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Forecasting the future shape of factories based on the laws of technical systems evolution

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ABSTRACT: Based on the perspective of system evolution, this paper uses the life curve theory in TRIZ theory, two independent Laws of technical systems evolution and six technological system evolution route theories to reasonably predict the future development trend of the manufacturing system represented by the factory. The system It discusses the future development direction of the factory comprehensively and theoretically. That is: the future factory will show the development trend of high density, efficiency, flexibility, miniaturization, intelligence, agglomeration and collaboration.

KEYWORDS:TRIZ theory, Factory, Laws of technical systems evolution, Development trend, Industry 4.0.

I. INTRODUCTION

TRIZ theory, the full name of which is teoriya resheniya izobretatelskikh zadach, is a highly efficient and modeled method for realizing inventions. In 1946, Dr. Altshuller of the former Soviet Union studied a large number of patents around the world, and extracted and summarized a set of method theories for solving inventions, that is, the classic TRIZ theory. The law of technological system evolution is a traditional tool of the classical TRIZ theory. On the basis of system engineering, this theory combines contradictory tools in TRIZ theory, with idealization as the ultimate goal. Among various invention methods, only TRIZ theory has a complete theory of the evolution law of technological systems[1].

After the 21st century, the research on TRIZ has become more diversified, and many scientific research achievements have emerged.Ruey-SenChiu and Shao-TsaiCheng et al [2] developed a new type of thermal insulation coating for colored steel structure roof panels based on the TRIZ theory, which improves the reflectivity and thermal insulation performance, and can save up to 24% of electrical energy The above greatly reduces the consumption of energy. DombE and KowalickJ et al. [3] used the TRIZ theory to design three new types of airbags, which solved the problems of high and low deployment thresholds and difficulty in determining the expansion power of traditional airbags. While protecting the driver, To the greatest extent, all car passengers are protected. ZHANG et al. [4] used TRIZ technology system evolution law as a tool to analyze the development status of the three-dimensional garage, proposed the evolution route of garage automation, spherification, intelligence, standardization and multi-system, and summarized the conceptual design of the three-dimensional garage. new model. With the continuous development of TRIZ theory, various enterprises have gradually paid attention to the research of TRIZ theory. The TRIZ theory has been widely used in enterprises such as ZTE Corporation of China, Boeing Corporation of the United States, Siemens Corporation of Germany, Ford Corporation of the United States, and Samsung Group of South Korea. It has brought good economic benefits and strong innovation capabilities.

Factories are the cornerstone of modern society, and they provide humans with a wide variety of products, including food, clothing, medical care, entertainment, and more. However, there are not many studies on predicting the future shape of factories in academia, and there is even more research on combining the evolution laws of technological systems. In order to meet the transformation of Industry 4.0, which is dominated by intelligent manufacturing, and accelerate the deep integration of traditional industries with intelligence, this paper introduces the laws of technological system evolution in TRIZ to summarize and predict the development of factories.

II. METHOD

The laws of technological system evolution is one of the important tools of TRIZ theory. It was originally derived by Mr. Altshuller, the founder of TRIZ theory, and his disciples by summarizing a large number of technological systems. Mr. Altshuller believes that technical systems, like living things, will continue to evolve over time according to certain laws. The most groundbreaking point of the law of technological system evolution is that it provides a systematic and theoretical prediction method for the future form of the system from a development perspective for the first time. The laws of technological system evolution include tools such as life curve theory, eight laws of evolution, and technological system evolution routes[5].

The specific content of the life curve tool is: a technical system, the relationship between its performance parameters and development time will generally show the shape of a capital letter "S". Therefore, the life curve is also called the "S" curve. Mr. Altshuller divided the technical system into four stages according to the S-curve, namely infancy, rapidgrowth, maturity and decline. The relationship between life curve performance parameters, number of patents, invention level, economic benefits and development time is shown in Figure 2-1.

As scholars have gradually deepened their research on TRIZ theory, many new TRIZ theories and tools have emerged, but most of them focus on supplementing tools such as contradictions, functional parameters, invention principles, and standard solutions. There are few new theories on the laws of technical systems evolution.

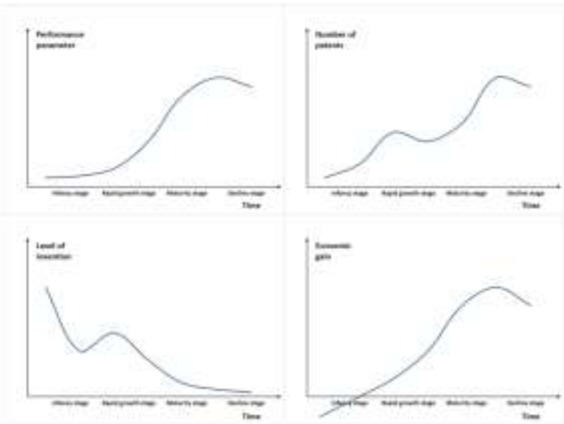

Figure 2-1 Relationship between life curve attributes and time

The laws of technological system evolution were summarized by Mr. Altshuller and his disciple Petrov on the basis of the S-curve. They are the law of system completeness, the law of energy conductivity, the law of harmonization, the law of dynamic growth, and the law of Irregularity of system's part evolution, The law of increasing ideality, the law of transition from macro to micro leveland the law of transition to the super system. The laws of technological system evolution elaborate on the possible evolutionary direction of the system in more detail and reveal the objective laws of system evolution.

When a technical system evolves, in addition to following the eight laws of technological system evolution, it often develops along a clearer evolutionary route of the technical system. The technological system evolution route is a more specific description of the eight evolutionary laws. Compared with the eight evolutionary laws, the technological system evolution route is more convenient to apply to a specific technical system and is more operable.

The main work of this paper is to use the life curve tool to determine the development stage of the factory system, and to use the eight evolutionary laws and the technology system evolution route tool to predict the future shape of the factory, while providing a route reference for factory improvement.

III. LIFE CURVE ANALYSIS

In the TRIZ system, depending on the life cycle stage of the technical system, the frequency

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of the evolutionarylaws of the technical system that it applies to is also different. The corresponding relationship between the two is shown in Figure 3-1, which reflects the different stages of the technical system. The life cycle should primarily refer to the laws of evolution.

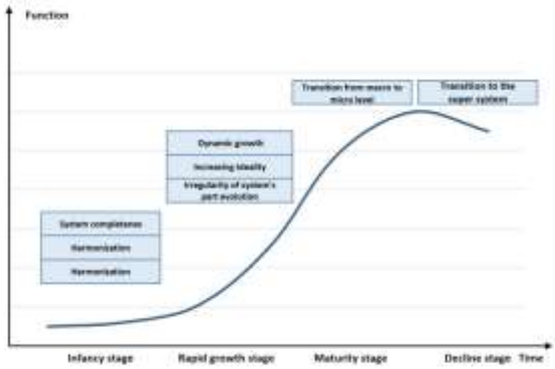

Figure 3-1 Correspondence between life cycle and evolutionary law

In this section, we will use the life curve for preliminary analysis, and use the Darrell Mann rapid diagnosis method to determine which stage of its life cycle the current factory system is in, focusing on using the corresponding evolutionary laws and technical system evolution routes to improve the system. The corresponding relationship between life cycle, evolution law and technology route is shown in Figure 3-2.

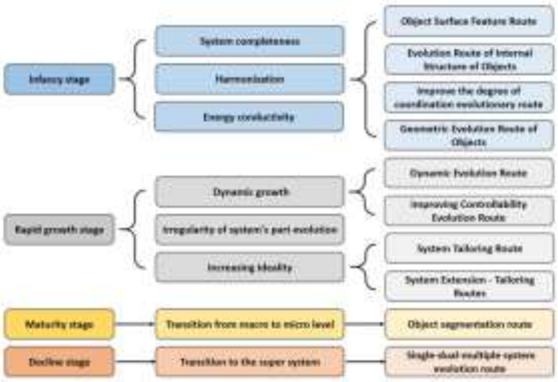

Figure 3-2 Correspondence between life cycle, evolutionary laws and evolutionary routes

When it comes to complex systems, it is often encountered that it is impossible to make a precise level positioning of the system. In this regard, American Darrell Mann proposed a simplified patent analysis level method, through the number and level of system-related patents, to determine the location of the system. The specific judgment method is as follows.

- Infancy stage: The process of a product from scratch belongs to the infancy stage. During this stage, the number of patents is small, but the level of invention is relatively high;
- Rapid growth stage: The period of continuous improvement of functions is called the rapid growth stage. During this stage, many patents appear to realize the functions of the product from different angles;
- Maturity stage: When functions are continuously improved and patents reflect solutions to other problems, it is a mature stage;
- Decline stage: When the function no longer meets the demand, it enters the decline stage. At this time, an alternative product will appear to meet the demand, and a new product will emerge as the times require.

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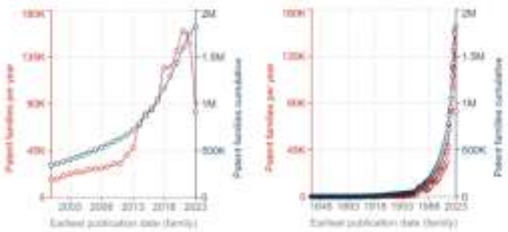

Figure 3-3 Number of factory-related patents

Based on the European Patent Office data, we searched and analyzed factory-related patents. We found that currently, factory-related patents are constantly emerging, and the types are focused on continuously improving the functions of the factory. Therefore, the current factory system belongs to the rapid growth stage. From the correspondence between the S-curve life cycle stages and the evolution laws of technical systems, it can be seen that for systems in the growth stage, the law of dynamic growth, the law of irregularity of system's part evolution, and the law of increasing idealityshould first be considered ; Secondly, you can also consider the evolutionary laws corresponding to other stages, and improve the factory system by comprehensively using the evolutionary laws and the technological system evolution route.

IV. ANALYSIS ON THE EVOLUTION LAW OF TECHNOLOGY SYSTEM

In this section, we will use the evolutionary laws and evolutionary routes corresponding to growth-stage systems to predict the future shape of the factory.

4.1 Dynamic growth

The law of dynamic growth means that the system should evolve in the direction of increasing flexibility, controllability and mobility in structure. As the dynamic nature of its structure increases, the entire technical system will also show a dynamic trend. The specific content of the dynamic evolution law is as follows:

1. Evolve the system in a direction that can increase flexibility
2. Evolve the system in a direction that can increase mobility (divisibility)
3. Evolve the system in a direction that increases controllability

There are two evolution routes for law of dynamic growth, namely the dynamic evolution route and the improving controllability evolution route. We analyze based on the specific content of the above two evolutionary routes.

4.1.1 Dynamic evolution route

The specific content of the dynamic evolution route is: by adjusting the internal parameters of the system, such as shape, temperature, speed, etc., the elements inside the system have degrees of freedom, so as to coordinate with the system environment, so that the system can better adapt to external changes. Its typical evolutionary route is shown in Figure 4-1.

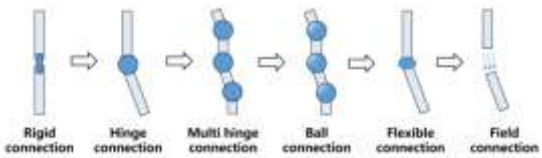

Figure 4-1 Dynamic evolution route

Bring the dynamic evolution route into the factory system. Before Industry 1.0, factories with waterwheels as the power system had machines that needed to be in fixed locations to complete production and had extremely low mobility; during Industry 1.0, factories can be driven by steam power, eliminating the need to be built next to a river. However, steam-driven machines are bulky, often difficult to move, and their dynamism is relatively low; during the Industry 2.0 and Industry 3.0 periods, factory logistics systems developed rapidly, and factories during this period achieved dynamism through logistics; Industry 4.0 and even future factories may realize the dynamization of machinery and equipment, that is, the vast majority of machines in the workshop are presented in a modular manner and can be moved and arranged arbitrarily. If a certain model does not need to be processed by this machine, Then the machine can be quickly transferred off the production line. By combining it with an intelligent material handling system, the efficiency of the factory's production of different types of products can be improved.

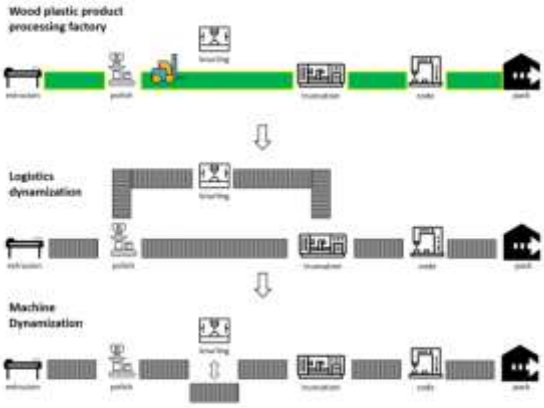

Figure 4-2 Dynamic evolution route of the factory

The goal of factory dynamics is to achieve flexibility, that is, the ability to replace a product in production with another product. Take wood plastic product factories as an example. In traditional wood plastic product factories, different types of wood plastic products need to be manufactured using different processing machines or even in different workshops. In the future flexible factory, these products can be produced on one production line, as shown in Figure 4-3.

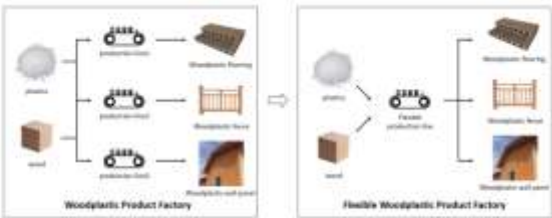

Figure 4-3 Flexible factory

4.1.2 Improving controllability evolution route

The goal of improving controllability is to reduce the interaction between users and technical systems, and ultimately realize the automatic response of technical systems to changes in the external environment. The steps of its evolution route are relatively fixed, generally evolving from manual control to semi-automatic control and automatic control. As shown in Figure 4-4.

Figure 4-4 Improving controllability evolution route

Improving controllability is the key goal of factory improvement since Industry 3.0, and it is also the direction for Industry 4.0 to make breakthroughs. Industry 4.0 integrates cyber-physical systems (CPS) into existing manufacturing systems, and factory control systems have developed rapidly. The factories of the future will be deeply integrated with the industrial Internet, and artificial intelligence, big data, and intelligent algorithms will make most decisions on behalf of humans. The manager logs into the CPS system, uses the Internet of Things technology to control the production machine, cooperates with the automated production line to complete the production, and gets feedback through the visual information platform. Intelligent production

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equipment greatly enhances the overall controllability of the factory, and the number of workers participating in front-line work will be greatly reduced. The responsibilities of most workers will be transferred to product development, brand operation, equipment innovation and other mental work.

Figure 4-5 Improving controllability evolution routeof the factory

4.2 The Law of Increasing Ideality

The ideality of a technical system can be expressed by the following formula:

$$\text{Ideality} = \frac{\sum \text{Beneficial function}}{\sum \text{Harmful function} + \text{Cost}}$$

Therefore, the essence of improving the ideality of technical systems is to maximize the useful functions of technical systems and minimize the harmful functions and costs of technical systems. The ideal system of classic TRIZ has the following basic conditions:

1. The energy required for system operation is 0
2. The space occupied by the system is 0
3. The manufacturing cost of the system is 0

The above three requirements can be regarded as the ultimate direction of the development of the factory system, and the final factory should be close to the ideal conditions. In this design, we use the system clipping route to deduce the development trend of the factory. The content of the system tailoring route is shown in Figure 4-6. In simple terms, it is to realize the evolution of the system by removing the elements in the system. Compared with the original system, the new system has lower cost, smaller size and stronger stability.

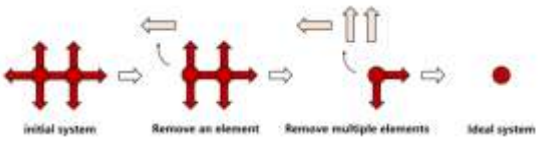

Figure 4-6 System tailoring route

Through the development and evolution of factory building systems, in the mid-20th century, factory buildings once had a style that emphasized beauty in size. It was not until the second energy crisis broke out in 1979 that the scale of factory buildings gradually became smaller. At present, the area of most factory buildings is controlled between 20,000 square meters and 80,000 square meters, and it is developing in the direction of reducing floor space and increasing equipment density. At the same time, the number of two-story and multi-story factories is gradually increasing. Combined with the system cutting route, the factory will achieve the final development direction of miniaturization by cutting out redundant elements.

4.3 The law of harmonization

In the traditional TRIZ theory, the harmonization of the technical system is mainly reflected in the coordination between the external shape, internal structure, performance parameters, material properties, carriers that realize functions and the actions issued by the various subsystems of the technical system, and through the subsystems The mutual coordination of systems reduces internal friction to improve the performance and efficiency of the entire technical system.

There are many evolutionary routes for the coordinated evolution law, including the object geometry evolution route, the evolution route to improve the degree of coordination, the internal structure evolution route of the object, and the object surface feature route, etc. This design mainly uses the object geometry evolution route and the evolution route to improve the degree of coordination to predict the future development of the factory system.

4.3.1 Object geometry evolution route

The object geometry evolution route is a representative evolution route of the coordinated evolution law. Its content is: geometry has a tendency to evolve from a simple structure to a complex structure, generally starting from a point, and evolving towards a line, a surface, and a body,

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as shown in Figure 4-7. Taking mechanical processing technology as an example, the initial mechanical processing relied on lathes, drilling machines, milling machines, etc., and then gradually evolved into laser cutting. Until now, 3D printing technology has confirmed the evolution route from line, surface to body.

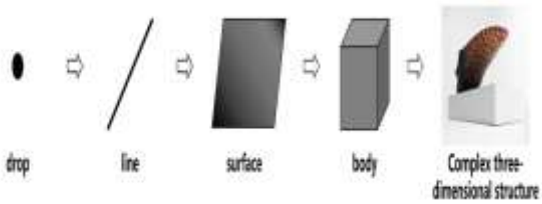

Figure 4-7 Object geometry evolution route

At the beginning of its birth, the factory was limited by the level of industrial buildings and appeared in the form of a single-story building structure. As early as the 1940s, factories with multi-story building structures appeared. Since then, industrial buildings with multi-story building structures began to develop rapidly. The building structure of future factories may be adapted to the products they produce. By adjusting the factory structure to achieve optimal logistics routes and facility layout, high-efficiency production can be achieved, and eventually developed into high-density factories similar to machines.

Figure 4-8 The object geometry evolution route of the factory

4.3.2 Improve the degree of coordination evolutionary route

The content of the evolutionary route to improve the degree of coordination is to adjust the parameters of each subsystem of the system so that each subsystem is relatively coordinated during operation, thereby achieving the stability of the entire system. There is no end to the improvement of system coordination. Absolute coordination can only be achieved in an ideal system. Therefore, compared with static coordination, designers should consider achieving dynamic coordination as the goal of improving the degree of coordination. The specific route is shown in Figure 4-9.

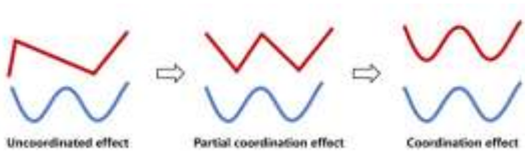

Figure 4-9 Improve the degree of coordination evolutionary route

Bring the factory system into the improve the degree of coordination evolutionary route. The initial factory implemented extensive production, resulting in a large amount of work-in-process inventory; later, assembly line production appeared. By setting up workstations, the production line rhythm became consistent and reduced a large amount of work-in-process inventory; future factories may adopt similar methods The fieldbus control system realizes dynamic control of production efficiency by connecting processing equipment to each other, thereby minimizing the inventory of in-process products and achieving stable operation of the entire factory system.

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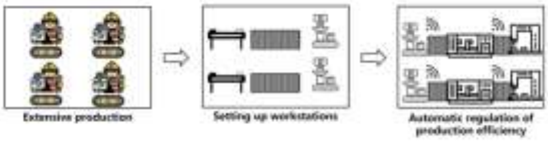

Figure 4-10 Improve the degree of coordination evolutionary route of the factory

4.4 The law ofirregularity of system's part evolution

The content of the law of irregularity of system's part evolution is: different parts of a technical system will have their own evolutionary routes, and their evolutionary speeds are not the same, and there are gaps in the development of parts, which will affect the performance of the technical system. Therefore, in order to improve the overall performance of the system, it is necessary to maintain coordination among the various parts.

There is no corresponding technical system evolution route for the law of irregularity of system's part evolution, so we analyze it from the aspect of content. Traditional TRIZ divides the parts of the technology system into four major systems, which we bring into the factory system and show the evolution trend of each part, as shown in Figure 4-11.

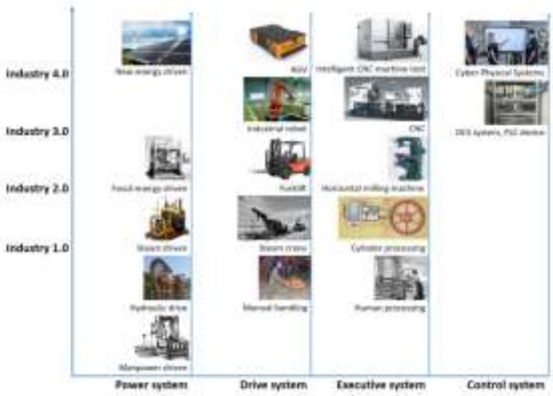

Figure 4-11 Evolutionary trends of various parts in the factory

Through analysis, it was found that before Industry 1.0., each system mainly relied on manual operation. Industry 1.0 brought a steam-driven power system to the factory, so the transmission system, execution system, etc. have also evolved; during the Industry 2.0 period, the evolution of the power system mainly came from the invention of electric motors, and the evolution of the transmission system was caused by the invention of the internal combustion engine. Leading; In the era of Industry 3.0, the leap-forward breakthrough of electronic computers has led to the development of CNC machine tools and industrial robots, and the execution system, transmission system, and control system have been innovated; now that Industry 3.0 and Industry 4.0 are alternating, the control system of the factory has developed the most Rapidly, the control system at this time belongs to the development stage, and its performance parameters and application scope have increased rapidly, which has also led to the evolution of the transmission system and execution system; while the execution system and transmission system belong to the mature stage, and the technical system at this time has already Encountering bottlenecks, it is difficult to achieve breakthrough progress, but the additional functions of the system are gradually increasing, the integrity is still improving, and there is still room for development; the power system has reached a period of decline, and due to the lack of theoretical breakthroughs for a long time, its development It is stagnant and will soon be replaced by new technology systems (new energy systems) with the same functions. Therefore, the recent development of factory systems will be driven by the evolution of control systems. Factories will continue to evolve towards highly developed control systems, that is, in the direction of intelligence. The next leap in development of the factory will most likely be driven by technological breakthroughs in the power system, such as the popularization of new energy, nuclear fusion technology, and superconducting technology, as shown in Figure 4-12.

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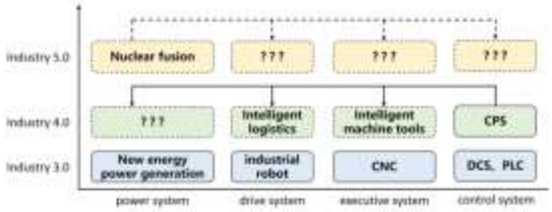

Figure 4-12 Unbalanced evolution of factory

4.5 The law ofEnergy conductivity

The core content of the law of energy conductivity includes the following three points:

- The development of technical systems will shorten the path of energy flow to reduce energy loss during energy conductivity.
- When the energy of the technical system is transmitted to each system component (subsystem or component), it must be guaranteed to be smooth and unimpeded.
- Technological systems will develop along the lines of reducing the number of energy conversions.

There is no corresponding technical system evolution route for the law of energy conductivity, so we analyze it from the aspect of content.

4.5.1 Energy conductivity process

Before the first industrial revolution, the heat conversion efficiency of steam engines was generally less than 3%; after Watt improved the steam engine, the heat conversion efficiency of steam engines could reach 8%; the heat conversion efficiency of generators was generally 35% to 38%. At present, There are even generators with a heat conversion efficiency of 42%. It can be found from this that in the continuous development of Industry 1.0 to Industry 4.0, the power system provides the same energy to the outside world, and the energy required is actually gradually decreasing. Therefore, the development of the power system is the basis for the factory to approach the ideal system.

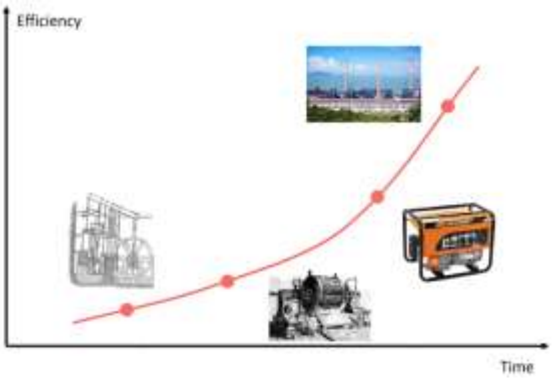

Figure 4-13 Development of power system

In addition to the development of power systems, factories should also minimize energy waste to ensure that the total energy required for operation is the lowest. Nowadays, academic circles generally divide the waste generated in manufacturing into nine major wastes. At present, how to solve the nine major manufacturing wastes within the factory is still a problem that every industrial engineer must face. The factory of the future will reduce waste as much as possible and use all energy for effective operations. In addition, the factory should also reduce the paths of energy flow and the number of energy conversions. In future factories, their machines and equipment will use direct power supply as their main energy source, and machines that use oil, coal, and batteries as their main energy sources will be eliminated. Circuit planning in the early stages of factory construction will become more important. Some large factories or industrial parks will be located near power plants to avoid power losses caused by long-distance transmission. Power storage facilities will be generally set up within the factory to avoid losses caused by temporary power outages.

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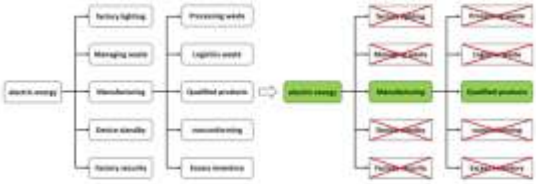

Figure 4-14 Improvement of energy conductivity in the factory

4.5.2 Information conductivity process

The energy conductivity in the classic TRIZ theory focuses on the energy conductivity process and ignores the information conductivity rules. In modern manufacturing, the transmission of information also plays an important role. The information conductivity here can be understood from three aspects, one is the information conductivity within the enterprise, the second is the information conductivity between enterprises and the third is the information conductivity between enterprises and consumers. The specific development trends are:

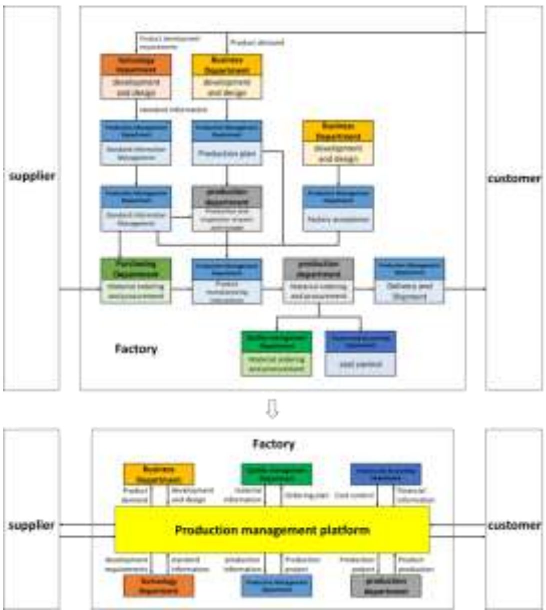

Figure 4-15 Improvement of internal information transmission within the enterprise

1. Within the enterprise: During the first industrial revolution, the factory-style organizational model was born, and detailed rules and regulations were formulated to ensure the smooth progress of production. Information conductivity at this time was usually linear person-to-person; during the second industrial revolution, as the production process of products became more complex, a departmentalized company system was born, and the information conductivity method at this time also evolved into intra-departmental Implement the method of information sharing and linear transmission of information between departments; in the era of Industry 3.0, the promotion of the business unit system has made the information sharing method between companies within the enterprise more mature. In Industry 4.0 and even future enterprises, a unified visual production management platform will be built internally. Each department in the factory will achieve in-depth information sharing and resource integration, and the cost of inter-departmental communication will be greatly reduced. In the product manufacturing process, each department will achieve collaborative control through the production management platform, as shown in Figure 4-15.

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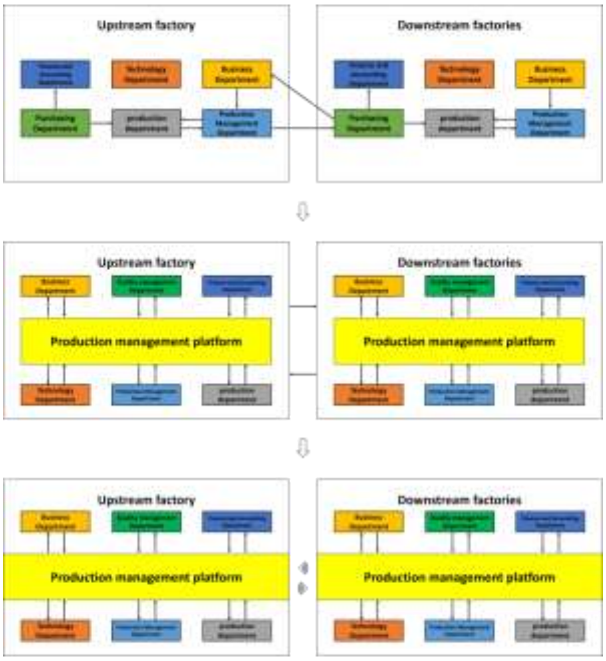

Figure 4-16 Improvement of information conductivity between enterprises

2. Between enterprises: At present, the responsibility for communication between enterprises is often the responsibility of specific departments. Communication through this method has long delays and low efficiency, and it is often impossible to obtain internal production information within the factory in the first time. Enterprises in the Industry 4.0 era and in the future will realize information sharing within the factory and improve the efficiency of external communication by building a unified visual production management platform. Eventually, the production management platforms upstream and downstream of the supply chain will be integrated with each other. Downstream companies can formulate production plans based on the supply situation of upstream companies, and upstream companies can determine production capacity demand plans based on the sales of downstream companies, ultimately achieving market control. Quick response, as shown in Figure 4-16.

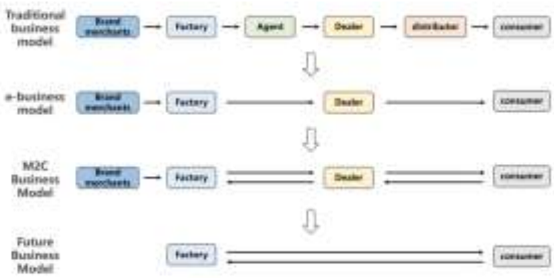

Figure 4-17 Improvement of information conductivity between enterprises and consumers

3. Between enterprises and consumers: In the traditional business model, there are dealers at all levels between factories and consumers, and some factories also rely on agents to sell products. Sellers and agents at all levels, as intermediaries between factories and consumers, not only promote the sales of goods, but also affect the information transmission between factories and consumers. When implementing traditional business models, it is difficult for consumers' opinions and feedback to be transmitted to factories. Later, electronic business models emerged. The electronic business model reduces the number of agents and sellers at all levels, lowers sales costs, and creates the possibility of communication between factories and consumers. Some merchants communicate directly with consumers by opening self-operated stores. Now, based on the electronic business model, some factories have implemented the C2M business model, that is, the factory collects consumer

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demand through various e-commerce platforms and then feeds it back to production. Through product adjustments, the factory's production efficiency is improved, and the factory's inventory backlog and operational pressure are reduced. In the era of Industry 4.0, with the popularization of virtual simulation design, remote monitoring and other tools and the rapid development of the logistics industry, the traditional business model of dealers acting as agents will be broken, and the new model will be carried out directly by consumers and factories. Communication business models will emerge. Through direct communication with the factory, consumers can participate in the production process, realize customized production through online design and product combination, and provide direct feedback to the factory. Its development process is shown in Figure 4-17.

4.5.3 Law of transition to the super system

The law of transition to the super system is generally reflected in the collaborative optimization and recombination of different systems. The content is: the technical system will develop from a single technical system to a dual technical system or even a combination of multiple technical systems. That is, when a technical system develops to a certain stage and its functions cannot meet the needs, the technical system may be combined with other technical systems to meet the needs. When its functions fall behind the needs again, it may be combined with more technical systems. merge.

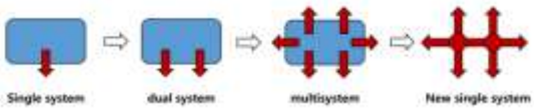

Figure 4-18 Single-dual-multiple system evolution route

The technical system evolution route corresponding to this rule is the single-dual-multiple system evolution route, as shown in Figure 4-18. Its specific content is: to achieve more functions by adding other complete technical systems to a single system. When the introduced system reaches a certain amount, it can even form a brand new single system different from the original system, that is, "quantitative change causes qualitative change".

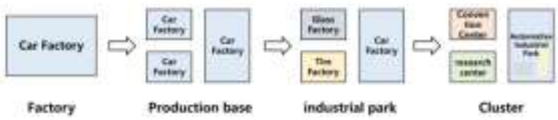

Figure 4-19 The single-dual-multiple system evolution route of the factory

According to the law of transition to the super system and the single-double-multi system evolution route, we predict the development of future factory systems: due to the underdeveloped logistics system, the initial factories are often built in locations close to urban areas. Factories are relatively independent; during the third industrial revolution, as the scale of industrial enterprises continued to expand, factories developed in the direction of large-scale and joint operations, and production bases composed of multiple factories of the same type began to emerge. At present, industrial parks composed of multiple factories of the same type, upstream and downstream of the supply chain, and dedicated industrial facilities are becoming the mainstream factory model. In the future, they may develop into industrial parks with huge industrial volumes, supporting scientific research institutes, and living facilities. Industrial clusters. After the agglomeration effect is formed, the factory's logistics costs, publicity costs, and recruitment costs will be reduced accordingly, and even relevant policies will be more conducive to the operation of the factory.

V. CONCLUSION

In this paper, we use six evolutionary routes: dynamic evolution route, improve the degree of coordination evolutionary route,improving controllability evolution route, system tailoring route, object geometry evolution route, single-double-multiple system evolution route; Two evolutionary laws:irregularity of system's part evolution and energy conductivity to predict the future form of the factory system. And it is concluded that the factory system will develop in the direction of miniaturization, high density, efficiency, intelligence, agglomeration, collaboration, and flexibility in the future, as shown in Figure 5-1.

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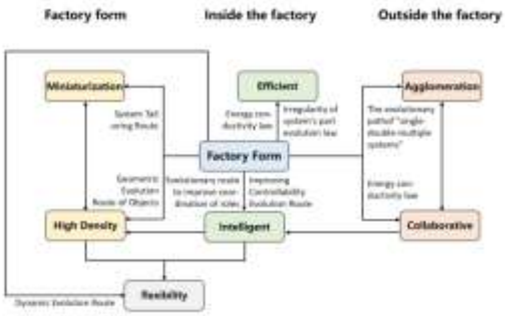

Figure 5-1 Future development trends of factories

- Efficiency: Looking at the history of several industrial revolutions, it is not difficult to find that the outbreak of each industrial revolution is inseparable from the rapid development of productivity. The first two industrial revolutions brought breakthrough changes to the power system of the factory. Industry 3.0 and Industry 4.0 achieved a leap in efficiency through automation and intelligent revolutions respectively, and their essence is to greatly improve the efficiency of energy utilization. The future factory will also continue to develop in the direction of further optimizing production efficiency through continuous innovation of power systems and continuous improvement of energy utilization efficiency.
- Flexibility: As personalized and differentiated products are increasingly welcomed by the market, multi-variety and small-batch production methods are becoming mainstream. The product will be split into multiple modules according to its structure. Users can design and combine products online through tools such as virtual simulation design and remote monitoring, and directly participate in the production process. Correspondingly, the factory's production line will also be spliced by a number of different modules, and the corresponding modules will be adapted to complete production according to the product model and structure to meet the customized needs of customers. Unlike the current situation where the factory realizes multi-variety and small-batch production by assembling products from different production lines in the final stage, the future factory will use IoT technology to accurately position products and realize high-efficiency and automated multi-variety production on the production line. Produced in small batches.
- High density and miniaturization: With the improvement of factory flexibility, its production line will also be presented in a modular manner, and the efficiency of the material handling system will continue to improve. Even the machine can be moved and arranged at will, and the staff No longer directly participate in the front-line production work, the production tasks will be issued by the core control system. Therefore, in the future smart factory, its production equipment must be highly intensive. High-density production equipment will significantly reduce the construction and operating costs of the factory, and the factory will develop in the direction of miniaturization and intensification.
- Intelligence: In the environment of Industry 4.0, with sensors and network interfaces, it can sense the current production progress and processing progress, and use the network to conduct big data analysis and machine learning to form optimal decision-making intelligent production equipment. Become mainstream and further promote the construction of smart factories through intelligent methods such as industrial Internet, digital twins, cloud computing, and machine learning. Data will become a new factor of production and will further become a key point for enterprises to compete with each other. The role of data will not only be limited to production aspects such as finding suppliers, generating quotations, calculating delivery times, and delay warnings. Sales data will also be reflected in production, and product production will be adjusted based on consumer feedback to form a "design- - production - sales "closed loop.
- Collaboration: The future collaborative production of factories will be reflected in two aspects. Internally, each enterprise will build a unified production management platform. Based on this platform, in-depth information sharing and resource integration will be achieved within the factory; internal

production, operations, management, sales, procurement and other departments of the enterprise will be highly Integrate and jointly participate in the product manufacturing process. At the same time, the human-computer interaction method inside the factory will also be greatly upgraded, and the new interactive equipment will achieve a high degree of comfort, flexibility, and ergonomics; externally, different companies will form networks with each other, and the division of labor among the companies will be It will be specialized and refined, and the upstream and downstream of the supply chain will realize the integration of production management platforms. Its raw material supply, in-process processing, and finished product distribution will all achieve rapid response, systematic execution, and high-efficiency transportation, minimizing shortening. The production cycle of the product reduces the cost of collaborative manufacturing.

As the carrier of industry, factories continuously produce a large number of production materials and consumer goods for modern society. It can be said that factories have produced our modern world. In the foreseeable future, the smart factory defined by Industry 4.0 is slowly approaching us. How to combine the new generation of smart technology with manufacturing technology to ultimately achieve high density, efficiency, flexibility, miniaturization, intelligence and collaborative smart factory will be the direction that every manufacturing worker needs to work on for a long time.

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