An investigation for improving knowledge management for design for manufacturing implementation in an aerospace company

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Abstract. Design engineers are under constant pressure to improve product design for better manufacturability and product performance. However, design issues and areas for improvements are normally identified in the aerospace industry during the production phase of a products' lifecycle where design engineers have begun working on other projects under tight schedules for delivery. This investigation focuses on the issues and limitations for managing the production line manufacturing knowledge that can benefit design engineers to implement design for manufacturing strategies at a large aerospace systems manufacturer in the UK. A framework is proposed to describe the current system in order to improve the management of manufacturing knowledge for the design engineers. A prototype solution is proposed to apply in the industry to improve the implementation of design for manufacturability in the engineering function.

Keywords. Knowledge Management, Design for Manufacture, High Value Manufacturing.

1. Introduction

One of the biggest challenges within the businesses today is to identify and preserve the knowledge being created across the organization so it can be effectively used to improve the efficiencies of the system operations as well as add organizational value [1]. Many industrialists, and academic researchers have been trying to develop ways in which the large amounts of data generated from internal processes within a business can be transformed into forms of useful knowledge for other functions to use effectively. The term 'big data' is widely being accepted amongst the research community as the phenomenon that resulted from the rapid transformation of industries into a higher degree of digitization [2].

In the manufacturing industry, research has been trying to focus efforts on new methods that are able to manage, contextualize, and effectively use large amounts of data from manufacturing processes in order to improve design for manufacturing knowledge for the design engineers.

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Additionally, very complex products are becoming harder to manage and communicate especially due to extended enterprises and the complex data management required. Collaboration technologies, communication technologies, and cloud computing capabilities are being developed in manufacturing system operations to improve decision making processes and centralization of project information for geographically dispersed teams, multi-disciplinary approaches and concurrent engineering [3] but are still limited in improved methods for accessibility, data interpretation and data analysis for improving design for manufacturing practice.

1.1. Design for Manufacturing Implementations

Design for manufacturing methods are typically an evaluation of the manufactured part and its related manufacturing processes against the issued design for manufacturing specifications. This can also be in the form of design review against estimated costs of assembly and manufacturing processes required when done in the design development stages. A survey conducted by the University of Cranfield shows that most people involved in design and manufacturing had personalized definitions of design for manufacture [4]; resulting in many interpretations of what good design for manufacturing practices are. The methods are summarized below:

- Guidelines – common practical know-hows developed by engineers showing product specific implementations that describe preventing a specific problem based on past experience. This includes manufacturing parameters that engineers can obtain from process variables or third party suppliers.
- Evaluation – use of scoring based analysis based on identifying greater impacts on assembly and manufacturing processes of unwanted costs associated with particular design for manufacturing issues.
- Design for Assembly and Automation – methods available to enable design optimization by expert systems such as CAD parametric modeling, CIM, CADCAM, DFME, FEA software that have built in manufacturing variables when the design intent is input in various forms.
- Cost and Reliability Engineering – approaches related to predictive simulation technologies, usually done at post concept stages for cost reducing strategies. Cost-re engineering in production also use this when customer requirements change.
- Design Optimization – approaches to ongoing issues in the manufacturing stages that include optimizing the design through change requests and design recommendations given by the various manufacturing teams involved.

There is a significant gap for researchers and industry to apply design for manufacturing approach by creating knowledge repositories based on manufacturing quality defect data and engineering implementation as a standard process of continuous feedback. There is also a significant gap missing that is able to fulfil this knowledge link in the high value low volume business context.

1.2. Research Approach

This project investigates the challenges for improving knowledge management for design for manufacturing implementation at a large aerospace company in the UK. The industrial investigation focuses on the current approach for design for manufacturing to model the direct and indirect impacts of quality, cost, and delivery on the assembly of aerospace systems in order to improve knowledge management. The proposed framework aims to address the challenge of how to make use of the manufacturing data in the production line to measure design for manufacturing performance and align it with the engineering function to continuously improve organizational learning. In order to achieve this, a case study on 5 complex products will be carried out to identify the current manufacturing system limitations that effect the implementation of design for manufacturing and the management of its knowledge for the engineering functions.

The research findings will form the framework that will be used to develop a system for managing the knowledge of the product defect data captured during the manufacturing stage in order for the engineering function to carry out effective design for manufacturing analysis for implementations and improvements. The system will also incorporate, centralization and provide data analysis to measure the impact this approach has on quality, cost and delivery on the production line.

The framework and the prototype system will have a significant impact on the way the collaborating company currently manages design for manufacturing knowledge. An empirical benefits study will be carried out to justify this. The prototype system that will be developed will provide the industry with the following benefits:

- Enabling first time right approach for new products to be manufactured.
- Reducing potential operation costs of the activities involved with quality defects.
- Reducing manufacturing quality defect issues caused by engineering.
- Improving manufacturing understanding and design practice to apply in the engineering.
- Improve corporate learning in the area of design for manufacturing.

2. Industrial Investigation

BAE Systems is an integrated electronic and electro mechanical manufacturing company. Electronic Systems where the investigation is carried out, employs some 500 engineering resources and 900 others in operations, supply chain, management and maintenance support. The main product ranges being developed and manufactured in this facility are in-flight heads-up display systems, pilot helmets, pilot control systems, flyby wire systems and integrated flight control systems; all of which considered highly sophisticated products with complex operations.

Although the company manufactures its own novel designs, many of the operations on the assembly line are based on integrating subsystems manufacturing by other partners including other BAE Systems facilities, third party suppliers and bespoke manufacturers. A large proportion of these parts are of high value, high technological electronics and bespoke components. The production line can run up to 20 projects are a single time, including assembling, testing, and qualification processes to incorporate into larger avionic systems. The volume output of each completed product can be in the region of 10-20 per month which is a very low volume output.

An observation study was carried out between May 2015 and May 2016 towards validating the preliminary investigation in order to elucidate the application issues this project will address. Many discussions were carried out throughout the study with the operations management team, manufacturing team, equipment operators, and engineering team. Presentations of the following findings to the 10 key stakeholders for this project was given to further justify industry aspects of this research.

The findings are illustrated in figure 1 below:

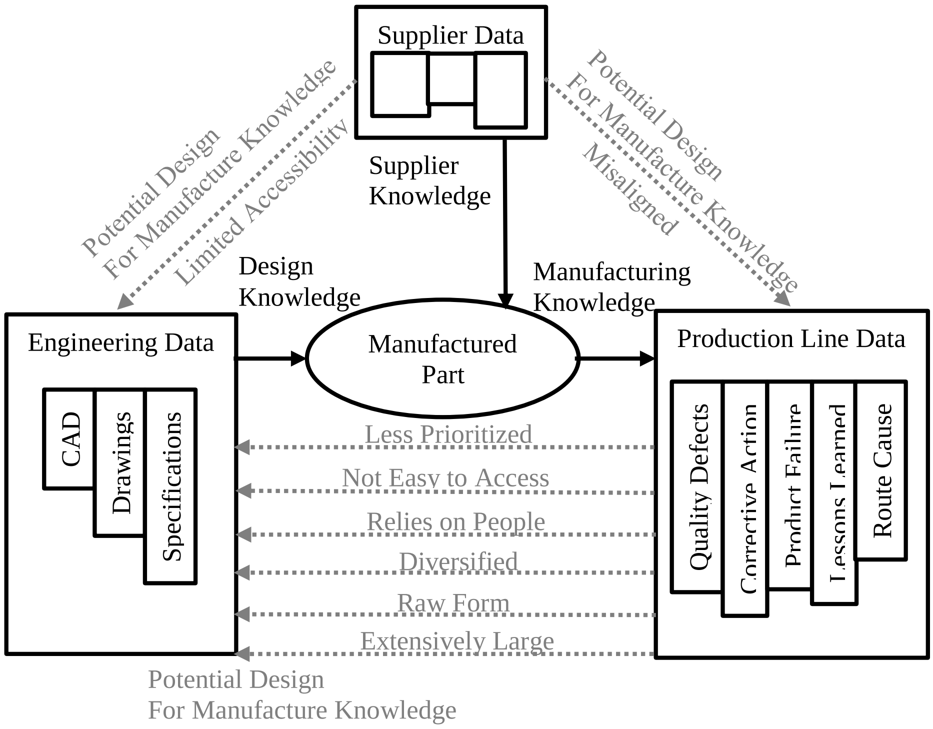

Figure 1. Framework describing the current system limitations and challenges with knowledge management for design for manufacturing implementations.

Many of the day to day difficulties are caused by the complex nature of manufactured systems, and aerospace products. This product complexity results that products, processes and operations to being managed by people, putting pressure on the project management to keep everyone’s knowledge communicated across the dispersed project team. Communications become increasingly complex amongst the different roles within a project and therefore becomes un-systemic and more selective due to the data required to process from the manufacturing system.

The manufacturing system also relies heavily on the production line data which is not fully appropriated, not centralized, and in many cases not fed back to implement engineering changes for improved design for manufacturability. This is because the customers of the aerospace industry have control over the time plan and can fast track defense related programmes depending on the geo-political context, which ends up driving the manufacturing operations to spend its time and resource looking at the shortest route for delivery that meets all the customer requirements and qualification as opposed to having additional time to implement design for manufacturing strategy that can improve knowledge for the next time the project is run.

The quality defect data is dispersed amongst the production line into various data banks. Some are related to the occurrence of the defect, some to the tracking of the corrective action, and others are collected for documentation purposes and reviewed at the end of a project in lessons learned database. This dispersity of raw tables of large data is extremely exhausted to collect in a central location. In addition, route causes and good practices can be in many cases documented within the manufacturing engineering's own locations to aid him to retrieve the knowledge required for himself.

Additionally, the performance metrics that reflect the defect data is related to production performance and not design for manufacturing impact. There is a significant gap found in understanding the impact of re-occurring defects; a deeper understanding of the lifecycle impact across the organization for a defect needs to be coupled with the design for manufacturing performance as opposed to solely focusing on the handling and resolving the situation at hand. There is a need for an effectively managed knowledge feedback solution that can enable permanently resolving quality defects found in the production, as well as at the root cause levels in design for a more effective continuous improvement approach.

Furthermore, suppliers across the supply chain are given contingencies for late delivery and quality defects because the manufacturing processes are externally controlled by the third party themselves. This has affected the way the company rectifying the defects because the ability to identify route causes for design for manufacturing is limited and the defect data is not available at hand, nor integrated, nor centralized. Many of aerospace components are manufactured with a low process yield resulting in increasing the value of the part, but the knowledge of that is missing in order to enable any kind of implementation for design for manufacturability improvement in a systemic manner.

3. Proposed Prototype Solution

A solution is proposed in collaboration with BAE Systems, Electronic Systems' manufacturing operations team. The proposed system will incorporate data from the manufacturing phase on 5 complex products in regards to quality issues and lessons learned. The data of the failure reports, corrective actions, quality defects, change requests, lessons learned, and supplier investigations will be centralized into a structured ontology. The data will be classified into the different lifecycle phases the defects were identified for ease of accessibility and transparency. This data will then be aligned to the engineering part number, and assembly structure using the engineering data of the released designs.

This data will be analyzed against a development of design for manufacturing performance metrics and visualized. The design for manufacturing performance metrics will apply a cost model of the defect on quality, a cost model of the defect on manufacturing, and a cost model of the defect on time delivery; from a lifecycle point of view. The performance metrics will give the ability to indicate the cost of processing a defect as well as the overhead utilization involved in order to provide an understanding of the impact of re-occurring defects.

The system will have the ability to feedback the knowledge accumulated from the raw data to the engineering function in a continuous mode of communications using the existing Product Lifecycle Management approach. This will provide accessibility benefits to any engineer required to improve design for manufacturing on products that are currently having defects on the production line. The tool will improve collaboration in the decision making process as it incentivizes the involvement of the operator whom picked up the defect, the production management team and the manufacturing engineer team to incorporate a root cause analysis and a design for manufacturing implementation in agreement.

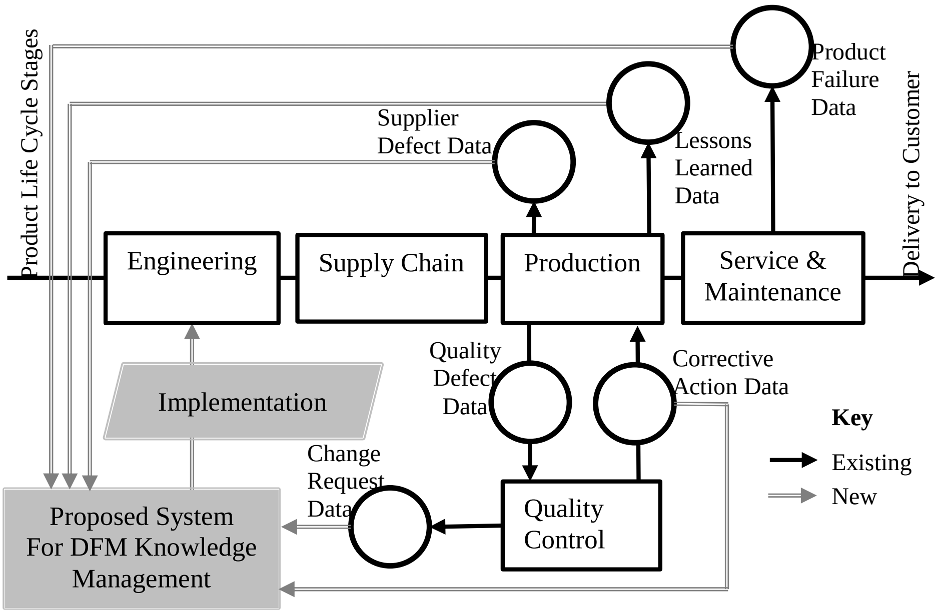

Figure 2. Framework describing the new knowledge links established by the proposed system with the existing databank links in the current system.

An empirical investigation will follow that evaluates the prototype system against the impact on design for manufacturing by measuring its effectiveness against quality, cost, and delivery.

4. Conclusion

The industrial investigation was used to identify the limitations in the current manufacturing system operations at a large UK based aerospace manufacturing company. The stakeholders verified the findings proposed in the framework and the benefits of the proposed approach. The solution is to be presented in the next phase to the key stakeholders for feedback. The industrial issues that have been identified will benefit from the evaluation of them against the prototype solution once fully developed. It will enable the centralization of quality defect data and contextualize it from a design for manufacturing performance view and its impact on quality, cost and delivery of 5 aerospace products in the next phase of the case study. This will be a very valuable asset to the organization and a useful front end solution for design engineers to implement design for manufacturing knowledge and reduce manufacturing issues.

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