CONCEPTUAL DESIGN OF A HARVESTING EQUIPMENT FOR FAMILY AGRICULTURE

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Oil Chemical Pole of Aromatic and Medicinal Plants – R. Ricardo Rucker, 235, CEP 98600-000, Três Passos/RS, Brazil

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Abstract. *This work presents the conceptual design of a harvesting equipment for family agriculture as an alternative to hand-harvest crops of aromatic and medicinal plants. An aromatic plant is valued for the naturally occurring essential oil in it and there is an increase demand in flavouring, cosmetics, soap and perfumery industry. These plants have been harvested by hand throughout most of smaller farm history and require large labor forces for relatively short periods of time. The aim of this paper is to research the need analysis and the conceptual design of a machine for aromatic and medicinal plants harvesting, in particular lemongrass (cymbopogon citratus). This machine must be adequated for family agriculture farms, self-propelled, low cost, easy handling and maintenance, robust and with appropriate travel speeds to the farm operation. The experimental prototype have been developed at the Design Laboratory in UNIJUÍ with finantial support by FAPERGS.*

Keywords*: machine design, conceptual design of harvesting equipment, family agriculture mechanization*

1. INTRODUCTION

The present work addresses the conceptual design of innovative harvesting equipment for aromatic and medicinal plants crops in family agriculture as an alternative to hand harvesting. The aromatic and medicinal plants are good valued for the naturally occurring essential oil in their and ones have an increase demand in phytomedicine, flavoring, cosmetics and soap industries. The aromatic and medicinal plants cultivation is an alternative for agricultural community, inclusive indigenous community (Sens, 2002). Among these plants, it is outstanding the lemongrass (*cymbopogon citratus*), which essential oil, according Mendes (2004), has high contents of the glycolipids. Carvalho (2006) shows that brazilian export market of these plants has increased 120% in last years and it is an alternative income source for family agriculture. Lima (2005) evaluated the Oil Chemical Pole of Aromatic and Medicinal Plants that was built with financial support by state government and she verified as results the improvement of the life quality, the educational formation opportunity and the environmental conscience in farmers, besides the increased income. These plants have been harvested by hand throughout most of smaller farm history and require large labor forces for relatively short periods of time. The study about the aromatic and medicinal plants crops has shown that hand-harvest limits productive capacity and it is unhealthy task.

The aim of this work is to present an innovative conceptual idea for aromatic and medicinal plants harvesting that must be adequate for family agriculture farms, self-propelled, low cost, easy handling and maintenance, robust and with appropriate travel speeds to the farm operation. In order to increase the probability of success of new harvesting equipment for family agriculture, the design process must be planned carefully and executed systematically. In particular, an engineering design method must integrate the many different aspects of designing in such a way that the process becomes logical and comprehensible (Pahl and Beitz, 1999). To that end, the design process of harvesting equipment must be broken down, first into phases and then into distinct steps, each with its own working methods. It is with these aims in mind that several authors (Back, 1983; Valdiero, 1997; Blanchard and Fabrycky, 1998; Pahl and Beitz, 1999) split the design process into main phases which can be translated as Need Analysis, Conceptual Design, Preliminary Design, Detail Design, Prototype Construction, Test and Evaluation, and Final Documentation of complete machine. Depending on the research group, other terminology have used for these phases, but the idea is same. In this work, we address with the development of harvesting equipment for family agriculture in first and second design phases, that are need analysis and conceptual design.

This paper begins with the need analysis of the harvesting equipment (section 2). The conceptual design is described in section 3 and the results of this phase are shown and discussed. In section 4, the conclusions are presented.

2. NEED ANALYSIS

The first phase of the design process involves the need analysis by collecting information about aromatic and medicinal plants crops in family agriculture and farmer requirements (customer requirements), and also about the existing constraints and their importance. It culminates in the elaboration of a detailed requirements list for harvesting equipment (design specification).

In this work, we intend design within the system life-cycle context that is different from design in the ordinary sense. Life-cycle focused design is simultaneously responsive to customer needs and to life-cycle outcomes.

Figure 1 shows the hand-harvest crops of aromatic and medicinal plants in a family agriculture farm of the Três Passos City (Rio Grande do Sul State, Brazil), where we have visited and interviewed farmers and agronomists to know, understand and listen the true customer needs from a life-cycle perspective.

Figure 1. Hand-harvest crops of aromatic and medicinal plants.

The identification of main customer needs can be represented as a requirements list shown in Tab. 1. When preparing a detailed requirements list it is essential to describe whether the individual items are demands or wishes. Demands are requirements that must be met under all circumstances. Wishes are requirements that should be taken into consideration whenever possible (Pahl and Beitz, 1999). The detailed description of need analysis is given in Valdiero *et al.* (2007).

Table 1. Requirements list for a harvesting equipment

Requirements	Quantify (where possible)	D = demand, W = wish
Required cutting height	0,1 – 0,4 cm	D
Lines space	0,8 – 1 m	D
Plants cutting width	0,25 – 0,50 m	D
Plants height	1 m	W
Appropriated travel speed	0,5 – 1 m/s	D
Good stability	Until 17^{o}	W
Good man-machine relationship	---	W
Low cost	About US$ 4.000	W
Operator safety	100%	W
Maintenance interval	> 300 hours	W

3. CONCEPTUAL DESIGN

The conceptual design phase of a harvesting equipment for family agriculture involves abstracting to find the essential problems of mechanization, establishing function structures for machine, searching for solution principles, combining solution principles into conceptions and selecting a suitable conception in according with need analysis.

According to the design process outlined in Pahl and Beitz (1999), the conceptual design phase follows the need analysis and results in the specification of a mechanization solution to plants harvesting problem. The representation of a mechanization solution can take the form of a function structure as shown in following section.

3.1. Function analysis systems technique (FAST)

The function analysis system technique (FAST) is a method of Value Analysis (Csillag, 1991) that in this work we used to create the function structure of the harvesting machine conception. The main aim of Value Analysis is to reduce cost in the further development of existing products, but we have used this systematic approach to the new machine with respect to required functions as in Valdiero (1994). Functional block diagrams are developed for the purpose of structuring system requirements into functional terms. Because of its emphasis on functions and the stepwise search for better solutions, FAST diagram was used for to describe the harvesting mechanization problem of aromatic and medicinal plants in Fig. 2 and, as shown, the objective is the division of the overall function, “to harvest plants”, into sub-functions of minor complexity, “to provide traction”, “to provide cutting”, “to collect plants” and “to carry plants”.

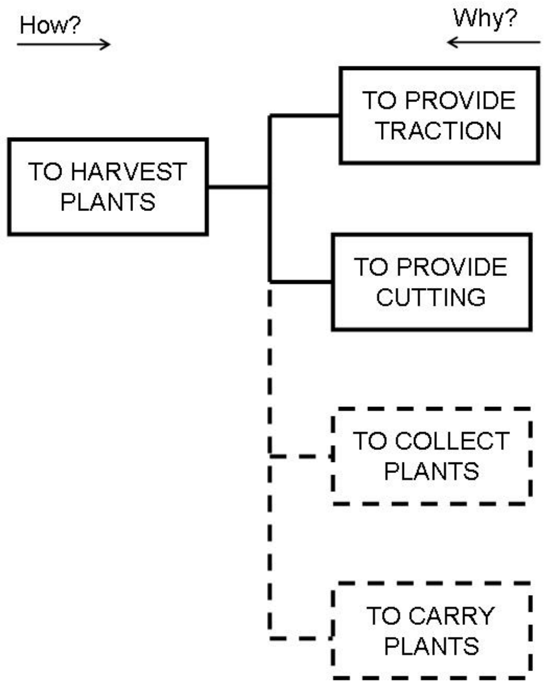


Figure 2. FAST diagram for the harvesting mechanization problem of aromatic and medicinal plants.

In this work, we consider “to collect plants” and “to carry plants” sub-functions as optional accessories in sense of modular design. The optional functions are enclosed in dashed blocks (Fig. 2). Therefore we have worked only with “to provide traction” and “to provide cutting” functions and they is presented in boxes enclosed by solid line. The “to provide traction” function permits to reduce labor fatigue and the “to provide cutting” function helps to increase production in harvest.

According to Blanchard and Fabrycky (1998), the translation task from the identified need for a system constitutes an iterative process of breaking down system-level requirements into successive levels of detail, and a convenient mechanism for communicating this information is the functional block diagrams. A function refers to a specific or discrete action that is necessary to achieve a given objective.

Figure 3 shows FAST diagram for the “to provide traction” function, where it is illustrated the division of this function into ten sub-functions of reduced complexity.

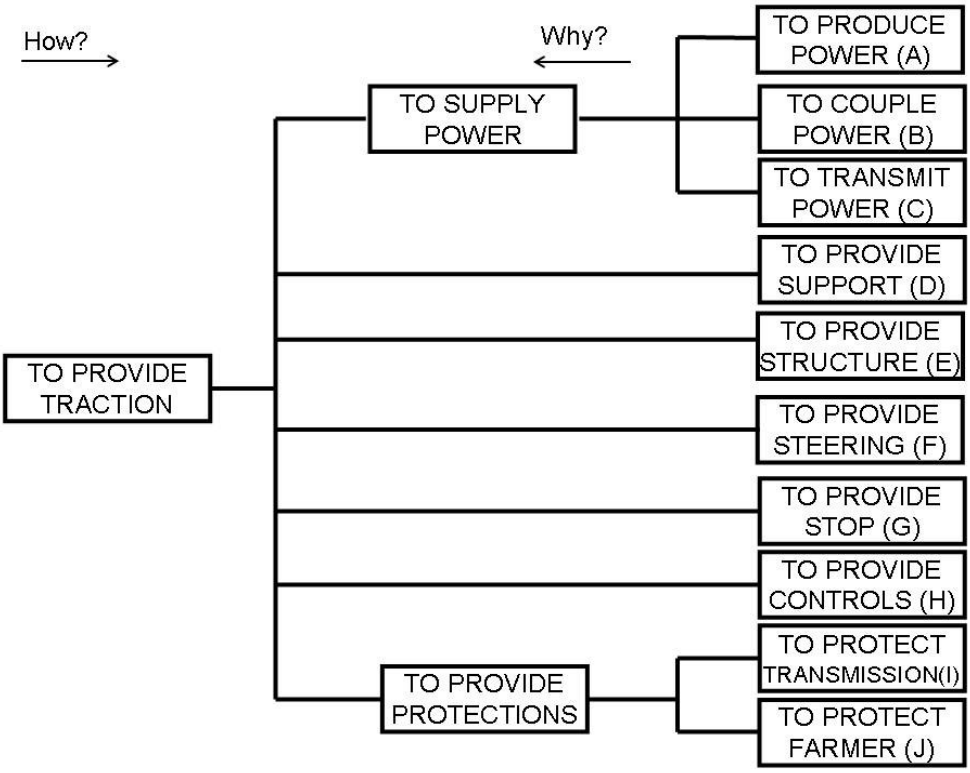


Figure 3. FAST diagram for the "to provide traction" function.

Figure 4 shows FAST diagram for the "to provide cutting" function, where also it is illustrated the division of this function into six sub-functions of reduced complexity.

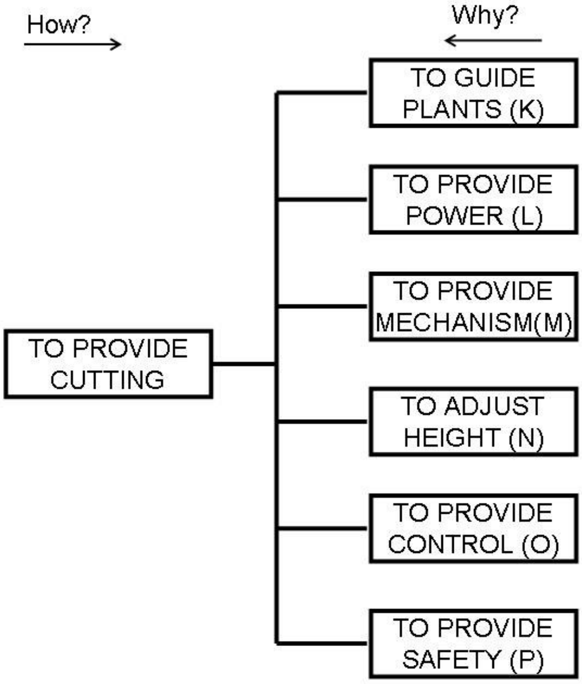


Figure 4. FAST diagram for the "to provide cutting" function.

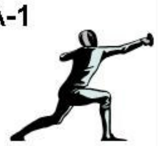
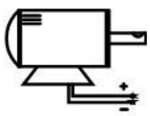
This step of conceptual design results in a set of sub-functions, named by "A" to "P" letters (see Fig. 3 and Fig. 4), that facilitating the subsequent search for solutions as presented in following section.

3.2. Morphological matrix technique

The morphological matrix technique (Pahl and Beitz, 1999) is helpful for the solution principles representation of each harvesting equipment sub-function in a compact form. Before of making the morphological matrix, the solution principles have to be found for the various sub-functions and these principles must eventually be combined into a working structure. A solution principle must reflect the physical effect needed for the fulfillment of a given function. It should be emphasized that this step is intended to lead to several solution variants to satisfy each particular sub-function.

Table 2 presents an example of several solution principles variants for “A - to provide power” sub-function. Note that for each solution principle, we associated an ideogram. Ideogram is a symbol that is used to represent the idea of solution principle.

Table 2. Example of the searching for solution principles to fulfill the “to provide power” sub-function.

A – To provide power	
Ideogram	Description of the solution principle
A-1 	Human work force. It is available in family agriculture and is composed by two to four people. As negative features, it has limited power and fatigue labor.
A-2 	Animal traction. It isn’t always available in small farm. It has required veterinary cares and also limited power.
A-3 	Electrical motor. As advantage, It has very slow pollution level and easy maintenance. It depends on electrical power supply or battery.
A-4 	Gasoline-powered combustion engine. It is available in large power-range and various models.
A-5 	Bio-fuel powered combustion engine. It has minor pollution level and used renewable source of energy. It isn’t available in various sizes and models yet.

For each sub-function listed in Fig. 3 and Fig. 4, from “A” to “P” letters, we have searched for solution principles as example shown in Tab. 2. The detailed description of the searching for solution principles to fulfill all sub-functions is given in Valdiero (2006).

After this searching for solution principles, it is making the morphological matrix with their ideograms as illustrated in Fig. 5 and Fig. 6. The morphological matrix is particularly useful for the purpose of systematic combination of solution principles (Pahl and Beitz, 1999). In morphological matrix, the sub-functions and the appropriate solutions (solution principles) are entered in the rows of the scheme.

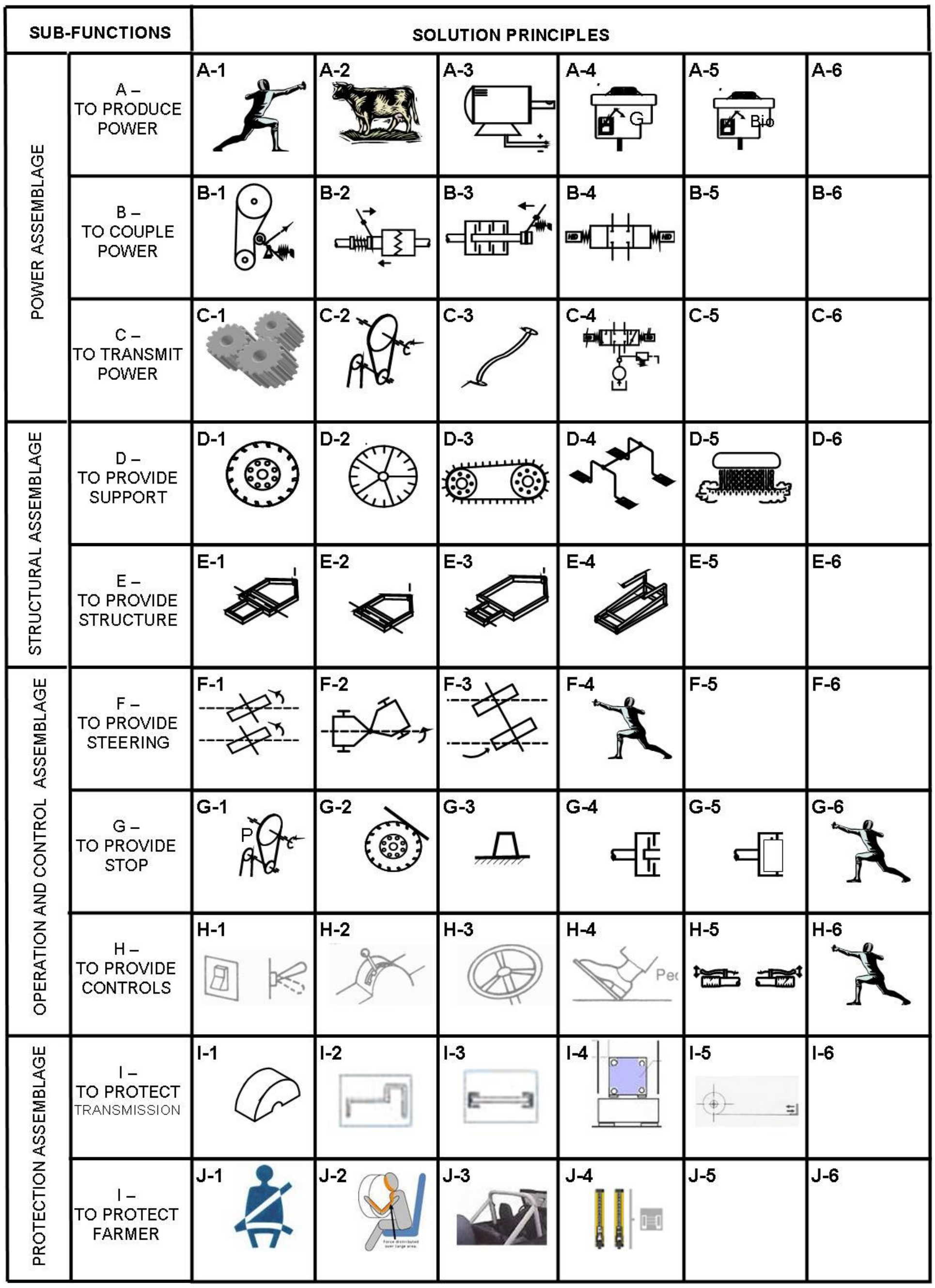


Figure 5. Morphological matrix scheme of the solution principles for traction sub-system ("A" to "I" sub-functions in Fig. 3).

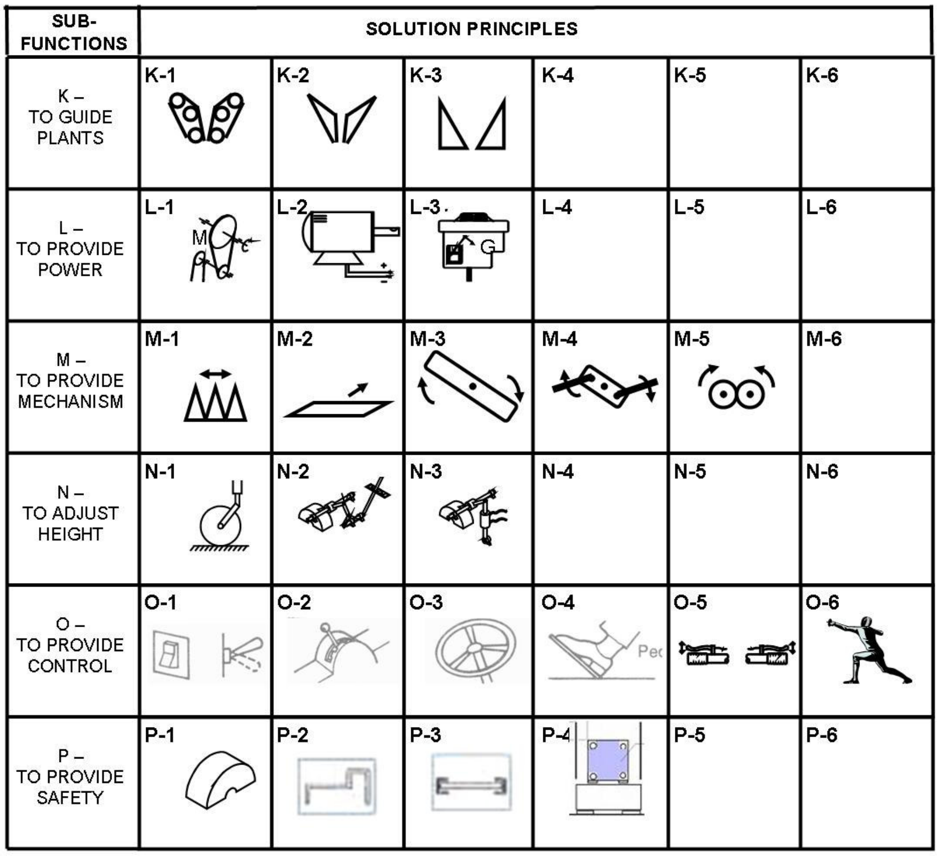


Figure 6. Morphological matrix scheme of the solution principles for cutting sub-system ("K" to "P" sub-functions in Fig. 4).

To fulfill the overall function, "To harvest plants", from morphological matrix, it is now necessary to elaborate overall solutions from the combination of principles, that is harvesting system synthesis presented in next section.

3.3. Conceptions synthesis

For conceptions synthesis of harvesting equipment, we have used morphological matrix. Then at least one solution principle must be chosen for every sub-functions. To provide the overall solution (machine conception), these principles must then combined systematically into an overall solution. The main problem with this design step is to decide which solution principles are compatible, that is, to narrow down the theoretically possible search field to the practically possible search field. The identification of compatible solutions is facilitated when we concentrate on promising combinations and establish why these should be preferred above the rest.

In this work, only three solution variants have been selected and their combinations are shown in Tab. 3.

Table 3. Three combinations of solution principles in accordance with morphological matrices in Fig. 5 and Fig. 6.

Overall solution variant	Traction sub-system combination	Cutting sub-system combination
Conception 1: animal traction	A-2, B-5, C-5, D-2, E-2, F-4, G-6, H-6, I-1, J-5	K-2, L-3, M-3, N-1, O-2, P-1
Conception 2: pedestrian machine	A-4, B-1, C-2, D-1, E-3, F-4, G-6, (H-2, H5), I-1, J-5	K-3, L-1, M-1, N-2, O-2, P-1
Conception 3: four wheel machine	A-4, B-1, C-2, D-1, E-4, F-2, G-1, (H1, H-2, H-5), I-1, (J-1, J3)	K-1, L-1, M-4, N-2, O-2, P-1

The detail description of each conception in Tab. 3 and the evaluating their characteristics are given in Valdiero (2006). The selection of the harvesting equipment conception provides the basis for starting the preliminary and detail design phases. Thus firming up of suitable structures into solution variants and the sub-sequent evaluation at the end of the conceptual design phase are of major importance for machine development success.

3.4. Description of the chosen conception

The chosen conception of harvesting equipment is a self-propelled machine that is composed by a four-wheel tractor unit and a cutting unit with horizontal-stroke knives as shown in Fig. 7. The tractor unit is formed by tubular structure (1), farmer seat (2) with safety belt, safeguard (3), controls (4) with steering hand wheel and levers, transmission system (5) with V-belt drives and chain drives, appropriate tires (6) and gasoline powered combustion engine (7). The cutting unit is a trailed implement, which power-transmission is a V-belt drive (8) from engine (7), with a rotary cutter (9) and a mechanism to guide plants (10). A rotary cutter (9) has two knives rotating in a horizontal plane with plant cutting height.

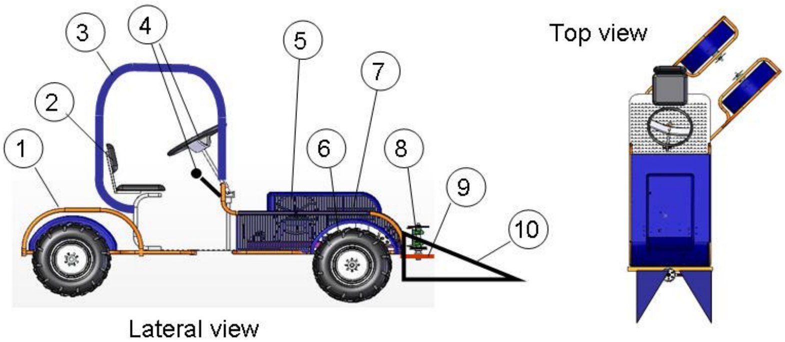


Figure 7. Chosen conception views for harvesting equipment.

4. CONCLUSIONS

In this paper the conceptual design of harvesting equipment for family agriculture was presented. The conceptual design considers the following steps: function structure analysis, solution principles searching, conceptions synthesis and chosen conception description for harvesting equipment. These steps are based on the design methodology that is available in international and national literature.

The function structure analysis has given an adequate division of the machine design into simpler sub-systems. This paper has addressed "to provide traction" and "to provide cutting" system sub-functions. In the solution principles searching step was applied the morphological matrix technique for these sub-functions and obtained several solution variants. At sequence, the conceptions synthesis was carried out resulting in three machine conceptions. The chosen conception is a four wheel self-propelled machine with a front cutting unit. The conceptual design of harvesting equipment was very important for starting the preliminary and detail design phases.

Preliminary design, detail design and experimental prototype phases are in development at the Design Laboratory in UNIJUÍ with financial support by FAPERGS. This innovative modular design intends to contribute for family agriculture mechanization, helping the fixation of man to the land, reducing labor fatigue and making a profit.

5. ACKNOWLEDGEMENTS

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