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Redesigning Mature Products for Sustainability

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Abstract

This contribution will discuss engineering design projects with various environmental and sustainable objectives. The automotive industry is facing a major vicissitude regarding the system layouts of their products. Given the rapidly increasing demands for environmentally acceptable and sustainable vehicles, developed even faster and under increasing competition, one could expect a future, or a period of transition where a "market pull"-situation will exact design methods more adapted for new propulsion technologies such as fuel-cells, bio-fuels, hybrid configurations and so forth. When looking at two-wheeled vehicles it's also a matter of a dramatic change in the safety requirements that would affect the design process in a similar way.

This paper presents studies made regarding development of two-wheeled vehicles with strict safety, environmental and sustainability requirements. It also describes what happens when a very mature product, such as a conventional motorcycle undergoes dramatic changes with propulsion system and safety features and becomes technically immature, but still has to preserve its traditional values in the eyes of the consumer. During the last two years, the Department of Mechanical Engineering at Linköping University has conducted different projects dealing with these issues using rapid, low cost, demonstrator development, together with digital models. The demonstrator is used as a vehicle to evaluate the integration of technology, as well as less tangible aspects such as ergonomics, drivability, appeal, visual impression etc. This approach has proven particularly fruitful when dealing with new technologies with a high level of innovation. The rapid nature of these projects also makes them suitable for exploring digital collaboration tools aimed for controlling and speeding up the design process.

Keywords: Innovation, Sustainability, Electric Motorcycle

Introduction

The products designed and produced by the automotive industry may in many ways be considered mature. Mature in the sense that innovations regarding these products rarely concern the product as a whole, but rather will be found at the lower levels of the system layout. It's obviously not very likely that three-wheeled vehicles will drive the four-wheeled car out of competition, not unless it will be marketed as a different product with superior benefits. The four-wheels-concept early became the dominant design, just like the concept of propulsion; the internal combustion engine (ICE), which has been the without competition most used propulsion technique for consumer (motor driven) vehicles ever since it was introduced some hundred years ago.

However, today's environmental situation demands different solutions to the propulsion task. This is not surprising news to the automotive industry, but the predicted efforts needed for converting the products in time might be underestimated. The oil price has increased rapidly lately. This is mostly due to political instability among important oil producers, but also uncertainty regarding the future demands from the rapidly developing industries in China and India. In addition to this, if the period of transition from fossil fuel engines to sustainable alternatives is shortened, it also means less time for market adaptation, i.e the consumer needs time to feel comfort about buying a mature product that builds on technology much less mature. Furthermore, global competition is likely to increase the demands for tools that speed up the development process in general. The products produced buy the automotive industry in particular, tends to become even more complex and at the same time represent shorter life cycles.

Given the above, the automotive industry may find itself in need for tools that supports the design process so that mature products can be rapidly and drastically redesigned but where the output is under control. This paper will put focus on two different approaches with potential of doing just that. The first chapter presents theory regarding the dynamics of innovation. The next chapter will discuss the benefits of using low cost demonstrators during the early phases of the product development process, exemplified with an electric motorcycle [1]. This is followed by thoughts on how multidisciplinary models can be used for simplifying the evaluation of complex product concepts with a high degree of innovation. These models can support product development teams when lacking specific know-how, needed for example when upgrading well known mature product with new unfamiliar technology.

Dynamics of innovation

Utterback [2] describes the general dynamics of product innovation. When a new product with a high degree of innovation is introduced, different design approaches will be explored, gradually improving the performance of the product. Eventually a dominant design evolves which accelerates the product performance. After major advances have been made, a period of more incremental and infrequent change sets in, as indicated by a levelling off of the product performance curve, showed in 0.

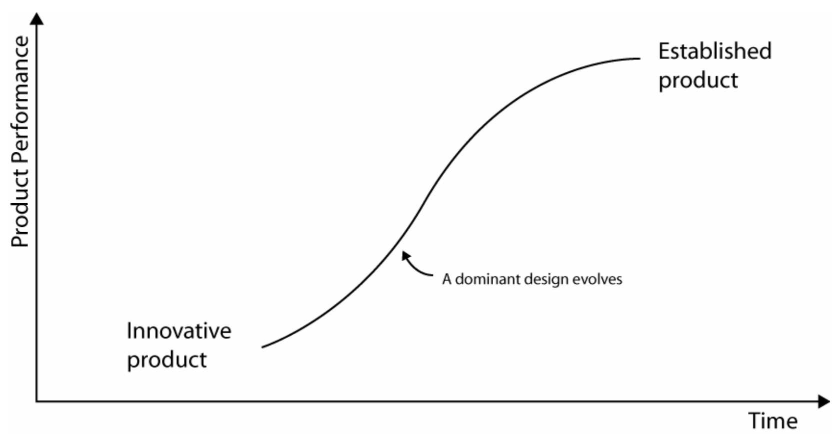

Figure 1. The effect of an emerging dominant design on product performance

This behaviour of the product evolvement can be observed with most products. In the automobile case, the internal combustion engine became the dominant design and is now the established solution for automobile propulsion. Furthermore, the internal combustion engine of today can without doubt be considered mature. Advances mostly comprise fine-tuning efforts, and major improvements such as fuel injection are rarely seen.

Utterback also describes the effects of an invading technology. The fate of the typewriter is often referred to as the standard case in which the early mechanical typewriter was followed by several waves of innovation; the electric typewriter, stand-alone word processors and today's computer based solution.

When an invading technology first appears (t_1, 0) the established technology generally offers better performance or economy compared to its highly immature challenger. The development of the new technology might be trigged by an emerging dominant design and therefore enters a period of rapid improvements. Eventually the newcomer performs better than the established technology (t_2, 0) and past it while it's in a stage of slow innovative improvements. The new technology is still under in a period of rapid improvements and naturally it will take over as the design of choice in the eyes of the market, while the former established technology naturally dies off.

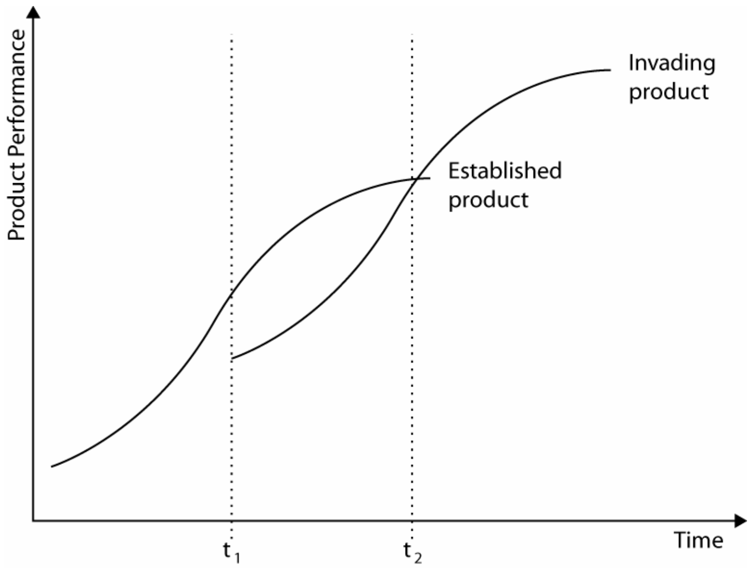

Figure 2. The effects of an invading technology

The ICE case

The scenario described in 0 is driven by the enhancement of product performance. The invading product simply has to perform better. Otherwise it will not drive the established technology out of competition. However, when put in this way, this situation does not seem to apply in the case with the ICE and its forthcoming sustainable successor. Today one may predict that the days of ICE will not end due to an invading technology performing better. The ICE will most probably be replaced due to high fuel prices or maybe even legislations due to restricted level of emission. It's also possible to stress that ICE as the technology for consumer vehicle propulsion will have to sign of to a successor with much less performance. To prevent this from happen the industry would need to find means that more rapidly leads to an emerging dominant design the ICE successor. This is described in 0.

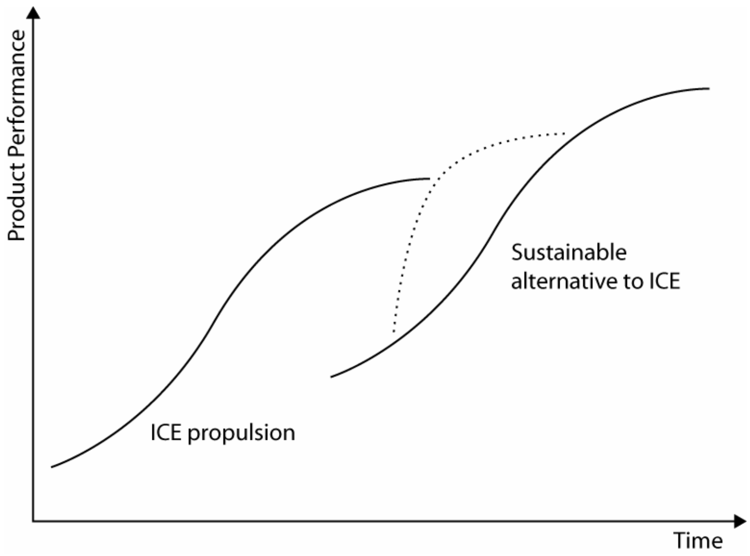

Figure 3. The relationship between the ICE technology and its forthcoming successor in terms of product performance.

Demonstrator as an innovation booster

Previous chapter stresses the need for tools or methods that speeds up the product development/innovation process. This chapter will present the usage of low cost demonstrators as a potential candidate to such a tool or method.

The ELiTH demonstrators

During the last three years the Dept. of Mechanical Engineering at Linköping University has conducted product development projects aimed at developing functional motorcycle demonstrators, called ELiTH. This is done within large project courses at the mechanical engineering masters program.

These projects are partly motivated by the arguments presented above. When extending the reasoning in the previous chapter to the motorcycle case as a whole one will find several areas where it's easy to predict a need for drastically redesign in a not to far future. The conventional motorcycle not only lacks sustainability regarding propulsion but has also become criticized for poor safety features. This becomes very clear when comparing with the large amount of safety technology that has been developed for automobiles during the last decades. During the same time motorcycles has become even more powerful and consequently more dangerous to drive. Initiatives regarding safety features are few.

Sweden is among those countries with the lowest number of traffic fatalities in relation to its population, and the Swedish parliament has ratisified a programme called "Vision Zero" which aims at a future with no deaths or seriously injured. According to Swedish statistics [3] from 1995-2003, approximately 50 persons are killed every year when driving a motorcycle or scooter, which equals some 10 percent of all casualties in traffic accidents. During 2004 alone 76 motorcyclists were killed which is 15 percent of all casualties. Furthermore, according to the same figures, the risk of being killed driving a motorcycle is 13 times higher per driven kilometre, compared to driving a car. Hence, if ambitious programmes like "Vision Zero" are followed by other countries, or maybe adopted by the EC, the motorcycle will need drastically redesign in order to meet the goals of these programmes.

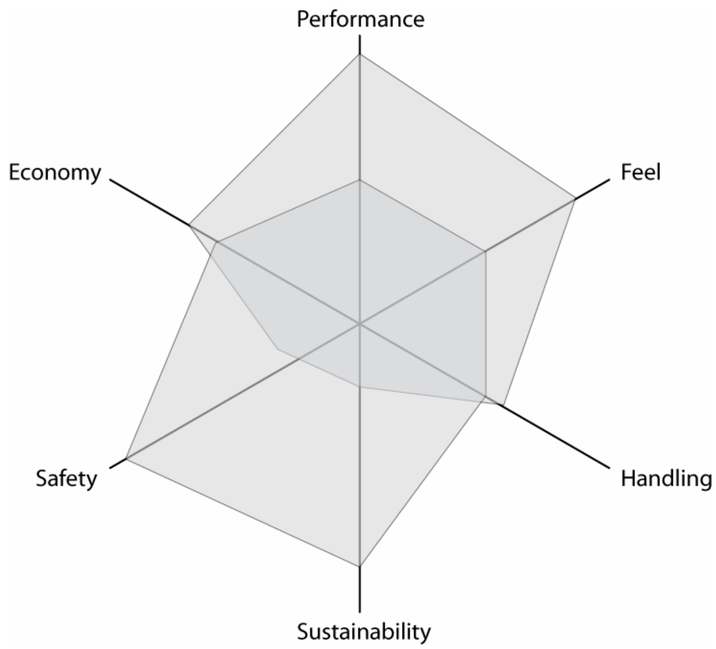

Figure 4. The figure explains a conceivable shift in focus regarding the products of the automobile industry.

0 displays some product properties that are usually taken in to consideration when designing motorcycles today. Furthermore, 0 shows a dramatic, but likely shift in focus that the developers have to face. Apart from safety, sustainability will most likely become much more important as environmental demands aimed for the automobile industry also will affect the motorcycle industry. As efforts are put into safety and sustainability, one could predict a renounce regarding feel and performance properties. The usage of demonstrators has proven particularly useful when evaluating these properties in cases when new and highly innovative concepts are being explored. [1] In addition there might be additional characteristics that a new technology introduces, that are not fully anticipated at the onset. With an electric drive system, the absence of engine noise produce a totally different "feel" that might balance some of the lack of performance.

Although some of the characteristics of a motorcycle are difficult to predict, others like performance can be calculated with reasonable effort. In order to achieve the optimum balance between the system characteristics design optimization can be used. From the demonstrator it was found that the safety equipment added a weight of about 15 kg to the motorcycle. In this way the influence of the safety system on safety and handling can be modelled as a weight penalty. Other characteristics, like appearance, can to some extent be regarded as decoupled from performance, and does not affect the choice of driveline component so much.

There has been two ELiTH demonstrators designed since 2004 [1], a third is currently being assembled. The projects are carried out by students under supervision from a PhD student acting as the project leader. One of the academic staff assumes the customer role. These are examples of efforts that are put into the project course in order to imitate the industrial situation. The students are addressed with the task of developing a working demonstrator within less than six months. Typically the group of students are divided into smaller groups each exploring different parts of the design space. After a few weeks the groups rejoins and agrees on the concept that should be demonstrated. 0 shows the outline of the first ELiTH project.

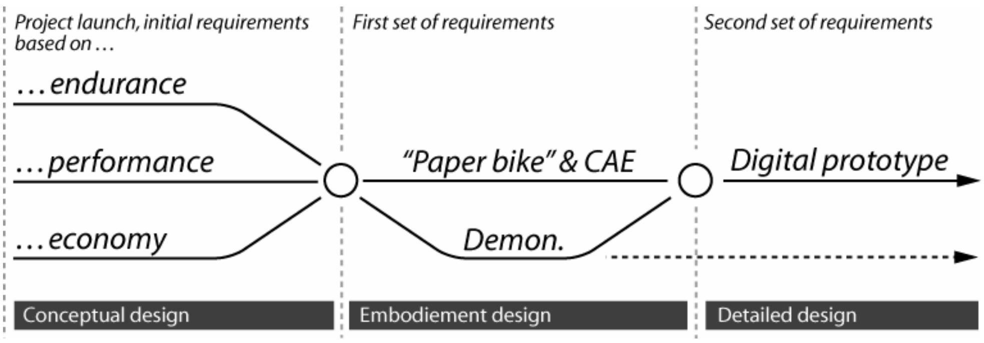

Figure 5. Project plan of the first ELiTH project.

Although the ELiTH projects have been slightly different in terms of initial tasks and outcome, there are some conclusions that can be made regarding the usage of demonstrators in order to speed up the product development process.

The role of the demonstrator is to demonstrate a limited number of properties or functionalities related to the developing product. There are also other roles. The most important, and also the ones that distinguish a demonstrator compared to a traditional prototype, can be summarized as follows

- To demonstrate the viability of a new concept
- To demonstrate the viability of a new technology
- To validate parts of the digital model
- To spot potential problem areas in the final product, thus defining the requirement on what technical areas that has to be incorporated in a digital model and subject to further analysis and development
- To refine the requirements on the product itself, since some requirement are not obvious until a physical manifestation of some kind, has been realized
- To provide inspiration and a vehicle for communication. The "reward" of actually seeing some hardware, as a result of the design effort, is a strong incitement for all involved parties in a project

Prototyping can in some cases be described as a “design-build-test” loop, but it is not always the case since one of the first issues is to design the goal itself [4]. Unlike a traditional prototype the demonstrator has no intention of being progressed towards a finished product, but can be used as a testing area where ideas are easily realized and evaluated. Developing a demonstrator within a project should be seen as a supporting activity among others, supplying different information for usage in the design process. Furthermore, a demonstrator seems to be most suitable when exploring new technologies.

Figure 6. The ELiTH demonstrators; ELiTH 2004 (upper left), ELiTH SSSV 2005 (upper right), early design study of the ongoing ELiTH project (lower left and right)

0 shows the two first ELiTH demonstrators and the developing digital model of this year's project. The physical demonstrator is developed parallel to a corresponding digital model. The idea is that the demonstrator should feed the digital model with information in order for it to become more focused regarding what needs more attention in digital modelling. Unlike the demonstrator, the digital model is treated as a representation of the forthcoming product. Hence, there is no digital demonstrator. Furthermore, this puts pressure on the digital model regarding flexibility with a strict top-down approach.

Tools for the future - Distributed multidisciplinary models during early phases of product development

The ELiTH projects have an outspoken ambition to find tools which can speed up the product development process. This is an absolute necessity if physical results will be achieved within less than six months and the low cost demonstrator is one result of that ambition. Additional tools and methods have also been discussed. A future potential approach to this matter is based on the following circumstances:

- Research at the Dept. of Mechanical Engineering has resulted in tools for distributed multidisciplinary models using web services. By wrapping computational tools into a web service, they can be integrated and accessed by any other application supporting web service communication regardless of computer platform or operating system. [5]

- The objective of design analysis is to obtain information about the nature of the design solution, and how it can be changed in order to fulfil the requirements. Here different matrix methods are useful, since they can be used to display the mapping of relations between system parameters and system characteristics.
- During the ELiTH project courses presented above, the students used PLM-systems in order to organize their work efficiently. The ongoing project is using UGS' Teamcenter Community (TCC) as a collaboration platform. TCC is basically a sharepoint web-server with additional TCC webparts.

The obvious next step is to merge distributed multidisciplinary models with collaboration tools such as Teamcenter Community. The Sharepoint technology used by TCC would be particularly suitable if the distributed models mentioned above could be transformed into webparts. Furthermore, the Sharepoint interface makes extensive use of spreadsheets and there is also a close connection to Excel.

The general purpose of doing this is to make tools for concept modelling easy accessible for designers that are unfamiliar with the domain that are being explored. There is a connection between this approach and the one presented in the previous chapter. The demonstrator is also used for exploring new unfamiliar domains that are put together with previously well known.

Conclusion

The rapid decrease in product life cycle coupled to an increasing complexity in products, and rapidly changing product requirements means that more integrated ways for product development are needed. This means a tight coupling between both technical disciplines and non-technical disciplines. The automotive industry in particular is facing different prerequisites for further development of their often mature systems, such as cars and motorcycles. This is due to increasing oil prices and changing requirements regarding sustainability. If a shift in use of technology becomes faster than expected, the industry may find itself in need for tools that speeds up the process of exploring new highly innovative technologies when implemented in mature systems. This contribution has exemplified the propulsion system as such a system affecting the performance, but the reasoning is also applicable to properties like safety, feel and handling. An example is given where the usage of low cost demonstrators supports the design process during its early stages. The demonstrator may show the viability of a new technology and are able to point out areas of the developing concept that needs more attention. It can also provide validation data for models used in the next design stage.

Furthermore, additional techniques with similar purposes are suggested. By making multidisciplinary models easy accessible from PLM-systems designers would be able explore concepts within unfamiliar domains. Like the demonstrator, these tools would act as easy accessible instruments for evaluating concepts.

References

[1] Hallberg, P, Krus, P, Austrin, L. 2005. ”Low cost demonstrator as a Mean for Rapid product realization with an Electric Motorcycle Application”. Conference paper, ASME 2005 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, Long Beach, California, USA, September 24-28, 2005.

[2] Utterback, J M. 1996. ”Mastering the Dynamics of Innovation”. Boston, Mass. Harvard Business School Press. ISBN 0875843425.

[3] Swedish Road Traffic Inspectorate. 2005. ”Svåra olyckor med moped och MC”. Memorandum TR 70-A 2005:3.

[4] Holmberg, G. 2003. “On Aircraft Development – Managing flexible complex systems with long life cycles”. Doctoral dissertation, Department of Mechanical Engineering, Linköping University. Also, Holmberg, G., Le Masson P. and Segrestin B. *How to manage the exploration of Innovation Fields? Towards a renewal of prototyping Roles and Uses*. Conference paper, EURAM Conference, Milan, 3rd-5th of April 2003.

[5] Johansson, B, Jouannet, B, Krus, P. 2003. ”Distributed Aircraft Analysis Using Web Service Technology”. Conference paper, Proceedings of SAE World Aviation Congress, Montreal, Canada, September 8-12, 2003.