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Integrated Management Systems for Agricultural Field Operations: A Conceptual Framework

[1,2]Yu Lin Li and [1]Shu Ping Yi
[1]College of Mechanical Engineering, Chongqing University, Chongqing, 400030, China
[2]College of Mechanical and Electrical Engineering, Shihezi University, Shihezi, 832000, China

Abstract: With the development of agricultural mechanization and modernization in China, a formalized management tool is needed to support the field operations management of agricultural production organization. Due to the complexity of agricultural field operation process, the management activities contain a range of logistical, economic and social links that constitute an overall management system and trying to improve efficiencies and reduce operational cost requires capturing for these linkages into a conceptual framework. This study, based on systematic analysis process, derives the contextual requirements of AFOs system and then proposes a conceptual framework for agricultural field operations management from a holistic view and scope of the system. The research results provide an understanding and insight of the integrated field operations management systems.

Key words: Agricultural operations, farm work management, system boundary

INTRODUCTION

In the early 1980s, Chinese agricultural production reforms were implemented to break up the collective management pattern. The Contracting Out System of Collective Land was formed and carried out in order to improve the effective utilization of agricultural land. Under this management system, farmers undeniably have to bear all the capital cost of agricultural production, e.g., the purchase expense of farm machinery. However, in the early stages of the policies implementation, farmers did not have enough capital to purchase efficient but expensive agricultural machinery for improving the level of agricultural mechanization. In recent decades, with the increase of farmers' income, especially by the "Law of the People's Republic of China on Promotion of agricultural mechanization" in 2004, much more agricultural machinery management corporations were established and the number of agricultural organization is expected to further increase in the future.

This organization type usually makes a profit by providing field operation services to local growers. Due to the complexity of Agricultural Field Operation (AFO), the execution of field operations needs to be carefully planned and highly controlled, in order to achieve organizational objectives in terms of work rate, quality and cost. Like other productive organization, considerable benefits in terms of costs reduction and efficiency improvement will be obtainable with a formalized management tool for field operations management which involves a number of interrelated subsystems, such as operational planning subsystem, operation control subsystem and logistics subsystem.

Recently, numerous researches have directed towards developing a dedicated conceptual models for a specific management task of field operations. These involve the Farm Management Information System (FMIS) (Nikkila *et al*., 2010; Sorensen *et al*., 2010, 2011), the Business Activity Monitoring System (BAMS) (Folinas *et al*., 2011; Tolmac *et al*., 2011), the Decision Support System (DSS) (Perini and Susi, 2004; Bochtis *et al*., 2012) and the Fleet Management System (FMS) (Sorensen and Bochtis, 2010; Bochtis *et al*., 2011), etc. These mentioned systems either belong to the operational planning level or field-logistics level of field operations management system. However, in the real-life production system, the management activities within agricultural field operation process contain a range of logistical, economic and social links that constitute an overall management system and trying to improve efficiencies requires capturing for these linkages into a conceptual framework (Higgins *et al*., 2004).

In this regard, this study, from a holistic view and scope of the system, proposes a conceptual framework for agricultural field operations management by integrating each subsystem. The objective of this study is to derive

Corresponding Author: Shu Ping Yi, College of Mechanical Engineering, Chongqing University, Chongqing, 400030, China
Tel: +86-023-65106939 Fax: +86-023-65105335

the contextual requirements of AFOs system and provide an understanding of the integrated field operations management systems.

PRELIMINARIES

Agricultural field operations characteristics: Agricultural Field Operations (AFOs) include a number of highly interconnected tasks which are often executed by a fleet of homogeneous or heterogeneous agricultural machines in an efficient manner. In general, field operations can be categorized in three types: material input operations, material output operations and neutral operations (Bochtis *et al.*, 2007). These operations are characterized by a number of special characteristics which include (a) Short operational time window, (b) Wide spatial distribution, trafficability and workability issues (Bochtis, 2010), (c) Weather dependency, (d) Land availability restriction and (e) Sustainability aspects (Folinas *et al.*, 2010).

Concept of agricultural field operations system: Based on a procedural definition of the system, the AFOs system is considered as the operating procedure of agricultural mechanization production which is the management for field operations. This constitutes the so-called "management cycle", i.e., planning, implementation and controlling. The agricultural field operations system plans and implements the operational activities to apply agricultural input/output to targeted requirements to meet production objectives and controls this process to reduce or eliminate the degree of deviation of actual performance from the operation plan.

FUNCTIONAL REQUIREMENTS OF AFOs SYSTEM

Functions concerning AFOs system: The functional requirements for the AFOs system were derived through a systematic analysis process which was based on the objectives for the AFOs program as a whole. Essentially, the following three main functions are to be executed in an integrated field operations system: (a) Operation function executed the operational service including all aspects of agricultural mechanization operation, such as the distribution of agricultural "commodities" by Application Unit (AU) within fields, the removal of biomass from the field by harvester and the transportation of various materials by transport vehicle, (b) Strategic planning function consists of decision-making of strategic issues and (c) Management function plans and controls agricultural field operations activities.

Relation of the basic functions involved in AFOs system: An outline of the above mentioned three fundamental functions is presented in the following while the flows of material, technological information and managerial information are also indicated, using Fig. 1:

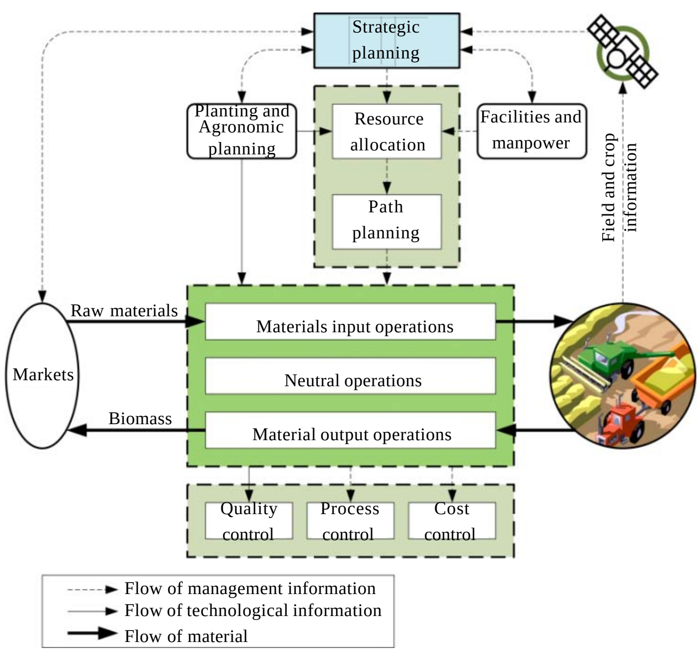

Fig. 1: Framework of relation of the basic functions involved in AFOs system

- The "operation function" is the key activity executed by cooperative machines. In the three types of agricultural field operations, IMF operation (e.g., seeding, spraying and fertilizing) involves the transportation of a quantity of a "commodity" and distribution in the field area by a PU; equivalently, OMF (e.g., harvesting) operation involves the removal of biomass from the field by a PU (i.e., harvester) and rural and public transportation by a SU. These two operation types involve a "flow" of a material between the field and the depot or factory. However, the difference is that the neutral operations such as tillage, cultivation and seedbed preparation do not involve such a material flow
- The "management function" establishes a master operation planning according to the planting planning or grower's demands. Based on this operation planning, it is decided which machine performs what operation (machine assignment) and which routes to assign to each one and then the actual field operation can be performed. However, the implementation of field operations might be disturbed for various reasons (e.g., agricultural machine breakdown, late delivery of raw materials). In order to reduce or eliminate the difference between these actual results and the plan and schedule, necessary control activities such as process control, quality control and cost control are needed. All above-mentioned functions are related to management; therefore, a series of such functions is called the "flow of managerial information"
- The "strategic planning function" involves the establishment of a strategic plan in both short and long terms based on the external information (e.g., crop planting area, number of grower's demand). Strategic management planning in its wider meaning involves the long-term business planning, profit planning, personnel planning and facility planning. It serves as the basis of operation implementation. Therefore, a series of these functions is called the "flow of strategic management information"

As mentioned above, AFOs are executed through the flow of materials, the flow of technological information and the flow of managerial information. These three flows are combined as shown in Fig. 1 and integrated in whole, generally via computer networks with a common data/knowledge base, such that the agricultural production organization can be operated efficiently and economically. This constituted a structure and procedure for computer-integrated field operation and information systems (Hitomi, 1996).

INTEGRATED FRAMEWORK OF AFOs SYSTEM

The integrated field operations management system of a agricultural machinery management enterprise is operated by the unification and coordination of the various interrelated functions and activities described above. This section provides a basic and general pattern of the integrated management system for Agricultural Field Operations (AFOs), following a framework depicted in Fig. 2.

Logistic system: The most important function in the agricultural machinery management enterprise is the operation function which is concerned with the material flow between different agricultural units (e.g., cropping field, facility unit, farm depot, factory, etc.). Taking crop harvest for example, one or more specific harvesters pull the biomass from the plant in the field while the harvested biomass is stored in a hopper on the harvester. When the harvester reaches its specified hopper capacity or load threshold, a transport vehicle approaches the harvester to unload material. After finishing the material transfer, the transport vehicle carries this material to a facility unit (e.g., reprocessing unit, factory, silo or farm depot, etc.). This is the "logistic system" which is a chain of collection, preprocessing and delivery for OMF operations. Equivalently, the "logistic system" involves a chain of procurement, inventory and distribution for IMF operations.

Operational planning system: Effective operation implementation conducted in the agricultural field logistic system is designed through the operational planning system. The major functions in this system include operational crop planning, machine assignment, path planning, material planning, manpower planning and process planning and scheduling. These functions establish detailed feasible plans/schedules for efficiently and economically operating the agricultural field logistic system.

Operation control system: During the implementation of agricultural field operations according to the operational planning, unforeseen situations often occur, e.g., the breakdown of primary machineries and delivery delay of raw materials. As a result, the logistic system cannot be executed as designed; the operation control system conducts follow-up or control. An audit of the progress and modification of the deviation of actual performances from the planned standards are performed: controlling operation resources (e.g., quality control, cost control, personnel control, facilities control and inventory control, etc.).

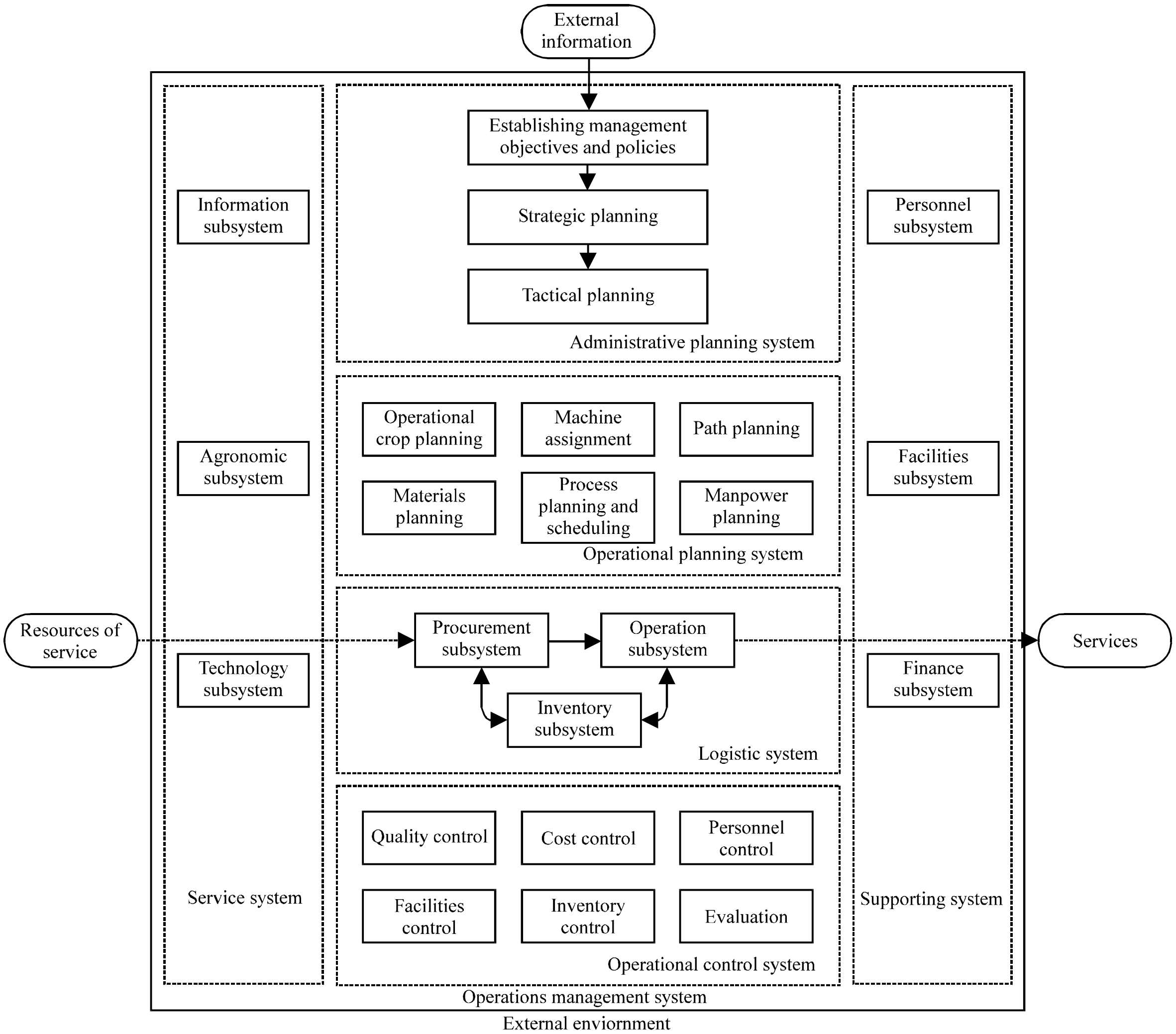

Fig. 2: A basic framework of the integrated field operations management system

Administrative planning system: This top management role supervises the stage of planning, implementation and control done in the logistic system. It issues appropriate directions and orders to such lower levels of the system. In this system proper management objectives and policies have to be established, so that the organization can grow under dynamically changing external and internal environments.

Service system: This executes, smoothly and effectively, the various functions of the administrative planning system, operational planning and control systems and the logistic system. Specifically, the information subsystem provides accurate information for various decision making points in the system at right times; the technology subsystem handles professional knowledge of operation technology, management technique, quality engineering, value analysis, etc., as a staff activity and the agronomic subsystem plans and develops crop production process.

Supporting system: This backs up the above-mentioned systems by acquiring necessary resources (e.g., men, machines and money) and aiding in their effective use. Specifically, the personnel subsystem acquires and allocates the operative and managerial human skills; the facilities subsystem procures agricultural machineries and the finance subsystem acquires and employs capital funds necessary for business activities (Hitomi, 1996).

SUMMARY AND CONCLUSION

This study has derived the functional requirement of AFOs system and from a systematic perspective, provided a basic and general pattern of the integrated management system for mechanized Agricultural Field Operations (AFOs), in which 6 subsystems are integrated as a whole system. The conceptual framework provides an overall understanding of the integrated field operations management systems.

As further research, the validity of the framework in agricultural field operations service industries needs to be examined. Moreover, with both academic research and practitioner-driven initiatives creative efforts are required to further develop each subsystem.

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