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BUILDING AGILE DESIGN TEAMS

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ABSTRACT
One of the most common problem in many organizations that have reached considerable dimension and complexity is the lack of communication and collaboration between the different departments. When considering companies producing highly engineered and complex products the design communication problems can lead to cost overruns, schedule slippage, and quality problems.
Using a structured multi matrix approach to analyze the existing project component staffing and team interaction we are able to identify firstly understaffed critical components interfaces, secondly instances of missing critical team interfaces and, last but not least, thirdly we are able to generate an improved team member allocation, to build an agile design team.
To demonstrate the model's practical utility we discuss a case study of a company operating in the automotive sector.

Keywords: communication, team, design, engineering, agile

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1 INTRODUCTION

Many scholars have focused their attention on increasing R&D performances. However R&D departments were considered to be rather unique, creative and unstructured yet critically important beasts that are difficult to manage and control (Kerssens-van Drongelen & Cooke, 1997). Hence, a considerable effort has been spent creating new approaches that could increase efficiency and effectiveness, especially in a fast growing competitive environment where both product quality and fast development are essential. Particular evidence has been given to topics such as measurement system identification (Kerssens-van Drongelen & Cooke, 1997) and the definition of valuable design processes (Cooper, 2000).

Though the problem or opportunity is quiet undisputed, few authors have given specific and structured methods that consider both the organization structure / processes and the product architecture. Both are critical aspects that need to be managed jointly in order to increase the success of a new design process (Manuel E. Sosa, 2007; Pasqual & de Weck, 2011). Being able to link appropriately the connections between the designers and the systems they work on, creates an alignment positively affecting the team member's work behavior. Correctly aligning the organization and the product architecture lead to numerous benefits such as reducing the cost of collaboration, freeing capital, designing more accurate product interfaces and significantly evolving change propagation management. With our Agile Design Team method, we attempt to do just that.

Our work is grounded in organization design, where it has long been recognized that organizations should be designed to reflect the nature of the tasks that they perform (Galbraith, 1973). Our purpose is to design a method to accomplish this goal considering the designers' needs on the interplay between the product structure and the engineering teams that has the task to design it. We know that the mirroring hypothesis applies (MacCormack, Rusnak, & Baldwin, 2011), but scholars are still arguing if it is the organizational structure that generates the product structure or vice-versa. We do not enter this debate, since we believe it is possible to study the situation in its specific context and then to redesign the organizational and product structure. As a result we aim to improve both, efficacy and efficiency, and in particular the extremely negative effects of communication overload (Manuel E. Sosa, 2007). Better interfaces and exchanges will lead to less rework (change requests at later stages of the design process) (Clarkson, Simons, & Eckert, 2004). Ultimately we propose a structured method that increases the learning capabilities (Beckman & Barry, 2007) of the team members. We aim to build agile design teams by balancing the product architecture, the interactions between its subsystems and the teams involved in the design. We are aware that this alignment should not be the only aspect to consider when designing the team configuration. However, in our idea, working on this aspect can positively influence other elements such as the appropriateness and timeliness of information exchange providing an environment that fosters communication and sharing.

Since the complexity of the problem hinders the development of a general theory driven solution, and following the Research as Design methodology (Boland & Lyytinen, 2004), we decided to focus our attention on a specific empirical and quasi experimental case as inductive foundation. Over a period of 12 months, we were able, through an embedded researcher, to study a high performance team that designs a complex engineering product in a hyper competitive and dynamic environment, a sport vehicle.

During an initial phase, we analyzed the design methodology applied by the company. It emerged that there exists an inappropriate coordination regarding the departments involved in the design process and a potential lack of communication between the designers and all the other people involved. Based on these conditions the designers developed a tendency to "throw issues over the wall", losing the focus on the big picture and the real reason why they were doing what they were doing. To counter this in a methodological way we designed the

Agile Team Building method as an innovative way to create better cross–functional teams and to transform the structure of the organization from a functional approach towards a lean and horizontal setup. In an experimental sense, we then iteratively applied our method studying the effects on the organization.

2 METHODOLOGY DEFINITION

The entire project was guided by the Design Thinking principles (Beckman & Barry, 2007). We wanted to gain a complete understanding of the designers' needs, to become empathic with their view of the world, in order to create an innovative and effective solution. Observing the engineers while working allowed us to discover what in our opinion was the main cause of their difficulties, an inherent lack of coordination maybe deriving from the functional structure adopted by the mother company. The horizontal dimension of the design process had been subdued in favor of the completion of specific tasks required by the vertical functions (technical specialty). This setup was causing significant trouble especially when dealing with (not uncommon) change requests and collaborative activities.
In order to maintain a methodologically structured approach in the face of a complex technical project, we have sequentially combined established approaches in our analysis and synthesis, namely the following tools: the Design Structure Matrix (DSM), the Domain Mapping Matrix (DMM), the Multiple Team Membership (MTM) and the Organizational Network Analysis (ONA). This innovative arrangement of those tools and the main principles of the theories cited above allowed us to successfully engage in the case company project and to develop a generalizable method. These following paragraphs give a brief overview over each tools.

The DSM is a square matrix with identical row and column labels which displays the relationships between components of a system in a compact, visual, and analytically advantageous format (Browning, 2001). Its main use is increasing the understanding of a complex product / system decomposing the product / system into subsystems about which relatively more is known. This operation eases the identification of the subsystems relationship and helps to identify their impact on the system as a whole. In other words the DSM gives many opportunities to improve the design process (Eppinger, 1991).

A DMM is a rectangular (m x n) matrix relating two DSMs, where m is the size of DSM1 and n is the size of DSM2. The DMM analysis offers several benefits. For example, it can help (1) capture the dynamics of product development, (2) show traceability of constraints across domains, (3) provide transparency between domains, (4) synchronize decisions across domains, (5) cross-verify domain models, (6) integrate a domain with the rest of a project or program, and (7) improve decision making among engineers and managers by providing a basis for communication and learning across domains (Danilovic & Browning, 2007).

The MTM represents the number of teams in which a person is simultaneously involved during his working activities. What strikes the attention is the change in the organizational behavior that creates a set of interesting opportunities and challenges for organizations that choose to structure their work in this way (O'leary, Mortensen, & Woolley, 2011). Multiple team memberships have implications for how individuals, teams, and organizations do, manage, and communicate about their work. They also have implications for the information systems designed to support the management of projects and the assignment of people to them. Paying attention to this index is possible to define the optimal trade-off between the resources' performance and their membership to multiple teams.

ONA (Cross & Parker, 2004) provides a powerful means for leaders to understand and drive value through the invisible aspects of organizations. What this kind of analysis wants to underline is the need to identify where the real knowledge of the organization lays and how this can be transferred and shared. The basic idea is to access a series of information that usually cannot be discovered if employing the standard analysis methods. The ONA can bring to light the real collaborative network of an organization resulting in useful insights for managers and leaders.

3 THE AGILE TEAM BUILDING METHOD

In our case project, the organizational structure defined by the company was a typical functional organization where employees are grouped according to their knowledge and competences. To ensure collaboration and coordination between the different departments, the organization had to spend a lot of effort and resources. Nonetheless, it emerged that still there exists a dangerous lack of coordination between the different departments involved in the design process of the sport vehicle. As a result, potentially ineffective components were designed in a way that may affect the general quality level and the performance of the vehicle.
Considering the hyper competitive nature of the environment the vehicle is competing in, the organization leadership agreed to engage in significant changes. It was suggested to introduce cross – functional teams composed by team members coming from each vehicle component relevant department of the company. Each team is headed by a Team Leader that is also the Process Owner. He / She is in charge of the components' development and of the coordination between the various departments. The role of the Team Leader is crucial and difficult: he has a high level of responsibility and not the corresponding level of authority. Hence, the Team Leader must rely on his communication skills in order to motivate and lead the team members to achieve the set targets. Then the real problem that emerged was how to design and staff the cross-functional teams. The teams had to be homogeneous enough to accommodate the highly dynamic environment and diverse enough to achieve true innovations.
Mitigating the design communication problems and managing the product interfaces, we were able to deploy and proof test our Agile Team building method to create and improve the cross – functional teams. The central idea is to couple each physical interface between components with at least one organizational interface, which corresponds to having at least one Engineer involved in the design of both components. Focusing sharply on these critical interfaces between the components ensures that everyone knows when and with whom they should be sharing information.

2.1. Identifying critically understaffed project components

We started by building the DSM in order to define the areas where each team will be working on. Analyzing the Bill of Materials, the product (a sport vehicle in our case) can be divided into components (the components selected are those that have the highest impact on the performances of the vehicle). This subsequently allows identifying the physical interaction between the components.

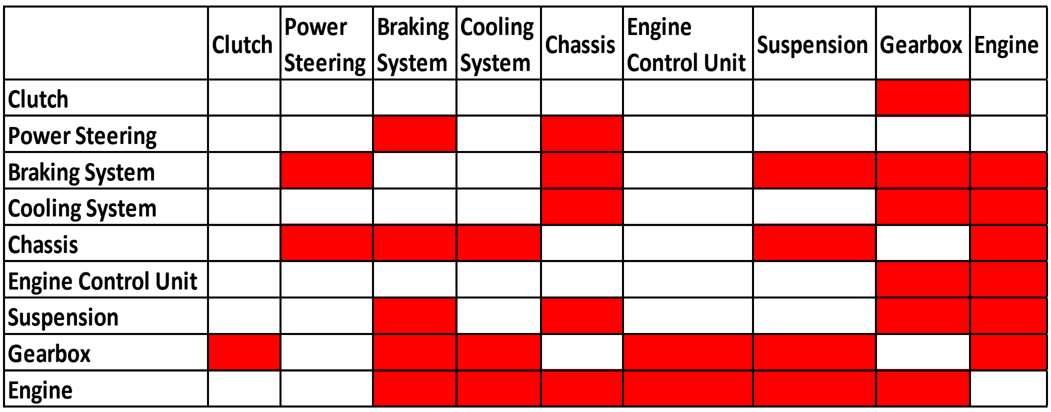

Figure 1 - Design Structure Matrix of the project components

Figure 1 shows the Design Structure Matrix obtained analyzing the data of our case study. The red cells resembles the architectural interfaces between components.
The second step of the method consists of studying the team members involved in the design process in order to identify the ***actual*** communication and the existing collaborative network. The team members involved in this study share a similar background (mechanical engineers) and comparable tenure. We are asking each team member with whom they collaborate, and what components they will be working on. They are asked to identify their main component. We show the responses in a Domain Mapping Matrix (DMM) as illustrated in Figure 2.

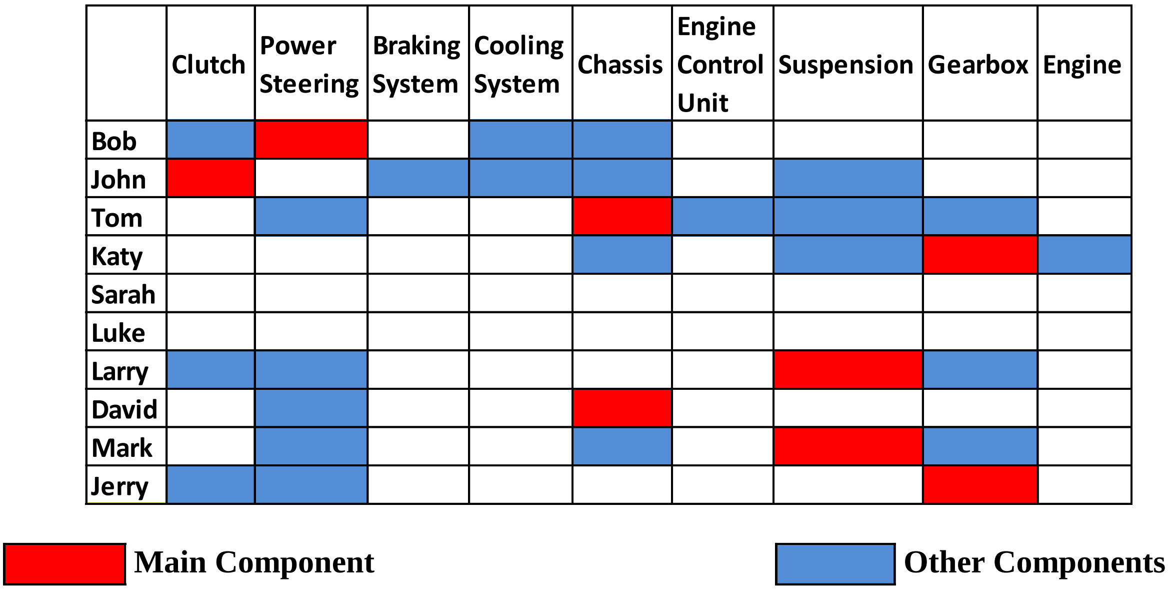

Figure 2 – Domain Mapping Matrix combining project components with human resources[1]

The DMM identifies which components are designed by each person and allows us to understand how the different subsystems are allocated to the designers.
This represents a 2-mode network that can be projected on each dimension (1-mode on components and 1-mode on team members) by the affiliation procedure on UCINet (Borgatti, Everett, & Freeman, 2002).
First, we associate the data considering the components dimension:

	Clutch	Power Steering	Braking System	Cooling System	Chassis	Engine Control Unit	Suspension	Gearbox	Engine
Clutch	4	3	1	2	2	0	2	2	0
Power Steering	3	6	0	1	4	1	3	4	0
Braking System	1	0	1	1	1	0	1	0	0
Cooling System	2	1	1	2	2	0	1	0	0
Chassis	2	4	1	2	6	1	4	3	1
Engine Control Unit	0	1	0	0	1	1	1	1	0
Suspension	2	3	1	1	4	1	5	4	1
Gearbox	2	4	0	0	3	1	4	5	1
Engine	0	0	0	0	1	0	1	1	1

Figure 3 – 1-Mode DMM associated on Components representing the number of team members affiliated with each component in red and the number of team members working on both, X and Y component

Elements on the diagonal represent the number of Engineers that work on a specific component; the Off-diagonal values represent the number of shared Engineers between each

[1] Team member Sarah was the boss and Team member Luke was on a long leave

couple of components. For example, 4 Engineers design the Clutch while Power Steering and Clutch share 3 Engineers. Analyzing this matrix allows to identify which interface are under controlled. If one engineer or more share two components, the interface between these two components is correctly attended.

Merging the DSM and the 1-Mode DMM associated on Components we obtain the **Component Alignment Matrix** that reveals how the interfaces are currently attended. In addition, the Component Alignment Matrix highlights mismatches between planned and factual communications.

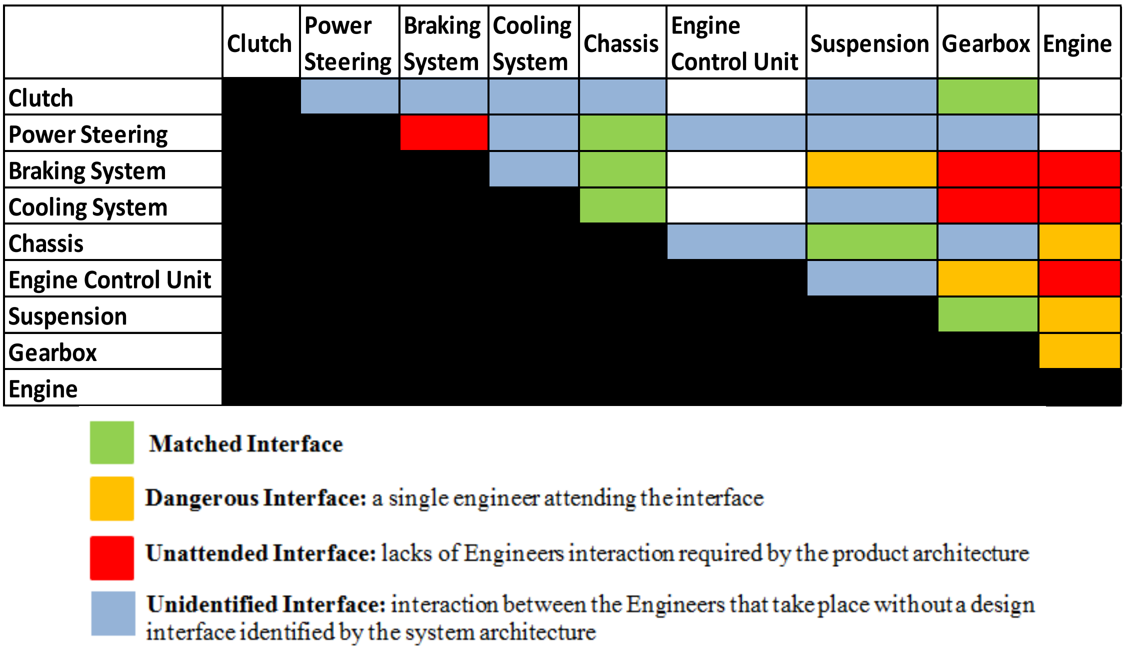

Figure 4 – Component Alignment Matrix displaying and evaluating the organizational interfaces of each component

As an example, the DSM suggests that there is an interface between Clutch and Gearbox. Two Engineers are taking care of this relation, thus this physical interface is under control.

2.2. Identifying critically missing team interactions

The same analysis can be conducted considering the team members: thanks to the survey data, we are able to identify the cooperation network between the engineers during the design process, depicted in the **Person Interaction Matrix**:

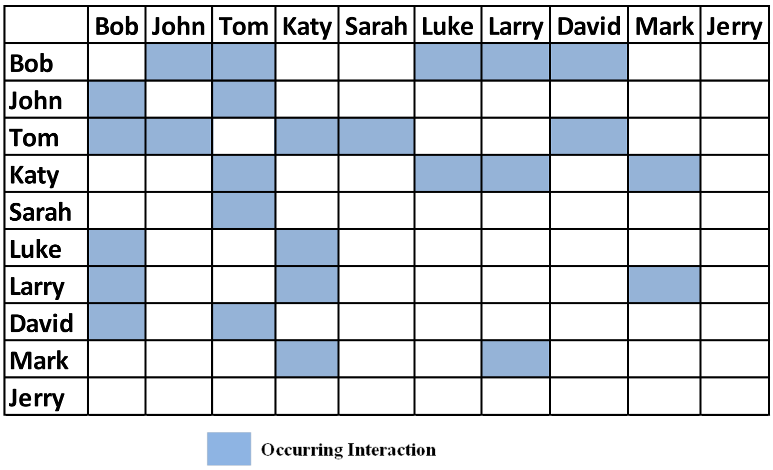

Figure 5 – Person Interaction Matrix, depicting team members[2]

[2] Team member Jerry was relatively new in this Department

At this point, we again construct the Domain Mapping Matrix followed by the 1-Mode DMM. This allows us to examine the allocated Team Members.

	Bob	John	Tom	Katy	Sarah	Luke	Larry	David	Mark	Jerry
Bob	4	3	2	1	0	0	2	2	2	2
John	3	5	2	2	0	0	2	1	2	1
Tom	2	2	5	3	0	0	3	2	4	2
Katy	1	2	3	4	0	0	2	1	3	1
Sarah	0	0	0	0	0	0	0	0	0	0
Luke	0	0	0	0	0	0	0	0	0	0
Larry	2	2	3	2	0	0	4	1	3	3
David	2	1	2	1	0	0	1	2	2	1
Mark	2	2	4	3	0	0	3	2	4	2
Jerry	2	1	2	1	0	0	3	1	2	3

Figure 6 – 1-Mode DMM associated on Team Members representing the MTM for each team member (in blue) and the number of components jointly worked on by ixj

Elements on the diagonal represent the engineers' Multiple Team Membership (MTM), while the off-diagonal elements show the number of components worked on by each pair of Engineers. Analyzing the 1-Mode DMM associated on the team members dimension enables us to understand how the real collaborative network from the survey is supporting the interfaces. As an example, Bob works on 4 Components and works jointly with John on 3 Components (Clutch, Cooling System and Chassis).

The merger of the DSM with the 1-Mode DMM on Team Members generates the **Missing Communication Matrix** that tells us if the collaborative relations suggested by the 1-Mode DMM overlap the real collaborative network. As an example Tom and Larry work both on Power Steering, Suspension and Gearbox but it's well worth noting that based on their survey feedback, there is no collaborative relation between them.

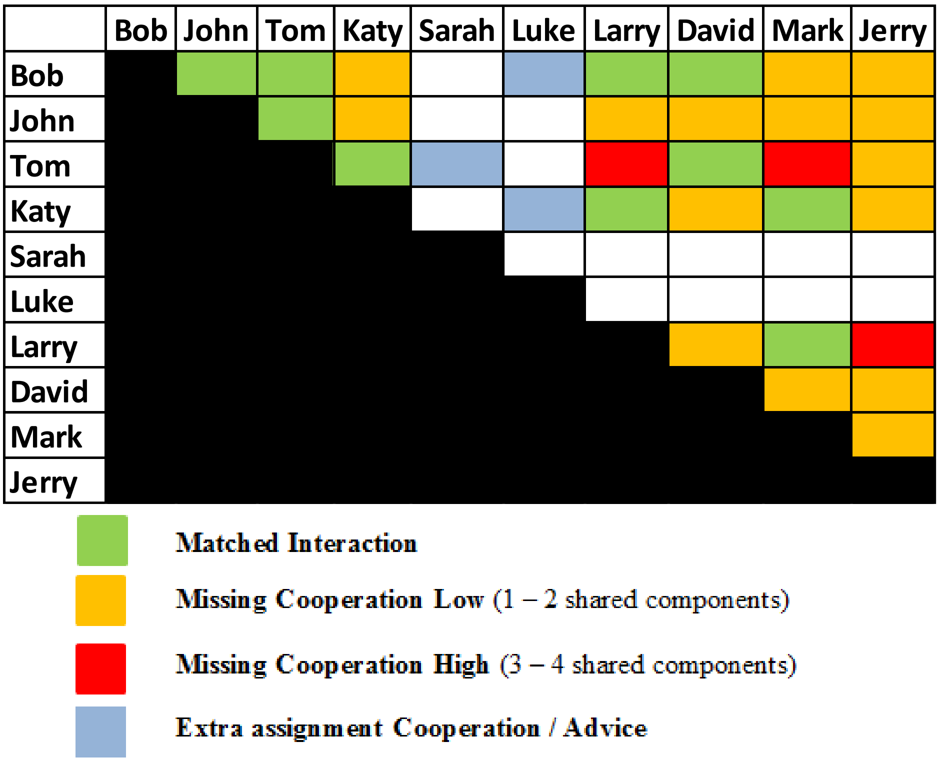

Figure 7 – Missing Communication Matrix displaying and evaluating the team interactions

2.3. Building an agile design team

Armed with the information in the matrices, we are able to create improved cross–functional teams that integrate the information collected from the DMM, the Component Alignment Matrix, the Design Structure Matrix and the Missing Communication Matrix. The goal is to match the unattended interfaces without radically changing the collaborative network in place as stated through the survey, and without raising the Multiple Team Membership too much.

We begin by modifying the job assignment of the team members in order to obtain the results described earlier; meaning the interfaces correctly matched observing the constraints imposed by the MTM, which is currently averaging 3,875. Increasing the MTM would introduce a variation in the resources' workload that can affect their performances. The following table describes the results obtained with the optimization procedure that considers the above constraints and the new team configuration: teams are built by identifying new designers' combination and by altering the job assignment in a way that the architectural interfaces detected by the DSM are matched correctly.

Team	**Designers**					
Clutch	**John**	Bob	Larry	Jerry		
Power Steering	**Bob**	Tom	Larry	David	Mark	Jerry
Braking System	John	Bob				
Cooling System	Bob	John	David			
Chassis	**Tom**	**David**	Bob	Katy	Mark	
Engine Control Unit	Tom	Katy				
Suspension	**Larry**	**Mark**	Tom	Jerry		
Gearbox	**Katy**	**Jerry**	Larry	Mark	Tom	David
Engine	Katy	John				

Multiple Team Membership	
Bob	4
John	5
Tom	5
Katy	4
Larry	4
David	4
Mark	4
Jerry	4
Average MTM	4.25

Table 1 – Team Configuration and MTM depicting proposed staffing changes in red

The new Component Alignment Matrix is:

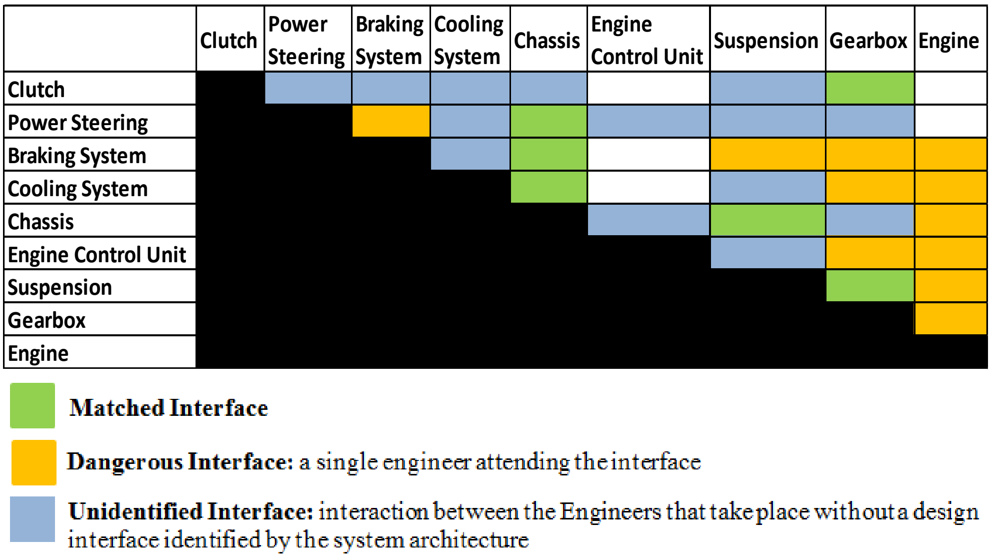

Figure 10 – New Component Alignment Matrix

As a result, all the interfaces are correctly matched (no more reds) and the ones that were not properly controlled are now supervised at least by one Engineer. The new team configuration produces a new DMM:

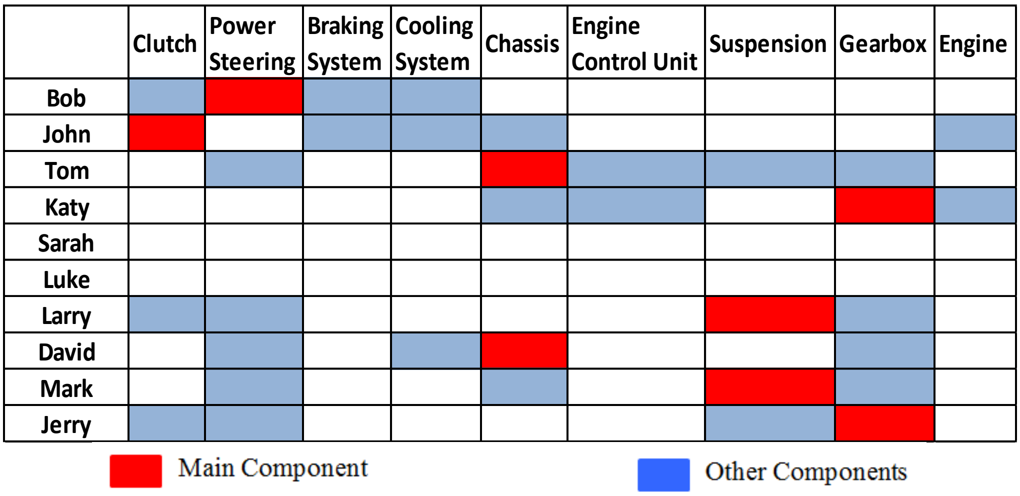

Figure 8 – New Domain Mapping Matrix of the improved team organization

Table 1 showed the MTM variations after introducing the cross – functional teams. Please note, that the illustrated example does not respect the constraint of keeping the average MTM untouched or lower (3,875 to 4,25). The necessary increase however suggests a potential under sizing of the current department involved in the design process.

4 CONCLUSION

This paper proposes a change in the organizational structure of a high performance development team, which is subjected to a high level of complexity due to the characteristics of the product and the hyper competitive environment. During our analysis, we discovered an inappropriate coordination level regarding the department involved in the design process. This kind of issue can be ascribed to the functional structure adopted previously by the company and to the practice of assigning tasks based on available capacity of designers. Our main contribution is the design and proof test of the Agile Team Building method to create cross – functional teams that focus on the development of specific components of the sport vehicle. The main achievement of this method is to foster an effective and efficient design process through the implementation of a product oriented and appropriate organizational architecture that eases the communication between the designers. The Agile Team Building is performed concurrently to the implementation of an established management tool: the Design Structure Matrix. This tool helps to share information between resources and allows managing the interfaces of the product architecture in a better way.
After the first prototypes, we presented our Agile Team Building Method to the Top Management that considered it interesting for the whole organization. Future works will concentrate on how effectively implement the method. In the current state, this was a first case study used as a proof of concept of our method. Studying other applications of the method, using optimization algorithms, simulations and through dyadic case comparison, we aim to validate our method in order to find the best organizational solution at any one time so that it matches the dynamically evolving product.

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