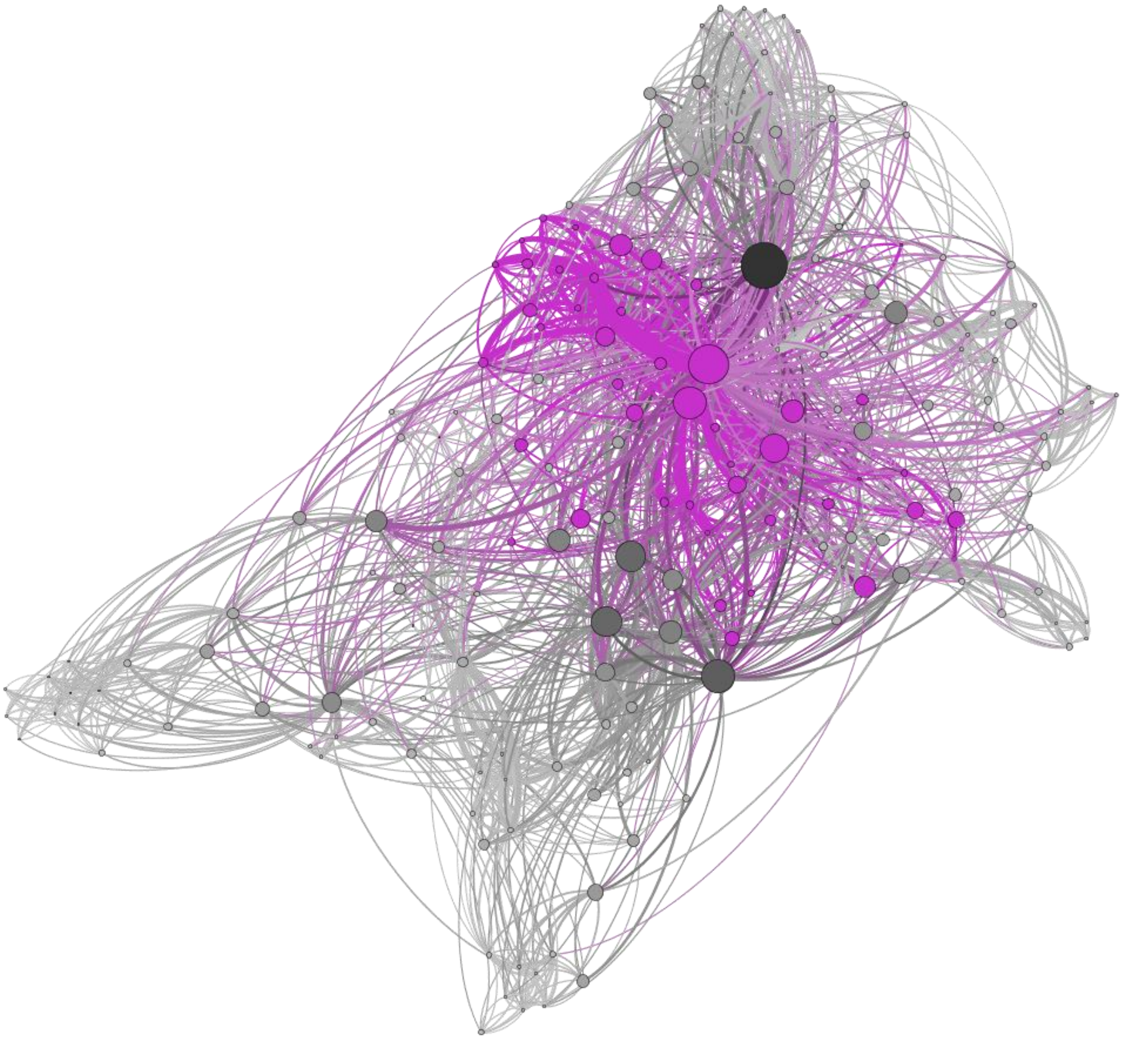
DESIGNING INNOVATION

Analyzing the role of design in a Design Driven Innovation process



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ABSTRACT

Although the various drivers of innovation have been discussed extensively by innovation scholars, design has only recently been acknowledged as a possible driver of innovation. This study builds on the study by Roberto Verganti (Verganti, 2008) on the Design Driven Innovation process and elaborates on the existing framework for this process. The framework on the Design Driven Innovation process suggests that upcoming innovations or changes in sociocultural context and technology are first picked up by interpreters who create visions. These visions are used by companies to create innovative products which are used by users in the sociocultural context. Therefore there should be a delay between the moment interpreters start discussing a topic and the moment it is picked up by the sociocultural context. This delay is equal to the time it takes a company to develop the vision from the interpreters into a product for the users. This consequence of the framework is tested in this study. The output from a group interpreters in the International Journal of Vehicle Design is analyzed and compared to the output of the sociocultural context, which is represented by newspaper articles in the New York Times. Word co-occurrence networks are used to identify the topic of the discussion at a certain point in time. Of the 12 identified topics, 8 topics show the expected delays. The total of 18 observed delays average at 5 years which is consistent with the expected time a company needs to develop a product. The main conclusion in this study is that an analysis of interpreters in an interpreter network may indeed provide useful information on changes in the sociocultural context and could thus be used to anticipate change. However, the limited amount of observed topics make future research in this field necessary.

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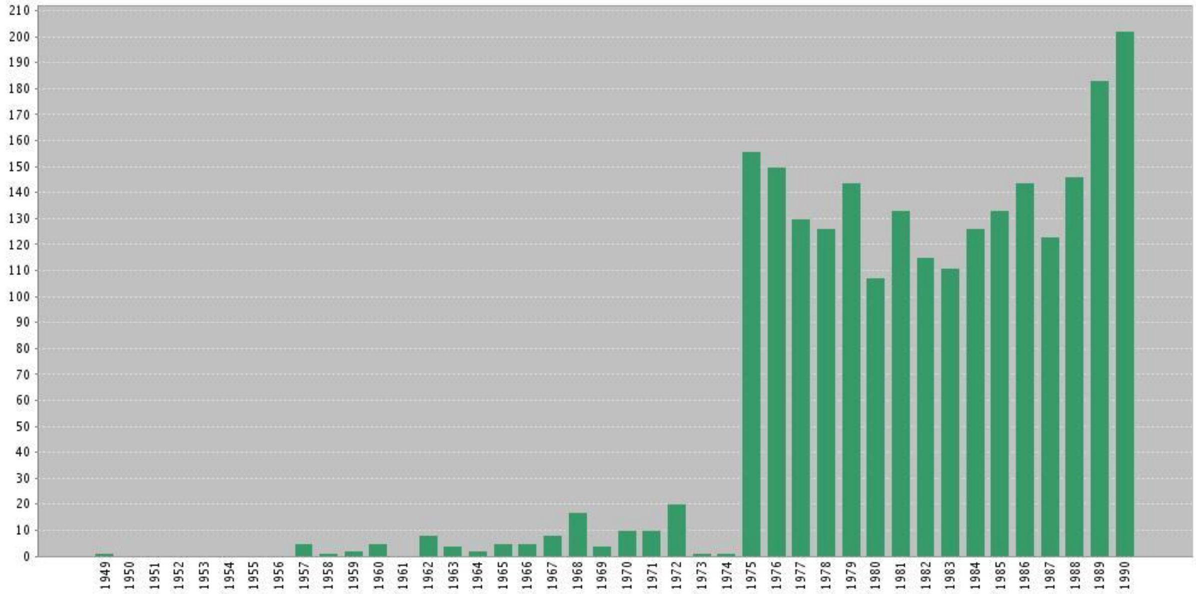
PREFACE

Here I will introduce the topic that attracted my attention after 3 years of training as an industrial designer at the Eindhoven University of Technology (TU/e) and 2 years of training in innovation management at the Utrecht University (UU). I became fascinated with the role of the designer in the innovation process. At the TU/e I learned that the designer could be, or maybe even should be, the starting point of innovation. The role of the designer is to interact with all the actors involved, like the engineers, users and marketing departments to create an innovative product. At the UU I learned that there are many different kinds of so called *drivers* of innovation, like a technology or the user but design was not discussed at all when looking at the drivers of innovation. So what is the role of the designer? And what is the role of design. The example below made me think even more about this topic and it was the first step towards the study in this report.

During the 1972 Olympic Games car manufacturer BMW revealed the brand new BMW Turbo Concept car. The Turbo Concept was not just any sports car, it was the first safety oriented sports car ever. Head designer Paul Bracq had a vision for what would become important in the future of sports cars, and cars in general, and he and his team of designers and engineers worked in the years before 1972 to create a concept car that reflected their vision of the future. The car was both from an engineering and design perspective something new. The Turbo Concept was the first sports car to feature ABS, radar-based distance warning and a lateral acceleration sensor (which is used today in the ESP system). The design eliminated blind spots, incorporated the roll-cage in the body and incorporated a special shock absorber to prevent deformation of the car in case of a collision at low speed. Although the BMW Turbo Concept did not become a production car it did serve as a template for many BMWs that were produced from the mid-70's onward. Did the vision and design of Paul Bracq and his team push or drive the innovation in the field of sport-car safety within BMW?

Although there might be various opinions on this specific case there is an interesting thing about it. When looking at the amount of scientific publications around the time the team of Paul Bracq started the development of the Turbo Concept, there are hardly any publications that write about 'car safety'. A little over 2 years after the presentation of the Turbo Concept there is a large increase in publications on this topic. Might there be a relation between the BMW Turbo Concept, designed from the vision of Paul Bracq and his team, and the sudden and sharp increase, shown in Graph 1, in scientific output on this topic a few years later? And if so, how could this help us understand innovation and the role of the designer (Paul Bracq in this case) in the innovation process?



Amount of scientific articles published on the topic of 'car safety'. Graph from Reuters Web of Science (x-axis represents the years from 1949 until 1990, the y-axis represents the amount of articles published)

INTRODUCTION

Innovation is known to be a complex subject in which lots of actors and influences should work together in order to be successful. Innovation scholars address these actors and influences in order to create a deeper insight in how innovation works. This helps to make innovation related decisions in companies and governments and allows a certain amount of steering and management of innovation. In this study the focus will be on a specific influence that might be able to drive the innovation process, which is design.

Drivers of innovation

The question on what drives innovation, or what the "*prime mover"* (Dosi, 1982) of innovative activity is, has been addressed multiple times, some of which will be discussed very briefly and somewhat stylized below as examples, and very different answers have been given over the years.

Joseph Schumpeter was one of the first to address *technology push* and *demand pull* as driving forces behind innovation, from his economically oriented approach. If innovation is 'pushed by technology' it means that there is a new technology available which, because it exists, results in new innovative products even when there is no market for this new product (yet). On the other hand, if the market has certain demands these demands will be met through new innovations, there will be developments and innovations that satisfy this demand (mainly due to economical drivers among the innovators). Later, in the Neo-Schumpeterian evolutionary tradition of economics, this evolved into the idea that innovation is a process which is balanced by both demand side factors and supply side factors, e.g. in a technological paradigm (Dosi, 1982). Many cases have been described using this knowledge, which has been proven very useful, however, there are cases that cannot be explained through technology push and/or demand pull. "*It is among the most basic tenets of innovation research that technology-push or demand-pull models cannot explain technological change adequately.*" (Peine & Herrmann, 2012, p. 1496).

In the 1970's Eric von Hippel investigated some cases in which technology push and demand pull were not sufficient to explain the observed innovations (Hippel von, 1976). In these cases some of the users where able to drive the innovation process and von Hippel addressed users as driver of innovation in his theory on *User Innovation*. User Innovation examines the possible role of the user in the innovation process. More specifically the role of the *lead users* in the innovation process, where the lead user is a user who experiences needs long before other users face this need and who benefits strongly from a new solution. In result, this user creates an innovation for own use which is picked up by other users and ultimately companies. The lead user in the User Innovation process can be seen as an entrepreneur. The main difference between the regular entrepreneur and in the User Innovation process is described by Heaflinger (Haefliger, Jäger, & von Krogh, 2010, p. 1198): "*Entrepreneurship, […], is a process where opportunity recognition precedes prototype development […]. In the case of user entrepreneurship, however, this process is reversed: users first develop prototypes and, while using and gaining experience with the new design, recognize a potential for commercialization of their product or service […].*"

A third, later study on the drivers in the innovation process is the work by Trevor Pinch and Wiebe Bijker (Bijker & Pinch, 1984) on the Social Construction of Technology (SCOT). They argue that in some cases *relevant social groups* are the drivers of innovation and that these groups drive innovation based on the meaning that they give to a new product. Their study focusses on *relevant social groups* which interpret innovations and 'battle' to establish a dominant design through certain closure mechanisms. Just like the previously discussed drivers of innovation, relevant social groups as the driver of innovation can be used to explain some cases, like for example the early developments in hydrogen storage technologies (van Lente & Bakker, 2010), but not all cases.

These 3 (simplified and stylized) examples of drivers of innovation above are only a portion of the identified drivers of innovation. Obviously, neither one of these drivers is able to explain each and every case of innovation. However, they all contribute to a canon that can be used for analysis and explanation of innovation cases. The above mentioned drivers of innovation have been studied extensively in the past decades and they are widely accepted and used for analysis. Quite recently a 'new' driver of innovation has been 'discovered': design. This study will focus on this specific driver of innovation because of the limited amount of knowledge on this topic.

Design as a driver of innovation

In the past decade design has evolved "*from the unspoken intuition of an individual designer*" (Verganti, 2008) to some kind of "*organizational process, […] to get closer to users and their actual needs*" (Verganti, 2008). The main reasons for this change is the increased attention to design as a tool for understanding users and innovation. This attention was mainly drawn by the success stories of, for example, design studio IDEO ((Kelley, Littman, & Peters, 2001); (Kelley & Littman, 2006)). Enormously popular books like 'The Ten Faces of Innovation' and 'The Art of Innovation' show how designers and design can play an important role in the innovation process mainly through a combination of learning about the user and a creative process.

The methodology described by Kelley is referred to as a *User-Centered Design* (UCD) approach. This approach is now used in more and more companies and organizations ((Venturi, Troost, & Jokela, 2006); (Mao, Vredenburg, Smith, & Carey, 2005)) but next to companies also scholars have adopted the UCD method in certain types of research ((Siebenhandl, Schreder, Smuc, Mayr, & Nagl, 2013); (Veinot, Campbell, Kruger, & Grodzinski, 2013); (Fitton, Cheverst, Kray, Rouncefield, & Saslis-Lagoudakis, 2005); (Johnson, Johnson, & Zhang, 2005), among others). The UCD method is based on large amounts of observations and interactions with the users. It takes a very anthropological approach to product development because it starts with a thorough investigation of the needs and desires of users. The user is involved in the design process and even before the design process as inspiration for new products, which should ensure products are tailored to the target group.

In the UCD approach the designer is usually part of the company, either in some kind of design department or as part of the engineering department, like for example described by the study during usability trails by Woolgar (1991) where engineering and design departments are entities within the company. Looking at this situation it can be described as a link in which a company (specifically the design and/or engineering department) creates a product which is sold to a user and this user is observed while using the new product by the company in order to create a another product, which is shown in Figure 1.

Figure 1. User-Centered Design approach according to Verganti (2008)

In 2008, Roberto Verganti observed another approach by certain design intensive firms in Italy, like Alessi, Artemide, and Kartell. These companies did not observe their users, as opposed to UCD and the usability trails from Woolgar (1991), but were still able to create innovation that was driven by design, for example the family follows fiction products by Alessi which was the first to use plastics in kitchenware. So how did design play a role in the innovation process of these companies? How are these companies different from UCD companies? And how are these companies able to create meaningful innovations without knowledge on their users? He named the approach the *Design-Driven Innovation* approach (DDI) and in contrast to the UCD approach it does not start from the needs or whishes from the user. The main reason for this is that the users are submerged in a "*sociocultural context*" (Verganti, 2008). This context is much like a paradigm in which it is almost impossible to come up with new solutions for problems because the context dictates a certain way of problem solving and a certain pattern of thought. Therefore users will not tell you anything radically different from the status quo, they are influenced by their context which makes it impossible to create innovative ideas. A famous quote by Henry Ford on the shift from transportation by horse to automobiles nicely illustrates this problem: "*If I had asked people what they wanted, they would have said faster horses*."

Because users might not be very helpful in creating innovation, DDI relies on the vision that a company has on what the future will look like. This vision is the basis for all the decisions that have to be made in a company, for example a decision on which product to develop next or decisions regarding *Intellectual Property Rights* (IPR). Such a vision in not merely based on sparks of creativity or randomness, like the term design is often associated with. Instead, these companies seem to have found a different source of knowledge than users, like in the UCD method. According to Verganti (2008) these companies acknowledge that they are part of a "*network of actors who explore future meanings and influence*" (Verganti, 2008, p. 444). This means that the company is not the only actor that tries to understand the changes in society or the changes in sociocultural context of users. Some of these other actors in the network could be: "

1. *Firms in other industries addressing the same user person in the same domestic context […] that are similarly willing to understand what people could want to experience in their domestic life.*
2. *Product designers, who have their own vision and language about domestic lifestyle, a vision developed by working with several different firms in the industry.*
3. *Architects, who design houses and living spaces.*
4. *Magazines and other media of interior design, which often develop domestic scenarios.*
5. *Suppliers of raw materials […].*
6. *Universities and design schools […].*
7. *Showroom and exhibition designers […].*
8. *Artists, who are recognized as "symbolic creators" […] and whose pieces eventually often appear in houses.*

" (Verganti, 2008, pp. 444-445)

These actors are all actively creating images of what the user might look like in the (near) future through their specific knowledge and experiences in their empirical field. The idea behind DDI is that, through interactions with these actors, it becomes possible to get a more comprehensive view on sociocultural changes and that combining knowledge from these actors increases the ability to create a successful innovation that anticipates societal change. This is what the companies in Verganti's (2008) study do, they maintain connections with several actors in a network to gain knowledge on what the user might look like in the future and from this they create their own vision of the future. The earlier mentioned 'Family Follows Fiction!' series by Alessi is an example of this since Alessi had the vision that kitchenware had to become more personal. To achieve this they asked designers for their interpretation of the research by Donald Winnicott on transitional objects from children (like teddy bears).

Due to this interaction with other actors in the same network it is possible to maintain a relatively small company that is able to output very interesting innovations, like the Italian design companies and more technological companies like Bang & Olufsen in Verganti's research. Verganti calls the actors outside the company that actively create visions on what the user might look like in the future *interpreters*, because they make interpretations of their own empirical field to create predictions. These interpreters actively interpret society and the user as well as new technological developments in order to create a more accurate view on what the future might look like. They are thus not limited to only observations of users (and the sociocultural context). Different interpreters can have different focus areas, e.g. product designers will have a different source of knowledge and different focus than suppliers of raw materials, where the first might interpret the behavior of users while the latter interprets the demands for certain materials. Companies that apply a DDI approach interact with a selection of these interpreters to create their own vision on the future.

Instead of the link presented in Figure 1, companies that apply a DDI process gain knowledge through interpreters rather than users. This situation can be represented by the scheme in Figure 2.

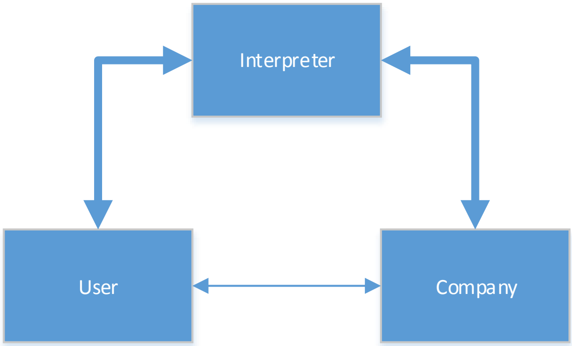


Figure 2. DDI approach according to Verganti (2008)

Like mentioned before, in a DDI approach the company is guided by a vision of the future. Verganti (2008) argues that this vision has to contain expected breakthroughs in product meaning, as well as expected changes in the sociocultural context. The company acts on these expected changes by making a *proposal*, which is a product that the company creates without empirical evidence that this product will become a success, which has parallels with technology push strategies. Verganti also observed that these companies are quite good at making innovative proposals, good enough to create a very successful company like Alessi.

Because the vision is created from the input of the interpreter network this implies that the interpreter network is able to say something meaningful about what can be expected in the (near) future in terms of changes in the sociocultural context and product meaning. Although the importance of product meaning and sociocultural context (which are strongly related concepts) for the success of an innovation is stressed by several authors (e.g. (Verganti, 2008); (Dell'Era & Verganti, 2011); (Utterback, et al., 2006)) the relationship between interpreters or the interpreter network and sociocultural change has not been investigated any further. Through some observations the relation has been exposed but there is no answer to the question how such a relation works and why it might be effective in a DDI approach. This study therefore seeks to gain more in-depth knowledge on the relation between the interpreters and the sociocultural context.

The main research question in this study is:

RQ. What is the relation between *interpreters* in an *interpreter network* and *users* in a *sociocultural context*?

The answer to this research question is another step towards a better understanding of the DDI process. Furthermore, by identifying the links between the interpreters and the sociocultural context it might become possible to measure these links and the performance of this innovation system over time.

The first step is to analyze the different links and interactions that exist or should exist according to the literature. The models in Figure 1 and Figure 2 will be elaborated so they will show the flows of information and products. After the models are completed the focus will be on the connection(s) between the interpreters in the interpreter network and the sociocultural context. To go deeper into these links it will be attempted to analyze and measure the links using network analysis tools.

Hypotheses

In order to answer this research question some sub-questions are posed which should provide a part of the answer. The first area of focus is the different relations that interpreters and the sociocultural context have. To find these relations and structure them, a theoretical framework will be constructed from the existing literature, mainly on DDI. For this the existing schemes in Figure 1 and figure 2 will be elaborated. It is expected that the link between interpreter and sociocultural context depends on the nature of the interpreter because there are many different kinds of interpreters in Verganti's study (2008).

SQ 1. What are the links between *interpreters* in an *interpreter network* and the *sociocultural context* according to existing literature?

SQ 2. What are the different *types* of *interpreters*?

The theoretical framework will be used to describe the links between interpreters and the sociocultural context. To go deeper into these links, and to show that the links actually exist, a semi-quantitative study will be conducted. To conduct this analysis both the sociocultural context as well as the output of the interpreters should be quantified. In this quantitative study the output of an interpreter and the output of the sociocultural context is compared over time. From the theory above we learned that in a DDI process the interpreters have a vision of what the sociocultural context will look like in the future. This means that if we would observe the interpreter over time and the sociocultural context over time we should observe a delay between the change in vision of the interpreters and the actual change in sociocultural context, where the vision of the interpreter changes before the actual change in sociocultural context.

SQ 3. How can the output of the *interpreters* and the *sociocultural context* be *quantified* for analysis?

SQ 4. Is there a delay between the changes in *vision* of the *interpreters* and the actual *sociocultural change*?

THEORETICAL FRAMEWORK

In order to investigate the research question some context is needed. In this chapter, several strands of literature will be combined to create a theoretical framework that can be used to investigate the research question. The framework will start from the User-Centered Design approach since there is a lot of knowledge on this topic and because it forms the basis for the knowledge on Design-Driven Innovation.

Developing a framework of DDI

The basis for the theoretical model is the scheme of User-Centered Design by Verganti (2008), which has been presented earlier in Figure 1. In this model there is a link between the company and the users and vice versa. According to the UCD method the company should base any product development on extensive observations of the (potential) users. These observations should reveal the *needs* that users have and the product that the company develops should fulfill this *need*. User *needs* should not be confused with *demand*, since *needs* refer to a quality, like a specific product feature, while *demand* refers to a quantity, e.g. the product can be sold to 100.000 potential customers (Peine & Herrmann, 2012). The link from the company to the users is the final product that is sold to the users. Through observations of the interaction between users and the new product another product development cycle can be started. Therefore the model from Figure 1 will now be represented as a continuous cycle (instead of the linear figure by Verganti).

Now that we have a starting point we will zoom in on the individual items of the model. Starting from the company side of the model we notice that the company takes observations of users as input and has a product as output. However, the company needs more than just user observations to create a product. Peine and Herrmann (2012) show that for innovation 2 types of knowledge are needed: *Use knowledge* and *Design knowledge*. The knowledge that is related to how a product is used by end users and what interfaces are needed for the user to access all the features of the product is called the use knowledge. There are several possible ways to acquire this knowledge. Peine and Herrmann (2012) identified 6 of these sources of use knowledge from literature. From these 6 sources the *direct representation* is the most used one in User-Centered Design. It basically means that the company (or the designers working within this company) create a representation of the end user through empirical investigations on the envisioned users, which is indeed the core concept of UCD. This approach is in design often referred to as *Personas*, which is a fictional representation of the end user. The design knowledge includes all the knowledge that "*[…] implies ideas about how a technology is designed, manufactured and marketed.*" (Peine & Herrmann, 2012). Design knowledge is therefore often integrated in the company; it's the knowledge and skills that the company has to create and sell a product in the first place, like engineers, marketers, etc.

Utterback et al. (2006), who also take a UCD approach to the role of design in the innovation process, add to this that a company also needs the knowledge about *product language* in order to develop (innovative) products. *"[Product language] concerns the signs that can be used to deliver a message to the user and the cultural context in which the user will give meaning to those signs."* (Utterback, et al., 2006). For the source of this type of knowledge we need to go back to the UCD approach that is used here. From the UCD approach we know that all knowledge regarding the user, or the context of the user, is almost exclusively acquired from anthropological studies of these users, which means that the knowledge about *product language* also comes from observations of the users.

All the knowledge that the company gathers, the design knowledge, use knowledge and knowledge about product language are combined to get to the final product. This process is guided by the direct representation of the user and *inscribes* the way the company expects the user to interact with the product (Woolgar, 1991).

In Figure 3 the company part of the model in Figure 1 is elaborated to incorporate the above discussed concepts.

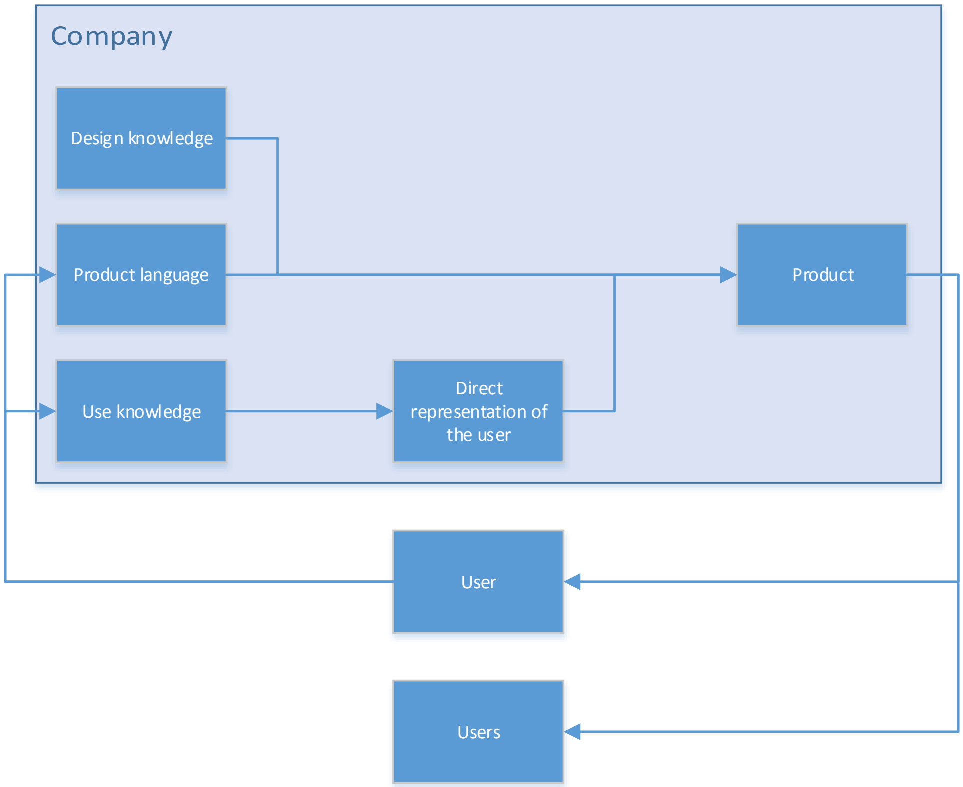


Figure 3. Elaborated model of User Centered Design

On the user side of the model there has not changed much. However, the model from Figure 1 is a little too idealistic in the sense that it assumes that the company has an interaction with all the users the product is sold to. Although this might be true in some extreme cases, i.e. a company with a very small user base like an aircraft manufacturer, such a company will be more of an exception. A more realistic assumption is that the product is sold to many users and some of these users will be included in the anthropological studies that the company conducts to gain use knowledge and product language knowledge. Therefore not all users are included in the feedback loop, which is included in Figure 3.

From this framework on UCD we learn that the creation and development of innovative products in the UCD approach is based mainly on flows of knowledge from the company to the user and vice versa. Use knowledge, design knowledge and knowledge about product language are important. Furthermore we've seen that the company inscribes their representation of the user into the product.

Now that we have a starting point, with the UCD method, we can look at how the identified influences, like the 3 types of knowledge, are present in the DDI method. The main difference with this approach is the extra actor (the interpreter) that becomes the link between the company and the user. This extra actor influences the flows of knowledge and also the inputs for the company.

DDI does not start from observations of the needs of users. However, use knowledge is still important for all innovations, which is also stressed by von Hippel (1994). The main difference between the UCD approach and the DDI approach is the way through which use knowledge is gathered and used within the company. Verganti (2008) shows that certain companies do not gather use knowledge themselves (or to a very small extend) but that they rather rely on interpreters, like shown earlier in Figure 2. For the company this means that the gathering of use knowledge and also the creation of user representations is done by an external organization. The company gathers use knowledge and visions from multiple interpreters in a network and this is used to create an own *vision* of what the user will look like in the future. Although use knowledge can come from other organizations the firm still needs design knowledge within the company itself to create and sell the final product, because knowledge on how to use materials or how marketing works are not bound to a single product and are part of the design knowledge. Again the company *inscribes* into the product how it expects the future user to use the product (Woolgar, 1991) however, this time it is based on the design knowledge and vision that the company has. This means that the company doesn't inscribe an image of how current users would use this product, like in the study by Woolgar but that it creates an image of what the user might look like in the future and that it inscribes how that future user will use the product.

The knowledge that the company has to gather as input from the interpreters should be enough to create a vision of the future. Such a vision should contain possible, or even expected breakthroughs in the future on a technological level, the level of the sociocultural context and product meaning (user level). Furthermore it should contain expectations on changes in product language (Verganti, 2008).

The interpreters deliver this input for the vision. The input consists of their own vision and possible use knowledge that they've acquired from their own empirical field. In some cases the interpreter will write the vision down but in most cases the vision will be tacit and not well accessible. Interpreters can generate use knowledge, which they also use to create their own vision, in different ways like *non-representation, implicit representation, indirect representation, direct representation*, *co-creation* and *domestication* (Peine & Herrmann, 2012). Which one of these is used depends very much on the type of interpreter. Interpreters can have 3 different types on which they base their vision for the future, although most interpreters will cover 2 or 3 of these types at the same time.

1. *User inspired interpreters*; who construct their vision through experiences with users

2. *Technology inspired interpreters*; who construct their vision through observed technological developments
3. *Environment inspired interpreters*; who construct their vision through macro-level developments, i.e. changes in the sociocultural context.

User inspired interpreters have an empirical field that is really close to the (end-) user. An example is product designers because they interact with users on a daily basis, e.g. to test their prototypes, to get inspiration or maybe because they're users themselves. User inspired interpreters will often use UCD methodologies and anthropology as their main source of knowledge. An example of this is the study by Woolgar (1991) where usability trails were conducted with users and early prototypes. In these trails the users were observed closely but without interrupting in order to understand the problems and needs that the users had. User inspired interpreters gain knowledge from their field, which is the user, and use this knowledge to make predictions on what users might look like in the future.

Technology inspired interpreters are usually not involved with end-users but they operate on a higher level. The main sources of their knowledge and vision is technology. They can, for example, be R&D related companies or producers of technologies but also local importers or retailers of technologies. They have lots of knowledge on specific technologies and also on the history and current developments of that technology, much like Gordon Moore who even created a law for the number of transistors on integrated circuits (often referred to as Moore's law). This makes them capable of creating a vision and predictions on technological developments in the (near) future.

The group of Environment inspired interpreters is a group that has no, or very limited, connection with the end users but looks more at society as a whole. An examples of these interpreters could be artists. Art is often not created to satisfy the needs of a specific user or user group but it rather seeks to express the present 'state of mind' of society. The pop-art movement, with Andy Warhol, is a good and famous example of this as it captured the rapid changes in culture and economy in the late 50's and early 60's (Jameson, 1992). Environment inspired interpreters will make visions of the future based on perceived changes in the sociocultural context, like the economic and political status.

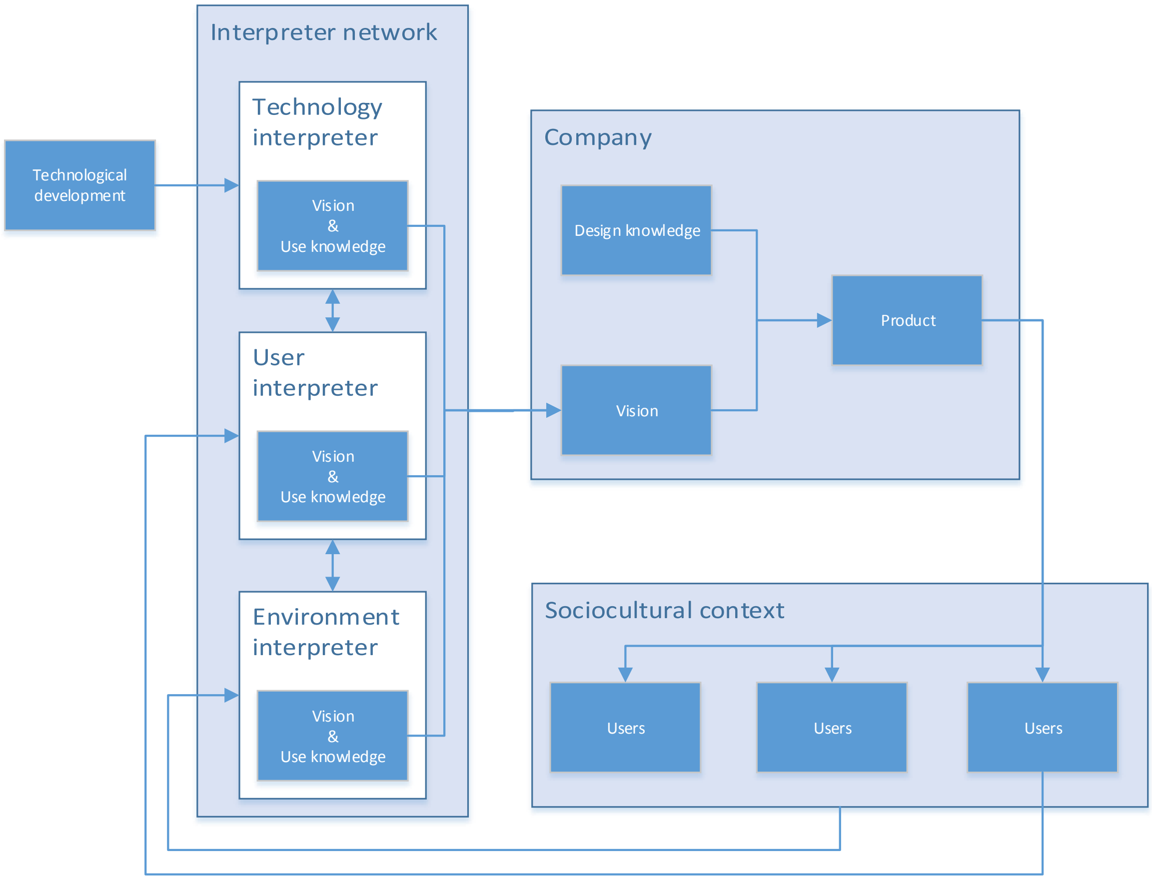


Figure 4. Elaborated DDI Framework

Figure 4 summarizes the insight described above on the flow of knowledge through the different actors in the DDI process. It shows that the company gathers information about the users, sociocultural context and technological developments through interpreters which are interconnected in a network. Note that the vision contains the use knowledge and knowledge on product language and that they are therefore not individually present within the company. Furthermore this model is written from the perspective of the company. In reality the company is not just connected to the interpreter network to receive visions and use knowledge but it is an active member of the interpreter network and it exchanges its vision for the vision of the other interpreters (Verganti, 2008). However, for the purpose of analysis this representation is more useful as it creates a better distinction between the different connections and flows of information.

So how does the framework in Figure 4 fit in the existing literature? First it will be positioned in the organization management literature to see if all the elements of a viable business are present. For this the "Model Innovation and Organization Structure" (MIOS) by Lekkerkerk (2012) will be used, which is based on Stafford Beers (1972) VSM model in combination with the 'Steady-Statemodel' by In 't Veld (1994) and SocioTechnical System Design literature from de Sitter (1998), Ashby (1956), de Leeuw (2000) and Nonaka & Takeuchi (1995). The advantage of this model is that it integrates a large portion of the existing knowledge on this topic and that it has been tested empirically. Lekkerkerk identifies 12 organizational functions in the literature above that have to be fulfilled by the company to be both viable and able to innovate. Furthermore he links these function together in a model, the MIOS in Figure 5.

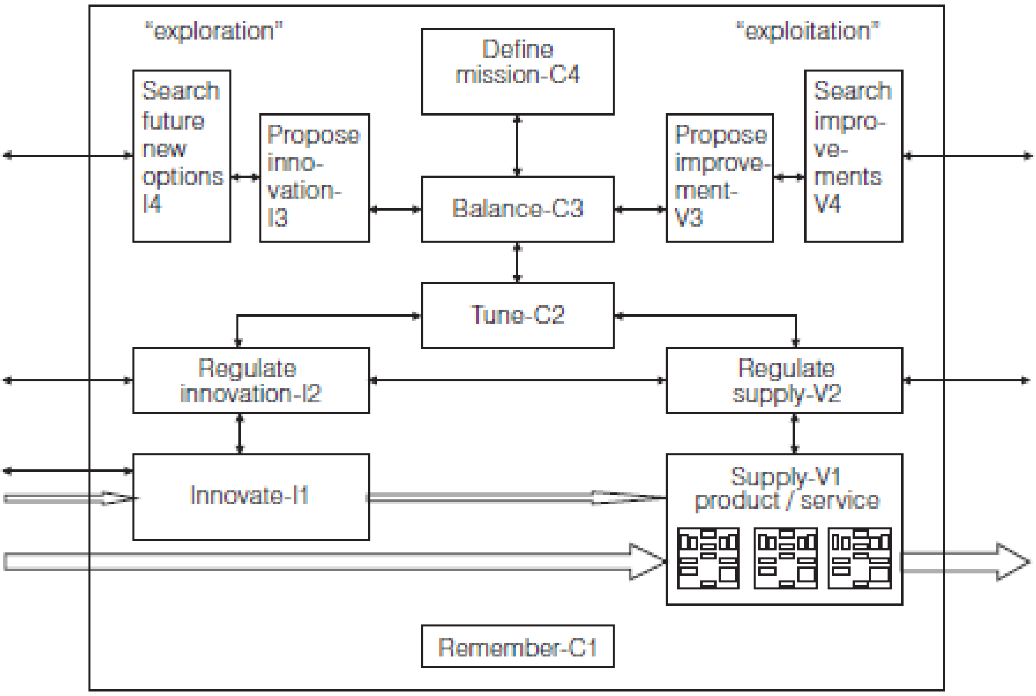


Figure 5. MIOS by Lekkerkerk (2012)

Table 1. Brief description of the functions in the MIOS (Lekkerkerk, 2012)

Name-code	Contribution of function to organization:
Supply product service-V1	Represents the primary process supplying products and/or services by transforming inputs in the required output. Includes recurring, order-related activities like logistic, sales, finance, procurement Includes supporting activities maintenance, facility management etc.
Regulate supply-V2	Operational regulation of the primary process including continuous improvement
Propose improvement-V3	Make project proposals for the best opportunities for improvement received from V4
Search improvements-V4	Search for and find ways to improve exploitation of current products, markets, facilities etc.

Innovate-I1	Carry out all approved innovation projects and improvement projects
Regulate innovation-I2	Operational regulation of individual innovation projects and operationally manage the portfolio of projects in progress
Propose innovation-I3	Make project proposals for the best future options for innovation received from I4
Search future new options-I4	Exploration of environment and search for future options for innovation, aimed at new and existing markets
Remember-C1	Organizational memory storing codified knowledge relevant for the organization
Tune-C2	Tuning V1 and I1 enabling smooth implementation of innovations and tuning the upper six functions contributing to the strategic planning process
Balance-C3	Balancing the project portfolio by strategically choosing which new proposals (from V3 & I3) should be funded and at the same time which of the projects in progress should be continued, paused or aborted
Define mission-C4	Define the mission, vision and strategy for the company and deriving lower level strategies for supply and innovation including performance indicators and budgets

Table 1 shows a brief description of the 12 functions of the MIOS model (presented in Figure 5). The bottom half of the MIOS in Figure 5 (Tune-C2, Regulate innovation-I2, Regulate supply-V2, Innovate-I1 and Supply-V1) is the representation of the actual production, regulation and implementation of existing products and innovation projects in the company. I1 and I2 are responsible for the management of innovation projects and the execution of these innovation projects. V1 and V2 are responsible for the management and execution of the final product production. These 4 functions are regulated by the central function C2. Looking at the framework in Figure 4 these functions should be performed within the boundaries of the company, although the actual production may be outsourced to a certain extend (Lekkerkerk, 2012). Because the production of the final product and the implementation of the innovations in the production process are not particularly interesting for the analysis of the DDI approach these functions will be summarized by the item 'Implementation and production' in the framework. The output of this block is the final product that can be transferred to the user. The input of this block is both the design knowledge and the vision of the company. The design knowledge is needed for the execution of the production, because it includes for example knowledge on materials, production processes and marketing. For the other input of this block we first need to look at the other part of the MIOS first.

The upper part of the MIOS is not directly related to the production of the final product. The search for new opportunities (Search future new options-I4) and the search for improvements of current products and services (Search improvements-V4) is, with the DDI approach in contrast to the MIOS, not limited to the boundaries of the company. This means that these functions can be fulfilled by the interpreters and the interpreter network, which consists of external organizations. These functions therefore appear to be ‘outsourced’. This is possible because these companies see themselves as a part of the interpreter network (Verganti, 2008). The interpreter network is thus part of the company although it actually consists of external organizations.

The search results, which are the results of ‘Search future new options-I4’ and ‘Search improvements-V4’ and thus the output of the interpreter network, are used in ‘propose innovation-I3’ and ‘propose improvements-V3’. These functions are the transition from the interpretations, with the expected opportunities in the future, to proposals that can be turned into improvements or actual products. The resulting proposals should be prioritized because, for example, the company is not able to handle all the innovation projects at once. This is done by the function ‘Balance-C3’. According to the MIOS this function balances the innovation and improvement projects through the mission, vision and strategy that the company has. The mission, vision and strategy are created by the function ‘Define mission-C4’. In a DDI approach these are created from the interpreter network (Verganti, 2008) because they depend on the vision for the future.

These insights from the MIOS model result in more detail at the company side of the framework and these insights are now present in the new framework in Figure 6.

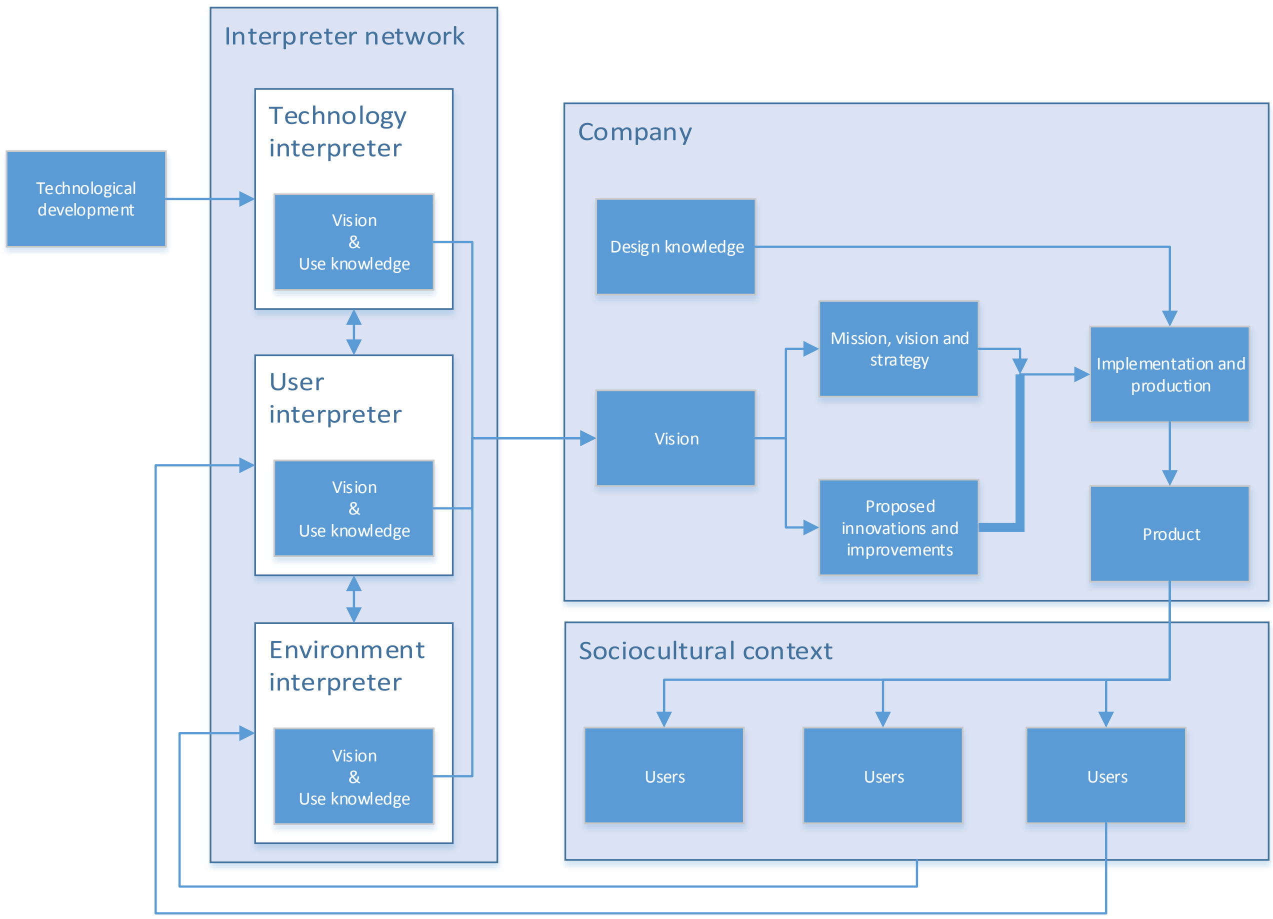


Figure 6. Final theoretical model of Design Driven Innovation

Because all the functions of the MIOS are now fulfilled and linked properly this framework of DDI could indeed result in a viable company and innovation system. However, the DDI approach somewhat fades the boundaries of the company when compared to the MIOS, as it 'outsources' or depends on other organizations for some of the functions that make for a viable business. Because some of the viable parts of the company depend on external organizations DDI can therefore be qualified as a high risk type of business.

We've established that DDI could result in a viable business. So let's zoom in a little more on the visions. In his article, Verganti (2008) observed that the interpreters create visions about the future. So what can be found about this observation in the literature? Is there any clue that interpreters indeed create (and share) visions? The definition of the interpreter is quite broad, which might be considered a good thing because it allows for a large variety of data to enter the design driven company. However, the problem is that it is difficult to say something about interpreters in general. Therefore we'll take a look at some of the interpreters Verganti observed. The full list is quoted in the introduction and can be found in Verganti (2008).

The first interpreter we'll discuss is other companies, which can be competitors or companies that have for example the same consumer base or technology. From the MIOS it already showed that the balancing and selection of innovation projects and improvement projects was based on the mission, vision and strategy that the company has (Lekkerkerk, 2012). This is the case for any company. Other companies are thus likely to have a vision on the future as well, and if they're part of the interpreter network they might share their vision.

Another type of interpreter is the (product-) designer. The importance of a vision for designers is addressed by the authors Kollmann, Sharp and Blandford (2009) who found that designers themselves consider a vision to be one of the most important themes within their profession. Furthermore they stress the importance of sharing the vision among the design team. Hummels & Frens (2009) add to this that the rapid changes in society are driven by the vision that designers have on the future and by research on the socio-cultural context.

Also in design education the role of a vision is stressed. In the book "Eindhoven designs" the approach of the Industrial Design faculty of the Eindhoven University of Technology is explained. Figure 7 below, which is in this book, shows the designer surrounded by society. The designer is a part of society and is in constant interaction with the society through reflection. The designer is surrounded by 10 competencies, which can be developed to a certain extend. At the core are 4 circles that are interconnected and that determine which features will be included in the final product (which is the center circle). The top circle contains 'envisioning' which is embedded in the society. For the educational program this means that the designers are trained to envision society and the transformations in society. Through the activities in the other circles they create a final deliverable (which is in the center of the figure).

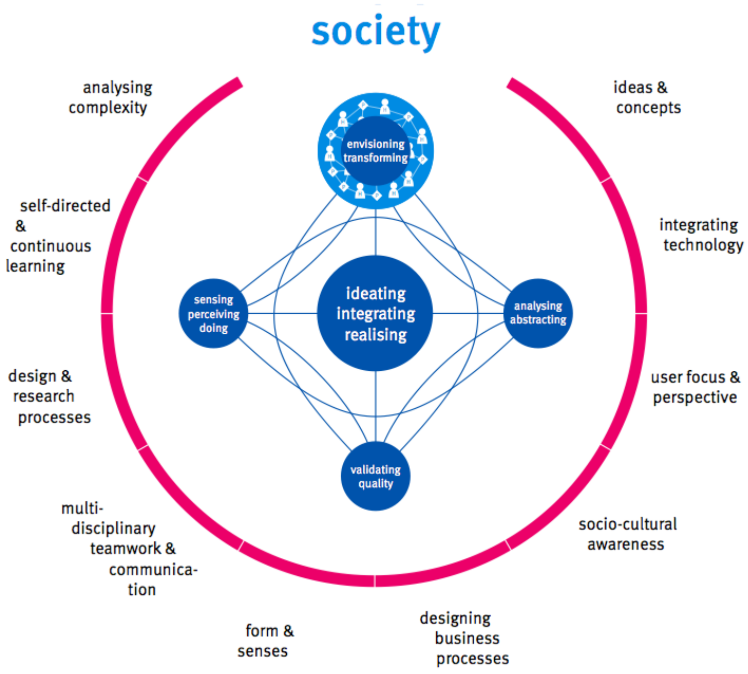


Figure 7. Competencies of a designer, from 'Eindhoven Designs'

In these few examples it has become clear that at least the above mentioned interpreters create visions on the future which they use to guide their activities and products.

Use of the framework

The framework in Figure 6 will be used in this study to zoom in on a specific component of the DDI method, the relation between interpreters and the sociocultural context. The framework exposes the different inputs and outputs that the interpreters have and shows the different types of interpreters. From the framework we can see that, when investigating the relation between the interpreter and the sociocultural context, the type of technological interpreters can be excluded from the analysis because they have no connection to the sociocultural context. However, their focus may influence the vision of the company.

It is also visible that the users are a part of the sociocultural context. To investigate the relation between interpreters and the sociocultural context the relation with users thus can be used although it does not provide a complete picture. To get the complete picture we need to address both the user interpreters and the environment interpreters.

The framework also clearly shows that the company cannot start the product development process until it receives and processes the visions from the interpreters. This means that changes in the output of the interpreters takes time to reach the users. In the analysis of the relation between interpreters and sociocultural context it can therefore be expected that the changes that occur at the interpreters can be observed at the users with a delay.

METHODOLOGY

In this section the selection of data sources will be discussed followed by the methods for data collection and data analysis.

Selection of data sources

From the theory on DDI, as described above, it can be seen that DDI is a complex system in which at least 8 actors (although the list is not inexhaustible) could create outputs which can be used by a company to create a vision for the future. Apparently such a vision can lead to a successful business and successful innovations. Like Verganti describes in his article, most of the knowledge that is involved in creating the vision is tacit of nature. It cannot be found in a codified way and is therefore very difficult to analyze with a quantitative method. The group of 'product designers' or 'artists' for example, is very difficult to analyze because of the tacit output they produce, which is their designs, and the somewhat fluid interpretation of what a designer is, raising the question who to investigate.

However, at least one of the actors that Verganti identifies does create a codified stream of knowledge and this knowledge is recorded very structured and precise in different databases. The interpreter 'Universities and design schools' outputs rather large quantities of codified knowledge in the form of journal articles, books and even some patents. This knowledge can be accessed through databases like the Web of Science from Thompson Reuters, and larger amounts of articles can be analyzed in relational databases to create an overview of the topics they cover at a certain point in time.

Universities and design schools can be qualified as a user interpreter because they teach their students to actively involve users in the design process. As shown earlier in Figure 7 which is used in the department of Industrial Design at the University of Technology in Eindhoven, exploring and validating in context (with the user), is a key activity of a designer. The same figure also shows that envisioning and transforming society is another key activity. This shows that design students (and staff), at least in Eindhoven, are actively taught to be both a user interpreter and an environment interpreter. This makes this group very suitable for the analysis of the link between interpreters and the sociocultural context, as they are involved in both links identified in the theoretical framework. Most educational institutions don't articulate their educational goals and strategies as well as the Industrial Design department in Eindhoven. However, in this study it will be assumed that they largely share the ideas and that they can be regarded as both user interpreters and environment interpreters.

Universities and design schools are not the only ones who publish articles in scientific journals. Therefore these journals will contain, next to the user interpreter and environment interpreter perspective, also the technological interpreter perspective. Because the research question does not focus on one interpreter in particular this is not a problem for the analysis. However, it's important to realize that the observations are not solely of a single type of interpreters.

Now that we have a way to analyze the output of the interpreters in a quantitative way the same is needed for the sociocultural context and users. One way to approach this is to look at direct output of the users themselves. Social media, such as Twitter or Facebook, could enable the analysis of large quantities of data that is created by their users. However, these social media have not been around very long. Facebook for example is only 10 years old at the moment of writing and in the early years there were only very few users. This makes social media a promising source of data in the future but not very useful in this study.

Another way to approach the output of users and the sociocultural context is an indirect approach. An example of this is journalism. Journalists describe situations in society and individual cases of people. The output can be in spoken words, images (on radio or television) or in text, like in magazines or newspapers. In this study the output in text will be used because the text can be analyzed in a similar way as the scientific output of the interpreters. The LexisNexis Krantenbank is a large database that contains newspaper and magazine articles from all over the world since 1980. It is possible to search this database for a specific topic and to output the results for analysis, similar to the Web of Science database.

Now that there are 2 sources of data the actual data can be collected and used for analysis.

Data collection and analysis

The scientific data from the interpreters will be collected first. Initially it was attempted to identify the design departments within the Web of Science database. These design departments were identified through a search in the database on research departments that include the word "design" in their name and that are part of a university or design school. Some research groups had multiple names or abbreviations, all of which are included in the search. The total amount of search terms used for data collection were 62. However, after the first analysis of the output it turned out that the data was very contaminated with articles from other departments and research institutions. A large portion of the data had very little to do with actual design. Although the reason for this remains unclear another source had to be used.

To get more specific data the focus was shifted to design related journals. A list of design related journals was created from the Web of Science list of journals (Figure 2).

Table 2. List of design related journals in the Web of Science database

ISSN	Journal title	Amount of Articles	Period of publishing
1476-8062	INTERNATIONAL JOURNAL OF ART & DESIGN EDUCATION	437	2003-2013
1991-3761	INTERNATIONAL JOURNAL OF DESIGN	140	2007-2013
0957-7572	INTERNATIONAL JOURNAL OF TECHNOLOGY AND DESIGN EDUCATION	340	2000-2013
0143-3369	INTERNATIONAL JOURNAL OF VEHICLE DESIGN	2038	1979-2014
1571-0882	CODESIGN-INTERNATIONAL JOURNAL OF COCREATION IN DESIGN AND THE ARTS	86	2009-2013
0747-9360	DESIGN ISSUES	845	1995-2014
1460-6925	DESIGN JOURNAL	139	2009-2013

Given the limited amount of time for this research, only a single journal could be used in this study. The chosen journal is the International Journal of Vehicle Design (ISSN: 0143-3369) because this journal spans the largest amount of time and has the largest count of articles.

All the articles from this journal were downloaded and the SAINT ISI Parser tool was used to turn the downloaded data into a relational database. The relational database contains tables with the articles, the abstracts, authors, year published and more.

First the SAINT Word Splitter tool is used to break the abstracts into individual words. A stop-word list is used to reduce the occurrence of words without specific meaning (like the words 'the', 'or', 'and'). This process is repeated to split the words of the titles into separate words. The main reason to use both the titles and the abstracts is that the Web of Science database started collecting abstracts since 1990, therefore the articles from before 1990 will not have an abstract. In order to compare different moments in time the table with articles is split into different tables via queries, which contain the articles from a specific year. These lists per year are used to create lists of the abstract words and in which articles they occur per year. The same is done for the title words.

Microsoft Access was used to query the results for the articles per year and to get the words used in these articles. The resulting 57 tables (23 tables with abstract words from 1990-2013, 34 tables with title words from 1979-2013) are exported and loaded in an excel sheet to create pivot tables. Each pivot table has the articles on the horizontal axis and the words on the vertical axis. The pivot tables are filled with a

COUNT function that results in a value that corresponds with the amount of times a specific word can be found in a specific article. The resulting matrix, after turning the empty cells into zeroes, is turned into a DL format file. This file contains a header which states the amount of rows and columns are in the file, and the names of the rows and columns. At the end of the file is the matrix that was produced with the pivot table in excel. The DL format is useful because it can be read by the Pajek software which can take the matrix and turn it into a network. Because we are interested in the relation between the different words this 2-mode network is converted into a 1-mode network of the columns (which contain the words). A link between two words shows that these words are used in the same article and are thus related.

The 1-mode networks are loaded in Gephi, which is a piece of software that can visualize network data. Now that the data is collected (and formatted correctly) the dataset contains 57 graphs because each table is converted into a graph containing the relation between words in a specific year for the abstract or the title. Gephi has the ability to load graphs on a timescale and show the changes over time. Furthermore it has a clustering algorithm that groups together words that are strongly connected. The graphs were both analyzed individually as well as on the timescale because the individual level provides a higher level of detail but the timescale shows the occurrence of new topics in time.

The analysis of the graphs, described below, results in the topic which are being discussed by the interpreters in a certain year. The hypothesis is that these topics can be found in the output of the sociocultural context with a delay of at least the time it takes for a company to translate the output of the interpreters to a product. According to Griffin (2002) the average development time depends on the type of project, where incremental improvement projects average 8.6 months, New-to-the-firm projects average 36 months and New-to-the-world projects average 53.2 months (almost 4.5 years). However, the car industry which is discussed in this particular journal is known to have longer development times and product life cycles.

To investigate the output of the sociocultural context the LexisNexis krantenbank (the output of the sociocultural context) will be searched for the topics identified in the analysis. This database has some limitations. The most important limitation is that it is only able to display up to 3000 articles per query and that only 200 articles can be downloaded per run. Therefore it is very time consuming to analyze all the newspapers and magazines in the database. Instead, a single newspaper will be used. The New York Times was chosen as newspaper because of the large amount of articles published, the rich history (since 1851) and the worldwide coverage (26 foreign bureaus in 2010).

The output of the LexisNexis database is unstructured. Although this would not be a problem for a qualitative analysis it very much is a problem for a quantitative analysis and therefore the output first has to be structured. This is done by collecting the output from the database in HTML format. A piece of software in Python that is specifically developed for this study (by the author) uses pattern recognition to extract the data from the HTML files. This software formats the output similar to the SAINT ISI Parser software, which means that it creates a relational database of the articles. However, the LexisNexis database has a very poor quality for some of the fields. The 'title' field, for example, should contain the title of the article. However, in most cases it's empty or even contains other information like the name of the newspaper. The only (useful) field that is properly documented is the 'keywords' field and the 'full text' field. It is possible to use the keywords however, these keywords have been added by the LexisNexis database and not by the author of the article, which makes the keywords less reliable for reflecting the content of the article. Instead the full text will be processed in the same way as the abstracts from the scientific journal (splitting the words, removing the stop-words, create a pivot table, use Pajek to create a 1-mode network, create a graph of the words in Gephi).

The first analysis is on the graphs that have been created from the output of the interpreters. The graphs display the words used and their relations per year. For each year the Modularity Class function is used to divide the words in groups. Coloring of the nodes is used to distinguish the groups in the graph. Furthermore a Degree Range filter is used to filter out nodes that are less connected or not connected at all, and thus used in fewer articles. An Edge weight filter removes the less important links, which results in a more effective grouping of the words. The degree of centrality is represented by the nodes size.

To identify the topics that are being discussed each cluster or group of nodes is labeled with a term that reflects what the nodes have in common. Some of the groups will represent the topic that is being discussed while other groups will reflect the methodology that is used. Therefore the identified groups of nodes will also be classified, since the methodology related nodes are not important for this study. The resulting list of topics per year can be used as input for the search in the LexisNexis database (like described above).

The output of the LexisNexis search, after formatting, is analyzed in 2 ways. The first is create a graph in Microsoft Excel that shows the amount of articles in the results per year. This graph thus shows when a certain topic (the topic of the search) is discussed more in the newspaper compared to the other years. This is done for each and every topic. The second analysis is only done for 1 topic as it is a time consuming process, making the analysis of every topic not feasible given the available time for this study. For this analysis the output is split in individual years and for each year the network is created of the relation between words in the full text (splitting the words from the full text, removing the stop-words, create a pivot table, use Pajek to create a 1-mode network, create a graph of the words in Gephi). It has been attempted to create a timescale in Gephi containing all the graphs per year however, because this is a full-text analysis, there are too many nodes and edges to process (half-way the software ran out of memory, which had been set to around 5.5 Gb).

The final step in the analysis is to compare the data from the interpreters and the sociocultural context.

RESULTS

In this chapter the results of the analysis will be presented. In total 2038 articles were downloaded from the International Journal of Vehicle Design, ranging from 1979 to 2014. For the years 1979 until 1990 the titles have been used to create the graphs, from 1991 until 2013 the abstracts have been used. The full list of identified topics (151) can be found in (Appendix B). The topics that are interesting for this study are the ones that are not present throughout the years but appear at a certain point in time. The moment of first occurrence can be compared between the output of the interpreters and the output of the sociocultural context. Furthermore some topics appear multiple times throughout the years. General handling of the vehicle is for example a topic that is discussed almost every year and is therefore excluded from the analysis. This leaves 12 topics to investigate.

The 12 identified topics were analyzed like described in the previous chapter. This resulted in 12 graphs that display the amount of articles published in the New York Times per year on that topic (Appendix A). Next to this the topic of "Electric Vehicles" was used to create graphs per year in Gephi to look into the focus of the discussion. First the findings for the 12 topics will briefly be discussed and then the "Electric Vehicle" topic will be elaborated.

1. "Airbag" – The airbag was first mentioned in the International Journal of Vehicle Design in 1980 in which year the technique and system were discussed. The first real increase in articles in the New York Times is from 6 articles in 1989 to 16 articles published in 1990. The next 4 years the amount of articles increases even further to 46 articles in 1994.
2. "Alternative fuels" – Although the first articles on electric vehicles (which will be investigated separately) are from 1981 the first articles on alternatives for oil as fuel are from 1983. In this year the future of engines is discussed and this includes hydrogen as an alternative fuel. In 1992, 1994 and 1996 the discussion continues with the focus on the reduction of greenhouse gasses and global warming. The publication data from the New York Times show 2 strong increases in the amount of articles published. The first sharp increase is from 7 articles in 1988 to 45 articles in 1989. The second sharp increase is from 44 articles in 2005 to 111 articles in 2006.
3. "Car aerodynamics" – Although this theme is first discussed in the International Journal of Vehicle Design in 1982 it shows up in multiple years (1986, 1988, 1991, 2002) and the data from the New York Times shows a similar image with no specific peaks and articles on this topic throughout the years.
4. "Car safety" – Similar to car aerodynamics the safety of cars is a topic that is covered by the interpreters in the 80s and early 90s (1984, 1986, 1988, 1990, 1995). Also similar is the newspaper data. Although the topic of car safety does show various peaks (1983, 1991, 1997, 2003, 2010) these peaks cannot be linked to the interpreter data or vice versa.

5. “Car tyres” – The tyres of the car are first discussed by the interpreters in 1981 and 1982. In these years there are no articles published on the topic in the newspaper. In 1984 and 1985 the amount of articles in the New York Times increases to 16 and 23 respectively. The next discussion on tyres in the journal is in the years 1988, 1990 and 1992. The newspaper publications remain steady in these years until the year 2000, where the amount of published articles increases from 15 in 1999 to 100 in 2000. The final discussion on tyres in the International Journal of Vehicle Design is in 2004. The final peaks in the output of the New York Times in 2011 and 2013.
6. “Ethanol fuel blends” – First it has to be noted that this search results in both the output for “ethanol” as well as “methanol”, which can both be used in combination with gasoline to drive a car. Blending gasoline with ethanol or methanol was first described in 1985 in the context of engine performance. Later, in 1991 the topic is mentioned again but this time among other engine developments like hybrid engines and conventional engines. The last appearance in the journal is in 2009, which is the first year that blends of ethanol and diesel are a separate topic in the journal. In the New York Times there are barely any publications in the first years. In 1987 and 1988 the first (small) peak is visible. The output remains low until 2005 and 2006 with an increase to 28 articles published in 2006. The last major peak is in 2012 (27 articles).
7. “Fuel consumption” – This topic appears a few times in the journal, the first time in 1982 and then in 1986, 1995, 1997, 2007 and 2009. There appears to be no link to the data from the New York Times, which has peaks in 1981, 1990 and 2006, and the link might even be considered the other way around.
8. “Phone while driving” – Although the mobile phone was around for quite a while the first appearance of an article about the use of mobile phones in cars was in 2001, perhaps due to the commercialization of SMS text messaging in the late 90s. The main topic was the distraction that the phone could be for the driver. The New York Times shows a large peak in the year 2001, although the 2 years right before 2001 already showed an increase in articles published.
9. “Fuel emission” – Emission is discussed a lot throughout the years in the International Journal of Vehicle Design. However, in some years the topic is contributing to another discussion (like engine performance) and in other years it is a stand-alone topic. The most important years for the topic “Fuel emission” are 1980, 1997, 1998, 2003 and 2009. In the New York Times the topic is discussed throughout the years as well, although there are noticeable peaks in 1981, 1989, 2000 and 2007.
10. “Vehicle pollution” – This topic is strongly related to the fuel emissions. However, the topic is discussed separately in the journal in 1984, 1998 and 2001. The newspaper articles show a strong increase in 1989 (357% increase from 21 to 75 articles published). Furthermore there is a clear peak in 1999 and a peak in 2007.

11. “Vehicle sensor” – This topic has very much to do with the introduction of various sensors in vehicles, like the sensors for airbags, air-conditioning and various engine control systems. The interpreters discuss sensors mainly in 1984, together with microprocessors and engine control systems. The newspaper output shows an almost steady increase in output with a strong peak in 2003 and 2013.

The 12th topic, which has been elaborated more extensively, is the topic “Electric vehicle”. The first time this topic occurred in the Journal of International Vehicle Design is 2 years after the journal started, in 1981. This year the journal published an article on the impact of hybrid and electrical vehicles on society. In 1982 the discussion focused on the influence of hybrid and electric vehicles on the energy consumption in the USA. In the years that followed the discussion shifted away from the electric vehicle and towards alternative fuels in general, like oil with ethanol blends and hydrogen vehicles (like described above) although the electric vehicle option never really disappears.

For the “Electric vehicle” topic all the publication data of the New York Times were downloaded and analyzed in Gephi per year. For the first years (1980 – 1984) the graphs in Gephi provide no insights, probably due to the very small amount of articles. Therefore these years are analyzed by hand, reading the content of the articles. The discussed topics are below.

1980 – Call for electric vehicles, which are needed to decrease the dependency on oil

1981 – Ford announced the electric car back in 1966 but still no commercial available car; Very limited achievements for electric vehicles; General disappointment in the electric vehicle

1982 – Electrical vehicle produced by Mazda (hybrid car); Abundance of oil reduces the need for electric vehicles, which is unexpected considering the recent energy crisis

1984 – Hurdles facing an electric car, on problems that might occur during the development of the electric car

The authors of the newspaper articles are rejecting the idea of an electric vehicle, by showing the abundance of oil, the limitation of electric vehicles at that time and by showing the hurdles ahead of the electric vehicle. The authors of the articles in the International Journal of Vehicle Design, on the other hand, show the opportunities for electric vehicles, like the influence on the energy consumption in the USA and the diminished dependency on oil (which was scares in 1979 and 1980 due to the energy crisis).

In the years from 1985 until 1988 the published articles seem to discuss small projects in individual cities and some announcements by small ventures. The graph from 1988, for example shows a link between Electric, Corporation, Venture and Kansas (Figure 8). The reports show a more positive attitude towards electric vehicles by showing successful projects in certain cities or states.

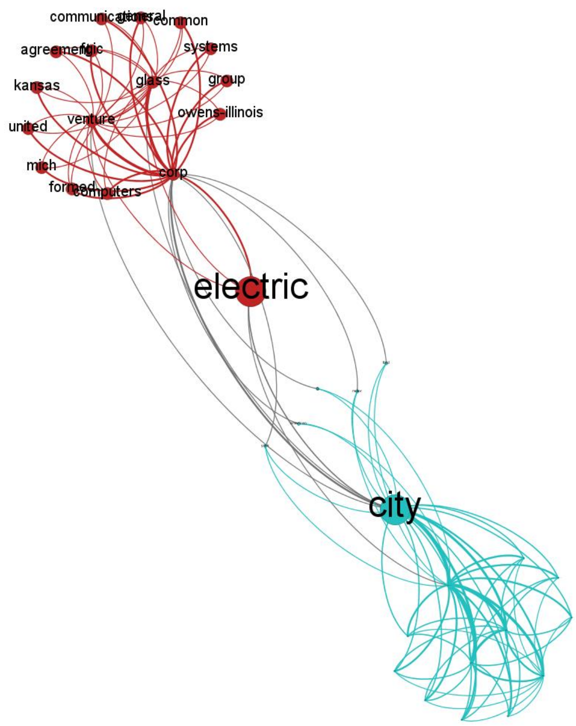


Figure 8. Word co-occurrence network in the full text of the articles in the New York Times (1988)

From 1989 the amount of articles published in the New York Times on the topic of “Electric vehicle” increased strongly. This is particularly visible in the article frequency graph (Appendix …). The main topic that is being reported is the division between driving electric and driving on natural gas. The goal is to reduce environmental pollution due to emission, mostly in California. In 1990 natural gas almost completely disappears from the articles. Between 1991 and 1998 more and more articles are being published on electric vehicles. At the highest point, in 1994, 46 articles are published compared to 22 in 1993. The main issues that are being addressed are the battery technology, the reach of electric vehicles and the impact on the environment.

In 1991 the International Journal of Vehicle Design publishes on hybrid vehicles in the light of engine developments and in 1993 and 1994 the electric engine is discussed. In 1996 electric vehicles are discussed among other alternative fuels for the future.

The period between 1989 and 1998 has not shown large changes in subjects in the newspaper. However in 1999 (Figure 9) the change starts as the New York Times starts reporting on the first hybrid electric vehicles on the market (especially the Toyota Prius which had been introduced in 1997). Not just the topic changes, also the amount of articles published becomes higher from 2000 and the amount becomes stable around 20 articles per year until 2007 (Appendix A – Article frequency table). The topics covered in this period are all around the hybrid vehicles, like the battery capacity and the range. 2007 itself shows the first changes towards the full electric vehicle. The hybrid vehicles start to fade to the background and plug-in cars and full electric vehicles become the focus of the articles. This trend continues and by 2010 the hybrid vehicle is hardly mentioned anymore in favor of the full electric vehicle.

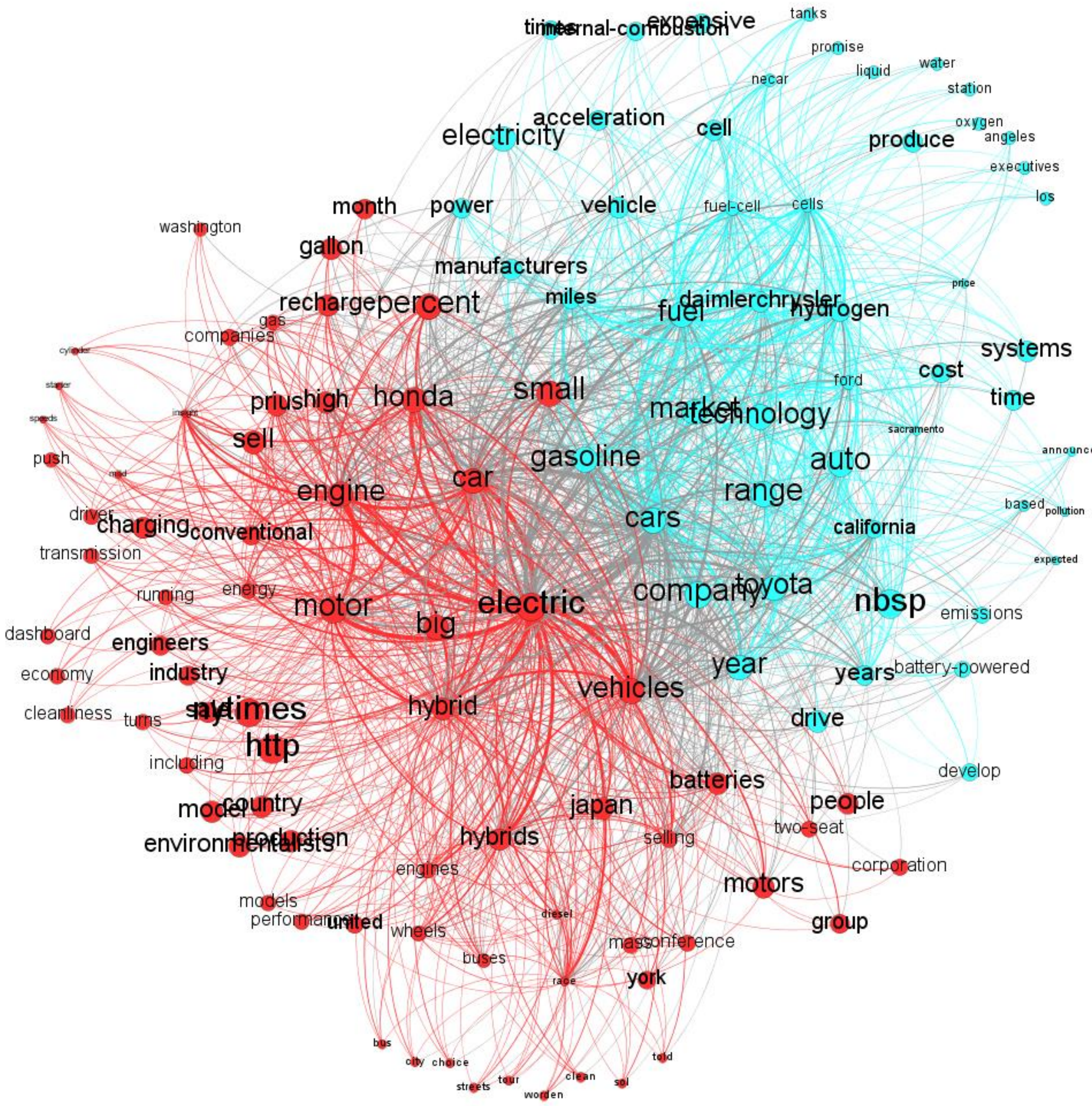


Figure 9. Network of abstract word co-occurrence in the New York Times (1999)

In the International Journal of Vehicle Design the last record of electric vehicles is in the year 2000. In this year the electric vehicle is discussed as the future of the automotive industry, thus well before the electric vehicles actually appear in the newspaper output. In this year the discussion on hybrid vehicles has already shifted to the background.

The overview in table … shows the found delays between the output of the International Journal of Vehicle Design and the New York Times. 3 out of the 12 analyzed topics did not show any relation and 1 topic showed the opposite relation, where the journal articles were published after the newspaper articles. In the remaining 8 articles a total of 18 links have been identified. The average delay between the journal articles and the newspaper articles is 5 years.

Table 3. Identified delays between interpreters and the sociocultural context per topic

Topic	Delay between interpreters and sociocultural context (years)
"Airbag"	9 (1980 – 1989)
"Alternative fuels"	6 (1983 – 1989) 9 (1996 – 2005)
"Car aerodynamics"	Not found
"Car safety"	Not found
"Car tyres"	3 (1981 – 1984) 8 (1992 – 2000) 7 (2004 – 2011)
"Ethanol fuel blend"	2 (1985 – 1987) 3 (2009 – 2012)
"Fuel consumption"	Inversed relation
"Phone while driving"	0 (2001 – 2001)
"Fuel emission"	9 (1980 – 1989) 2 (1998 – 2000) 4 (2003 – 2007)
"Vehicle pollution"	5 (1984 – 1989) 1 (1998 – 1999) 6 (2001 – 2007)
"Vehicle sensor"	Not found
"Electric vehicle"	7 (1981 – 1988) 3 (1991 – 1994) 6 (1996 – 1999) 7 (2000 – 2007)

CONCLUSIONS

This study has first attempted to identify the different links that exist between the interpreters in an interpreter network and the sociocultural context in a Design Driven Innovation system. These links have been described in a theoretical framework (Figure 6). The framework has been compared with the Model Innovation and Organization Structure (Lekkerkerk, 2012) from which it was found that the DDI approach could indeed result in a viable business. Furthermore the interpreters, as described by Verganti (2008), were split into 3 different types of interpreters to gain more insight in the link between interpreters and the sociocultural context. It was found that the user interpreters and the environment interpreters both have a link to the sociocultural context through the company and from the sociocultural context as input. The technological interpreter also has a connection to the sociocultural context but only through the company.

To study the link from the interpreters to the sociocultural context the output of both had to be quantified. For the output of the interpreters the journal publications of the International Journal of Vehicle Design were chosen and for the sociocultural context the articles of the New York Times newspaper were used. Although the topics were rather general, it was possible to identify the topics that were being discussed per year in both the journal and the newspaper.

The hypothesis was that there should be a delay between the appearance of a topic in the International Journal of Vehicle Design (interpreter network) and the appearance of that same topic in the articles from the New York Times (sociocultural context). This delay would be due to the time it takes for a company to translate the vision from the interpreters to a product that is introduced in society. For 8 of the 12 identified topics such a delays were indeed observed. In these 8 topics there were 18 delays between the journal and the newspaper with an average delay of 5 years. The average product development time for innovative products is 53.2 months (4.43 years) according to Griffin (2002). This is very much in line with the average found delay of 5 years. Although the amount of topics identified and the amount of delays found were only limited it can be concluded that an analysis of the output of interpreters in an interpreter network (in this case the journal) may provide insights in the changes in the sociocultural context in the following years.

DISCUSSION

In this study the newspaper the New York Times has been used as a reflection of the sociocultural context. Although there was good reason for choosing this newspaper it also has downsides. The analysis of a single newspaper might not provide a rich enough reflection of the sociocultural context. The authors of the articles might be biased and there is a chance that the articles don't reflect the actual situation, as it is the interpretation of a journalist of a certain situation. Future research on this topic might therefore consider the use of more newspapers to reduce bias, or other sources of knowledge. Already mentioned upcoming sources are the social media channels which could provide a more direct representation of the user by eliminating the interpretation of the journalist.

If future studies wish to use the newspaper articles from the New York Times for a similar analysis the LexisNexis database is not recommended. Instead, the New York Times (and possibly other newspapers as well) has released an API which allows the researcher to interface with the databases of the New York Times itself. This database contains every article that has ever been published by this paper since 1851 and is very well structured. However, the use of an API requires even more programming and was therefore beyond the scope of this study.

In the article by Verganti (2008) the observed companies had relations with individual interpreters, who were part of a larger network of interpreters. Therefore, in this study it has been attempted to perform the same analysis on a single interpreter, in this case a single design department or design school. First the Industrial Design department from the University of Technology in Delft (TUD) was tested. The first issue that occurred was the collection of data. Although the university has a list of all publications by this department there is no central place where these articles are collected, the list is incomplete and very inaccessible. The same was attempted at the University of Technology in Eindhoven (TU/e). In the database of the Web of Science some publications could be found by this department but there are only very little articles attributed to this department. A search that included all the staff members of the design departments also didn't result in proper data. An analysis of a single interpreter is therefore not possible in a quantitative way. Another study might look into the possibilities of analyzing a single interpreter via a qualitative research method.

This study did not take into account the time it takes for a study to become published. Although there are no numbers available on the time the average study takes to execute and publish it can be expected that this time influences the observations in the output of the interpreters (since the interpreter data in this study is scientific of nature). This could increase the delay time observed.

Future studies could focus on a higher resolution of the data. The results in this study, and the topics that were identified, are quite general and not specific enough on one innovation. The topic "Electric

Vehicles", for example, is not specific enough as it includes several innovations in the field of battery technology and electric engines. Next to this the resolution in time could be increased. In this study the year was used but it is also possible to increase the resolution to the level of months or even weeks in case of the newspaper articles. The higher resolution could help to expose the delay between interpreter output and sociocultural output when the delay is shorter than 1 year, usually in smaller innovation projects or innovations that are easier to implement.

Something that has not been accounted for in this study is the decreasing development times and shorter product life cycles. This means that the pace of the development of new products increases over the years. This might mean that the observations from the 80s cannot be compared to results from the 90s or 00s, or that a correction is needed. The currently analyzed data does not indicate that such a correction is needed.

MANAGEMENT IMPLICATIONS

In this study it was found that an analysis of the output of the interpreter network may provide insights in the changes in the sociocultural context in the following years. For the management of innovation this has several implications which will be discussed in this chapter

The first implication is that it is important to have a proper way of getting information from interpreter networks. The main reason for this is that it may allow the company or government to respond in time or even prior to changes in the sociocultural context, with appropriate innovations and products or legislation. The quantitative methodology used in this study may be interesting to monitor the interpreters when the resolution is increased, like described in the discussion, but such a quantitative method will not show information from all interpreters. Interpreters that do not produce codified knowledge, like artists or several types of designers, are not represented by this data. Therefore the company or government should also maintain 'qualitative' connections with interpreter networks and exchange visions with other interpreters in the network, for example through projects with students, conferences or collaborations with other companies. Although there is no evidence that points to a certain type of interpreter as the best interpreter to follow it makes sense that all the types should be represented. User interpreters will have a more difficult time picking up on technological changes while technology interpreters are less likely to tell something about changes on the sociocultural level due to the source of their information, as indicated in the theoretical framework.

The dependency on other interpreter network is what makes the DDI approach a higher risk for companies. This study has also shown that the interpreter output does not reflect all topics and that in some cases the interpreters are even behind on the changes in the sociocultural context. Although this was only observed in 1 out of the 12 topics it does form a treat for companies that depend on this data. From a management perspective it may be more advisable to have all the functions, like described in the MIOS (Lekkerkerk, 2012) within the company, without dependencies on other firms. However, for a DDI approach the MIOS might be complemented with a link between the external interpreter network and the functions I3-Propose innovation and V3-Propose improvement, since the interpreters might fulfill the same function as I4-Search future new options and V4-Search improvements.

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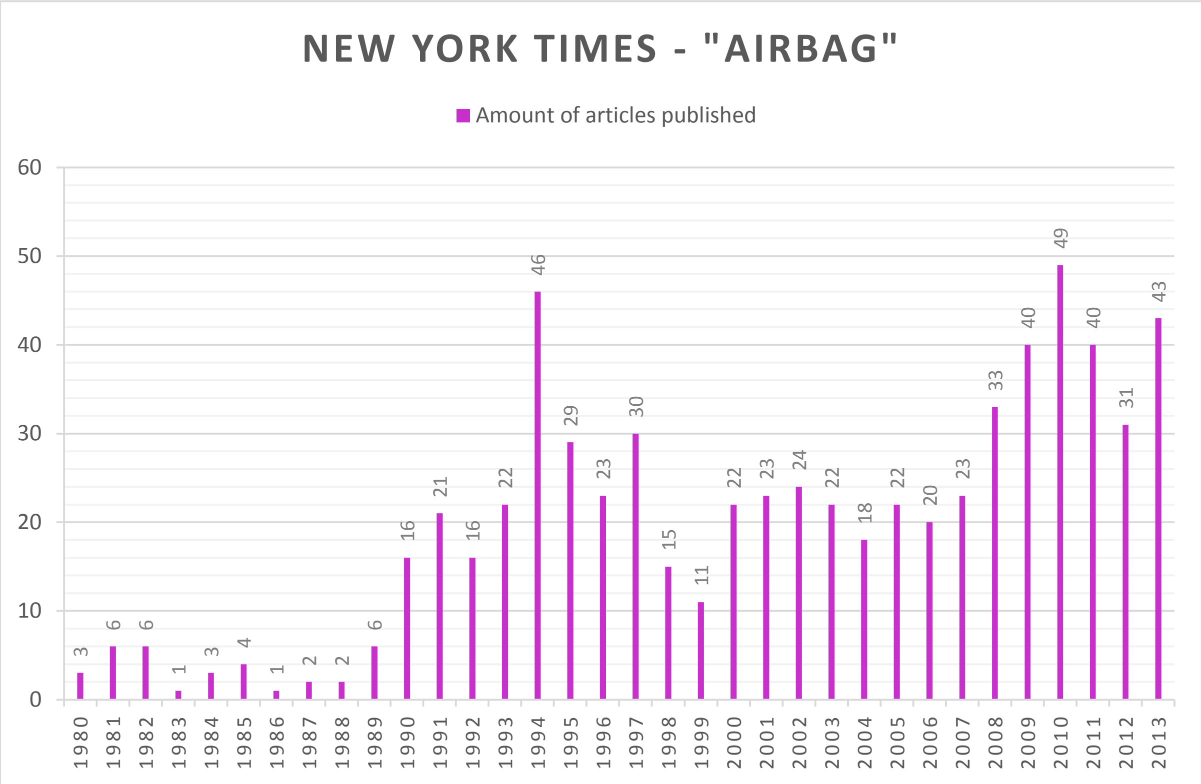
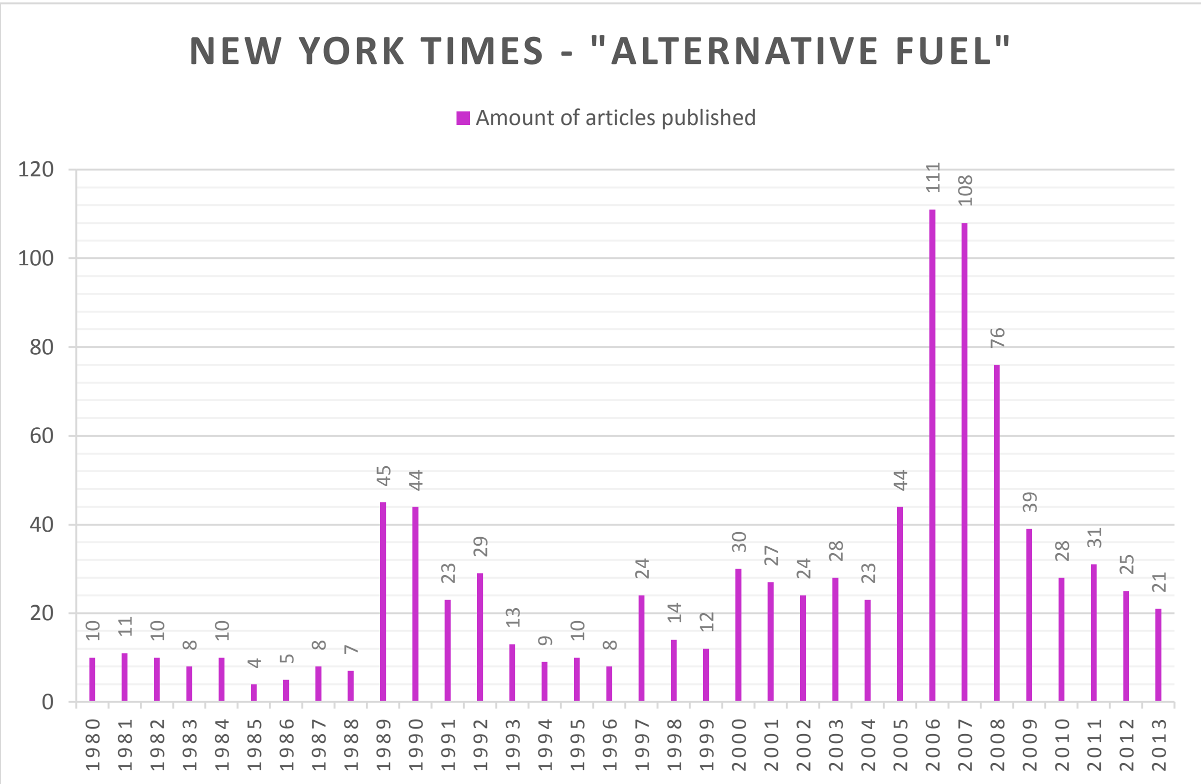
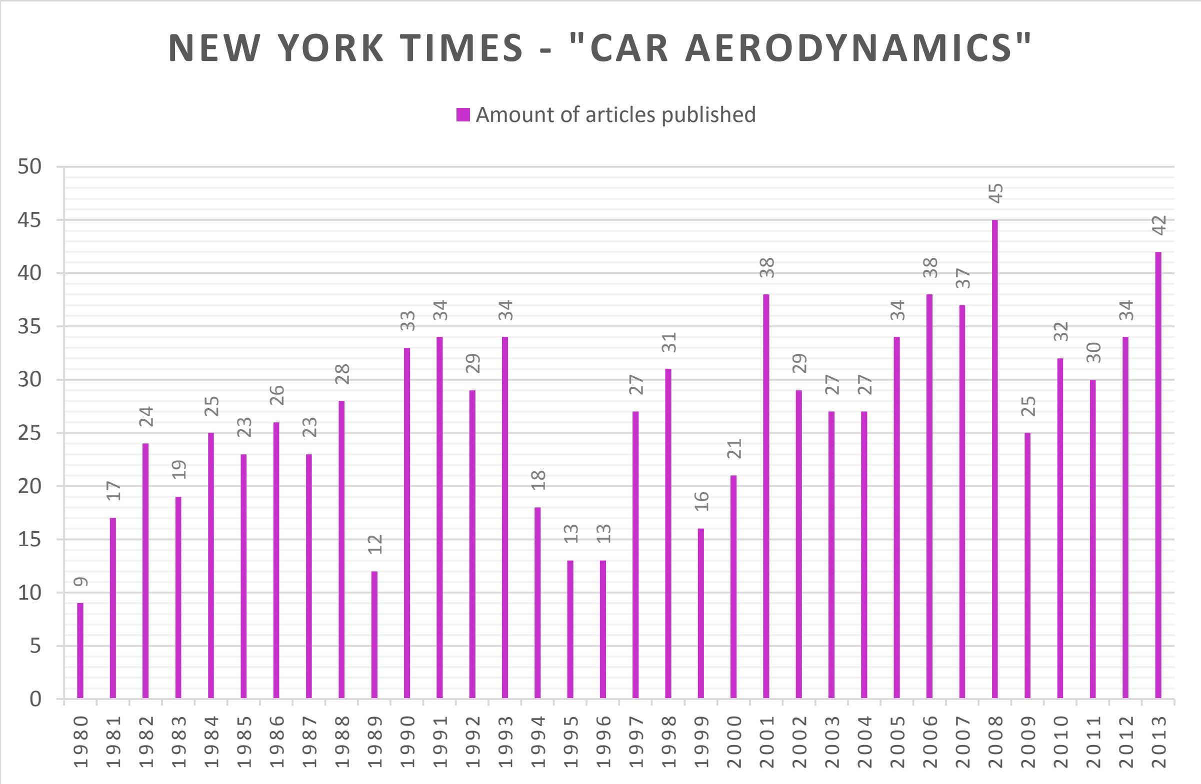
APPENDIX A – ARTICLE FREQUENCY TABLE



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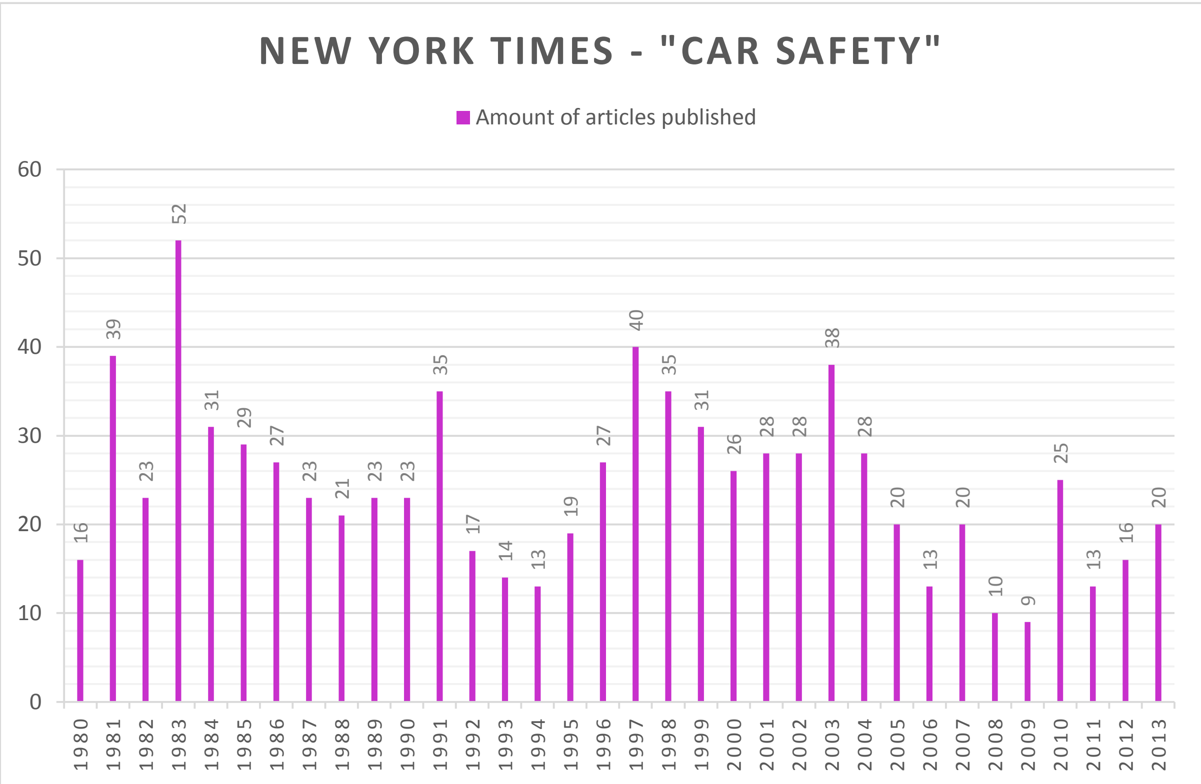
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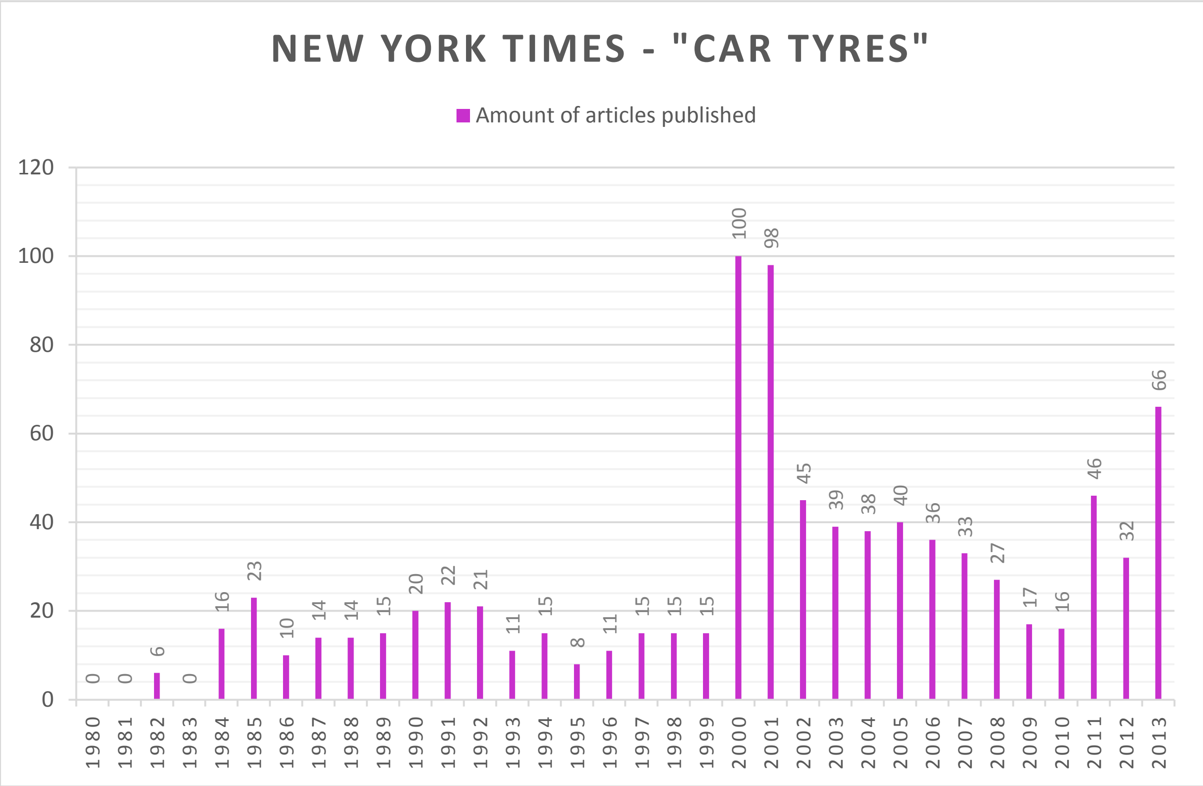
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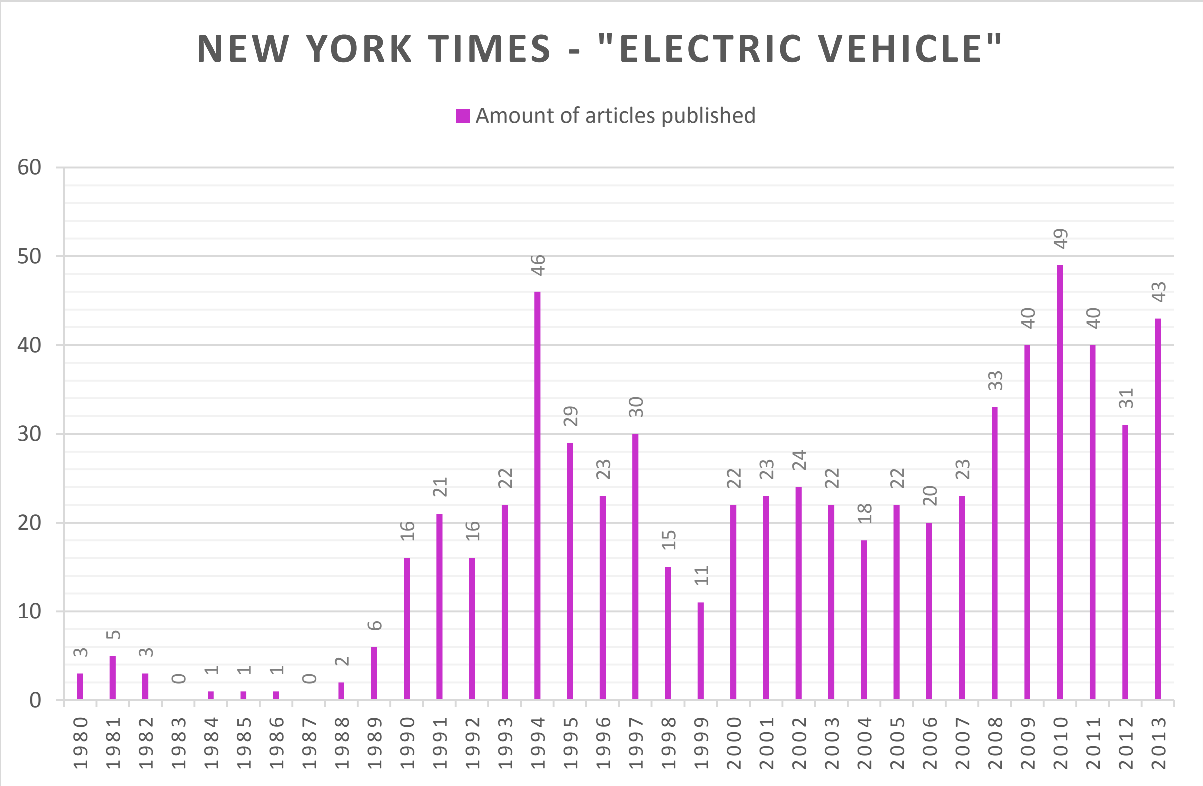
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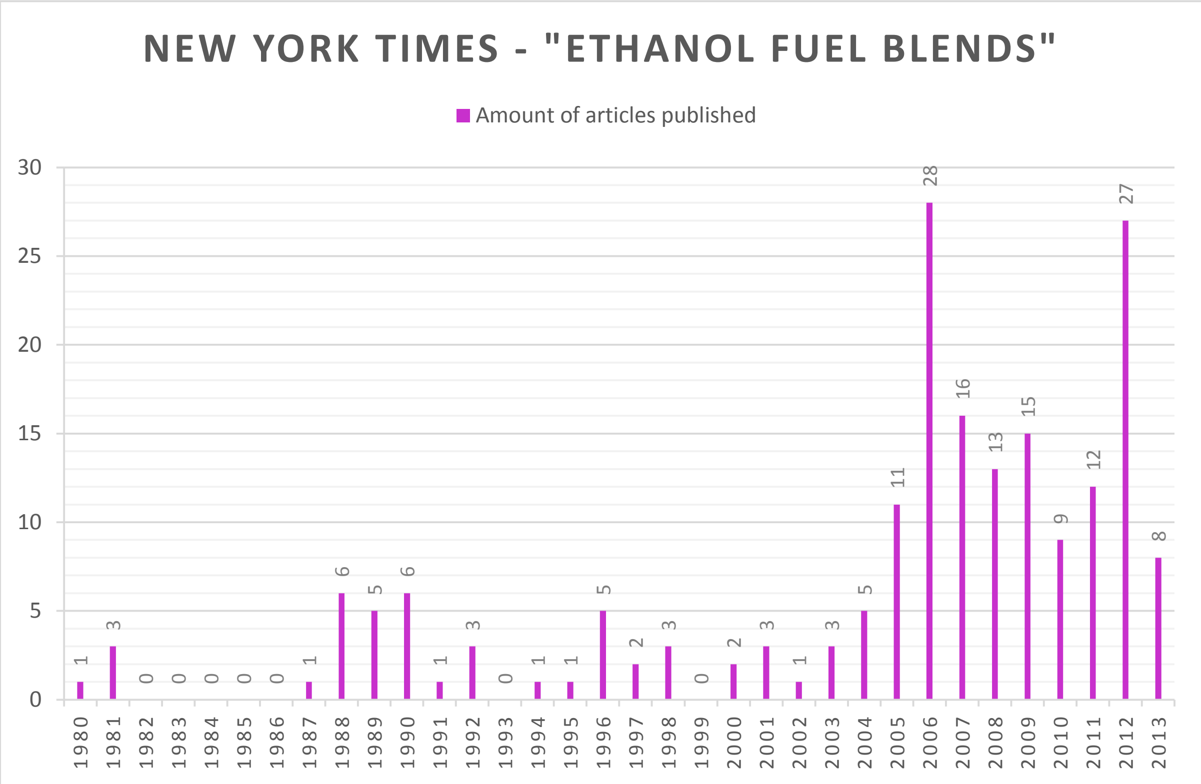
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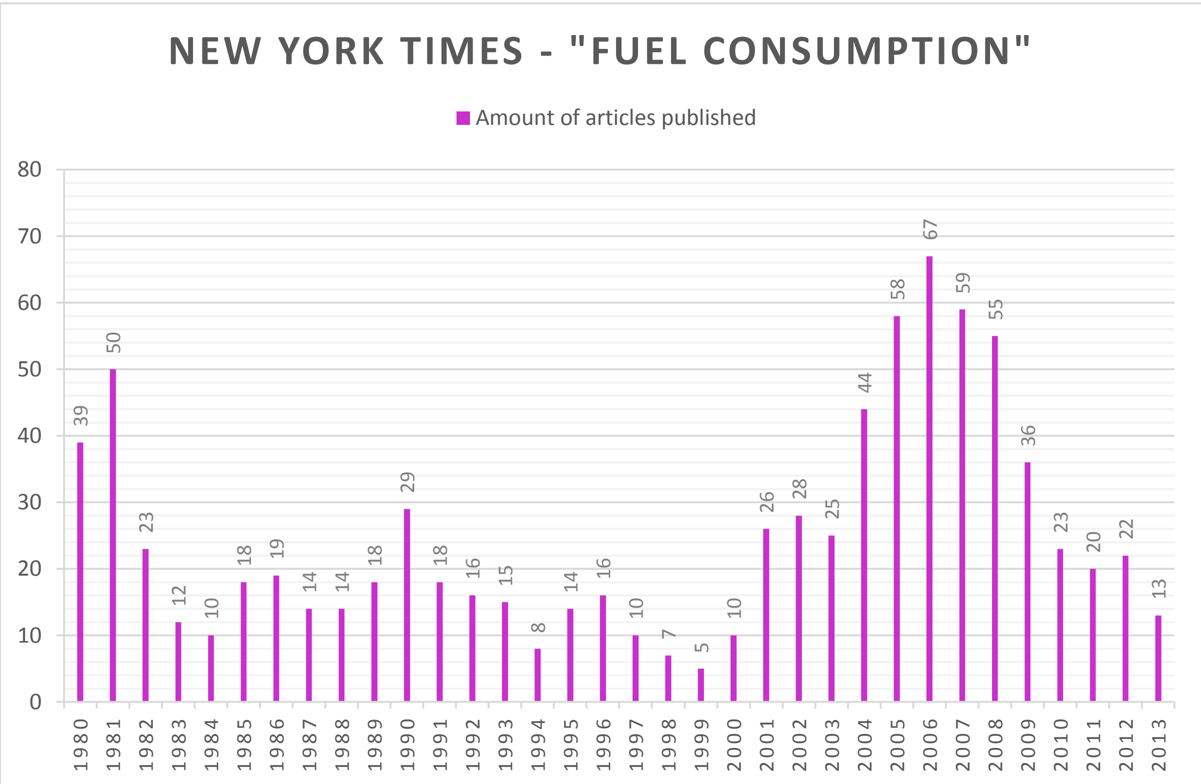
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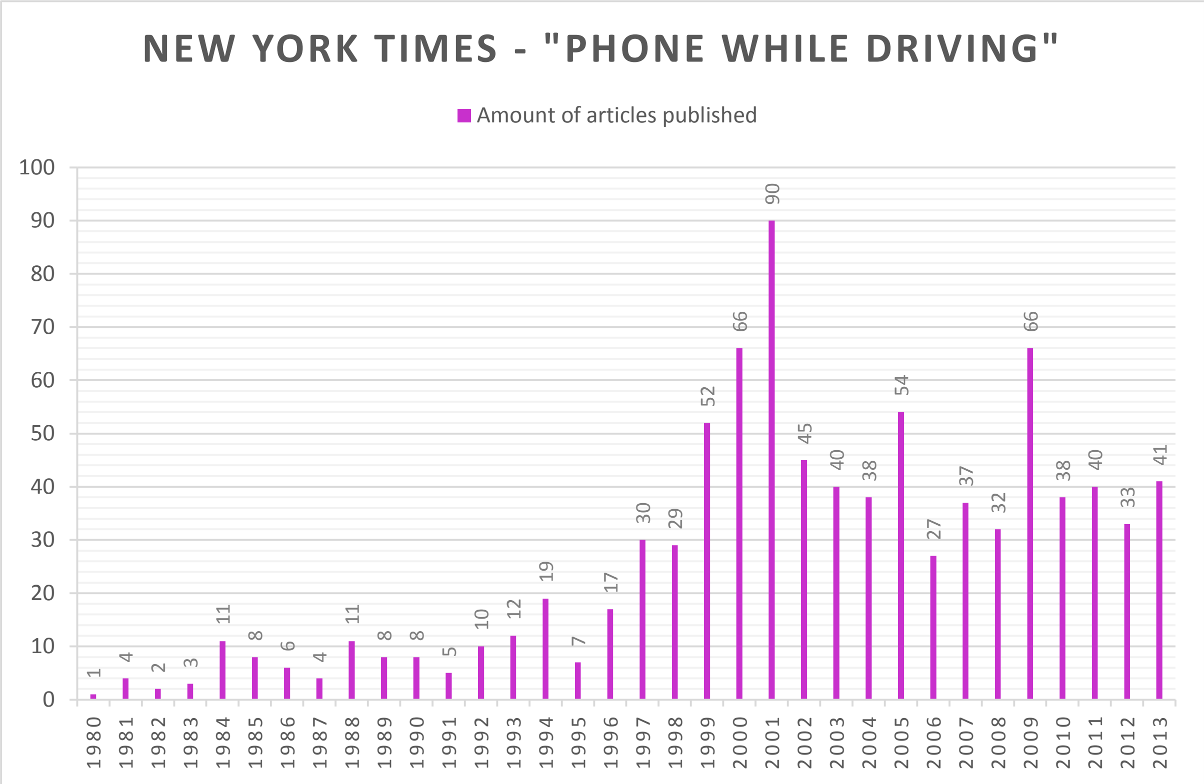
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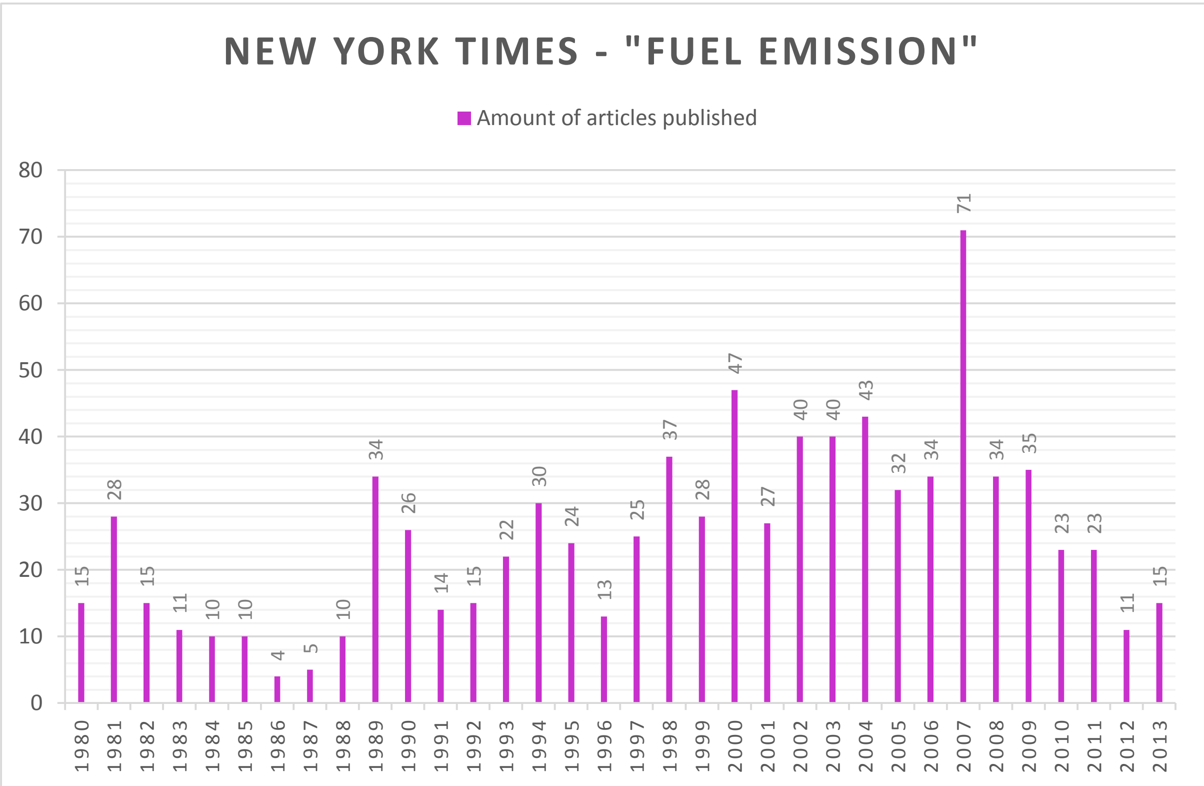
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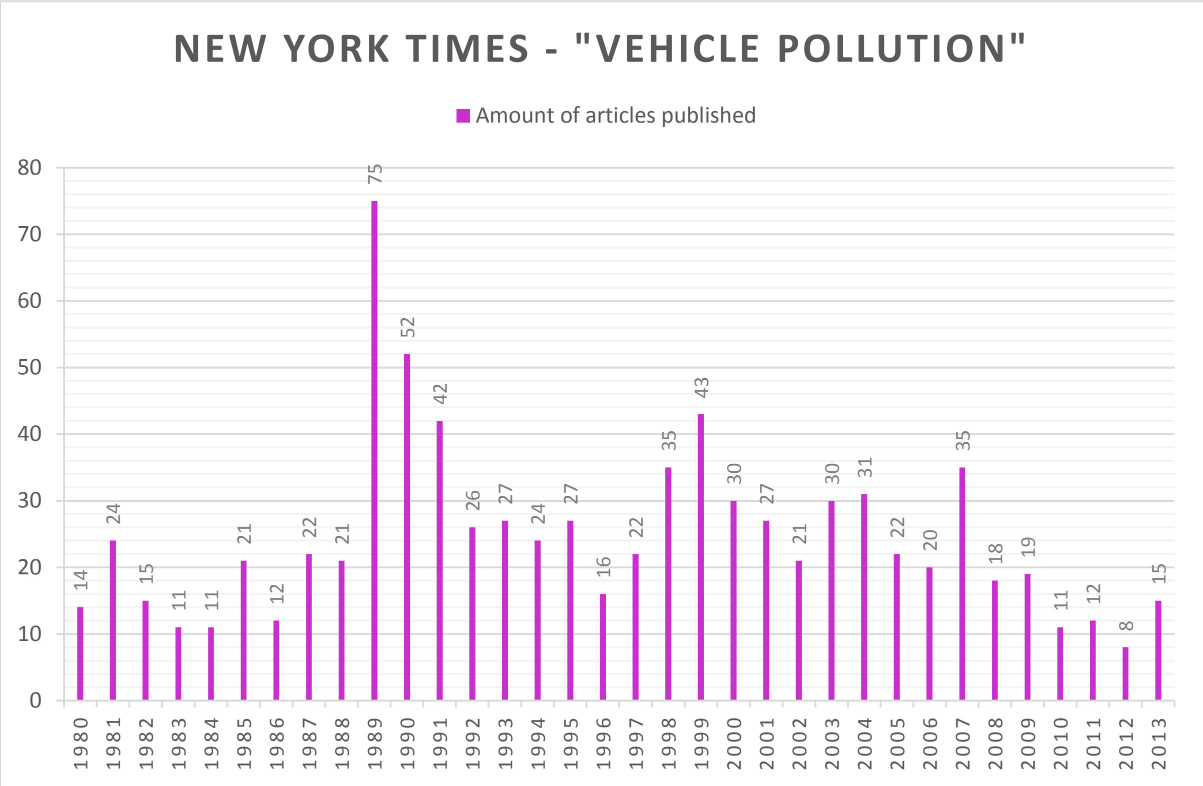
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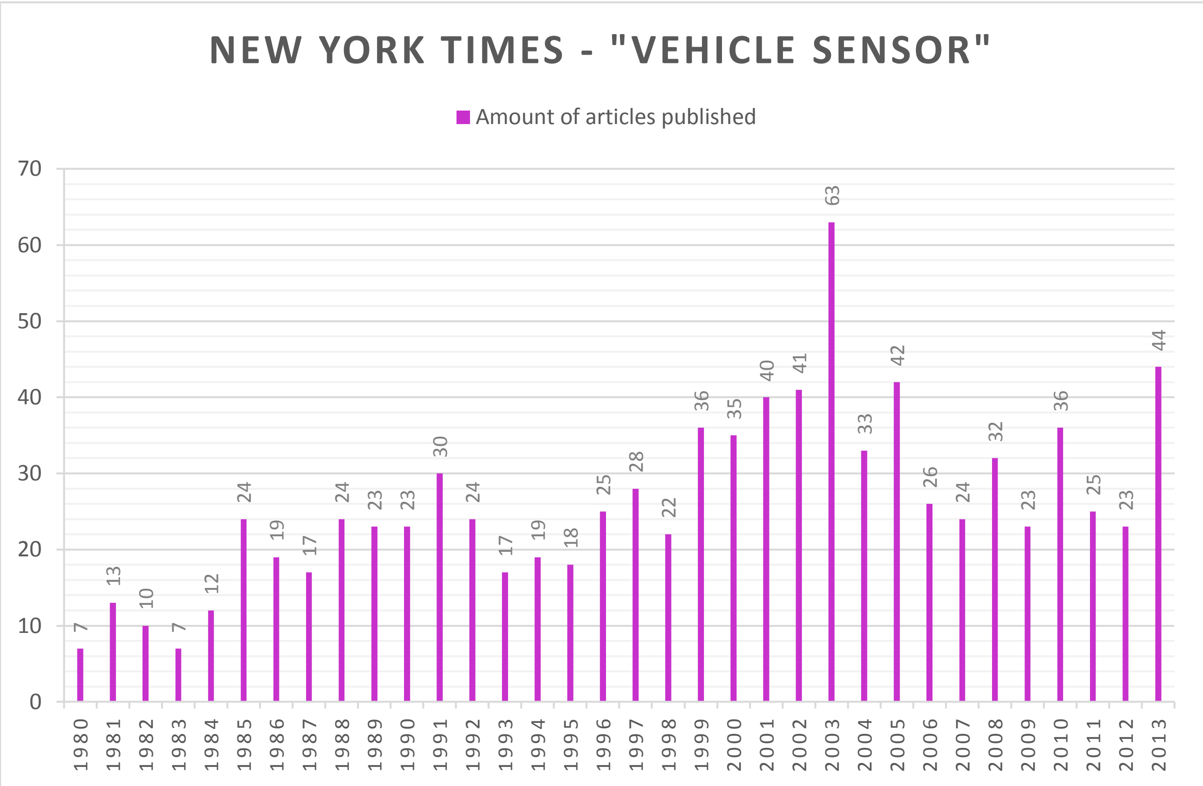
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Appendix B – Table of identified topics per year from the International Journal of Vehicle Design

Year	Topic	Keywords
1979	Diesel smoke reduction	Fuel; Diesel; Smoke; Suppress; Additives
	Handling	Vehicle; Surface; Road; Handling; Tyre; Factors
	Reliability	Reliability-analysis; Cars; High-utilization
	Collision analysis	Collision
1980	Airbag	Bag; System; Air; Charging; Inflation; Combustion; Passive
	Brake lock-prevention	Brake; Anti-lock; Performance
	Impact protection	Car; Driver; Protection; Impact; Injuries; Steering; Passenger; Safer
	Emissions	Emission; Standard; Japanese; Engine;
	Transmission	Transmission; Characteristics; Total
	Vehicle safety	Vehicle; Safety; Torsion; Joints; Warping; Defects; Motor; Primary
1981	Tyres	Tyres; Elastic; Wall; Force; Deformation; Maneuvers; Braking; Response; Rubber-friction
	Airconditioning	Air-conditioning; Compress; Heating; Climate
	Engine	Transmission; Engine; Fuel-economy; Combustion; Diesel-engine; Exhaust
	Electric vehicles	Vehicles; Hybrid; Electric; Impacts
	Handling	Wheel; Slips; Turning; Suspension; Air-cushion
	Agricultural vehicles	Harvester; Agricultural; Trailer; Weight; Tractor
1982	Future of cars	Cars; Future; Future-prospects; Trends; Art; Designing; Development
	Steering	Steering; Suspension; Shimmy; Application
	Electric vehicles	Hybrid; USA; Electric; National; Energy-consumption
	Conditions	Conditions; Dynamic; Tyres; Properties; Influences; Experimenting
	Tyres	Wheel; Bump; Road; Slip; Stopping; Forces; Elastic; Wall; Behaviour
	Engine	Engine; Throttle; Torque; Fuel; Emission; Efficiency; Power; Spark-ignition
	Aerodynamics	Aerodynamics; Interior; Noise; External
1983	Future engines	Engines; Laser; Hydrogen-fuelled; Future-trends; Technique
	Collision	Vehicle; Maneuvers; Severe; Braking; Rapid; Lane-changing; Steering; Shock-absorber; Road
	Traffic accidents	Traffic; Accidents; Velocity; Energy-based; Hazard; Man; Weak; Link
	Fuel efficiency	Diesel-engine; Development; Fuel-economy; Turbo-charged; Emission; Exhaust;
1984	Engine	Engine; Spark-ignition; Fuel-efficient; Oil; Combustion; Microprocessor; Control-system
	Pollution	Vehicles; Pollutants; Emission; Unregulated;
	Future of electronics	Automotive; Electronics; Sensors; Future; Industry; Information-systems; Reliability
	Low-noise materials	Combustion; Low-noise; Materials; Effective; Development
	Car body design	Car; Body; Influence; Acoustic; Wind-tunnel; Endurance; Acceleration

	Truck safety	Safety; Truck; Crew; Payload
	Vehicle design	Engineer; Interaction; Vehicle; Design; Performance; Suspension
1985	Steel alloys	Steel; Phosphorus; High-strength; Sheet; Hot-rolled; Paintability
	Diesel-engine	Diese-engine; Radiated; Microcomputer; Emissions; Signal; Hydraulic-brake
	Transmission	Transmission; Gear; Teeth; Residual-stresses; Energy; Movement; Drive; Control-system
	Vehicle performance	Vehicle; Performance; State-of-the-art; Methanol; Petrol; Quiet; Durability; High-speed
	Kevlar	Fibers; Kevlar; Asbestos-free; Reinforced; Brakes; Clutches
	Body production	Steel; Sheets; Spot-welding; Press; Forming; Panels; Surface; Plastics; Coating
1986	Collisions	Collisions; Head-on; Safety-belt; Subcompact-car
	Accidents	Car; Body; Steel; Injury-causing; Risk; Accidents; Injury; Motor; Energy-absorption
	Fuel consumption	Engine; Low-friction; Savings; Lubricants; Transmission; Fuel; Gear
	Aerodynamics	Aerodynamics; Aircraft; Wind
1987	Traffic noise	Noise; Traffic; Control; Strategy; Dynamic-programming; City; Street; Viewpoints
	Electronics	Electronics; Future-trends; Status; Technology; Chassis; Control-systems; Fuel-injection
	Fuel economy (trucks)	Truck; Fuel-economy; Turbocharged; Diesel-engine
	Body design	Stiffness; Car; Joints; Body
	Noise reduction	Vibration; Noise-reduction; Mechanisms;
	Brakes	Brake; Damping; Disk; Generation
1988	Safety	Safety; Brakes; Human-factors; Stiffness; Driving
	Tyres	Tyres; Lateral; Lowering; Cross-bar; Noise; Pressure; Handling; Rolling;
	Aerodynamics	Aerodynamics; Force; Ground; Stationary;
	Engine	Engine; Powertrain; Future; Fuel-economy; Vibration; Crankshaft; Torsional
	Collisions	Collisions; Barrier; Car-to-car; Behaviour; Characteristics
1989	Exhaust gasses	Exhaust; Fumes; Filter; Cancer-causing; Removing; Black; Smoke; Diesel-engines; Particulates;
	Engine	Engine; Diesel; Odor; Fuel; Spark-ignition
	Collision	Collapse; Crashworthy; Fiber-reinforced; Composite; Plastic; Section
	Suspension	Suspension; Load; Stability; Ride; Braking; Torsion; Elastic; Light
1990	Human capabilities	Human; Physiological; Vibrations; Effects; Simultaneous
	Rollover	Safety; Stiffness; Rollover; Crash; Structure
	Bus (public transport)	Vibration; Bus; Powertrain; Suspension; Hydraulic; Interior; Noise; Accessibility; Mobility
	Body design	Car; Body; Panels; Sheets; Aluminum; Manufacture; Structural
	Tyres	Pneumatics; Rolling; Slips; Vehicle
1991	Driving characteristics	Vehicle; Characteristics; Forces; Requirements; Control; Track; Analysis; Deformation

	Faster and more efficient design	Model; Design; Cost; Time; Environment; Motor; Development; Process; Reduction
	Safety	Vehicle; Early; Response; Safety; Conditions; Drivers
	Skidding	Slip; Tyre; Angle; Friction; Traction; Force; Driving; Steering; Torque
	Aerodynamics	Flow; Aerodynamic; Air; Distribution
	Automotive industry	Industry; Automotive; Product; Japanese; Companies; Competition; Development
	Engine developments	Fuel; Performance; Conventional; Hybrid; Economy; Methanol; Test
1992	Effects of speed on the materials	Speeds; Materials; Energy; Conducted; Absorption; Crush; Tube; Square; Geometry
	Tyres	Tyre; Force; Ground; Contact; Rolling; Frequencies; Driving
	Alternative fuels	Cars; Co2; Emissions; Greenhouse; Global; Warming; Experimental; Engine
	Driving characteristics	Vehicle; Characteristics; Driver; Ride; Behaviour; Suspension; Handling; Performance; Wheel; Effects; Optimizations
	Mobility technologies	Mobility; Technology; Personal; Human; Transportation; Shock; Transfer; Vibrations; Noise
1993	Vehicle noise	Sound; Measured; Pressure; Flow; Velocity; Car
	Driving Characteristics	Braking; Combustion; Tyre; Characteristics; Control; Performance; Robust; Road; Mass; Comfort; Quality
	Fuel	Engine; Considered; Energy; Electric
	Power distribution	Differential; Input; Output; Ratio; Limited-slip; Degrees
1994	Handling	Handling; Accelerations; Effects
	Fuel	Gas; Fuel; Engines; Alternative; Energy; Efficiency; Combustion; Injection; Electricity
	Engines	Engines; Force; Speed
	Driving Characteristics - Body	Car; Body; Rigid
	Driving Characteristics - Handling	Handling; Acceleration; Motion; Performance; Tyre; Road; Conditions; Characteristics; Force
1995	Recycling materials	Materials; Recycling; Plastic; Industry; Car
	Vehicle performance	Vehicle; Performance; Safety; Road; Parameters; Tyre; Traffic; Lateral; Emergency
	Fuel consumption	Fuel; Consumption; Braking; Acceleration; Transmission; Gear; Engine; Conditions;
	Vehicle production	Process; Stages; Product; Quality; Manufacturing; Technology; Firm; Industries; Plant;
	Safety	High; Speed; Impact; kph; Injury; Frontal; Crash; Severe; Deformation
1996	Alternative fuels	Vehicles; Emission; Combustion; Engine; Fuel; Gasoline; Future; Hydrogen; Gas; Electricity; Source; Requirements; Power; Energy
	Industry	Industry; Production; Government; Oil; Japan; Role; Components
	Production	Development; Projects; Market; Strategy; Organization; Automobile
	Handling	Control; Maneuvers; Steering; Wheel; Braking; Velocity
1997	Emissions	Emissions; Fuel; Car; Fuel; Speed; Driving; Consumption; CO2; Acceleration; Exhaust; Gas

	Handling	Driver; Control; Braking; Steering; Performance; Lateral
	Driving characteristics	Tyre; Contact; Material; Road; Behaviour
1998	Air pollution	Traffic; Air; Pollution; Road; Exposure; Conditions
	Emissions	Emissions; Urban; Pollutant; Engine; NOx; City; Driving;
	Handling	Control; Suspension; Characteristics; Performance; Acceleration; Wheel; Steering
1999	Engine	Engine; Gas; Geometry; Internal; Temperature; Spark; Ignition; Contact
	Plastic	Test; Plastic; Deformation; Load; Power; Compound; Condition; Safety
	Industry	Industry; Development; Product; Process; Management; Engineering; Automotive; Economic; Commercial
2000	Computer guided driving	Obstacle; Avoidance; On-line; Off-line; Matrix; Area
	Future of the automotive industry	Automotive; Industry; Future; Up-to-date; Development; Electric; Heat; Thermal
	Engine	Engine; Emission; Speed; Frequency; Optimization
	Brakes	Friction; Forces; Disc; Time; Brake; Motion; Element
	Handling	Wheel; Road; Feedback; Stability; Conditions; Control; Performance
2001	Air quality	Air; Traffic; Quality; Road; Pollution; Urban; Exposure;
	Pollution	Emissions; Fuel; Engine; Pollutant; Diesel; CO2;
	Phone	Driver; Phone; Accidents; Potential; Car; Time; Visual; Interface
	Vehicle performance	Performance; Control; Speed; Characteristics; Motion; Body; Wheel; Suspension; Stability; Steering
2002	Traveling comfort	Passenger; Seat; Vehicle; Road; Seating; Vibrations; Quality; Hydraulic
	Body design	Body; Shape; Structural; Aircraft; Wing; Aerodynamics; Efficient
2003	Traveling comfort	Vibration; Ride; Comfort; Suspension; Characteristics
	Safety	Crashes; Injury; Impact; Stiffness
	Emission	Fuel; Emission; Air; Transport; Road;
	Engine	Speed; engine; Acceleration; Torque; Hybrid; Powertrain; Conditions
2004	Alternative energy	Fuels; Automotive; Economic; Engines; Alternative; Gas; Emission; 2-Stroke
	Shape	Shape; Form; Structural; Optimal; Tyre; Load; Design
	Tyres	Profile; Tyre; Roughness; Road; Speed; Friction
	Driving characteristics	Braking; Force; Driving; Characteristics; Behaviour; Temperature; Control; Operating; Conditions; Performance; Pressure
2005	Vehicle control	Vehicle; Control; Forces; Terrain; Suspension; Friction; Driving; Yaw; Motion
	Driver assistance	Systems; ABS; Braking; Pedal; Airbag; Passenger;
	Crash	Deformation; Energy; Impact; Penetration; Tension;
	Safety	Material; Shape; Deformation; Foams; Engine; Fuel; Modelling
2006	Engine optimization	Combustion; Emission; Diesel; Engine; Nox; Oil; Exhaust; Efficiency; Thermal; Heat;

	Handling	Mass; Characteristics; Stability; Dynamics; Performance; Suspension; Road; Steering; Behaviour; Speed
	Driver alertness	Driver; Sleep; Physical; Safety; Women; Aging; Alertness
2007	Engine optimization	Engines; Combustion; Diesel; Performance; Injection; Compression; Temperature; Consumption; Pressure; Noise
	Conditions	Condition; Mass; Steel; Torsion; Variables; Optimization
	Friction reduction	Design; Flow; Tyre; Shape; Vibration; Optimal
	Handling	Vehicle; Driver; Steering; Higher; Speeds; Disturbance; Chassis; Suspension
	Design techniques	CAD; Form; Tool; Image; Perception; Consumer
2008	Efficiency	High; Efficiency; Mode; Assembly; Inlet
	Vehicle control	Vehicle; Control; Road; Performance; Condition; Acceleration; Disturbance; Braking; Suspension
	Engine optimization	Development; Design; Engine; Optimization; Vibration; Fuel; Damping; Mass; Crankshaft
	Stability	Stability; Roll; Properties;
	Durability	Durability; Responses; Test; On-road; Simulation;
2009	Engine optimization	Fuel; Diesel; Engine; Performance; Combustion; Injection; Oil;
	Fuel mix	Blends; Content; Ethanol; Ethanol-diesel
	Emissions	Emissions; Exhaust; Gasoline; Turbocharged; Effects; Oxide; Consumption; NOx
	Crash impact reduction	Impact; Reduction; Human; Collision; Velocity; Elastomeric
	Auto-ignition	Auto-ignition; Start; Chemical; Firing; Delay; Cycle
2010	Air flow	Air; Flow; Vents; Windshield; Pressure; Inlet
	Cabin temperature	Cabin; Thermal; Solar; Radiation; Surfaces; Transfer; Interior;
	Car roll	Rollover; Stiffness; Roof; Crush
	Engine performance	Engine; Performance; Diesel; Emissions; Injection; Exhaust; Temperature
	Production optimization	Production; Manufacturing; Employed; Materials; Distance; Operations; Virtual
	Assembly	Body; Assembly; Technology; Welding
	Road interaction	Road; Effect; Suspension; Bump; Acceleration; Range; Deflection; Mass; Responses