

# Study on the Evolution and Law of Manufacturing Chain Manufacturing Innovation Chain - Manufacturing Innovation Methods Chain

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## Abstract

*Manufacturing Innovation Methods Chain (MIMC) is not only the deepening and sublimation of innovative methods, but also the development trend of Chinese manufacturing industry, attracting common attention from industry and academic circles. The work reviewed the evolution of manufacturing chain - manufacturing innovation chain - manufacturing innovation methods chain. Theoretical and realistic basis of innovation chain was analyzed, revealing the characteristics of MIMC. Finally, measures and suggestions were proposed for the MIMC's application manufacturing industry in China.*

**Keywords:** *Manufacturing innovation methods chain; manufacturing chain; manufacturing innovation chain*

## 1. Introduction

Innovation refers to a conceptual process with characteristics—new thinking, new inventions and new description. It is also the unique cognitive ability and practical ability of human and driving force to promote national progress and social development [1]. In terms of innovation process, there are general rules and generic methods, even if no universal method and fixed mode exist. Especially, innovation activities are active in manufacturing, thus various innovative experience, principles, methods and tools are urgent to be summarized and refined to set up a system of innovation methods. Thinking and exploring manufacturing innovation methods chain is necessary and feasible, proved with practice in the world. From manufacturing chain to manufacturing innovation chain to manufacturing chain innovation method, each concept transition reflects great, profound changes in manufacturing. The concept of manufacturing innovation methods chain is not proposed by accident, but the inevitable outcome of manufacturing chain and manufacturing innovation chain in advanced stage. Further research on the development of manufacturing chain-manufacturing innovation chain-manufacturing innovation methods chain contributes to the understanding of attribute characteristics. Thus the evolution rule can be grasped to explore its application.

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## 2. Evolution of Manufacturing Innovation Methods Chain

Innovative method is not prescriptive but heuristic one. Innovation method can reduce the blindness and uncertainty of innovation to a certain extent, but there is no method ensuring the inevitable success of innovation on the whole. The attempt—seeking rules or channel for ensuring success of innovation through innovative methods—is the misunderstanding of innovation process and innovation method. Although being essentially a kind of heuristic methods, innovation still makes sense to improve the efficiency of innovation. Various conditions of innovation can be clearly understood through continuously discovering and enriching instructive ways to promote innovation. The influence of different factors on innovation can be identified to avoid blindness of innovation [2].

### 2.1. Change from Manufacturing Chain to Manufacturing Innovation Chain

Manufacturing chain, as the most basic unit of manufacturing and the most basic manufacturing activity chain, determines the key links of operation in supply chain. Its competitive ability reflects the power level of manufacturing industry [3]. Manufacturing chain aims at product realization—achieving ultimate goal (See Figure. 1) from obtaining technology to materializing technical achievement in product design, through product manufacturing process. High-level manufacturing chain can produce competitive products and reduce product inventory. Production cycle can be shortened to reduce production cost, thus ensuring products quality. Therefore, user requirements can be quickly satisfied to improve the overall efficiency of enterprises and market competitive ability.

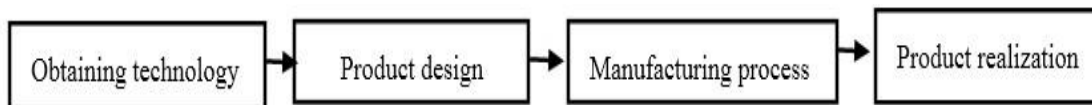


Figure 1. Typical Structure of Manufacturing Chain

In the development of manufacturing chain from junior level to senior level, complete innovation chain (See Figure 2) in enterprises should be gradually established to support comprehensive competitiveness of manufacturing chain. Innovation chain can be understood from the following aspects. One or more innovation subjects are regarded as the core around an innovation goal. Meeting market demand and raising value are taken as the guide through series of organized and systematic innovation activities [4]. The target function chain of related participants in innovation is connected, thus realizing the optimization of innovation object and innovation system. From the structure, manufacturing innovation chain is based on innovation process separated from specific manufacturing chain. Six links are involved in manufacturing innovation chain, including demand analysis, idea generation, product research and development, knowledge materialization, product manufacturing and market realization. Ideal innovation chain can automatically search innovation target in the market, driving innovation activities of each link in manufacturing chain. Meanwhile, system innovation can be spontaneously completed throughout the whole life cycle of products.

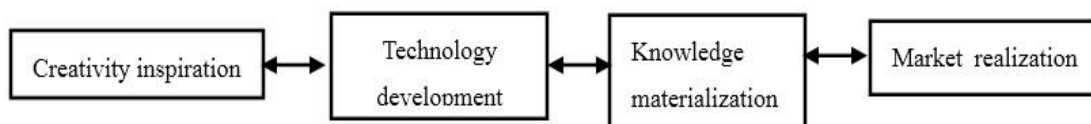
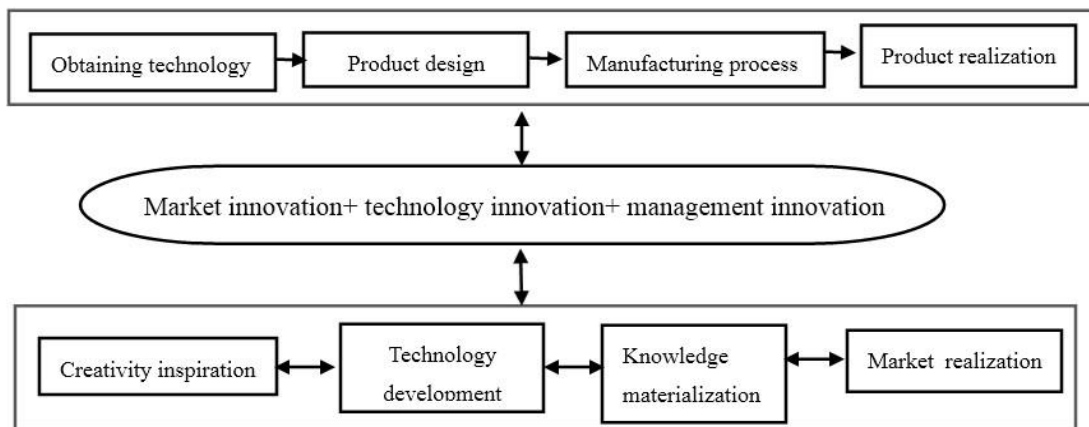


Figure 2. Typical Structure of Innovation Chain

Further development of manufacturing chain to advanced stage will be promoted with the support of innovation chain. Thus, it objectively requires three-dimensional collaborative innovation of market, technology and management. Maximum utility of manufacturing chain will be difficult to realize without good synergy among markets, technology and management; if three-dimensional collaborative innovation can be realized, not only the proper roles can be fully played, but also the synergy effect of "1 + 1 > 2" can be exerted among them [5]. Therefore, the innovation capacity and performance of manufacturing chain can be enhanced to drive sustainable growth of enterprises. As manufacturing chain and manufacturing innovation chain develop to a certain stage, it will inevitably aim at realizing the three-dimensional collaborative innovation of technology, market and management. The integration of manufacturing chain and innovation chain can be achieved to structure manufacturing innovation chain (See Figure 3). Building manufacturing innovation chain for enterprise is the integration process of various internal innovation resources. Finally, the integration of manufacturing resources and innovation resources can be realized in enterprises.

Manufacturing innovation chain consists of manufacturing chain and innovation chain. The two sub chains are connected by the objects—three-dimensional collaborative innovation of market, technology and management. Manufacturing chain is the foundation, providing carrier for value realization of innovation chain and advanced practice conditions; Innovation chain is knowledge origin of manufacturing chain, ensuring the maximization of products value in manufacturing chain; Three-dimensional collaborative innovation is the goal—the power source promoting the integration of manufacturing chain and innovation chain.



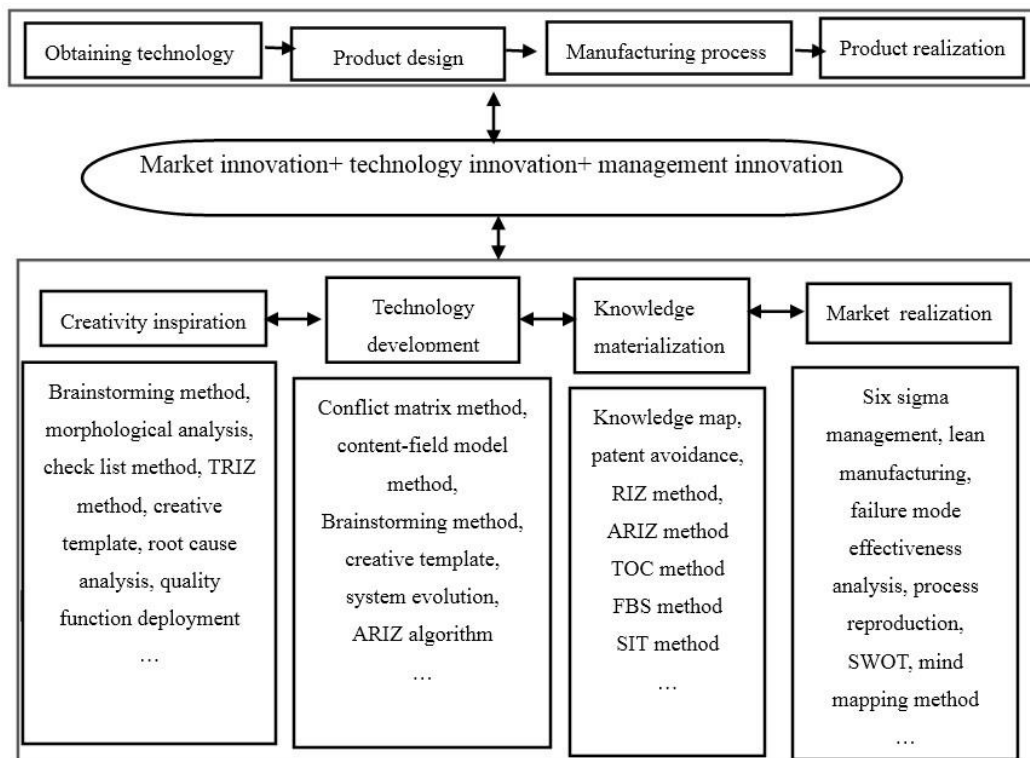
**Figure 3. Structure of Manufacturing Innovation Chain**

## 2.2. Transformation from Manufacturing Innovation Chain to Manufacturing Innovation Methods Chain

Manufacturing chain is not automatically transformed into manufacturing innovation chain in enterprises. The important way to achieve the transformation is the application of innovation method. Various and distinctive method groups emerges in every link of manufacturing innovation chain. The innovation methods can be screened and systemically designed, and the organic connection between different methods can be strengthened, thus making up innovation methods chain based on manufacturing innovation chain [6]. Innovation methods corresponding to each link of manufacturing innovation chain specifically includes: idea generation stage—brainstorming method, morphological analysis, check list method, TRIZ method, creative template, root cause analysis, quality function deployment, *etc.*; technology research and development phase—

conflict matrix method, content-field model method, system evolution and ARIZ algorithm, *etc.*; knowledge materialization stage—knowledge map, patent avoidance, *etc.*; product development phase—FBS, SIT, TRIZ, six-hats-thinking method, *etc.*; manufacturing stage—six sigma management, lean manufacturing, failure mode effectiveness analysis, *etc.*; market implementation phase—SWOT method, mind mapping method, *etc.*

Innovative method has been widely applied to the construction of innovation chain, gradually developing innovation methods chain suitable for enterprises. Eventually, manufacturing innovation chain obtains effective support from innovation chain. The work called the manufacturing innovation chain with effective support from innovation method (chain) as manufacturing innovation methods chain (See Figure 4), which is the highest development level of manufacturing innovation chain. Manufacturing chain innovation method consists of innovation chain and innovation methods chain. Innovation chain is the foundation providing methodology for manufacturing innovation chain; manufacturing innovation chain is the carrier, providing practical conditions for innovation chain. Three-dimensional collaborative innovation of market, technology and management is their common object, finally forming independent innovation ability of enterprises.



**Figure 4. Elements of Manufacturing Method Innovation Chain and Their Relationship**

### 3. Derivation and Innovation of Manufacturing Innovation Methods Chain

#### 3.1. Derivation Characteristics of Manufacturing Innovation Methods Chain

Derivation—development and change for its original meaning—is used to describe the gradual evolution of objects. Development reflects inheritance while change emphasizes innovation. Development evolution of manufacturing innovation chain shows significant characteristics of derivation, which means the product of interaction between inheritance

and innovation. The derivation of manufacturing innovation methods chain can be understood from the following aspects.

Firstly, manufacturing innovation methods chain is derived from traditional manufacturing chain. Manufacturing chain is not only the most basic activity chain, but also the patterns for traditionally developing new product. However, the combination of creativity and development with market is particularly important under current business environment, as requirements cannot be satisfied by traditional manufacturing chain. Traditional manufacturing chain should be supported with innovation ability. Specifically, the core role of creativity, research and development, knowledge should be highlighted before product manufacturing; meanwhile the pull of market to creativity should be focused in production tail. Thus, the modules of creativity and development are emphasized at the forepart of manufacturing chain, while markets realization and market demand analysis are focused in chain tail. And manufacturing chain can be reshaped in all-round innovation, thus constituting manufacturing innovation chain. Then, manufacturing innovation chain should be combined with innovation methods chain, purposefully applying innovative methods to product development, and gradually forming manufacturing innovation methods chain suitable for enterprises.

Secondly, manufacturing innovation methods chain inherits traditional innovation methods rather than building innovation methodology system without foundation. Rich innovation methods have been accumulated in scientific research and production of human, which should be summarized and refined for further popularization and application in enterprises. With opening innovation black box from method, methodology basis can be provided for independent innovation practice of enterprises, thus guiding innovators to find the direction of independent innovation and process of organizing and designing independent innovation. The purpose of generalizing innovation methods is to not only increase innovation efficiency and benefit, but also implant innovation gene into enterprises. Endogenous innovation strength will be generated in enterprises through bringing in innovative methods. Thus, innovation teams are set up to make enterprises truly become independent innovation subjects [7].

Thirdly, composition structure and working mechanism of innovation methods chain is equipped with derivation features. Manufacturing innovation chain consists of six links, each of which has a corresponding method. Demand information of product is acquired through market research. Then, useful design parameters, technical requirements and product constraints will be extracted by designers through demand analysis; product information becomes conceptual product in designing process; in structure design and detailed design of product, technical parameters of the conceptual product will be further concretized, thus determining production requirements, machining accuracy and technological process; products are sold through marketing methods after being processed and manufactured with appropriate materials<sup>[8]</sup>. Whether the development of product is serial or parallel, the phases and their method group are mutually independent and closely related to each other.

### **3.2. Innovation Characteristics of Manufacturing Innovation Methods Chain**

Manufacturing innovation methods chain, sorting method problems in innovation along the main line of idea generation—idea realization, contributes to better organizing and designing innovation process. The re-interpretation of innovation process from innovation methods promotes better understanding of enlightening significance in past successful cases. General rules and methods of innovation practice are summarized, refined, reconstructed and applied to manufacturing innovation methods chain, thus breaking the misunderstanding—innovation process, path and results are all unpredictable, and there is no innovative method. The blindness of innovation behavior can be avoided to save lots of repeated attempts [9]. Nevertheless, people will fall into the opposite extreme contrary to there is no innovation method, with the thought that a universal scheme of innovation

and standard innovation model can be directly provided by manufacturing innovation methods chain. Innovation characteristics of manufacturing innovation methods chain can be understood from the following aspects.

Firstly, innovation is the soul of manufacturing innovation chain. Though inheritance is contained in manufacturing innovation methods chain, innovation is the real power source and soul. Experiences, rules, and methods involving past innovation cases are summarized and refined by manufacturing innovation methods chain, thus building innovation system. Finally, innovation methods with test of practice can be popularized for wide application. This can be activated through innovative thinking to make it work. In other words, the process of innovation can be designed and organized by the combination of past successful methods, and the new way of innovation through the changes and breakthroughs of traditional methods.

Secondly, enterprises should use innovative method and realize the innovation of method to construct manufacturing innovation methods chain. Manufacturing chain innovation method contains two levels of meaning: on the one hand, innovation methods should be mastered for independent innovation; on the other hand, the key of independent innovation is method innovation. The former is called innovation method, and while the latter is innovation of method. Actually, effective use of existing innovation methods contributes to the achievement of innovation, meanwhile discovery and application of new methods is used to break through traditional methods [10]. Some innovations refer to the changes of methods, or major innovation with method changes. Discovery of innovative method and conduction of innovation of method are often two interconnected aspects in complex innovation activities. Research on innovation methods should study innovative methods, and seek innovation of methods. The contents of manufacturing innovation methods chain are mainly manifested in four aspects as follows. Firstly, the awareness and determination of breaking through old tradition and exploring new paths should be established, which is the ideological premise of promoting capability of independent innovation; Secondly, innovative ideological education, innovation method research and development innovation tools should be arranged in priority under independent innovation strategy. Third, research and popularization of innovative methods should be regarded as the groundwork for promoting independent innovation; Fourth, innovation of methods should be the priority target to promote the capability of independent innovation.

Finally, continuous innovation practice is the foundation of manufacturing innovation methods chain [11]. The exploration of innovative methods and innovation of methods is closely linked to concrete practice of innovation. In the whole innovation system, method chain can only be regarded as auxiliary tool of innovation; the real subject is human with subjective initiative—namely general scientific and technical workers and practitioners of innovation. They are constitutors of innovation schemes, as well as the main force ensuring the realization of intended target in innovation activities. Humans have continually made and accumulated new experience, laws, principles, methods, and tools in innovation practice. Thus, manufacture innovation methods chain can be continually expanded and updated. Moreover, the vitality of innovation methods chain is stimulated by implanting innovative thinking, thus forming new innovative solutions to meet new demands of innovation. Therefore, innovation is the basic characteristic of manufacturing innovation methods chain, as well as the real reason for functioning and maintaining vitality.

#### **4. Results and Discussion**

The research and promotion of innovation methods have been focused in western developed countries. Special funds have been set up to encourage creative thinking training, innovation methods training, independent research and development of scientific

tools. Moreover, various innovation methods have been proposed including TRIZ, brainstorming method and six-sigma quality management, thus providing promotion and guarantee to enhance the capacity of independent innovation and technological competitiveness. As Chinese premier Wen Jiabao pointed out in 2007, innovation is the fundamental source of independent innovation, and methods should be prior to independent innovation. Several opinions on strengthening work of innovation methods was jointly issued by Ministry of Science and Technology, National Development and Reform Commission, Ministry of Education, and China Association for Science and Technology. National special project of innovation methods has been launched by Ministry of Science and Technology and supported by Ministry of Finance, with pilot enterprises having obvious results.

"We will take innovation methods work as an important focus of national science and technology in the twelfth five year plan, to provide support of talents, methods and tools for conducting strategy of independent innovation and building innovative country"<sup>[12]</sup>, said Chen Xiaoya, vice-minister of Ministry of Science and Technology in China. In newly historical period, further strengthening innovation methods work has great significance to innovation drive and endogenous growth with enhancing capacity of independent innovation from the source in China. "We are considering to build an innovation methods chain in manufacturing with five links, namely finding corresponding effective innovation methods for each link—idea, marketing, research and development, materialization, molding ", said Zhou Yuan, secretary-general of Innovation Method Society, in 2012 [13].

Manufacturing innovation methods chain is the product that human innovation practice and innovation research have developed to a certain stage. Its emergence marks that human's understanding on innovation theory and method has risen to a new level. In conclusion, manufacturing innovations method chain will be the emphasis of industry and academia in the future, as well as inevitable choice of Chinese manufacturing enterprises. Industry should unite with academia, based on the standard of relatively intact theory, relatively practical technology and effective practice. Theory system and method system of manufacturing innovation methods chain should be further improved with popularization and application in manufacturing industry.

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