

## Human Capital in the Industrial Scenario 4.0: A theoretical study

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### Abstract:

In order to make the Industry 4.0 approach a reality, several requirements need to be met, one of them is the need to qualify people to work in industries. This study aimed to explore the possible changes and perspectives of human work in Industry 4.0. A systematic literature review was carried out following a structured script. 50 were chosen for content analysis, following criteria for qualification and selection of studies. As a result, a number of changes in human skills and tasks, as well as job prospects, were found, standing out the greater flexibility of people, ability for decision-making, among others.

**Key-words:** Industry 4.0, Strategic Management, Human Resources, Human competencies.

## Capital Humano no Cenário Industrial 4.0: Um estudo teórico

### Resumo:

A fim de tornar a abordagem da Indústria 4.0 uma realidade, vários requisitos precisam ser atendidos, um deles é a necessidade de qualificar as pessoas para o trabalho nas indústrias. Este estudo teve como objetivo explorar as possíveis mudanças e perspectivas de trabalho humano na Indústria 4.0. Uma revisão de literatura foi realizada para fornecer suporte ao estudo. 50 artigos foram escolhidos para análises, seguindo critérios de qualificação e seleção de estudos. Como resultado, foram encontradas diversas mudanças nas habilidades e tarefas humanas, assim como nas perspectivas de emprego, destacando-se a maior flexibilidade das pessoas, a capacidade de tomada de decisão, entre outras.

**Palavras-chave:** Indústria 4.0, Gestão estratégica, Recursos humanos, Competências humanas.

### 1. Introduction

Throughout history, people and industries have witnessed multiple industrial revolutions, which have occurred gradually, beginning with the mechanization of production enabled by the steam engine, followed by the introduction of mass production and automation of production processes (HADDARA; ELRAGAL, 2015).

Recently, numerous questions have been raised about the upcoming industrial revolution, named by the Germans as Industry 4.0 (LEE; KAO; YANG, 2014). According to Hecklau et al. (2016), from the integration of automation and process digitization, Industry 4.0 aims to create a diversity of opportunities for industries. Nevertheless, it also triggers a series of issues, some of them inconclusive yet.

According to Spath et al. (2013), an essential requirement for Industry 4.0 is the qualification of people, whose participation will be vital, with no substitution of human labor for artificial intelligence taking place. What will occur is a task redirection, that is, people will perform other tasks, such as the programming of robots on assembly lines, system operations, supervision and decision-making (SINGH; SELLAPPAN; KUMARADHAS, 2013).

In Park and Lee's concept (2017), in the Industry Scenario 4.0, the management of human resources is one of the most important elements. For Becker and Sterm (2016), in Industry 4.0, human work will be modified, and the changes to be made still requires more scientific discussion, which highlights the importance of studies on this regard.

In view of the presented research problem, this study aimed to explore the set of changes and perspectives of human work in Industry 4.0, based on a literature review.

## 2. Industry 4.0

As a precursor to the term Industry 4.0, Germany has been conducting changes in the industrial scenario in recent years, based on production and innovation enabled by Cyber-Physical Systems (CPSs) (LEE; KAO; YANG, 2014). According to Lee (2008), CPSs consist of digital integrations with physical processes, where integrated computers and networks monitor and control physical processes.

By means of CPSs and other technologies, intelligent processes provide fast responses to changes in production and to faults that may occur throughout the industrial production chain (HADDARA; ELRAGAL, 2015; JASIULEWICZ-KACZMAREK; SANIUK; NOWICKI, 2017). Industry 4.0 requires an effective integration of equipment, people, processes, and products (GEBHARDT; GRIMM; NEUGEBAUER, 2015; HADDARA. ELRAGAL, 2015), providing competitive advantages such as cost and time efficiency in production and product quality improvement (ALBERS et al., 2016).

Overall, industries will be positively affected by changes arising from Industry 4.0. In Germany, the automotive and food industries, as well and industries producing components and systems stands out (RÜßMANN et al., 2015). According to Gorecky et al. (2014), the automotive sector is one of the leaders in the adoption of technologies such as the Internet of Things (IoT) and cyber-physical systems.

### 2.1 Pillar 1: Big Data

The use of Big Data in analyses has recently emerged in some industries, aiming to improve production and product quality, ensure equipment efficiency and assist in real-time decision making (RÜßMANN et al., 2015).

Big Data is a set of data processed with analytical technology, which includes unstructured data and without compatible formats, such as social network service data, blog data, news data, photos, among others (PARK et al., 2017). That way, it is possible to provide personalized services to clients, assist in decision-making processes, among other advantages (WITKOWSK, 2017).

### 2.2 Pillar 2: Autonomous robots

Robots are machines developed for the purpose of performing specific tasks autonomously or by means of remote control commands (ULLAH et al., 2016).

Robots present different degrees of autonomy according to each one's purpose and need of development. In this context, while some robots are programmed to perform repetitive,

standardized, and precise tasks, other robots are extremely flexible as to the orientation of the object and/or the task to be performed (SINGH; SELLAPPAN; KUMARADHAS, 2013).

In industry 4.0, the participation and intensification of autonomous robots in industries is a reality (RÜßMANN et al., 2015). This occurs for several reasons, one of them being the fast technological advance (TASEVSKI; NIKOLIĆ; MIŠKOVIĆ, 2013).

Singh, Sellappan e Kumaradhas (2013) describe in their study the advantages of using robots in industries, as a work factor, in the following categories: – Productivity: i) Robots develop more accurate and high quality work; ii) Robots rarely make mistakes; iii) They produce more products in a shorter amount of time; (iv) They work at a constant and uninterrupted speed; v) They are faster in performing tasks; – Work safety: i) Robots can perform dangerous tasks; (ii) They can work in places hazardous for humans, such as places with poor lighting or tight spaces, and; iii) They are capable of lifting heavy loads without the risk of accidents; – Time saving: i) Robots save time due to higher productivity for a certain period, and; – Money saving: (i) Robots reduce wasted raw material due to high production accuracy, and; ii) Ensure greater financial returns to long-term industries.

### 2.3 Pillar 3: Simulation

Simulation is the process of creating and designing a real or imaginary system by using physical or mathematical models, or models of other kind, for modeling, in order to evaluate and predict system behavior (RODIČ, 2017).

In industries, simulations of products, materials and/or processes in three-dimensional scenarios are already developed, but over the years they will intensify and encompass data in real time (RÜßMANN et al., 2015).

In order to meet the needs of intelligent industries, where computer systems can be used to design, simulate and monitor integrated physical processes, new simulation tools are developed, whose main objective is to create increasingly accurate virtual maps of reality and facilitate the decision-making process (GEBO CERMEX, 2016).

### 2.4 Pillar 4: Horizontal and vertical system integration

A reality nowadays is that industries, suppliers, and customers are not totally interconnected. In industry 4.0, the integration of global data will generate value chains involving industries, departments and other internal and external context elements (RÜßMANN et al., 2015).

### 2.5 Pillar 5: Internet of Things

The Internet of Things (IoT) consists of intelligent communication systems using IP addresses, which allows the interconnection of objects to the network (ANDERL, 2014; HADDARA; ELRAGAL, 2015).

Although in industries some technologies are already connected to machines and the network, with the internet of things, a greater number of devices and sensors will be incorporated into the processes and connected to the network, providing real-time responses (RÜßMANN et al., 2015). According to Porter and Heppelmann (2014), intelligent products connected to the network offer exponential expansion opportunities for new features. The Internet of Things presents itself as an important technology and should reflect on economic opportunities (HOFMANN; RÜSCH, 2017).

## 2.6 Pillar 6: Cybersecurity

As a result of the greater incorporation of data and information into the digital environment, in Industry 4.0 system security will be indispensable (RÜßMANN et al., 2015). In Intelligent Industry, a complex and efficient approach to cybersecurity should be adopted to protect data, information, knowledge and/or other intellectual elements (ANNUNZIATA; BILLER, 2014).

## 2.7 Pillar 7: Cloud computing

With the increase in data and information sharing, the intelligent industry will require cloud technologies with a higher performance, in order to provide appropriate processing, storage, and connectivity (RÜßMANN et al., 2015).

## 2.8 Pillar 8: Additive Manufacturing

Industries already employ principles of the manufacture of additives, such as 3D printing of prototypes; however, it will also be used in the production of small volumes of batches of custom products (RÜßMANN et al., 2015).

In industry 4.0, new production techniques will be developed and intensified, such as printing in 3D technologies, which offers greater flexibility in creating product prototypes faster and with better costs, as well as benefit product development stages, prototyping, and production (ANNUNZIATA; BILLER, 2014).

## 2.9 Pillar 9: Augmented Reality

In this pillar, information about services to be treated in the industries, such as selecting parts from a warehouse or product repair instructions, will be displayed to workers through augmented reality devices (RÜßMANN et al., 2015).

## 3. Method

From the point of view of the problem approach, the research is classified as qualitative (SILVA, MENEZES, 2005) as it aimed at the interpretation and description of phenomena related to the configuration of human work in the Industry 4.0 scenario.

Considering its objectives, the research is classified as exploratory, since it aimed to provide greater familiarity with the problem under study (GIL, 2008).

From the point of view of technical procedures, it is classified as a bibliography exploratory research, since it was elaborated from studies disseminated in periodicals (GIL, 2008).

To explore the current reality and perspectives on human work in the Industry 4.0 scenario, a systematic literature review was carried out, using the protocols of Pagani, Kovalski and Resende (2015), which presented the following steps: i) Selection of bibliographic databases; ii) Establishing keywords and combinations of keywords; iii) Defining search criteria in databases; iv) Performing searches in the databases; v) Eliminating duplicate articles; vi) Defining and apply criteria to eliminate articles incompatible with the proposed theme; vii) Qualifying articles from the calculation and analysis of InOrdinatio values; and viii) Full reading of selected articles.

According to the objectives and intention of the research, the selected keywords were “Industry 4.0”, “Smart Manufacturing”, “Fourth Industrial Revolution”, “Smart Industry”, “Human”, “Worker” and “Technology Transfer”, which were then combined and explored in some databases.

Subsequently, combinations of keywords and search criteria were defined in the Science Direct and Scopus, and Web of Science databases (Chart 1 and 2, respectively).

| Keyword                        | Database - Science Direct and Scopus                                          |             |           |
|--------------------------------|-------------------------------------------------------------------------------|-------------|-----------|
|                                | "Human"                                                                       | "Employee*" | "Worker*" |
| "Industry 4.0"                 | Procedures: i) Keywords in Abstract-Title-AND-Keywords, and;<br>ii) AllYears. |             |           |
| "Smart Manufacturing"          |                                                                               |             |           |
| "Fourth Industrial Revolution" |                                                                               |             |           |
| "Smart Industry"               |                                                                               |             |           |

Chart 1: Relevant information for systematic literature review.

| Keyword                        | Database - Web of Science                                                                                                                                                                  |             |           |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------|
|                                | "Human"                                                                                                                                                                                    | "Employee*" | "Worker*" |
| "Industry 4.0"                 | Procedures: i) Keywords in Title ("Industry 4.0", "Smart Manufacturing", "Fourth Industrial Revolution", "Smart Industry") AND Topic ("Human", "Employee*", "Worker*"), and; ii) AllYears. |             |           |
| "Smart Manufacturing"          |                                                                                                                                                                                            |             |           |
| "Fourth Industrial Revolution" |                                                                                                                                                                                            |             |           |
| "Smart Industry"               |                                                                                                                                                                                            |             |           |

Chart 2: Relevant information for systematic literature review.

The bibliographic databases selected were: Science Direct, Scopus, and Web of Science. The choice was based on the fact that these bases presented the greatest amount of articles on the subject researched, even containing articles present in other databases.

In order to select only articles directly related to the research theme, the following filtering procedures were applied: i) Eliminate duplicated articles; ii) Eliminate articles published in conferences, and iii) Eliminate articles unrelated to the topic under study.

From the application of the filtering criteria, for the final result of articles, the Phase 7 of the Methodi Ordinatio (PAGANI; KOVALESKI; RESENDE, 2015), named InOrdinatio, was performed in order to qualify and organize articles according to scientific relevance, equating impact factor, year of publication and number of citations of each article. The InOrdinatio values were organized in Microsoft Excel® spreadsheets, enabling the qualification and selection of articles.

## 4. Results and discussion

### 4.1 General analysis of publications on Industry 4.0

The results obtained in the searches for the keyword combinations in each of the three databases are described in Table 1, 2 and 3, respectively.

| Keyword                        | Database - Science Direct |             |           |           |
|--------------------------------|---------------------------|-------------|-----------|-----------|
|                                | "Human"                   | "Employee*" | "Worker*" | Result    |
| "Industry 4.0"                 | 23 results                | 5 results   | 8 results | 36        |
| "Smart Manufacturing"          | 6 results                 | 1 result    | 2 results | 9         |
| "Fourth Industrial Revolution" | 4 results                 | 1 result    | 1 result  | 6         |
| "Smart Industry"               | 1 result                  | 1 result    | 0 result  | 2         |
| <b>Result</b>                  |                           |             |           | <b>53</b> |

Table 1: Results for systematic literature review.

| Keyword                        | Database - Scopus |             |            | Result     |
|--------------------------------|-------------------|-------------|------------|------------|
|                                | “Human”           | “Employee*” | “Worker*”  |            |
| “Industry 4.0”                 | 108 results       | 31 results  | 32 results | 171        |
| “Smart Manufacturing”          | 44 results        | 8 results   | 10 results | 62         |
| “Fourth Industrial Revolution” | 22 results        | 6 results   | 4 results  | 32         |
| “Smart Industry”               | 6 results         | 1 result    | 1 result   | 8          |
| <b>Result</b>                  |                   |             |            | <b>273</b> |

Table 2: Results for systematic literature review.

| Keyword                        | Database – Web of Science |             |           | Result    |
|--------------------------------|---------------------------|-------------|-----------|-----------|
|                                | “Human”                   | “Employee*” | “Worker*” |           |
| “Industry 4.0”                 | 8 results                 | 0 result    | 2 results | 10        |
| “Smart Manufacturing”          | 6 results                 | 0 result    | 0 result  | 6         |
| “Fourth Industrial Revolution” | 2 results                 | 1 result    | 1 result  | 4         |
| “Smart Industry”               | 0 result                  | 1 result    | 0 result  | 1         |
| <b>Result</b>                  |                           |             |           | <b>21</b> |

Table 3: Results for systematic literature review.

Among the databases researched Scopus presented the highest result of articles compared to Science Direct and Web of Science.

The respective results of articles found are described in Tables 1, 2 and 3, and organized in Table 4.

| Database       |             |                | TOTAL |
|----------------|-------------|----------------|-------|
| Science Direct | Scopus      | Web of Science |       |
| 53 results     | 273 results | 21 results     | 347   |

Table 4: Results for systematic literature review

A total of 260 articles (elimination of duplicates) were obtained. The filtering processes applied are described in Table 5.

| Filtering procedure                          | Gross total of articles | Total articles after filtering |
|----------------------------------------------|-------------------------|--------------------------------|
| Conference articles                          | 260                     | 135                            |
| Unrelated articles to the scope of the study | 135                     | <b>88</b>                      |

Table 5: Filtering of articles.

The portfolio of 88 articles was submitted to the seventh phase of Methodi Ordinatio, called InOrdinatio. From this total, 50 articles were selected for content analysis using the information presented in Table 6.

| Description                                                                                                                   | Total |
|-------------------------------------------------------------------------------------------------------------------------------|-------|
| Total articles submitted to Methodi Ordinatio                                                                                 | 88    |
| Articles with best InOrdinatio results                                                                                        | 50    |
| Items discarded due to low InOrdinatio results (zero values for impact factor and citations in the literature, predominantly) | 26    |
| Articles inaccessible to researchers                                                                                          | 12    |

Table 6: Selection criteria for articles for the systematic literature review.

The number of articles selected was significant for discussions on human work in the Industry 4.0 Scenario.

Not all articles selected address exclusively the subject qualification of people for work and related aspects. However, even in other matters related to Industry 4.0, some of the articles provide relevant contributions. Some studies deserve special mention, such as the one by Hecklau et al. (2016), who identified human competencies for work in Industry 4.0, classifying them into four categories, professional, methodological, social and personal competencies, as well as the study by Romero et al. (2016), in which the authors describe the key competencies needed to operate cybernetic and automated systems.

Qualification of people is the process used in the development of competencies, through training and other practices (GRAßMANN, 2005). However, the qualification becomes complex in Industry 4.0 since, in order to qualify people, knowing how to measure the necessary human competencies is key. Studies by Spath et al. (2013) and Becker and Stern (2016), discuss human work perspectives in Industry 4.0, with greater emphasis on the production department, namely: the permanence of people in productive processes as central elements, but with new skills, and the structuring of new tasks.

#### **4.2 Competencies for Industry 4.0 in the manufacturing industry**

In industries featuring the Industry 4.0 design, new tasks will be created, as well as others will be perfected (DOMBROWSKI; WAGNER, 2014; GORECKY et al., 2014; BECKER; STERN, 2016).

New tasks will be created, since the current production tasks, characterized as easy, repetitive and stressful, will be automated and executed by intelligent systems (GEBHARDT; GRIMM; NEUGEBAUER, 2015; BECKER; STERN, 2016; VYSOCKY; NOVAK, 2016).

According to Jasiulewicz-Kaczmarek, Sanik, and Nowicki (2017), the integration between the Internet and production machines, intelligent sensors, and autonomous systems, will increase the complexity of human tasks.

The control of intelligent systems and processes will be the paramount human task in Industry 4.0 (RÜßMANN et al., 2015; MARSH; EYERS, 2016). The monitoring of network devices and services, integrated into the production systems, will also intensify in the industries (GEBHARDT; GRIMM; NEUGEBAUER, 2015; STOCK; SELIGER, 2016; DING; LIN, 2017; JASIULEWICZ-KACZMAREK; SANIK; NOWICKI, 2017; LALANDA; MORAND; CHOLLET, 2017).

Due to the insertion of intelligent processes in the industries, it will be operator's job to monitor and supervise the production systems, with the aid of specific software and technologies (WITTENBERG, 2016; LALANDA; MORAND; CHOLLET, 2017; PACAUX-LEMOINE et al., 2017).

In addition to the monitoring tasks, human participation in Industry 4.0 will also encompass decision-making processes. Worker will play the role of creative problem solver when faced with complex and dynamic problems (GORECKY et al., 2014; STOCK; SELIGER, 2016).

In their study, Pfeiffer et al. (2016) cite the main groups of people involved in the context of Industry 4.0. They are: Software developers; Developers of system components; Project manager; System tester; Maintenance and machine operators; Programmers of robotic and computational systems, and; Process supervisors.

In the industry of the future, although the integration of automation and digitization of concurrent processes occurs, people will continue to play a key role in the work (SPATH et al., 2013; BECKER; STERN, 2016; PFEIFFER, 2016; VYSOCKY; NOVAK, 2016; PERUZZINI; PELLICCIARI, 2017). However, it will probably result in a significant impact on the loss of workers' jobs (SACKEY; BESTER, 2016) and processes of redistribution of human capital (SINGH; SELLAPPAN; KUMARADHAS, 2013).

In the midst of changes in production processes and in the industrial setting, changes in people's qualification and skill development will surely arise (CHRYSSOLOURIS et al., 2013; GEBHARDT; GRIMM; NEUGEBAUER, 2015; SACKEY; BESTER, 2016). Competency is a generalized term that involves attitude, knowledge, and skills that a person must have to meet an expectation of performance (ARMSTRONG, 2014), or perform tasks.

For Industry 4.0 some human competencies for work in the manufacturing industry are essential in a multidisciplinary context. The Chart 4 presents the main groups of people involved in the context of Industry 4.0 by Pfeiffer et al. (2016), and some of the key human competencies.

| Profession                    | Competence                                                  | Authors                                                                                                              |
|-------------------------------|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| 1. Project manager            | Ability to follow changes in the global industrial scenario | Gebhardt, Grimm and Neugebauer (2015)                                                                                |
|                               | Future perspective                                          | Do, Yeh and Madsen (2016)                                                                                            |
|                               | Communication at a global level                             | Becker and Stern (2016) and Hecklau et al. (2016)                                                                    |
|                               | Creativity                                                  | Gorecky et al. (2014), Jäger et al. (2015), Hecklau et al. (2016), Romero et al. (2016) and Stock and Seliger (2016) |
|                               | Innovation                                                  | Lee, Kao and Yang (2014), Joerres et al. (2016) and Romero et al. (2016)                                             |
| 2. Developers of technologies | Communication at a global level                             | Becker and Stern (2016) and Hecklau et al. (2016)                                                                    |
|                               | In-depth knowledge of technologies of industry 4.0.         | Gebhardt, Grimm and Neugebauer (2015)                                                                                |
|                               | In-depth knowledge of IT.                                   | Gebhardt, Grimm and Neugebauer (2015), Rüßmann et al. (2015) and Hecklau et al. (2016)                               |
|                               | In-depth knowledge of industrial automation.                | Hecklau et al. (2016)                                                                                                |

|                                                                         |                                                                                                      |                                                                                                                      |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| 3. Developers of system components<br>5. Software developers            | Creativity                                                                                           | Gorecky et al. (2014), Jäger et al. (2015), Hecklau et al. (2016), Romero et al. (2016) and Stock and Seliger (2016) |
|                                                                         | Technologic innovation                                                                               | Joerres et al. (2016) and Romero et al. (2016)                                                                       |
|                                                                         | Communication at a global level                                                                      | Becker and Stern (2016) and Hecklau et al. (2016)                                                                    |
|                                                                         | In-depth knowledge of IT.                                                                            | Gebhardt, Grimm and Neugebauer (2015), Rüßmann et al. (2015) and Hecklau et al. (2016)                               |
| 6. Programmers of robotic and computational systems<br>7. System tester | Communication at a global level                                                                      | Becker and Stern (2016) and Hecklau et al. (2016)                                                                    |
|                                                                         | In-depth knowledge of IT.                                                                            | Gebhardt, Grimm and Neugebauer (2015), Rüßmann et al. (2015) and Hecklau et al. (2016)                               |
| 8. Maintenance operators                                                | Detailed knowledge of technological components and technologies.                                     | Gebhardt, Grimm and Neugebauer (2015)                                                                                |
| 9. Process supervisors                                                  | Communication at a global level                                                                      | Becker and Stern (2016) and Hecklau et al. (2016)                                                                    |
|                                                                         | Efficient language.                                                                                  | Hecklau et al., 2016                                                                                                 |
|                                                                         | Ability to transfer knowledge.                                                                       |                                                                                                                      |
|                                                                         | Careful observation.                                                                                 | Wittenberg (2016)                                                                                                    |
|                                                                         | Sensitivity to predict problems.                                                                     | Jäger et al. (2015) and Joerres et al. (2016)                                                                        |
|                                                                         | Problem-solving ability.                                                                             | Gorecky et al. (2014), Hecklau et al. (2016) and Stock and Seliger (2016)                                            |
|                                                                         | Analytical skills for decision making.                                                               | Hecklau et al. (2016)                                                                                                |
|                                                                         | Flexibility to real-time decision making at the tactical and operational levels of industry, mainly. |                                                                                                                      |
|                                                                         | Flexibility in the control of productive systems.                                                    | Spathet al. (2013), Becker and Stern (2016), Joerres et al. (2016) and Romero et al. (2016)                          |
| 10. Machine operators                                                   | Comprehensive IT knowledge.                                                                          | Gebhardt, Grimm and Neugebauer (2015), Rüßmann et al. (2015) and Hecklau et al. (2016)                               |
|                                                                         | Knowledge of technologies.                                                                           | Hecklau et al. (2016)                                                                                                |
|                                                                         | Flexibility to real-time decision making at the operational level of industry.                       |                                                                                                                      |

Source: Elaborate by the authors from research data (2017).

In order to achieve the competencies explored in this study, the qualification of people thought interdisciplinary professional training is needed (GORECKY et al., 2014; PFEIFFER, 2016).

It is important that each professional presents a set of specific skills. However, an essential requirement for Industry 4.0 is the IT knowledge and characteristics and particularities of intelligent systems and technologies. It was observed a basic and essential need of the contextualization of Industry 4.0 concepts and application.

## 5. Conclusion

Qualifying people for work is one of the primary requirements and can be considered a challenge for industries, research institutions, and governments, who must unite in favor of better policies and practices. Thus, the analysis of real changes and prospects of human work is essential for the qualification of people in the Industry 4.0.

Depending on the industrial sector, certain human competencies and tasks may stand out from others, due to the divergence of processes in the automotive, food and other sectors.

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