Design and Development of Decision Support System for Equipping Farm Machines

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Abstract—Equipping farm machines is the key link of agricultural production process. The decision support system of equipping farm machines is able to aid managers to make scientific and effective decision. In this paper, the decision support system of equipping farm machines is designed and developed based on the related theories and the thought of prototype. The system chooses Delphi 7.0 as development language, and uses three classic equipping methods to establish system models. For the complex linear programming model, firstly it is established by M-file of Matlab, then COM components are generated; finally Delphi calls the COM components to solve. The database of the system is established and managed by SQL Server 2005. It can be seen from the result of the system application study that the system could assist users to equip farm machines more scientifically and dynamically.

Index Terms—Farm Machines Equipping; Decision Support System; Delphi; COM Components

I. INTRODUCTION

In recent years, with the implementation of farm machine purchase subsidy policy in China, many farms purchased high-power machines. However, it’s difficult to choose machines for farms owing to the appearing of various models. In the process of equipping farm machines, it may delay farming season owing to the lack of equipment or cause a large amount of idle ones owing to the excessive equipment. Therefore, it is very important to reasonably equip farm machines for the development of agricultural mechanization.

With the development of information technology, many agricultural mechanized management systems have been developed, and some were used in practice.

In 1998, Lilburne et al [1] developed the prototype decision support system to evaluate irrigation management plan, which could provide farmers with reasonable irrigation demand according to different environment. In 2001, Bao and He [2] developed the multimedia decision support system of farm machinery; Zhang [3] developed the information management system of agricultural vehicles; and Hu [4] developed the farm machine selection system. In 2002, Wu [5] developed the information management system of agricultural mechanization based on GIS that could realize data management such as grain cultivated area, yield, operational level of farm machines and so on, could predict the development of agricultural mechanization and produce the thematic map according to user’s demand. In 2003, Li [6] and Zhang [7] developed the information management system of agricultural mechanization based on Web. In 2004, Camarena et al [8] developed the comprehensive program that used the mixed integer linear programming model to select agricultural machinery for Multifarm systems. Gao [9] studied the decision support system of grain harvest machines selection. In 2005, Li [10] designed the decision support system of farm machinery replacement based on the models proposed. In 2006, Zhu [11] developed the intelligent decision support system of web-based farm machinery selection, which used the comprehensive evaluation, AHP and projection pursuit based on genetic algorithm to select models of equipment. In 2007, Tang and Ying [12] developed the decision support system for agricultural mechanization information management based on GIS by using VB 6.0, MapInfo 7.0 geographic information system, and Access 8.0 in Windows environment. Qiao [13] designed and developed the agricultural mechanized production expert system based on prototype method. In 2008, Sahu and Raheman [14] designed the decision support system of tractor equipment system matching and performance prediction by using VB 6.0. Wang et al [15] designed and developed agricultural machinery information management system based on web database. In 2010, Gupta et al [16] developed a greenhouse seedling production decision support system by using VB6.0. Nikkila et al [17] established management information system architecture of precision agriculture. Squiresen et al [18] built the concept model of the future agricultural management information system. In 2011, Wang and He [19] used ASP.NET and SQL Server 2000 to design and develop the fertilization decision support system. Mehta et al [20] designed the expert decision support system by system modeling method that could choose suitable tractor implement system according to different soils or operational environment. Luo and He [21] designed and developed the agricultural mechanization knowledge management system in order to make workers obtain information and knowledge related to agricultural mechanization more easily and quickly. Feng [22] constructed the agricultural mechanization decision support system based on multi-agent technology by designing multi-agent development platform in combination with the system analysis and evaluation.
methods, which could analysis, evaluate, simulate and predict agricultural mechanization systems of Henan province. Wang et al [23] designed the precision irrigation fuzzy control system based on crop water stress acoustic monitoring, which could realize safety and efficiency in precision irrigation. Ning and Kuang [24] developed the agricultural machinery information inquiry system of Yunnan province by using Access. In 2013, Zhao et al [25] proposed the intelligent agricultural forecasting system based on wireless sensor network technology that could provide intelligent services for guiding irrigation control, disease prevention and so on.

In summary, some systems about agricultural mechanization have been developed and used in practice. However the decision support system of equipping farm machines has not been reported until now. Therefore, it is necessary to develop the decision support system for equipping farm machines in order to improve the equipping efficiency.

II. GENERAL DESIGN OF DECISION SUPPORT SYSTEM FOR EQUIPPING FARM MACHINES

The detailed design of decision support system for equipping farm machines plays an important role in developing the system. In this phase, database, model library and human machine interface will be designed carefully, which provides the guidance for the further development.

A. Design of Database System

Adequate data are the basis of scientific management and decision. Database system is the basis of decision support system and the bridge of information delivering among parts in system.

The database of the system mainly stores some basic data and primary data used to calculate. According to the classification of the data, database can be divided into 5 sublibraries: (1) crop type database; (2) agronomic stage database, which is used to store the agronomic stage of each crop in the agricultural process; (3) user management database, which is used to store some information about users to protect the system; (4) power machinery database, which is used to store all types of power machinery and relevant performance indicators related to crop cultivation, growth and harvesting in China and abroad; (5) operating machinery database, which is used to store all types of farm machinery and the indicators related to crop cultivation, growth and harvesting. The design prototype of decision support system database is as Figure 1.

B. Design of Model Library System

Model library system is an important part of decision support system. The decision-maker decides through various models in model library rather than through the data in the database. Therefore, model database is the center of decision support system. According to the rules of establishing models and the theory of farm machines equipping, this system mainly establishes three models of linear programming, workload method and energy method.

1) Establishment of Linear Programming Model

The method of establishing linear programming model can be described this way: in the agricultural production process, at the premise of knowing the basic operating requirements and on the basis of agricultural process, the tractor unit required by each operation is set as a decision variable. The number of farm implement will thus be determined by these decision variables. Then several decision variables are set according to the number of tractors required during each operation. Finally, equations are set with operating areas as constraints and the total cost of all farm machinery as the objective function. The process is as follows:

1) Operating areas constraints

\[ \sum_{i=1}^{M} D_i W_i X_i \geq A_k \]  \hspace{1cm} (1)

The meaning of formula (1) is: the sum of each unit’s workload cannot be less than the operating area of the same operation; \( M \) is the number of variables; \( K \) is the number of operations; \( A_k \) is the kth operating area (Ha); \( D_i \) is the number of times of the kth operation (Duty); \( W_i \) is the operating efficiency of the unit (Ha/Duty); \( X_i \) is the number of tractors equipped; \( i \) is the variable of tractor unit.

![Figure 1. Database structure design of equipping farm machines decision support system](image)
2) Power machinery equipment constraints

\[ \sum_{i=1}^{M} X_i \leq X_j \]  

(2)

The meaning of formula (2): the total of the number of tractors required cannot be greater than the number of the same tractor; \( X_i \) is the number of tractor \( j \).

3) Operating machinery equipment constraints

\[ \sum X_j \leq X_k \]  

(3)

The meaning of formula (3): in the farming process, the number of operating machinery can be the total number of machinery used in the operation; \( X_j \) is the number of the \( k \)th operating machine used in the \( i \)th operation; \( X_k \) is the number of the \( k \)th operating machinery.

4) Non-negative constraints

All variables in the model are greater than or equal to zero.

5) The objective function

The target of equipping farm machines is the minimum operating cost. The cost can be divided into two parts: fixed cost (\( C \)) and variable cost (\( F \)) (the fixed and variable cost of farming machinery in this paper is listed in appendix).

\[ F_{\text{min}} = C + F \]

\[ C = \sum B_j X_j \]  

(4)

\[ F = \sum_{i=1}^{M} D_i C W X_i \]

\( B_j \) is the fixed fees of each tractor (Yuan/ Ha); \( C_i \) is variable fees of each type of operating machinery unit (Yuan / Ha).

2) The Establishment of Workload Model

Calculate the number of each type of tractors needed in this operation, according to the number of each operations, suitable operating dates, days of practical operation, average working times of everyday and the productivity of each type of tractor in each operation.

\[ n_{ji} = \frac{S_{ji}}{D_i P_i \theta_{ji}} \]  

(5)

\( n_{ji} \) is the number of tractor \( j \) tractor needed in the \( i \) operation; \( S_{ji} \) is the operating area (Ha) of \( j \) tractor finishing \( i \) operation; \( D_i \) is the practical operating days within the \( i \) working time (D); \( P_i \) is the average working times (Duty/ D) within the \( i \) working day; \( \theta_{ji} \) is the productivity of tractor \( j \) operating \( i \) (Ha/Duty).

3) The Establishment of Energy Law Model

Energy method is to determine the number of tractors needed on the basis of the required energy during an operation and the chosen tractor’s rated power.

\[ n_j = \frac{W_j}{W_j} \]  

(6)

\( n_j \) is the number of tractor \( j \); \( W_j \) is the traction power (KW/D) needed of tractor \( j \) for \( i \) working days; \( W_j \) is the traction power of tractors (KW).

The \( W_j \) formula is as follow:

\[ W_j = \lambda \frac{KS_j}{D_i \delta} \]  

(7)

\( \lambda \) is unit conversion factor; \( K \) is specific resistance of agricultural operations; \( \delta \) is weather factor.

4) Function Design of Models Selection

In model library management system, there are linear programming, energy method and workload models, which are established on the basis of the three methods of agricultural machinery equipping. When users are using the system, it can help to choose suitable models to equip machines according to user types and the data of their existing farm machines. The analyzing procedure is in Figure 2.
C. Detailed Design of Human Machine Interface System

Human Machine Interface (HMI) system is a pass for human being and computers to transfer data, information and knowledge. In the using process of decision support system, the decision-maker will operate and control the sub-system (database system and model library system). Therefore, HMI is an important part. In the design process, if a good human machine interface is established, it is helpful for users to operate the system easily. This system use the human machine interface with the user as its center, and the interface is nice and natural, clear and concise, and easy to operate. The basic structure of the system menu is shown in Figure 3.

III. FUNCTION ACHIEVEMENT OF DECISION SUPPORT SYSTEM OF EQUIPPING FARM MACHINES

The developing and operating environment of decision support system for farm machines equipping is mainly Windows platform. Database is established through software SQL Server 2005. In the model library, linear programming model is established through M-file of Matlab 7.0. Then COM components are generated with this M file, Delphi uses this COM components to calculate model. This system designs a concise and nice human-machine interface with Delphi 7.0 language.

The decision support system of equipping farm machines includes four functional subsystems of user management, agricultural product management, agricultural procedure management and decision analysis. The interface is showed in Figure 4.

A. The Function Achievement of User Management Subsystem

When opening the system, we can first see the login interface (Figure 5). Only when the user inputs a correct account and password, the user can enter the interface. At the bottom of the login interface, the login date and time will be shown in the status bar. In the status bar of the lower part of the interface, the dynamic words “Hello,
welcome to the agricultural machinery equipping decision support system" will be shown. If the user logs in the system for the first time, he needs register firstly. Press “Register” button, we can enter the register interface. The registered account and the password of the user will be stored in the database.

B. The Functional Achievement of Agricultural Product Management Subsystem

Agricultural machinery mainly includes power machinery and operating machinery. This module can help the user to inquire relevant agricultural machinery parameters to pave the way for agricultural machinery equipping. The operational interfaces are shown in Figure 6 and Figure 7.

C. The Functional Achievement of the Agricultural Procedure Management Subsystem

Agricultural production process refers to the whole production process of the preparing, plowing, harrowing, sowing of some crop target. Agricultural process is the shorten form for agricultural production process. This process complies with a certain agricultural technology, uses machinery and chemistry as its measures, and processes soil and crops. It is a comprehensive measure. The whole production process of a certain crop in an area consists all relevant technological procedures according to some sequence [26]. Every technological process may include one or several operations. Agricultural production process generally includes tillage, basic construction of farmland, sowing and transplantation, field management, harvest and transportation and so on. The agricultural process management interface is shown in Figure 8.

D. Functional Achievement of Decision Analysis Subsystem

The design of model selection analysis subsystem is to utilize the model properly to solve the practical problems.
for users. In this system, user type should be first chosen. Then the subsystem will recommend suitable model according to the user’s data, suggesting the user to use a proper model to equip. The operating interface is shown in Figure 9.

IV. APPLICATION IN CASE

Hongxing farm in Heilongjiang Province is divided into five operating areas. This paper takes the main crops, beans and corn, in the 3rd operating area as examples to equip farm machines. Recently, the 3rd operating area primarily cultivates beans and corn, with its acreage being 2210.9 Ha and 400 Ha. Research shows that the machine type in this area is complicated. Thus, according to the degree to which users are satisfied with different types of machines. We choose JD7830, Dong Fang Hong 1804, 2BDY-11 blowing planter, 4720 self-propelled spraying machine, JD9660 harvesters, folding heavy harrow X19 and 6488 corn harvester as the equipped target. The mechanized process table is shown in Table I.

A. Optimization Results of Linear Programming Sub-module

In the developing process of agricultural equipment decision support system, linear programming module mainly uses the solving idea of original simplex method in operation research. The application of this module needs relevant basic of linear programming module establishment. Firstly, establish the right model according to the actual situation; Then operate the system. The results are shown in Figure 10.

B. Optimization Results of Workload Method Sub-module

This model is designed according to the workload method. The result is the number of machine unit in the farming process. The calculating result and the preview are in Figure 11. We can see from the results in combination with the practical situation that the number of JD7830, Dong Fang Hong 1804, 2BDY-11 air-blowing planter, 4720 self-propelled spraying machine, JD9660 harvesters, folding heavy harrow X19 and 6488 corn harvester are respectively 10, 11, 21, 1, 2, 3, 1.

C. Optimization Results of Energy Method Sub-module

This model is established according to energy method theory. The optimization results are shown in Figure 12. With the practical operating time, we can see that the number of required farm machines is 3 JD 7830, 3 Dong Fang Hong 1804, 7 air-blowing planter 2BD Y-11, 1 self-propelled spraying machine 4720, 1 soybean harvester 9660, 1 folding heavy harrow X19, 1 corn harvester 6488. It can be seen that different equipment method can give different equipping number. Among these methods, linear programming model is more practical, because it takes in account of the whole year’s operating process of a certain crop. However, its establishment process and solving process are complicated. Workload method model and energy method model are easy to establish, but they are not connected closely with the practical operating process. Therefore, linear programming method is better for large-scale farm equipment and energy method and workload method are better for individual farmers because they are convenient and concise.


V. CONCLUSION
Agricultural machinery equipping is an important part of the modern agricultural mechanization. In paper, the decision support system for equipping farms machines is designed and developed according to the developing methods of the decision support system and the basic theory of the agricultural machinery equipping. In the process of design and development of the system, the Delphi 7.0 is used to design human machine interface simply and beautifully, which could make a good information exchange between the user and the system. SQL Server 2005 is used to establish the database, which can improve the security of the database and make the database extensible. The model library management subsystem stores linear programming workload and energy models, and the development of the linear programming model mainly adopts the technology of Delphi calling COM component which is generated by Matlab. Besides, the case study shows that the system can provide reasonable numbers of agricultural machines for users according to the selected model and can help the users to make scientific decisions and improve the efficiency of equipping farms machines.

ACKNOWLEDGMENT
This work was supported by Heilongjiang province natural science fund (G201206); the research fund for the doctoral program of higher education of China (20132325120022); and postdoctoral science research starting foundation of Heilongjiang Province

REFERENCES

TABLE I. THE MECHANIZATION PROCESS OF THE SOYBEAN AND CORN

<table>
<thead>
<tr>
<th>NO.</th>
<th>Operating Project</th>
<th>Start&amp;End dates</th>
<th>Dynamic models</th>
<th>Operating models</th>
<th>Operating frequency</th>
<th>Weather factor</th>
<th>Productivity (ha/ classes)</th>
<th>Operating area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Corn ridging clip fat</td>
<td>4.25-4.30</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.25 1.25</td>
<td>0.8</td>
<td>39.6 35.6</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>Soybean sowing</td>
<td>5.1-5.10</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.25 1.25</td>
<td>0.8</td>
<td>39.6 35.6</td>
<td>2210.9</td>
</tr>
<tr>
<td>3</td>
<td>Corn sowing</td>
<td>5.5-5.15</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.25 1.25</td>
<td>0.8</td>
<td>39.6 35.6</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>Soybean subsoiling</td>
<td>5.25-6.5</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.5 1.5</td>
<td>0.8</td>
<td>42.2 38</td>
<td>2210.9</td>
</tr>
<tr>
<td>5</td>
<td>Corn fertilizer</td>
<td>6.15-6.20</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1 1</td>
<td>0.8</td>
<td>46.5 40</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Cultivator once</td>
<td>6.15-6.20</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.25 1.25</td>
<td>0.8</td>
<td>46.5 40</td>
<td>2210.9</td>
</tr>
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<td>7</td>
<td>Soybean Fertilization</td>
<td>6.20-6.30</td>
<td>4720 Self-propelled spraying machine</td>
<td>1.5</td>
<td>1.5</td>
<td>0.8</td>
<td>168</td>
<td>2210.9</td>
</tr>
<tr>
<td>8</td>
<td>Cultivator twice</td>
<td>7.1-7.10</td>
<td>JD7830/ DongFangHong 1804</td>
<td>2BDY-11 Blowing planter</td>
<td>1.25 1.25</td>
<td>0.8</td>
<td>46.5 40</td>
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<td>9</td>
<td>Soybean harvest</td>
<td>10.1-10.16</td>
<td>JD9660 Soybean harvest</td>
<td>2</td>
<td>2</td>
<td>0.8</td>
<td>48.6</td>
<td>2210.9</td>
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<tr>
<td>10</td>
<td>Autumn harrow</td>
<td>10.5-10.25</td>
<td>JD7830</td>
<td>Folding heavy harrowX19</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>37.9</td>
</tr>
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<td>11</td>
<td>Corn harvest</td>
<td>11.1-11.6</td>
<td>6688 Corn harvest</td>
<td>2</td>
<td>2</td>
<td>0.8</td>
<td>14.3</td>
<td>400</td>
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</table>


**Appendix A**

**Table Fixed cost of farm machinery per year**

<table>
<thead>
<tr>
<th>NO.</th>
<th>Machine Name</th>
<th>Fixed Fee (RMB / year)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>JD7830</td>
<td>62500</td>
</tr>
<tr>
<td>2</td>
<td>DongFangHong1804</td>
<td>49875</td>
</tr>
<tr>
<td>3</td>
<td>2BDY-11 Blowing planter</td>
<td>4563</td>
</tr>
<tr>
<td>4</td>
<td>4720 Self-propelled spraying machine</td>
<td>156250</td>
</tr>
<tr>
<td>5</td>
<td>JD9660 Soybean harvest</td>
<td>111250</td>
</tr>
<tr>
<td>6</td>
<td>Folding heavy harrowX19</td>
<td>5040</td>
</tr>
<tr>
<td>7</td>
<td>6488 Corn harvester</td>
<td>48500</td>
</tr>
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</table>

**Appendix B**

<table>
<thead>
<tr>
<th>Operating unit name</th>
<th>Fuel costs (yuan / mu)</th>
<th>Maintenance fee (yuan / mu)</th>
<th>Staff salaries (yuan / mu)</th>
<th>Standard acres conversion factor</th>
<th>Total (yuan / mu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JD7830 Corn fertilization ridging clip fertilizer unit</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.6</td>
<td>51.66</td>
</tr>
<tr>
<td>DFH 1804 corn ridge clip fertilizer unit</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.7</td>
<td>60.27</td>
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<td>JD7830 soybean planting crew</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.7</td>
<td>60.27</td>
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<tr>
<td>DFH 1804 soybean planting crew</td>
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<td>3</td>
<td>1.5</td>
<td>0.7</td>
<td>60.27</td>
</tr>
<tr>
<td>JD7830 corn sowing machine</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.75</td>
<td>64.575</td>
</tr>
<tr>
<td>DFH 1804 corn sowing machine</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.75</td>
<td>64.575</td>
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<tr>
<td>JD1804 soybean subsoiling unit</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.6</td>
<td>51.66</td>
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<td>DFH 1804 soybean subsoiler unit</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
<td>0.7</td>
<td>60.27</td>
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<td>JD7830 corn fertilizer unit</td>
<td>4.11</td>
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<td>1.5</td>
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<td>3</td>
<td>1.5</td>
<td>0.45</td>
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<td>4.11</td>
<td>3</td>
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<td>1.5</td>
<td>0.45</td>
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<td>4720 spraying machine unit</td>
<td>4.11</td>
<td>3</td>
<td>1.5</td>
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<td>9660 harvester unit</td>
<td>4.92</td>
<td>3</td>
<td>1.5</td>
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<td>JD7830 heavy harrow unit</td>
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<td>6488 corn harvester unit</td>
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<td>1.5</td>
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<td>90.405</td>
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