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Hybrid Process Management: A Collaborative Approach Applied to Automotive Industry

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Abstract

Today, manufacturing is moving towards customer-driven and knowledge-based proactive production. Shorter product life cycles lead to increased complexity in areas such as product and process design, factory deployment and production operations. To handle this complexity, new knowledge-based methods and technologies are needed to model, simulate, optimize and monitor manufacturing systems. Existing large Enterprise Information Systems (EIS) impose structured and predictable workflow, while processes "on the ground" are often unpredictable and involve a large number of human based decisions and collaboration. This is leading to a major shift on EIS paradigm and leading to development of a set of specialized small applications, each one with fewer features, but highly specialized, flexible, cross linked and easy to use. This paper presents a hybrid management solution intended to support collaboration and decision in the scope of automotive engineering and planning. The solution, labelled as HPM - Hybrid Process Manager, encompasses a set of tools for work, information and communication management fully integrated with knowledge based engineering processes. Its overall aim is to ease the flow of information between all the partners, making it more reliable and actual, allowing a closer control and faster reaction to upcoming events. The adoption of HPM approach proves to be quite effective and efficient, leading to significant results in terms of cost and time saving. When using the solution, managers no longer need to constantly ask for reporting, leading to a significant reduction on email and paperwork. It is relevant to underline that the proposed approach allowed planners to concentrate in important issues improving the product and avoid non-value added efforts and time on collateral activities. Another main advantage stays on the experience retrieval module built in top of the solution, allowing easy access to expertise, knowledge and best practices generated by previous projects, so that they can be readily incorporated in the design of new processes as a factor of knowledge sustainability.

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Keywords: Hybrid Process Management; Knowledge Based Engineering; Collaborative Engineering; Product Design and Development; Manufacturing Planning

1. Introduction

Nowadays, manufacturing industry is moving from mass production to customer-driven and knowledge-based proactive production. Shorter product life cycles, an increased number of product variants, high performance processes and flexible production processes result in an increased complexity on manufacturing systems, involving Knowledge Intensive Services (KIS) [1]. To handle this complexity, new knowledge-based methods and tools are emerging [1]. Currently, enterprise information systems are often large applications encompassing multiple functionalities that are expensive, difficult to use, hard to maintain and not cross linked. It is also observed that in many cases existing ICT tools are not prone to manage effectively daily activities due to lack of flexibility [2]. Large enterprise information systems impose structured and predictable workflows, whereas "real world" processes are hardly predictable once they involve several human based decisions and collaboration [3]. Moreover, many times, large enterprise information systems are not able to manage communication and information together with the knowledge-based process itself [4]. As a

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result of this, it is observed that existing enterprise information systems are just employed to store and collect data. Indeed, in the context of related engineer project activities, team members are forced to use office productivity tools such as spreadsheets and text editors as well as shared folders and internal email and phone to manage processes in flexible and unpredictable work environments. This is leading to a major shift in the Enterprise Information Systems (EIS) paradigm and to the development of small applications with few features, highly specialized, cross linked and easy to use in order to support daily activities with a special focus on supporting collaboration in flexible work environments [5].

This paper presents a complete solution to support collaboration in flexible work environments in the scope of automotive engineering, including integrated work, information and communication management. Section two highlights the theoretical issues related to this research work. Section three briefly describes the considered business case. After that, in section four and five we explore the main processes, starting with the diagnosis, followed by a short reference to the designed solution. The next sections present the implementations issues as well as the validation process. Finally, overall conclusions are mentioned in Section 8.

2. Background on semi-structured processes

Workflow management research tends to focus on situations that are prone to formal analysis and modelling. However, in several business areas, there are domains, such as knowledge intensive work environments and collaborative engineering environments [6], in which it is not possible to fully structure and model processes using formal notations [7] [8] . The flow of so called semi-structured processes is not known a priori, and many times, only the main phases and baselines may be specified a priori [1] [9] [10]. Efforts have been made to classify this kind of processes based on formal approaches, but the results achieved so far are limited [11]. The characteristics of a structured process include a totally defined scope, clear initial and goal states, and clear potential transitions [12].

Despite the apparent simplicity of the above characteristics, many companies try to implement workflow systems to manage non-structured processes with no success due to the fact that a formal definition of a semi-structured process is not possible [4] [13]. In fact, humans are better than computers for non-structured and fuzzy situations: e.g. case management [1] [10]. On the other hand, workflow systems tend to be better than humans for totally structured processes. The interesting finding is that, many business processes fall in between the two extremes, as shown in Fig. 1. This kind of situation leads to difficult decisions as companies have to decide if a process should be automated or not [14] [15] [16]

A semi-Structured process consists of both structured sub processes and non-structured sub processes, which interact in a known way. It is believed that many decision processes are semi-structured, and that this concept can help to understand human-automation decision systems [9].

In summary, decision making involve two types of processes: a structured process is a process that can be reduced to fully-defined rules leading to high efficiency but low flexibility (typical workflow management systems), while a non-structured process is not reducible to fully defined rules, leading to high flexibility but low efficiency and control (typical ad-hoc managed processes) [17]. A process is semi-structured when it contains both structured and non-structured sub-processes leading to a flexible and efficient hybrid approach (Fig.1). This process distinction has many implications in process management systems design, including the allocation of processes to humans and automation [18] [19].

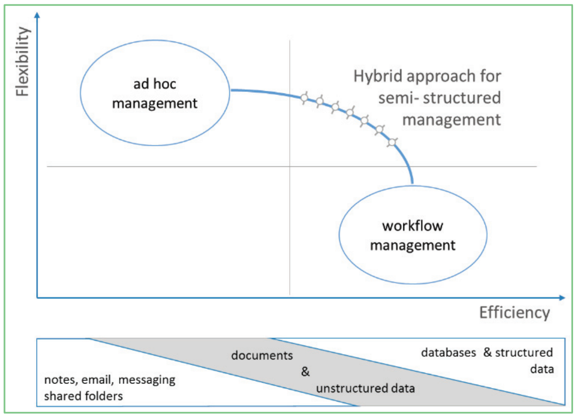

Fig. 1. Flexibility vs. Efficiency in Process Management.

3. Business case presentation

The business case considered in the context of this research project, involves an automotive industry plant producing multiple car models in a single assembly line. It presents a very highly dynamic and flexible behaviour, achieved through qualified and motivated people, continuous improvement and innovation.

In this automotive plant, a specific Business Unity (BU), dedicated to dies construction, together with other four tool shops, supports die constructions as a core technical business worldwide. With a workforce around 230 employees and equipped with modern milling machines and try-out presses, this BU is able to follow-up several die-sets projects from analysis phase till the process validation phase.

Every time a new car model is to be launched, a set of stamping dies have to be designed, produced and validated. This set of dies is managed by a dedicated team that has to handle a huge amount of information flowing thru the different stakeholders and during several phases of project. Having the right information at right moment, to take fast and well based decisions is usually a challenge managers have to face.

The die-set development process was split into three main stages: planning, machining and evaluation stages. In fact, each process instance can be deployed and implemented in partnership between the buyer and suppliers, or simply by the buyer or the supplier. Here, the decoupling point depends on the level of expertise of the buyer to deploy and control this process.

The planning is one of the most critical stage of the die-set (DS) development process, since the outcomes of the activities involved can strictly affect the performance of the overall process execution. Based on the assumptions that the DS specifications have, the following activities must be performed: Team Definition, Simulation & Feasibility Study, Capacity & Resources Allocation, Die Concept & Process Simulation and Components Design.

Starting from the project's team definition, each technician is responsible for a series of die-sets, distributed to a small number of suppliers (one or two maximum in order to enhance the buyer-suppliers relationship). Then it is necessary to execute the right simulations and feasibility tests, in order to understand if the technical specifications of each die are correct from a product and manufacturing point of view. After validation of the technical specification for each die-set, it is important to understand if the plant, where the die-set is going to be used, has the resources necessary to apply the die-sets designed. In other words, if the facilities have enough space to store the die-sets, during the "homeline" try out and production, as well as understand if there is any available press capable to apply, for instance, the forces and torque necessary. Known and validated the die-sets, as well as the necessary resources, it is possible to build a 3D model of each die-set, as well as plan the die-set construction, in terms of budget, time and quality. Here it becomes critical to specify the quality standards to be validated at the end of the process execution.

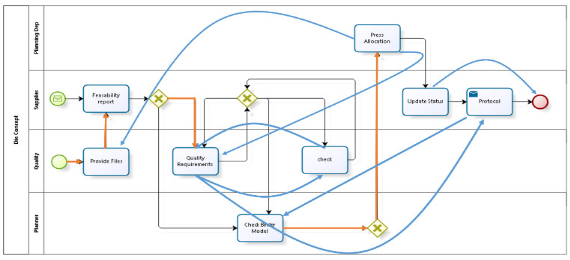

Fig. 2. Expected vs. Real Process Flow.

The following stage, the machining, is where the supplier has to transform the die-set 3D model into a final and usable die-set, capable to produce the parts as specified by the product owner.

The final stage must be focused on the evaluation and improvement of the die-set model built, towards the successful production of the idealized parts. Here, both company requirements and quality standards defined during the planning stage must be taken into account. Thus, as first action, technicians must build some prototype parts in order to validate if the dies are fulfilling the expected quality standards. After all product requirements being validated the manufacturing process is tested thought a pre-series evaluation. If minor problems are identified, then correction action must be taken in buyer's house, following an iterative approach.

4. Business case diagnosis

After analysing the as-is processes, it was possible to assert that the continuous updates on each die-set (DS) status were consuming a considerable amount of time and resources making the decision making process more reactive instead of the desired pro-active approach. It was also possible to see that the information is spread by numerous departments and specialists and can be in paper format, PDF/Word format or even plain text in e-mails. This approach in the data gathering represents a severe concern since it can be the cause of wrong or slow decisions due to misinformation in a process that is very time dependent.

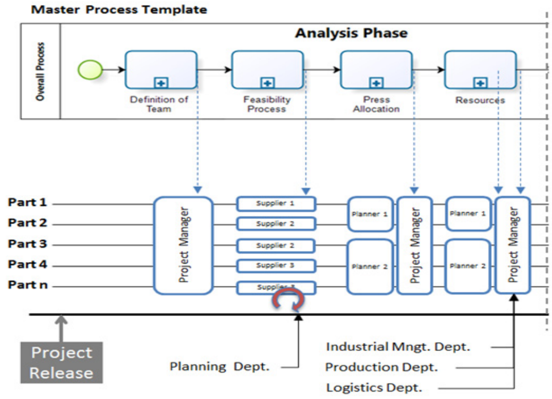

Fig. 3. Main interaction inside the collaborative process.

A practical example is the one where two tasks revealing important updates in the process are made. If the process runs perfectly and everything is considered correct in the first execution, the information along this process can be simply one document by task, otherwise, it can generate multiple files depending on the number of iteration need to achieve a valid result. This show us that this process can possibly generate high amounts of information that need to be searched, organized, reported, kept, tracked and stored for future projects causing the concerns regarding the reaction times and reliability of information.

In fact, we know that an initial plan is expected for the process. However, based on the nature of the case, every instance may flow in a completely different way, activities may be performed in any order and so we have a mix of structured and unstructured flow (Fig. 2).

The current state of the process weaknesses can be summarized and identified in the following list: Human intensive processes with high level of improvement and feedback loops; Transversal and hierarchical projects involving several departments and objectives within the organization; Management based on individual trust; Low capacity for knowledge capture and reuse; The number of people involved and information's storage formats are incompatible with a proactive approach; Ad-hoc communication flow; The reliability of the data is compromised because of the communication methods and data formats; The current storage method for data makes it difficult to gain access to it; Time dependent processes that do not allow on-time/online monitoring; Lack of standardized knowledge based databases fed by past experience and personnel knowledge; Processes dependent on individual expertise; Processes do not incorporate a best practices repository or past experiences; High risk of misinformation. Another important characteristic of this kind of processes is the change of cardinality during the process life cycle. As we can see in Fig. 3, activities may be tackled together or separately, depending on its nature and/or corresponding actor(s). For instance, the definition of team is done once for all process instances at the master process level, while feasibility studies are realized per supplier and the press allocation depends on the number of parts that each planner is responsible for.

Having analysed the as-is state in detail by considering the BPMN mapping it is possible to understand that all the weaknesses can be eliminated by providing means to have a pro-active approach in the die-set manufacturing process, as presented in the next section. Given this scenario, it is clear that managing a die-set program for a new car project or for a new car variant requires a holistic view of managing several hundreds of individual instances that depend on each other. When some decisions are being made individually it can affect other running projects. For example a decision in the development of one DS can have indirect consequences in other running DS development projects. Additionally, it requires managing several suppliers, stakeholders and documents that are being continuously updated into new versions due to improvements or unpredictable changes in the product development. The challenge is how to manage effectively the product development process when the information collected is dynamic, comes from multiple sources (stakeholders and software tools) and has dependences.

The process of dies manufacturing is highly complex and very human intensive (only highly skilled resources based on experience and expertise are chosen). It has a step-by-step methodology with a high level of improvements and feedback loops, through the lifecycle of the product development, demanding a very flexible and real time monitoring process.

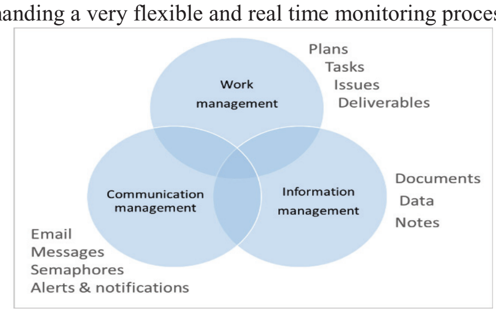

Fig. 4. Main functionalities of the solution.

Despite this, the complexity of the DS development process increases because each step can be performed by a different expert team with different goals. The existing interdependencies must be taken into account to avoid lack of consistency. Additionally, there is a huge amount of information and communication flow being managed.

The need to control this flexibility due to product development time constrains led to the development of the Hybrid Process Manager (HPM) application that is helping to control the several steps and sub-steps, tasks and activities of the process in terms of time, information and communication flow. Moreover, information generated along the different activities of the process life cycle, is classified and achieved according to its relevance for process execution, reducing the time and effort need to undertake decisions.

Communication inside the concurrent die projects was employing traditional paper or e-mail messages, which were easily forgotten, lost or ignored when the work environment becomes overloaded. The communication tools that were developed allow connecting all stakeholders and interdisciplinary teams that are involved in the product development, guaranteeing real-time information regarding updated documents, problems and other relevant issues, thus saving time and improving the decision making processes.

As stated before, the product development process of building a new die, requires a lot of expertise, experience and knowledge that are valuable on solving problems and which were not captured, stored or re-used. The knowledge reuse process will be made through ticketing functionalities where the user can document in detail the problem of the part being developed, list of actions, method, solution, and verification and action plan. This information can be re-used when needed through a database with a problem-solution-result repository.

The product development process, as stated before, is very complex and requires the management of a high quantity of tasks with their problems and constrains. In order to keep track on the status of the tasks it will be monitored by an application which will allow the user to identify if a task has a delay.

Traditional project management is mostly seen as a mono-causal and non-dynamic work system with a linear structure that is unsuitable to solve the above challenges. The flexibility desired due to the dynamic system of product development requires a new approach that will allow to breakdown the communication and collaboration barriers between the product-process-factory-production levels. The adoption of the developed tool supports the company in facing this challenge and enables a faster and a more efficient product development process.

For example, in case here considered, when a new car project starts, the top management defines only some milestones that are controlled in an automatic way. However, the work that needs to be done between each milestone cannot be automated once it relies on human intensive knowledge and decision tasks, even if the final results are known. The combination of these structured and unstructured activities are equally important in terms of leading the project to its success [11] [14].

5. Solution design

The aim of the proposed solution is to facilitate the flow of information among partners, making it more reliable and actual, allowing a closer control and fast reaction. Thus, the aim of the proposed solution is strictly linked with planning activities on the stamping area, covering a special challenge related with the launch of a new model. Working in cooperation with other departments or external partners, stamping planning department has to manage a pack of dies sets (the tooling necessary to produce new parts for a new model), track the flow path, schedule, define milestones, handle project changes, evaluate risks and define actions, as well as control costs and capacities along the project development.

In order to successfully accomplish this mission, for each project this department need to collect and manage huge amount of information and knowledge, coming from inside and outside of the factory. Indeed, managing all this information not only is intensively time consuming, slowing down decision-making process, but also hinders project reliability, increasing its uncertainty. Specifically, the aim of the solution is to manage the product development process. Currently these actions have been done manually using numerous physical, electronic files and calls. Therefore all the information needed and used in the process is spread around several departments, reducing the reliability of the entire process to a minimum. To solve this, a new approach and solution is needed.

HPM solution addresses the main challenges that are typical in this kind of semi-structured and knowledge intensive collaborative environments by implementing the following functionalities, as depicted in Fig. 4: Dashboard for holistic view of project status; Real time monitoring and control of the ongoing work activities; Totally integrated knowledge and documents management; Technical integration with Windows and office tools, which are widely used by project teams; Integrated communication/messaging along the process activities in the scope of each project/phase/to-do, eliminating the internal and project related email; Problem solving support, including tickets management integrated with all entities. Fig 5 shows an example of the HPM user interface.

6. Solution implementation

The process manager solution relies on an ASP.NET web application and taking advantage of Microsoft SharePoint foundation services. The application runs on Microsoft Windows Server on top of Microsoft SharePoint Foundation Server and its data model is implemented in SQL Server RDBM System. LINQ-TO-SQL is used to enhance the connection between server side C# programming and database. Several libraries are used in order to integrate the application with native windows functionalities as well as Microsoft Office tools, which are widely used by knowledge intensive workers. The process manager UI is a totally web-based HTML5 and JavaScript technologies enabled. Several control libraries such as Telerik for AJAX.net and HighchartsJS were also employed in order to have a rich and high usable and flexible interface.

During the requirements elicitation process, it was clear that all stakeholders were using Microsoft productivity tools in their daily work. Thus, it became clear that a seamlessly integration with Microsoft productivity tools such as Windows Explorer and Outlook was critical. Giving this context, is was decided to develop the application on top of .NET and SharePoint foundation frameworks in order to take advantage of its functionalities. Thus, the eApp is designed to run on windows server IIS using Microsoft SQL server and SharePoint Foundation services. Nevertheless, a Windows Communication Foundation (WCF) RESTful API was developed in order to have an integration endpoint with any kind of application such as java EE, android, iOS and others. Moreover, MVC Frameworks such as AngularJS can be employed to develop customized GUIs for specific devices like smartphones or tablets.

Several required services and respective endpoints for data interoperability were developed using WCF RESTful web services.

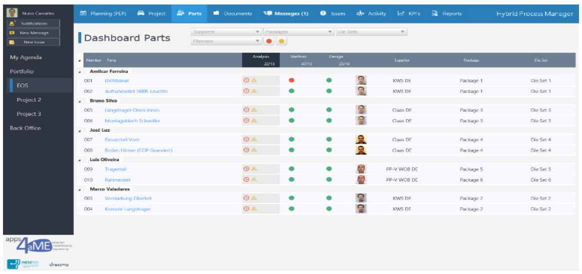

Fig. 5. Example of the solution UI.

7. Solution validation

During the process analysis and re-definition, a set of Key Performance Indicators (KPIs) was defined in order to measure the impact of the solution. Thus, for the successful implementation of the solution, the following KPIs were defined: Overall Report Lead Time (ORLT): Required time necessary to create an overall report in hours; Overall Report Resources (ORR): Required resources necessary to create an overall report in persons; Reaction Time on Critical Status (RTCS): The Reaction Time on Critical Status KPI, measures the mean elapsed time between the problems raise moment till its closing, when they're solved. Phase Lead Time (PLT): The Mean time between the start of a project type phase and the effective closing of that phase; Project Schedule Variance (PSV): The variance between the project schedule and its real execution time.

Table 1. KPI values and savings.

KPI Acronym	Units	AS-IS Result	Actual Result	Savings (%)
TACD	minutes	30	5	83,0%
ORLT	hours	3	0,5	83,0%
ORR	persons	9	2	77,8%
RTCS	hours	20	5	75,0%
PLT	months	4	3,5	12,5%
PSV	%	10	5	50,0%

The solution was evaluated in real engineering environment inside the company, by the stamping planning team, which involves eight planners and a manager for each project. During this evaluation phase, a specific project has been used to test and verify the functionalities implemented. Each stakeholder has a specific credential to access, test and validate the functionalities, giving feedback for continuous improvement. At the moment, by using a comprehensive Performance Measurement Engine, it was possible to measure and calculate the KPIs previously defined and compare the results, lead to the savings that are presented in the following table.

8. Conclusions and further research

As shown by the results of KPIs from previous section, the introduction of the HPM in the automotive engineering collaborative environment prove to be very effective and efficient, leading to good results in terms of savings. The introduction of the HPM made possible that managers avoid asking for reports and a lot of time and paperwork is now saved. Hybrid Process Management solution allowed planners to concentrate in important issues improving the product and avoid non-value added efforts and time on collateral activities. Other advantage is the data collection built in the solution storing historic and experience retrieval modules, allow access to expertise, knowledge and best practices collected from previous projects and available to incorporate in future as a factor of knowledge sustainability.

The comprehensive dashboard allows the real time report of the project status, leading to savings in reporting time and resources. Due to integrated documentation and information management, engineering project's team members have now instant access to the right information at the right place and in the right moment, leading to a reduction of time to access critical data. The communication and issues tracking functionalities, allows key players to participate more actively in process management and improvement, thus enforcing team spirit. This solution has proven to be very effective and efficient when applied in hybrid work systems and in particular in the automotive engineering collaborative processes.

In summary, the project has improved the communication, the cooperation and trust the exchanged information, which are key factors for a successful project. In future, with the integration of suppliers, the solution aims to allow a chain reaction and a huge impact on speeding up the product development and time to market allowing also a faster response to external changes.

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