Modern Systems of Information Transmission on Agro & Food Supply Chain

Silvius STANCIU
sstanciu@ugal.ro
Costel NISTOR
costel.nistor@ugal.ro
Loredana DUMITRASCU
loredana.dumitrascu@ugal.ro
Nicoleta STĂNCIUC
nicoleta.stanciuc@ugal.ro
Dunărea de Jos Universityof Galați, Romania

Abstract. Global food commodity diversification requires the application of new methods of data identification, monitoring, collection and processing in the production or distribution area. Classical systems of information transmission are currently widely used, but also present some inconvenience addressed by the emergence of new generations of information carriers. Current requirements for technical processes monitoring, quality assurance, traceability and customer orientation led to the emergence and evolution of modern identification systems based on dynamic information transmission and global databases development. The development of computer technology and the Internet are factors that allowed the development of these systems.

Keywords: agro & food supply chain, food products identification, information carriers, barcodes, RFID, GLN, GTIN, SSCC, EPC

JEL Code: D 66

1. Introduction

Food products trading requires the use of modern and rigorous monitoring methods leading to real, fast and complete information on each stage of the product chain. Tracking the physical and temporal evolution of food products on the manufacturer-customer route represents a current concern for specialists in commerce, industry and nutrition. Food quality is achieved in production, is kept on the commercial circuit links and is assessed at the consumer level by means of the well-being achieved and by meeting the designed functions. Traceability of products in agrofood supply chain, tracking and collecting the related information would not be possible without the use of technology based on advanced identification systems. The material support used for information storage, transmission or processing is called an information carrier. The development of information carriers assumes static media storing the information for previous processing / use and dynamic variables transmitting information in space.

2. Identification methods for food commodities

Normal circulation of products on the agro & food supply chain involves a good knowledge of their characteristics and factors involved in their evolution. The primary identification represents the determination of the product origin using DNA techniques specific methods that allow the material entities identification with a high degree of confidence. The core of primary identification methods is the ability to recognize the entity based on an unique component or feature.

The secondary identification carries out the product identification based on an identifier accompanying the entity, in part or in its integrity, on the entire path covered. The secondary identification uses numeric or alphanumeric strings based on food commodities specific standards for identification and numbering.

Secondary identification may be used at source, by attaching chips to animals, marking particular batches of raw materials (cereals, genetically engineered organisms, etc.) or finished products. Secondary

identification is commonly used to identify the individual entities at different levels of packaging, the transport and loading units, containers etc., based on basic traceable unit (BTU).

The category of secondary identification systems includes paper or other materials labels, plastic or metal plates, microchips, etc. They are a physical entity directly attached to the product, accompanying the product and facilitating its identification. The main advantage of secondary identification systems is that they allow for different information encoding using barcodes and symbols under the conditions of an easy access to information. External identification has the disadvantages of a difficult support management alongside the complex processing and distribution systems, easy removal off the product, loss or forgery. In case of an excess of information, the systems can become ineffective.

Electronic data management plays an important role in improving the efficiency and accuracy of information handling in the food chain.

The currently operational resources commonly used are:

- *numeric-only barcodes*:
  - EAN 13: International barcodes for retail products (European Article Numbering).
  - EAN-8: Compressed version of EAN barcodes, specific to small size products.
  - UPC-A: Universal barcode used by most retail products in the U.S. and Canada.
  - UPC-E: Compressed version of UPC barcodes, specific to small size products.
  - Code 11: Used especially in telecommunications equipment labeling.
  - Interleaved 2 of 5: Compact numeric barcode, primarily used in industry, air transport and other applications
  - Industrial 2 of 5: Barcode, an older and rarely used system.
  - Standard 2 of 5: Barcodes, an older and rarely used system.
  - Codabar: Barcode intended mainly for products sale in bookshops or for codification used in blood banks.
  - Plessey: Barcode widely used in shelf labels printing.
  - MSI: Version for "Plessey" barcode type, frequently used in U.S.A.
  - PostNet: Barcode used by U.S. Postal Service for automated sorting of mail.
- *alphanumeric barcodes*:
  - Code 39 – general-purpose code, widely used worldwide.
  - Code 93 – compact code, similar to code 39.
  - Code 128 – very reliable and efficient code, with excellent density, globally used.
- *two-dimensional codes* (biaxial barcodes, matrix and composite, including direct marking);
  - PDF 417: Barcodes recommended to encode large amounts of data;
  - DataMatrix: Barcodes that store large amounts of information concentrated in small spaces;
  - Maxicode: Fixed length barcode used by United Parcel Service for automated parcel sorting;
  - QR Code: Barcodes used for materials management and order confirmations;
  - Data Code;
  - Code 49;
  - 16K.
- *storage devices;*
- *radio-frequency identification (RFID) systems;*
  - *EPC - based on smart tags (passive and active devices).* (*source: www.coduridebare.com)*

3. Classical systems of information transmission

The classic coding systems use bars to transmit information and are in use since 1970. The application of these coding variations in data processing, asset management, document management, access control, inventory and distribution management represented a key element in commerce development.

The appearance of linear codes is relatively simple, but the way the white and black spaces (bars) are structured to encode information in digital form is sophisticated. Their configuration significantly determines the encoding type and the specific characteristics.

The encoding area comprises an alternating number of bars and white spaces of different width. In addition to bars and spaces, which encode information, encoding also includes a series of symbols that facilitate the scanning and decoding process and secure the code. The code size and print quality are two critical issues for the fluency of information stored.

The symbolisation of barcode may contain some or all of the elements shown in Figure 1.

Figure 1. *The barcodes features*

Start / Stop area ("quiet area or free area") represents relatively large spaces / areas located on both sides of the code structure. They provide reflection areas that allow the optical reading system to establish a benchmark for information decoding.

Start and stop characters are particular groups of bars and spaces, contained in a symbol, which facilitate the differentiation of the start and stop areas in data encoding. A symbol that can be read in both directions is called bidirectional. Check characters are represented by derived digits or symbols used to check the coded data. Depending on the symbolism, this area may be mandatory or optional. The characters decipherable by the human senses are printed under the bars and white spaces rotation area to allow manual typing when the automated capture of information can not be performed.

Self-control structures are encoded structures of bars and spaces for a set of characters designed to avoid the potential decoding errors due to a printing failure that denotes an item transposition error in the symbol. Inter-character disconnecting spaces are blanks between encoding characters due to sequential symbols printing using mechanical methods with printing devices. Vertical redundancy means the symbol height that enables different scanning in order to avoid decoding errors due to blanks or printing stains in the code structure. Reading these symbols involves scanning with a laser beam and detecting changes in the amount of light reflected by the surface. Intensity variations are converted into a digital signal which is then subjected to an electronic decoding process.

The code symbolism is a set of rules by which a system of bars and white spaces encodes a set of characters and numbers. The coding rules are generally standardized and are used in open applications (food chain). The symbols were developed to include numeric or alphanumeric data, to encode a high density of data or to reduce the printing costs and are distinguished by the character number and the alternation method of black bars and white spaces.

Numeric-only codes are made up of a sequence of numbers, placed on tags located on products or their packaging. The system design is simple and economically efficient, but the management requires a large human resources volume if the code inscription and deciphering are not automatically executed. The performance of these external systems may be limited by the large amount of information manually managed, with the risk of corrupting data integrity. Alphanumeric codes consist of a sequence of numbers and letters of different sizes, placed on tags located on products or their packaging. The system design stage is simple, economically efficient, but the management requires a large volume of human resources.

In order to unify the information, the European Article Number Association (EAN) has introduced a series of new codes, the most widely used being the Global Location Number (GLN), now universally accepted for information identification and communication in the food chain. The system consists of three components:

- identification numbers – used to identify the product, service or price logistics location;
- information carriers – represented by the barcode or the RFID system. The structure of these systems varies depending on the level of information required and the available space. For traceability, EAN 128 barcode is used to encode additional information;
- electronic messages – they are related to the connection between the products and the electronic flow of information. These technologies are used in meat traceability, providing a robust tracking system for most items in the meat food chain and play an important role in labeling.

Bar codes can be applied directly on the product packaging, on labels affixed to the packaging or by labeling at the product packaging location. The location of the symbols is usually chosen in a part of the package bearing some other inscriptions. In order not to limit the visibility of the code, there are some rules to be followed, dictated by the packaging shape and size.

4. Radio Frequency Identification System – RFID

RFID is an advanced technology for automatic objects identification and related data collection without the need for physical or visual contact. The system is expanding rapidly in commerce and production, as users understand and use it. The requirements related to the technological process monitoring, quality assurance, traceability and customer orientation led to the development of RFID from a system rarely used to a system necessary in today's industrial automation. The benefits for logistics and management have imposed it as a solution adapted to modern standards of production and trade.

The system is similar to barcode technology, but works by proximity, without direct contact. Thus, if the barcode system requires labels glued on objects and a corresponding optical reader, RFID requires a reader equipment and special integrated "tags" or cards attached to articles to be tracked. The barcode is scanned through the reflection of a light beam on the label containing the printed code, while RFID method uses a low power radio frequency field. The operating principle is based on the emission of an electromagnetic field by a reader, which will be received by a radio label (tag). The electromagnetic field activates the tag and creates the conditions for transmitting the information contained to the reader. The tag scanning with radio waves does not require precise positioning of the object when reading. The radiofrequency field penetrates any non-metallic material, so there is no need for direct contact between the tag and the reading equipment.

The analogy between the simple identification applications by proximity and barcode type systems is not valid for sophisticated RFID devices. In these cases the system is more complex, by using interfaces with external sensors to measure specific parameters or GPS systems for satellite tracking of objects / entities position.

RFID identification systems mainly consist of four components:

1. *Tags (radio labels)* – mobile components of the system, also representing the information carriers, with a storage capacity of up to 2kB (FRAM or EEPROM). Theay are physically attached to the product, allowing information writing and reading and thus ensuring product identification (traceability). They are available in various geometric constructions (disc, cylinder), have a high degree of protection against dust and water (IP68), covering a range of temperatures from -40 to +210 Celsius degrees.

2. *readers – writers (transceivers)* – allow information reading and writing from / to tags. By connecting to dedicated modules (RFID modules), they allow to write / read tags in motion, with a high degree of protection against dust and water ingress (IP67).

3. *communication interface* – ensures information transmission to / from tags

4. *management system and database* – provide the storage, processing and management of the production process information.

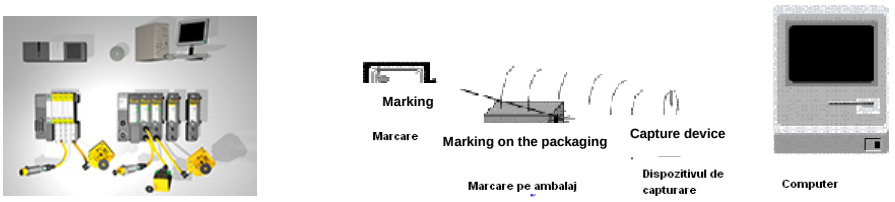

Fig. 2 *Identification system RFID scheme (processed based on www.csean.ro)*

Types of RFID systems

The following categories of *RFID* systems can be used in practice:

a. *EAS systems (Electronic Article Surveillance*) – they have a small storage capacity (about 1 bit), sufficient to detect the presence or absence of an object. They are used in retail trade to detect thefts, reading devices with a large antenna being installed at each entrance / exit point of the store or section.

b. *portable data capture systems* – they contain a *RFID* reader that captures the data which are then transmitted to an information host management system via a radio frequency link or are maintained for transmission via a connection in the form of data packages.

c. *network systems* – the reader has a fixed position and is directly connected to an information management system in the network. The *transponder* is placed on objects or living beings in motion.

d. *positioning systems* - in this case the reader is placed on a vehicle, is connected to a board computer and communicates the data to an information management system using radio frequencies. The *transponders* contain identification data and location data by means of the programming. The role of this system is to enable the automatic location and to provide support for guided vehicles movement.

Advantages and limitations of RFID systems

Implementation of new RFID technologies focuses mainly on advantages and disadvantages, being made a comparison with the *AIDC (barcode)* system which becomes relatively omnipresent in commodity trading. As compared with *AIDC* technology, *RFID* technology has the following advantages:

- **high storage capacity.** Conventional labels (based on barcode) are able to maintain an information amount of only 20 characters. *RFID* tag offers the advantage of storing a larger amount of information.
- **increased speed.** Compared to *AIDC* technology, RFID technology enables faster information reading and communication.
- **automation possibility.** The reading of information stored in the *RFID* tag does not require the presence in the sight and does not require a specific product orientation.
- **flexibility.** A number of *RFID* tags are dynamic databases. There are labels that can contain *read / written* type information.
- **selectivity.** *RFID* technology allows labels to selectively respond to reader requests.
- **total cost of ownership and use.** Type *read / written RFID* tags offer economic advantages due to repeated use. Although more expensive, the costs are amortized relatively quickly. In comparison, the labels using the barode can be used only once.
- **simultaneous reading.** An *RFID* system can read multiple tags simultaneously.

As with other identification technologies, *RFID* speeds up data acquisition and eliminates human intervention in control and sorting processes. The large amount of data needed to automate production becomes very difficult or impossible to control when using human operators, the processing times reaching unacceptable levels, with a high error rate. The only practical method for this type of data automatic collection is the use of computer identification and tracking systems. Automatic data collection increases the working speed, eliminates the errors, increases the information value in the system with real time access to it. For example, if some finished goods from a warehouse are sent to a wrong destination, the information is useful only if processed in timely manner to correct the error.

5. GLN, GTIN and SSCC systems

EAN.UCC system is applied in different areas – trade and logistics, property and location codes. The records are data structures type defining all the product criteria and used as a means of access to databases. The information encoded in this manner also represents elements of traceability, identifying the production, distribution and trade units involved in the transaction stages.

Data structure is meant only for recognition, without having a numeric value. Full product, services or properties information can be found in the database. Usually, this information is provided by the supplier to the consumer before the first commercial operation through standardized messages or electronic catalogue. These systems allow for product-related information dissemination between trading partners, ensuring uniqueness within the scope of use.

The numbering system includes three basic elements:

- Global Trade Item Number (GTIN),
- Serial Shipping Container Code (SSCC),
- Global Location Number (GLN).

GTIN represents the global trade item number which allows exact identification of the unit at international level. Identification and marking of trade items enables the automation of retail sale by the electronic cash register with files-money associations, goods receipt, repeated orders inventory, sales analysis as well as other commercial operations stored in its memory. In the basic specifications of the EAN/UCC system, GTIN code includes the following information:

- indicator, usually applied to specify the type of transport container,
- company prefix, established by EAN or UCC administrators,
- product number, which identifies a particular class of objects,
- check digit.

SSCC is a number or a data structure used for unique identification of logistic units (transport and / or storage). The logistic unit is an assembly designed to transport and / or to keep a group of products anf that can be controlled throughout the product cycle. SSCC is coded by the UCC/EAN-128 barcode. The scanning of the SSCC applied on the logistic unit allows the monitoring of each load unit through the connection between the physical circuit and information. The system can perform the automation of the physical logistics with information support, facilitating the orders fulfillment, rail load streamlining, automated receipt of goods and so on.

SSCC number consists of 18 digits and includes the following information in the EAN*UCC system:

- extension – a digit used to indicate the type of load;

- company prefix, established by EAN or UCC organizations (7 digits encoding the organization prefix and the enterprise number).
- serial number, established by the enterprise of each load unit (9 digits);
- check digit.

GLN is a global code for the address of the economic operator, which identifies it as a legal unit. In multifunction companies, the system is also used to identify the physical placement of functional units. The GLN structure, mentioned in the core specifications of the EAN*UCC system, includes information elements: the company prefix and reference to the location (location code). The location code can be used to identify physical and logical objects.

6. EPC encoding system

EPC – Electronic Product Code is defined as the next generation of barcodes, much more evolved than that. EPC is a system that uniquely identifies any commercial unit (from object or good of individual consumption to logistics unit), also called the product factory brand (*source www.gs1au.org)*.

Currently, approximately 150 companies worldwide actively participate as subscribers to the activity of EPCglobal Operational Group, performing common commercial operations (BAG), to the program supply (SAG) and equipment (HAG) development *(source www.csean.ro).*

EPCglobal Inc is a project developed in 1980 through cooperation between EAN International and Uniform Code Council Inc. (UCC), aiming to develop standard solutions for global delivery network. In legal terms, EPCglobal Inc is constituted as the non-commercial association of all partners in the global delivery network, which performs the framing of EPCglobal Network technology. Thanks to the use of EPC (Electronic Product Code ™) and RFID (Radio Frequency Identification) technology, the EPCglobal Network technology will enable instant, automatic and accurate identification of each business units in the delivery network of any company, in any industry and corner of the world.

The application of an EPC encoding system requires six basic elements:

- Electronic Product Code (EPC),
- Marks (tags, signs),
- information capture devices,
- Savant data processing system,
- *Object Naming Service (ONS),*
- *Physical Markup Language (PML).*

In terms of appearance, EPC encoding consists of a numeric string that identifies the manufacturer, the product, the version and thw serial code. Additional functions can be added to the EPC code, to encode / decode information in consumer accessible formats. Such data are stored in a marking RFID microscheme attached to the product, while the remaining information is related to the serial number in the database. The information is no longer printed on a physical medium, such as classic barcodes paper, but it is stored in an electronic label that can be read using radio waves, creating the possibility of locating and tracking products throughout the distribution channel length.

EPC number includes:

- title, identifying the length, type, structure, version and generation of EPC code
- administrative number, identifying the company or organization
- object class – analogous to storage unit or SKU
- serial number – representing the object class.

The main advantage of the system is the exact identification of the product, in terms of origin and evolution over time. Thus, bar coding, used in almost all areas and on most products on the market, only identifies the manufacturer and the type of product, without being able to specify the features related to the product physical unit (the barcode applied to food products manufactured by a manufacturer at different times is the same, without being possible to identify the manufacturing time or the expired products).

Figure 4. *The structure of the EPC code*

The system use is based on a circuit that records the responses created by the RFID network of capture devices (also called interrogators). A capture device is installed at the point of product entrance in the factory warehouse and and in each section. When a products pallet arrives, the capture device placed at the entrance records the factory number and transmits the information to the inventory system. When the pallet is placed in a section, for example A, the capture device receives the signal that the product with the respective number is in the section A.

EPC system uses RFID features that allow the tracing of the product circulation and their related information transmission, usually via the Internet. The task of identifying every single product manufactured anywhere in the world is a complex action, requiring a large volume of material resources.

Computer systems correlate the electronic product code with the information on the product stored in a database. EPC system uses the Object Naming Service – ONS to identify the product, indicating the computer the Internet address where the information on the product is stored. The computer system requires this method of transforming the electronic product code, recorded by marking, and the product data code, stored in the PML files. ONS is analogous to DNS – Domain Naming Service, which performes the management of Internet domains. ONS service tells the company computer system receiving the load that the necessary information about the product is stored in the computer file, located at particular Internet address.

Automatic identification of products allows computers to collect and process information. For this purpose a new computer standard system is used – Physical Markup Language (PML) together with an EPC Global Architecture Framework, a collection of independent universal computer standards, extended on physical objects, processes and media. The language is based on the eXtensible Markup Language (XML) used to describe the general types of data (addresses, dates, invoice numbers, etc.) and transactions (purchases, prices, etc.). The PML files are stored on the PML servers of the computers designed to deliver information throughout the network. The PML files will store the information on each product – name, category, date of manufacture, shelf life, current place of storage, temperature conditions, etc. PML files will provide information for existing and future applications. In order to manage data and to avoid the overloading of corporate and public networks, the Savant software is used, employing the distributed architecture of a new EPC network computers, managing the information flows.

Optimization of information storage is achieved by using the Task Management System, which allows the companies to establish the start-up applications such as sending messages about products delivery. The basic element of the system is the electronic product code – the product identification standard. It does not replace the existing standards of bar coding, performing the transition from the existing standards for barcodes to a new electronic code. For this purpose, the basic structures of the Global Trade Item Number (GTIN) are adopted. The Uniform Code Council (UCC) and EAN International are participating in this process, monitoring the basic coding standards.

Currently, two EPC variants are used, differentiated by a memory capability of 64 bit and 96 bit respectively. The use of codes with higher coverage capacity is expected, that will determine the number of the EPC version. The 96 bit version is commonly used, including the title and three data sets:

- the first data set – the number given to the manager code, usually the number assigned to the company manufacturing the product;
- the second data set – the number of the object class, under the SKU classification (Stock Keeping Unit) and the exact type of product, respectively,
- the third data set – the unique data number for the physical object encoded, which indicates the particular design option. This can be useful, for example, to identify the product with limited validity, approaching to the expiration date.

The 96 bit EPC code is applied mainly for economic reasons related to marking cost reduction. The version is currently sufficient for the global traded amount of goods and allows the identification of 268 million of companies, each manufacturer being able to encode 68 billion of units of each of the 16 million of production types.

Records marking (tags) can be made in passive or active version. RFID specific passive radio marking, also applied in the EPC system, includes a system of receiver, transmitter, antenna and memory for information storage. The receiver, transmitter and memory are constructively obtained as a separate microscheme, the consumers distinguishing two components: antenna and microscheme. The version doesn't have its own power supply, the energy required for operation being provided by the electromagnetic signal emitted by the capture device.

If the microscheme also includes a power supply (lithium battery), which allows the transmission of the signal to the capture device, the marking becomes active. The semi-passive markings include a battery to maintain the microscheme operation, but receive the signal energy from the capture device. The

active or semi-passive marking options are more expensive, being used for high-value products requiring identification over large distances, over 30 m.

The information capture device consists of transmitter and antenna, that emits an electromagnetic field with a certain frequency. The signal is received by the capture device antenna and transmitted to the computer for processing.

EPC data capture devices receive large amounts of data, their management and transmission representing a complex problem. Savant data processing system, developed by Auto-ID Center does not process data in a singular manner, but uses the EPC Global distributed architecture. The program will be applied in commerce (shops, wholesale warehouses), production and transportation. Compared with existing databases that can not handle more than a few hundred of transactions per second, Savant performs the real-time processing of events related to database memory. The system takes data about the electronic product code in real time, data it make available for others applications without overloading the database. In parallel with these features, the system allows the inventory and supply management.

The data quantified in the PML language will have a tree structure, specific to non-flexible classifications. In addition to information on product, which does not change, the PML language includes data to be constantly exchanged (dynamic data) and date with discrete change over time (temporary data). These data can be recorded, providing comprehensive information on product development.

The advantages of the EPC system

EPCglobal Network system provides complete transparency of the delivery system, promoting the international transactions. The main advantages presented by the system promoters are related to:

- storage and distribution costs reduction;
- urgent deliveries costs reduction, by optimizing the loading, assembling, packaging and reception operatons;
- food products and pharmaceuticals tampering prevention;
- it represents a base for property management in the administrative system.

Due to technological progress, the price of marking and capture devices has decreased considerably in recent years, overwhelming the main drawback of the system. The technology development was allowed for at global level, as well as a growing number of users, which will further lead to costs mitigation.

Acknowledgment

The authors acknowledge financial support from the National University Research Council (NURC, PN-II-ID-PCE-2008-2, Idea, ID 517) Romania (www.trasilact.ugal.ro).

Selective bibliography

1. *Chrysochou, P., Chryssochoidis, G., Kehagia, O., 2009, Traceability information carriers, Appetite 53.3: 322-331.*
2. *Folinas, D., Manikas,I., Manos, B., 2006, Traceability data management for food chains", British Food Journal, Vol. 108/8, 622 - 633*
3. *Fenu, G., Garau, P. 2009, RFID-based supply chain traceability system, Industrial Electronics, 2672-2677*
4. *Furness, A., Smith, I., 2006, Improving traceability in food processing and distribution, Woodhead Publishing, London, UK*
5. *Kelepouris, T., Pramatari, K, Doukidis,G., 2007, RFID-enabled traceability in the food supply chain, Industrial Management & Data Systems, Vol. 107 /2, pp.183 – 200*
6. *Natsui, T., 2003, Traceability System using RFID and Legal Issues, avaible from www.sics.se*
7. *Popa, V., 2009, Supply chain management in consumer goods industry and retail, Valahia University Press, Târgoviste*
8. *Popa, V., 2000, ECR Efficient Consumer Response, Editura Economică, Bucharest*
9. *Rowe, G., 2005, Traceability and EPC/RFID:It starts with standards, Atlantic Fisheriea Technology Conference*
10. *Rotaru, G., Stanciu, S., 2007, Commodity Science, Editura Didactică si Pedagogică, Bucharest*
11. *Stanciuc, N., Rotaru, G., 2009, Food Safety Management, Editura Academica, Galati*
12. *Sugara, K., 2009, Traceability System For Agricultural Products based on Rfid and Mobile Technology, Computer and computing technologies in agriculture, vol.295, 2293-2301*
13. *www.barcodes.com. accessed in July - October 2011*
14. *www.csean.ro, accessed in August - October 2011*
15. *www.gs1.ro, accessed in July - October 2011*
16. *www.trasabilitate.ase.ro, accessed in January - October 2011*