 90 to 95 % of the use cases we want to implement in logistics, we don't need legs.«

The human appearance, on the other hand, is rated as secondary or even critical by the respondents. In industrial applications, there is concern that a highly human-like design could be perceived as threatening. Accordingly, alternative concepts such as "mobile cognitive robotics" or "advanced robotics" are also considered potentially suitable solutions. Bipedal locomotion is also given low priority; one interview participant sums this up succinctly: "The issue of walking and legs is overrated."

In terms of the framework conditions (see Figure 9), safety is considered to be of paramount importance. Safety is regarded as a basic prerequisite for the use of humanoid robotics, especially in the European context. Since humanoid robots are expected to work directly with humans without physical protective measures such as fences, appropriate safety concepts must be considered from the outset.

Industrial readiness is considered a key area of action (see Figure 10). It forms the basis for productive use and is directly related to the gap between technological progress and expectations described above. Companies see a particular need for development in terms of handling capabilities. One interviewee sums up the challenge: "What is missing today is sensitivity and dexterity – the systems are not yet capable of handling different objects in a truly flexible manner."

Despite these challenges, the overall mood is open but cautious. Over 80 % of companies expect humanoid robotics to be used productively within the next ten years, and around 40 % even expect this to happen within the next four years. At the same time, 43 % say they currently have no concrete plans for implementation. Many companies are observing developments or conducting initial tests. A sober and objective assessment is considered crucial to realistically gauge the impact of the hype.

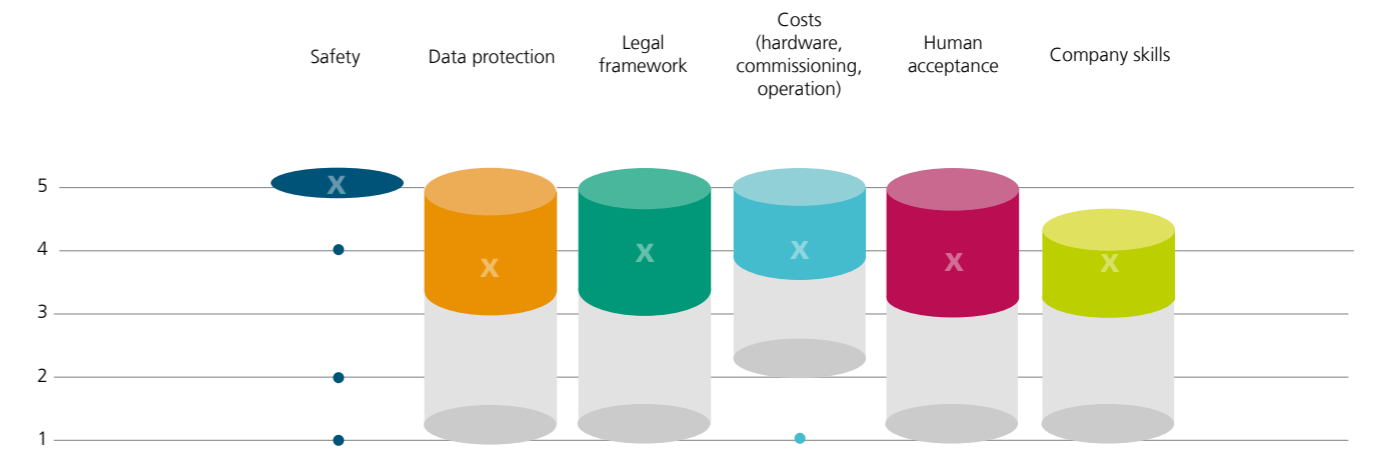


Figure 9: Relevant framework conditions for the use of humanoid robotics as seen by respondents

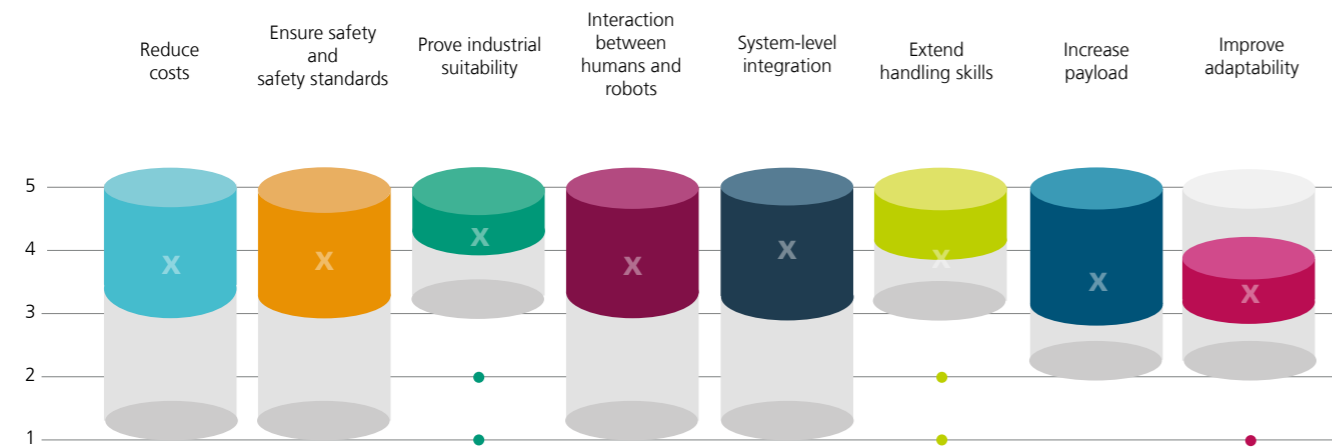


Figure 10: Open fields of action for the use of humanoid robots as seen by respondents

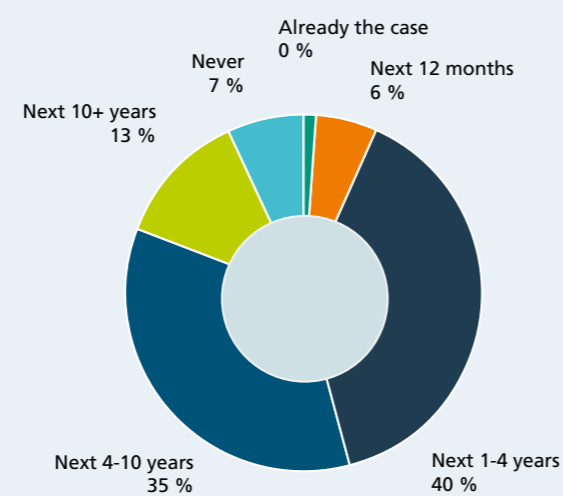
Conclusion of the Industry Survey

The use of humanoid robots in logistics is still at an early stage, but it is already attracting a great deal of interest and openness. Companies see particular potential in the automation of previously non-automatable process steps, in alleviating the shortage of skilled workers, and in increasing the efficiency of existing processes.

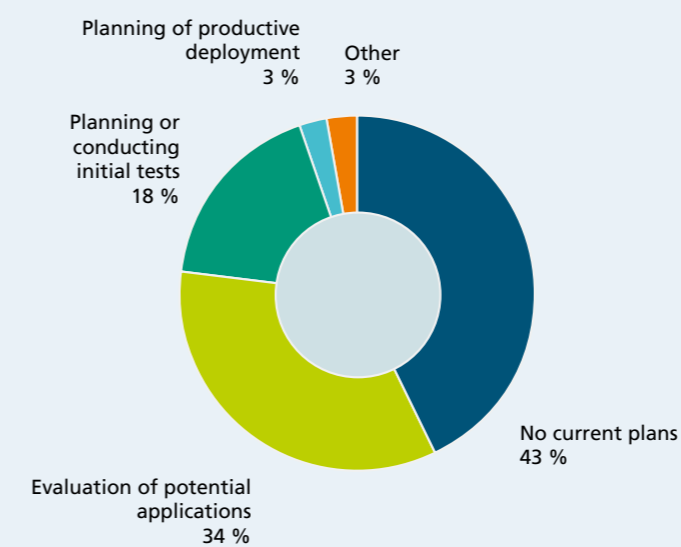
At the same time, clear challenges remain. The gap between technological maturity and public expectations is particularly evident. Key requirements for handling, flexibility, robustness, and integration have also not yet been met. However, the prioritized use cases – above all, order picking – emphasize that humanoid robotics has the potential to become relevant where classic automation solutions reach their limits. It will be crucial to systematically address the identified areas of action and to shape the transition from pilot projects to resilient, productive applications.

Expected productive use, deployment plans, and company opinions

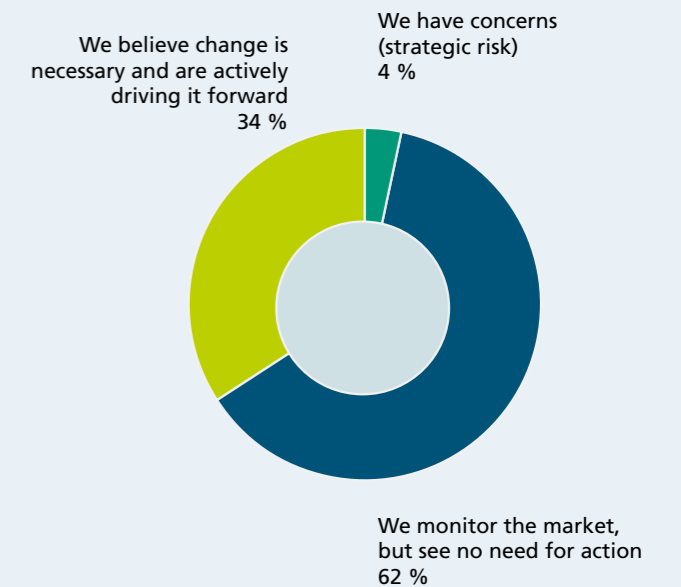
»80% of companies anticipate productive use within the next 10 years, and over 40 % within the next 4 years.«



Expected productive use



Deployment plans



Company opinions



Market Study

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Image: Debi Kurma Putra – stock.adobe.com



Overall, this is a strategic topic that needs to be addressed – and that is what we are doing .«



Market Study

Multiplicity instead of a one-size-fits-all solution: How far the market for humanoid robots has really come

The logistics industry is following the technological development of humanoid robotics with great interest – and growing expectations. Hopes are to tap into automation potential that has not yet been achieved with traditional technologies. At the same time, there is uncertainty about how far the systems available on the market have actually progressed and whether the target vision of humanoid robotics can already be achieved today. This market study now offers a systematic overview of the current state of humanoid robotics for logistics applications.

Search Mode

The market for humanoid robotics is fragmented worldwide, and not all suppliers are already strongly marketing their products. Companies are finding it increasingly difficult to keep track of the multitude of terms, technical features, and application scenarios and to evaluate them for their own logistics. Against this background, Fraunhofer IML has compiled a comprehensive market overview based on the criteria for humanoid robotics defined at the outset.

As part of the systematic market research, all robots that are publicly announced or marketed as “humanoid” or human-like systems for (production) logistics applications were first identified. The research material included trade journals, publications, search engines, trade fair portals, and expert interviews. Of all the robots found, 80 systems met the following criteria, which are necessary for possible use in logistics systems:

- **Workspace:** comparable to the range of human movement
- **Perception and agility:** the ability to understand the environment and act flexibly
- **Lifting and carrying capacity:** minimum comparable to human requirements
- **Availability:** shortly before market launch or already available

Evaluation and System Overview

»The market shows a remarkable range of technical concepts and designs.«

The analysis of the 80 identified humanoid robot systems reveals a remarkable range of technical concepts and designs. These range from mobile platforms with one or two arms to robots with human-like anatomy to systems with legs, arms, hands, and head-like sensors. The systems differ not only in their external appearance, but above all in their fundamental technical characteristics, which are decisive for logistical use (see Figure 11).

Locomotion:

The mobility concept significantly determines the potential applications of a robot. Moving on two legs offers maximum flexibility for overcoming stairs, level differences, and obstacles, for example – an advantage in existing facilities or less standardized work environments. However, these systems are technically complex, resulting in higher costs, maintenance requirements, and slower process speeds. In structured logistics environments, mobile platforms with wheels or tracks are often sufficient and score points with higher stability, speed, and lower total costs.

Manipulation:

Manipulation capabilities are crucial to the logistical added value of humanoid robots. Systems with two arms and human-like proportions enable complex handling tasks to be performed in confined spaces. The design of the end effectors is crucial here: Human-like hands offer maximum versatility, but are technically complex and potentially prone to failure. Specialized grippers increase process reliability and speed, but reduce universal applicability. Systems with modular, interchangeable grippers offer a pragmatic compromise here – however, the optimal solution is always application-specific.

Sensors:

A comprehensive sensor package, usually arranged in a head-like configuration, is essential for navigation, object recognition, and safe interaction. 3D cameras, LiDAR, and other sensors enable human-like perception geometry. Especially in mixed operation – i.e., working in parallel with humans – these systems are an indispensable component for meeting safety requirements.

Power supply:

The vast majority of systems operate with powerful battery packs that allow for several hours of operation. Fast charging or replacement mechanisms are often implemented to minimize downtime. Optimizing energy efficiency and charging infrastructure remains a key area of development for reliable shift operation.

Software/AI:

In addition to hardware, the performance of the software is a key factor in determining the practical usefulness of humanoid robots. Modern systems rely on AI-based environment analysis, planning algorithms, and autonomous decision-making. While some providers rely on end-to-end architectures that closely integrate perception, planning, and control, others pursue modular approaches that facilitate adaptation to specific logistics processes and IT landscapes. Particularly relevant is the ability to learn from experience (“learning by demonstration”), adapt to new tasks independently, and interact with digital process control systems. The degree of autonomy and adaptability varies significantly between systems and is a key selection criterion for the industry.

Modularity:

The ability to flexibly exchange manipulators and end effectors is a core element of multi-purpose robotics. Highly modular systems can be adapted to changing tasks, thereby

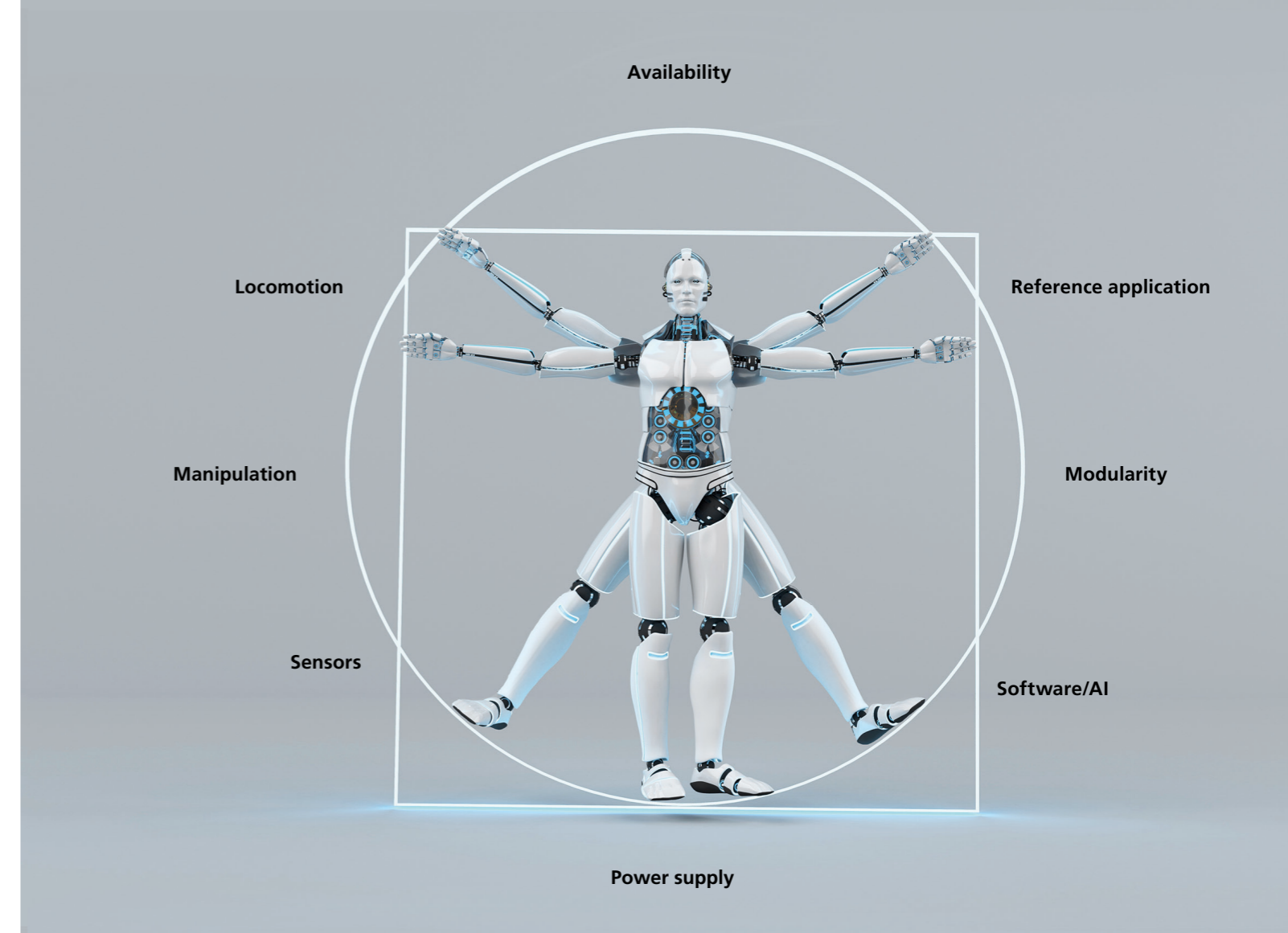


Figure 11: Categories for the analysis of humanoid robots

increasing cost-effectiveness and practicality. Solutions that enable the easy integration of new gripper or tool technologies are particularly in demand, as they allow different logistics processes to be covered with the same robot.

Reference application:

The transferability and practical testing of the systems is a decisive criterion for market evaluation. Many humanoid robots were originally developed for industrial applications such as assembly or production and are currently being further developed for logistics tasks. Reference applications in logistics have so far been limited mostly to pilot projects or initial tests. Systems that are already being used in real logistics environments provide valuable insights into process integration, reliability, and scalability.

Availability:

The majority of humanoid robots are still in development, in the pilot stage, or part of early access programs. None of the providers can currently point to established, productive applications in logistics. Market dynamics are high, and it remains to be seen which systems will eventually be able to advance from piloting to industrial use and the breadth of the industry.

Overall, the evaluation shows that the optimal characteristics of humanoid robots for logistics applications are highly application-specific. Mobility and manipulation concepts must be tailored to the spatial, procedural, and operational requirements of the respective use case. The overview on the following pages compares selected systems according to the categories of mobility, manipulation, sensor technology, energy supply, software concept, modularity, reference application, market availability, and market presence. It illustrates the diversity of solutions and underscores the need to always evaluate humanoid robotics in the context of logistical challenges.

Evaluation and System Overview



Boston Dynamics, Atlas

Supplier	Model	Country	Year	Link	Locomotion	Manipulation	Power supply	Software/AI	Sensors	Modularity	Reference application
Agility Robotics	Digit	USA	2019	agilityrobotics.com/solution	Modified legs (up to 5.4 km/h)	Gripper (handling up to 15.88 kg)	Replaceable battery (up to 4 hours of runtime)	AI-based Control/ Agility Arc Cloud Platform	Camera and sensorarrays, LiDAR-system	Hands	Container handling
Appttronik	Apollo	USA	2023	appttronik.com/apollo	Human-like legs (up to 3.4 km/h)	Articulated hands (handling up to 24.95 kg)	Replaceable battery (up to 4 hours of runtime)	Apollo's Software Suite for Control	Multiple cameras (head and body)	Chassis	Warehouse environments
Boston Dynamics	Atlas	USA	2013	bostondynamics.com/atlas	Modified legs (maximum velocity unknown)	Gripper (handling up to 30 kg)	Replaceable battery (up to 4 hours of runtime)	AI-based Control/ Orbit Enterprise Platform	360° camera and tactile sensors	Hands	Handling task
Figure	Figure 03	USA	2023	figure.ai	Human-like legs (up to 4.3 km/h)	Articulated hands (handling up to 20 kg)	Battery (up to 5 hours of runtime)	Helix AI System	Multiple cameras and tactile sensors	Hands	Handling task
Hexagon AB (Publ)	AEON	Sweden	2025	robotics.hexagon.com/product	Chassis with rollers (up to 8.6 km/h)	Articulated hands (handling up to 15 kg)	Replaceable battery	AI-based Control	Multimodal sensors	Hands	Logistics sector
Humanoid	HMND 01	UK	2025	thehumanoid.ai	Human-like legs (up to 5.4 km/h)	Articulated hands (handling up to 15 kg)	Battery (up to 4 hours of runtime)	KinetIQ System	(Depth-) cameras, tactile sensors	Chassis	Industrial/ logistics application

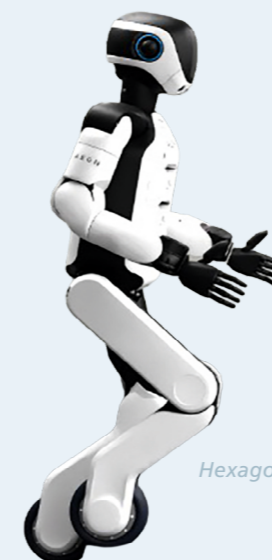
List of selected humanoid robots for use in logistics and production



Appttronik, Apollo



Agility Robotics, Digit



Hexagon AB, AEON



Humanoid, HMNE 01

Figure, Figure 03



Evaluation and System Overview

Sanctuary AI, Phoenix



Xpeng, Iron



Neura Robotics, 4NE1



Supplier	Model	Country	Year	Link	Locomotion	Manipulation	Power supply	Software/AI	Sensors	Modularity	Reference application
Neura Robotics	4NE1	Germany	2022	neura-robotics.com/products/4ne1	Human-like legs (up to 5 km/h)	Articulated hands (payload 10-100 kg)	Battery (up to 4 hours of runtime)	Multimodal AI/ Neuraverse Platform	NEURA OmniSensor/ SenseKit	Replaceable forearms and chassis	Manufacturing
Sanctuary AI	Phoenix	Canada	2023	sanctuary.ai/technology	Human-like legs (up to 5 km/h)	Articulated hands (handling up to 25 kg)	Battery (no runtime known)	Carbon AI System	Multimodal sensors	Hands	Industrial application
Tesla	Optimus Gen 2	USA	2021	tesla.com/en_eu/AI	Human-like legs (up to 2 km/h)	Articulated hands (handling up to 20 kg)	Battery (no runtime known)	No further information	Multimodal sensors	Hands	Manufacturing
UB TECH	Walker S2	China	2018	ubtrobot.com/en	Human-like legs (up to 7.2 km/h)	Articulated hands (handling up to 15 kg)	Automatic battery replacement	UBTECH Co-Agent	Stereo cameras, tactile sensors	Hands and chassis	Handling of cardboard boxes
Unitree	H1	China	2025	unitree.com/h1	Human-like legs (up to 11.4 km/h)	Articulated hands (handling up to 7 kg)	Replaceable battery (up to 2 hours of runtime)	No further information	360° depth-camera, 3D-LiDAR	Hands	Industrial application
Xpeng	Iron	China	2024	xpeng.com/news	Human-like legs (up to 7 km/h)	Articulated hands (handling up to 20 kg)	Battery (up to 4 hours of runtime)	Tianji AIOS System	720° AI vision system	Hands	Manufacturing and warehousing

List of selected humanoid robots for use in logistics and production

UB Tech, Walker S2



Tesla, Optimus Gen 2



»The practical usefulness is determined primarily by the performance of the software.«

Unitree, H1



Conclusion of the Market Study

The market environment for humanoid robots is highly dynamic and constantly evolving

The optimal design of a humanoid robot depends on the specific application: In structured industrial environments, mobile platforms with one or two powerful arms and modular grippers are often sufficient. In constantly changing environments, a human-like design with legs and head-mounted sensors can offer additional advantages, but requires higher investments to ensure complexity, control, and robustness.

Analysis of the current market landscape leads to several overarching conclusions:

- Firstly, there is a wide variety of competing robot designs and concepts. It remains to be seen which technical features will prevail in the long term for the requirements of the logistics industry. Different approaches – from specialized platforms to humanoid systems – will probably coexist and offer specific advantages depending on the application.
- Secondly, the market is currently dominated by non-European suppliers, particularly from China and the US. Technological leadership currently lies outside Europe – a circumstance that, from the perspective of German technology providers, creates pressure to act. It is important to strengthen our own technological developments, promote industrial applications in a targeted manner, and help shape regulation and standardization to secure long-term technological sovereignty and value creation.
- Thirdly, there are substantial technological and regulatory gaps. Key challenges remain to be overcome, particularly in the areas of safety in mixed operation, robust integration into heterogeneous environments, and scaling pilot projects to industrial series applications. The goal of humanoid robotics thus faces a twofold test: in addition to technological performance, social acceptance, safety, and economic efficiency are also crucial for sustainable market success.
- Fourthly, the integration of humanoid robotics into logistics should be understood as a long-term transformation process. In the short term, specialized and modular systems will primarily be used, while the vision of a universal, human-like robot must be further developed in the medium term. Consequently, companies can benefit from focusing their activities on pilot projects, test fields, and close cooperation with suppliers and research institutions to gain practical experience and develop realistic expectations.

These findings form the basis for the following recommendations for action and underscore that, although humanoid robotics in logistics is still in its infancy, it has the potential to significantly shape logistics as the next stage in the development of automation.



The optimal design of humanoid robots for logistics is highly application specific.«



Image: Curioso Photography – stock.adobe.com

Recommendations for Action

The logistics industry has high expectations for humanoid robots. The market is complex and volatile.

The central question is: what needs to be done? Based on the findings of this study, we derive recommendations for action for system operators and integrators, research and development, and political decision-makers.

What is missing for the application of humanoid robots?

- There is no humanoid robot on the market that fully meets the logistics industry's target specifications.
- Humanoid robots are not yet being used productively in logistics.
- Mixed operation with humans is not yet possible.
- Their multi-purpose capability, i.e., their ability to perform various tasks, cannot be measured or tested
- The logistical performance of humanoid robots as well as business cases have not yet been identified
- Most humanoid robots do not originate from Europe
- There is still no industry consensus on the optimal robot design

Suggestions for system operators and integrators

- Experimentally evaluate robot capabilities and identify corresponding business cases
- Develop industry standards for certifications for safe mixed operation
- Promote strategic vertical partnerships from robot manufacturers to system integrators to operators
- Ensure process digitization and digital infrastructure as a basis for the introduction of robots

Empowerment through research and development

- Publicly promote technology scouting and flagship projects, especially for small and medium-sized enterprises
- Create pragmatic safety regulations
- Provide funding for manufacturer-independent test fields
- Promote Europe-wide networking between companies and research institutes

Regulatory and political framework

- Funding technology scouting and flagship projects publicly, especially for SMEs
- Creating pragmatic safety regulations
- Providing funding for manufacturer-independent test fields
- Promoting Europe-wide networking between companies and research institutes

Appendix – Overview of Relevant Humanoid Robots

Supplier	Country	Model	Link	Supplier	Country	Model	Link
AgiBot	China	AgiBot Raise A2	https://www.agibot.com/products	Borg	USA	Borg 01	https://www.borgrobotic.com
AgiBot	China	AgiBot Raise A1	https://www.agibot.com/products	Boston Dynamics	USA	Atlas	https://bostondynamics.com/atlas/
AgiBot	China	AgiBot Raise A2 ultra	https://www.agibot.com/products	Clone Robotics	USA/ Poland	Clone Alpha	https://clonerobotics.com/android
Agile Robots	Germany	Agile One	https://www.agile-robots.com/de	Cyan Robotics	China	Orca	https://www.teams-design.com/en/work/cyan-robotics-the-future-is-curious?utm_source=copilot.com
Agility Robotics	USA	Digit	https://www.agilityrobotics.com/solution	Dataa Robotics/ Aldebaran Robotics	China (since 2025)	Pepper	https://aldebaran.com/en/pepper
Apptronik	USA	Apollo	https://apptronik.com/apollo	DEEPRobotics	China	DR01	https://www.deeprbotics.cn/en/index/humanoid.html
AstriBot	China	AstriBot S1	https://www.astribot.com/en	DLR	Germany	Toro	https://www.dlr.de/de/rm/forschung/roboter-systeme/humanoide/toro
Beijing Galaxy General Robot Co. Ltd	China	G1	https://www.galbot.com/g1	Dobot Robotics	China	Atom	https://www.dobot-robots.com/insights/case-studies/dobot-atom.html
Beyond Imagination	USA	Beomni	https://www.beomni.ai	EngineAI	China	PM01	https://en.engineai.com.cn/?utm_source=copilot.com
Boardwalk Robotics	USA	Alex	https://boardwalkrobotics.com	Engineered Arts	UK	Ameca	https://engineeredarts.com/robot/ameca

Supplier	Country	Model	Link	Supplier	Country	Model	Link
Figure	USA	Figure 01/02/03	https://www.figure.ai	Kepler Exploration Robot Co.	China	Kepler	https://www.gotokepler.com/apps/mobile/pages/product/index?id=2
Figure	USA	Figure 3	https://www.figure.ai	KIT/Karlsruhe Institute for Technology	Germany	ARMAR-6	https://h2t.iar.kit.edu/397.php
Foundation	USA	Phantom MK1	https://foundation.bot/phantom	LG	Korea	Kapex	https://robohorizon.de/de/news/2025/10/lg-humanoid-roboter-vorstellung/?utm_source=copilot.com (keine Firmenhomepage)
Fourier	China	GR-2	https://www.fftai.com/products-gr2	Leju Robot	China	XTRON KUAVO-MY	https://www.lejurobot.com/en/application/kuavo-my
Hexagon AB (Publ)	Sweden	AEON	https://robotics.hexagon.com/product	Leju Robot	China	KUAVO 3.0	https://www.lejurobot.com/en/application/kuavo-3
Humanoid (SKL Robotics)	UK	HMND 01 Wheeled	https://the-humanoid.ai/product	Limx Dynamics	China	LimX Oli	https://www.limxdynamics.com/en
Humanoid (SKL Robotics)	UK	HMND 01 BIPEDAL	https://the-humanoid.ai/hmnd-01-alpha-bipedal	Macco Robotics	Spain	Kime	https://www.aparobot.com/robots/kime
Igus	Germany	Iggy Rob	https://www.igus.de/automation/news/humanoider-roboter	Magic Atom Technology Co., Ltd.	China	MagicBot	https://www.aparobot.com/robots/magic-bot?utm_source=copilot.com (zu beachten: Webseite keine Firmenwebseite)
Kawada Robotics	Japan	HRP-Serie	https://www.kawadarobot.co.jp/en/products/#product3	Matrix	China	MATRIX-1	https://www.matrixrobotics.ai
Kawasaki	Japan	Kaleido	https://kawasakirobotics.com/asia-oceania/blog/story_22	Mentee	Israel	Menteebot	https://www.menteebot.com/bot

Appendix – Overview of Relevant Humanoid Robots

Supplier	Country	Model	Link	Supplier	Country	Model	Link
NASA/GM	USA	Valkyrie	https://www.nasa.gov/technology/r5/?utm_source=copilot.com	PNDbotics	China	Adam SP	https://pndbotics.com/humanoid
Neura Robotics	Germany	MiPA	https://neura-robotics.com/products/mipa	Poppy project	France	Poppy	https://www.poppy-project.org/en/robots/poppy-humanoid
Neura Robotics	Germany	4NE1	https://neura-robotics.com/products/4ne1	PUDU	China	D7	https://www.pudu-robotics.com/de/news/917
Noetix Robotics	China	N2	https://en.noetix-robotics.com/products-277.html	PUDU	China	Pudu D9	https://www.pudu-robotics.com/de/products/d9
Noetix Robotics	China	Dora	https://en.noetix-robotics.com/products-278.html	PUDU	China	FlashBot Arm	https://www.pudurobotics.com/de/products/flashbot-arm
PAL Robotics	Spain	Kangaroo	https://pal-robotics.com/robot/kangaroo	Reflex Robotics	USA	Reflex Robot	https://www.reflexrobotics.com/#product
PAL Robotics	Spain	ARI	https://pal-robotics.com/robot/ari	RoboterA	China	L7	https://www.roboterA.com/en
PAL Robotics	Spain	TALOS	https://pal-robotics.com/robot/talos	RobRos	Korea	IGRIS-C	https://robros.co.kr/igrisC?scrollTo=image1Section
PAL Robotics	Spain	REEM-C	https://pal-robotics.com/robot/reem-c	Rokae powered by Jaeger Engineering	China/Germany	HumanX	https://www.rokae.com/en/product/show/597/Humanoid-Robot-Human.X.html
PHYBOT	China	PHYBOT C1	https://www.phybot.tech/en/phybot-c1	Sanctuary AI	Canada	Phoenix	https://www.sanctuary.ai/technology

Supplier	Country	Model	Link	Supplier	Country	Model	Link
Supcon	China	Supcon Navigator 2	https://global.supcon.com/robotics	Vinmotion	Vietnam	Motion 2	https://vinmotion.net
Tesla	USA	Optimus Gen 2 (Tesla Bot)	https://www.tesla.com/en_eu/AI	Vizum	China	Xiao Wei	http://www.vizumtech.com/EN/?page_id=175
Ti5 robot	China	T230	https://www.ti5robot.com/en	WR Westwood Robotics	USA	Themis V2	https://www.westwoodrobotics.io/themis
Tokyo Robotics	Japan	Torobo	https://robotics.tokyo/technologies/torobo	XPENG	China	Iron	https://www.xpeng.com/news
Toyota	Japan	T-HR3	https://global.toyota/en/detail/19666346	XPENG	China	XP5	https://kr-asia.com/xpeng-motors-unveils-px5-humanoid-robot-underlining-its-vision-for-the-future
UB TECH	China	Walker S2	https://www.ubtrobot.com/en	Xiaomi	China	CyberOne	https://www.mi.com/global/discover/article?id=2754
UB TECH	China	Cruze S2	https://www.ubtrobot.com/en	X-Humanoid	China	Tien Kung 1.2 MAX	https://x-humanoid.com/yncj.html
Unitree	China	G1	https://www.unitree.com/g1	X-Humanoid	China	Tien Kung 2.0	https://x-humanoid.com/detail/jstg.html
Unitree	China	H2	https://www.unitree.com/h1	1X	USA	Neo Beta / Neo Gamma	https://www.1x.tech/neo
Unix-Group	China	Martian	https://www.unix-group.ai/martian/1822.html	1X	USA	EVE	https://www.1x.tech/eve

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The Fraunhofer Institute for Material Flow and Logistics IML has years of experience in automation research and consulting. It has extensive expertise in robotics and brought groundbreaking concepts to market in collaboration with industry partners.

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