Integration of Production Control and Enterprise Management Systems in Horticulture

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Abstract. Production processes in horticulture are increasingly industrialized. Greenhouses have developed towards high-tech production plants that are highly automated by advanced systems for climate control, irrigation, crop monitoring, harvesting, internal transportation, sorting and packaging. At the same time, horticultural production nowadays is a complex managerial task, which needs advanced management information. However, this information is often registered manually in enterprise management systems. This paper aims to contribute to a better integration of production automation systems and enterprise management systems in the Dutch horticulture. It investigates the current situation and existing related standards (ISOBUS and ISA-95). Moreover, the paper identifies barriers for the adoption of integration solutions, including the economic situation, a decrease of the high-end market, a low willingness to cooperate, a relative low scale of growers, a high perceived complexity and path dependency, a negative perception of the relative advantage and a limited willingness of growers to invest.

Keywords: Production and enterprise integration; Interoperability; ISA-95; ISOBUS; Horticulture; Adoption barriers

1 Introduction

Production processes in horticulture are increasingly industrialized. Greenhouses have developed towards high-tech production plants that are greatly automated by advanced systems for climate control, irrigation, crop monitoring, harvesting, internal transportation, sorting and packaging [1]. At the same time, horticultural production nowadays is a complex managerial task, among others due to scale enlargement, volatile markets and stringent quality and environmental standards [2]. As a consequence, there is a high need for advanced management information. However, much of the information that is generated on the workfloor is not registered automatically in enterprise management systems. The level of integration of automated systems in the greenhouse is still poor [1], leading to the following negative effects:

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- It takes farmers much time and effort to collect, convert and exchange necessary data manually, while the risk of making errors is high;
- A lot of valuable data generated by greenhouse automation systems is not used in decision-making;
- Transparency and accountability requirements often lead to administrative burdens;
- Greenhouse automation systems cannot be instructed and controlled by enterprise management systems, which results in errors and less efficient and effective production processes.

Hence, the objective of this paper is to contribute to a better integration of production automation systems and enterprise information systems in the Dutch horticulture. More specifically, it investigates the current situation and available standards, and identifies the barriers for the adoption of integration solutions. Established standards and associated best practices from the international production industry are currently not incorporated in software solutions in the Dutch horticulture sector. Therefore their expected impacts on improvements in efficiency and efficacy of production processes in the Dutch horticulture sector are expected to be considerable.

2 Methodology

The present research has been carried out as part of the research and innovation program the Digital Greenport Holland. The Digital Greenport Holland is the Public Private Partnership (PPP) of Greenport Holland in which businesses, knowledge institutes and the (national) government are working closely together towards a common vision and action plans on digital information management and standardization in the Dutch horticultural cluster [1]. The core of this Public Private Partnership is formed by three active industry associations for chain information in the Dutch horticulture, i.e. Frug I Com (fruit and vegetables), Floricode (flowers and plants) and EDIbulb (flower bulbs).

The research was carried out in four phases: i) Definition of the research scope: relevant processes, information systems; ii) Inventory of related standards; iv) Assessment of the current situation through in-depth structured interviews; and iv) Identification of the main adoption barriers for integration solutions in the horticultural sector. In total 5 industry experts, 6 growers and 7 technology suppliers were interviewed based on a structured questionnaire. The respondents were selected based on the input of the business experts of the Digital Greenport Holland.

The remainder of this paper introduces the results following these research phases: definition of the research object, related standards and adoption barriers.

3 Definition of the research scope

The research focusses on the control of production activities in horticulture. Horticultural production is concerned with the transformation of plant material (seeds, cuttings, etc.) and inputs such as soil, water, energy, fertilizers and pesticides, into packaged and identifiable vegetables, fruits, flowers, plants and other horticultural products. Figure 1 visualizes the production activities including seeding, plant cuttings, bedding out young plants, planting young plants, irrigating, fertilizing, climate control, pest control, monitoring crop growth, monitoring production conditions, harvesting, picking, internal transportation, quality inspection, sorting, packing and preparing for shipping. Production activities are carried out with the help of resources including human resources, machines, greenhouses, fields, buildings and other facilities. Production control ensures that the production system's objectives are achieved, also if disturbances occur. Basically, this implies that the performance is measured, the measurements are compared with norms and in case of disturbances, corrective or preventive actions are effected. This is done on multiple levels with different time horizons.

The present research focusses on the integration of enterprise and production control. The next section will introduce two relevant standards for this interface.

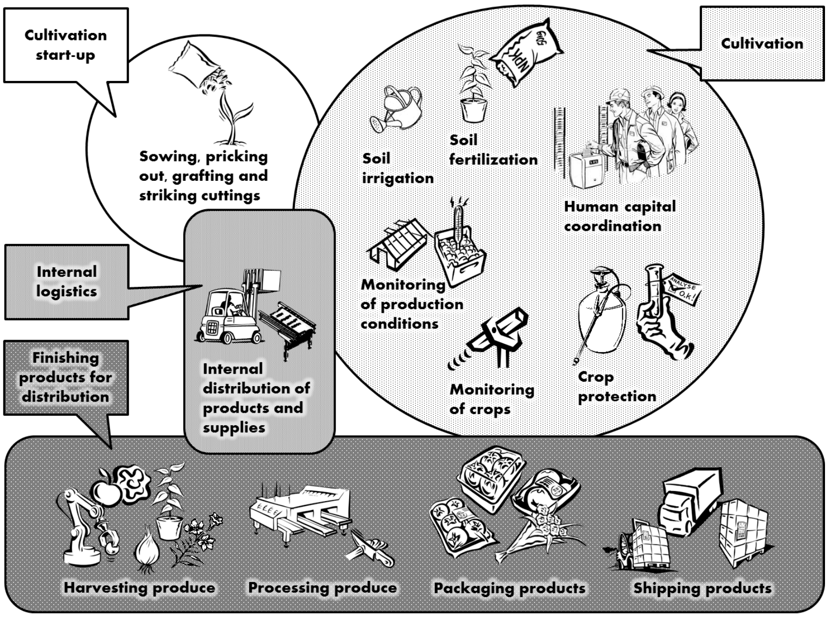

Fig. 1. Main production processes in horticulture

4 Existing standards for production and enterprise integration

The inventory of related standards identified ISOBUS and ISA-95 as the most relevant related standards.

4.1 ISOBUS

ISOBUS is a universal protocol for electronic communication between implements, tractors and computers, which is widely accepted by the agriculture industry around the world [3]. The Agricultural Industry Electronics Foundation (AEF) and Association of Equipment Manufacturers (AEM) work together to boost the development and application of ISOBUS technology. The most important topic is the interaction between agricultural vehicles and their implements. Also, the interaction between task controllers and Farm Management Information Systems is of increasing interest to the developing work groups.

The core of ISOBUS is the ISO-11783 standard "Tractors and machinery for agriculture and forestry - Serial control and communications data network". ISO-11783 specifies a serial data network for control and communications on forestry or agricultural tractors and mounted, semi-mounted, towed or self-propelled implements [4]. ISO 11783 comprises 14 parts [5], i.e. a general standard for mobile data communication physical layer (part 1), and standards for the data link layer, network layer, network management, virtual terminal, implement messages application layer, power train messages, tractor Engine Control Unit (ECU), task controller and management information system data interchange, mobile data element dictionary, diagnostics services, and sequence control (parts 2-14).

The main advantages of the ISOBUS language are that one terminal can control several machines instead of having a separate terminal for every machine. Machines and implements can be connected to the vehicle plug & play. The terminal, subsequently maps and displays the control and configuration options. For the farmer this leads to reduction of costs and the ease of use is increased, because the central terminal enhances the farmer's oversight and control while carrying out his tasks. Additionally as the developments on the interaction of control terminals and farm management information systems progress, more benefits of the systems arise as the link between enterprise planning and task management improves and the quality of process information increases.

4.2 ISA-95

The International Society of Automation (ISA) is a non-profit technical society for industrial automation and instrumentation with about 36000 members (isa.org). ISA is recognized as a leading one of the foremost professional organizations in the world for setting standards and educating industry professionals in automation. Two of its standards have become international standards that are important for the purpose of the present paper: ISA-88 and ISA-95.

ISA-95, formerly known as S95, is a framework that focusses on the integration of office automation and production automation and mechanization [6, 7]. It is widely adopted in the international production industry, among others, in the pharmaceutical, petrochemical and food processing sectors.

The framework was developed because the wide usage of Enterprise Resource Planning (ERP) systems in the industry raised the need to integrate these systems with the operational production systems, but many integration projects still fail. The main intended benefits of ISA-95 are: i) to decrease costs and complexity of integration of business logistics systems and manufacturing systems, ii) to enable comparisons between best practices for the operation of manufacturing, iii) to facilitate discussions about it by creating a common vocabulary and framework, and iv) to decrease costs and complexity of the integration of systems that operate manufacturing systems [7].

ISA-95 consists of models and terminology about: i) information exchange between enterprise management systems and manufacturing operations systems; ii) activities in manufacturing operations systems; and ii) exchanged information within manufacturing operations systems. More specifically, Figure 2 discerns the four control levels of ISA-95 which are based on the Purdue Reference Model [7, 8]:

- *Level 0 & 1*: the actual physical processes and its sensing and actuation;
- *Level 2*: manufacturing operations management systems that supervise, monitor and control physical processes, especially Supervisory Control and Data Acquisition systems (SCADA), Programmable Logic Controllers (PLC) and Distributed Control Systems (DCS);

- *Level 3*: systems, which manage the work flow of batch, continuous or discrete production operations, especially Manufacturing Execution Systems (MES);
- *Level 4*: business planning & logistics systems that manage business-related activities of production, including production planning and scheduling, material use, shipping and inventory management, especially in ERP systems.

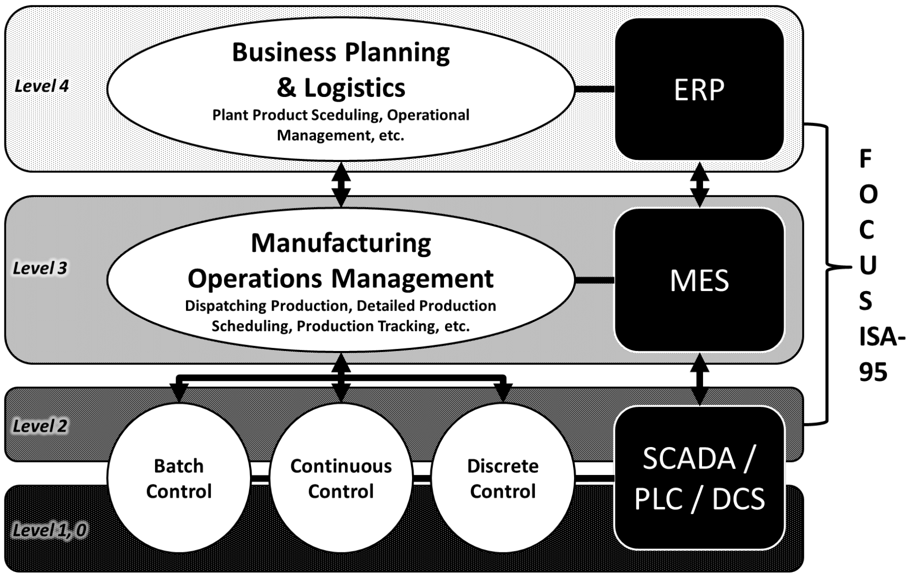

Fig. 2. Control Levels as defined in part 1 of ISA-95 [6, 7]

The core of the framework is the definition of the information flows that link

ISA-95 focuses on the integration of levels 3 and 4. The integration of the control levels 0,1 and 2 are supported by other ISA standards, including ISA-88. The ISA-95 framework includes six standards (www.isa95.org):

- *Part 1 "Enterprise Control System Integration 1: Models and terminology"* [7]: standard terminology and object models based upon the Purdue Reference Model, which can be used to decide which information should be exchanged;
- *Part 2 "Object Model Attributes"* [9]: describes the attributes for every object that is defined in part 1;
- *Part 3 "Activity Models of Manufacturing Operations Management"* [10]: provides reference models for describing production, quality activities, maintenance and inventory activities on the shop floor;
- *Part 4 "Object and Attributes for Manufacturing Operations Management Integration"* [11]: technical specification of the information that is exchanged between different manufacturing operations management categories and activities (as defined in part 3);

- *Part 5 "Business to Manufacturing Transactions"* [12]: defines transactions that specify how to collect, retrieve, transfer and store information of objects for enterprise-control system integration (as defined in the other parts);
- *Part 6 "Messaging Service Model"* [13]: specifies the transaction of part 5 in a set of messaging services.

Moreover, the data models of ISA-95 are implemented in XML schemas in the Business to Manufacturing Markup Language (B2MML) standard by the Manufacturing Enterprise Solutions Association (MESA) [14].

A core element of the ISA-95 framework is the definition of the information flows that link enterprise management (level 4) with production activities on the shop floor (level 2 and down) as visualized in Figure 3. These flows are concerned with [7, 10]:

- *Operations definition:* instructions about the work that is to be carried out;
- *Operations capability:* information about capabilities needed for the work defined;
- *Operations request:* information about the accompanied work schedule;
- *Operations response:* information about the work performance.

The information flows are broken down into detailed data streams for the materials, equipment and personnel relevant to the information exchange. The standard sets up specific models for this information and data breakdown for quality management, production control, maintenance management, and inventory management. Additionally ISA-95 describes the information model that underlies the data exchange. This information model is the basis for the definition of messages which are modelled in detail in UML diagrams. MESA implements these data definitions in XML message.

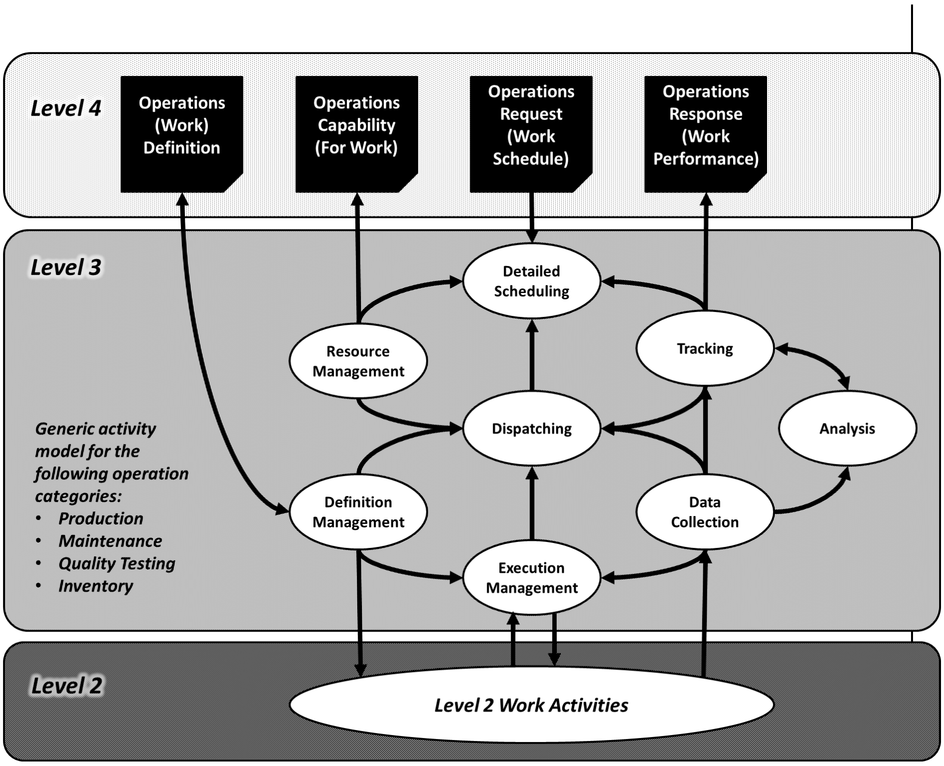

Fig. 3. Information flows with level 3 control activities [10]

5 Production and enterprise integration in the Dutch horticulture

5.1 Current situation

The interviewed experts and suppliers indicate that a majority of the growers have not yet integrated their production and enterprise management systems. Most of the others have implemented specific interfaces that are fully customized by system vendors. There are a few examples that implemented a separate middleware layer, which however is not based on standards. Only one example of an standardized interface is found. This standard was developed based on ISA-95 and B2XML by Plantform, an association of around 75 indoor plants growers that cooperate in the development and implementation of integrated enterprise management systems [15]. However, the Plantform standard has a limited scope since it specifies the communication of a sales order from the enterprise management system to an automated picking system.

In sum, it can be concluded that, although the Dutch horticulture is very innovative in the application of new production technologies, it lacks behind in the integration of production and enterprise management systems in comparison with the regular manufacturing and processing industry. The next section explains this situation by discussing the adoption barriers as addressed in the interviews.

5.2 Adoption barriers

The relative low adoption of integrated production and enterprise management systems can be explained by the barriers that are visualized in Figure 4.

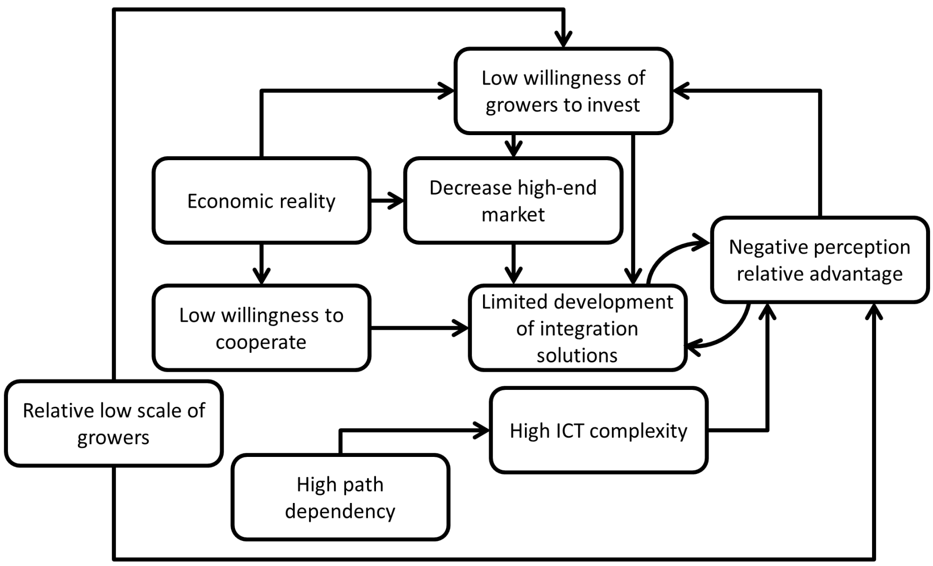

Fig. 4. Adoption barriers as addressed by the respondents

The *economic situation* was identified as a significant barrier for the adoption of integration solutions. In 2014, 37% of greenhouse horticulture businesses faced some degree of liquidity problems [16]. Approximately one fourth of businesses needed to at least defer more than half of their loan repayments. As a result, there is a low financial headroom for innovation. However, this is expected to be a temporal effect: in the first quarter of 2015 the confidence among greenhouse growers increased slightly [16].

The Dutch market is a high-end market for suppliers of horticultural productions systems. Due to the economic situation and the resulting low willingness to invest, the *emphasis shifts to (more low-end) markets* that demand less advanced solutions and that do not necessarily require a good connectivity.

The integration of different production and enterprise management systems requires a close cooperation between growers and suppliers, and among suppliers. The respondents indicate that currently there is a *low willingness to cooperate*. An important reason is the increased competition due to the economic situation. Other reasons mentioned include the absence of a dominating organization that can force cooperation, a mismatch in innovativeness and a lack of trust.

In 2013, on average size a Dutch greenhouse employed 32 Full Time Equivalents (FTE) [16]. Although horticultural companies are relatively large in comparison with other agricultural sectors, *growers are still low-scale* in comparison with the manufacturing and processing industry, which are the main users of the ISA-95 standards.

Solutions to integrate production and enterprise management systems are perceived to be *complex*. Suppliers expect that it will deeply impact the architecture of their systems. For growers it is difficult to understand how business processes will change by the implementation of integrated solutions.

The perceived complexity is enlarged by a high *path dependency* due to the installed base of systems with a limited interoperability. These systems are often based on outdated technologies that do not allow for a 'plug-and-play' integration approach. As a result, integration is much more difficult and costly than in case of greenfield implementation. There high dependency on the existing systems and suppliers (vendor lock-in) often blocks innovation with respect to system integration.

The respondents recognize the benefits of a better integration of production and enterprise management systems, especially if integration focuses on specific cases such as order climate control, picking & harvesting, sorting & packaging, and production time registration. However, most interviewed growers expect that the benefits are still outweighed by the costs, in particular because of the expected complexity and the relative low company scale. They perceive a *negative relative advantage* and consequently they take a wait-and-see attitude.

A combination of a negative perception of the relative advantage, a relatively low scale and the economic situation results in a *limited willingness of growers to invest* in integration solutions. If new systems are selected, price is a dominating factor, while the connectivity is often not taken into account. As a consequence, suppliers are confronted with an unfavorable business case to invest in integration technology.

6 Discussion

The objective of the present research was to contribute to a better integration of production automation systems and enterprise information systems in the Dutch horticulture. It has investigated available industry standards, the current situation, and it has addressed main barriers for the adoption of integration solutions.

The main related standards addressed are ISOBUS and ISA-95. Especially the ISA-95 standard is well suitable to the integration of production automation systems and enterprise information systems in horticulture. The sector is highly industrialized, resulting in many similarities with the manufacturing industry.

However, the research shows that, although the Dutch horticulture is very innovative in the application of new production technologies, it lacks behind in the integration of production and enterprise management systems in comparison with the regular manufacturing and processing industry. This low adoption can be explained by the following barriers that are addressed in the interviews: the economic situation, a decrease of the high-end market, a low willingness to cooperate, a relative low scale of growers (in comparison with the manufacturing and processing industry), a high perceived complexity, a high (path) dependency on the existing systems and suppliers, a negative perception of the relative advantage and a limited willingness of growers to invest in integration solutions.

The poor integration of production and enterprise management systems in the Dutch horticulture contrasts with the high need for advanced management information. This contract is expected to limit further growth and it could even threaten the current strong international competitive position. To break out of this situation, the sector is advised to:

- Stimulate the awareness of benefits in concrete cases and demonstrations;
- Stimulate the cooperation between growers and suppliers, and among suppliers and among growers;
- Reduce the perception of complexity by providing practical tools and applicable knowledge;
- Take the lead to develop international horticulture-specific standards based on existing reference frameworks and standards such as ISA-95;
- Don't focus on standardization as such, but emphasize the importance of integration for a professional management.

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References

1. Verdouw, C.N., N. Bondt, H. Schmeitz and H. Zwinkels, Towards a Smarter Greenport: Public□Private Partnership to Boost Digital Standardisation and Innovation in the Dutch Horticulture. Int. J. Food System Dynamics 5 (1), 2014. 5 (1): p. 44-52.
2. Verdouw, C.N., R.M. Robbemond, and J. Wolfert, ERP in agriculture: Lessons learned from the Dutch horticulture. Computers and Electronics in Agriculture, 2015. 114: p. 125-133.
3. AEF. About ISOBUS. 2015 [cited 2015 June 15th]; Available from: http://www.aef-online.org/en/about-isobus/.
4. ISO. ISO 11783-1:2007 Tractors and machinery for agriculture and forestry -- Serial control and communications data network -- Part 1: General standard for mobile data communication. 2007 [cited 2015 15 June]; Available from: http://www.iso.org/iso/catalogue_detail.htm?csnumber=39122.

5. ISO. ISO 11783-10:2009 □Tractors and machinery for agriculture and forestry -- Serial control and communications data network -- Part 10: Task controller and management information system data interchange. 2009 [cited 2015 15 June]; Available from: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=39124.
6. ISA. ISA-95: the international standard for the integration of enterprise and control systems. 2015 [cited 2015 15 June]; Available from: http://www.isa-95.com/.
7. ISA, ANSI/ISA-95.00.01-2010 (IEC 62264-1 Mod) Enterprise-Control System Integration - Part 1: Models and Terminology. 2010.
8. Williams, T.J., The Purdue Enterprise Reference Architecture. Computers in Industry, 1994. 24(2-3): p. 141-158.
9. ISA, ANSI/ISA-95.00.02-2010 (IEC 62264-2 Mod) Enterprise-Control System Integration - Part 2: Object Model Attributes 2010.
10. ISA, ANSI/ISA-95.00.03-2013 Enterprise-Control System Integration - Part 3: Activity Models of Manufacturing Operations Management. 2013.
11. ISA, ANSI/ISA-95.00.04-2012 Enterprise-Control System Integration - Part 4: Objects and attributes for manufacturing operations management integration. 2012.
12. ISA, ANSI/ISA-95.00.05-2013 Enterprise-Control System Integration - Part 5: Business-to-Manufacturing Transactions. 2013.
13. ISA, ANSI/ISA-95.00.06-2014, Enterprise-Control System Integration--Part 6: Messaging Service Model. 2014.
14. MESA. Business To Manufacturing Markup Language (B2MML). 2015 [cited 2015 15 June]; Available from: http://www.mesa.org/en/B2MML.asp.
15. Verloop, C.M., C.N. Verdouw, and R. van der Hoeven, Plantform: Horizontal cooperation in realizing integrated information systems for potted plants production, in 7th EFITA conference. 2009, Wageningen Academic Publishers: Wageningen. p. 217-224.
16. LEI. Agro & food portal. 2015 June 11; Available from: www.agrimatie.nl.