Optimisation of the production process in manufacturing a smart equipment for precision agriculture

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Abstract. The paper presents the optimizing process of a production system that it is intended for manufacturing process of a customized smart equipment. The initial variant (already in use) of this equipment dose no longer fit the requirements for precision agriculture so, new concept and, further, prototype development are to be done. The objective is to have smart innovative equipment suitable for digging furrows with controllable depth and geometric shape, not to mention its ability to determine soil’s moisture. The depth and geometric shape of the trench section are important elements in preparing the soil for irrigation as they ensure controlled slope for water runoff. Humidity is important for establishing and controlling the irrigation norm. Once the new equipment prototype is manufactured, tested and validated, it will be produced in series. For this it is necessary planning, programming and optimization of the production process so that to obtain a competitive product on the market through quality and price. Also, the transition from single production to series production involves great adaptability of the production process using self-optimization, self-configuration and self-diagnosis procedures, which are able to support and assist the human operator in the complex process of handling workpieces in the process.

1. Introduction
Due to the globalization of the sales markets, one of the biggest challenges of the new trends in the area of production processes is its rapid adaptation to the current trend with lowest possible costs and high quality conditions, under the assumption of reducing the negative impact on the environment. One important factor that ensures a guarantee of success for new products, especially new equipment’s, on the market is quality. The problem of optimizing production processes is another topic that can be developed, especially due to the fact that production processes become increasingly complex due to a certain amount of variability which in some cases can strongly affect the quality of the result [1].

The development of new equipment also involves analysis of the efficiency of the processes which it will be used to. An important aspect is that of applying informatics and informative technologies to traditional concept of agriculture. As a result, machines and devices used by farmers are equipped with devices that enable precise performance of agricultural treatments and precise dosing of mineral fertilizers and crop protection substances [2, 3]. The optimised production plan and capacity dimension, including resource allocation, scheduling, analysis of the time required to carry out the operation and mission planning, are integral parts of modern agricultural operations management which supplement traditional agricultural operations planning methods [4], cited by [5].
This paper presents research results on conceptual development for a smart innovative equipment suitable for digging furrows with controllable depth and geometric shape and for determination of soil moisture. The optimized plan for equipment components manufacturing process has been determined, so that to obtain a competitive product on the market through quality and price.

2. Methodology
In any production process for obtaining new equipment’s with high characteristics, the planning and scheduling working flow activities of each of the machining processes refer to decreases of production costs and of the costs related to the exploitation life of the product [6–8].

The main purpose of the equipment to be developed is that of digging furrows with controllable depth and geometric shape and to enable the determination of soil’s moisture. The equipment has a coulter that executes a furrow with a depth of 150 mm, squares a distance from the left row of 150 mm, and the amount of soil dug is stored on the opposite side but not further from the next row of crops. Initially, it was tried with a disc, but the soil gets back into the furrow faster than the compaction wheel reaches to fix it. The initial tests were done with four and five rows, digging simultaneously. The conclusion was that the forces must be evenly distributed, otherwise the compaction wheel does not pass where it should, and the equipment would not dig furrows according to the requirement. Depending on how many rows the tractor rides, four or five rows are chosen.

The equipment is high enough so that work can be performed when the plant is in vegetation, see figure 1. Basically, the limiting moment occurs not because of the machine, but because of the tractor, which can no longer pass through the crop due to the ground clearance it has.

![Conceptual model of the new equipment for digging furrows](image)

**Figure 1.** Conceptual model of the new equipment for digging furrows. 1- Equipment frame; 2 - Connection system with tractor; 3 - Wheels for adjustment of coulters penetration depth; 4 - Mould board; 5 - Supports for fixing the mould boards on frame; 6 – Coulters; 7 - Compaction wheels; 8 - Frame for fixing the wheels on the basic frame.
The equipment has a 100x100 mm square profile frame with a 10 mm thick wall, so that the existing forces do not damage the basic frame on which the whole assembly is built. The coulter adjustment mode is manual. In front of the equipment there are two wheels that follow the ground. They are fixed on a bar with several positioning holes, so that if it is necessary to deepen the pit, the coulter is raised and the bolt is inserted in the whole corresponding with the required depth. The wheel battery has the role of compacting the ground and the one that fell into the furrow, but also the one that was removed.

In figure 2 it is presented the Work Breakdown Structure (WBS) of the new conceptual model.

Figure 2. WBS of conceptual model of the new equipment for digging furrows.
Having the starting point WBS, the planning of activities within the manufacturing process was carried out, considering the equipment and human resources available. The planning of the manufacturing steps was done using Primavera Project Planner (PPP) software. The overall image of this planning for the conceptual model is presented in figure 3.

![Figure 3](image)

Figure 3. Initial planning of the manufacturing process of new equipment for digging furrows (partial view).

The planning has been done for two types of manufacturing process. The first process is the one already in use, with available equipment’s and the second process is a new intended one, with new specialised equipment’s. As it seen in the figure 3(a), the total time of first production process is 70 working hours and the total cost of this manufactured process is estimated at 12,229 euro. For the second planning, the manufacturing process takes place on two high performance equipment’s: a CNC centre for turning and drilling operation; an equipment for water jet for cuttings operations. With this second process type, the total time is 65 working hours and the total cost is 10,663 euro (figure 3b). The cost includes the human resource costs and equipment’s’ operating costs. The cost of material is not included in this analyse because this will be the same for any of the production planning cases considered.
In this initial planning it has not been considered the availability of resources. For this manufacturing process there has been allocated 8 human resources and 7 equipment’s for the first analysed planned and 7 human resources and 6 equipment’s for the second analysed planned. The thermal treatment activity of mould board is planned to be released at thermal treatment service provider. By analysing the resources availability, there were identified some overallocated resources. In figure 4 is presented the list of resources used for this manufacturing process (figure 4(a) for the first analysed process and figure 4(b) for the second analysed process) and in figure 5 are presented the six, out of seven, overallocated resources for the first planning analysed. This is how there were pointed out three overallocated equipment’s (cutting machine, wire welding machine and turning machine) and associated operators and also, the assembly operator is overallocated by few hours.

![List of used resources in manufacturing process.](a)

![List of used resources in manufacturing process.](b)

**Figure 4.** List of used resources in manufacturing process.

For optimising the manufacturing analysed process, we will use tool of PPP for levelling of activities according with priority criterion “minimum total float of activity”. The total float is the reserve time for an activity which does not change the duration of the whole process.
The planning results after removing the overallocation resources are presented in figure 6 and it is noticed that the total time for whole process is longer by 35 working days. The total duration of whole process is 105 working days.

Figure 6. Optimised plan of the first type manufacturing process (partial view).
For the second analysed situation the total duration after removing the overallocated resources is presented in figure 7. The total duration is 100 working days.

Figure 7. Optimised planning for the second type manufacturing process (partial view).

3. Results
The research results evidenced by this paper refer to the optimisation process of a production systems for the manufacturing process of component parts in a customised smart equipment for precision agriculture. The smart innovative equipment will be suitable for digging furrows with controllable depth and geometric shape and will enable the determination of soil’s moisture.

Once a new equipment prototype is manufactured, tested and validated, it will be produced in series. For this it is necessary planning, programming and optimization of the production process so that to obtain a competitive product on the market through quality and price.

There were analysed two types of manufacturing processes, the “old” one (already in use at the producer) and the “new” one (intended to be applied by new investments).

The total time of “old” production process is 70 working hours and the total manufacturing cost is estimated about 12,229 euro. The planning of “new” manufacturing process resulted in the estimation of 10,663 euro total cost and 65 working hours. These mentioned costs include the human resource costs and equipment’s operating costs while cost of material approximately the same for any of the production planning cases considered.

From the point of view of equipment, the “old” manufacturing processes use machine-tools, like, drilling and turning machines, while for the “new” manufacturing process, an increase of efficiency is to be obtained by replacing these two types of machine-tools with a high productivity CNC machine. For doing that it is necessary to have a good investment analyse by feasibility study because sometimes the cost of replacement cannot be fully recovered in reasonable period of time (5 - 8 years). Comparing the two analysed situations, it resulted that in the case of using more efficient equipment, the production process is more efficient even if the cost related to the manufacturing process is higher.

Even in some case the using of some efficient equipment’s, the production costs are higher, overall, for a large series or mass production the production cost is amortized.

4. Conclusions
By optimizing the production process it is identified, a great potential for reducing the production cycle, increasing the degree of automation, making high-tech products in limited series and also an efficient use of many production data that so far were not exploited.

In order to optimize the production process, the following parameters will be considered:
- process efficiency (through high decision-making capacity, due to the relatively small number of employees and high level of automation);
- process agility (by knowing in detail the specifications product);
- innovation (production line must be adapted to series production as well as unique production);
- customer experience and requirements (availability of information in the production process provides the customer with a special service system, going in some cases to self-service);
- production costs (the initial investment is high, but the costs will be amortized, by making quality products, without scrap, without material losses, with reduced personnel costs due to the automation of the entire process).

5. References

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