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BUSINESS PROCESS ANALYSIS AND SIMULATION: AN INDUSTRIAL APPLICATION

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Abstract. Analysis and automation of business processes are a relevant topic in Industry 4.0. This document describes a framework called BP-M* for the analysis, restructuring and implementation of business processes, starting with the creation of a process model and ending with the implementation of the process itself on a workflow management system. The BP-M* framework has been applied to a real case study, the production of fabrics for the collection that will be distributed worldwide by an Italian woolen mill. This process was analyzed and automated, providing the company with useful information to simplify processes and support human operators.

Keywords: Business process management, process analysis, process modeling and restructuring, process automation

1 INTRODUCTION

The industrial field is an area where the application of analysis, simulation and automation of business processes [1] is an essential toolbox for validating methods and architectures before applying them on the factory floor [2]. Typical business process analysis focuses on execution times, resource planning, risks management and compliance systems. Industry 4.0 focuses on interconnectivity, automation, machine learning and real-time data in order to manage processes more effectively and make the necessary decisions faster. Process automation is based on streamlining the team's workload, as it facilitates the integration of people and processes through automated workflows that can be programmed to perform actions that were once managed manually by humans [3]. Moreover, it focuses on documenting and managing the team's processes to make sure everyone knows what is going on and how to perform their tasks [4]. Workflow management systems have been proposed for the manufacturing industry internet of things [5], also in combination with blockchain [6], dynamic multilevel workflow concepts [7].

In this paper a framework for automation of business processes in small and medium-sized enterprises will be introduced. The framework, called BP-M*, provides three different stages:

1. the process under analysis is modeled and this model (called As-Is model) is validated,
2. the As-Is model is restructured in order to increase efficiency and effectiveness of the process and
3. the resulting To-Be model is converted into an executable specification which is then deployed and executed via a workflow engine.

In particular, this paper describes business process modeling with the Business Process Model and Notation (BPMN) standard language. The choice of BPMN relies on its flexibility that makes it preferable if compared to other similar languages. It offers two levels of representation: the graphical notation, that makes it simple to understand, and modeling constructs to represent the message-based interactions and the event-based decisions, and then relevant features such as dynamics. Additionally, such a modeling allows early detection and resolution of critical issues.

The framework has been worked out in the project "Textile Digital Process Platform" (TexDigit) funded by Regione Piemonte (Italy) that aims to develop and validate an innovative software platform for the management of digital business processes, with the primary objective of managing the processes for small and medium-sized enterprises, in particular for the textile industry. The innovative aspect is to digitize fully the execution of the process, in which the actors involved will be able to carry out their respective activities, having constantly updated information and data, specific to the context in which they operate, without having to carry out research or requests. The framework will allow interconnections with IT environments, for the exchange of data with applications, systems, machines etc., in use in the company, through connectors that will be made available in the project itself. Therefore, the framework developed in this work may provide a company with a robust solution for their business processes, with a reduction in cost and implementation time. The proposed framework is based on the experience gained on the industry field with the KeystoneGRC workflow engine developed at the Mindset S.r.l. company, which participate in the project together with the textile company Lanificio Zignone S.p.a. and the public consultancy company C.R.A.B. S.r.l. The practical application concerns the world-class wool industry located in Biella.

This paper is structured as follows. Section 2 presents some related work, while Section 3 introduces the methodological framework, which is used in Section 4 to develop and discuss the case study. The paper ends with Section 5 and conclusions as well as some ideas for future work.

2 RELATED WORK

The adoption of computer-based simulations to business process analysis and modeling was first applied in industrial re-engineering [20, 21]. Various research areas have already used analysis and simulation techniques, i.e., Computational Social Science [22], public policies [23], risk management [24], sustainable supply chain management [25], business ventures [26], as well as diffusion processes [27]. Several techniques have been developed for analysis and modeling of organization's processes. Among them, statistical approaches, i.e. queuing modeling, Agent-Based modeling, system dynamics, computer-based Decision Support Systems. Scenario analysis (or "What-If" analysis) have been applied to explore different options for restructuring an existing process before any change is effectively made. However, computer-based Discrete Event Simulation (DES) is one of the most used analysis approach.

When a process has been analyzed and possibly re-structured it can be transmitted to a BPMS (Business Process Management System) to be automated. In recent years, Robotic Process Automation (RPA) has emerged as a novel solution for business process automation. Process automation is based on streamlining the team's workload, as it facilitates the integration of people and processes through automated workflows that can be programmed to perform actions which were once managed manually by humans. Moreover, process analysis and data mining algorithms focus on documenting and managing team's processes based on real event log. The process mining techniques improve knowledge of what is going on and how to perform business tasks [28].

2.1 Existing Approaches to Process Improvement

The traditional approach to process improvement historically encompasses several techniques, but there are essentially two that have emerged, the Lean technique and the Six Sigma technique.

Lean. The Lean approach to process improvement involves a set of principles, practices, and methods for designing, improving, and managing processes, with the goal of improving efficiency by eliminating waste that absorbs time and resources but does not add a value for the customer.

Six Sigma. The Six Sigma approach, like Lean, is a business management strategy used to improve the quality and efficiency of operational processes. While Lean focuses on identifying ways to optimize processes and reduce waste, Six Sigma primarily aims to make processes more uniform and accurate through the application of statistical methods that can reduce defects at a rate of 3.4 defects per million opportunities.

Various combinations of Lean and Six Sigma techniques have been developed (often described as Lean Six Sigma approaches). Proponents of the combined approach assert that organizations can benefit from both the waste elimination techniques inherent in Lean and the statistical tools and systematic defect reduction strategies found in Six Sigma.

Business Process Management. The BPM approach is the result of the evolution, in these years, of three research strands related to the disciplines of:

1. business management,
2. quality control (to which the Lean and Six Sigma approaches date back), and
3. ICT technologies that have allowed the realization of advanced tools such as process modelers, simulators, statistical analyzers and so on.

The BPM approach has therefore absorbed techniques and tools from these disciplines, building a global vision of the company in which the search for critical business process problems is more significant. The fundamental concepts of the BPM approach form the basis of this project.

2.2 The Business Process Life-Cycle

BPM studies focused on the business process life-cycle which usually consist of 6 phases:

Process identification: In this phase, processes that are relevant to the business problem under analysis are identified and related to each other. The outcome is a process architecture that provides an overall view of the organization. Process discovery: each process identified in the previous phase is modeled using a suitable modeling language (As-Is process model).

Process analysis: In this phase, problems related to the As-Is process are identified and possibly quantified in terms of performance measures. In this way, analysts realize the weaknesses of the process and their impact on performance. Process redesign: the goal of this phase is to obtain a new model (To-Be model) of the process, identifying the changes that allow the organization to achieve its performance objectives.

Process implementation: In this phase, the changes required to move from the As-Is process to the To-Be process are prepared and performed. An executable specification of the To-Be process is produced and this executable model is deployed in a Business Process Management System (BPMS).

Process monitoring and controlling: While the redesigned process is ongoing, relevant data are collected and analyzed to determine the efficiency of the process. Bottlenecks, recurrent errors or new problems may then arise, requiring the cycle to be repeated on a continuous basis.

3 THE BP-M* METHODOLOGY

The BP-M* framework includes:

1. the BP-M* methodology for the analysis, the engineering and the automation of business processes;
2. the BP-M* multi-level model,
3. the BP-M* toolbox that support the methodology, the analysis of simulation results and the implementation of the processes under analysis.

The BP-M* methodology consists of 4 phases:

1. Context Analysis,
2. Process Analysis,
3. Process Restructuring and
4. Workflow Implementation,

that can be described as follows:

Context Analysis: It is an initial phase that focuses on organizational analysis. Its purpose is to set the overall strategic scenario relevant to the company and to determine the functional components related to the processes under analysis.

Process Analysis: The initial purpose of this phase is the determination of the activities performed in the company functions involved in the process and the causal relationships existing between them. The process is then reconstructed starting from facts external to the system (events and objects in input/output to the process). In this way, the process diagram (sometimes referred to as process map or flowchart) is derived, which will be specified using the Business Process Model and Notation (BPMN) language [8].

The process diagram must therefore be integrated with all the information necessary to simulate the process in real operating conditions [12]. In particular, they concern:

1. the resources that carry out the activities of the process,
2. the characteristics (capabilities, allocation policies, costs, etc.) of the resources themselves,
3. the execution times of the activities,
4. the policy of queue management,
5. the actual workload to which the system is subjected.

Real data can be used to automatically discover the process [9]. In this way, a virtual model of reality, called the As-Is model, is built as close as possible to reality itself.

Process Restructuring: The objective of this phase is the introduction of corrective actions to restructure the As-Is model in order to increase the efficiency and effectiveness of the process. The corrective actions enable the construction of different evolutionary scenarios (and the respective models). The simulation of the different scenarios (What-If analysis) allows comparing the scenarios, among themselves and with respect to the starting As-Is model. This makes it possible to inspect several different To-Be models, in addition to decreasing the risk [10], predicting the process [11], or to explore emergency scenarios [12].

Workflow Implementation: When a To-Be model has been selected, it has to be transmitted to engineers for implementation. In the BP-M* methodology, two implementation aspects are considered:

1. the specification of the Data Environment, and
2. the specification of the Workflow Environment.

The first three phases are described in detail elsewhere together with real case studies, the admission process organization [13], or social network analysis [14]. In this paper, the Phase 4 (Workflow Implementation) will be illustrated with the help of a real case study developed in a textile industry.

4 THE CASE STUDY

Based in the heart of a center of excellence for wool production (Biella, in the Piedmont region of Italy), for over fifty years Zignone has been producing fabrics of contemporary elegance for the biggest names in the international clothing sector. The mill controls the whole production cycle, from the selection of the raw material and the spinning to the finishing, thus transforming a noble fibre into collections that interpret the evolution of lifestyles. For each season, Zignone presents a collection of fabrics for clothes or jacket and pants, to be distributed all over the world. Creating a collection is a complex process that includes many activities. This paper describes the first step of the process (called the Production process), which describes the production of fabrics for the samples to be included in the collection: the launch phase of the production, the realization of a new fabric and its qualitative analysis.

4.1 Process Control Flow Modeling

According to phase 2) of the BP-M* methodology, resources, activities, events and decision points of the production process were analyzed, as well as the causal relationships existing between them. The result of the analysis is a BPMN diagram that expresses the process control flow and, to allow simulation, each element of the diagram must be integrated with a descriptor that specifies its dynamic behavior with respect to a given workload.

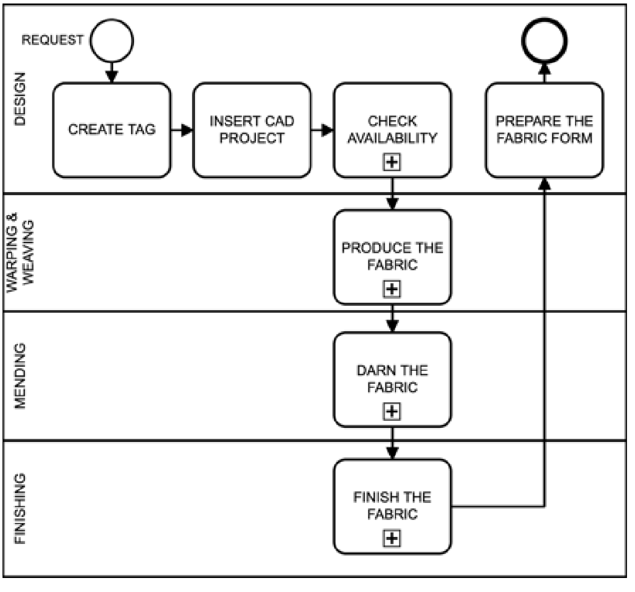


Figure 1. BPMN diagram for the production process

Figure 1 illustrates the Production process diagram in BPMN. The diagram includes four lanes that correspond to the Zignone departments interested in the process and five sub-processes. Activities and sub-processes can be described as follows. The first three steps of the process concern the launch of the new fabric. In the first activity (Create Tag) the designer prepares the tag for the production of the fabric and inserts the initial data. The fabric tag is shown in Figure 2.

In the next activity (Insert CAD project) the designer inserts the technical specifications for the processing of warping and weaving. Once the bill of materials and all the characteristics of the new fabric have been defined, a check on the availability of the yarns (sub-process Check availability) is made before bringing the provisions to the production departments. After this check, work orders are delivered to these departments. The fabric to be processed must undergo several steps. The first concerns warping and weaving (sub-process Produce the fabric), all the necessary information has already been entered in CAD and transmitted to the department. The department manager (the weaver) must follow the progress of the new fabric and report any anomalies or non-conformities, if necessary.

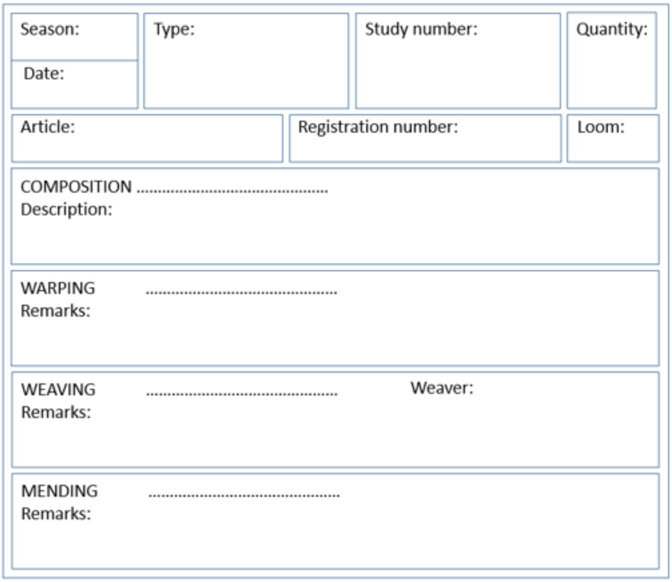
In the subsequent phase of mending (sub-process Darn the fabric) the raw fabric data (meters, weight, height, etc.) are recorded and the department manager (the mender) consults the designer to report any problems. In the next finishing phase (sub-process Finish the fabric) the fabric is washed, dried and fixed according to the designer's orders. The department manager (the finisher) follows the fabric step by step and then releases a final report on it. Once the fabric is finished, the final data is collected and the designer proceeds to complete the fabric quality form (sub-process Prepare the fabric form), filling in all the data necessary for an economic evaluation.

Regarding the sub-processes, Figure 3 shows the Check availability sub-process that can be described in this way:

- Before launching the production of the fabric, the designer checks the presence in the production department (Warping and Weaving) of the necessary yarn (activity Control yarn availability). If the yarn is available, the sub-process ends.
- If the yarn is coming from a company warehouse, the designer closes the activity Wait for yarn to arrive when the required yarn arrives.
- If the yarn is not available, the designer orders the yarn outside or requests its production (activity Order/produce yarn); the activity is closed when the yarn has arrived.

4.2 The Execution Framework

According to phase 4 (Workflow implementation) of the BP-M* methodology, the BPMN process diagram has to be translated into the execution framework. This



Season: Date:	Type:	Study number:	Quantity:
Article:	Registration number:		Loom:
COMPOSITION .... Description:			
WARPING .... Remarks:			
WEAVING .... Weaver: Remarks:			
MENDING .... Remarks:			

Figure 2. The fabric tag

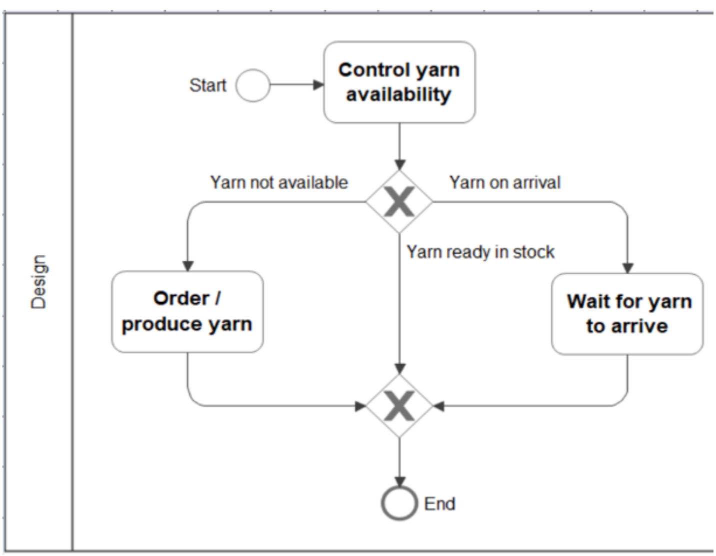


Figure 3. Diagram for the Check availability sub-process

framework is based on the KeystoneGRC tool [15], that is a complete BPM suite that allows the conversion of the To-Be model into an executable specification that is then deployed and executed.

The tool includes two components, a "drag and drop" user interface, that provides the graphical interface to specify the process behaviour, and a workflow engine, that provides the runtime environment for the workflow execution, together with all the supporting services [15]. Furthermore, the engine is extensible with plugins, allowing almost any functionality to be included in the workflow. Table 1 shows the main elements of the user language.

Figure 4 illustrates the translation of the diagram represented in Figure 1, while Figure 5 shows the translation of the sub-process described in Figure 3.

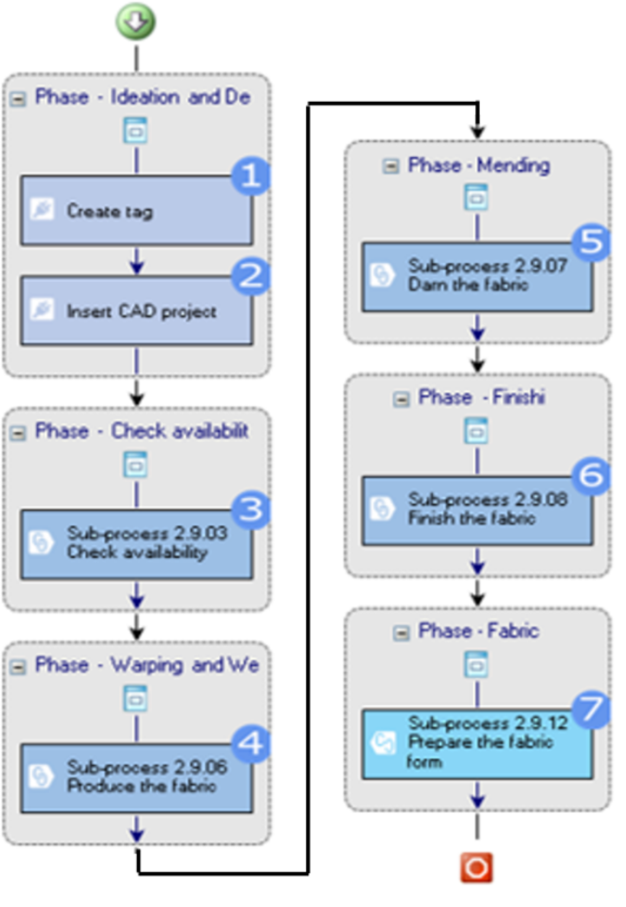


Figure 4. KeystoneBPM diagram for the Production process

Element	**Description**
	Basic activity: a basic activity requires three steps for a user who will perform it: 1. taking in charge (using a 'Start' button from the To-do list) 2. report to the system on completion of the activity (through a 'Close' button) 3. final accounting of the activity (time spent, measures, closing report)
	Select activity: proposes to the user to choose between two or more options. The outcome of the choice will be processed in the next activity.
	End activity: closes the execution of the process instance, terminating all the activities of an instance of the running workflow.
	Parallel flow: defines paths that can be run in parallel; the process runs all the paths, and moves on to the next activity only when all the paths have been completed.
	Alternative flow: defines alternative execution paths; each path is characterized by a condition that specifies whether to follow this branch. Usually the conditions are based on the choice made by the user in the immediately preceding "Select Activity".
	Cycle: requires the workflow engine to repeat an activity cyclically as long as a condition is met.
	Sequence: groups together multiple activities, which are executed in sequence: one passes to the next only after the completion of the previous one, and so on until the completion of the whole sequence.
	Synchronous sub-process: allows to recall another sub-process and execute it in a synchronized way with respect to the calling process (i.e. it passes to the next activity only at the conclusion of the sub-process).
	Asynchronous sub-process: allows to recall another sub-process and execute it independently from the calling process (i.e. the subsequent activities will be performed regardless of the conclusion of the sub-process).

Table 1. Graphical elements of the implementation model

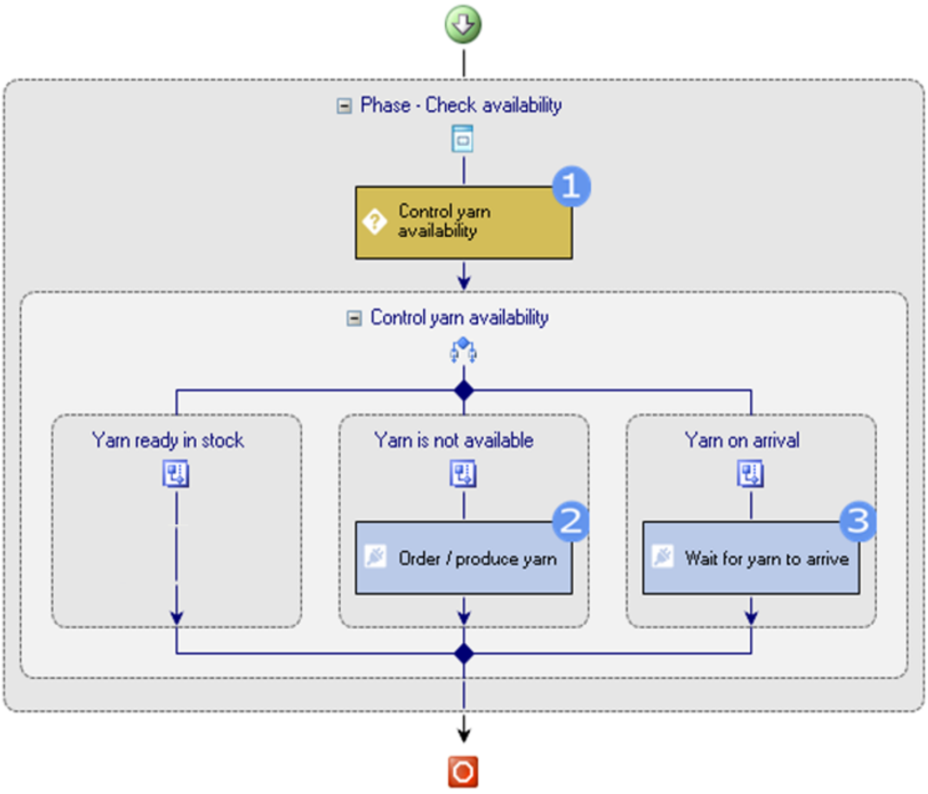


Figure 5. KeystoneBPM diagram for the Check availability sub-process

Let us consider now the translation of the activities, taking the Create tag activity as an example. At the conceptual level, the activity is integrated with a descriptor, shown in Figure 6, which specifies the necessary resources and the duration of the activity.

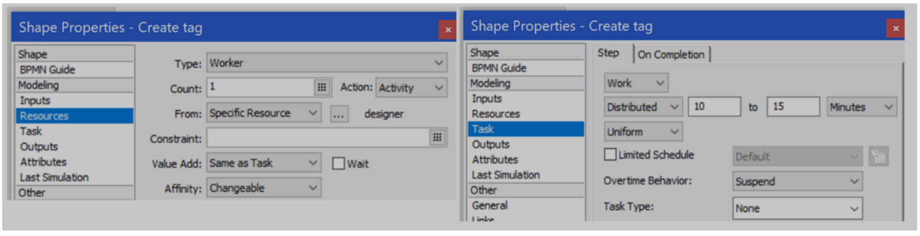


Figure 6. The descriptor of the Create tag activity

The data that the activity needs to be performed are summarized in the fabric tag shown in Figure 3 and the activity data schema is illustrated in the UML class diagram of Figure 7.

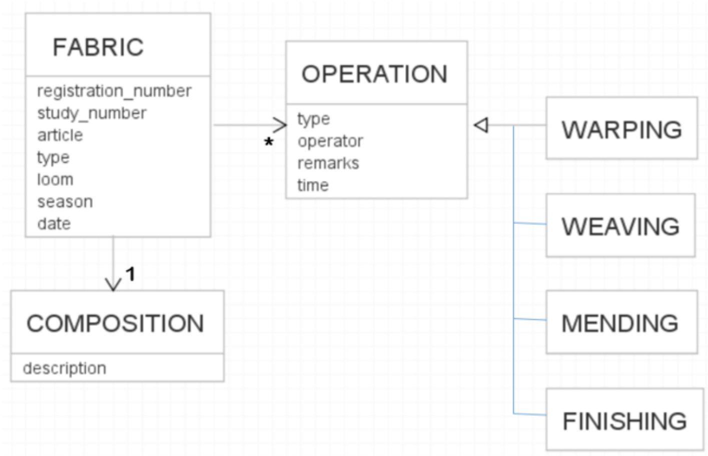


Figure 7. The data schema of the create tag activity

At the execution time, the operator (the designer) will find the Create tag activity in his To-do list (Figure 8).

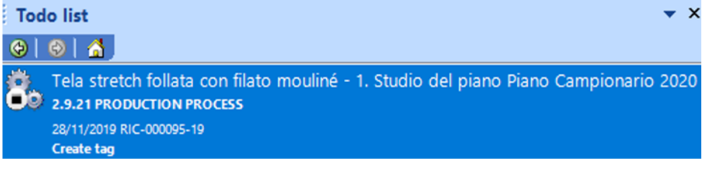


Figure 8. The To-do list of the designer

When the designer selects the activity, the digital tag containing the input data is displayed on his workstation. Input data is loaded via a plugin that reads the information in the company system. Then the designer is guided interactively to insert the data in output and close the activity, and the next activity will be put on the To-do list of the operator who must perform it. The Production process is just one of the processes that have been implemented in the Zignone wool mill. In particular, the entire production of the sample of fabrics that Zignone distributes to its customers has been automated.

4.3 The Framework Usability

In agreement with the company management, a customer satisfaction survey was conducted at the end of a period of training and initial use of the system, in order to evaluate the usability of the framework by actual users and decision-makers [16]. The survey involved all the 24 operators actually engaged in the process activities. Usability was assessed on the basis of the following factors, that have been assessed in advance with the help of management and users:

1. It is easy to learn.
2. It is useful for monitoring the various processes.
3. Its use is intuitive and/or easy to remember.
4. It allows few errors during its use and, in any case, of low gravity.
5. It is an agreeable tool, pleasant to use.

Each parameter was assigned a score by each actor involved in the different processes used in the survey. The scoring scale for the evaluation was as follows: 0 = negative, 1 = insufficient, 2 = sufficient, 3 = positive. The judgments that emerged are overall positive. Specifically, Table 2 shows the parameters, the results of the survey and some considerations suggested by the analysis of the results themselves.

It would also be necessary to determine customers' expectations (or the importance) they attach to the different parameters, otherwise resources could be spent raising satisfaction levels of things that do not matter. The measurement of expectations is more difficult than the measurement of satisfaction and the related investigations could not be conducted. In any case, the results obtained were considered very satisfactory by the company that decided to continue the process analysis and automation project, including administrative processes.

5 CONCLUSIONS

Nowadays, the analysis and automation of industrial processes are receiving increasing attention. However, most research and solutions for process automation are focused on large and complex organizations. In this paper, the usefulness of applying a modeling, simulation and automation framework in small and medium-sized enterprises has been demonstrated. The BP-M* framework presented here includes a methodology to model, analyze and automate business processes, an extended process model that allows the simulation of the processes under analysis, and a set of tools to implement the obtained solutions. It has been evaluated in different case studies and by users, decision-makers, and subject matter experts who positively validated its applicability, usability, and perceived usefulness. In particular, an important process of the textile industry was discussed in this paper, the creation of a collection of fabric's sample to be distributed to customers. The process was analyzed and automated and the result was evaluated favorably by the operators and the management of the company.

	Parameter	Result	Considerations
1.	It is easy to learn.	19/24 (79 %) positive	The judgment that emerged is positive. The least rewarding scores are to be attributed mainly to the subjects who must start the process, as in this phase it is necessary to learn several different steps. In fact, there are no messages from the system that guide the manager in carrying out the activities.
2.	It is useful for monitoring the various processes.	16/24 (69 %) positive	The judgment that emerged is overall positive. The highest scores were assigned by the designers as they can view in real time the updated situation of the sample.
3.	Its use is intuitive and/or easy to remember.	14/24 (58 %) positive	The judgment that emerged is not very good. The less gratifying judgments are due to the fact that being the sampling processes used in a non-daily way, there is a risk of forgetting the steps. It was therefore requested to implement instructions for the various activities during process execution.
4.	It allows few errors during its use and, in any case, of low gravity.	20/24 (83 %) positive	The judgment that emerged is very positive. The plug-ins inserted into the processes regulate the activities that must be carried out. Managers do not need to remember where to go to open the next module within the platform. The only critical points are due to the “slowness” of the system in some passages.
5.	It is an agre-eable tool, pleasant to use.	13/24 (54 %) positive	The judgment that emerged is not very good. The platform is regarded as pleasant to use, but some steps are considered as an overload of actions that are added to the others already present in the activity that is being performed. We will then proceed to make some changes to the process execution module to try to streamline some steps.

Table 2. The customer satisfaction survey

The research project aimed to investigate the possibility of developing methodologies and tools to create a support system for the company in view of continuous improvement. The aim of continuous improvement is to continuously increase the efficiency and effectiveness of the company’s processes, in order to better satisfy the requirements derived from the management strategy. The means by which to achieve this objective is a set of methods and techniques to be used for the analysis of problems presented by the process, the identification of their causes and their resolution. Continuous improvement is therefore a process that the company should keep constantly active, at least as far as its critical processes are concerned, such as those that are on its value chain and therefore directly linked to the customer. This paper illustrated a hypothesis of the architecture of the Support System (SdS) that we intend to develop in future work, discussing both the methodological aspects and those related to the use of commercially available tools to be used as components of the system.

In order to obtain statistically more significant measurements of usability, a larger population of projects and users would be useful. The current project therefore intends to continue with further testing of the framework in multiple processes in the same organization, as well as in other different organizations. Future activities aim to investigate agent-based approaches [17] or to create a better integration between the available tools [18]. In particular, a system is being developed to support the automatic conversion of the BPMN process diagram into the implementation language.

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