STANDARDIZATION OF DATA FLOWS ON EARTHWORKS AND ROAD PAVEMENT SITES USING INFORMATION SYSTEMS

by

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ABSTRACT: The work described in this paper is the follow-up of the first analysis presented in the previous ISARC on the same theme. The paper start by recalling the background with is the ISO TC-127 WG2 standardization initiative. Then he applies a basic logical model of site information system for civil-engineering sites to various existing or under development such European systems (CIRC and OSYRIS) to identify and specify the main categories of information flows that are worth to be standardized. The paper ends with some considerations about these categories and the way to continue the work.

KEYWORDS: standardization, site information systems, civil-engineering, computer integrated construction, data flows.

1 INTRODUCTION

Still much time and money are lost all along and between the various phases of construction, due to the lack of information and the very poor quality of the management of this information, making very small use of the new available Information Technology. Clearly, the new challenge in the construction world is now the information management.

Due to the presence, on more and more work sites, of novel operator-aiding systems using smart positioning and processing systems, people have become aware of the value of all the relevant data that can be collected from such systems, for instance for quality assessment and relationships with the road owner. These data, that need to be exchanged between different information and processing systems are really valuable only if they are standardized

2 BACKGROUND

To address this issue, the ISO TC-127 standardization committee launched a new working group, WG 2, focused on the scope of *Work site data controlled earth-moving operation* in October 2000. This group, gathering experts from Japan, USA, France, Germany, Sweden and Italy, already met 3 times, in Tokyo, Bologna and Denver and the main decisions which came out from the discussions are the followings:

- to focus upon road construction works, including earth moving operations and pavement construction,
- to start with the standardization of the definition and content of the information exchanged, then to study the format, then the protocols,
- to stay close to the site, and more precisely to the machines itself, that is to say not to study, in a first step, the higher level exchange of information between road authorities and the contractors.

To structure its work, the WG decided to subdivide it into 3 projects: *Terminology*, *System Architecture* and *Data Dictionary*, the first two ones being under the responsibility of Japanese experts, the third one of the French experts, co-operating with the American ones.

Terminology should set up the basis of common understanding for all the work, *System Architecture* should define how the data will be handled in the various exchanges and *Data Dictionary* should define what data should be standardize and propose a common definition and representation of them.

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This paper presents mainly the work achieved by LCPC, composing the French delegation, about data identification and clustering for preparing the work of establishing the relevant data dictionary to be included in the tentative standard.

3 THE LOGICAL MODEL

The paper presented at last ISARC in Warsaw [1] already presented differences between logical and physical modeling and explained why we proposed to start the standardization discussions at the logical level. This paper also introduced the important concept of 'road product model'. The core part of the paper was the proposal of a logical model of a *Site Information System* which was based upon the analysis of the functional design made for the OSYRIS project [2].

A 'system' is a group of functions providing a 'service' (can be an action but generally a piece of information) as answer to a 'demand' (always a piece of information). Each system can be decomposed into several sub-systems, thus giving a fractal structure to the representation.

The logical model of our system is presented in Figure 1, is composed of four main sub-systems which play well-separated roles in the global process: *Temporary Data Storage*, *Data Collection and Processing*, *Assist For Operation* and *Work Execute* systems.

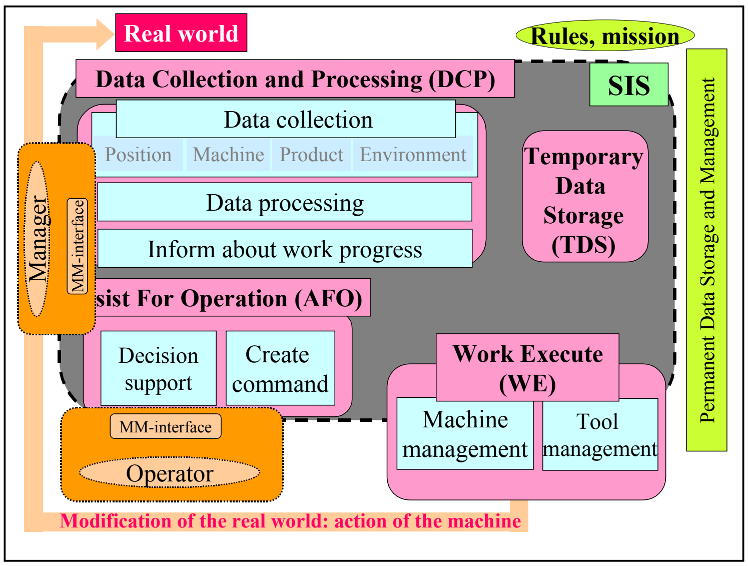

Figure 1: The basic logical model

- *The Site Information System (SIS)* (formerly called *Data Operation System*) means the whole system itself which is managing information to improve the quality of the work. The SIS can be physically distributed at various places, on the machines. It has generally one 'office' segment and one 'site' segment.
- The *Work Execute (WE)* sub-system is the part of the SIS who is managing the machine and/or the tool. It might not exist when the operator is steering manually.
- The *Assist For Operation (AFO)* sub-system, which can also be called *Execution Management* sub-system, is the sub-system which is making the decisions for the execution of the work, with or without the help of the operator.
- The *Temporary Data Storage (TDS)* sub-system is in charge of storing all the temporary data that important for the quality assessment, before transmitting it to the external 'Permanent Data Storage and Management System'.
- The *Data Collection and Processing (DCP)* sub-system, is a composite and intermediate system which is in charge of acquiring the necessary data from the Real World or from the TDS and in charge of processing them for the other sub-systems. It also prepares the data for visualization if necessary.

The human beings participating to the execution, grouped into two classes: *Manager* and *Operator*, are considered external to the SIS, thus contributing essentially to the process. The machine itself, that is to say the piece of equipment composed mainly of hardware but also of software, under the form it is provided

by the manufacturer, is considered also external to the SIS.
The data flows that are in the scope of the standardization work are those exchanged between: SIS and machinery, SIS and measurement instruments, SIS and contractor or consultant office.

4 DATA EXCHANGED BETWEEN THE VARIOUS SUB-SYSTEMS.

4.1 Analysis Of Existing Systems

To support our analysis, we studied carefully the data flows existing in several SIS already developed or under development. The SIS we analyzed are dedicated to road pavement construction, but we make the assumption that the results would be valid for earth moving sites too, with maybe some minor differences.
First, we considered the *Computer Integrated Road Construction* [3] products, that is to say the CIRCOM system, dedicated to the rollers, and the CIRPAV system, dedicated to the pavers.

CIRCOM
CIRCOM [4] is an operator-aiding system which provides, through an accurate and ergonomic display (colored map), to the operator the position of its machines, its speed and the already achieved number of passes. The positioning component, called CIRCOM POS, is a quite sophisticated one, using various sensors, in particular a high-precision GPS. The preparation of the mission and the transmission of the design data are made on a computer called CIRC GS (for Ground Station) and the on-board processing is done by the CIRCOM OB (for On-Board) computer.
The CIRCOM data flow analysis is presented on Figure 2.

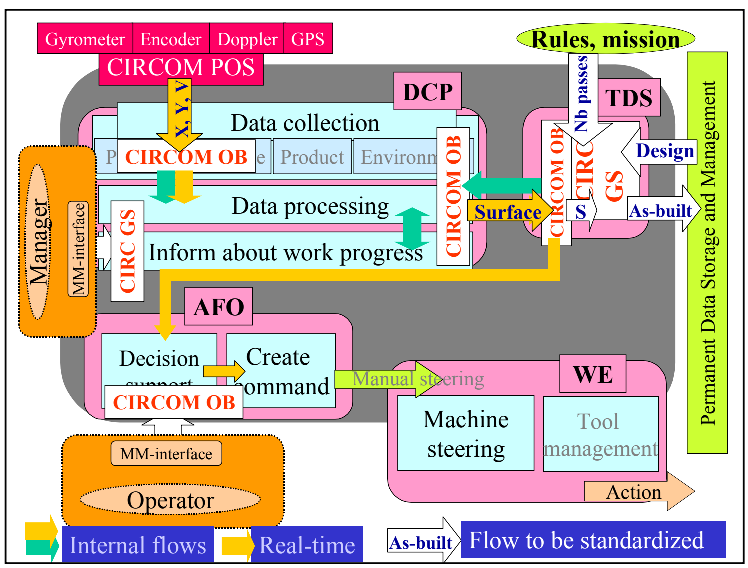

Figure 2: The CIRCOM data flows

The first thing to remark about the CIRCOM SIS is that the Work Execute sub-system (WE) doesn't exist as the steering of the machine remains manual, or can be considered as external.
The second point to notice is that the physical 'components' of the system are distributed among the various logical sub-systems, meaning that a physical component provides generally different kind of services, from a logical point of view (e.g. temporary storage, intermediate data processing and display to the operator for the on-board computer).
The data flows that are activated by the operation of the system are of different kinds. Some are 'internal', meaning that they should remain proprietary and thus, are not to be considered for standardization. Some are real-time and some are not. The important data flows for standardization are those which are exchanged either between the SIS and external systems or between sub-systems, when it is necessary. This has to be discussed case by case.

1. Data exchanged between the SIS and external systems:

- *design* data (description of the road geometry);
- *mission* data (target number of passes and target speed)
- *as-built* data (compaction map showing the actual achieve number of passes on the road);
- *positioning* data (plane position and speed), from the positioning component, considered external.

2. Data exchanged between sub-systems:

we took into consideration what we called the *achieved surface* data, that is to say the 'just achieved' work of the roller that might be interesting to transmit and to use in real-time. This is justified for this kind of system because these data have to be exchanged between the different compactors and they might be equipped with similar systems from different manufacturers.

The *achieved surface* data are representing, in the case of CIRCOM, the surface compacted by the machine, to which is associated the speed and the indication whether the roller is vibrating or not. More attributes about the compaction energy of the machines can also be added: amplitude, frequency, etc.

CIRPAV

CIRPAV [3] is a little more complicated since it provides two main functions: assistance to the driver for the steering of the machine, thanks to a color display similar to the CIRCOM's one, and automatic elevation control of the screed. The positioning component, called CIRPAV POS, can be based upon different technologies, but has to provide both position and attitude of the screed. The preparation of the mission and the transmission of the design data are still made on the CIRC GS and the on-board processing is done by the CIRPAV OB.

The CIRPAV data flow analysis is presented on Figure 3.

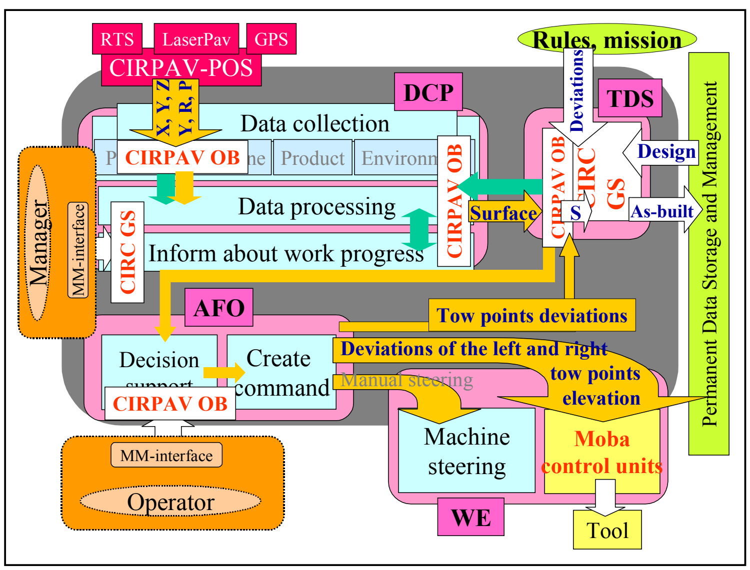

Figure 3: The CIRPAV data flows

Most of the data flows are similar to the CIRCOM's ones, albeit with a different content: *design*, *as-built*, *mission*, *position*, and *achieved surface* data.

The main difference is in a new data flow that is exchanged between AFO and WE (which exists this time due to the automatic control ensured by the CIRPAV SIS): the deviations between the actual tool position and the target tool position.

This data flow category we can call: *deviations for machine control*.

OSYRIS

OSYRIS [2] is an even more complex system where more data flows are addressed, as it includes work execution functions and quality documentation functions. It is a system also where there are several data exchanges between different kind of machines (paver to rollers).

OSYRIS system is mainly designed for standard asphalt pavement sites, executed with 1 paver and 2 compactors. A basic configuration is proposed, with additional options for on-board functions and office functions.

- The TDS sub-system functions are executed by several pieces of software that are physically located in office computers or in on-board computers, depending of the version of the product.

In the 'full' version of OSYRIS, the whole package includes the office *Design and Documentation* piece of software that allow a full mission description and a full documentation of the achieved work consistent with the geographical data base (OSYRIS Product Model).

These pieces of software can also be located at the level of the *Permanent Data Storage and Management* system which is outside of our SIS, since they are also designed to manage the permanent information after the execution of the work.

- The DCP functions are executed mainly by the on-board computers, located on the paver (*Paver OB*) and on the rollers (*Roller OB*). This means that wireless exchanges are addressed, for instance for temperature data, position data, etc. The visualization of the progress of the work is ensured by the office *Work Documentation* software component (WD) and by the *Work Site Web* (WW) service.

Many on-board sensors are also concerned in OSYRIS, as inputs to the DCP and these data flows are necessary to be standardized .

As far as AFO and WE are concerned, the functions are quite closed from those of CIRC system.

The OSYRIS data flow analysis is presented on Figure 4.

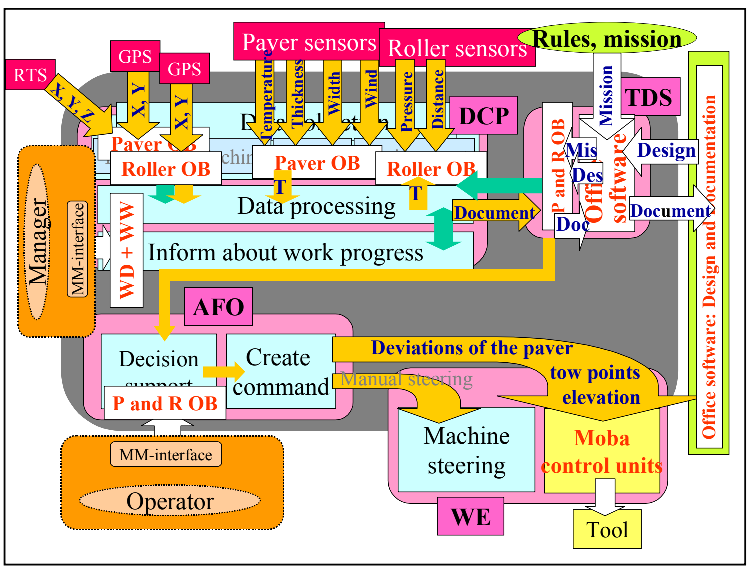

Figure 4: The OSYRIS data flows

The new data flows that are involved in this kind of SIS are material-related measurements that are carried out on the machines, for documentation, operation or transmission to other machines purposes, like: temperature, thickness, width and volume of the layer, environment parameters.

Let us call this new category: *machine sensors data*.

5 SYNTHESIS ABOUT THE DATA FLOWS TO STANDARDIZE

Our analysis, from road construction SIS, has yielded the following 6 main data flows categories:

1. *Design data,*
2. *Mission data,*
3. *Real-time Position and speed data,*
4. *Real-time machine sensors (and achieved surface) data,*
5. *Real-time deviations for machine controls,*
6. *As-built and work documentation data.*

(As *achieved surface data* are obtained from sensors on-board of the machine, they can be grouped with *machine sensors data. Position and speed data* are for the moment considered apart, given their very specific importance).

These categories have different time scales:

- 1 and 6 have very long evolution periods (from several days to several months),
- 2 has medium long evolution periods (from several hours to several days),
- 3, 4 and 5 have short evolution periods (from some milliseconds to several seconds).

Type 6 is the counter part of types 1 and 2, *as-built* corresponding to *design* and *work documentation* to *mission*. These 3 categories are composed of static data. As far as format is concerned, XML seems to be an excellent candidate given its universality and flexibility. In this respect, the new LandXML standard under development [5], proposing both data model and data format should be considered, although non addressing documentation data so far. Raster formats are also to be considered for presenting synthetic documentation maps.

Categories 3 to 5 are real-time data, attached to the machine itself. An important remark is that these data have necessarily to be processed with respect to the position of the machine (this is obvious for category 3). An interesting way of representing these data is to use the *Ribbon* data base structure which has already been used in both CIRC and OSYRIS projects and is described in [6] and [7]. Ribbons allow the description of geometry, this way they can be used also for design and as-built data, but they can also store parameters with respect to the position of the machine. These parameters can be either machine sensors data or deviations for tool control. Ribbons are generated by a generator moving along an oriented polyline and allow parameter interpolation as wall as curvilinear transformation. They are time-tagged and each machine is generating its own ribbon. All the different ribbons can be merged to output the synthetic maps for as-built documentation.

6 CONCLUSION AND PERSPECTIVES

Our analysis has brought to the fore several data flows categories that must be considered separately since they play different roles in the process. Still these different categories need to be described more precisely to continue the work, but experience from European projects such as CIRC or OSYRIS already tells us that the *Ribbon* structure can be considered as a universal digital model for real-time data. As far as static pre-execution and post-execution data are concerned, existing standards as LandXML or raster format must be used.

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