An application of AHP for parameter importance evaluation for farm machinery selection

Abhijeet U. Karmarkar
Department of Mechanical Engineering, K J Somaiya College of Engineering, Mumbai, India
abhijeet@somaiya.edu

Nandkumar R. Gilke
Department of Mechanical Engineering, K J Somaiya College of Engineering, Mumbai, India
nandkumargilke@somaiya.edu

Abstract. The farm machinery selection is a complex decision making task. It involves a variety of variables associated with farming which include social and economic aspects of the decision maker. The aim of this work is to develop decision support architecture for tractor selection process. Different parameters for selecting tractor were identified; their importance was studied by literature survey and evaluated with AHP. The study concludes that the parameter operation type receives highest importance in tractor selection process. Other parameters like, service, type of business, brand and cost are also important in tractor selection process.

Keywords: Agriculture, Farm Machinery, AHP, decision support architecture

1. Introduction
The tractor is one of the most commonly used farm machinery for various farming related applications. Thus the tractor selection is an important part of farm machinery selection and management. The farm machinery selection is the process of assessing the suitability of machinery and their possible usage in farming domain for a sustainable and profitable crop production. The farm machinery selection is also a significant process for ensuring effective utilisation of available mechanical power. This makes the decision making process most important for the farming domain. The selection process encompasses a variety of factors such as, financial, social, technical etc. The involvement of multiple parameters adds to the complexity of the decision making process and thus the problem can be modelled as a multi-criteria-decision-making (MCDM) problem. Such MCDM problem deals with evaluation of a set of alternatives while considering the set decision criteria. In recent years, researchers have introduced a large variety of tools, techniques and methods for solving different MCDM problems. Most of the MCDM approaches incorporate the pairwise comparison approach for calculation of weights for decision alternatives.
This study introduces a Decision Support Architecture (DSA) for helping decision-makers in decision making for complex MCDM problems. The DSA is a tool which can support in structured decision making. The novelty of this DSA is that the decision making process involves the implementation of the pairwise comparison method for evaluating the importance of features associated with decision making instead of the alternative. The development of DSA is the first phase of development of the Decision Support System (DSS) for supporting farmers. The alternative selection phase of the DSS is not a part of this work and will be considered separately later.

This paper is structured as follows. Section 2 describes the research method followed in this work. Section 3 provides a glance into the literature of tractor selection methodologies and related parameters. Section 4 describes the development of decision support architecture for tractor selection process. Section 5 highlights the results obtained from the study along with the analysis of obtained results. Section 6 gives the discussion on obtained results and offers the directions for future studies regarding tractor selection.

2. Materials and methods
In this study the problem of the tractor selection is under consideration. The problem typically arises due to the gap in the understanding and analysis of product requirements of the manufacturer and the buyer. The tractor manufacturer tries to develop more and more advanced versions of the product by incorporating latest trends in technology. This results in a large mix of products and the buyer has to select required product from this mix. The buyers who are typically from farming background may face difficulty in understanding farm specific requirements and thus may fail to efficiently select the product. This results in wastage of mechanical power.

In recent years, researchers have implemented different strategies for addressing the power wastage problem. A commonly used strategy is not to select tractor specifically but to select different parameters associated with tractor. These parameters include various parameters like, tractor power, implement size etc. The prediction of tractor performance is also studied by researchers. The focus of these studies was to predict how tractor will perform under the operation and soil conditions. In these types of work, objective of researchers was to support the buyer by considering technical requirements of the tractor for farming operations. Some researchers have considered other parameters or rather non-technical parameters along with technical parameters for tractor selection. These non-technical parameters include financial attributes like price, cost of maintenance etc., social parameters like, buyer’s background, age, education etc. Table 1 illustrates some selected support system approaches from the literature. Most of the tabulated work as observed in table can be classified as either associated with technical or with non-technical parameters being considered for tractor selection. In only a few cases, combination of both technical and non-technical parameters is considered in a single system. Even in such systems, many other parameters associated with tractor selection are ignored.

The other attribute of the support systems considered in literature is the type of MCDM approach used for addressing tractor selection problem. In most of the studies, DBMS based approach is used where a support system uses a database at background for selecting suitable tractor. In case of such system, there is a problem of empty selection, i.e. no suitable product is found which can fulfil all necessary requirements completely. The AHP based systems are advantageous in such MCDM problems as these systems can be used to find most suitable option out of available options. These systems depend on a pairwise comparison of various attributes pertaining to different options and whenever list of options or attributes is modified, the whole evaluation process for AHP model has to be conducted again. Further this method is dependent on technology advances which can cause entire pairwise comparison invalid and will require a re-evaluation of system. Table 1 highlight the technology used which can be DBMS or AHP in support system approaches from literature.
Table 1. Overview of the tractor selection and performance prediction systems from literature

| Author(s)                  | Domain                      | Modeling Approach     | Technology Used     | Input Parameters                        | Output Parameters                        |
|----------------------------|-----------------------------|-----------------------|---------------------|-----------------------------------------|------------------------------------------|
| Al-Hamed & Al-Janobi (2001)| Tractor Performance prediction | Mathematical Model   | DBMS, Visual C++    | Weight, Tractive Efficiency             | Traction Ratio, Pull, Drawbar Power, Actual Speed |
| Rizwan-ul-Haq, Muhammad, Shafi (2003) | Tractor Selection | Mathematical Model | Statistical Analysis | Tractor Size, Crop, Implement            | Field Time, Number of Tractors, Tractor Size |
| Catalán et al. (2008)      | Tractor Performance Prediction | Mathematical Model | Visual Basic        | Drawbar Pull, Tractor, Tires, Terrain   | Dynamic Axle Load, Slip                   |
| Sahu & Raheman (2008)      | Tractor Performance Prediction | Mathematical Model   | Visual Basic, DBMS  | Tractor, Implement, Soil Condition, Operating Condition | Coefficient of Traction, Pull, Engine Torque, Slip |
| Mehta et al. (2011)        | Tractor Selection           | Mathematical Model   | Visual Basic, DBMS  | Field Area, Available Time, Speed       | Speed, Drawbar Power                      |
| Bialobrzewski and kolator (2011) | Tractor Performance Prediction | Mathematical Model    | MATLAB & Simulink  | Drawbar Pull, Implement                  | Speed, Tractive Efficiency, Slip           |
| Patel et al. (2012)        | Tractor Performance Prediction | Mathematical Model   | Visual Basic, DBMS  | Implement, Tractor, Soil Condition, Type of Land | Draft, Drawbar Power, Slipp, Tractive Efficiency, |
| Lotfie et al. (2013)       | Tractor Selection           | Mathematical Model   | Visual Basic, Excel | Crop Type, Implement                     | Tractor Size, Power Required, Fuel Consumption |
| Civelek, Say (2016)        | Tractor Selection           | Expert System        | DBMS                | Tractive Efficiency, Time, Implement     | Drawbar Power                             |
| Awulu et al. (2016)        | Tractor Selection           | Expert System        | Visual Basic, DBMS  | Soil Type, Operation Type, Implement     | Tractor                                  |

Notes: The first column ‘Domain’ points out problem domain. The second column ‘Modelling Approach’ denotes the type of modelling approach used in study. The third column ‘Technology Used’ specifies the programming or conceptual tool used in the study. The fourth and fifth columns namely ‘Input Parameters’ and ‘Output Parameters’ signify the input and output parameters involved in the study.
In this work, a MCDM system is discussed which can aid in the product selection process. The MCDM system deals with problem solving through help of the DSA. The DSA deals with structuring of MCDM problem which concerns a set of criteria: (1) Parameter identification, (2) Parameter Selection, (3) Feature extraction, (4) Selection of weighing method, (5) Applying selected method, (6) Evaluation of parameter importance in decision making process.

The DSA proposed in this work is based on Analytic Hierarchy Process (AHP) methodology for evaluation of parameter importance. The goal of DSA is to provide a generalised parameter importance values for a structured decision making. The DSA is inspired by expert knowledge which is gathered through series of interviews. Total nine experts (tractor dealers representing different tractor manufacture located in different parts of State of Maharashtra, India) participated in this research to evaluate parameter importance. The methodology for incorporating the views of these experts into the DSA design is shown in figure 1. The survey was conducted in an interview format with open ended survey questioner. The questioner was designed as an open ended questioner for effectively capturing the expert opinions. The parameter and domain importance was evaluated from expert opinion. These importance values were used for development of relative importance matrix for parameters. The developed relative importance matrix was analysed by calculating consistency ratio for the matrix and comparing the calculated value with the set threshold value.

3. Decision Support Architecture
The main aim of this study is to develop DSA for effective selection of farm machinery. The DSA is represented by means of a block diagram in figure 2. In order to develop the DSA, a prerequisite was to collect information and acquire knowledge regarding the tractor selection process. The required knowledge was acquired through a series of interview of experts. This acquired knowledge was then
used for system model development. The system model comprised of various parameters and domains associated with the farm machinery selection. This parameter domain relation along with the respective weights formed the knowledge base for decision making. This knowledge base can be further used by an inference engine for decision making purpose. The design and functionality of each block is discussed in further topics.

3.1. Knowledge Acquisition
As discussed earlier, acquisition of knowledge was a prerequisite for development of DSA. The information gathered for knowledge acquisition was from available literature, system model designers and from experts working in farm machinery selection domain. After study of available literature, around 40 different parameters were identified. These parameters were largely spread over various phases of farm machinery. These parameters typically belonged to technical, financial, social, psychological and farming domains. All of these parameters were considered for developing parameter description for farm machinery selection. The inputs were also taken from farm machinery selection experts for understanding importance of identified parameters. This expert knowledge was used for system model designing.

3.2. System Model
The system model for the DSA comprised of the parameter relation model which was used for development of inference engine which are the most important aspects of any MCDM system. The domain and parameter definitions formed the base of system model. These specified parameters and domains were the products of analysis of parameters extracted from the literature. In order to facilitate
effective decision making, the parameter dependency was modelled by means of weighted domain parameter dependency. An AHP based weighted parameter matrix was used for this purpose.

The AHP is a method of decision making which incorporates the pairwise comparison of parameters with reference to input data. This AHP methodology is capable of supporting a complex decision making process while dealing with a variety of input parameters. As suggested by Saaty [18] AHP considers problem definition, decision hierarchy, pairwise comparison of parameters and assigning priorities to parameters for providing an organised way to decision making. The AHP method is based on evaluations of the available alternatives with reference to the weight or importance assigned to the criteria by the decision maker. The weight is in terms of relative importance of the criteria in decision making process. The AHP methodology is easy to implement for a decision maker in order to make a correct decisions. The AHP based problem solving approach mainly consists of four main steps, which are problem definition, formation of decision hierarchy, pairwise comparison matrix formation and priority determination [19].

Table 2. Satty’s Scale for Pairwise comparison [19]

| Intensity of Importance | Definition                              | Explanation                                                                 |
|-------------------------|----------------------------------------|-----------------------------------------------------------------------------|
| 1                       | Equal importance                       | Two activities contribute equally to the objective                          |
| 3                       | Weak importance of one over the other  | Experience and judgment slightly favour one activity over the other        |
| 5                       | Essential or strong importance         | Experience and judgment strongly favour one activity over the other         |
| 7                       | Demonstrated importance                | An activity is strongly favoured and its dominance demonstrated in practice|
| 9                       | Absolute importance                    | The evidence favouring one activity over the other is one of the highest possible validity |
| 2-4-6-8                 | Intermediate values between the two adjacent judgments | When compromise is needed                                                   |
| Reciprocals of above nonzero numbers | If activity 1 has one of the above nonzero numbers assigned to it when compared with activity 2, then activity 2 has the reciprocal value when compared with activity 1 | |

The AHP methodology finds a large number of applications in decision making and decision assessment domains. In this work, a modified AHP (M-AHP) method was used for analysing the data gathered regarding the tractor selection parameters and building a maintainable and evolvable DSA. The M-AHP approach as suggested by Nefeslioglu et. al [20] is useful in compensating the expert subjectivity encountered with the parameter comparison. The M-AHP method uses basics of AHP methodology and builds on the concepts with certain modification. The steps involved in M-AHP in approach are:

- Inputs from Experts are used for assigning maximum scores for each parameter in the system.
- Based on the parameter scores, the parameter score difference matrix is prepared.
The parameter score difference values are normalised with reference to the maximum parameter scores assigned.

The parameter comparison matrix is then constructed with help of the conversion scale.

The parameters under consideration in this study demonstrate a correlation with few other parameters. This correlation in form of parameter inter-dependency must be considered in the decision making process. In order to incorporate this parameter dependency in DSA, multi-level implementation of M-AHP approach is performed. The parameter importance obtained from analysis of data highlights the necessity of every parameter in tractor selection process. The major challenge was to incorporate the maintainability and resolvability with DSA for tractor selection. This was achieved through a step wise implementation of approach. This stepwise approach utilised for DSA development involves, domain and parameter description, knowledge base and decision model as fundamental sub-parts.

Figure 3. Parameter grouping into different tractor selection categories
3.3. Domain and Parameter Description
At the initial stage of work, various parameters associated with tractor selection were identified and studied. The similar parameters from literature were grouped together in order to formulate the parameters for tractor selection. This parameter grouping was done with reference to the similarity between the parameters. The parameters which showed similarity with other parameters were grouped into a single parameter. The parameters which exhibited an overlap of concept or meaning or definition were also grouped together. The parameters which were not pertaining to any of the above criteria were considered separately. There were 18 such individual parameters which were formulated. These 18 parameters were then classified into 5 tractor selection domains. This classification was not unique i.e. a single parameter may have been a part of multiple domains. These parameters were both technical and non-technical parameters and were quantitative or qualitative in nature. Figure 3 shows the domain wise classification of the formulated parameters.

3.4. Knowledge Base
In order to evaluate the importance of parameters, views of 9 experts were considered. These experts were tractor dealers pertaining to selected regions of state of Maharashtra. Their views on importance of each parameter in tractor selection were recorded by means of a survey. The parameter importance level was mapped by means of a predefined scale which is shown in table 3. This importance scale provided a structured data for further processing. The parameter importance was used for development of knowledge base for decision model. The knowledge base also included domain and parameter definitions along with weightages. The knowledge base was utilized for effective decision making and machinery selection.

| Level of Importance               | Not Important | Moderately Important | Strongly Important | Very Strongly Important | Extremely Important |
|-----------------------------------|---------------|----------------------|--------------------|-------------------------|---------------------|
| Numerical Importance assigned     | 0             | 1                    | 2                  | 3                       | 4                   |

4. Result and Discussion
Table 4 illustrates the result of analysis carried out for parameter importance evaluation. The use of AHP based methodology proved effective in assessment of importance of tractor selection parameters. The analysis was carried out not only for parameter importance but also for importance of domain in tractor selection process. The domain wise importance was also used for evaluating parameter importance. The analysis of AHP model formulated was carried out by evaluating ‘Consistency Ratio’ of the relative importance matrix which is the heart of AHP methodology. This analysis showed consistency ratio had value within limits which proved the feasibility of relative importance matrix. The parameter ‘Operation Type’ was found to be of maximum importance in tractor selection process. This analysis also showed that the parameters like, ‘Service’, ‘Type of Business’, ‘Brand’, ‘Cost’, ‘Buyer’s Background’ were also important while dealing with tractor selection. The ‘Operation Cost’ parameter was found to be a neglected parameter in tractor selection process. The parameters like, ‘Working average’, ‘Resell Price’, ‘Field Area’ were found to be of lower importance in tractor selection process.

5. Conclusion
In this work, the AHP method is implemented for development of DSA. The implementation of AHP methodology allows the evaluation of parameter importance in decision making process. The analysis of consistency ratio for the decision matrix showed that the decision matrix was acceptable. Thus this decision matrix was usable in actual decision making scenario. The analysis also showed that
parameter ‘Operation Type’ received maximum importance. This result was in union with the literature as many other parameters of tractor selection were directly or indirectly dependent on this parameter. Parameters like ‘Service’, ‘Type of Business’ and ‘Brand’ were also found to be important in tractor selection. The ‘Cost’ parameter was found to be less important than expected. The parameter importance evaluated in this work provides a feasible relative importance matrix for DSA. The use of step wise importance evaluation enables easy evolution and modification of DSA. The DSA developed in this study can be further used for a development of DSS for actual tractor selection.

Table 4. Parameter importance and importance wise ranking for tractor selection parameters

| Potential Parameter                                | Parameter Ranking |
|----------------------------------------------------|-------------------|
| Operation Type                                     | 1                 |
| Service                                            | 2                 |
| Type of Business                                   | 3                 |
| Brand                                              | 4                 |
| Cost                                               | 5                 |
| Buyer's Background                                 | 6                 |
| Maintenance                                        | 7                 |
| Implement                                          | 8                 |
| Tractor Popularity                                 | 9                 |
| Power required                                     | 10                |
| Soil Hardness and condition                        | 11                |
| Type of crop                                       | 12                |
| Reference from other farmers                        | 13                |
| Future requirements                                | 14                |
| Field Area                                         | 15                |
| Resell Price                                       | 16                |
| Working average                                    | 17                |
| Operation cost                                     | 18                |

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