

# Biomass supply chain event management

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**Abstract:** The biomass supply chain constitutes a system that is highly dynamic and stochastic. The developed and proposed systems architectures for the management of the supply chains of typical industrial products do not directly apply to the case of the biomass supply chain. Nevertheless, it is imperative that a dedicated framework is needed according to the industrial standards. In this paper a framework for the biomass Supply Chain Event Management (SCEM) supporting the efficient management of inter-organizational events within the examined supply chain is proposed and analyzed. The conceptual model includes the identification and specification of events and for the preparation of necessary notification based on information needs.

**Keywords:** biomass, bioenergy, bio-fuels, logistics, management

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## 1 Introduction

Biomass has been recognized as one of the most promising renewable energy sources in the near to mid-term perspective. The biomass supply chain is characterised by a number of special characteristics and thus, it is not adequate to analyse it in the same way as a general supply chain. In the case of the traditionally biomass supply chain aimed at producing ethanol and biodiesel, i.e. corn, and soybean, the special characteristics include:

- *Long distance transportation.* It must adhere to the economies of scale and be cost effective in terms of facility sizing and thus requiring a large arable area dedicated to “raw material supply”. This characteristic increases the need for long distance transportation. Furthermore, due to the wide spatial distribution of the fields that constitute this area, the transportation will have to take place through a complicated public as well as rural road network.

- *High inventory cost.* Although bioenergy is used all year around, the “raw material” is produced once a year.

- *Short operational time window.* The short harvesting time window is caused by the time-sensitive crop maturity. Furthermore, these operations have to be carried out within a short time-window using resources also necessary for other concurrent field operations.

- *Weather dependency.* The weather conditions are a restrictive factor in terms of the available time period for the operation’s execution and thus can create variations in time, cost and equipment. For example, if harvest conditions regarding crop maturity are poor, the moisture of harvested material may be more than the permissible moisture content for long-term storage and a drying process should be added to the total procedure.

- *Land availability restriction.* Since there is an upper limit associated with the land available for the cultivation of the “raw material”, the market prices are highly connected to the demand, and thus the increase or decreases of the demand will subsequently increase or decrease its price.

- *Sustainability aspects.* The soil must be in a

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condition for the machinery to operate minimising damage to the soil. Soil condition depends upon soil type, crop type and current as well as recent weather conditions.

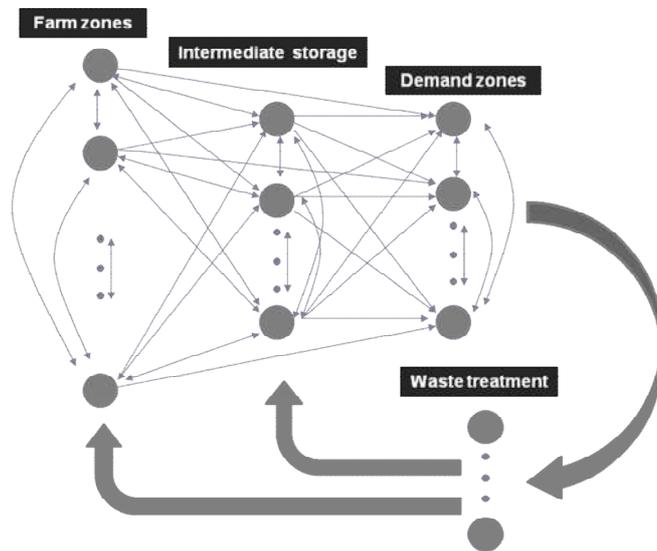


Figure 1 Generic network of the biomass supply chain

It is estimated that about 20% – 40% of the cost of ethanol is related to the biomass supply chain, while about 90% of that cost is logistics related cost (Reynolds, 2002). In order to partially overcome the uncertainty imposed by the above mentioned factors, research studies were considered as an alternative the use of ligno-cellulosic biomass to produce bioenergy. Ligno-cellulosic biomass includes by-products from forestry and agriculture, referred to as biomass waste (*e.g.*, residues from maintenance work in green parks, thinning wood, and straw from cereal farming), municipal solid waste, and perennial grasses (Aden et al., 2002). Potential benefits include harvesting windows that differ across the different species which increase the annual use of the specialized field machinery reducing the fixed costs of harvesting and collecting biomass, less inventory of biomass due to the fact that biomass is supplied all year around. Furthermore, perennial grasses can grow on land that is not suitable for grain production, and finally, using a variety of perennial species enables a diversified landscape and reduces the potential for insect and disease risk inherent with monocultures (Ekşioğlu et al., 2009). Also, solid waste as a “raw material” for bioenergy production including waste from household

and industry (food, paper, demolition wood, and saw dust) is available at a very low cost.

Although that a vast amount of literature exists in the area of supply-chain design and logistics management for industrial products, the previously described special characteristics of the biomass supply chain determine that the biomass flow within a network cannot be considered in the same way as the flow of, *e.g.*, heat, electricity, and gas. As a result, a number of dedicated optimisation models related to biomass supply network have been presented. Following some selected examples from the recent literature. From bo et al. (2009) developed a decision support system based on geographic information systems (GIS), which involved a non-linear mixed-integer programming for the optimal planning of forest biomass use for energy production. Rentizelas, Tolis and Tatsiopoulos (2009) analyzed logistic issues of biomass related to the storage problem and the advantages a multi-biomass supply chain might have on the logistic cost. Sokhansanj, Kumar and Turhollow (2006) presented a dynamic simulation program for collection and transportation of large quantities of biomass, which considers time-dependent availability of biomass under the influence of weather conditions and predicts the number and size of equipment needed to meet a certain demand. The delivered cost of biomass was calculated based on the utilization rate of the machines and storage spaces. Freppaz et al. (2004) presented a non-linear decision support model which considers the optimal exploitation of biomass resources with several dispersed harvesting sites and a number of centralized combustion plants on a regional level aiming to find the optimal capacity of heat and power generation as well as the optimal utilization of biomass resources and transport options in a time horizon of one year. Dyken, Bakken and Skjelbred (2010) presented a linear mixed-integer modelling framework that can be applied to components in a biomass supply chain, including sources, handling/processing, storage and end use.

For the field-logistics level, recent comprehensive research has been conducted to adapt and implement formalized planning tools and methods from the industrial domain in planning and scheduling of the field

operations in the perspective of the connection of the first link of the chain, which is the production of the material that flows within the supply chain, with the rest more industrialised links. Bochtis et al. (2010) evaluated the functionalities, feasibility and long-term perspectives of implementing a modelling suite for determining the optimal time for initiating various operations related to the harvesting and treatment of grass forage based on moisture content predictions. Basnet, Foulds and Wilson (2006) presented an approach aimed at the scheduling of crop harvesting in multi-farms operations. Guan et al. (2008) introduced Hybrid Petri nets into the modelling of farm work flows in agricultural production. This procedure is based on the fundamental that agricultural operations involve both continuous and discrete events. By using appropriate abstracted representations of field operations planning problems, Bochtis and Sørensen (2009) and Bochtis and Sørensen (2010) developed a methodology for casting these planning problems as instances of the well known combinatorial optimisation problem, the Vehicle Routing Problem. Sørensen and Bochtis (2009) developed a conceptual model based on participatory approach for the fleet management of agricultural vehicles.

From the literature dedicated to the biomass supply chain, it is clear that the biomass supply chain constitutes a system that is highly dynamic and stochastic. The developed and proposed systems architectures for the management of the supply chains of typical industrial products do not directly apply to the case of the biomass supply chain. Nevertheless, a dedicated framework is needed according to the industrial standards.

This paper proposes a framework for the biomass supply chain event management (SCEM) supporting the efficient management of inter-organizational events within the examined supply chain. The developed conceptual model will support the identification and specification of events and for the preparation of necessary notification based on information needs.

The paper is organized as follows: in the first section the concept of SCEM is examined from the biomass supply chain perspective. The identification and categorization of the analogous events are the main

objectives of the second section. Furthermore, the main requirements of a SCEM generic conceptual model are presented. These requirements will help the design of the proposed model.

## 2 Concept of supply chain event management systems

During the last decade an increasing focus for the SCEM has been observed. Moreover, as Zimmermann (2006) argued this had been addressed also by a large number of available SCEM systems in the IT market. Generally speaking, the main objective of a SCEM system was to introduce a control mechanism for managing events, in particular, exceptions, and responding to them dynamically (Meydanoğlu, 2009). An event is just a signal that the internal data of a system which are being monitored has changed. In case of the SCEM systems the event is any individual outcome of a supply chain cycle, logistics process, activity, or task (Alvarenga and Schoenthaler, 2003). Enterprise information systems have already generated events, if only for their own internal use. Events can originate from various sources, including logistics information systems and applications, data flow over a messaging platform, database updates, and messages from typical web applications.

The following table synthesises the existed literature defining the SCEM systems and presenting their main characteristics (Table 1).

It is possible to examine and evaluate the SCEM systems by three perspectives: a conceptual, a technical, and a business point of view.

From a conceptual point of view, a SCEM system is subdivided into the following five core aspects: 1) monitoring, 2) notification, 3) simulation, 4) controlling, and 5) measuring (Knickle and Kemmeter, 2002). Based on the above aspects Knickle and Kemmeter (2002) proposed the following tasks: 1) definition of supply chain processes, 2) identification of relevant logistical reference objects, 3) definition of related events, and 4) the design of status notifications with relevant information.

Moreover, from a technical view the SCEM systems

promise to unlock additional value from supply chain processes beyond what has been realized from the implementation of Supply Chain Planning (SCP), Supply Chain Execution (SCE), Customer Relationship Management (CRM), and Enterprise Resource Planning (ERP) systems.

From a business perspective a SCEM solution aims to improve the management of supply chain processes and support the decision making, by providing the required information in order for supply chain partners to act proactive.

In the section that follows, the operational requirements of SCEM system dedicated to the case of the biomass supply chain are presented.

**Table 1 Literature review of the SCEM systems**

Definition	Author(s)
... they are application systems that monitor, register, and evaluate disruptions, deviations within an enterprise and/or among enterprises of a supply chain in real time to be able to take actions in real time	Hunewald, 2005
... they can help the simulation, control, and measurement functions in supply chains	
... monitoring and notification are their two core functions	Nissen, 2002
... they decide by a set of rules how to react to occurred supply chain and logistics events	Meydanoğlu, 2009
... they gather logistics processes performance data	Straube, Vogeler and Bensel, 2007
... they allow the short-term planning, management and controlling of information regarding the operative logistic processes. It is a proactive concept that allows diverging high process complexity	Winkelmann, Beverungen, Janiesch, and Becker, 2008
... they foster the inter-organizational visibility of critical objects throughout the supply chain	Wieser and Lauterbach, 2001
... they introduce a control mechanism for managing events, in particular, exception events, and responding to them dynamically	Liu, Kumar and Aalst, 2007
... they ideally should be able to link the entire supply chain monitoring the flow of goods and information and alerting any time an event arises	Fantozzi, 2003

### 3 What the “E” means in the SCEM systems: the case of biomass supply

From the literature a number of events’ categorization efforts can be identified. At first, Nissen (2002) categorised the events based on the exact time of their occurrence; an event is early or late if it occurs before or after the planned point of time. Heusler, Stölzle and

Bachmann (2006) identified the events that occur as a result of an unplanned, unpredicted process (called unexpected or unplanned events) or not (expected or planned events). Bretzke and Klett (2004) identified two categories based on the same criterion: those that required no corrective actions (regular events) and those that were unexpected (irregular events).

For the examined supply chain the categorisation can be based on the requirements of the corresponding logistics and operations processes (Folinas, Bochtis and Sørensen, 2010) (Table 2).

**Table 2 Types of events appeared at biomass supply chain**

Type	Description
Monitoring of urgent events	Events that can cause an operational situation preset to be labelled an emergency (e.g., machine failure). The detected error/alert information should be provided by barcodes, Radio Frequency Identification (RFID) or sensors and automatically being sent to an appropriate server, which can be accessed and analysed by the manager, service engineer or manufacturer
Monitoring of ordinary events	Events that although they are expected, the exact time and place where they will take place are only known with uncertainty
Monitoring of the system’s performance	This monitoring type provides the data required for the estimation of the predetermined metrics that measure the system’s progress against the initial goals or latest planning.
Monitoring of the discrete events	This monitoring type provides the information of the start and termination of the continuous processes as well as of the discrete events occurring

Furthermore, in order to establish an effective and efficient framework for monitoring biomass supply chain activities (as well as field operation activities as far they are directly connected) the following characteristics/challenges need to be achieved:

- Information is gathered in real time from the native data sources (tags, sensors, etc.) without any attempts to duplicate data in a secondary repository
- Associations, transformations, and metadata elements are implemented in real time to further describe and enrich existing data in the underlying data sources
- Both structured and un-structured information are incorporated under a common framework with reference data being transferred from one format to the other
- Monitoring requirements are easily represented within the architecture according to semantics, without technical interpretation and the heavy need of information technologies to cope with the data sources

- Vital information is monitored and real-time events and intelligence are delivered directly in a totally visual manner to decision-makers that need to take action
- Only exception conditions in the operations process are delivered to decision-makers, in order to be further analyzed and examined in detail

#### 4 Biomass supply event management

A generic conceptual model was proposed for the management of events in a biomass supply chain. The focus was on the event management of inter-organisational logistics processes. The outline of the proposed model is depicted in Figure 2. The model constitutes a generalisation of the one presented by Folinas, Bochtis and Sørensen (2011) on the in-field logistics process management which was based on the business activities monitoring system paradigm. The devised framework for that proposed architecture was divided into off-line and online activities, since it refers to the operational planning and execution of field operations (mainly to the harvesting operation). The proposed architecture for the biomass supply chain is not divided in on-line and off-line activities since it regards the activities and events that take place concurrently with the physical 'flow' of material, i.e. biomass.

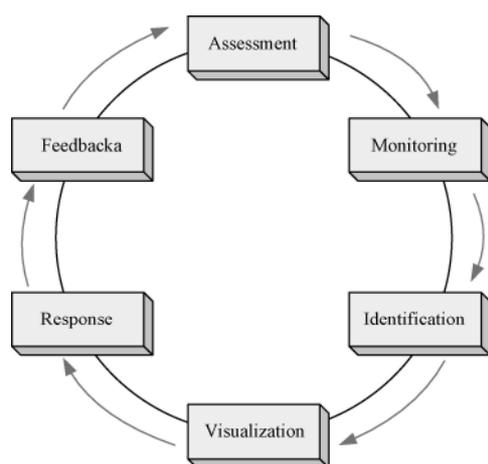


Figure 2 Conceptual model for a SCEM system for the biomass supply chain.

The main structural elements of the conceptual model are presented and analysed in the following sections.

##### 4.1 Assessment

Initially, the related events of the examined supply

chain need to be assessed and documented. Thus, this action involves the identification of the various types of events (urgent, ordinary, system's performance and discrete events) that are presented in the previous section. Furthermore, this step includes the identification of the *rules* and the corresponding *key factors*. An important aspect of supply chain management is that the various rules must comply with the constraints formed by the stochasticity of the 'raw material' production system (agricultural operations management) in terms of availability and capacity of the labour and machinery resources, the biological attributes of the crop and soil, and the development of the weather. This layer consists of the identification of the thresholds and events that are important to monitor, note and / or will activate automatic behaviours.

##### 4.2 Monitoring

This step includes the data acquisition process. First, it will be necessary to acquire detailed information about the actual machinery system that operates within the biomass supply chain (type, performance rate, reliability, operational state, etc.) and the crops to be harvested (yield maturity state, etc.). Secondly, at a particular point in time of the harvest season, the situation should be recognised with regard to development state of the crop, whether or not the schedule has been met so far, etc.

##### 4.3 Identification

The role of this layer is to identify and capture the event that occurs and provides appropriate action to take according to predefined rules or settings. The next step will be the presentation of these events to provide the appropriate action to take, according to predefined rules or settings, and the collection of the required contextual information to enhance these events.

##### 4.4 Visualisation

Once the events have been identified and described, information needs to be delivered to the appropriate person or system for review and action. The visualization layer is simply a visual exception report and involves multi-delivery mechanisms such as alerts via e-mail, dashboards, instant messaging, wireless devices, cellular phones, etc. The purpose of the visualization layer is not to overwhelm users with arrays of reports or

analytical options but only to provide the information users need and when they need it. Thus, it must keep things simple by highlighting anomalies that users need to investigate and providing additional information only as needed. Once the events have been captured and visualized, the next step is to provide context to these events so that they can be analyzed. For example, context may come from historical or real time sources, so, there is a need to understand and pass critical information without delay. Sometimes events need to be analyzed and business rules applied to derive key factors and alert content. In this stage, the proposed framework acts as an analytical tool that the user access by clicking on a metric or performance icon. It enables users to quickly see when performance is above or below expectations. Then, if desired, they can 'click-on' a metric and get more information about what is causing the exceptional condition.

#### 4.5 Response

The next step is the deployment of a specific and pre-defined action based on the contextual information that appears in a visualised manner to the decision maker.

#### 4.6 Feedback

Response outcomes are linked in a system monitoring effects of actions, unexpected events and any new information that can attribute to a validation, a refinement,

or a reconsideration of the inter-organisational logistics processes, so that supplementary knowledge from observations, databases, sensors, etc., can be incorporated in order to revise plans. Finally, the above steps are deployed from the start since monitoring is a continuous operation.

## 5 Conclusions

In this paper, a conceptual model for the management of inter-organizational events within the biomass supply chain was proposed. The proposed model is built on the Supply Chain Events Management technology. The goals of this model are:

- The identification and specification of events that occur during the execution of logistics and production processes in the biomass supply chain.
- The provision of real time information in a visual manner (this is very critical in the examined business domain where users do not have a technical background) regarding critical data and performance measurements indexes.

The preparation of necessary notification based on information needs of the end users and managers. The main objectives are the provision of real-time information.

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