Czech University of Life Sciences Prague

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Bachelor Thesis

Multiple decision making in practice

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Thesis title

Multiple decision making in practice

Objectives of thesis

This thesis is separated on first and second objectives. Main goal is to explain the process of multiple decision making, methods and then implement it in practical part with usage of Weighted sum approach method. Main purpose of the first objective is to compare options for the most profitable way of harvesting tulips. In this thesis using of different types of harvesting machines will be analyzed, comparing it with hand work by changing criteria: quantity of tulips, price of machine, risks, performance, cost of machine, ROI, investment, work hours. Second objective is to describe the importance of determination the significance of the criteria and to determine the most advantageous variant. Taking into consideration those two parts, next step is to draw a conclusion and provide recommendations.

Methodology

The thesis is divided into two parts which are theoretical and practical. Theoretical part will be based on relevant literature. The main subject is the decision making process, its methods, principles, components and problems of models of multi-criterial analysis. The practical part is divided into two parts. The first part is focused on implementation of the theoretical knowledge into a practical example, which is represented by the selection of the main criteria and usage of the Weighted sum method and choosing the most important value.

The practical example demonstrates the selection procedure using the Weighted sum method, comparing with other methods such as: difference in results with hand work harvesting and usage of machines in tulips production applying the methodology described in theoretical part. Results of individual methods are compared and according to the results of the comparison is derived evaluation of used methods, their expediency, advantages and disadvantages. In the second part, there is a sensitivity analysis that demonstrates the effect of weight distribution on the final order of the variants according to their significance. During weight reduction of the first criterion and dividing this value among the other criteria according to the specified ratio, the effect of this procedure is observed and conclusions are made.

The proposed extent of the thesis

30-40

Keywords

harvesting, tulips, decision making, weighted sum approach

Recommended information sources

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Declaration

I declare that I have worked on my bachelor thesis titled "Multiple decision making in practice" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 22.03.2020 ______________________________

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Multiple decision making in practice

Abstract

This thesis is targeted on research and comparison of multiple attribute decision methods. There are theoretical and practical part.

Theoretical part is mainly focused on studying and researching of professional literature about decision making process and multiple attribute decision methods with deduction approach. There are few chosen methods, where one of those mentioned methods will be implemented to practical part.

The first part of practical part is focused on example of the purchase of the harvesting machine for tulip greenhouse. There is demonstrated dissimilarity of the used methods of the choice of the best variant in the first part. The second part is focused on sensitivity analysis. The analysis demonstrates the intensity and allocation effect on the final rating of the variants. A conclusion is deducted and describes advantages and disadvantages from the results from both parts of the thesis.

Keywords: weighted sum approach, tulip growing, decision making, harvesting

Table of content

List of pictures:

List of tables:

1 Introduction

Decision making process is part of our everyday life. In everyday life as well in in work situations where certain complex situations must be solved with the most optimal solutions. Complexity is one of the aspects which determines how we will proceed to solve the problem optimally. Every day choice what people are going to eat for breakfast or what to wear to work? From the first glance it can be the problem of the choice, from the deeper glance it is problem of decision making process. In the most basic everyday situations such as: go by metro or bus the solution depend on the person instinct, so the choice goes far more readily and easily than decision about more complicated issues. The choice which is based on instincts is not always sufficient, therefore necessary to resort to empirical selection procedures to achieve the most advantageous result.

Multi-criteria analysis is something we meet every day in our life, so often that we do not always realize it. Whatever choice is we always meet and evaluate multiple criteria and multiple options. As an example choice of a new car, apartment or vacation destinations. It is always choice of the best and most advantageous option from a given list of alternatives when the most effective alternative is assessed according to established criteria, but can be different for decision maker.
That is how to approach to the main point which will be proceeded and pay attention in the work with use of quantitative selection methods. Methods of concrete science will be used with deduction approach. Those are mathematical methods for selecting the most suitable alternative and elimination of the most unsatisfactory variants, according to given criteria that reflect the preferences and needs of the person they identify with using the mathematical formulas suitability of the given variants and then, according to the results, choose the best alternative.

The subject of the bachelor thesis is harvesting machines for tulips in greenhouses while also comparing to hand work. The best machine will be chosen by changing the importance of criteria and observation how the result would be affected. The Weighted sum approach will be used as my main method but also it will described and compare with other methods of multi-criteria analysis. This will lead to certain results which will show how the result can change by change any of the criteria.

2 Objectives and methodology

2.1 Purpose of the work

This thesis is separated on first and second objectives. Main goal is to explain the process of multiple decision making, methods and then implement in practical part with usage of weighted sum approach method. The main purpose of first objective is to compare options for the most profitable way of harvesting tulips.

In this thesis will be analysed usage of different types of harvesting machines, comparing it with hand work by changing criteria: quantity of tulips, price of machine, risks, performance, cost of machine, ROI, investment, work hours. Second objective is to describe the importance of determining the significance of the criteria and to determine the most advantageous variant. Taking into consideration those two parts, next step is to draw a conclusion dealing with expediency selected methods applicable to the situation.

2.2 Methodology

The thesis is divided into two parts which are theoretical and practical. Theoretical part will be based on professional literature. The main subject is decision making process, its methods, principles, components and problems of models of multi-criterial analysis.

The practical part is divided into two parts. The first part is focused on implementation
of the theoretical knowledge into a practical example, which is represented by the selection of the main criteria and usage of Weighted method and choosing the most important value.
The practical example demonstrates the selection procedure using the weighted method and comparing with other methods such as in my case: hand work and usage of machines in tulips production with using methodology described in theoretical part.

Results of individual methods are compared and according to the results of the comparison is derived evaluation of used methods, their expediency, advantages and disadvantages. In the second part, there is a sensitivity analysis that demonstrates the effect of weight distribution on the final order of the variants according to their significance. During weight reduction the first criterion and dividing this value among the other criteria according to the specified ratio is the effect of this procedure on reordering is observed and conclusions are drawn.

2.3 Decision making process

“Decision making process is nothing but a process through which it is possible to make a decision”- Padoa Schioppa, 2010. Exact term” decision” (from Latin. *decision-onis*, past verb “decider” which means” to cut something, end” which express the will to solve a problem (Dizionario delle Scienze Fisiche, 1996) Additionally, Kreitner and Kinicki (2008) describe decision making process as a search for alternative options to get to ideal situation, which we can simply call the solution.

Decision making process is one of the most important not only in ordinary life situations but in many business activities. The implementation mostly represented by initiative behavior, not by professional insight problem. Big part of decision making process include the analysis of finite set of alternatives described in terms of evaluate criteria. Sometimes we can get that all of the alternatives similar attractive to us, however it can happen that we need to find best alternative or to determine the relative priority to each alternative. In this case we approach to the multiple criteria decision analysis.

Decision making process is important component of any business activity and it also has a perspective background in certain principles based on technical point of view. (Mann, Leon; Harmoni, Ros; Power, Colin, 1991) Decision making process takes place in several disciplines like economics, social sciences with the goal to provide the solution with conceive such models to help decision-makers with formulation of plan and strategy. The meaning of decision has been widely discussed and analyzed in economics. Organizational decision is an action to classify and solve problems. (Daft, 2010).

That process includes two stages: “what is the problem?”, identification, the second is to gather information about environmental and organization conditions to understand whether the performance is advantageous or not, if not-find causes of deficiency. (Daft, 2010)

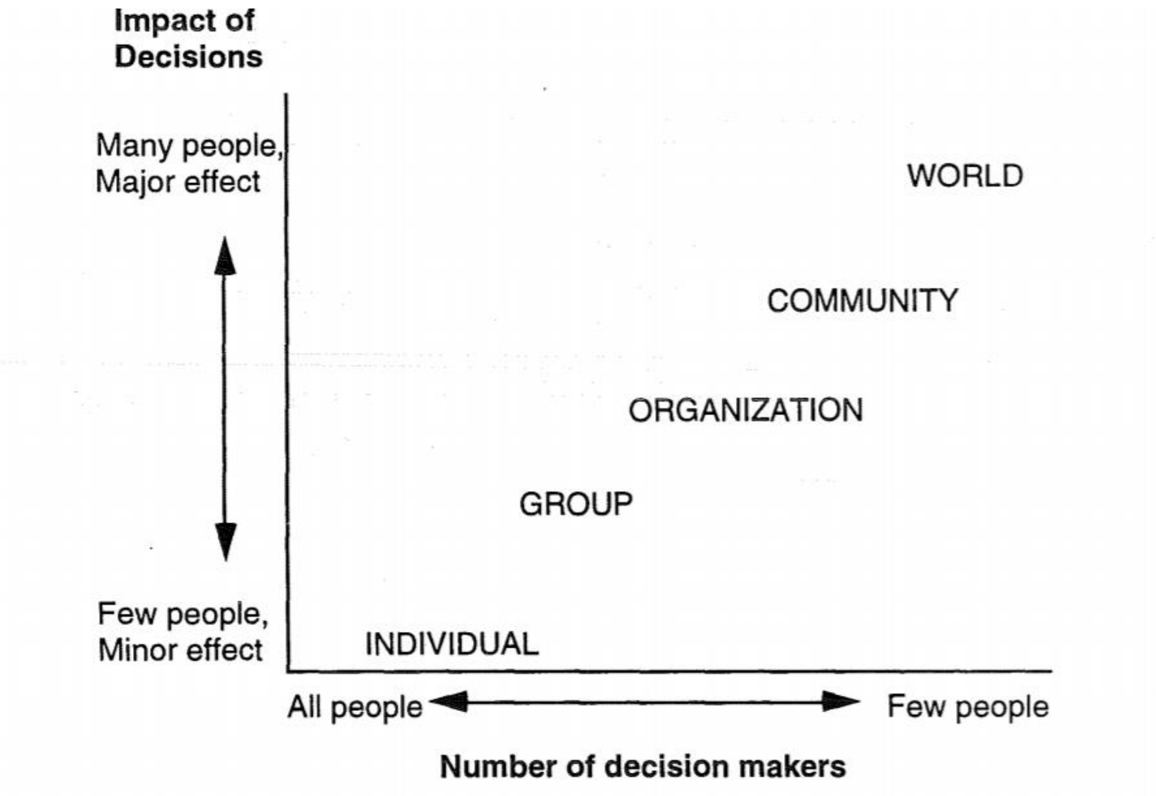
2.4 Value-based decision making

„When your values are clear to you, making decisions becomes easier“-Roy Disney. Our values is important from our everyday decision making. Values influence and motivate our goals, where the goals help to establish priorities, affect our decisions and lead to success and happiness. When we think about values, we think about success. Person can feel satisfied and accomplished only when he match decisions to the values he has in life.

However not all decisions needs a lot of thoughts or can lead to some consequences: those are every day decisions like what to eat or what to wear today, but when we make a decision concerning our future business then it can either match with our values and lead to success or it can be the reason of big disappointment.

There is the rational decision making model which includes steps, where leads to the best choice. In this model we start from identifying the problem, establish decision criteria, weigh decision criteria, generate alternatives, evaluate them, choose the best alternative, implement the decision and evaluate it. (Cool, 1998)

Figure 1- Hierarchy of Decision Making based on Harrison



(A Hierarchy of Decision Making based on Harrison, 1987), Picture 1

Problems concerning how many people has been involved in decision making and the number which was affected. (Harrison, 1995) marks that when all individuals make decisions which influence small groups of individuals, a few make decision have a very wide ranging impact.

"Decisions are active operations which bring forth and hence privilege discrete 'events' and 'entities' at the expense of movement, action and becoming. Such events and entities thereby appear to be unproblematic discrete, independent, identifiable [e.g. a decisional 'event'] and hence readily amenable to systematic analysis." (Chia, 1994)

"Decision-making is best understood as a process of reality creation through organization members' representations of their own role and activity". (Laroche, 1995)

2.5 The Bradford studies of decision making

We call that research project which has been created by Bradford management, in UK. They have discovered how the decision has reached top and how they have been used in practice. (Astley, Hickson & Miller, 1992) Both formulation and implementation are also dependant on the decision maker's script.

Thompson & Tuden (1964) has effected the Bradford studies. Considered as the model of decision strategies. Decision making process is simple calculation if conclusion beliefs are certain. Such a tame. If only those beliefs are uncertain then only inspiration can be the solution and provide the answer: a wicked problem. In Bradford studies decisions categorized as concerns, processes and problems. (Rowe, 1989). That research has created a model where decision making can differ and be different complexity (intricate, ambiguous, uncertain etc.) including the cleavage.

If level of complexity and cleavage is weak so are the levels of uncertainty, qualm, discontinuity and centralization, where a decision can be programmed. In this case the decision with high probability will be made transiently with the results admissible and satisfactory to all. (Rowe, 1989). (Hickson, 1992) found that the decision making "is never a matter of solely of calculations" and that the process which can be easily explained by reason of complexity does not exist. That can be united into three kinds of subject matter: vortex, tractable, familiar explain Rowe and Hickson & Muller in 1992.

• Vortex-sporadic- complex. Likely to be protracted with disrupting delays.
• Tractable fluid - less complex. "Delays are less likely as fewer people are involved. The issues are not likely to be serious and the process can be steadily paced, formally channelled 39 and speedy. They set precedents for later decisions. This decision type is closest to the 'rational economic man' view" (Rowe, 1989)
• Familiar-constricted - least complex and less political. Normal, basic situations. "There can be considerable discontinuity and delays." (Muller, 1992)

Figure 2- Types of decision strategies

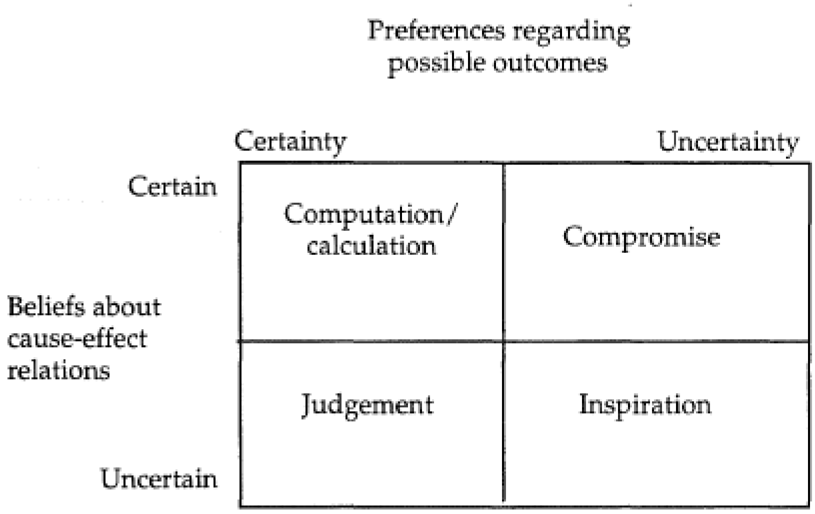
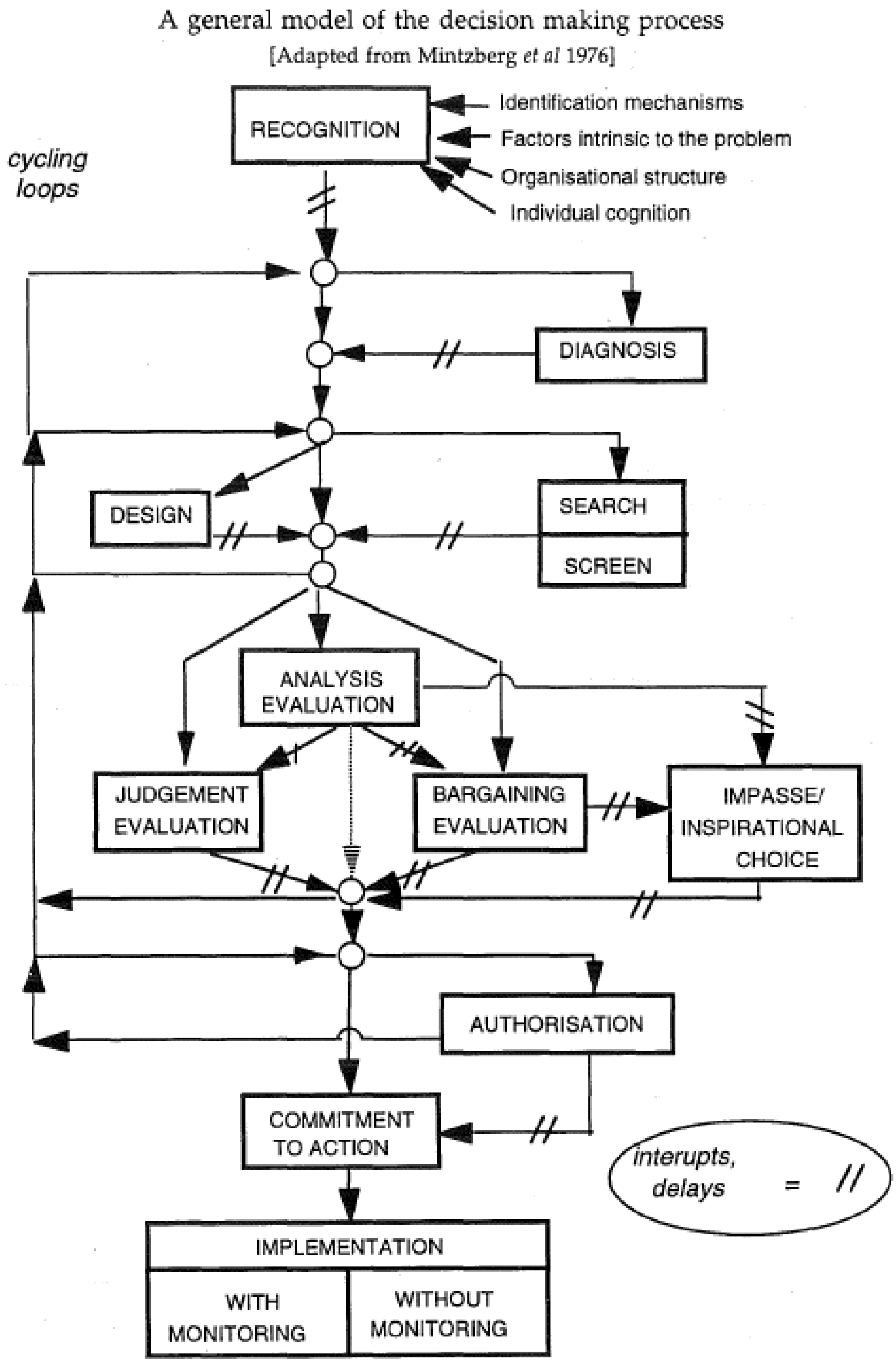


Figure 3- General model of decision making process



3 Basic elements of decision making

3.1 Purpose of decision making process

A careful review of the decision-making process with a view to its better understanding leads to the need for a clear definition of goals and objectives. Often goals or, in any case, directly related factors are both quantitative (objective) and qualitative (subjective). In these cases, the application of scientific decision-making methods requires maturity of judgment and foresight, as well as analytical and mathematical skill (Vassilis M. Papadakis, 1998).

It should be considered that sometimes in order to achieve the goal it is necessary to strike a balance between two or more factors under consideration, and in certain situations some of them will be included in the task as limitations, and not as components of the set goal of decision making (Vassilis M. Papadakis, 1999)

3.2 Alternatives in management decisions.

Decision makers often do not realize the importance of compiling a list of alternatives. It is quite obvious that ultimately not the best alternative among those considered can be chosen. In this sense, the quality of choice is limited by the quality of alternatives. An exhaustive list of available alternatives is of great help in making decisions. Decision making is the choice of one of the alternatives (2010, Muller), and compiling a list of them is an integral part of the process. In a sense, compiling a list of alternatives is exactly the same as defining a problem in an analysis. (Karel Cool, 1998)

When alternatives are uncertain, their list is incomplete or even ill-conceived, it is impossible to make a decision. However, when alternatives are clearly listed, the task is no longer intangible. There is one alternative that is almost always, at least at the very beginning, present in any list. It is an alternative to not make decisions at all. Sometimes (and only sometimes) the optimal compromise is to postpone decision-making in order to have more time to accumulate new facts. If the goal is to be achieved immediately, then, of course, decisions cannot usually be delayed indefinitely. (Belton, 2002)

3.3 Factors considered in making management decisions.

Under the factors associated with resources understand time, money and production capabilities (1997, research paper). Here, production capabilities are meant such diverse things as the availability of materials, parts, technical and scientific skills, organizational capabilities, etc.
It is typical for decisions that without special study or research, information on the essential aspects of such factors may not be complete enough. (Belton V, 2002)

Technical factors include factors that are directly related to the analysis or development of design requirements. Typically, technical factors are specific and quantified. In addition to resources and technical factors, purely human factors play an important role in decision-making. These factors express not only the requirements of the political or social feasibility of implementing or achieving an alternative, but also the requirements of human ethics and morality. To make the right decision requires not only technical competence in assessing resources and technical factors, but also taking into account purely human factors (1999, Margaret Higgins).

3.4 Rational order of making managerial decisions.

Before the decision-making task takes a form that can be analysed by one of the scientific methods, it is necessary to consider a large number of factors and exclude many alternatives. Prior to this, a decision can only be made subjectively or by guessing. It is important to fully understand the circumstances in which decisions are made. For this purpose, a methodology for transforming a decision-making situation is outlined here (Muller, 2012) to such a form when it becomes possible to use one of a variety of scientific methods:

1) The goal is formulated

2) A more complete list of alternatives is compiled. (Creativity and ingenuity are needed here)

3) A more complete list of factors is compiled

4) The list of factors considered is used to reduce the number of alternatives, while attention is drawn to the reason for the exclusion of each alternative. At this stage, you can see that many alternatives are unrealistic. Other alternatives may be highly impractical. This process can be extremely subjective, and in some cases it is based on conjectures.

However, if you need to make a decision, then there is no other choice. In constructing these subjective guesses and making judgments about value, the art of the decision maker is manifested. It should be remembered that one of the alternatives may be an alternative to not making any decision at the moment, until one of the factors (for example, time) removes this alternative from the list;

5) The remaining alternatives are used to reduce the list of factors, some of which can now no longer be considered. Other factors may apply equally to all remaining alternatives, and therefore they also need no longer be considered. The question of how much time should be devoted to the analysis of alternatives is largely an art. In addition, it is necessary to decide whether it is worth adhering to a decision once made or whether it needs to be reviewed.

The answers to these questions, in turn, are associated with the adoption of certain decisions, however, at present they are largely determined by taste, inclinations and personal qualities. The concept of "decision" in the scientific literature is interpreted differently. It is understood both as a process, and as an act of choice, and as a result of choice. Solution as a process is characterized by the fact that it, proceeding in time, is carried out in several stages (Johnson, 2012).

In this regard, it is appropriate to talk about the stages of preparation, adoption and implementation of decisions. The stage of decision-making can be interpreted as an act of choice, carried out by an individual or group person making a decision using certain rules.

The decision as a result of the selection is a precept for action (work plan, project option, etc.).

The decision is one of the types of mental activity and a manifestation of the will of man. It is characterized by the following features:

1) The possibility of choosing from a variety of alternative options: if there are no alternatives, then there is no choice and, therefore, there is no solution;
2) The presence of a goal: aimless choice is not considered as a solution;

Management decisions can be well-founded, made on the basis of economic analysis and multivariate calculation, and intuitive, which although they save time, but contain the probability of errors and uncertainty (Johnson, 2012).

Decision making in itself is a compromise. When making decisions, it is necessary to weigh judgments about value, which includes consideration of economic factors, technical feasibility and scientific need, and also take into account social and purely human factors. To make the “right” decision is to choose an alternative from the possible one in which, taking into account all these various factors, the overall value will be optimized.
Often it is necessary to give up a little of one of the characteristics (for example, reliability) in order to win in another (for example, in costs) (Daft, 2010). The task of the decision maker is to find alternatives that are an optimal compromise when all the factors considered are taken into account.

In some cases, the optimal compromise can be found by turning to scientific decision-making methods, i.e., using mathematical optimization methods, probability theory, mathematical statistics, or utility theory. In other cases, decision-making is an extremely complex issue that is subjective in nature and involves the consideration of non-quantitative human factors and value judgments. However, most often, when making decisions, both quantitative and qualitative factors are taken into account, which should be considered simultaneously.(Cool K., 1998)

It is believed that decision making is essentially an art. This belief is firmly rooted in the minds of many people employed in the field of administrative and public administration. However, the emergence of computer technology and the successes achieved in the development of scientific decision-making methods have led to a change in these views. Previously it was believed that decision-making is of a completely qualitative nature and is a subjective affair. Currently, quantitative methods are being intensively introduced in this area.(Rowe, 1989)

Decisions made should be based on reliable, current and predicted information, an analysis of all the facts that influence decisions, taking into account the anticipation of its possible consequences. Managers are obliged to constantly and comprehensively study the incoming information for the preparation and adoption of management decisions based on it, which must be coordinated at all levels of the internal hierarchical pyramid of management. (Rowe, 1989)

The amount of information that needs to be processed to develop effective management decisions is so large that it has long exceeded human capabilities. It was the difficulties of managing modern large-scale production that led to the widespread use of electronic computer technology, the development of automated control systems, which required the creation of a new mathematical apparatus and economic and mathematical methods.

Since the manager has the ability to choose solutions, he is responsible for their implementation. The decisions taken go to the executive bodies and are subject to control over their implementation. Therefore, management must be focused, the goal of management must be known. In the control system, the principle of choosing a decision from a certain set of decisions must be observed (Hickson&Miller, 1992).

The greater the choice, the more efficient the management. When choosing a managerial decision, the following requirements are presented to him: the validity of the decision; optimality of choice; competency of the decision; brevity and clarity; concreteness in time; targeting performers; efficiency of execution.

The methodology of a managerial decision is a logical organization of activities for the development of a managerial decision, including the formulation of a management goal, the choice of methods for developing decisions, criteria for evaluating options, and drawing up logical diagrams of operations. (Miller, 1991)

Methods for the development of management decisions include methods and techniques for performing operations necessary in the development of management decisions. These include methods of analysis, information processing, and choice of options for actions, etc.

Organization of the development of a managerial decision involves streamlining the activities of individual departments and individual employees in the process of developing a solution. Organization is carried out through regulations, standards, organizational requirements, instructions, responsibility. (Tolman, 1948)

The technology for developing a management solution is a variant of the sequence of operations for developing a solution, selected according to the criteria of rationality of their implementation, the use of special equipment, staff qualifications, and specific conditions for performing work. (Mason&Mitroff, 1981)

The quality of a managerial decision is the totality of the properties that a managerial decision has that meet, to one degree or another, the needs for successful resolution of a problem. For example, timeliness, targeting, concreteness. (Rowe, 1998)

4 Methods for determination of criteria weights

When we consider multi-criteria analysis it is important to understand the set of criteria which represent the view point taken into account while making decision. There are different types of view and they all have different level of importance for decision maker. In case we are talking about the importance it does make sense only when compare.
All information assembled from decision maker about the importance, representation, usage and effect of the final result bet on aggregation procedures used in methods. (Solymosi, 1986)

Most of them would use numbers to show the "proportion" of importance. The numbers are used to inflect supplement quantities as weights. In the additive utility model, concerning the function as normalized, importance appear as coefficient in convex combination of the MUF. In judgment of additive utility function we can determine the weights of criteria as estimated parameters of the model to be as rational as possible with known subjective preference judgments among the alternatives. Many known methods require some amount of the importance criteria as input data, but it does not treat the determination of weights. For example Tactic method where the result was obtained through linear programming model. The importance is shown by positive numbers which are used to determine and compare subspace of criteria independently of the evaluation of the alternatives of criteria.(Hilliard, Rokeach, 1950)

4.1 Point allocation method

One of the simplest methods used to determine criteria weights according to the priority.
The more points criteria receives, the more importance it has. Decision maker is allocating a certain points to the criteria. The total sum up of weights must be equal to the number of points decision maker needs to allocate. At the same time, considering this method, weights which were obtained from point allocation method is not very precise ad more difficult when the criteria is 6 or more. (Hilliard, Rokeach, 1950)

4.2 The direct rating method

In this method the decision maker ranks the criteria according their importance. Rating does not constrain the responses comparing to fixed point scoring method. In this method there is a possibility to alter the importance of one criterion without adjusting the weight of another. (Arbel, 1998)

4.3 The pairwise comparison method

In case there are multiple populations in pairs and we need to decide if they are significantly different one from another. Additionally, it is a method to compare each criterion with others and find out the level of preference for each pair of such criteria. Usage of ordinal scale from 1 to 9 helps to determine the preference value of one criterion against another. And one of the most common applicable methods is analytical hierarchy process.

Number of comparisons can be determined by:

$$Cp = \frac{n(n-1)}{2} \qquad (1)$$

c= number of criteria

n= number of criteria

This method has 3 steps. First, we create a comparison matrix, then we fulfill the matrix with different values which representing importance level: from equal importance to strong importance and extreme. Second step is to calculate criteria weights, which is known as priority value. There we use multiplication of the matrix entries of the row together and then taking the Xth root of that approximation gives us pretty clear results. Third step is to estimate the consistency for sensitivity analysis, also known as consistency ratio (CR).

$$CR = \frac{CI}{RI} \qquad (2)$$

If the ration is less than 0.1 then it shows the reasonable level of consistency in pairwise comparisons, but if it is greater than 0.1it shows that comparison is inconsistent in judgment. We accept matrix when consistency ratio is less than 0.1, 10%. Higher numbers shows that comparison is less consistent, with smaller number vice versa which means more consistent. That indicates if comparisons should be revisited or reversed (Prof, Delta State University Nigeria, 2008)

4.4 Ranking method

We use this method to simply assign criteria weights, when they are ranked from most to worst important. There are three approaches how to calculate weights with usage of ranking method. Calculations include: rank sum, rank component, and rank reciprocal. Formula for rank determination by (Raczkowska M., 2013)

$$Wj\ (RS) = n - pj + \frac{1}{n}\sum n - pk + 1, k = 1 \qquad (3)$$

Where p_j is the rank of the j-th criterion, j = 1, 2,.., n

Ranking method is also used in format of question-answer while put the priority within the set of object. Rokeach (1968) did explain value as “a type of belief about how one ought to or not ought to behave, or about some end-state of existence worth or not worth of attaining”. It turns and define certain values into set of desirable goals which are rated in importance hierarchy. Important part is that someone can understand that certain important of one value only considering the relationship to others. (Hilliard, 1950) By using the ranking method we want to create the list of values by their importance, highly important mentioning that those values can be differently important to different people. This method was used by Rokeach in his value survey in 1968. This method is used with ranking scales which are measuring instruments which are used to measure people’s attitude to variety of stimuli.

4.5 Weighted sum approach

In the vast majority of cases, decision-making problems turn out to be multi-criteria: using (particular) criteria) f1,…, f(m), m ≥ 2. Since, as a rule, each of the criteria identifies “its own” best option, i.e. Since there is no option that is simultaneously the best for each of the criteria, multi-criteria problems are fundamentally more complicated than single-criterion problems (when m = 1) and require special methods and approaches for their solution. Considering general case, where are the criteria have different scales by virtue of their “nature” (as an example where one criteria can be costs, another criteria-reliability or production and third criteria- environmental impact), where are different level of importance. In this case it is not possible to use classic formula. Therefore, need to normalize the criteria. Normalized criteria are dimensionless and their values lie in the same range, usually from 0 to 1. As the result we would use formula:

$$F(\hat{f}|w) = w_1\hat{f}_1 + \cdots + w_m\hat{f}_m \quad (4)$$

Even though, the method is often used, it has its advantages and disadvantages. From advantages it can be highlighted its convenience for calculations, applicable for solving decision problems in different settings. Correct methods for solving multi-criteria problems require a lot of effort and serious work on obtaining and processing information. Weighting sum approach let in many cases find the right solution.

The analysis of multi-criteria tasks is carried out on the basis of information on the preferences of the decision maker therefore such tasks do not have objective solutions with which, as with the standards, it can be compared the results obtained by the weighted method amount.

Considering the disadvantages of the methods, first to mention would be "intellectual error" which caused by the independence of the procedures for normalizing criteria and assigning their weights. First, must be asked:" How legitimate is the approach based on formula above?" To get an answer to it, we turn to the theory of additive value functions, having the formula:

$$v(f) = v_1(f_1) + \cdots + v_m(f_m) \quad (5)$$

Since need to maximize all criteria, each frequent value function Vi is increasing.

Using the value function, each option is evaluated by its value – the number v (f(x)): the larger this number, the more preferable it is.

The conditions for the existence of an additive function v'=v'1+…+vm'-another function, then existence of number k>0 and li, then $vi` = kvi + li$, i=1,….,m.

Positive k is common to all criteria. Scientifically based methods for constructing additive value functions has been created but they are quite complex and therefore did not receive wide distribution. Let f*I and fi* be the largest and the smallest values of the criteria fi(x) on the set of options X. If necessary adding Vi from –vi(fi*)=0, I =1,…,m. Then the function can be represented in the following form:

$$v(f) = w_1\hat{v}_1(f_1) + \cdots + w_m + \hat{v}_m(f_m) \quad (6)$$

Where: $\hat{v}_1(f_1) = v_i(f_i)/v_i(f^*{}_i)$,

$$w_i = \frac{v_i\left(f^*{}_i\right)}{\sigma} \qquad (7)$$

$$\sigma = v_1\left(f^*{}_1\right) + \cdots + v_m(f^*{}_m)$$

Note that all $\hat{V}i(f * i) = 1$, then it is clear that numbers " by its origin" the numbers Wi are scaling factors.

Comparing (4) and (6) formulas, we can see that consider them as normalized criteria f^I, and the factors Wi are the weighted criteria, which take into account not only the relative importance of the criteria fi, but also the magnitude of the values of the functions vi(play more complex and important role then the coefficients).

It seems clear now that we cannot assign weights Wi without taking into account the values fi* and f*i. The assignment of Wi values in violation of this provision is called an intellectual mistake. The error cannot be excluded by conducting the sensitivity analysis, which is where finding out to what extent the weight of the criteria can be changed, while maintaining the solution to the problem unchanged, for example-highlighting the best option.

4.6 History of tulips

"Tulip, (genus Tulipa), any of a group of cultivated bulbous herbs in the family Liliaceous."(Encyclopedia Botanica, 1986). There are 100 species that origin from Austria and Italy eastward to Japan, with 70% origin to the eastern Mediterranean and the southeastern parts of the Soviet Union. Tulips are one of the most common in home harvesting. (Encyclopedia Botanica, 1988)

Easy recognize that the word has come from Dutch or German "tulipe", French "tulipe" all ultimately from Turkish "tülbent", "gauze, muslin"; from Persian "dulband", so called from the fancied resemblance of the flower to a turban. From Turkey to Europe, where in middle of 16th century was

earliest cultivation in the Netherlands in the garden of Johann Heinrich Herwart in Augsburg, popularized in 1587 by Clusius.
The tulip-mania raged in Holland in the 1630s. Word “tulip” back then was changed from original Turkish name among countries, for instance: in Italy- “tulipano”, in Spain- “tulipan”, the ending – and would later drop to Germanic language group and will be mistakenly took for a suffix. . Tulip tree (1705), a North American magnolia, so called from its tulip-shaped flowers. (Hoad, Oxford, 2000)

Augier Ghislain de Busbecq, Viennese ambassador to Turkey was the first person who has introduced the tulips to the Western world by sending some seeds to Austria. The arrival at Antwerp in 1562 of a cargo of tulip bulbs from Constantinople (now Istanbul) was the beginning of the tulip horticultural industry in Europe. A speculative frenzy over tulips in the Netherlands in 1633–37 is now known as the Tulip Mania. (Encyclopedia Britannica, 2000)

In the beginning of 17th century population of the world already have known double tulips. Tulips have spread around the world and was very popular. It fitted and was liked by all ages and sexes. (Encyclopedia Britannica, 2000)

In the early 17th century, craziness started in France, when population was ready to change property for one single tulip bulb. The value of the flower strongly increased, and numerous publications describing the various varieties were published at this time, cashing in on the value of the flower (Encyclopedia Britannica, 1998). An export business was built up in France with Dutch, Flemish, German and English buyers. The trade moved from the French to the Dutch. The French tulip craze probably sparked the infamous tulip mania in Holland which started in 1634 and reached its height in 1636, the market collapsed three years later as a result of oversupply, leaving many people bankrupt and causing the Dutch government to introduce trading restrictions on bulbs (Encyclopedia Botanica, 1999).

However it did not decrease the demand of flowers. This “mania” was not unique event in “new comers”, still demand was high but supply is low, which has caused new similar pattern and it lead to dramatic fall of prices due to now common flower. Despite criticisms, tulip mania appears to have been a financial speculative bubble with major social impacts, similar to what we see today in the banking sector. (Garber, 1989)

Today the Netherlands is the world's main producer of commercial tulip plants, producing as many as 3 billion bulbs annually, the majority for export. (Earth-observatory, NASA data, online, 2020)

In horticulture, one of the classification method based on time of bloom and form:

Single Early Tulips are among the earliest tulips to bloom. The flowers, available in a wide range of colors, are produced on strong, long stems. The flowers of several varieties have a sweet fragrance. Single early tulips are excellent for rock gardens, beds, and forcing.

Double Early Tulips produce semi-double to double, peony-like flowers. The flowers are borne on strong, short stems. The color range of double early tulips is smaller than for most other tulip classes.

Greigii Tulips are noted for their brightly-colored flowers and purple striped or mottled foliage. Because of their short stature, Greigii tulips are excellent choices for borders or rock gardens.

Kaufmanniana Tulips are long-lived perennial tulips. In sunlight, the flowers open fully. The open flowers resemble a star or waterlily. Flower colors include white, yellow, pink, and intermediary colors. The foliage is bluish green or chocolate brown striped. Kaufmanniana tulips are small plants. Their compact size makes them good choices for border edges and rock gardens.

Fosteriana Tulips produce some of the largest flowers of the genus. They also perennialize well.

Species Tulips include wild species, horticultural varieties, and hybrids. Most are early blooming, short-statured plants. Species tulips are available in a wide array of colors. They perennialize well and are excellent plants for rock and heirloom gardens.

Darwin Hybrid Tulips are highly prized for their large, brilliant flowers. Flowers are available in shades of red, pink, orange, and yellow. Blooms are borne on strong stems which are up to 30 inches tall (76 cm). Darwin hybrid tulips often bloom well for several years, making them one of the better perennial tulips.

Triumph Tulips produce cup-shaped flowers on strong, medium-length stems. Average plant height is 10 to 16 inches (25-40cm). This is the largest class of tulips and offers the widest range of flower colors. Triumph tulips are excellent for forcing.

Parrot Tulips have deeply feathered, curled, or twisted petals. Flowers may be single or multi-colored. Many varieties have a green spot at the base of their petals. Parrot tulips are sensitive to poor weather and should be planted in a protected spot.

Single Late Tulips incorporates the former Darwin, cottage, and breeder tulips. Along with the **Darwin hybrid tulips**, they are the some of the tallest tulips. Flowers are available in a wide range of colors.

Double Late Tulips are often referred to as peony-flowered tulips. The many-petaled flowers are borne on 12 to 20 inch stems. Plant double late tulips in protected locations as the large flowers can be damaged by rain and strong winds.

Viridiflora Tulips produce long-lasting flowers which have prominent green markings on their petals. The unusual flower characteristics make it a novelty item in the garden.

Lily-flowering Tulips have long pointed petals which arch outward, the flowers somewhat resembling a lily. Flower colors include white, pink, red, yellow, and purple. Several varieties have petals edged or feathered in contrasting colors. Plants grow to a height of 20 to 30 inches.

Fringed Tulips have flowers with elegant fringed petals. Many varieties are mutants of single late tulips. Also known as “crispa tulips”.

Rembrandt Tulips produce striped or “broken blooms”. The white, yellow, or red petals are striped with red, bronze, or purple. These types were bought for huge sums during the
“Mania” in the Netherlands in the seventeenth and eighteenth centuries. The unusual markings were actually caused by a virus. Due to the virus, the original Rembrandt tulips are no longer sold. However, there several modern, virus-free Rembrandt tulips available.

Multi-flowering Tulips produce 3 to 7 blooms per stem. The main stem of multi-flowering tulips branches into secondary stems. Each secondary stem produces a flower. The flower on the main stem is slightly larger than those on the secondary stems. Many of the multi-flowering cultivars belong to the single late tulip class.

5 Technologies in processing of tulips

There are two main types of bulb, pre-cooled and non-pre-cooled. (University of Maryland Cooperative extension center, fact sheet 837) And there are also three ways of forcing tulips: in soil in beds, in boxes and on water.

5.1 Forcing in the greenhouse soil

Five-degree tulips

Usually the bulbs are stored with 5°C to 2°C cold temperature for 9 to 14 weeks. The bulbs are then planted in the greenhouse soil where, depending on the greenhouse temperature, flowers will be harvested in 35 to 60 days (the warmer, the earlier). The cold treatment is given in the Netherlands before the bulbs are shipped. If the duration of transport is long, however, part of this cold treatment can be done during shipping. These five-degree tulips are usually brought into flower from late November to early March.

Nine-degree (pre-cooled) and non-cooled tulips

Surmise on flower period, non-cooled bulbs have cold treatment by exposing them to circumjacent temperature in the greenhouse soil for 13 to 20 weeks. "If part of the cooling treatment (no longer than 9 weeks) is applied to the dry bulb (i.e. not planted), this is done in a cold store set at 9°C or possibly 5°C (the 9° setting being used for pre-cooled tulips). Nine-degree tulips can be brought into flower from early December to early April". (The encyclopedia Botanica, 1988)

Nine-degree (pre-cooled) and non-cooled tulips

After being planted the tulips receive the cooling 13 to 20 weeks. Firstly, the temperature is set at 9°C then it reduces to0°C (non-cooled bulbs). For pot tulips, the cooling period is 2 weeks shorter, the cooling treatment flowers get after being planted into the boxes. Part of the cooling treatment can be applied to the dry bulbs (nine-degree pre-cooled tulips) before planting them in boxes for completion of the cooling treatment. After the cooling process has been completed bulbs will be taken to the greenhouse. At a greenhouse temperature of 18 to 20°C, the flowers are stored 3 to 4 weeks (the warmer, the earlier). Planted December-April.

Using bulbs produced in the Southern Hemisphere for 9°C tulips. These bulbs are delivered in May and will already have received part of their required cold period during their transport from the

Southern Hemisphere. After that, bulbs needs to be put into the boxes immediately and stored for 4 weeks at 7˚C. Next, the temperature in the storage room can be reduced to 0˚C until the housing date. By providing a greenhouse temperature of 14 - 15˚C, flowering can be expected within 15 to 18 days. Depending on the greenhouse climate, flowers can be produced from October to 15 December.

5.2 Forcing in water

Nine-degree tulips

Those bulbs receive 13 to 20 weeks of chilling. Beginning of the cooling period, the temperature is set at 9°C but is slowly reduced to 0°C. During the rooting period, tulips are kept at a temperature of 5°C. After cold phase completed, bulbs are taken to the greenhouse. At a greenhouse temperature of 16 to 18°C, the flowers are kept in

3 to 4 weeks (the warmer, the earlier). Depending on the greenhouse temperature and cultivar, flowers are produced from December to April.

5.3 Storing in the boxes

Ice tulips

These bulbs are planted in boxes in November and then allowed to root at 9°C or 5°C for 3 to 6 weeks. After this rooting period, the boxes are frozen, wrapped in plastic and stored at –1.5 to - 2°C. Usually, the boxes are taken into the greenhouse or put in a cool place outside after the summer months at which time the tulips are allowed to come into flower. This method is used to force a limited range of tulips during the autumn months. Unfortunately, the attractiveness and keeping quality of these tulips is sometimes less than ideal. Flowers can be produced from May to late November.

6 Multi-criteria analysis and decision making process on harvesting machines

In this chapter my attention will be paid towards the problem of choosing the best harvesting machine for tulips in greenhouse. I will use the weighted sum approach which I have explained in chapter 5.5, knowledges and real calculations which I have got from visiting Havatec mechanization exhibition in Netherlands and interviewing the farmers who has world's largest tulips production. Additionally, interviewing the organizers of such exhibitions I got knowledges not only in the technical side such as machines and liners, but also about business in general. My main focus will be on production of Havatec Company which has big offer of harvesting machines for the tulip business.

6.1 Havatec harvesting machines

In the beginning of 21st century Havatec has established first machine for the mushrooms, however not so long after that Havatec has progressed and created advanced machine for profiling and bunching of flower bulbs by using X-ray techniques. 3 years later Havatec is one of the first advanced producers on market which has vast band of machines for automatic profiling and bunching of flowers. Additionally to this, was developed machines for packaging flowers in boxes and machines which can do everything at once for big green-houses. It has been almost 500 machines which has been ordered by big companies around the world from Havatec. And since that time Havatec is the leading supplier for the flower business. "Always ahead in technique but ever with the key values in mind that go alone with mechanization in agriculture: simple, reliable, affordable." – (Fikkers, Mark – commercial director of Havatec)

Havatec is also called as High-tech simplicity due to high performance techniques and simple usage of machines which are able to operate 24h unstoppable. All machines are established in close co-operation with a group of potential end-users, which includes 1 to 30 parties and guarantee market potential. From 2008 company organized Service free charge as a part of guarantee of machines which is 15 years. It include: yearly online check-up, service 24h/daily, quality control and free of charge replacement of broken parts even after guarantee has finished. It does attract a lot of customers around the world to the yearly Havatec exhibitions which takes place 15km from Amsterdam south, where you can buy and test machines, order bulbs and get a chance to meet world's best farmers.(Havtec official data, presented on the official web page, data is updated in 2020)

6.2 Subject of the thesis

The subject of my thesis will be 4 original automated harvesting machines for large-scale production. I will describe "Handline Havatec" with automated bunching, "Havatec Q.B. 2.0, semo-automated" which is known as a perfect solution for large and small tulip businesses, famous for easy operations and high capacity, "Bercomex Flora" stand almost in the same line with "Handline" but has higher capacity and full automated "Tulip Star" which is famous for its huge capacity, lowest cost per tulip and the least amount of mistakes during work.

Figure 4- Automated "Tulip-Star"

(Source: (Havatec official, gallery of equipment " Tulip-star")

Figure 5- Semi- automated Quality-Buncher 2.0.

(Source: (Havatec official, gallery of equipment “Q.B.2.0”)

6.3 Greenhouse dimensions and quantity.

Greenhouse where will be chosen the harvesting machine will have dimension of 15 hectare (15000 square metres) due to the volume of 15000000 tulips. It is average production where we can still consider hand work to machines however purchase of machine already must be considered to speed up ROI and increase productivity which will lead business to next level. One bulb must be planted with respecting of 2 cm space. That mean that for green house with volume of 15000000 tulips the dimension of greenhouse is 15 hectare because in one square meter 100 tulips can be planted, so the S (square) of the green house is:

$$S=\frac{15000000t}{100\frac{t}{m}} = 150000\, m^2 \qquad (8)$$

Formula (8) shows 150000 square meters is needed for the volume of 15000000 tulips, where 150000 m is equal to 15 hectares.

6.4 Why harvesting machine? Comparison to hand work

Official data which have been obtained from the general manager of Havatec Antonio Dos Santos shows that average number of tulips which 1 person can pick in 10 hours is 1750. Average time farmer needs to pick the tulips before the main holidays where the most of tulip business is concentrated (Valentine's Day or international women day) is 20 days. Number of tulips per day is:

$$N= \frac{15000000t}{20d} = 750000t/day \qquad (9)$$

Formula (9) shows how many tulips per day must be picked up to be able to finish the process in 20 days. Considering the average number one person can pick up per day the procedure is:

$$N= \frac{75000t/day}{1750t/day} = 429\ people \qquad (10)$$

Formula (10) shows that we would need 429 people to work in green house to pick up the flowers on time. Average salary (Antonio Dos Santos, general manager of Havatec) is 30 euros per work day, which means that 12870 euros must be paid daily to employees.

- 30x429=12870 euros –daily

- 12870x20=257400 euros –season expense for salary

Additionally we can mention the risks in hand work, those are dependence on people, problems with labor qualification, risk of mistakes in counting when packing, low efficiency on a person, at least 4-5 coffee breaks and at least 1 lunch break.

Considering machine work needs to be paid once investment which will take some years to ROI. However even if we take the most expensive machine with the price of 265000 euros, just 2600 euros more expensive then hand work example we need to take into consideration that investment will be made only once. Guarantee is 15 years for machine which means that next 15 years after ROI farmer will get only profit (not taking into account bulbs purchase).

Advantages of using of Havatec harvesting machine:

- ROI compare to hand work:

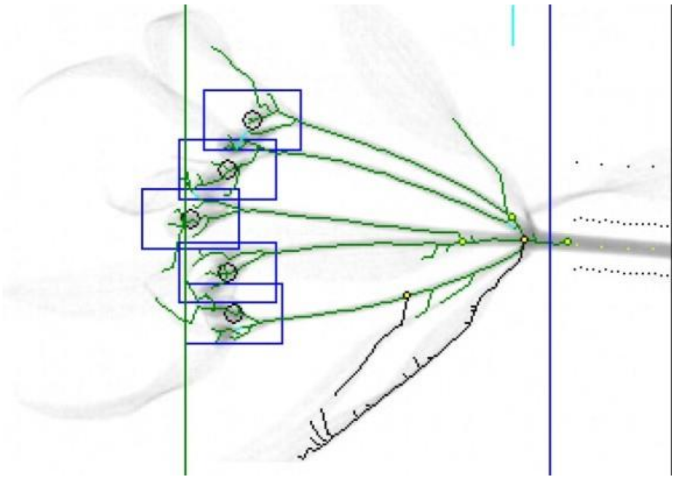
  *Where cost on one tulip is 0, 00175 (Havatec machine with price 265000) with number of tulips in greenhouse 15000000:

  ROI=0, 01-0, 00175=0, 00825x15000000=123750 euro/year, which means 2, 1 years.

- All process is automatic
- X-Ray scanner for bed/ broken flowers*
- Up to 16000 stems/hour
- Guarantee 15 years
- Investment must be done only once

.

Figure 6-X-Ray Scanner Havatec Advanced



(Source: Havatec official, gallery), Picture (6)

Considering all the calculations and advantages to increase the business profitability for the business with the volume of 15000000 tulips per season the best option is the purchase of harvesting machine. There are 4 options of harvesting machines which will be considered and criteria for decision. Using the knowledges from chapters 3.1 “Decision making process”, 4.1. “Purpose of decision making process” and 5.5“Weighted sum approach” will proceed with choosing the best option of harvesting machine for tulips in green house.

7 Evaluation criteria

The Havatec has set minimum requirements for technical specification for each of the machines and represent the technical specification of each machine on (Private access: online Havatec specifications, technical review and requirements 2000-2019), and further evaluation criteria as follows:

Table 1- Evaluation criteria for harvesting machines

Criteria	Name	Weight
1 criteria	Price	0,29%
2 criteria	Capacity per day	0,23%
3 criteria	Fuel consumption	0,17%
4 criteria	Cost on tulip	0,20%
5 criteria	Review	0,11%

(Source: own created)

Table 2- Measuring of importance

From 1 to 10, where 10 is the best

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Sum
m	10	8	5	7	4	34
K%	0,29%	0,23%	0,17%	0,20%	0,11%	100%

(Source: own created)

Considered that the highest value of importance is 10 lead to the conclusion that the most important criteria is price, then capacity per day which has been measured by 8, after which it was 7 for cost of tulip, 5 is for fuel consumption and 4 is for review. To estimate criteria evaluation values into percentage which will be needed for the weighted sum approach must be used the following formula:

(11)

$K(\%)1 = \frac{m(1)}{\sum(m)}$; $K(\%)2 = \frac{m(2)}{\sum(m)}$;….;$K(\%)n = \frac{m(n)}{\sum(m)}$, where $\sum(m)=34$

As an example measuring first criteria is following:

$$K(\%)1 = \frac{10}{34} = 0{,}29\% \tag{11}$$

Additional remarks are made on the weighting of the criteria. Price is evaluated in Euros (€). Capacity per day is measured in number of tulips, taking into consideration that all the data has been officially provided by Havatec Company. Fuel consumption is not restricted and does not have limits and is measured in liters. Cost on tulip is measured in euros (€) and has not been changed, the data is sufficient and updated. Reviews is measured in points, which was obtained by multiple years reviews and feedbacks on customer usage experience and estimation online quizzes. Maximum is 10 points.

7.1 Methods of evaluation criteria

Based on the analysis of the table "Measures of importance" scoring will be analyzed with Rubric method (Global Assessment scale), mainly used for evaluating criteria. It has one or more dimensions on which performance is estimated, attributes are measured. Most of the times rubric method is being used for delineate certain criteria for grading. Machines are being analyzed with next criterions:

1. Price
2. Capacity per day
3. Fuel consumption
4. Cost on tulip
5. Review

By using Rubric method and scoring those criterions, price has been chosen and scored by 10 as the most important due to few reasons: it helps define value, define the investment customer must pay to get the product. Customer will determine how much ready to pay for certain machine and if it is worth that amount. Capacity per day is rated as 8, it mean how much certain machine can produce for certain period of time, which can be second decisive factor in final decision. Cost on tulip is third important criteria and measured as 7 and dedicated to show the tulip assembly price. Shows the expenses of one tulip. Fuel consumption is evaluated as 5 as fuel-efficient machines save more money in long term, which lead to less expenses. The more energy is extracted from fuel, the better the fuel-efficiency is. The last criteria is reviews and estimated as 4. Reviews shows the feedback of people who has already purchased the harvesting machine and use it If there are doubts weather machine is worthy to buy, it is good to check online reviews on certain model to understand if this machine is working properly or what problems could have been appeared while usage.

7.2 Process of applying weighted sum approach

Table 3-Data for tulips harvesting machines and criteria

Machine names	Criteria 1 (10-importance)	Criteria 2 (8-importance)	Criteria 3 (5-importance)	Criteria 4 (7-importance)	Criteria 5 (4-importance)
Machine 1	45000 €	25000 t	6 L	0,0056 €	5
Machine 2	85000 €	56000 t	10 L	0,0035 €	7
Machine 3	265000 €	100000 t	8 L	0,00175 €	8
Machine 4	60000 €	30000 t	7 L	0,0050 €	6

(Source: own created; data is sufficient and obtained from Havatec official, 2020)

Machine 1 will be machine called “Hand-line” from Havatec; automated bunching, easy and fast counting, machine maintains speed. Machine 2 is Semi-automatic, Havatec “Q.B. 2.0” no mistakes in counting, automatic counting. Machine 3 is automatic line from Havatec “Tulip Star”, which is known as a good choice for big businesses, reliable and has famous x-Ray scanner. Machine 4 is Bercomex which is not big different from the Machine 1 in price but has bigger capacity, commonly used for small, middle and large scale businesses.

7.3 Evaluation

be used called “Weighted sum approach”, it is needed to count the importance of weights where the process has been described in Chapter 7.8 lists the selected evaluation methods with the Rubric method which has been descried in chapter 7.6, used method is from chapter 7.5:

Table 4- Evaluated criteria and importance weights

Name machines	Price	Capacity per day	Fuel consumption	Cost on tulip	Review
Handline Havatec	45000	25000	6	0,0056	5
Q.B.2,0 Havatec	85000	56000	10	0,0035	7
Havatec “TulipStar”	265000	100000	8	0,0175	8
Bercomex	60000	30000	7	0,0050	6
Importance Weights (y)	**0.29**	**0.23**	**0,17**	**0,20**	**0,11**

(Source: own created; data is sufficient and obtained from Havatec official, 2020)

Requirements:

∑ Of Importance weights= 100%;

∑ (0, 29+0, 23+0, 17+0, 20+0, 11) = 1, which means 100%.

Conditions and requirements are met.

Sorting of variants then proceeds on the basis of y, the variant with the highest total the ranking is the winning variant.

7.4 Weighted sum approach and normalization of weights.

Among the various methods have been mentioned in chapter 5 it has been chosen to continue in practical part with method Weighted sum approach because it is complex method which is due to normalized sum weights lead to the most accurate result. Method is the best when choosing the most appropriate option among certain objects with few criterions. Weights are calculated and normalized for criteria. The criteria weights shows the relative importance of the criterion for the decision maker. Weighted sum approach requires that all of the scores are changed to comparable units. All scales must be the same, then the scores can be compared. The procedure is called normalization. With normalization procedure the units of measure are made unified. There are few methods which can be used for normalization process: maximum standardization, interval and non-linear value function approach.

According to weighted summation, there is an internal methods which used for normalization and it is the most common known method. The point is that the function has two parameters, the lowest and the highest score (ci), commonly known as min and max values. Sij(=Ci(aj)) are convert into the relative value on given interval between the minimum and maximum scores via the interval [0,1]. The following formula is represented according to the description above:

$$\text{Vi(SiJ)}= \frac{Sij - \text{Min}(j)(Sij)}{Max(j)(Sij) - Min(j)(Sij)} \qquad (12)$$

According to formula (12) S-real value which will be value of each of the criteria: price, capacity per day, fuel consumption, cost on tulip and review. Each real value will be taken for each type of machine: Handline, Q.B.2, Tulip Star, and Bercomex.

For (Min (j)) will be taken the worst value from each column. The worst price, which means the most expensive price, the worst capacity which will be the lowest capacity, the worst fuel consumption which will be the biggest fuel spending, the worst cost on tulip which will be the highest the worse and review, where the worse review is taken as the lowest number in the column.

For (Max (j)) will be taken contrary the best value from each column. The best price is the cheapest price, the best capacity per day is the highest number in the column, the best fuel consumption is the lowest fuel consumption, the best cost on tulip is the lowest number and the best review is the one which got the highest score points. Per table below are calculated and normalized values and procedure:

Table 5- Normalization of weights, priorities

Name machines	Price	Capacity per day	Fuel consumption	Cost on tulip	Review	Preference score
Handline Havatec	**1**	0	**1**	0	0	x
Q.B 2.0, Havatec	0.81	0.41	0	0,54	0.66	x
Havatec “Tulip star”	0	**1**	0.5	**1**	**1**	x
Bercomex	0.93	0.06	0.75	0,15	0.33	x
Weights	0.29	0.23	0.17	0.20	0.11	x

(Own created; normalization of weights in WSA)

In Weighted Sum Approach it has been required to normalize numbers, convert them into the relative value on given interval between the minimum and maximum scores via the interval [0, 1]

According to the table (5), taking into the consideration the best machine in different criteria is shown as 1, the worst is zero and mean is 0.5. Considering only the best values it is noticeable that Handline Havatec is winning as best machine among the price criteria. In capacity per day the best machine is Havatec “Tulip Star”. In Fuel consumption the best option is Handline Havatec. In cost on tulip and review the best option is Havatec “Tulip Star”.

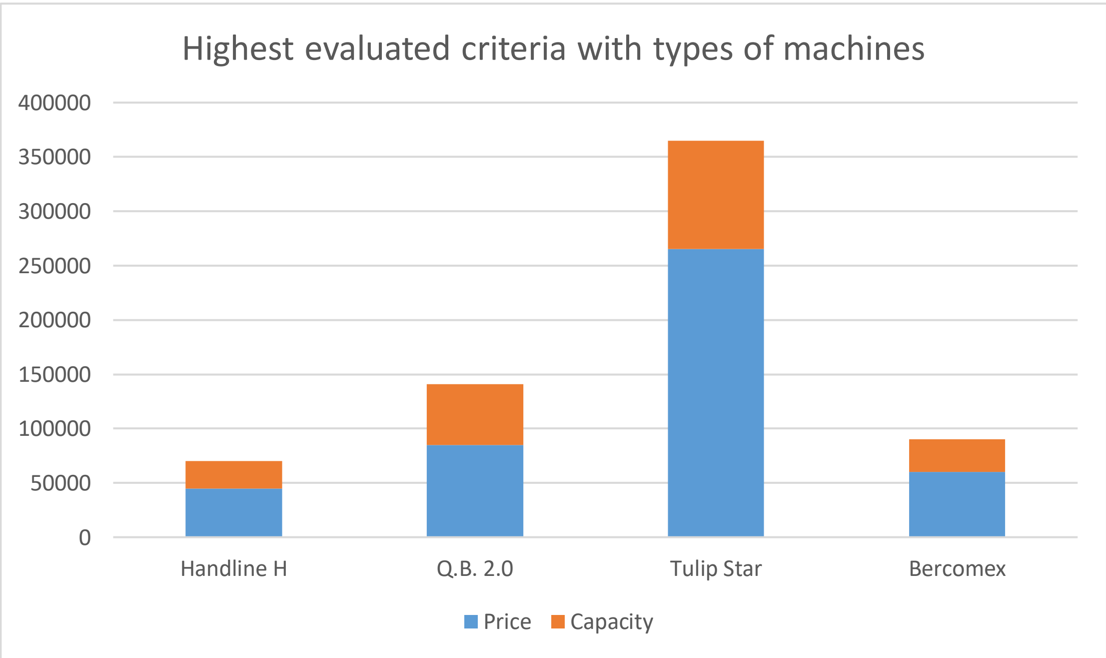
However, in price criteria the Havatec “Tulip Star” is the most expensive option which means the worst option. In capacity per day the worst option is considered to be Handline Havatec. Fuel consumption the most unprofitable option is emphasized Q.B.2.0. Cost on tulip shows zero as the worst value with machine Havatec Handline. Worst review goes to Handline Havatec.

Taking into consideration the weights, which are measured by 0.29 %, 0.23 %, 0.17 %, 0.20 %, and 0.11 % with the sum of 1 % to count the normalized sums of weights and to achieve the result in choice of the best machine for greenhouse with dimensions 15 hectares, simplifying the formula mentioned above (12), it is seen:

$$Vi = \frac{Real\ value - wosrt\ value}{best\ value - worst\ value} \qquad (13)$$

As an example of calculation, according to price criteria, where original price for machines are: Havatec Handline is 45000 €, Havatec Q.B.2.0 is 85000 €, "Tulip Star" is 265000 €, Bercomex is 60000 €. The chart 1 is representing graphically criteria, which has been evaluated with highest importance such as: Price and Capacity. The price has been evaluated as the most significant criteria in decision making and marked as 10 (0, 29 %), capacity has been marked as second criteria with weight 8 (0, 23 %) (Chapter 7.5, evaluating criteria)

Chart 1.Graphical representation of the highest valuable criterions.



(Source: own created, based on Havatec official)

With the price example, calculation for the determination the best price machine option are following:

$$\text{Vi(SiJ)}= \frac{Sij-\text{Min}(j)(Sij)}{Max(j)(Sij)-Min(j)(Sij)} \quad (14)$$

In simplified form:

$$\text{Vi}= \frac{Real\ value-wosrt\ value}{best\ value-worst\ value} \quad (15)$$

Where the real value (Sij) for first machine is 45000 € (changeable), worst value (Min(J, Sij)) is 265000 € (the most expensive machine) and best value (Max(J, Sij) is 45000 €.

$$\text{Vi} = \frac{45000-265000}{45000-265000} = 1$$ (Mentioned in table (5), example of the calculation) (16)

Obtained result is equal to 1, which represent the normalized result in the limit [0,1]. It shows the best price option among other machines, where it is the Handline Havatec. Proceeding with calculation for next machine Q.B.2 from Havatec, following the same formula:

$$\text{Vi}= \frac{85000-265000}{45000-256000} = 0.81$$ (mentioned in table(5), example of calculation), (17)

The result which has been obtained stands in between, means that it is still good price option comparing to others, the result is approximate and close to 1 and located within limit [0,1].

$$Vi= \frac{265000-265000}{45000-265000} = 0$$ (mentioned in table(6), example of calculation)(18)

Zero shows the worst price, in other words the most expensive price, the result is located within limits and being normalized [0,1].

$$Vi= \frac{60000-265000}{45000-265000} = 0.93$$ (mentioned in table(5), example of calculation) (19)

The result is approximate to 1, very close to the absolute best option, stands within the limit [0, 1].

By calculating the normalized option using the same formula for all of the criterions, it has shown to each either the best, the worst or in between options. After the alternatives has been defined, the criteria has been defined and selected the values has been allocated and scores have been assessed. Following with the standardization procedure as has been calculated and shown in Table (5) and examples of calculation. The last step before the ranking of the alternatives is to weight the criteria and assign the priorities to them. Calculation of the total score for each alternative can be measured by the following equation, when Aj, score (aj):

$$\text{Score (aj)} = \sum_{i=1}^{N} WiVi(Sij) \qquad (20)$$

Where N- number of criteria,
Ci-criterion,
Vi-value function for criterion Ci,
Sij- score from alternative Ci,
Wi-weight for criterion Ci.

The method of weighted summation is being complex due to the reason of choosing the right value function to normalize the scores of the criteria and the weights allocation.

Table 6- Weighting summation

Name machines	Price	Capacity per day	Fuel consumption	Cost on tulip	Review	Preference score
Handline Havatec	1	0	1	0	0	**0,460**
Q.B 2.0, Havatec	0.81	0.41	0	0,54	0.66	x
Havatec "Tulip star"	0	1	0.5	1	1	x
Bercomex	0.93	0.06	0.75	0,15	0.33	x
Weights	0.29	0.23	0.17	0.20	0.11	x

(Source: own created, sum of the normalized weights)

The score in the last column of sum of normalized weights for Hanline Havatec is 0.460, which is less than 0.5 and cannot be the decision in the choice of harvesting machine.

Score (Aj) = 0.29+0+0.17+0+0=0.460 (Handline Havatec)

Score (Aj) = $0.81 \times 0.29 + 0.41 \times 0.23 + 0 + 0.54 \times 0.20 + 0.66 \times 0.11 = 0.5098$ (Q.B.2.0)

Score (Aj) $= \mathbf{0 + 0.23 + 0.085 + 0.20 + 0.11 = 0.625}$ (**Tulip Star**)

Score (Aj) $= 0.93 \times 0.29 + 0.06 \times 0.23 + 0.75 \times 0.17 + 0.15 \times 0.20 + 0.33 \times 0.11 = 0.58$ (Bercomex)

Table 7- Summation of normalized weights

Name machines	Price	Capacity per day	Fuel consumption	Cost on tulip	Review	Preference score
Handline Havatec	1	0	1	0	0	**0,460**
Q.B 2.0, Havatec	0.81	0.41	0	0,54	0.66	**0.5098**
Havatec "Tulip star"	0	1	0.5	1	1	**0.625**
Bercomex	0.93	0.06	0.75	0,15	0.33	**0.58**
Weights	0.29	0.23	0.17	0.20	0.11	100

(Source: own created; complete table, present of the scores and result of the research)

Using weighted sum approach is possible only when there is initial data about certain criterions. The decision maker has to decide and estimate the priorities with respect to the evaluation criteria include into decision model. Those preferences expressed in weights and specify exchange between criteria. Final weights in table (7) has been calculated by multiplying the group weights by the weights within the group. In practice, the weights common assigned by the professionals and the weights between groups is assigned by the policy. Weighted summation is easy to apply and helps to obtain clear result. Weighted summation has been used all over the world to solve different decision problems and difficulties. Complexity is to assign the weights to criteria due to subjectivity. In the case of choosing the best option for greenhouse with dimension of 15 hectares all data has been real and significant from official sources.

The summarized weights is there to show the best option for greenhouse when choosing the machine. Result of Handline Havatec which was best in price, the lowest fuel consumption but was the worst result in capacity, cost on tulip and review showed 0.460≤ 0.5, where less than 0.5 and cannot be the best solution. The machine Q.B.2.0., where most of the criterions show the average values, average 0.81 (close to the best) price, less than average capacity which is 0.41, middle value in cost on tulip and review, but the highest fuel consumption. The weighted sum score for Q.B.2.0 is 0.5098, where the machine can be good average option and also considered for purchase. Next option is "Tulip Star" which has obtained in sum 0.625, which is the biggest and the closest result to 1 make the machine the best choice for greenhouse with dimension of 15 hectares. Last machine "Bercomex" can be estimated as "the same level purchase" as Q.B.2.0. It is clearly seen that the results of those both machines is very similar and average option. The worst option is machine Handline Havatec and the best option is graphically seen the third option "Tulip Star". Important to know that the results can be different if the amount of tulips is changed or due to other affection on business such as political, economic and social influencers.

After the weighted normalized decision matrix has been obtained, and all the values has been multiplied and summed. Each machine will get the preference score based on which the result can be ranked.

Table 8- Ranked preference scores

Name machines	Price	Capacity per day	Fuel consumption	Cost on tulip	Review	Preference score	Rank
Handline Havatec	1	0	1	0	0	**0,460**	**4**
Q.B 2.0, Havatec	0.81	0.41	0	0,54	0.66	**0.5098**	**3**
Havatec "Tulip star"	0	1	0.5	1	1	**0.625**	**1**
Bercomex	0.93	0.06	0.75	0,15	0.33	**0.58**	**2**
Weights	0.29	0.23	0.17	0.20	0.11	100	

(Source: own created)

In table above (N) evidently that machine Havatec "Tulip Star" is ranked 1 among other alternatives based on rank and preference score. If the machine is not available on the market then it is possible to choose next alternative which is ranked as 2, Bercomex machine with preference score 0.58.

8 Conclusion

The aim of this research was to identify the most effective, profitable and suitable variant of the mechanical processing of the tulips of the greenhouses. With usage of empirical approach, decision making analysis, primary and secondary data, four main machine types have been analyzed and compared.

Method chosen for analysis, weighted summation, as the most convenient calculation, applicable to different complex decision making problems and with lowest chances of choosing wrong alternative. The calculation and the ability to prioritize the criteria allow to the decision maker ease of bringing crucial investment decision.

With the implementation of the theoretical background the weighted sum approach have and decision making process has been studied in details and used in practical part to determine the most profitable alternative.

In practical part firstly the criteria has been identified and scored with importance level, then the weights has been assign and normalized that resulted in calculating of preference score. Multi-criteria decision making has proved their importance in practice in choosing the most advantageous variant among many alternatives. Furthermore, showed the most unprofitable variant and average variant which helped to choose the best option among others on market.

With five criteria based on qualitative and quantitative approach most advantageous machine was "Tulip Star" Havatec. According to the criteria of price, capacity, fuel consumption, cost on tulip and review the machine ranked as number one "Tulip Star" has been identified as the best alternative for scale of observed greenhouse production of tulips.

The "Tulip Star" Havatec machine has the largest processing capacity, average fuel consumption, the lowest cost on tulip in the determined greenhouse dimension and scale of production. With the machine producer review, “Tulip Star” has the highest tulip processing quality with lowest percentage of damaged flowers in production.

Handwork approach in large-scale processing production of tulips has been considered and analyzed with showed conclusion of being not most suitable, profitable and cost effective option. Therefore, for observed large-medium addressed market the machine approach has to be implemented in order to achieve ROI, revenue and maintainable cash flow.

With that said, chosen harvesting machine is meeting the highest scored criteria among other alternatives and is proving most suitable option to be implemented in large scale tulip production.

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