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Bridging the Hype Cycle of Collaborative Robot Applications

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Abstract. This paper investigates manufacturing companies' current and planned usage of collaborative robots along with possible reasons for the observed slow growth in implementing Collaborative Robot Applications (CRAs) in the industry. The paper also discusses whether similarities can be seen in the Gartner Hype Cycle for technology adoption. Findings from an industrial survey suggest increasingly positive attitudes towards using CRAs in manufacturing and final assembly operations as tools and support mechanisms aiding human operators. Better methodologies and best practices are urgently needed for successful CRA implementation and efficient manufacturing human-robot collaboration design.

Keywords: Collaborative Robot Applications · Human-Robot Collaboration · Manufacturing · Final Assembly · Gartner Hype Cycle · Survey

1 Introduction

Manufacturing is an inherently labour-intensive industry. Human workers face a multitude of challenges, for example, repetitive and tedious tasks; working in hazardous environments; and managing heavy loads [1, 2]. Such challenges often lead to safety risks, fatigue, and injuries affecting worker productivity and well-being [3]. Recent, emerging technologies like *Collaborative Robots (Cobots)* can help address the challenges by taking on dangerous or repetitive tasks for humans. Thereby they free up worker time and energy for more valuable and creative work [4], while still unobtrusively sharing workspace with the operators [5, 6]. The Cobots' potential to enhance operators' physical and cognitive capabilities has been emphasized within *the Operator 4.0 paradigm* [7]. Moreover, robots have proven valuable in enhancing resilience, as presented in *the Operator 5.0 vision* [8]. Thus, rapidly increased industrial use of *Cobot Applications (CRAs)* would seem consequential but is that really the case in the industry today? This paper aims to clarify this question based on a survey study of manufacturing companies and a hype cycle analysis of CRAs' maturity in the industry.

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1.1 Collaborative Robots (Cobots)

Cobots are industrial robots designed to work alongside a human operator; the ISO/TS 15066:2016 technical specification emphasises external safety features required when using a collaborative robot [9]. *Collaborative Robot Applications (CRAs)* thus encompass additional safety features necessary for a safer collaboration with a human operator [10]. In major surveys conducted by Vicentini [4], Liu et al. [11], and Matheson [2], the development and use of collaborative robots over the last few decades, are highlighted. One of the significant factors behind this development is the need for higher flexibility in adapting to fast-changing manufacturing environments [10]. The *International Federation of Robotics (IFR)* figures show, on average, 6% growth in the application of *cobots* [12]. CRAs can also work in hazardous environments, such as extreme temperatures, chemicals, or radiation, minimising the risk of human exposure to harmful substances [13]. Additionally, *cobots* can aid heavy lifting, reducing physical strain on workers and minimising the risks of ergonomic injuries [11]. However, the adoption of CRAs in manufacturing also poses its own set of challenges, such as ensuring safety [13]; integrating robots into existing workflows [14]; and upskilling workers to effectively operate and collaborate with robots [15].

The popularity of CRAs in academia is visible in the number of publications. Publications on CRAs have increased by 19% on average from 2007 to 2021, as shown in Fig. 1. Simultaneously, reluctance from the industry is visible in shares of *cobots* over the past five years, remaining steady within an average of just 6% of total robot installations, according to the data from the IFR shown in Fig. 2 [12]. Lacking IFR data from 2022, the scientific publications from 2022 are excluded as well.

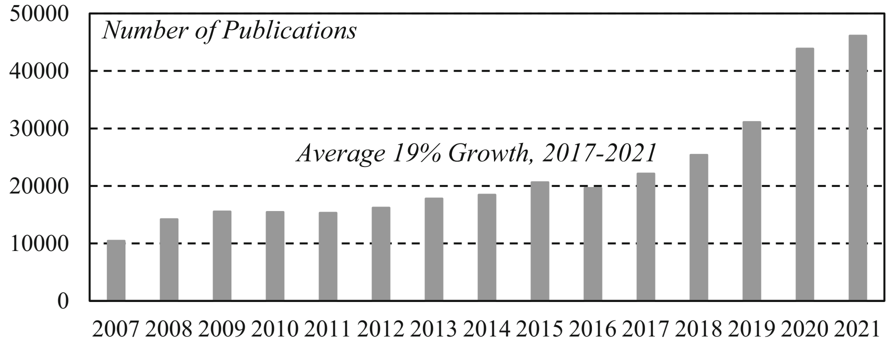


Fig. 1. Number of Publications in Scopus Database [16] (Search Terms: Collaborative Robot*, Cobot*, Collaborative Robot* Applications, Search Areas: Title, Abstract, Keywords)

The technology concerning the safety and security of using CRAs is maturing. There is enough evidence in the scientific literature on proofs-of-concept and real examples of using CRAs in manufacturing. Nevertheless, numbers from IFR do not reflect an expected fast growth, as seen in Figs. 1 and 2. The maturity of technologies is widely assessed using the *Gartner Hype Cycle* shown in Fig. 3.

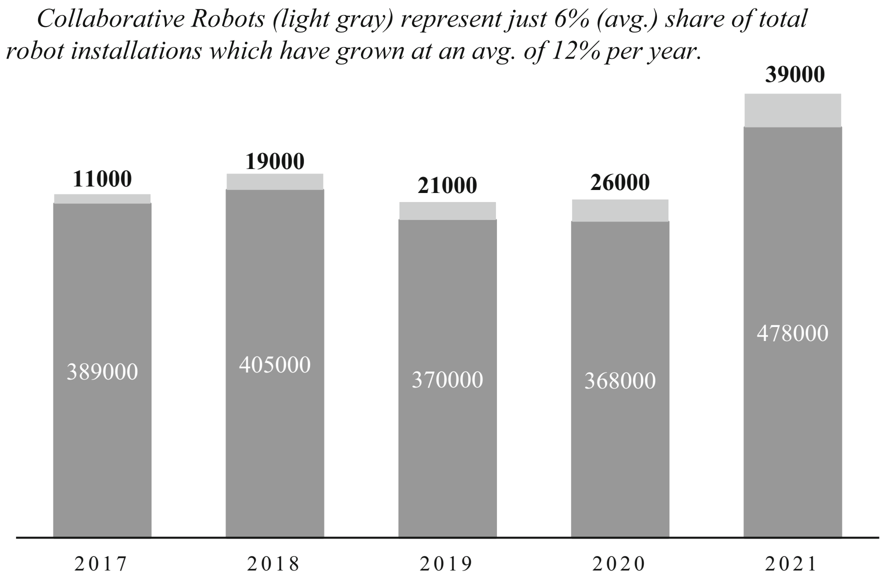


Fig. 2. Number of Annual Robot Installations [12]

1.2 Gartner Hype Cycle

The *Gartner Hype Cycle* is a widely used model that describes technologies' adaptation and relative maturity in particular domains [17]. Initially introduced in the 1990s by Gartner research, the Gartner Hype Cycle has become a crucial resource for technology analysts and strategists [18]. This model consists of five key stages: the Technology Trigger, the Peak of Inflated Expectations, the Trough of Disillusionment, the Slope of Enlightenment, and the Plateau of Productivity [17]. Its effectiveness in comprehensively comprehending how technologies are adopted and transformed has been widely acknowledged. Research has demonstrated that new technologies often experience a cycle of overhyping and attracting excessive media attention, leading to unrealistic expectations. Consequently, when the technology fails to meet these expectations, it enters a disillusionment phase where investment and interest decline. The "slope of enlightenment" marks a phase where people have more practical expectations and better understand the technology's limitations and potential uses. During this stage, individuals and organisations develop practical strategies and use cases for implementation. The "plateau of productivity" indicates when technology has become mainstream and is widely adopted. This phase is characterised by stability, established best practices, and widespread benefits. The *Gartner Hype Cycle* provides insights into expectations that most technologies will inevitably progress through successive stages, pronounced by the peak, disappointment, and recovery of expectations [17, 18].

Gartner Hype Cycles have been used to analyse the technological maturity of Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain and other widely popular (Industry 4.0) technologies. They are also used in innovation application decision-making [19, 20].

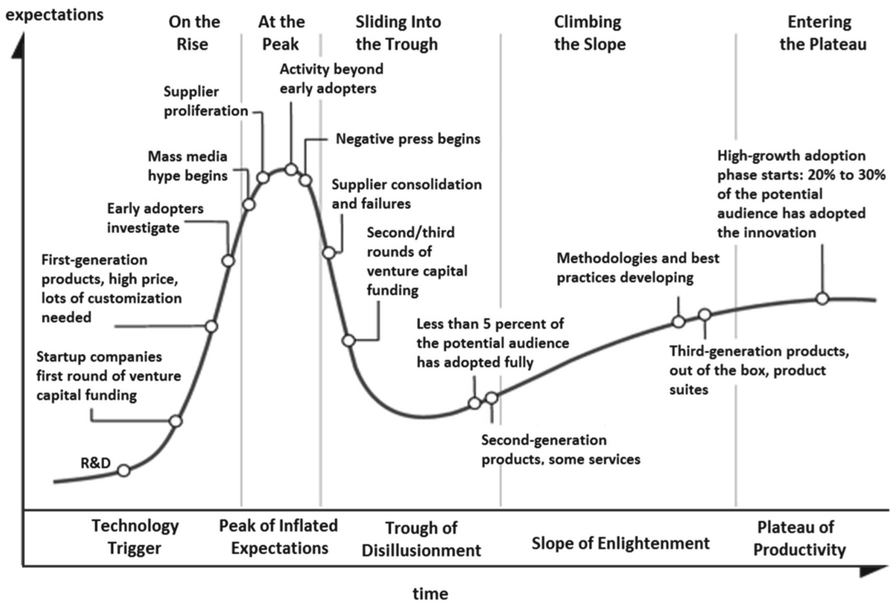


Fig. 3. Gartner Hype Cycle [17]

This paper aims to investigate the current and planned usage of *cobots in manufacturing companies*, along with possible reasons for the slow growth in the implementation of CRAs in the industry and what connections can be drawn based on the Gartner Hype Cycle.

Structure of the paper: Sect. 2 explains the research methodology used; Sect. 3 presents the results from the survey conducted with professionals with manufacturing and final assembly backgrounds from Sweden and Denmark; Sect. 4 discusses in detail the results of the study, and Sect. 5 provides conclusions and future directions for this research work.

2 Research Methodology

This section outlines the research methodology used to investigate the use of *cobots in manufacturing,* including identifying their current usage and implementation challenges. The research design for this study is *quantitative* and based on the use of *surveys* to collect data from manufacturing companies currently using or planning to use CRAs in their manufacturing operations. *Surveys* effectively collect data from large sample sizes and provide statistical analysis to identify patterns and trends [21]. This paper follows the methodology presented in designing surveys by Blair et al. [22]. The target population for this study is manufacturing companies in Sweden and Denmark that are currently using or planning to use CRAs in their manufacturing operations. Production engineers with a position of team leaders and managers with at least two years of work experience were selected for this survey. Data is collected in person using an online form to ensure the correct person fills in the survey. The respondents were provided explanations where required.

The collected data is analysed using *descriptive statistics*. *Descriptive statistics* is an essential tool in research that helps with summarising and presenting data meaningfully. *Descriptive statistics* aims to describe and analyse data meaningfully and provide a comprehensive summary of the data that can be used to draw inferences and make conclusions [23]. *Ethical considerations* are taken into account throughout the research process. Informed consent is obtained from all participants, and their privacy and confidentiality are protected under university regulations.

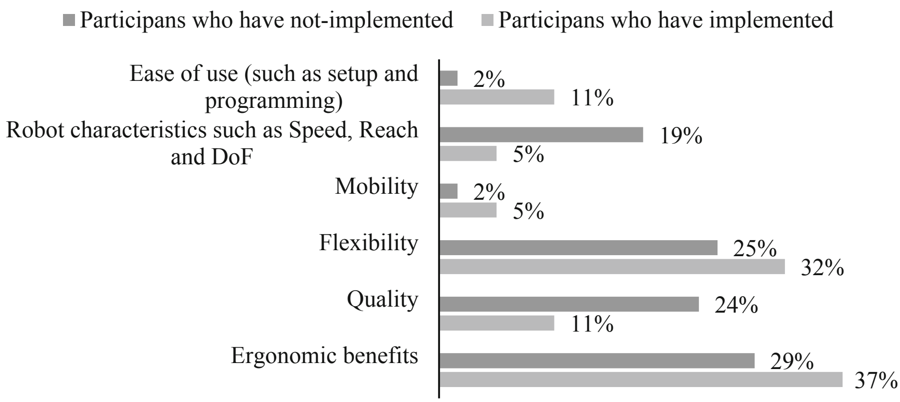
3 Survey Results

The questionnaire in the survey was designed based on an extensive literature study combined with the results from a workshop conducted to identify strategies for implementing CRAs [24]. A pilot study was conducted with 10 participants to refine the questionnaire, and those responses are not included in the presented results. The selection criteria for these participants are similar to those selected for the main survey and are explained below. To protect the identity of the respondents, the survey has not been clustered by company sizes, types, and locations.

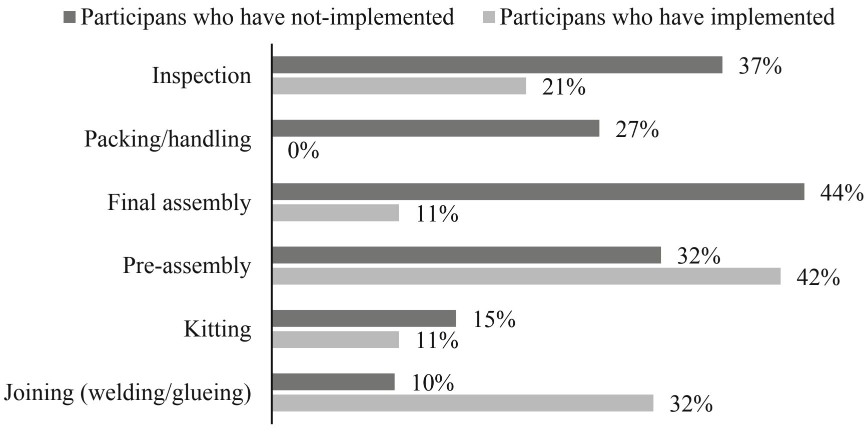
Participants from 15 organisations, ranging from SMEs to OEMs in Sweden and Denmark participated in this survey. The survey was conducted during demonstrations for visitors at SII-Lab – https://www.sii-lab.se/ Respondents with merely manufacturing and final assembly backgrounds and with at least two years of work experience have been selected to fill in the survey.

A total of 78 in-person responses were collected. From those 78 responses, 19 participants or 24% of the total participants, had already implemented at least one *CRA. In contrast,* 59 participants or 76% of the total participants, stated they had not yet implemented a CRA but were exploring options to implement it. The results are presented below. Questions, where participants could choose multiple choices have been indicated as "select all applicable".

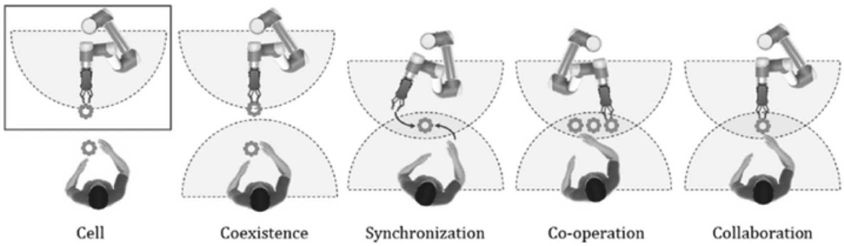
1. *The main driver to implement a collaborative robot application.*



2. *Current or planned collaborative robot applications (Select all applicable).*

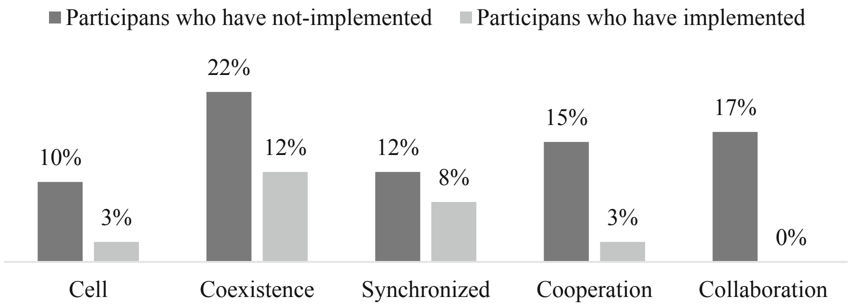


3. *Type of collaboration suited for the specific application of the participant.*

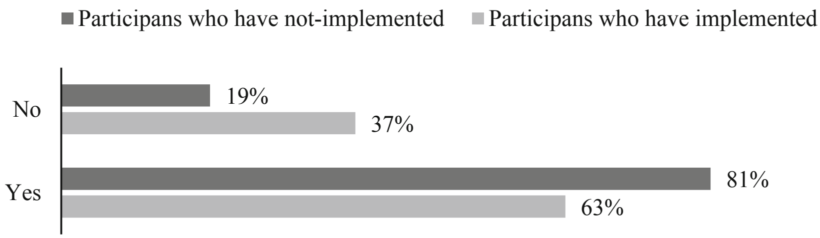


*The different levels of collaboration adapted from [25] are shown in the picture above. These levels are explained below:

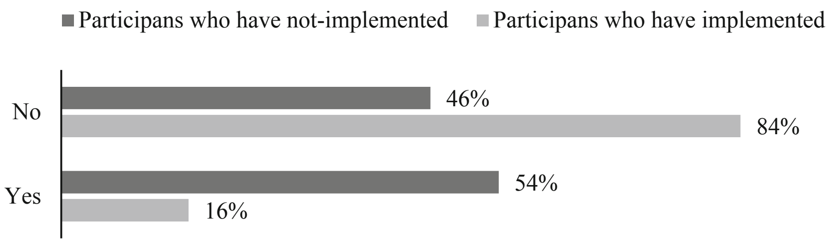
a. *Cell:* Traditional cage scenario where the robot is isolated in a cage; no true collaboration.
b. *Coexistence:* Humans and robots work alongside each other without the presence of any cage though the workspace is not shared.
c. *Synchronised:* Human and robot shared workspace. Only one interaction partner (i.e., either human or robot) is actively working in the workspace.
d. *Cooperation:* Shared workspace where both humans and robots have tasks to perform. This task is not simultaneously performed at the same location as a product or component.
e. *Collaboration:* Humans and robots work simultaneously on the same product component.



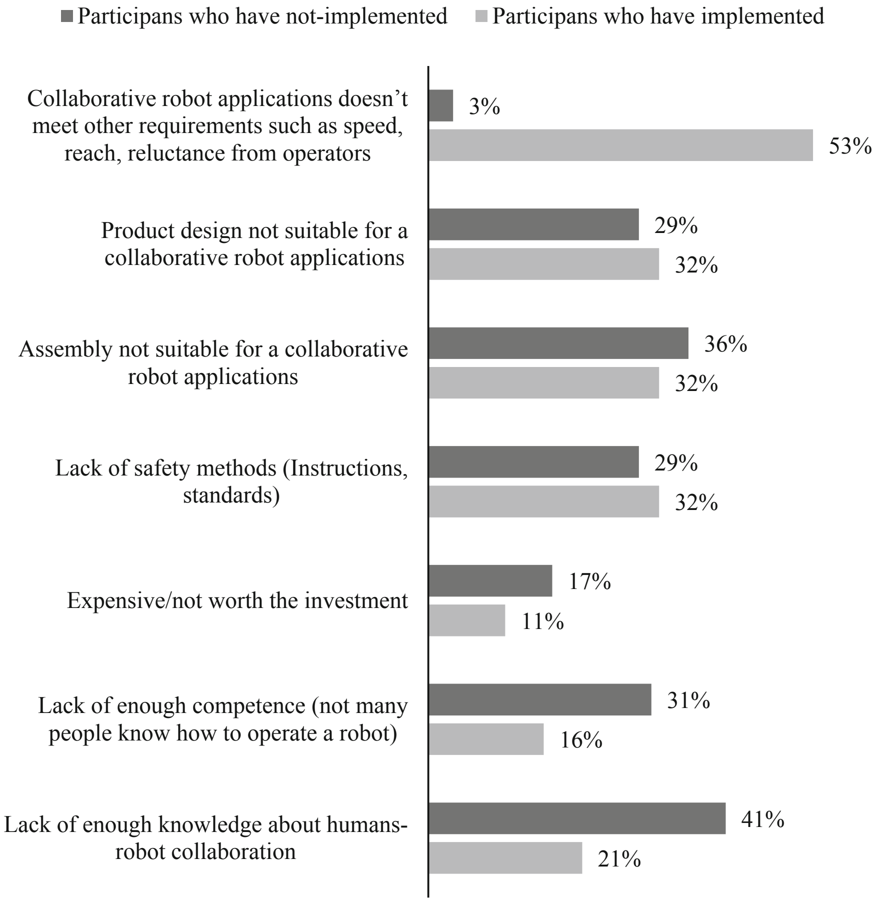
4. *Planned or executed changes (respectively) in the production/manufacturing system's design/layout for implementing collaborative robot applications.*



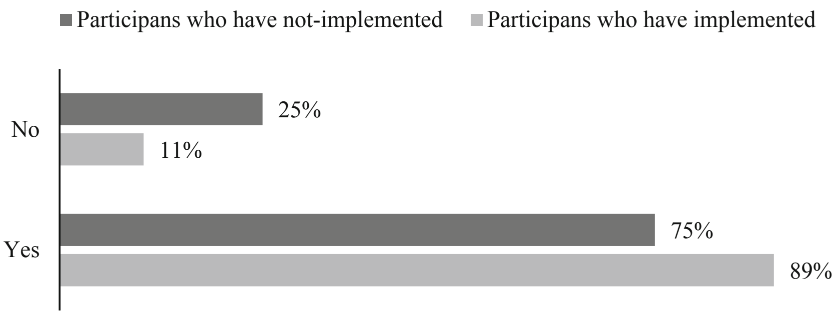
5. *Planned or executed changes (respectively) in the product design for implementing a collaborative robot application.*



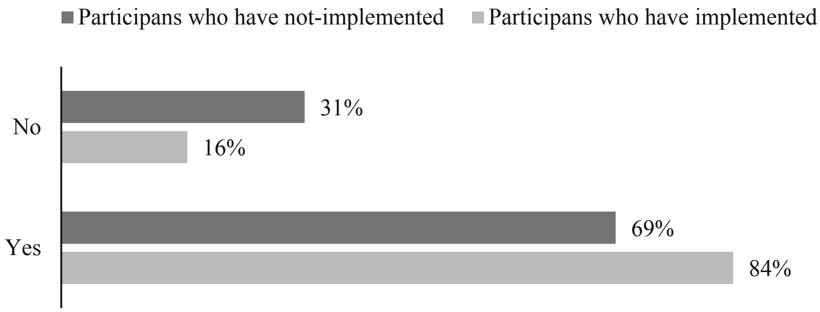
6. *Challenges of implementing collaborative robot applications (Select all applicable).*



7. *Planned to develop or already developed in-house competence to operate the collaborative robot application.*



8. *Planned to get help or already received support from an external system integrator in developing your collaborative robot application.*



4 Discussion

4.1 Findings on Collaborative Robot Applications (CRA) Implementations

Survey findings suggest increasingly positive attitudes towards using CRAs in manufacturing and final assembly operations. The technology's purpose is also quite broad, as seen in responses to Questions 1 and 2. Still, most respondents tend towards using CRAs to increase the system's flexibility, quality, and productivity. These Key Performance Indicators (KPIs) are often associated with the characteristics of human operators. These findings, specifically the intention of use (Question 1), suggest that companies are looking for automated solutions capable of working with humans without causing many work and workplace disturbances. This debunks the misconceptions that low-cost automation, like CRAs, will replace human operators. Instead, the survey clearly shows that CRAs are perceived as *coexisting* with human operators.

From a research perspective, *cobot technologies* are well known. A large number of *Proofs-of-Concept (PoCs)* have been developed for different CRAs such as pre-assembly, inspection, kitting, joining, final assembly, packing, and pick-n'-place/load-unload operations [24]. Yet, survey results indicate that the transition from PoCs to actual implementations is not happening. Just a quarter of participants have implemented at least one CRA, even though potential implementation areas have different PoCs readily available. This raises the question of whether there could potentially *be a lack of clarity on human-robot collaboration from a task and function allocation perspective.*

Survey findings show that for respondents who have implemented at least one CRA, their expectations regarding speed, reach, and acceptance by operators still need to be met. Furthermore, for those planning to implement a CRA in the future, a more significant concern is the need for safety methods; competence and skill sets; knowledge of the collaboration between humans and robots; and product suitability. *Product design* can be optimised for automated assembly, but safety is still a significant concern. The underlying indications for *safety-related concerns* are intrinsically linked to a lack of knowledge on *Human-Robot Collaboration (HRC)*, it appears knowledge related to HRC is insufficient, resulting in a need for simple, easy-to-use methods (e.g., Lean Robotics [26]). Conducting a meticulously thought-through task allocation between humans and robots will address many of the concerns mentioned earlier [27, 28].

Companies do not expect CRA implementations to be easy and smooth, yet there is an apparent willingness to go endure the difficulties. *Automation* is highly reliant on product and production design. However, *product design* is not a primary focus, neither for those who have implemented at least one CRA nor for those thinking of doing so. Making changes in product and production design is crucial for successful CRA implementations. The selection of a low level of HRC indicates that companies want some sort of collaboration between humans and robots but initially not the highest level. This step-by-step approach, perhaps exploratory, can be linked to economic or quality risk assessments. One significant advantage of *cobots* is their flexibility, which highly relies on the ability of operators to program the robots. For successful CRA implementations, *in-house competence* is essential. Survey results show a zeal for developing *in-house competence* for those who have planned to implement and those who have already implemented at least one CRA. This indicates that operators and group leaders will be at the forefront of programming and reprograming the robots to achieve higher flexibility and additional KPIs. At the same time, the willingness to rely on external help also shows that it is a "step-by-step process".

4.2 Bridging the Hype Cycle of Collaborative Robot Applications (CRAs)

According to the IFR [12], CRAs have had an average of 6% installation over the last five years. This would put CRAs as technology on the slope of enlightenment in the Gartner Hype Cycle (see Fig. 3). Based on participant survey responses, reflections, and general comments, these can be divided into four major blocks on the Gartner Hype Cycle, as summarised graphically in Fig. 4. The *technology trigger* for cobots can be accredited to the release of the UR5 cobot by Universal Robotics (UR) in 2008, with the *peak of inflated expectations* tipping in 2017.

This group of participants are either *heading to the peak* or *has peaked* and is betting on the advantages of the new technology, such as flexibility, ease of use, ability to work alongside the human operator, and low-cost automation. Participants that are *nearing disillusionment* have either implemented or conducted some preliminary studies. The technology is still promising for this group, but some challenges have arisen. Among those challenges is cobots' inability to match the required speeds for the process, such as takt time requirements. Other reasons for *disillusionment* include the limitations to the ease of programming and that CRAs are not a plug-n'-play type of technology application. The underestimated need for in-house competence; overall cost-to-return; and lack of knowledge on collaboration between humans and robots can also be accredited to the *disillusionment.* Participants in the group on the *slope of enlightenment* have passed disillusionment. The group has realised the underlying limitations of the technology and is acting on it. For example, to fully utilise cobots' flexibility and mobility, requires in-house competence for any changes needed in a production system and product design. From the survey, there is a willingness to adapt the product and production to HRC requirements. There is also a step-by-step approach to using the levels of HRC, for instance, starting and the lowest level, which is coexistence and moving upwards: synchronisation, cooperation, and collaboration. There is a willingness to develop in-house competence while getting support from external partners.

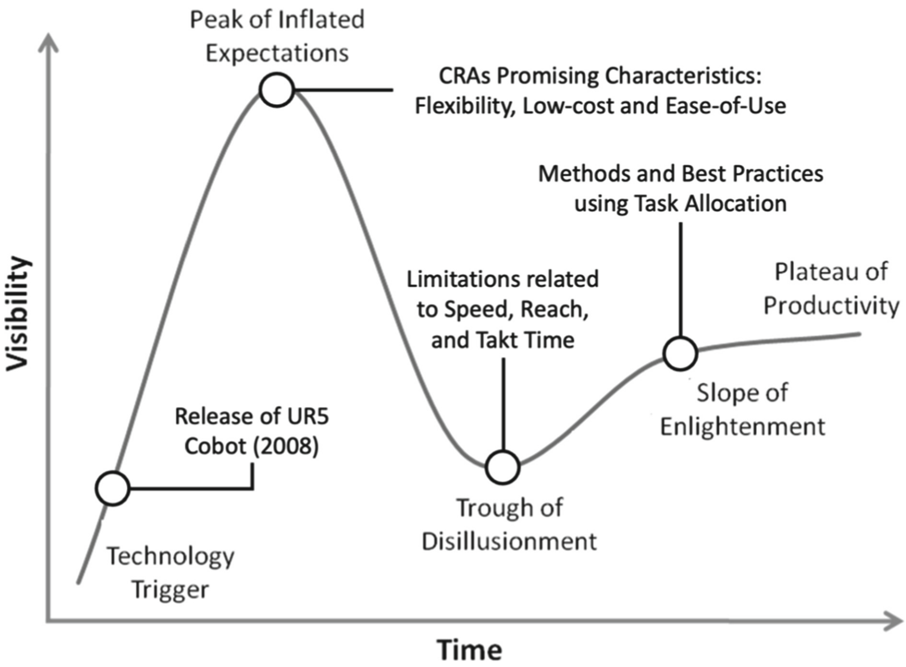


Fig. 4. CRAs Hype Cycle based on Survey Findings. Adapted from Gartner Hype Cycle [17]

5 Conclusions and Further Work

Rapidly increased industrial use of *Cobot applications* would seem consequential from the apparent hype of *Collaborative Robot Applications (CRA),* but is that really the case in the industry today? The research shows that companies act in an increasingly realistic way when adopting *CRA tools* and *support mechanisms* to aid and augment human operators in their production system work situations. Further, there seems to be a consensus among the survey respondents that *CRA* is a promising technology. The responses also indicate industrial over-reliance on the technical capabilities of robots, while *human-centric approaches,* necessary for successful CRAs implementations, have not yet received appropriate attention. Survey results show that manufacturing companies need comprehensive and application-specific knowledge of *Human-Robot Collaboration (HRC).* In addition, increased skills are needed to program collaborative robots to reach further steps on the Gartner Hype Cycle. Lack of knowledge and skills can be exploited to "bridge the hype cycle gap", focusing on *methods* and *best practices* that are easy to understand and universally applicable. Hence, further work can delve into the implications of these survey results on the design and development of future CRAs, and best practices for industries planning to adopt CRAs.

In addition, *Task allocation* between humans and robots is a method that can be used in developing new methodologies (e.g., [6]). Extensive knowledge of task and function allocation in humans and machines is available, simplifying collaboration between humans and robots in a CRA system. Future research could focus on simplifying task allocation for HRC. Specifically, workstation design and implementation of CRA areas still need attention [5].

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