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WORKFLOW ARCHITECTURE FOR A DISPERSED AUTOMOTIVE DEVELOPMENT NETWORK

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Abstract

Increasingly, stakeholders in the automotive development process are sited in dispersed locations; one of the major challenges has been to find a way for all those involved to participate effectively.

We propose a workflow architecture that permits globally dispersed stakeholders to enter the development process, quickly get up to speed, and contribute with meaningful and concise information. The workflow architecture consists of functional units, events, enablers, and rules. A fundamental part of the suggested process is the relocation of responsibility to stakeholders which are directly involved in the process steps.

We find that by organizing the workflow in such a way, the possibility to effectively include all stakeholders into the development process is good. Such a high level of participation is beneficial as it lessens the probability of late changes and error, and enhances the likelihood for product success and competitiveness. Furthermore, relocating responsibility enhances innovative, high quality work and promotes participation.

Keywords: Automotive development, Design information management, Integrated and distributed product design, Supply chain management, Workflow management, Work organization

1 Introduction

The development of an automobile is a joint effort of a number of actors, including the Original Equipment Manufacturer (OEM), suppliers, and external third party contractors. These stakeholders are in many cases dispersed around the globe. Creating a dispersed development network (DDN) is a socio-technical endeavor, where people (often with different backgrounds, beliefs, goals, and visions) and technical artifacts (e.g. software, hardware, and standards) have to interact to effectively and efficiently design desirable products[1]. Good collaboration in the development process is important due to a number of reasons; to name a few, late identification of problems within the development process are costly and time consuming [2], participation of all relevant stakeholders can boost innovation

[1] This terminology is adapted from Actor-Network Theory (ANT). For further information on ANT see e.g. Monteiro [1]

[3] and therefore increase the likelihood of product success, and it can change the nature of organizational boundaries in a way which improves cooperative relationships [4].

The problem is that without a proper structure of the workflow, it is extremely difficult to fully exploit the knowledge from all members of the development process. For them to work efficiently together, an effective workflow architecture has to be created; one which takes into account all relevant information from each stakeholder, at the right time, and in the appropriate format.

In this paper we set the stage for dispersed automotive development by examining today's status and trends. Thereafter we propose a method which ensures that all relevant stakeholders are integrated into the development process and able to contribute effectively and efficiently with information at the right time[2].

2 Automotive development

Developing an automobile is a complex venture. An average car has over 14.000 parts, many of which are developed in dispersed settings by different stakeholders. In this section we will set the background for automotive development by introducing the status and trends.

The automotive industry

Traditionally, the demand for automobiles has been higher than OEMs could supply. Today however, the established markets of North-America, Western Europe, and Japan are in effect saturated [7]. In addition, the automotive industries negative impact on the environment has caused governments to impose tough regulations on emission levels and the level of recyclables. Under these conditions, OEMs are under great pressure to develop desirable vehicles, and at the same time cut costs and follow legislative issues [8]. To meet these objectives, car manufacturers have launched a number of initiatives; to name a few, lean-manufacturing, outsourcing of manufacturing and design activities, platform engineering, flexible manufacturing facilities, mergers and acquisitions, establishment of facilities in low-cost countries, and greater focus on styling.

Outsourcing of manufacturing and design

Outsourcing has transformed the once almost completely vertically integrated automotive industry[3] into a horizontal one [10]. What started as simple outsourcing of non-core wage-intensive manufacturing has now expanded to outsourcing of knowledge-intensive activities, e.g. industrial design and development. In effect this means that developing activities are not undertaken in one location, but rather in dispersed settings. The prognosis is that by the year 2010, 80% of the automotive design work will be performed by the suppliers [11]. The Volkswagen AG has already reached this state, where 1200 of their worldwide suppliers do 80% of their overall design. One could so argue that 80% of VW's engineering capability and

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[2] One of the major challenges in creating a DDN lies in understanding how the users (OEM, suppliers, etc.) *really* work and not just how they *say* they work (or how the designers of the system perceive they work) [1: 77; 5: 128; 6: 42]. Conveniently, this topic is not within the scope of this paper.

[3] OEMs not only designed and made all automotive parts and assembled them into complete vehicles, but in many cases they owned the facilities which provided the raw material. As an example, in the late 1920's, Henry Ford owned several million acres of rubber plantation in the Amazon region, solely to provide rubber for Ford automobiles [9]

their intellectual capacity around product development is located with the suppliers and partners [12].

Global manufacturing and design facilities

OEMs run global manufacturing facilities, first and foremost to supply to local markets and in many cases to benefit from a lower wage-rate. In recent years more and more OEMs have opened up design centers in fashionable areas; the idea being that designers need to be close to the end-user to understand customer preferences[4].

Stakeholders

The stakeholders in the development process are the OEM, suppliers, and third party contractors. The OEM consists of numerous departments, most of which can contribute in one way or the other in the development process; e.g. research, design, marketing, and procurement. The supply base can be divided into a three tiered structure. A tier1 producer is normally a systems developer, providing parts, modules and systems directly to the assembly. Furthermore he usually owns proprietary rights to one or more systems and is responsible for product design, R&D, production, validation, warranty, and supply chain management [14]. Tier2 producers build parts or subsystems for tier1 producers. Finally tier3 producers supply raw material and services to tier1 and tier2 companies. Third party contractors include design studios, logistics providers, contract engineers[5], etc.

Collaboration in the development process

With the globalization of activities in parallel to the explosion of information and information technology, firms have evolved a dispersed product development process. Good collaboration can improve manufacturability and product quality, lower the cost of designs, improve time to market, generate greater buy-in and reduce late costly change orders; it helps incorporate ideas into design early on in the process and so gets the product right the first time and on time to market [16].

For the increasingly horizontal structure of the automotive industry, traditional collaboration tools are often inadequate. The telephone offers no data transfer and is only effective in one on one communication. E-mail offers only a limited file size and no version control and has limited access controls. Finally physical meetings are in many ways inefficient as they offer no electronic data [16]. Advances in micro processing power and adoption of Electronic Data Interchanges (EDI) and the Internet, have catapulted the potential of dispersed collaboration. With barriers to remote communication and collaboration reduced, there is a cultural shift to less centralized control [17]. More and more, such advanced collaboration is transforming and speeding up the development process. Collaboration between all the stakeholders implies that there has to be a creation and maintenance of relationships, security (firewalls, etc), and standards.

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[4] As an example, Ford opened a design studio in Soho London in 2000 where the aim is to *give designers the opportunity to explore other design mediums, and open their minds to a different way of creating products for the consumer* [13].

[5] In recent years, OEMs are having a harder time attracting and retaining engineers [15].

In this section we have tried to describe some of the key dynamics influencing automotive development and found that the dispersed development activities we see today are a direct consequence of (1) a more and more horizontal industry with increased outsourcing of manufacturing and design, (2) opening of manufacturing and design facilities abroad, and (3) advances in affordable IT solutions.

3 Workflow architecture for a dispersed development network

In this section we will introduce a method to control the workflow of a DDN[6]; the goal being to maximize the creative input from all relative stakeholders in a controlled manner.

The workflow architecture proposed here consists of functional units, events, enablers and rules. The functional units define the stakeholders or actors in the system, and the events are treated as a tool adding structure to the process. In addition, the enablers facilitate effective and efficient joint collaboration in between and during events, while the rules define the relations in the overall workflow architecture, or between functional units, events and enablers.

3.1 Functional units

This category consists of the stakeholders in the DDN; different OEM departments (e.g. design, development, manufacturing, procurement, assembly, logistics, and sales), suppliers (tier1, tier2, tier3) and third party contractors (e.g. design studios and contract engineers). The barriers of entry into the process should be low, as in theory this stimulates competition [19].

In the automotive development process hundreds of people are involved, distributed around the world with different backgrounds, agendas, mother tongues, work habits, education, age, wages, religion, ethnicity, etc[7]. A side-effect of including so many heterogenic[8] stakeholders into the process is that there is a sense of competition of displaying competency. It is important that such competition is harnessed in a positive way (quality, innovation, timeliness, etc.).

3.2 Events

The events discussed here are events which function as connection points between the functional units. These events are categorized in kick-off sessions, milestones, on demand

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[6] Setting up a DDN can only be successful if all users participate in its establishment and if (1) it makes a difference for the participants, (2) implementation of the results is likely, and (3) it is fun (Ackoff, 1974. From [5]). Ehn [5] finds that really participatory design requires a shared form of life – a shared social and cultural background and a shared language. This means that not only should the users participate in the design process but also the designers participate in use. Furthermore, implementing new technology has an effect on the overall organization. Levin [18] argues that technology is made up of material artifacts, skills, knowledge and culture and that one has to conceptualize technology transfer as forming a seamless web with organizational change. Successful technology transfer depends on human skills in enabling necessary organizational developmental processes to take place. We will keep these contemplations in mind but these issues are outside the scope of the paper.

[7] Hauser [16] finds that establishing the right culture is one of the most important tasks; product development teams acting autonomously (and in their own best interests) should take actions and make decisions with respect to defined goals in a manner that maximizes the overall long-term profit of the firm.

[8] Here meaning that the stakeholders have different agendas, backgrounds, levels of expertise, nationality, etc.

collaboration, and project-end sessions. Each event type fulfils a specific role in structuring the information flow.

Kick-off sessions form the start of the product development process with the physical gathering of all main stakeholders. The main objective is to form a joint understanding of the overall project, and for the participants to get to know each other [20]. The stakeholders decide upon main objectives, milestones, and Development Step Owners (DSOs). The DSOs are the stakeholders which take responsibility for the different life-cycles in the process. The decisions made in the kick-off meeting are accepted by all stakeholders with an official "sign-off".

Milestone events are held after a development step is completed. Milestone events are important arenas for information exchange and knowledge sharing during the project [20]. All DSOs should be present, along with the on-demand collaborators have to confirm their acceptance with an electronic "sign-off." The milestone sessions should also serve as an arena to display and reward extraordinary performance, e.g. exceptional innovation, professionalism, or indeed effective collaboration. Such recognition for good work motivates stakeholders to improve the quality of their work and level of performance.

On-demand collaboration is used as the basis for daily project collaboration and coordination to ensure proper project progress between milestones. When information is needed from stakeholders which are not DSOs, on-demand collaboration can be initiated. Ideally, on-demand collaborators can be summoned quickly into the process, get concise information about the problem, evaluate, feed information into the system, and exit the process. Here it is vital that the on-demand collaborators get information which is presented in a way fitting to their background, and not be over-whelmed with irrelevant information[9].

Project-end sessions are sessions which enable the development team to analyze how the development process was executed as a whole; what went well and what not. All relevant material should be documented and made accessible to stakeholders. Furthermore, substantial key learning experiences can be presented, future aspects for the developed product discussed, possible variants along the horizon. The sessions should also serve as an arena to award stakeholders for extraordinary achievements, e.g. due to quality of work, savings, innovation, good collaboration, etc.

3.3 Enablers

The enablers are a set of new elements that, when combined, will assist the process of bringing all the elements into a joint, powerful collaborative platform. A standardized, collaborative design system forms the technological infrastructure. Using a collaborative design portal is identified as a key element in creating powerful workflow architecture. Using this as a platform ensures that all stakeholders have full access to important information throughout the process. Software and common use of language are examples of enablers.

[9] Alternatively, any stakeholder which feels that he might be able to contribute to the development step can enter the development process and offer assistance. Key motivation for such self-initiated involvement would be responsibility and so recognition for a job well done; such recognition possibly leading to further and/or larger contracts. Using the same logic, the on-demand collaborators which are summoned into the process are motivated to perform quality work as they are officially responsible for their work and so gain from a job well done and vice versa lose from unprofessional conduct. In an open-ended dispersed development setting, this argument plays an especially strong role, as the barriers to switch partner should be relatively low.

Software and hardware

Powerful and moderately priced off-the-shelf systems offering a combination of CAD (Computer Aided Design), CAM (Computer Aided Manufacturing) and CAE (Computer Aided Engineering) are easily obtainable. Stakeholders can virtually put together a system of parts and so explore the interrelated effects of motion on the complete product or subsystem – not just the individual parts. A designer models parts and connects them with joints and constraints to produce a fully functional computer model of the full-system assembly. The user then applies forces and motions and runs the model through a series of physically realistic 3D motion tests [17]. In recent years, a major focus of software developers has been to enable collaborative use of CAD/CAE/CAM systems. Similarly on the hardware front, there have been tremendous advances, both in processor speed, information network velocity, data storage, graphics execution, etc. [21]. Collaboration software and hardware is seen to be a key-enabler in dispersed development and a lot of effort is put into improving the overall experience for the user. An important and widespread application of inter-organizational computer networks is the Electronic Data Interchange (EDI), which refers to the computer-based exchange of standardized business-related information between buyer and supplier firms [3].

Common understanding

Words have different meanings to different people. This can e.g. be due to previous experiences, background, nationality, education, age, or areas of interest. Language as a means of communication requires agreement not only in definitions, but also in judgments (Wittgenstein, 1953. From [5]). This means that intersubjective consensus is more fundamentally a question of shared background and language than of stated opinions. In using a DDN, it is of vital importance that all participants reach common understanding of the language used.

Workspaces

Previous research efforts at NTNU and in the Norwegian oil industry (similar to the automotive industry in complexity and number of overall contributors) strongly supports the notion that implementing a collaborative design portal can enhance collaborative performance in dispersed teams [22]. In particular, web-based workspaces makes it possible to effectively leverage the collaborative methodology normally used within companies to include external contributors as well, connecting OEMs with their partners in virtually integrated value chains. Hence, implementing a collaborative design portal can facilitate new working modes with greater flexibility, allowing on-demand problem solving sessions and more effective project coordination. This can improve the workflow and reduce lead times.

3.4 Rules

Integrating the functional unit events and enablers, demands a clear set of rules. These rules are set up to ensure seamless collaboration, maximizing the effectiveness of the time spent in the process.

Development step owners (DSOs)

For each development step, a group of teams and individuals are officially responsible. They have to ensure that the project runs on time, and that all relevant stakeholders are included into the process. In figure 1[10] we see as an example that the members of the OEM development and marketing team, along with some of the tier1 suppliers have responsibility for the process, i.e. are DSOs. Typically the stakeholders which have the "strongest connection" to the step are chosen as DSOs.

Theoretically being chosen as a DSO should be a challenge and sought-after. This is due to the fact that the DSOs are responsible for the outcome, and again if the outcome is positive, the work is recognized favorably in form of reputation or/and in other ways (e.g. new-projects, in monetary disposition, etc.). In the same way non-core DSOs should be eager to attribute with ideas and information.

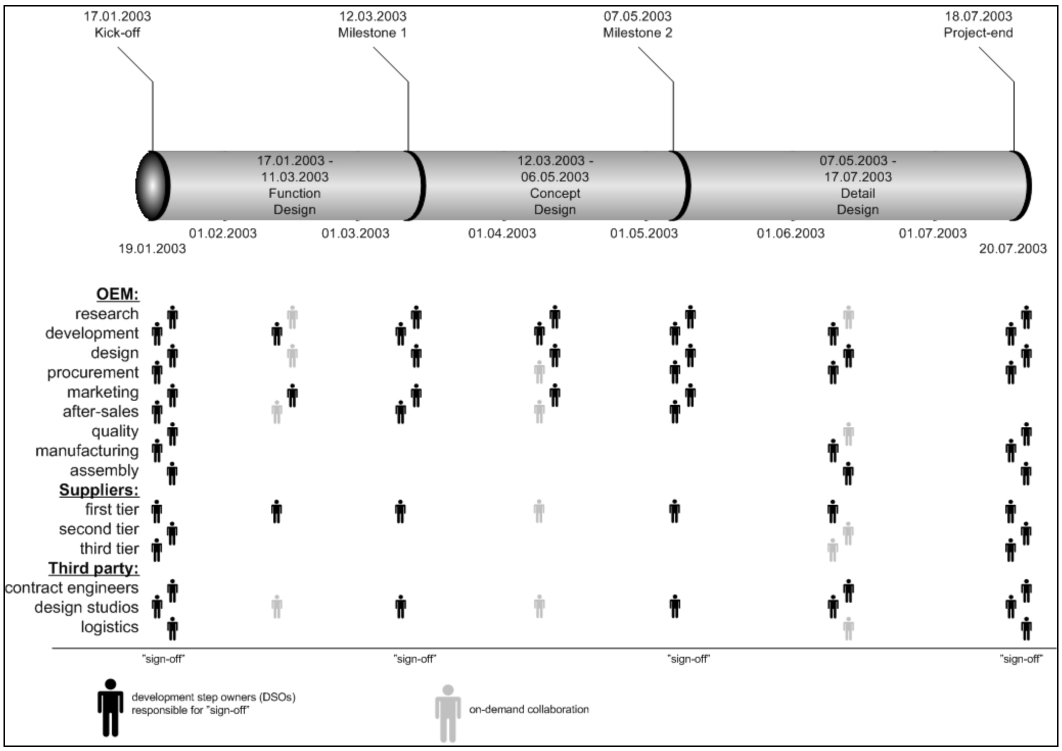

Figure 1. In the different steps of the process, stakeholders are either "development step owners", on-demand collaborators, or inactive.

Sign-off

After the kick-off and milestone sessions, a formal "sign-off" is conducted by the DSOs and the on-demand collaborators. This is of great significance as it enforces reflection upon the work performed, whether it is satisfactory or whether changes need to be made. The sign-off is also the incentive for DSOs to perform well as it displays responsibility.

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[10] The illustration is simplified to the extent that some stakeholders are integrated together; e.g. there exist numerous first tier suppliers, only some of which are responsible for the step. Likewise the OEM has multiple research departments dispersed globally, only a few of which may be involved.

4 Results and comments

We understand from contemplating the state of the automotive industry that there is a general trend towards dispersed development. Such dispersed development can be difficult due to its socio-technical nature, where people with different backgrounds have to collaborate with often new uncharted methods.

The paper offers a preliminary theoretical method of how to design a dispersed development network, and perhaps even promote a new paradigm in design approach, where multiple-minds work synergistically in healthy competition; stimulating innovation, quality, and the general attractiveness of the final product[11]. By following the workflow architecture, the functional units can contribute as on-demand collaborators or as development step owners. The rules, events, and enablers secure that all get equal opportunity to contribute, in a timely and unambiguous manner.

The workflow architecture may seem overly simplified, but it should serve well to demonstrate a *general* effective structure which facilitates the efficient participation of all stakeholders in the development process[12]. The process has not been industry tested yet. Neither have potential users been included in the creation of the process[13]. The actual potential of the improvement remains therefore hypothetical.

5 Key conclusions

Outsourcing of design and manufacturing stimulates the development teams to be innovative and deliver good quality work. This is due to the fact that the OEM is in most cases free to choose whichever supplier he finds most capable. Add these conditions to an organized dispersed global development network with easy access, and the likelihood of positive competition is even higher.

We believe that the workflow architecture suggested in this paper has a potential to increase the effectiveness of dispersed development networks. The main hypothetical contributions of the process being that (1) all relevant stakeholders are included in the development process, (2) no time is wasted as information is presented on a need-to-know bases, (3) innovation is stimulated as there is a competition amongst stakeholders to perform well, (4) the iterative nature of the process lessens the likelihood of late changes, (5) healthy competition is generally increased as more stakeholders have a chance to perform, and (6) the likelihood of market acceptance is higher as joint minds, each with know-how in their specific area, contribute to product attractiveness throughout the whole development process.

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[11] Hutchins [23] finds that that the properties of groups of minds in interaction with each other, or the properties of the interaction between individual minds and artifacts in the world, are frequently at the heart of intelligent human performance.

[12] The chance of being deemed technocratic and perhaps paternalistic is risked as it is important to leave a number of factors out for the sake of clarity; Hatling and Sørensen [24] criticize system designers who conduct *boundary work*, i.e. where designers construct rather solid boundaries between themselves and users, not only in terms of computer systems design competence, but also in terms of the understanding of the users' organization.

[13] There are numerous reasons for participation in the workplace [25]. Ehn [5] finds that designer(s) and users of the system have to work together and understand each others needs.

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