Modelling of the Cuttlery Process for CPPS Experimentation

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***Abstract*—SMEs are the most active and common company profile in the northern part of Portugal. Their willingness to the integration of CPS modules in their manufacturing processes and adhesion to CPPS systems is firmly based on their perception that value-added services will result from that technological evolution and in the future better tools are expected to guarantee process control, surveillance and maintenance. This CPPS solution was developed and implemented in a cutlery producing SME, to investigate the applicability of the BEinCPPS components for improving the performance of industrial processes, with an experimentation of these components in the factory. As a result of this work, this paper presents the technical evaluation and lessons learnt, and the measured business performance indicators.**

Keywords*—*CPPS, BPMN, Industry 4.0, Modelling, KPIs

I. Introduction

The target of the presented study focuses on the production system of a company called CRISTEMA[1] which is a young SME company focused on cutlery manufacturing. The cutlery industry is one of the main industries in the region, being the main metallurgical industry, in Guimarães, along with textile industries that represent 70% of the companies, and footwear production [1]. In the year 2011, the cutlery sector reported almost 40 million euros in sales (Internal, EU and non-EU) [2]. CRISTEMA has more than twenty years of history, but fork production only started in 2001. Since then it has been (along with the complete cutlery set) the main objective of the company and future investments will be for supporting cutlery production in order to improve performance. The make-to-stock strategy was implemented since the beginning for rapidly serving each customer and continues to be one of the main key features of CRISTEMA when compared to the competition. This specific sector had a quite linear technological progress since the mid-80s and 90s, where the production lines were basically based on human work., Since then, the industry has undergone a bold transformation in labor-intensive tasks through automation and robotisation of their production lines. More recently, the in-house machines and tools development has made a great contribution in production scenarios, enabling some flexibility of the production process, a quality increase of final products and diversification of their catalogue. Furthermore, the cutlery industry has been paying attention to recent Industrial 4.0 initiatives, IoT and CPPS developments to keep their competitiveness and update to modern production lines and efficiency of their process, providing production agility, increased production status awareness and delivery time reliability.

Industry 4.0, the fourth Industrial Revolution is a broad concept and a new trend in manufacturing. The term was first introduced in 2011, in Germany, at the Hannover Fair as “Industrie 4.0” [3], [4] and is mainly represented by Cyber-Physical Systems (CPS), the Internet of Things (IoT) and Cloud Computing [4]–[8]. A CPS can be described as “the integration of computation with physical processes where embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa” [9]. The adoption of CPS in the industry is defined with the term Cyber-Physical Production Systems (CPPS) [2] and the goal is to interconnect available digital technologies with physical resources associated with manufacturing processes [7].

This study (analysis of the problem, requirements, solution, deployment) was performed in the frame of the European Project CPMinCPPS[2] (Cutting edge Process Modelling and Simulation). This experiment was selected in the second open call of BEinCPPS (Business Experiments in Cyber-Physical Production Systems) project to carry out innovative Modelling & Simulation (M&S) experiments in CPPS-based manufacturing systems, based on the components/artifacts of the project reference architecture.

The deployed CPMSinCPPS project solution currently being tested at CRISTEMA’s, with focus on the used components of BEinCPPS is presented in section III. The experiment was conducted on a part of CRISTEMA’s production system related to cutlery industry, with particular emphasis on the polishing process since the polishing activity is the bottleneck of the production due to high setup time and low processing capacity (it is a single polishing machine for

[1] https://cristema.com/

[2] The CPMSinCPPS experiment, can be found in the Experimentation menu in http://beincpps.eu/

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different production lines). The technical evaluation, where the technical indicators of the platform and the technical lessons learnt are described in section IV-A. The technical evaluation shows the almost total fulfilment of the user requirements, strong learnability, understandability, user attraction, and efficiency of the BEinCPPS components. The technical lessons learn are related to integration as a major obstacle, modelling as a key learning, reusing past knowledge as a best practice and further development of the BEinCPPS components as next steps. The business evaluation of the platform, where the different business performance indicators of the platform are described, and the results of the business questionnaire are presented in section IV-B. The measured Business Performance Indicators show improvements regarding the defined Business Objectives (BO). The overall lessons learnt and recommendations, as a result of the validation done in CRISTEMA, are also described in section V.

Full integration cannot be achieved without involving the ERP software company and machine suppliers from the very beginning of the project. Process modelling using the GRAI [10] method and BPMN [11] provides a global view of the production system, creating opportunities for the creation of "to be" scenarios.

II. Industrial Relevance and Potential Impact

The production process of cutlery manufacturing is a complex process involving different steps, which is composed of both manual and automated processes. The company's objective is to position itself as an important player in its sector, by creating a solid brand and a reference in the national and international market, whether as a key integrator of the value chain or as a key brand, as it is strategically positioning in the medium/ long term.

TABLE I - Expected Impact.

Business Impact	
Cost	10% savings in production costs through the optimisation of the planning
Delivery Time	Optimisation of the planning of the manufacturing tasks based on optimization in order to meet the delivery time of the customers (customer satisfaction)
Technical Impact	
Equipment Performance	Improvement of the equipment performance through a better combination between the manufacturing activities and the maintenance activities
Productivity	Improve the productivity by the optimisation of the planning thanks to optimization
Quality	The improvement of the quality procedures through the modelling of the processes
Innovation Impact	
	To improve the efficiency of the CPPS in the production lifecycle.
	To convince the companies in the sector of the role of the modelling and simulation to improve the efficiency of the CPPS.

The company believes that the introduction of BEinCPPS will allow:

- To improve the flexibility of the manufacturing system by analyzing several production scenarios;
- The decrease of costs of the manufacturing by optimizing the production plan;
- The improvement of the CPPS capability by analyzing multiple usage scenarios;
- Real-time tracking and optimization of production and maintenance plan.

The expected impact of the project is presented in TABLE I.

A. *Current Practice and Existing Problems*

Most of the scheduling and managing of ongoing operations are currently manually organized close to the work cells using paper-based documentation. The polishing schedule shows orders, products, the planned date with quantities for each day when the polishing is performed. Despite the paper-based polishing schedule, the Production Orders are digitalized in the production software. The orders provide the details of the order itself (e.g. ID, article, product name, etc.) and production activities (e.g. cutting, polishing, stamping etc.) that have to be performed for each order. The barcodes provide a unique identifier for each activity in each production order. The current approach is lacking the flexibility demanded by the increasing pace of the business, mainly because of the fact that the operators have to perform manual monitoring, planning and scheduling activity.

Quality standards are usually materialized in a jig [3] (a model) for every product that passed through cutting, teeth trimming, stamping and polishing activities. When doubts arise, a reference model is used to check for defects. When the packaging activity finishes, an operator counts every defected part and registers the value. These defected parts are in a container that goes through every activity, so each operator can place the defected parts during each activity.

The issues, weaknesses and points to improve in the production systems prior to BEinCPPS components implementation were identified by the analysis of the current practices and through several brainstorming sessions among CPMSinCPPS technical persons and CRISTEMA production stakeholders, mainly production management and maintenance responsible. The identified points to improve can be further detailed in TABLE II**Error! Reference source not found.**.

TABLE II - Points to Improve.

Points to improve in Physical Sub-System	Machine setups are very time consuming and laborious activities and often lead to delays in the production and the production of defected products. CRISTEMA must optimize the machine setup process or at least reduce the number of times it has to be performed in order to be competitive.
Points to improve in Decisional Sub-System	The writing process of the Production Sequence (leading to the Production Order) relies mainly in the experience of the Production Responsible who has the experience about tools, machines, resource capacity and processes required manufacturing different cutlery products. Since no information is "stored" in the company, the execution of the Product Sequence relies mainly on one person.
	Production Plan is the sequence of Production Orders. This document is written by the Production

3 type of custom-made tool used to control the location and/or motion of parts or other tools.

	Responsible based on Order priorities (includes internal orders and priority orders), unscheduled orders, orders that were not performed during the previous weeks, setup times and machine availability. This process is performed without the assistance of an IT tool and is based on manual calculations, the experience of the Production Responsible and the feedback from the operators. This is very prone to errors and lack of optimization due to the daily changes required each week and the number of different possible combinations of sequences and resulting delivery times. Production reschedule decisions usually result in extra time necessities, with all associated costs and/or delays in the delivery. Additionally, uncertainty is created even when small changes are introduced, resulting in high-stress levels in the workshop and further Plan modifications to minimize other order rescheduling impact.
	Maintenance function in CRISTEMA has low integration with Production mainly due to the lack of feedback between machine usage time (present and future), machine availability (due to machine failure) and preventive maintenance requirements.
Points to improve in Information Sub-System	CRISTEMA mainly uses custom-built and "simple" IT solutions. One of the drawbacks is the low integration between software, modules and machines. For example, the production software only has the possibility of creating Production Orders and assigning an operator, but does not have the possibility to predict the delivery time with that specific sequence;
	Additionally, it does not allow simulating different Production Order sequences in order to estimate and improve the delivery time. When rescheduling is required, delivery time improvements and delays cannot be quantified since is based on hand calculations and time consuming;
	Production planning software does not take into account the preventive maintenance schedules so a machine can be assigned to produce during the preventive maintenance scheduled stoppage time.

III. CUTTLERY PROCESS EXPERIMENT

As a result of the project, the developed CPMSinCPPS platform was implemented and validated [12] in the cutlery factory. The platform (Fig. 1) is divided into two different states (Fig. 1), the Design Time where the representation and formalization of the user's knowledge gain shape. Each type of user (of the different roles in the company) has its own understanding of the factory and of the production system. Only when their knowledge is put together, the modelling activity can bring real value and feedback to enable a better strategic planning, allow a better integration during the production execution and control of the overall process. The Runtime is where the execution of the modelled processes occurs, enabling the monitoring and control of the production, in this case focusing on the polishing process.

This solution allows the factory to control and monitor the production of the polishing process based on the existing activities, over a period of one week. The control and monitoring of the polishing process was designed and specified (in the design time) using the Process Modeller Module. The plan is created through the Scheduler tool, which helps the Production Responsible to set the polishing schedule for the next week. For the tool to define the sequences of activities, some rules were defined, prioritizing the urgent activities and considering the different types (or families) of cutlery.

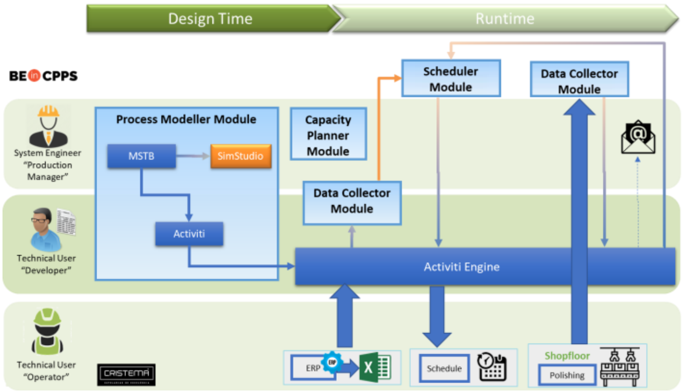

Fig. 1. CPMSinCPPS platform.

The types are related to the shape of the cutlery and, for each different type, it is necessary to make a specific re-configuration of the polishing machine. To optimize the timeline, the scheduling tool groups the maximum number of activities of the same type together, to avoid the machine preparation/re-configuration, which results in time saved. The activity monitor is done by executing the process in the ACTIVITI tool. It monitors the activities in real time, counting the cycles of production and allowing the perception of the number of produced products during that period. To allow the platform to follow the production in real-time, a sensor was deployed in the polishing machine, giving the capability to count its cycles, see Fig. 2.

Fig. 2 IoT at CRISTEMA Polishing Machine.

With this real-time cycle counting capability, the Administrator is able to know when the activities are completed (in real-time), the number of re-polished and wasted products, and production and setup times for the machine. For the Operator, the Production Responsible and the Administrator to know how to use the platform, a 'User Manual' has been prepared. To develop the platform, several components of BEinCPPS were used, which are:

- **SLM Toolbox[4] [13]** – This solution has been used by the company's business users for modelling the production system at the MDSEA BSM level (i.e. physical and decisional subsystems) using the process modeller (Extended Actigram Star - EA* - Language)

[4] http://interop-vlab.eu/service-lifecycle-manufacturing-tool-box-slmtb/

and the decision modeller (GRAI Grid) [14], [15]. It reuses this knowledge to enable the system engineers to continue modelling at the TIM level, namely further specifying the physical subsystem and taking advantage of the BPMN notation (process modeller). This solution belongs to the CPPS Design Engineering Tools of the BEinCPPS platform.

- **ACTIVITI BPM Editor**[5] – It is one of the components of the ACTIVITI solution for the definition of business processes at the MDSEA TSM level. Reusing the results of the SLM Toolbox modelling, technical users can parameterize and configure the business process needed for the use-case (i.e. the polishing process). This solution belongs to the CPPS Design Engineering Tools of the BEinCPPS platform.
- **ACTIVITI BPM Engine** – It is a framework that is responsible for deploying the process definitions (in BPMN), executing and orchestrating them at runtime. The engine runs any BPMN2.0 standard process and supports additional features such as asynchronous workflow execution, event listeners to add custom logic to the business process, etc. To satisfy the use case, the ACTIVITI Engine is configured to communicate with other architectural components using REST APIs.
- **Fiware Context Broker** [6] – This component is composed of the Orion context broker, is responsible for the registration, connection, acquisition, filtering and storage of the data from the shop floor IoT devices. Using publish-subscribe topics it is able to listen and collect data from multiple devices, and, by being connected to the ACTIVITI engine, provides the necessary input for several service tasks defined in the process model (e.g. count products).
- **CPPS Publishing Services (IoT Agent)**[7] **[16]** – This component simplifies the management and integration of the different devices. It collects their data using heterogeneous protocols and translates it into the standard platform language. The CPPS Publishing Services works over FIWARE Context Broker as an integrator and a facilitator between the broker and the device.

IV. CPMSinCPPS Experiment Evaluation

This section is divided into two sections; the first section is the study and technical evaluation of the platform developed in this experience, where the technical indicators used in the evaluation are presented, explaining their results and the lessons learned from the experience. In the second section, a study and evaluation at a business level is carried out, where the Business Requirements (BR) used [17] throughout the experience are evaluated and it is concluded whether or not they were reached along with a description of the result. As this work is an experience of the BEinCPPS project, the used evaluation methods follow the specification defined by the BEinCPPS project [18].

A. Technical Evaluation

In this section, the technical description and evaluation of the experience are performed, and tables with different indicators have been added to facilitate the description.

1) Technical Indicators

The implementation results were evaluated with experimentation providing technical indicators by inquiring the company's internal stakeholders. The business assessment results are presented in TABLE IV .

TABLE IV . Business Assessment.

Experiment Technical Indicators (TI)	**Average grade of the experiment by participants in a 5 (I strongly agree) to 1 (I strongly disagree) scale**
Fulfilment of user requirements: "The solution fulfils the business requirements, that is, at least 75% of planned business requirements have been met at the current date"	A score of 10 out of 12 possible points Score: 83 %
Learnability: "It is easy to start to use the solution and learn functionalities"	The learnability is good, through the use of the user manual (modelling) and the ease of use of the user interface Score: 4
Understandability: "The solution is easy and self-clear to understand and the concepts and terminology are understandable"	The user interface is easy to understand Score: 4
User attraction level: "The solution is attractive to the user. I feel satisfied and comfortable when using it"	Based on the application's interface Score: 4
Efficiency: "The time and resources required to achieve the objectives of the solution are reasonable, the solution is fast enough and does not require too many steps"	Based on testing during week 30 Score: 5

Regarding the fulfilment of 83% of the user requirements, the proposed scoring method is to provide a score of 2 points to a completed A priority Business Requirement, a score of 1 point to a completed B priority Business Requirement and 0 points to the rest.

A score of 10 out of 12 possible points satisfies the fulfilment of 83% of the Business Requirements as presented in TABLE III.

TABLE III. Applied score for the addressed Business Requirements.

Business Requirements (BR)	**BR Fulfilled (Yes/No)**	**Priority**	**Score**	**Possible max. score**
BU_RQ 02: Estimation of Lead Time at operational level	Yes	A	2	2
BU_RQ 05: The proposition of corrective/preventive actions at the operational level	Yes	B	1	1
BU_RQ 07: Simulation of the	No (Simulation	B	0	1

5 https://www.activiti.org/
6 https://fiware-orion.readthedocs.io/en/master/
7 https://fiware-iot-stack.readthedocs.io/en/latest/device_gateway/

production behaviour	tool was not fully achieved.)			
BU_RQ 09: Visualisation of production at the tactical level	No (The Capacity Planner was not developed.)	B	0	1
BU_RQ 10: Visualisation of production at the operational level	Yes	A	2	2
BU_RQ 11: Visualisation of production at the executional level	Yes	B	1	1
BU_RQ 13: Enhance communication from operational to the execution level	Yes	A	2	2
BU_RQ 15: Enhance communication from execution to an operational level	Yes	A	2	2

2) Technical lesson learnt

The section reports the main lessons learnt from the assessment of the experimentation and recommendation for the implementation of the BEinCPPS components. These recommendations were obtained by observations of internal stakeholders and discussions after the experiment had taken place. The technical lessons learnt are compiled in TABLE IV.

TABLE IV - Technical Lesson Learnt.

Experiment qualitative analysis from the technical point of view	
Major obstacles	- To receive the set of Production Orders from the ERP to the CPMSinCPPS prototype; - To group the production orders for the polishing in order to optimise the sequence,
Key learning	- The advantage of the modelling phase which allows to understand the search for solutions at BSM level with a language understandable by the end-users, - The advantage of using the BPMN process to control and monitor the shop-floor using IoT as a support
Best practices	- Some results and methodologies from CPPS and other projects where used; - The implemented solution does not create too much distraction to the operators and to the established procedures.
Next steps	- Extension of data collection; - Use of simulation on development; - Use of capacity planner at the tactical level; - The extension of the solution to the other activities/machines particularly to collect data along the manufacturing line

B. Business evaluation

In this section, the business description and evaluation of the experience is performed, where the Business Requirements that have been identified throughout the experience are evaluated and validated with the presented prototype.

1) Business Performance Indicators (BPIs)

A set of BPIs has been identified for each of the selected BPs. For each indicator, an “As Is” value, measured during the “Scenario Analysis”, has been linked to a “Target” valued to achieve. The latter is then compared with an actual value, measured in the experiment after the solution implementation. The table below reports the assessment of the BOs, according to the identified BPIs.

TABLE V. Business Assessment.

Business Process (BP)	**Business Process Indicator (BPI)**	**BPIs “As is” value**	**BPIs Target ”To be” value**	**BPIs Actual value measured**
Awareness of the Production Planning	BPI = Number of modelled activities	0	4	4
Production Sequence	BPI = Number of activities able to be monitored	0	1	1
Alternative Production Sequence	BPI = Number of simulated delivery times simulated with alternative processes	0	1	0
Production Order	BPI = Number of machines with data being collected	0	1	1
Awareness on Polishing Activity	BPI = percentage of notifications per total of polishing activity finished	0	100%	100%
Preventive Maintenance Alerts	BPI = number of machines with preventive maintenance alerts capability/total amount of machines	0 %	100%	100%
Capacity Planning	BPI = Number of recalculation of production capacity according with the events	0	N/A	N/A
Feedback to Customer	BPI = Time spent generating Product Order sequences	3 hours	10 minutes	25 minutes[8]
Sequence Optimization	BPI = Time spent generating Product Order sequence with unexpected Production Order	N/A[9]	< 10 minutes	5 minutes
Preventive Maintenance Scheduling	BPI = Number of preventive maintenance activities performed during weekdays/number of preventive maintenance activities performed	0	> 5 %	N/A

The results presented in TABLE V can be further described as follows:

- **Awareness of the Production Planning:** it is related to the Process Modeler (SLM Toolbox). The awareness of the Production Responsible regarding production status is enhanced by having an understandable model of each activity (cutting, Teeth trimming, stamping and

[8] Time to schedule Production Orders for two weeks. Only the time to fill the Excel file and generate the schedule was measured;

[9] Currently they cannot predict the Delivery Time when changing the Product Order sequence because it would be too laborious.

polishing). The awareness regarding this BP can be improved by increasing the number of modelled activities;

- **Production Sequence:** by using ACTIVITI Engine and the Data Collector to monitor one of the activities (polishing), the awareness is again enhanced. This can be further improved by replying the Data Collector module in other activities in order to be able to monitor different manufacturing processes;
- **Production Order:** by using the Data Collector in the polishing activity, data is being collected for one machine representing the polishing activity. This can be further improved by using the Data Collector module in other activities in order to be able to collect data from other manufacturing processes;
- **Alternative Production Sequence:** simulation was not fully achieved;
- **Awareness on Polishing Activity:** by using the Data Collector and ACTIVITI Engine in the polishing activity, every time a polishing order is finished, a notification is provided to the Production Responsible. In order to be globally improved, the alerts could be extended to the rest of the manufacturing activities;
- **Preventive Maintenance Alerts:** data collecting from the polishing machine (only one machine was involved in the experiment) provides the ability to send alerts when preventive maintenance target number of cycles is being reached increasing production agility. Improvement could be obtained by collecting data from other machines. Further improvement could be obtained if a connection with Maintenance software was established;
- **Capacity Planning:** was not developed;
- **Feedback to Customer:** related to Data Collector and ACTIVITI Engine in the polishing activity, the Production Responsible spends on average, 3 hours to create the Production Order sequence for polishing activity. With BEinCPPS components, only 25 minutes are necessary, in order to fill the associated spreadsheet and generate the schedule. The delivery time reliability and production agility are increased. Further improvements could be obtained by exporting the Production Order information from the ERP, eliminating data reentry;
- **Sequence Optimization:** related to Data Collector and ACTIVITI Engine in the polishing activity the ability to modify the Production Order sequence when an unexpected Production Order was introduced wasn't possible before the project. The re-scheduling currently only takes 5 minutes to be performed;
- **Preventive Maintenance Scheduling:** Related with Scheduler, Data Collector and the ACTIVITI engine in the Polishing Activity, it was not possible to measure, because it requires a long-term analysis and historical data available.

V. LESSONS LEARNT AND RECOMMENDATIONS

Several experiments were conducted during the project. The awareness of the production system was improved regarding the use-case, using SLM Toolbox modelling and the GRAI method. Several improvements were introduced (not related to BEinCPPS) and are being tested within the company, mostly related to procedures and team building that were only possible with an improved awareness of the production system.

The ability to produce automatic Production Order sequences for the polishing activity improved the company's awareness about the process' constraints, and mostly, provided the means for an agile response to the Production Plan modifications. Experimenting with the user interface provided feedback from the operators on what kind of information would improve their performance. The ability to monitor the polishing machine's production status provides the user with preventive maintenance alerts enables an additional integration possibility with the currently used maintenance software. Machine status monitoring also improved the polishing activity awareness by sending status messages via email to the Production Responsible. Further experimentation will show additional points of improvement.

The main problem during experimentation was due to the integration of BEinCPPS components with the ERP system and the lack of integration with proprietary machines. The first problem occurred due to the absence of assistance by the ERP software company. The second problem results from the complexity of used machines that required further studies and assistance from a specialized company.

During the development of the platform, some problems appeared that were not expected. First the integration between the Scheduler, ACTIVITI and CPPS Publishing Services, where it was necessary to pass the data between the different technologies, and it was necessary to standardize the interoperability in the messages. The second point was to improve the user interface that depends on BPMN, as it does orchestrate the process. In order to solve this, the best approach was studied, and a connection from a webpage to ACTIVITI was developed, thus achieving better usability by the machine operator.

Several opportunities emerged during the experimentation, mostly related to procedures and team building that was only possible with an improved awareness of the production system. The process awareness and the control of the production were improved, since at this moment it is possible to know the production state in real-time, due to the e-mails with the status of each activity.

CRISTEMA considers that th goals were fully achieved, since the Business Requirements were mostly fulfilled. Experimenting with CPPS provided the opportunity to further improve communication between different levels and to identify further possible improvements in the production system, related to BEinCPPS components. Starting with their integration, using the current ERP system, through the inclusion of an IT partner company, to provide a better workflow.

During the development of the platform, some ideas were successfully concluded, but others were difficult to implement, making it necessary to adapt these ideas in order to achieve the desired goal. The first unsuccessful attempt was the involvement of the ERP software company and the supplier machines that could not be integrated with our solution, which could make the system reliable and faster.

Despite this difficulty, it has enabled the improvement of the tool and demonstrated that it is a good solution for the company even without the connection to the ERP software. This was demonstrated with the use of BPMN and the GRAI method, providing a global view of the production system, connecting with the shop-floor through the use of sensors and creating opportunities for the creation of "to-be" scenarios.

Based on the BEinCPPS experimentations, BPMN, GRAI method and EAStar knowledge is required for the RTOs in order to successfully model the production system. Managers/Professionals knowledge concerning the GRAI method and EAStar are required. Fortunately, the learning process was eased by the Research and Technology Organisations (RTOs) for this use-case.

Linear programming skills, IT and electronics are required by the RTOs in order to develop the BEinCPPS components and generic computer skills are required for the actors contacting with the BEinCPPS components, mainly for dealing with the simple interface. For the Technology providers: electronics and IT skills are required.

VI. CONCLUSIONS

In this approach, a CPPS system composed of several collaborative entities that connected the polishing machine and sensors to the data in an internet environment was implemented. It allows monitoring and controlling the production of cutlery in real time, giving the company the ability to forecast maintenance, knowing the production status or be aware of production planning. Throughout this paper, an evaluation of the results of the project and the experimentation in the factory was presented. A face-to-face meeting was organised in CRISTEMA, with the development team, and the management of the company expressed a satisfaction on the performed work.

For the technical evaluation, the Business Requirements were satisfied at 83% (target was 75%) and the value of the technical indicators (learnability, comprehensively, user attraction and efficiency) reached the score of 4 on 5 with one Technical Indicator at 5.

The technical lessons learnt are related to:

- Integration between the existing ERP and the BEinCPPS solutions as a major obstacle but also data to represent the Production Orders (and the grouping of these Production Orders to optimise the performance of the last activity (polishing);
- Modelling as a key learning facilitation allowing to the end users to understand the search of solutions and also to reuse past knowledge as a best practice and further development of the BEinCPPS components as next steps.

Concerning Best Practices, some results and methodologies from BEinCPPS and other projects where used. The implemented solution does not create distractions to the operators and to the established procedures. It was perceived that the use of modelling facilitates the search of Best Practices.

Measured Business Performance Indicators, shows improvements with respect to the Business Objectives.

The optimization of the introduction of a new production order in an already established production order sequence was not possible before the experiment.

For the future, the improvements and the next steps have been well identified. Concerning the improvement, a list of actions has been established. For the next step, the capacity planning must either be developed or bought on the market, the difficulty is to find a suitable tool for an SME. The capacity planning is recognized as of great importance in order to improve the planning decision at the technical level and also the related produced information facilitates the improvement of the scheduling. Another future work is to develop an APP for Android to connect with the platform, improving the interface and accessibility for the operator.

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