Research *progresses* *progress* in technological innovation and integration of agricultural engineering
ABSTRACT: Based on the technical characteristics of agricultural engineering, this research develops a theoretical system and methodology for the integration of agricultural engineering technology by studying the classification of the constituent technologies, technology technological evaluation and integration, and optimization of agricultural engineering patterns. Thirty-two integrated agricultural engineering patterns are proposed according to the methodology for different regions with having different local industry backgrounds, different operating scales and different objectives. The research also provides a solid foundation for the study of the agricultural engineering technical schemes, patterns and construction standards, etc., which can help to provide a comprehensive solution to problems relevant to modern agricultural-relevant problems in agriculture.

Keywords: agricultural engineering, methodology, technology technological integration, technology classification, patterns

1. Introduction

1.1 Agricultural engineering and Agricultural engineering its technology

Agricultural engineering is the an integrated knowledge system consisting of many technical factors and non-technical factors, which can be include a production system or a social-service system, being constructed for large-scale specialized and sustainable agriculture. It is the key link that transforms of agricultural knowledge transforming into the real productivity. Agricultural engineering technology is a comprehensive subject that comprehensively methodically combines engineering, biology, information and management science, constituting thereby constituting the top three top technology technological backbones of modern agricultural science, along with agricultural biotechnology and agricultural management technology. As the most important key factor of in agricultural engineering, the developing level of agricultural engineering technology directly affects the construction level of agricultural engineering directly. In recent years, the Chinese Communist Party Central Committee pays has devoted much attention and invests much more on investment toward the construction of agricultural infrastructure, which in turn promotes the innovational strength and achievements in agricultural engineering. But it is worth noticing that there are still existing big differences in innovation, R&D investment and construction effects of agricultural engineering among the different districts, sectors and specialty fields in China still exist. There is still a gap to cover comparing to the in comparison with developed countries, a gap such as characterized by an insufficient supply of agricultural engineering technologies, low levels of assembly equipment, weak infrastructure which is built in on a small scale, being fragmented, disordered and repeated, and etc. remains to be covered. Therefore, it is very important and urgent crucial to carry out the agricultural engineering technology research of into key technologies, construction patterns and construction standards, as because the results could promote the construction and efficient operation of agricultural engineering systems efficiently and provide generally general engineering and technology technological support for the development and modernization of Chinese agricultural modernization agriculture.

1.2 Integration of agricultural engineering and technology

Integration is the activity process of blending or uniting two or more elements integrating, which means two or more elements set into an organic functioning whole, process or results. It's the core idea is being the a synergistic integration
unification. It is in a way to manner that solves complex system problems and to improves the function of the whole entire system. Any engineering project, regardless of size, is constitutes an entirety entire of a series of technology technologies that related relate to each other for a designed goal. The relationship between technology and engineering can be understood as the elements (the former) and the system (the latter). An agricultural engineering project must be consist of the application and integration of multi-subject technology technologies and technology technological groups. In addition, agricultural engineering involves constraints of within multiple-body organizations and the their external environment. It needs to carefully plan The resource mobilization and reasonable matching need to be carefully and systematically planned, which should take into account of project the economic benefits, social benefits and environmental benefits systematically. So Thus, the systemic essence of agricultural engineering relates it to integration inseparably. To get achieve improved improvement in agricultural engineering, it must study on the integration process must be studied. A study on of agricultural engineering technology integration is to must focus comprehensively on the overall objectives of the engineering project, organically integrate agricultural engineering the technical elements organically under the that influence consideration of the organization, the environment and other factors comprehensively, so as to fully realize the complementary advantage and greatly enhance the overall effect of agricultural engineering the system.

Although there has been a large number amount of technology technological integration practice in agricultural engineering, most of the literature is limited on to the research of on pure technology patterns, organizational modes or depending dependence on practical experience, with less consideration of social factors or environmental factors. It There is a lack of systematic and comprehensive research on the such integration. There is also as well as a lack of scientific theory and methodology which has already been established for a systemic integration of agricultural engineering systemic integration. Therefore, based on the this view of system theory, the existing research focuses on the formation of an integrated route incorporating agricultural engineering technology integrated route and a methodical system, by studying from the technical factors, organizational factors, the and social-environmental factors and so on encompassing to the study of agricultural engineering technology integration. The This methodology can enrich and develop the system engineering theory.

2. Technical route stages
Academician Yin Ruiyu pointed out that the engineering technology integration is divided into two stages. The first stage is of at an technology elements elemental level, which is called the engineering technology assessment and integration phase, where multiple disciplines and technologies are integrated by selection, organization and optimization on to a larger-scale quantity. The second stage is encompasses the an optimization of the engineering technology pattern phase, wherein the technical elements are comprehensively optimized within certain economic, social, management and other boundary conditions of economic, social, managing and other factors comprehensively.

2.1 Agricultural engineering technology Assessment and integration
The Integration on at the technical elements stage is to involves screening the appropriate technical sources and to provide feasible technical solutions. The
technological sources of technology can be divided into different types in order to cover as many as possible technology resources as possible. The structure-function analysis method can be used to establish the classification clusters of within agricultural engineering technology according to the different status, roles and relationships of each individual among the respective technologies. The Such classification constitutes the effective beginning of the technology integration.

In the integrative process of technology integration, a very important step is to evaluate an evaluation of the possible technologies, so as to make a reasonable choice. Technology evaluation includes the evaluation an assessment of advances, reliability, economical efficiency and assembly etc. The An integrated scheme of engineering technology is can thus be formed after evaluation and optimization of the relevant technologies. [In the flowchart in Fig. 1, 'pattern' should be revised to 'pattern'.]

2.2 Optimization of engineering technology patterns
Organizations (such as investment or operational organizations) and environments (such as economy economic, society societal or industry industrial) are both supportive and restrictive conditions of for agricultural engineering. Any technical integration scheme has limitations, and each technical scheme can only adapt to only certain conditions. So Hence, it is not only a variety of technologies but also various organizations (such as enterprises, cooperatives, and farmers, etc.) and environmental factors that are involved in the engineering technology integration process. Therefore, on the basis of the first phase of technology in technological integration, a system for evaluation and optimization system should be built by combining technical, economic, social and environmental evaluations with quantitative and qualitative analysis analytical methods. Then engineering technology the integration patterns can be derived by integration the merging of technology, organizations and environmental conditions, which are suitable for specific conditions and specific scales of organizations.

The technical root is shown in Fig. 1. [I had to delete the boxed caption for Fig. 1 because I found that it had moved and was covering some text on the next page.]

3. Agricultural Engineering Technology Classification
Technology classification research can reveal the a panorama of technology systems and its their typical characteristics, internal structure and mutual relationships, which in turn can provide technology resources for the integration of agricultural engineering technology.

3.1 Classification Methodology
The linear classification method classifies the objects into several levels of categories according to the selected attributes or features, and sorts them into a hierarchical system, expanding step by step (GB/T7027 – 2002). Linear classification This method is a traditional one of the traditional classification methods, which has the advantages of a clear hierarchy, and can fully reflect the logical relationships of different categories. It both conforms to the tradition of manual information processing and be is easy to processing information by computer-processed. In order to reveal the structure and function of agricultural engineering technology systems concisely, agricultural engineering technology classification used the linear classification method is used for its longitudinal hierarchy, which classified classifies the agricultural engineering technology according to the selected number of attributes or features into the
corresponding number of levels of categories, then assorted sorts them into a hierarchical, gradually expanded classification system.

3.2 Classification System

Because of the integrity and intersection of engineering technology, it there will be too much overlapping and be very hard to difficulty in reflecting on the purpose of the technology if it classification is classified implemented according to the its technical attributes and technical forms. Therefore, it is more reasonable to take consider the full functionality of agricultural engineering technology as the fundamental basis for classification, and thereby use using the basic idea of integration integrating of the technology chain and industrial chains and with technology covering encompassing the entire producing production process to guide the agricultural engineering—technology classification. According to In accordance with the linear classification methods, the research presents reveals four classification- catalogue cataloging levels of within agricultural engineering technology, namely, major classes, middle classes mid-level, and minor classes and subclasses, which can reflect encompassing the agricultural engineering technology chain, technical links, technical functions and technical measures, respectively. The hierarchical relationship is shown illustrated in Figure 2. [The text in the flowchart in Fig. 2 should be revised so that it agrees with the editorial revisions in the main text above.]
3.3 Classification results

According to agricultural logistics engineering, agricultural environmental protection engineering, and agriculture information engineering (Figure 3), and gradually subdivided into 39 mid-level classes, 151 minor classes, and 369 subclasses (Figure 4). The results can reflect the whole entirety of agricultural engineering technology in detail, construct a relatively complete system and make up for the gap in agricultural engineering technology research.

Note: “Hectarage” in the metric system corresponds to “acerage” in the American and British system(s). In English it is quite common to refer to “farmland” as “acerage” because it is measured in “acres.”
4. Integration of research of agricultural engineering technology

Integration is the activity process of integrating combining multiple elements, which combine two or more related elements into an organic functioning whole, and the core idea is being integrate and synergy synergistic unity. The fundamental cause goal of in the integration of engineering technology is from integrated effect, especially its economic effect. Because of the attracting attraction and inducing inducement from of an economic benefit, of integrated, makes the idea of integration can penetrate into the engineering practice. In the integration process of within agricultural engineering technology, the a proper evaluate evaluation can make sure ensure the best technical configuration, that is, a lower cost and more efficient greater efficiency, and leading resulting in the lower transaction costs and the better economic effects.

4.1 Methodology of integration

Technology integration is a systematic process including encompassing input, transformation and output, in which the input is consists of the single agricultural engineering technology as a whole (containing subclass technology, middle mid-level class technology, and minor classes technology, etc.); output is the preferred integration program of agricultural engineering technology; and transformation (technology integration) is the process that by which the single technology whole forms the integration an integrative system (or module) by matching. Integration of agriculture engineering technology is a systems engineering methodology, its general approach is being setting goals, building schemes, evaluation evaluating and optimization optimizing. This study formed formulated three kinds of integration methods.

(1) Construction-Evaluation-Optimization method

Based On the basis of technological classification of agricultural engineering technology, screen single the whole technology from the production process and its technical aspects and to constitute the preliminary, alternative integrated technology scheme (alternative scheme). Then, evaluate the alternative scheme result and get to obtain the a viable integration scheme of agricultural engineering technology based on the evaluation results, as illustrated in the flow.

**Fig.4 Middle Mid-level classes of in agricultural engineering technology** [The word “technology” is redundant in this flowchart. Using this word once in the caption and once in the phrase “Agricultural Engineering Technology” is enough!]

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chart is shown in figure 5.

Fig. 5 **The flow-chart of Construction-Evaluation–Optimization method** [Revise this flowchart thusly: Integration scheme Evaluation and Integration scheme Optimization]

(2) Evaluation-Construction-Optimization method

Based on the basis of technological classification of agricultural engineering technology, evaluate the various technologies in with regard to their different aspects. According to the evaluation results, construct the an alternative scheme in three levels: high, medium, middle and low three levels. Then combine these with production practice and expert experience to recommend the a feasibility scheme in different constraints, as depicted in the flow chart is shown in figure 6.

Fig. 6 **The flow-chart of Evaluation–Construction-Optimization method** [Delete redundancies from this flowchart thusly: Single Technology Evaluation and Integration Scheme Optimization]

(3) Goal-Evaluation-Optimization method

Based on the basis of technological classification of agricultural engineering technology, construct the best integrated scheme of agriculture engineering technology from the production perspective and technical aspects. Construct the an evaluation index system of agricultural engineering integration

for the integrated scheme, and use it to evaluate the practical integrated scheme version. Compared to with the best integrated scheme; then, propose the optimized content for the practical integrated scheme, as illustrated in the flow chart is shown in figure 7.

Fig. 7 **The flow-chart of Goal-Evaluation–Optimization method** [Revise this flowchart thusly: The Best program... (use headline grammar, which omits “the”) and Integration Scheme Optimization (delete redundancy)]
4.2 Technologically integrated schemes

According to the concept of technology integration, this study formulated 71 feasibility schemes of for agricultural engineering technology for in different regions, which covering including farmland infrastructure, agricultural mechanization, agricultural facilities, agricultural products processing and storage of products as well as their agricultural products circulation, agricultural environmental protection and agriculture information services. These schemes can be replicated as follows.

(1) Technology—Integrated scheme of Farmland infrastructure engineering

By using the Goal-Evaluation—Optimization method to structured construct the technology an integrated scheme of farmland infrastructure engineering of projects in plain, hilly and modern irrigation areas from five aspects: fields project, irrigation and drainage project, roads project, forest protection project and electrification project.

(2) Technology—Integrated scheme of agricultural Mechanization engineering

According to the Construction-Evaluation—Optimization method to resolve and compared compare the fully mechanization mechanized technologies, and reconstruct those technologies them in every link. Then, formulated the Technology integrated mechanical schemes of—Mechanical engineering for the key link of the field, and the entire all of the field and as well as the whole entire production chain.

(3) Technology—Integrated scheme of agricultural facility engineering Facilities

According to the Construction-Evaluation—Optimization method to reconstruct the greenhouse horticultural technologies from three aspects, includes including facilities, production facilities, original logistics and general management; and then, got formulate a technology—technologically integrated scheme of for agricultural facility engineering for plastic greenhouse, greenhouse and multi-span greenhouses.

(4) Technology—Integrated scheme of agricultural products Processing and storage engineering of products

Using the Construction-Evaluation—Optimization method and from the production flow chart and technical link of processing and storage, constructed to formulate the technology an integrated scheme of agricultural products for the processing and storage for of four crops, including corn, potatoes, bananas and peanuts, from the corresponding technical links in the production flowchart.

(5) Technology—integrated scheme of agricultural products Circulation of products engineering

Using the Evaluation-Construction-Optimization method focused to focus on harvesting, commercialized treatment, pre-cooling, loading and unloading, storage, transportation, trade, quality control and monitoring and as well as other aspects of circulation formed to formulate high- level, mid- level and low-level circulation integrated circulation schemes for fruits and vegetables, fresh fish and eggs.

(6) Technology—Integrated scheme of agricultural Environmental protection engineering

Using the Construction-Evaluation—Optimization method constructed the to formulate an integrated scheme of agricultural for waste recycling technology, from two aspects: waste-water treatment and solid-waste disposal. Then, got the further devise Integrated schemes of agricultural wastewater treatment and the integrated scheme of solid waste disposal of fuel technology, for the technologies addressing
fertilizers technology, feed processing technology, binders technology and materials technology. [Note: keep ‘feed,’ if it is for animals; but revise to ‘food,’ if for human consumption.]

(7) Technology-Integrated scheme of agricultural Information engineering

Using the Evaluation-Construction-Optimization method aimed at to focus on different aspects and control points of for regulating the Agricultural products quality regulation quality of agricultural products and agricultural establishing an information service. Then, formulate the high-, medium mid- and low-level integrated schemes for monitoring the aquatic product quality and safety monitoring of aquatic products and vegetables. quality and safety monitoring and. Thus, agricultural information services were can be formed.

5. Optimization of Agricultural Engineering Technology Patterns

Pattern is the a methodology to solve some certain classification problems which by emphasizes emphasizing the law in formal laws; moreover, this methodology is the constitutes a summary of experience to solve the problems. Agricultural engineering technology patterning is the a new paradigm of agricultural engineering technology for developing modern agriculture agricultural construction, which being based on regional characteristics, and has possessing good economic benefits, and ecological environment benefits, and as well as being easily extendable. Due to regional differences in climate, climatic conditions, economic levels and the subjects of construction and operation, the agricultural engineering such patterning has the is characteristics of characterized by regional, phased, systematic and hierarchical and diversity. There is as well as having no fixed pattern that can be copied. Therefore, optimize optimization of a regional agricultural engineering technology pattern should be in accord with the local conditions and seek truth from facts, in order to improving improve the matched-degrees and collaboration of agricultural engineering major agricultural engineering organizations, service object objectives, industry types, technology and equipment. Then, establish appropriate technology patterns can be established for developing local economic, economies and promote promoting agricultural the transformation and upgrading of agriculture.

5.1 Pattern Construction

An agricultural engineering technology pattern is comprises a whole with a specific target, function, and structure, which is made up consisting of subjective, objective, technology technological, organizational and environmental conditions and as well as other basic elements. Based on the system theory, industry industrial-chains and value-chain theory theories, this study proposed a systematic and complete operational method of for an engineering technology system which coupled couples technology pattern, organization pattern and industry patterns. Whereby In such a system, the technology pattern is the basis of the general pattern one; the feasible solution set is from technology integrating integration, and the organizational mode is the organization way of the operation manner in which the subject operates. At present, the cultivation of the family farms, specialized households and peasant specialized peasants’ cooperative organizations, as well as the agricultural leading agricultural enterprises and other new agricultural management subjects is are major tasks for rural reform and development, which has also having great vitality and potential. This study focuses on the organizational pattern of new agricultural management
subjects in different development scales (family farms, specialized households, farmers' cooperative organizations and agricultural leading agricultural enterprises), and different developmental stages (new construction, reconstruction, expansion). After considering the regional industrial layouts, development environments and supporting capacity capacities and other factors, the industry pattern was set. The purpose of coupling of patterns is to make render technology, organization and industry three systems system-specific and ordering ordered at a higher level, and get that obtain three kinds of patterns which can support each other and show the demonstrate a new systematic emergence which couldn't that cannot be obtained in single isolation. Then formed the an integration integrated pattern of agricultural engineering technology can be formulated for different scales and developing developmental stages.

5.2 Methodology of pattern for optimization
Pattern optimization is a feasibility analysis process based on the pattern construction, and a—decision-making process. Based on technology integration, pattern optimization of agricultural engineering technology carry out a—implements holistic research about the concerning technology integration schemes, operating-services subjects, socio-economic developments and environmental sustainability, which content consist of four stages: pattern construction, pattern evaluation, pattern demonstration and pattern optimization, as illustrated in Figure 8. This study put forward proposed the agricultural engineering technology patterns for different regions, subjects, industry industries and scales, all of which make all encourage the elements components of agricultural engineering to play achieve the best economic, social and ecological benefits in engineering design, project construction and resources allocation of resources.

![Fig. 8 The Flow chart of Pattern optimization of agricultural engineering technology](image)

The word “Pattern” is redundant in the illustration because “Pattern” is a key word in the figure caption; hence, you should use this word only once in all of Fig. 8. Although the remaining words are adequately explained in the main text, the figure is self-explanatory.

5.3 Pattern evaluation
Evaluation of pattern optimization evaluation is a decision-making process. Because the complex giant systems characteristic of agricultural engineering technology patterns that encompass vast areas, complex operating subjects, big vast related content and strong comprehensives, it is very necessary imperative to establish the pattern an evaluation system in order to examine the effects of patterns, as well as promote the improvement and development of the patterns. There are Many factors are involved in the problem of comprehensive evaluation
of complex systems: technological, economic, social, environmental and other factors must be comprehensively considered, all of which can make the comprehensive evaluation become uncertainty, randomness and fuzziness in the process. Hence, it is difficult for using to use the rigorous and accurate evaluation method to evaluate. At present, the comprehensive evaluation such methods mainly rely mainly on qualitative and quantitative approaches, objective statistic states and subjective descriptive descriptions, such as analytic hierarchy process, fuzzy comprehensive evaluations method, as well as multi-attribute and multi-objective decision-making methods. The Analytic Hierarchy Process (AHP) is a decision-making method, which first resolves the elements related to the a decision into objectives, standards and indices, then followed by qualitative and quantitative analysis. By using AHP, this study analyzed and integrated all kind types of the elements impacting the pattern. Therefore, the evaluation system of for an integrated pattern was divided into the objective layer, standards layer and index layers, in which the whole entire index system is a system also and each standards level is a complete subsystem. After determining the index system, the Delphi method was used to determine measure the weight of every standard-to-objective and every index-to-standards.

5.4 Typical Optimization Pattern
Based on the technology technological classification and integration, focusing on the needs of economic, social and natural conditions in different regions and different various operational subjects, this study undertook systematic and integrated research in seven agricultural infrastructure and equipment engineering fields, including farmland engineering, agricultural mechanization engineering, protected-area agricultural engineering, agricultural products processing and storage of products, agricultural logistics engineering, agricultural environmental protection engineering and agriculture information service engineering, and optimized 32 typical agricultural engineering patterns for verification and demonstration (Table 1).

<table>
<thead>
<tr>
<th>NO.</th>
<th>Pattern Name</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>The Construction pattern of for paddy mono-cropping system in Northeast China plain</td>
</tr>
<tr>
<td>2</td>
<td>The Construction pattern of for paddy double-cropping system in North China plain</td>
</tr>
<tr>
<td>3</td>
<td>Farmland optimization pattern in the for arid areas of Northwest China</td>
</tr>
<tr>
<td>4</td>
<td>The Integration pattern of for modern irrigation engineering technology</td>
</tr>
<tr>
<td>5</td>
<td>Produce-entire Complete mechanization engineering pattern of for corn production for in large cooperatives</td>
</tr>
<tr>
<td>6</td>
<td>Field-entire Complete field mechanization engineering pattern of for wheat/corn for in medium-size cooperatives</td>
</tr>
<tr>
<td>7</td>
<td>Produce-entire Complete mechanization engineering pattern of for wheat / corn for in medium-size cooperatives</td>
</tr>
<tr>
<td>8</td>
<td>Produce-entire Complete mechanization engineering pattern of for wheat / corn for in large enterprises</td>
</tr>
<tr>
<td>9</td>
<td>Field-key-link mechanized mechanization engineering pattern of for rice / wheat for in large cooperatives</td>
</tr>
<tr>
<td>10</td>
<td>Field-key-link mechanized mechanization engineering pattern of for rice / Cole [what's that? Corn?] for in medium cooperatives</td>
</tr>
<tr>
<td>11</td>
<td>Field-key-link mechanized mechanization engineering pattern of for rice / wheat for in small cooperatives</td>
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### 6. Results, application and discussion

(1) This research provides an advanced theoretical method for integrated innovation of agricultural science and technology. Original innovation, and integrated innovation, and as well as re-innovation after introduction and absorption are the three major areas of technological innovation. However, integrated innovation has been lacked of supportive scientific and systematic theory, especially for agricultural science and technology innovation, which is constitute a complex system involving biotechnology as well as engineering technology, and information technology technologies and plus other subject areas disciplines, and being all of which are used in the whole an entire industry industrial chain that combined links planting, breeding and processing, and as well as combined combining production, supply and sales. By using system knowledge, this study constructed an integration a methodically integrated system of agricultural engineering technology from technical classification and technical integration to pattern optimization, discussing how to build, how to evaluate and how to optimize an agricultural engineering technology pattern completely and systematically. It also provides provided a
theory theoretical guidance of for integrated innovation not only for agricultural engineering, but also for the whole all agricultural research, which thereby playing an important role to promote in promoting an integrated innovation level of for agricultural science and technology and its conversion rate.

(2) This research provides a holistic solution for constructing modern agriculture. The research content covered seven agricultural engineering fields, including farmland engineering, agricultural mechanization engineering, protected-area agricultural engineering, agricultural products processing and storage of products, agricultural logistics engineering, agricultural environmental protection engineering and agricultural information engineering, which covering comprise the key agricultural engineering technologies in the whole the entire industry industrial chain of agricultural production before, during and after. Our research results can provide the technology a roadmap of technical standards and construction programs of for agricultural engineering in different various typical regions, different industries and different operators’ subjects, which is constitutes a comprehensive and systematic solution of for agriculture agricultural engineering technology for in the mixture blending of the agricultural machinery and agronomy, the promotion of good farmlands, good seeds and good ways manners, and as well as the coordination of production, living and ecology during the an adjustment of in agricultural production.

(3) This research put forward formulated 32 integrated optimization patterns of in seven agricultural engineering fields and has achieved good results in their practical application. But However, these integration patterns are limited in to the their individual fields, respectively. The more comprehensive integrated agricultural engineering patterns, which cover the whole entire industrial chain for a certain crop the production of certain crops, need further exploration. The Management information systems which can provide agricultural engineering technology query queries, engineering technology optimization patterns, and project performance evaluations shall should be developed in the future to further support for the main food crops of our country China.

References


