ARTIFICIAL INTELLIGENCE IN BUILDING SITE MANAGEMENT

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ABSTRACT

The paper documents the research program entitled "SY4.0, Smart Yard: Industry 4.0 Production Process" financed with European funds under the ERDF Regional Operational Program 2014-2020.
The research, through the use of automatic field data processing systems and their integration in the design, through the realization of technological demonstrators and through the improvement of operating activities and disseminating and sharing information, aims to come up with a new modalities for yard management based on digitized processes able to collect and monitor the computational data and to direct them towards specified purposes of production processes optimization.
In particular, the specific objectives of the project concern: the exploitation of operative technologies; the rationalization of resources through the reduction of waste and reuse in the life cycle of the building of some construction site devices; the protection of the safety, security and well-being of workers.
These intentions are reflected in the proposition of an evolved organizational and management model which, through the prefiguration of the working steps, allows a more reliable control of the production process, mitigating the inevitability of the characteristic uncertainty scenarios and achieving more rational use of resources.
In order to achieve the objectives, the methodological measures proposed concern: base scenario analysis; recognition on the construction site management technologies in Industry 4.0 perspective; IT platform development and sensors design.
The results of the research are: high-performance power supply systems, power bank recharging hubs; hybrid lighting systems; remote monitoring tower of construction sites; smart dust suppression; IT platform for workflow digitization; work stations and devices based on low-invasive sensors and wireless communication protocols.
In order to test their actual effectiveness, the devices developed will be individually checked by their producers and then, connected in the new management model, validated in a pilot yard.

Keywords: Smart Yard, Building Process, IoT, ICT, Smart Grids

INTRODUCTION

In a context where ‘aggregating’, ‘sharing’ and ‘relating’ are keywords, the new organization of production processes, for the productivity recovering and in order to pursue agile management, develops increasingly digitalized relationships between the elements based on numerical and computational structures that are new to workers in the construction sector.
It involves understanding in real time, and in specific contexts, how the components can quickly be configured, related and assembled, allowing the product to evolve, adapt and ensure performance coherent with the needs that motivated its realization.

With a view to value generation, digitization, based on Data-driven Process, uses the Information Model to systemize the whole supply chain, increasing the degree of co-liability between the various operators and overcoming the intense fragmentation that today, both horizontally and vertically, characterizes, and penalizes, the productive sector.
These processes require the sharing of large amounts of data. The sharing ability is the main competitive factor of the new industrial paradigm with the aim of making forecast elaborations and guiding the operators actions that the sensors translate into digital terms.
In this logic the physical entities built must be virtually anticipated by a corresponding digital "twin", generated by the information modeling coordinated and managed by the company, which, inspired by the outcomes resulting from the negotiations established with its suppliers and subcontractors, represents them with all their characteristic properties in alpha-numerical terms and in an analytically coherent way with the breakdown structures from the geometric-dimensional point of view.
The optimized options capable of probabilistically predicting the manifestation of non-compliance and detecting critical aspects in terms of safety are generated by algorithms which, cooperating with the devices that govern automata, equipment and preparations and with immersive multi-sensory technologies able to associate performance simulations with operation simulations, allow a significant reduction of waste that generally connote the current production processes.
On the basis of a scenario requiring a radical review of the traditional modalities for yard management, the research, assuming the Predictive Analytics algorithms, the semi automation devices for decision making and the Data Modeling Systems that oversee the Information Modeling, as primary factors of digitization, aims to renewing traditional paradigm. Testing of digitalized management models which cooperate with machines, operators and their personal protection devices and yard supervisor, make it possible to monitor and memorize works in progress and transfer to the system responsible for product management reliable information on the conclusive information model (as built). This with the aim of rationalizing the activities, protecting the safety of the workers, encouraging the sharing of information and the reduction of waste and, more generally, achieving the qualification of the entire production process.[1]

METHODOLOGICAL APPROACH

The methodology uses data-driven technologies that acquire data at the very moment they are generated and, processing them in a predictive and prescriptive way, due to the learning algorithms and the large data availability that characterize the Machine Learning procedures, update their value in real time, supporting decision-making processes with projections and hypotheses that tend to be increasingly precise and truthful. [2]
The use of these information systems assists the development of the intelligent yard management model, supported by ICT technologies, which connects operators, machines and devices in the network.
In order to activities rationalization and information qualification significant advantageousness are found in the processes revision and more current organizational models testing. For this reason, the management model development cannot ignore the analysis of the base scenario and a careful survey on the Industry 4.0 technologies and not take into account the main yard typologies, their operational sequences and correlated flows to be summarized in coherent schemes within a general layout of management structure that highlights constants and improvement factors.

For each yard typology, the connoting characteristics, its corresponding procedures and minimum equipment are identified, which are the basis on implementing data management applications and developing the low environmental impact yard organizational structure and its management models, experimenting new power supply mechanisms; lighting solutions, polluting dust soppressors, low-invasive sensors, smart workstations; monitoring activities and interactive safety aid devices.[3]
The outcome translates into the IT platform project supporting the yard operations that acquires, examines and computationally relates machinery and devices functional data representing the digital information management system for decision-making.
The process of developing platform is built on the basis of informatic models selection and analysis, consistent protocols and their validation through demonstration tests, in laboratory and on site. The console comprise of physical entity with accommodation and recharging functions and IT unit that connects reports and documents to the network and manages information and decision-making flows, inducing direct effects on quality management. It constitutes the centralized point of integration between systems capable of displaying information models data on an interactive dashboard, in real time.
Communication with devices and workstations is entrusted to sensor systems applying to personnel equipment, machinery, site preparations and worksite spaces, able to operate devices, block means and alert operators,
Testing involves demonstrators for acquiring and transmitting, on the basis of sensors, machines functional data to the platform that interprets and notifies them to the specific recipients, on tablets and augmented reality wearable devices in real time, as useful operational guidelines, speeding up decision-making interactions.
All sensors require an advanced IoT conception capable of combining receptors and actuators, data flows arising from sensors and data flows deriving from information models and monitoring and control system.
In the yard where events tend to systematically disprove timing, the need arising is to correctly set work breakdown within the information model. The MoSCoW prioritization technique selecting what is indispensable, desirable, optional and negligible, allows to hierarchize the activities to be carried out and increase the chance of compliance with the deadlines governing the obligations, avoiding the application of sanctions and rationalizing the production process. [4]
With reference to the document management system, whether they are static to be displayed exclusively or dynamic to be accompanied by annotations and images, exploring the integration possibilities with external systems commonly used in the field of construction, is provided a selective access device, easy to use, that shares documents with interested operators in real time.
The verification of the integration opportunities between the data acquisition and document management systems and the advanced electronic modeling tools collaborates for identifying a specific information transferring interface to the building management system, in the optic of resources rationalization, waste reduction and maintenance operations supporting.
In order to the production process efficiency, it is essential exploiting the technologies and qualify the operators working conditions. In this sense, the rational use of traditional and advanced equipment and the experimentation of power supply, lighting and dust suppression systems, work stations and their vocations in terms of adaptation and repeatability, allow to highlight the most significant aspects in terms of integration and provide the detailed solutions to be tested.

The research makes use of the multidisciplinary contributions made available by the participating partners that, on the basis of consolidated organizations and quality systems, collaborate in synergy with specific skills, in the definition, validation and testing of the results.[5]
One component operates on the energy supply chain selecting generation, conversion and conservation configurations, focusing specifically on low environmental impact hybrid generation systems in order to identify optimized devices for lighting, safety protection and dust suppression. On the basis of its elaborations, a further partner studies the power supply systems and collaborates in defining the users access procedures to the platform information, verifying, at the same time, the devices' ability to communicate with each other, with management system and workstations. Others deal with the information systems prototyping and IT platform design. Some confirm the solutions developed on the wooden artifact construction, on which the installation of the system responsible for document management and batteries recharging devices for tool and transmitter is planned.
The academic components contribute to the management model definition and integration, in particular as regards the yard innovative power supply systems and the tools recharging devices. They also coordinate the planning of high energy efficiency yard temporary works.
The hardware and software solutions developed are direct on-site verified and at a pilot site, in order to confirm their real added value, also on the basis of the users involved feedback.

SUMMARY RESULTS

With reference to the specific objectives, the research aims to achieve the following results.
Regarding the low environmental impact yard management logistic structure prefiguration, the main outputs concern the new management model requirements definition, the devices on-board communication systems and workstations development and the operational and decommissioning procedures determination.
In relation with the ICT platform, the outcome is connected with the system hardware / software architecture project, its characteristics and operating scenarios, machinery and IoT devices identification and console / BIM interface specifications.
The technological demonstrators aim to elaborate and validate power supply, lighting and dust suppression systems, smart workstations, IT platform, management model and its documentation about the functions.
All of the above is oriented to outline new systemic solutions that achieve more or less formalized relational complexes collaborating in order to determine the following effects:
- yard management costs contraction, between 10 and 25%;
- productivity increase during the structures assembly, between 5 and 15%;
- defects reduction due to misinterpretations, malfunctions in the decisions and actions coordination and in the informative flows management, work in progress variations, between 15 and 30%;
- decrease of noncompliance in management system use, economic risks induced by project documents deficiencies, between 20 and 40%.

More precisely, the research aims to achieve the planning and realization of:
- more performative power supply systems in terms of consumption and polluting emissions;

- power banks recharging devices for portable tools supply;
- hybrid power lighting systems;
- remote activity monitoring Tower, as CDE, able to read the events through the data that represent them;
- smart dust suppression for on earth moving equipment and on debris disposal equipment;
- IC platform that, in presence and remotely, submits everything that happens to measures and assessments in terms of Business Intelligence supporting dematerialization and digitalization processes, able to manage information more rationally and efficiently;
- devices and smart workstations equipped with low-invasive sensors and wireless communication protocols, able to communicate with each other and with the outside.

A further contribution can be found in the opportunity to re-use some devices, artifacts and machinery during decommissioning.

Compared to these intentions, the different competences involved, thinking in supply chain and value chain terms, have collaborated through systemic attitudes achieving the following effects.

On the basis of the exploration of the yard supply methods and its dimensional and localization classification, hybrid systems with battery storage devices aimed to increase the expected performance have been developed, measured and then validated.

A survey on electrical safety has result in the personal protective smart equipment solutions prefiguration.

Regarding the decommissioning phase, solutions increasing efficiency and containing environmental impact have been designed.

All the preparatory activities for the design, preliminary verification and prototype realization to be tested on site were carried out.

Issues related to instrumentation, predictive maintenance models, impact measurement parameters, safety and monitoring mechanisms were investigated.

Based on a survey of yard machinery and their power a typical load diagram was drawn up. The energy model was validated by means of experimental measures carried out at a work in progress site. Different hybrid supply typologies have been examined and a calculation tool has been developed for the system elements identification and sizing.

For the each yard typology, a documents integrated management model with selective access compatible with BIM technologies has been structured. The collecting, analyzing and streaming processing information system has been defined, the field data acquisition devices have been selected and the process of transferring the model into the software has been started. The project of the wood and steel light prefabricated system to be tested was developed.

The sensors list was performed, the use vocation was verified and the projects of hybrid machines decreasing consumption and pollutant emissions, noise pollution reduction mechanisms, dust suppression systems, full battery hybrid lighting towers, video surveillance devices and remote telemetry and machine monitoring technologies were elaborated.

Preliminary checks concerning the hybrid production system components functioning were also carried out.

The Technological demonstrators, produced and to be built, will be preliminarily verified at the manufacturing sites, then validated in a pilot yard.

The report of the results achieved experimentation will return the actual effects of the new digitized management system for work monitoring and checking and its degree of

consistency with the expected results.

DISCUSSION

The research, through the resources rationalization, waste reduction and the more efficient and innovative devices use aims to mitigate the dysfunctions that the customary yard management procedures generate.
The yard is a process of materials transformation that converts resources into constructive elements competing for the buildings and infrastructures construction, where the latest innovations experiment and share tools and executive methods handed down over the centuries, in a surprising technological promiscuity not found in others productive sectors.
The study identifies and develops demonstrators of a renewed yard management system which by conceiving in dynamic way production through people, products, machinery, information and decisions flows, material and immaterial, uses devices and smart workstations able to dialogue, regulate themselves when using, communicate their status, report consumption and to program and record the building conservation activities for the exercise phase.
In cognitive yard interpretation the data and information sharing becomes a necessary condition for making the production process more efficient.
A model capable of monitoring and storing the building state, during commissioning also allows the "as built" data transfer of the to the IT system that will manage the life cycle.[6]
The research project clearly defines the objectives to be achieved, also specifying in detail the actions to be implemented, the development technologies and the outcome control processes.
The management of the medium/small-sized yard with a view to optimizing processes, the central objective of the work, is pursued through the information systems testing that represents the technological assumption of the data-driven approach underlying its management.
In this sense, in the updating process of the management structures and conventional organizational models, the effects of technological innovation in the mechanization, energy carriers, automation, information processes (ICT) and use of distributed "intelligence" (IoT) sectors assume particular relevance.
These innovations, progressively implemented over the years, allow to achieve process efficiency, rationalization of the phases and economy of the activities and, more generally, the qualification of the products as well as the operators well-being and safety.
The new opportunities, both instrumental and conceptual, imply a significant renewal of the production processes that determines the working phases operational predetermination, the activities control, the rights and security protection and helps to mitigate the inevitability of the uncertainty scenarios characteristic of the sector.
Projects of products in the framework of low environmental impact hybrid generators and prefabricated construction in wood and mixed wood/steel sectors, definition of document management system IT architecture (pre requirement for the development of operable software) and procedures identification for instruments calibration, remote measuring, electric energy consumption metering, distribution network architecture classification and survey of sensors to be tested on the prefabricated wooden prototype, are consistent in achieve of the expected

CONCLUSION

The research development produces important innovations both in terms of products and in relation to processes. The results usability is immediate and determines positive repercussions for all the partnership companies in the short term.
The advantages can be found in multiple aspects: economic-financial, productive, organizational and social. The yard management companies also benefit from important effects in terms of operability and savings.
Another important fallout concerns the organizations involvement that produce particularly advanced open source software packages which operate in the fields of machine learning, data analysis and artificial visualization. In fact this assure sustainable costs of their experimentation and adoption in the yards.
The main results achieved relate to defining the characteristics of the new management model in the Industry 4.0 logic for each yard typology. In particular were developed: the document collection and management system, the attributes of the on-board systems and their communication, the hybrid power supply devices, the on board monitoring and communication mechanisms, the operational management procedures for limiting consumption and material resources, the actions for recover spaces, infrastructures and volumes built during the management phase, demonstration scenarios, system specifications, IoT devices, machinery, hardware / software system architecture, console design and its interface specifications with BIM systems and power system design.
The IT platform, through the processes that put to system the supply chain, homogenizes the data and information regarding the construction elements starting from their characteristic properties up to including the installation and life cycle functioning methods.
Console and individual specialized devices, which can be consulted via mobile and wearable devices, as tablets and smart phones, connected in real time to the yard, during the in acceptance and relating to implementation checks will allow, not only to digitally display the object production with its geometric-dimensional and alpha-numeric dimensions, but also to report any non-compliance by quickly correcting quality registration.

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