Improving the ideation process in GE Lighting, Budapest

How can the generation of possible design solutions be improved in GE Lighting by using knowledge in the field of Industrial Design Engineering?

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1 Abstract

The lighting industry is evolving at high-speed. With many new entrants, increasing quality and warranty requirements and other many developments going on about efficiency, LED-development, 'smart' products and modular design, the question rises if a change in the produced products is enough. Since making the process more effective and better aligned with the current market is an on-going task, the design process itself might need to change too. This report searches for possible improvements in the design process, focussing at how the generation of ideas can be improved.

Due to the big influence of the internal and external factors in this process, any change should fit really well in the as-is context of GE Lighting in Budapest. Therefore, the design process for GE and its context is analysed in this report. The notion of the current situation as a top-down process, with the use of a detailed stepwise methodology that is embedded in a strong management and engineering perspective provides a clear framework of internal factors. Combining them with the external influences gives shape to one of the specific criteria: "The purposed script fits in the context of the current situation". (This script refers to a guiding, stepwise approach that can be followed in order to improve the generation of ideas.) The other main criteria for the script are: "Generates a variety of product ideas", "Shortens the time to pick the next development" and "Improves communication among different disciplines". To work with this limited set of criteria, implications have been made, resulting in a clear reference for what should be achieved.

The purposed script finds its base in the knowledge area of industrial design engineering (IDE) and fulfils the listed requirements / implications often in principal more sufficient then GE Workout which is used within GE Lighting. In the tenth chapter, this script is evaluated for the generation of alternatives for the modularity design for GE Lighting's R-250 product family. Showcasing how IDE-knowledge can be used to trigger the development of alternative and clearly varying ideas.

The case results show several clear-cut suggestions for concepts, while keeping a low level of detail. Besides that, the assessment and selection shows that the possibility for a company to start any of the suggested ideas still has several obstacles that might be too high. Mainly patents are said to be limiting certain developments whereas open innovation might be the road to stimulate a successful integration of IDE-knowledge in the design process.

2 Samenvatting

De technologische ontwikkelen gaan razendsnel, ook in de lichtindustie. Met vele nieuwkomers, alsmaar hogere kwaliteits- en garantieeisen en daarnaast nog de ontwikkeling van zaken rond efficientie, LED, 'slimme' producten en modulair ontwerpen, komt de vraag omhoog of deze veranderingen niet verder horen te gaan dan alleen de producten an sich. Het verbeteren van de efficientie en de afstemming met de markt blijft namelijk altijd doorgaan en het ontwerpproces zal hier wellicht ook onderhevig aan moeten zijn. Dit verslag zal zoeken naar de mogelijkheden die verbeteringen in het ontwerpproces kan bieden op het gebied van ideegeneratie. Vanwege de grote invloed van zowel interne als externe factoren, zal elke verandering goed afgestemd moeten zijn met de context zoals die op dit moment binnen GE Lighting in Boedapest is.

Vanwege deze sterke invloed is het huidige ontwerpproces van GE en de daarbij behoorende context geanalyseerd. De notie van de huidige situatie als een van bovenaf gestuurd proces, met een gedetailleerd stapsgewijze methodologie dat zijn plaats heeft in een duidelijk management en engineering perspectief, geeft een heldere basis voor de interne factoren. Gecombineerd met de spelende externe invloeden, geeft dit vorm aan één specifiek criteria: dat het voorgestelde script moet passen in de huidige situatie. (Met dit script wordt gedoeld op een stapgewijze benadering van het process die kan worden gevolgd om de ideegeneratie te verbeteren.) De andere criteria voor het script zijn: "Genereren van een variatie aan product ideeën", "verkorten van de tijd voor het kiezen van een volgende ontwikkeling" en "verbeteren van de communicatie tussen verschillende disciplines." Om met deze beperkte hoeveelheid criteria aan de slag te kunnen, zijn er implicaties die resulteren in een duidelijke referentie met wat behaald oogt te worden.

Het voorgestelde script vindt zijn basis in het vakgebied industrieel ontwerpen (IO) en vervult het merendeel van de gestelde specificaties / implicaties vaak in principe vollediger dan GE Workout, de methode die op dit moment gebruikt wordt binnen GE Lighting. In het tiende hoofdstuk wordt het script geevalueerd op het genereren van alternatieven voor het modulaire ontwerp zoals dat nu wordt toegepast in de GE Lighting's R250-productfamilie. Het tonen van hoe IO-kennis kan zo laten zien hoe het gebruikt kan worden om ontwikkeling van duidelijk verschillende ideeën kan stimuleren.

De case toont kort geformuleerde suggesties voor verschillende conceptmogelijkheden, waarbij het detaillevel laag wordt gehouden. Daarnaast is duidelijk geworden dat bij de beoordeling en selectie van ideeën de mogelijkheden voor een bedrijf sterk verhinderd worden door patenten. Om deze reden zal de ontwikkeling richting open innovatie een interessante route zijn om de integratie van IO-kennis in het ontwerpproces succesvol te maken.

3 Glossary

Approach	The way of handling and taking steps, often implies a more free way of taking steps.
External aspects	The aspects outside the design process itself.
IDE-knowledge	The knowledge about Industrial Design Engineering, mainly focussing at the knowledge of design approaches.
Internal aspects	Aspects or factors inside the design process.
Lamp	The system that produces the actual light.
LED light engine	The whole part with the LEDs.
Luminaire	The product as a whole.
Method	A procedure, technique or way of doing something, especially in accordance with a definite plan.
Methodology	The combination of structured methods as a whole.
R250	One of the variances of the R250 LED Road luminaire product line.
Script	The plan which sets out what should be done, always has a clearly prescribing character.
Top-down	Refers to the way decisions are built-in to a company. Top-down means that the decisions or structures are generally made at the high hierarchy level and from there on defined for the tasks of lower hierarchies.

4 Preface

This project is done to expand the expertise in the field of industrial design engineering (IDE) and more specifically to deepen the knowledge about design methodologies. Thereby it is aimed at linking theory and education with a commercial environment and getting a clearer grip at the less exact parts of design processes. Of course, this is done in combination with the pleasure of an ideal location as Budapest such that not only knowledge, but also mental progression is stimulated during the time of this project.

I want to thank the ERASMUS program, for stimulating students to take possibilities like my trip to Budapest; the Budapest University of Technology and Economics, for their good environment during the period I studied for this project and several other courses. Including some very helpful and inspiring teachers; József Váncza, for all his time and help for this project. Something what I really appreciated and someone that seemed to be there whenever it was needed. It was very good to notice that I felt almost at home at SZTAKI. László Balázs, whose view and insights were really helpful and eye-opening. I really appreciate the time and patience he had with me, as I was sometimes a naïve bachelor student. Lastly, I want to thanks Eric Lutters, for his help in this project.

All together it was a wonderful experience, which came to a success by the grace of a lot of people. I was really happy to do it and I hope that many other students will get the possibility to have this privilege too. Thanks, hopefully you will enjoy looking back and for now, enjoy reading this report.

5 Introduction

"GE's latest outdoor luminaire sets new standard for road lighting solutions", a headline that is always welcome for the worlds most experienced company in outdoor lighting. A leadership GE had from the start of developments with the electric bulb and aims to continue nowadays with LED (Light Emitting Diodes) [1].

That the market evolves has always been very clear. From the beginning of time, customers and companies have always been looking for the 'next thing', causing increasing wealth and according to that, the rise of new needs, values and redefinition of standards. An often slowly, but ever occurring process. Since technical developments started to develop more and more quickly, evolutions got more influential and so the called technology push and market pull seem to be responsible for an on-going rising speed of innovative market changes. This trend is still going on today and does not seem to be slowing down.

The adaptation to this trend is getting essential for companies nowadays, especially for markets in or related to technology. Not only research showed the competitive edge for organizations in quick development of new products [2], but also history showed us already many examples about the importance of the openness for those adaptations. For instance in the case of IBM, which went along with the shift from producing goods towards delivering services. While IBM started as being fully focused at the manufacturing of hardware, nowadays they have a very big amount of their company working at services (including software, consultancy and customized solutions) [3]. But the other side is also shown by history; big companies have collapsed in the past due to a not successfully adaptation. Like in the situation with Polaroid, once a big company in the area of photography, with not only big market share in analogue film and cameras, but also being the top seller of digital cameras. However, as digital cameras flooded the market, the Polaroid leaders continued to believe in the importance of the paper print, an idea that was in line with their thorough market research [4]. However, the market developed differently and the losses that followed made it very clear to Polaroid that their 'known' tens-of-years-existing market was not a static one. That a lack of evolution along with the market indeed showed to be essential, clearly underlined by what happened at 11 October 2001 [5], only a rough ten years after being the market leader;Polaroid went bankrupt. Besides those examples of life and death of companies, the amount of success might also be based heavily on this adaptation. Finding or defining of the next evolution in a market for instance seemed to have boosted Philips in the consumer market with the ambilight and 'living colours' [6].

Although those shifts might seem to be rare or accidental, the accelerating speed in which markets evolve together with the huge impact it can have, makes it an essential part of doing business nowadays. Looking at research in the car industry can emphasize this feeling and gives the firm's business orientation a role with a major effect on the performances. It also warns for the inertia that may be built up as the business grows, saying that the ability to respond to market changes is a very important issue for big companies [7].

The response to market changes can be only improved by better preparation or developing the market change yourself. Both activities have difficulties to get a clear understanding of their consequences. However, a study with the state-of-the-art knowledge in this area will be relevant to keep track of those possibilities and might shine a new light on what might be the new 'next thing'. This study will try to do that, by answering the following main question:

> *"How can the generation of possible design solutions be improved in GE Lighting by using knowledge in the field of Industrial Design Engineering?"*

To answer this question first of all there will be taken a look at the product developments that are going on in the lighting industry. After that a design process found at GE Lighting will be analysed in a general perspective towards the process of product innovation. Based on those findings, several design methodologies will get highlighted with showing their potential for improving the current design process. This potential will be merged into a final proposal that will be drawn as a script for possible implementation in GE's current situation. To end the project, the proposal will be evaluated according to a given topic by GE, presenting the way to clear alternatives for modularity in the R250 Road luminaire.

6 Lighting industry's product development

What is the context in which the improvements have to take place?

The first step towards making the generation of design solutions more successful is to understand its context. This chapter will try to improve that understanding. Therefore there will be taken a look at the vision of the lighting industry and a few of the internal and external influences that somehow affect the design process. Concrete examples of this will mainly be showed via some design scenarios from the practice of GE Lighting.

6.1.1.1 *Lighting industry's vision*

What is the lighting industry's vision towards the future developments of lighting designs?

Several trends can be seen within the lighting industry. Almost all of those seem to rely heavily on the development of LED and have energy efficiency as one of their key point. Besides that safety and security improvement, modular design and 'smart products' seem to be belonged topics for the near future too. Especially those last two points can also be seen clearly in the recent press release of GE Lighting Asia, stating that: "The formation of a new global alliance of lighting industry players, aiming to promote and stimulate the development of open-standard wireless lighting solutions and offer maximum interoperability" [8], this includes GE Lighting, Lutron Electronics, OSRAM, Panasonic, Royal Philips Electronics and Toshiba. This group of companies already represents a very big part of the total lighting industry. At one hand they all have their own vision, but are at the other hand their goals and look towards the future seem to be very well connected.

6.1.2 Energy efficiency

Improving energy efficiency seems to be an on-going development for the future. With results continuing to improve and relevance in almost every company in the lighting industry. So is 'sustainability' a clear topic at OSRAM and Philips [9] [10]. With Philips stating the goal "to contribute to a better and higher quality of life for everyone on the planet" [10]. Next to this, GE Lighting has for instance as vision statement: "GE Lighting invents with the vigour of its founder Thomas Edison to develop energy-efficient solutions that change the way people light their world in commercial, industrial, municipal and residential settings." [8]. But energy efficiency is also a key topic on company fairs within the lighting industry [11].

6.1.3 Temperature of delivered light

Both GE Lighting and Philips argue that the temperature of light and therefore its colour is an important factor for what amount of safety is 'delivered'. While Philips states mainly to improve the perception and experience of people, GE gives an even more influential image: "Outdoor lighting plays an increasingly crucial role in the safety and security of public places. … Creating safe environments, roadways and public places and illuminate architectural land without increasing light pollution." [12].

6.1.4 LED development

LED plays a key role within the whole market and also in the perspective of GE. This technology provides an innovative new way of lighting roads with many benefits. For example the 'biological effects of light', focussing at improving the seen perception [13]; but it is also seen as 'key to creative design' [14] with its applications expected to grow rapidly [15] [16]. An expectation that is in line with the one that the market will move to the energy efficient lamps [17] and research done by IMS Research also indicates to a large scale adaption of LED in the years to come [18].

6.1.5 Modular design

Besides the developments with LED, there are also other developments going on. For instance modularity; which is said to be quite beneficial for future lighting owners, because they can invest in products knowing that those products can be around for much longer because of their future proof module inside [19]. Also several other big developments are going on, like outsourcing and standardizations, benefitting manufacturers and end users alike with within the lighting industry for instance the Zhanga-compliant products that are used by its so called 'Zhanga Consortium' including GE [20].

6.1.6 Smart products

According to Lorenzo Dini -- product manager for LED Indoor Luminaires -- the future perspective of luminaire design will be a 'smart' product that interacts with its environment [21]. Another trend that might be combined with the increasing the efficiency of light. So far, the T4 6,000 hours sensor stick lamp, which has 2 built-in sensors that automatically switches on at dusk and off at dawn, is a nice existing example on the market [22].

All those aspects listed above are often already seen as coming together in the latest products that are being produced. However, as stated in some of GE's latest articles [23], the future might well possibly take those developments to a level much further than what is available now.

6.2 Internal influences of the design process

What 'internal' factors influence the design process?

Now that the general vision of the market is presented shortly, the focus can be shifted to the specific design process found at GE Lighting. The process will be covered along with its influences that are encapsulated within the current way of working, the company and the approach of employees.

6.2.1 Top-down process

Since GE Lighting is a big company with many divisions, those parts have to work together in a good way. To coordinate work, a well-defined structure and several checklists are being used and together with this comes a clear defined and divided set of responsibilities. All of those aspects are in principle top-down decided, following the main structure the Toll Gate NPI Process shown in Figure 1.

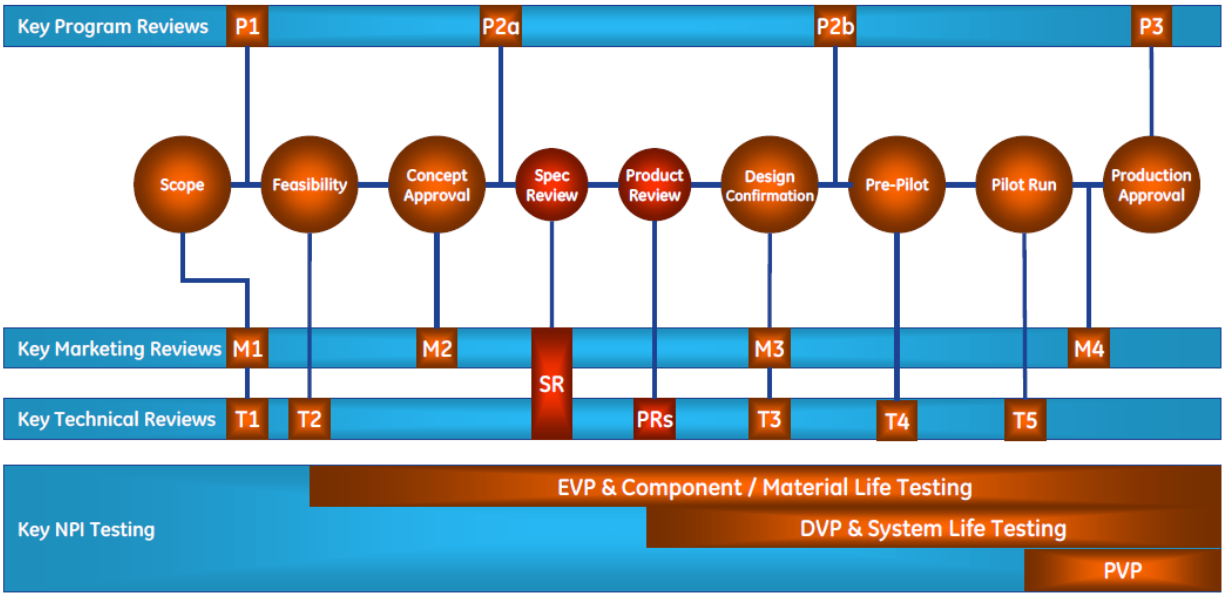


Figure 1: The Toll Gate NPI Process as leading structure within GE Lighting. The central circles represent the main phases, the P#, M# and T# squares represent the points where checklists need to be fulfilled before it can be passed on. Each letter of the checklist's name refers to the aspect that is reviewed (program, marketing or technical) [53].

6.2.2 Fully detailed stepwise methodology.

Although the borderlines are clearly and top-down defined, the phases and part between those checklists seem not to be defined top-down. On the one hand, this gives each area a lot of possibilities for having their own approach and provides opportunities for applying their preferred methods freely. On the other hand, this also means that it is often not documented or known how activities elsewhere in the company are exactly done and tools, tips and approaches are not shared by definition. The role of someone's approach in this context is thus mainly guidance to reach the next checklist.

6.2.3 Strong reputation for management process

The design process within GE is strongly influenced by several specific management processes. One of those is known as 'GE Workout', a method developed at GE in the late 1980's and still successfully applied within GE Lighting and some educational institutes today.

The method is said to focus on fast implementation of measurable improvements with clear lines of accountability – obtained with speed, simplicity and self-confidence. This brings a cross-functional group of people closest to the problem together, and helps develop actionable recommendations to a specific business challenge (identified by leadership as a priority for improvement.) The developed recommendations are then tied to action plans that should be capable of being implemented within 90 days [24] [25] [26].

GE Workout can be seen as a very successful method for quick adaptation implemented within GE, a method that gives GE Lighting already the possibility in their daily business to cope with needed changes.

6.2.4 Strong engineering perspective

Due to the clear engineering character and capabilities of GE Lighting, it seems to be somewhat hard for 'out-of-the-box'-thinking to occur. Although, several out-of-the-box ideas were successfully implanted in the past, it looks as if those ideas often rely on individual people who brought a different viewing angle from their previous department. A process that does provides new insights from time to time, but the generation of out-of-the-box-ideas can well possibly be improved. However, once an idea is generated, the engineering expertise can kick in and the optimisation of the idea towards a product can be well executed by all previous experience.

6.2.5 GE imagination at work

Within GE as a whole, innovation always got a key position. This focus can be noticed by such a statement as “GE Imagination at work”, by their developed indicators like the ‘GE Innovation Barometer’ or the many online posts in which they write about innovation [27]. In many cases this focus has resulted in bigger innovation focused activities like ‘Ecomagination’ where their focus towards innovation narrows in the business strategy to create new value by helping to solve energy, efficiency and water challenges. It is a business strategy which also covers many recent GE Lighting products [28]. Besides this, GE’s recent start with adopting a more open attitude towards product development (‘open innovation’) seems to be in line with the on-going focus towards innovation too. [29] This shift towards an open attitude can be seen clearly in several other companies in the market, with Philips [30] stating this shift already back in 2005 [31].

6.3 External influences of the design process

What ‘external’ factors influence the design process?

Besides the internal factors of the design process, there are also several external factors. One of them -- and probably the most important one -- was already referred to in the introduction, but other aspects should be taken into account, too.

6.3.1 High speed developments

The technological developments are moving rapidly. The lighting industry is no exception in this and the importance and possible implications of this process is huge. As shown in the introduction the speed of adaptation to the market can either make or break the success of a company. And since high speed developments lead to quickly outdating products, the risk of investing money becomes bigger and especially the products on stock can cause big losses if the market develops quickly.

6.3.2 New entrants

The amount of players in the lighting industry is big. Besides traditional companies like Philips, OSRAM and GE itself, many new entrants are found in the lighting industry. Together with the shortened time for return on investments, this causes extra cost pressure on the products that are delivered. In a market that watches each other closely and customers that can pick the best product easily, the need for companies to show their specific quality increases. Where OSRAM presents itself as “a high-tech company in the lighting sector” [32]; Philips as a “diversified health and well-being company, focused on improving people's lives through meaningful innovation in the areas of Healthcare, Consumer Lifestyle and Lighting.” [33]; and GE Lighting as inventing “to develop energy-efficient solutions that change the way people light their world in commercial, industrial, municipal and residential settings” [8]. However, collaboration between companies seems also to be stimulated, leading to for instance new global alliances within the lighting industry [8].

6.3.3 Increasing quality and warranty requirements

Before introducing a new product, there are always risks at stake. The chances for some unforeseen problems are always there and testing them for limiting uncertainties takes a lot of time. Since every new product variety should be tested and certified, quality and warranty requirements are increasing and the role of risk management and certification becomes more and more important, the time it takes to get a new product on the market stays relatively long.

7 Elaborate analysis of the design process

What kind of improvements are needed in the current situation?

After having seen the context of the lighting industry in and around GE, it is important to take a closer look at the design process itself. GE Lighting's current design process will be analysed in a general perspective towards product innovation. Together with criteria for a methodology that should improve the generation of design solutions, this will help getting a grip on the improvements needed.

7.1 Current situation

What aspects of a successful methodology are lacking in the current situation?

Describing the current situation of product innovation and GE's design process contains a certain degree of complexity. Therefore, a first grip of the product innovation process in general is needed. With that in mind, a more detailed description can be taken into account for a comparison with the current process structure at GE. Due to that overview, the criteria suggested by the company along with its implications will be approachable in relation to the full product innovation, giving a clear indication of the aspects that might be lacking.

7.1.1 Product innovation process

First of all, we start with the process of product innovation. A process can be described by a couple of different models. A very basic representation of the structure is the one in Figure 2 [34].

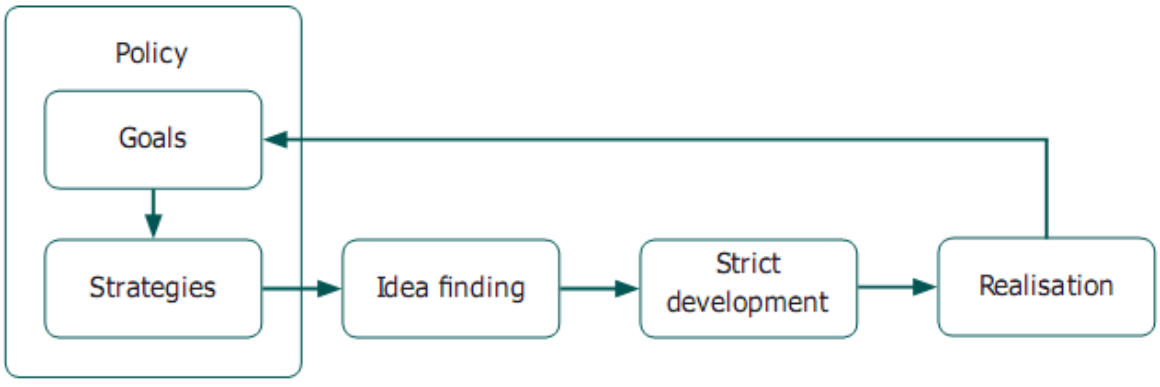


Figure 2: The structure of the product innovation process by Roozenburg and Eekels [35].

The structure by Roozenburg and Eekels clearly shows the product innovation process as an on-going process. A company's policy is here indicated as what should contain the goals and strategies that are needed to start idea finding. The simplicity can be very helpful to get a first grip on the process, but for a deeper analysis a more detailed overview is preferred.

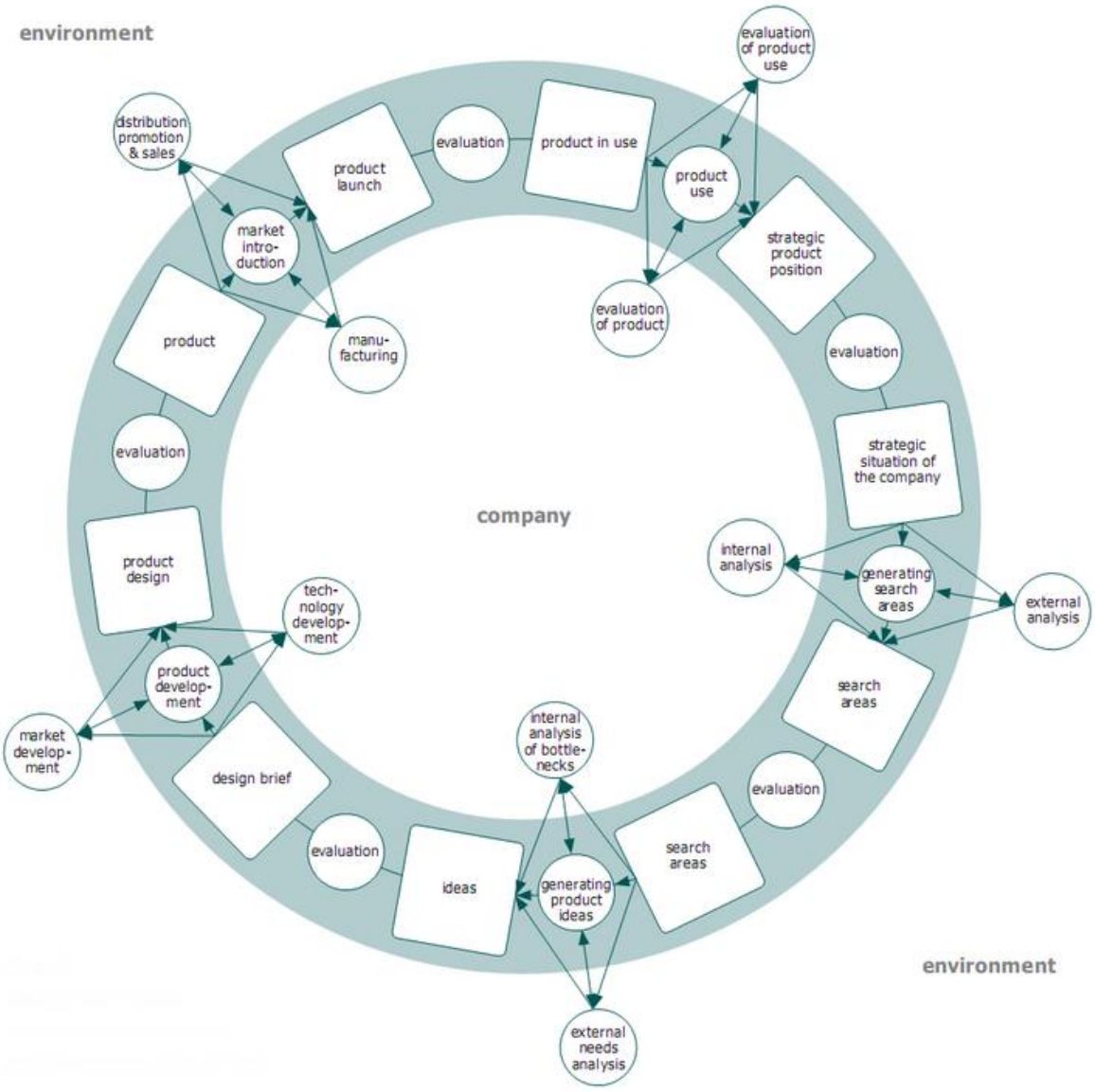


Figure 3: The innovation phase model according to Buijs and Valkenbrug [36]. The processes are shown inside the circles and the results of those processes in the squares.

7.1.1.1 *Innovation phase model - Buijs and Valkenburg (2004)*

The innovation phase model according to Buijs and Valkenburg (2004) is this 'more detailed overview'. It tends to describe the product innovation process as a whole. In Figure 3, the blue ring itself shows the development of a product, the outside the ring represents the product's environment (like its market and competitors) and at the inside of the ring are internal activities of the company described. The evaluation of the strategic aspects (the white evaluation circle in the ring at the upper right-side half of the scheme) is seen as the key starting point of the innovation process [37].

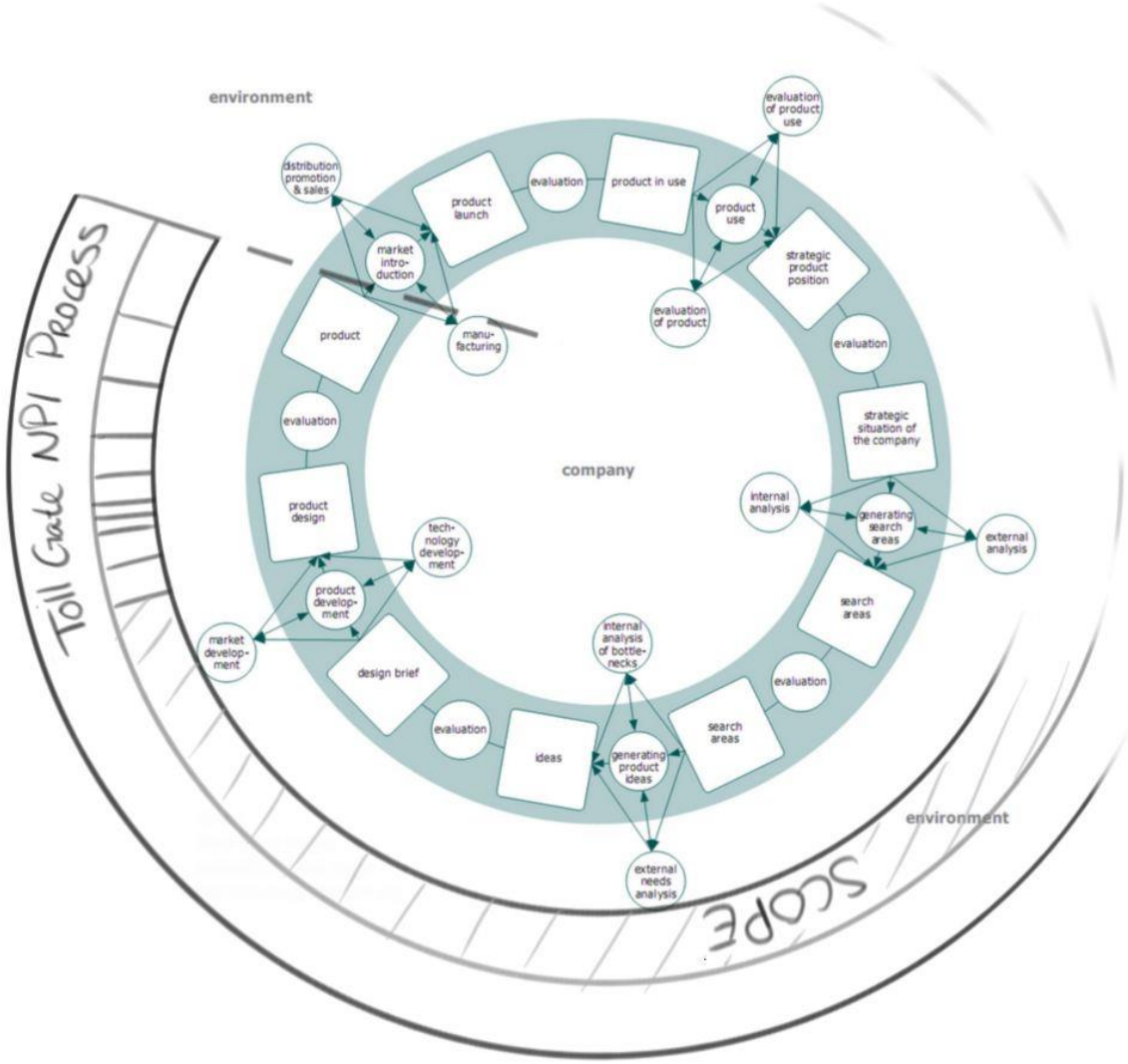


Figure 4: Toll Gate NPI Process's coverage of the innovation phase model by Buijs and Valkenburg [36].

7.1.2 The current situation in perspective

In Figure 4 the innovation phase model places the Toll Gate NPI process in perspective. This shows that, although having more detail, the Toll Gate NPI process does not cover the whole process. With the 'scope' as its starting phase, a very broad range of stages is covered. But only the end of first phase is well defined. Due to several checklists: T1, M1 and P1 (the technical, marketing and program review resp.) the further development is limited by for instance checks as: "No inventions required". In contrast to its start, the Toll Gate NPI process as a whole does have a clear end, a design with production approval. This final approval is possible after successfully testing the test version with all function aspects, when the product is ready for manufacturing.

At that moment the Toll Gate NPI Process ends. But manufacturing, market introduction, distribution, promotion and sales are starting and aim for a successful product launch. Those

processes are covered by several specific departments within GE Lighting. What approach is used within those departments is left on the side in this project.

The product use is the process that follows the Toll Gate NPI Process in the innovation phase model. Here the exact way a product is used gets shape and this is subject to analysis. The results of certain evaluation often count a clear end- or starting point. The strategic aspects listed in the innovation phase model ('strategic position of the product' and 'strategic situation of the company') can be very useful for placing the results in a desired situation and thereby generating input for the possible start of the 'scope' phase in the Toll Gate NPI process.

Product evaluations and other ways of collecting feedback are known processes in GE Lighting. Combined with the existence of GE's strategic vision in for instance annual reports [38], a strategic product position is being made. Although product evaluations might provide new insights and direct links for new ideas, continuation of this project will be done with the assumption that those processes are already used appropriate. The strategic situations described based on the evaluations should make it clear if starting product development is needed. If issues appear, an innovation project will be started within GE, but when there are no issues new developments are desired too. The extent to which those kind of new developments are starting seems to be limited. So-called issues or tasks might therefore well be based on a future perspective, a very important factor in the quick developing lighting industry. So, while the future developments are analysed and watched closely, the link from a strategic perspective towards clear search areas is relatively open in GE.

When a new innovation project is being started, the possible search areas can be generated by the use of internal and external analysis. After the evaluation of the generated search areas, one or a few search areas can be selected to be targeted. Internal analysis will include the long-term strategy of the company. This part covers a company's vision and their long-term goals which (if formulated right) should lead to clarification of more specific and tangible search areas. The external analysis will aim at aspects like the request of the market, this might influence the search areas either via a change in the company's long-term strategy or directly by targeting this in particular by selecting a closely related search area. Within GE the topics listed in part 6.1 seem to be the main search areas as they are known within GE. Although a short list gives a clear vision, the search for new ones and the selection of specific area(s) should be look at closely since they form a clear basement for how and why ideas are being generated.

With the selected search area(s) the road towards product ideas is made, the generation that follows can be influenced by internal bottlenecks and external needs. The analysis of them forms the two key

processes in this stage. This part is within GE considered as the main challenge. It covers the capability of generating possible ideas and needs a skill that can always be improved and will never reach a final stage. Improving this generation of product ideas will have to lead to more valuable ideas, which can either evoke or make an impact in the final design brief that is generated. On that moment, the Toll Gate NPI Process model can guide further product development like now, starting with the checklist that defines when the design brief can pass from the scope to the feasibility phase.

In this paragraph the current situation of GE has been described by placing it in the context of product innovation as a continuous process. It showed every part of the process that can be aimed at for a better innovation process and thereby indicating some of the limitations and challenges that can be found in the current situation.

7.2 Criteria

What are the criteria for a methodology (or tool) to successfully improving the current process of generating possible design solutions?

After having mapped the current situation of GE's design process, the search for improvements can almost begin. But before this can really start, the criteria for a good or bad suggestion should be defined. Therefore, several conversations had to shine a light on the many aspects. The acquired information resulted in the following criteria for a final script:

1. **Generates a variety of product ideas.**
   Generating a variety of alternative product ideas is the main task that should be achieved in this project. It means that the methodology is capable of generating ideas that can be clearly distinct from other generated results, while the generated results might be applicable now or anytime in the future.
2. **Shortens the time to pick the next development.**
   The creation and selection of a new development or innovation should have the possibility to be quicker and better. There should be searched for a clear context and framework for developments to stimulate this process.
3. **Improves communication among different disciplines.**
   Since the communication within a team seems to be good, the focus should be at the communication among different teams. This aspect is seen to have clear possibilities for improvements and good potential to result in a better context for innovations.

4. **Fits in the context of the current situation.**
   The purposed script should not interrupt with its context to work properly. Of course its preferably to have a script that is in line with the parameters of its internal and external environment as analysed in 6.2 and 6.3.

The extent to which those criteria can be leading is somewhat limited. Attempts to get more objective data were not possible. Therefore, those criteria will mainly find their use as the lead for setting up a proposal. Reflection afterwards was intended to be less subjective.

7.3 Implications

The criteria listed are not as concrete as an evaluation should be. Therefore, implications of the criteria have to be set, making a clear reference for assessment of existing methodologies. The implications of the criteria are set as described in this part.

1. *Generates a variety of product ideas.*
    a. Provides a prescribing approach to come up with clearly varying product ideas.
    b. Includes the analysis of internal and external aspects.
    c. Has results based on a well-defined search area.
    d. Finds its basement in the search areas and strategic perspective of the company.

2. *Shortens the time to pick the next development.*
    a. Bases the search areas heavily on the long-term ambitious vision, so that there will be plenty of space for future developments.
    b. Creates an overview of the previous choices that have been made and the alternatives that are left behind. (This counts for the alternative ideas as for the search areas.)

3. *Improves communication among different disciplines.*
    a. Uses clear communication about what have to be done, is going to be done and has been done.

4. *Fits in the context of the current situation.*
    a. Is not counteractive with a strong engineering perspective:
        - The script provides a clear working structure
    b. Gives shape to ‘imagination at work’:
        - Stimulates imagination and creativity
    c. Is applicable in the quick developing market:
        - Is open for the bigger picture and long-term changes
    d. Fits in a market with many new entrants:
        - Is capable of keeping the product / development costs sharp
    e. Can cope with increasing quality and warranty requirements:
        - Limits the risks of a new product

8 Using Industrial Design Engineering-Knowledge

Which improvements (based in the field of IDE-Knowledge) are the best to make the generation of possible design solutions become more successful in GE?

After the current limitations and challenges design theory showed, it can also be accessed for possible solutions. Therefore it should link the theoretical challenges back to concrete guiding in the process. In other words, the description of the situation at 7.1 should be the basement for the prescribing guidance what can be done as improvement. To do this, the structure of several available prescribing design methodologies and tools will be shown. Those methodologies and tools have the task to fulfil the criteria by being in line with to the implications listed at 7.3. After the overview of the methodologies and tools available, their implementation possibilities will be covered. This will make the basement for the proposal of a final script in chapter 9.

8.1 Prescribing design methodologies and tools available

What design methodologies and tools are available for improving similar situations?

Based on the implications of the criteria for a successfully improving the current process, there are several design methodologies and tools that come in sight. One of them is the 'GE WorkOut' method and the other one covered here is TRIZ and some of its variations. Based on this information the construction for an implementation in GE Lighting is covered in the next paragraph.

8.1.1 GE Workout

GE Workout is a method that is currently already implemented in GE for generating new ideas, Although it is in certain situations very effective, the method does not seem to be fully sufficient. The blueprint of the process is found on the internet:

"A general template for the WorkOut process can be summarized as follows. First, a group of employees (and other key stakeholders as necessary) and their leader meet. Second, the leader charges the group(s) with solving a problem or set of problems shared by the people but which are ultimately the leader's responsibility. Third, after the leader leaves, the group(s) spends two or three days working on developing solutions to the problems under the guidance of skilled facilitators. Fourth, at the end of the meeting, the responsible leader re-joins the group(s) and hears its recommendations. Many leaders in the organization are also invited to be present during this wrap-

up session. Fifth, the leader has two response choices on each recommendation: "yes," or "no." Sixth, the entire activity has strong management support, and middle-level resistance to the process or outcome is not tolerated. In fact, it is acknowledged in GE that obstructing the efforts of the WorkOut process is "a career-limiting move" …" [24].

Summarized, the steps are the following:

1. Pre-Session Activities:
    a. Identify the facilitator(s);
    b. Select problem domain;
    c. Select and prepare management sponsors;
    d. Identify potential participants;
    e. Prepare participants;
    f. Prepare the groups represented by the participants;
    g. Select and prepare the site.
2. Conducting the WorkOut Session
    a. WorkOut introduction and team charge;
    b. Presentation to responsible leader.
3. Post-WorkOut Period
    a. Sponsoring leader's role;
    b. Participant's role. [24].

8.1.2 Particular development overview taught at the University of Twente

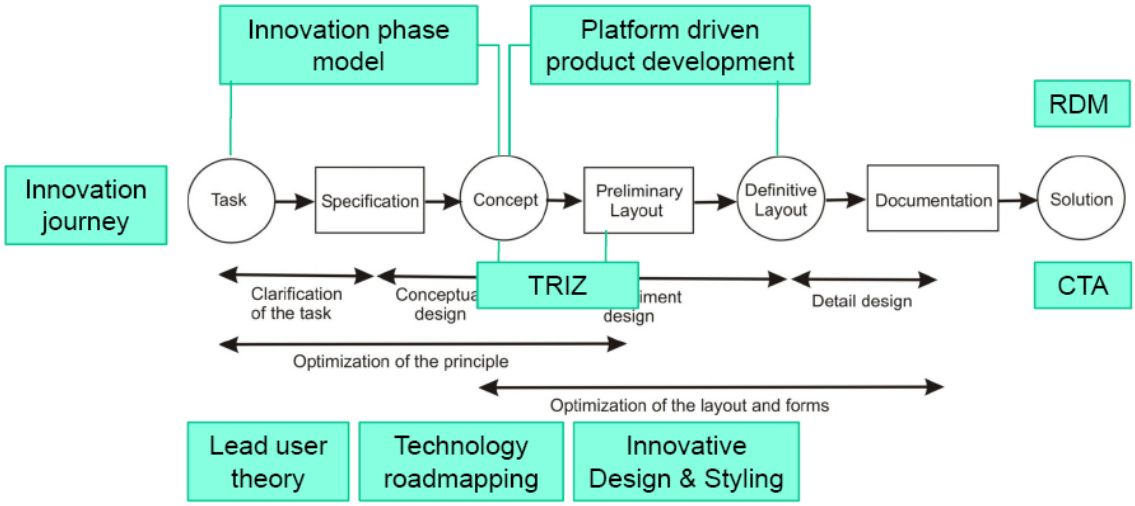


Figure 5: Flow chart representing innovation methods presented in the course Sources of Innovation. Placed in the basic framework of the basic industrial design method of Pahl and Beitz [39].

To place several available methods in the development process an overview taught at the University of Twente is used. This overview is seen in Figure 5 and uses a description of the design process as its basement (the basic industrial method by Pahl and Beitz) [39]. It describes the process starting with a task to the stage of solution. Based on this, several methods and tools are placed in context:

- The “Innovation Phase Model” is the circular process model of Chapter 7.1.2.
- “Platform driven product development” implements the modularity principle in design.
- “TRIZ” is a big toolbox with many views, mainly known for its problem solving practises. Its further details are described on 8.1.3.
- “Lead User Theory” is a tool to define the needs of the users in the “near” future.
- “Technology roadmapping” is a tool to map what technologies will be developed worldwide around what time / year.
- “Innovative Design & Styling” is about analysing the looks of a product.
- “RDM”: Risk Diagnosing Methodology.
- “CTA”: Constructive Technology Assessment.

The part of the development process in Figure 5 that focuses at ideation is referred to as “Optimization of the principle”. It starts with the task and going to the specification (so called “Clarification of the task”), then it focusses at the conceptual design and ends with the “Preliminary Layout”.

8.1.3 TRIZ

TRIZ is a set of problem-solving, analysis and forecasting tools based on a study of patterns of inventions in patent literature. It includes not only the tools but also guidance about how they should be applied and work together. Thereby it consists of a practical methodology, sets of tools, a knowledge base, and a model-based technology for generating new ideas and solutions for problem solving. Applications of those tools can be found in problem formulation, system analysis, failure analysis, and patterns of system evolution. It has the potency to show several possible solution routes and many variations are known due to its open development character. A note that is often made about TRIZ is that its complexity can be easily be used wrongly. Or, as Valeri Souchkov stated in one of his presentations: *"Important: TRIZ is complex. It contains many techniques and knowledge bases. Learning full TRIZ takes considerable time. Currently TRIZ is available as a number of independent modules that can be learned and used independently."* [40].

8.1.3.1 *Variation xTRIZ*

xTRIZ is an extension to TRIZ under the development of ICG Training & Consultancy. It contains a full task oriented roadmap for the application of a set of tools cover in or related to the original set known in TRIZ. This xTRIZ roadmap (showed in Figure 6) was set up by Valeri V. Souchkov and shows a stepwise approach through a set of tools based on the task to achieve. The tasks focus at problem solving (targeting at a specific problem or at finding problems and improvements for system's functionality) or creating what's next (targeting at finding new working principles or creating future system generations. Individual methods and tools are chosen according to those tasks. The outcome of a method or tool will influence which step is taken next.

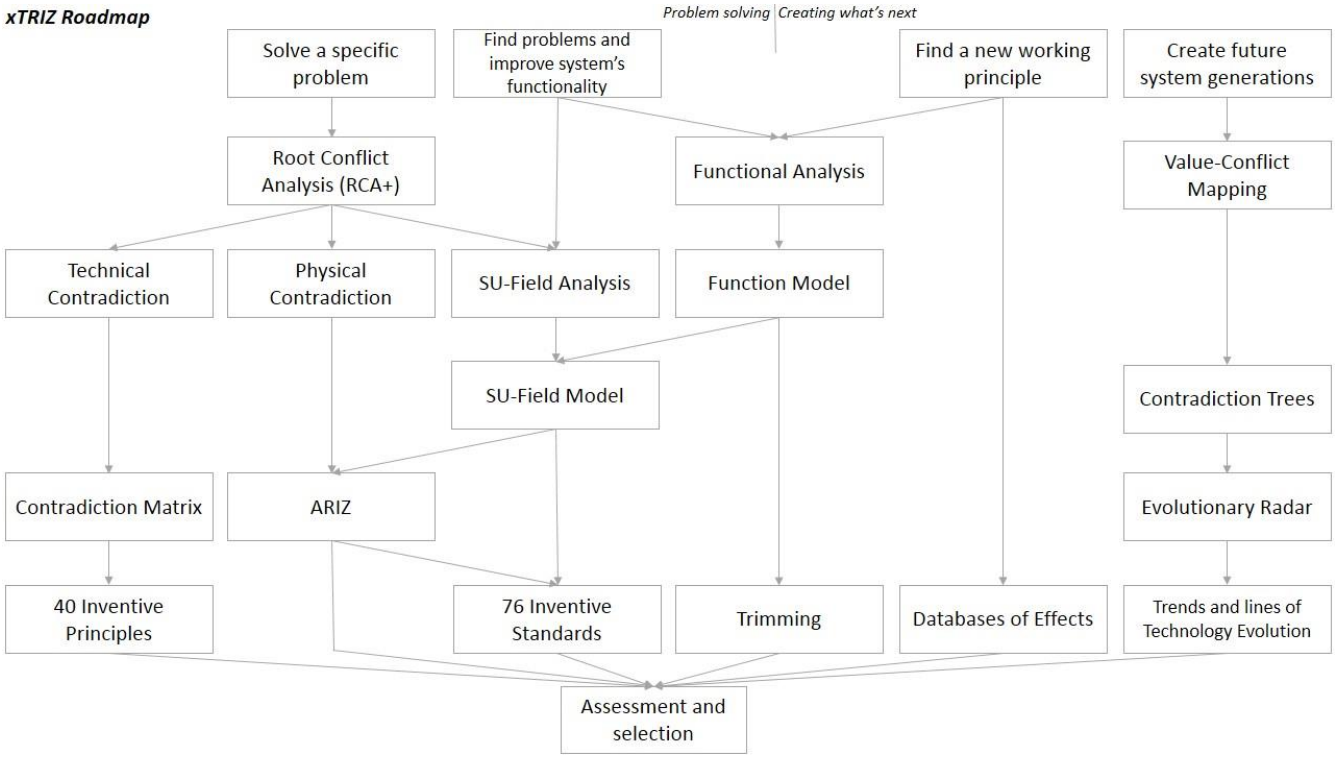


Figure 6: Flow chart representing the tools and methods covered in xTRIZ. Which should be chosen can be based on the task stated at the top 4 blocks.

8.1.3.2 Basic TRIZ Process with RCA+

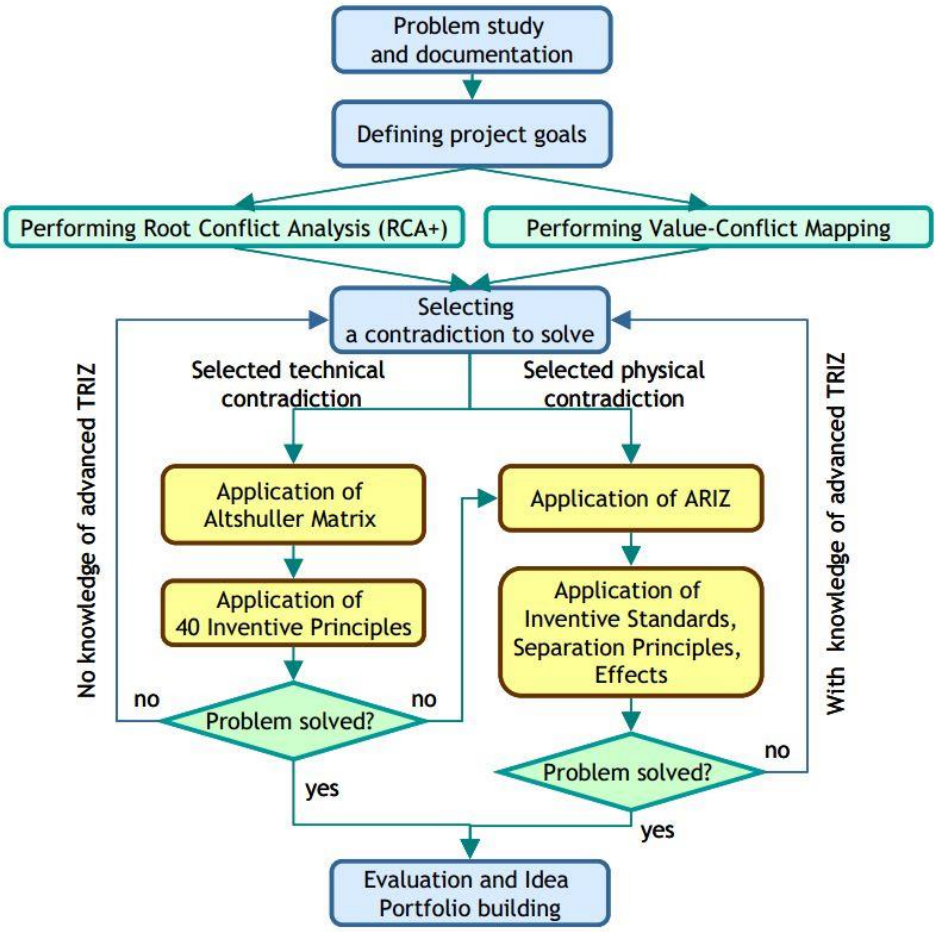


Figure 7: Flow chart representing the TRIZ process with Root Conflict Analysis (RCA+) giving the designer a step-by-step walkthrough for generating ideas [40].

The TRIZ process with Root Conflict Analysis (RCA+) of Figure 7 shows an overview in structured steps. It consists of a few elements that need a little explanation:

- "RCA+" is an analysis that searches in a structured way for the root(s) of a specific issue or problem. It generates a cause-and-effect-tree that shows where the targeted problem could be solved based on the contradicting properties involved.
- "Value-Conflict Mapping" is an approach that maps the values to deliver and provides an overview what values are conflicting.
- "ARIZ" a variance of TRIZ which is generally more intense therefore mainly used to overcome problems that cannot be solved with normal TRIZ.

The overview also shows that there are choices to make during the process. Those are based on the (goals in) the project itself. Either RCA+ or Value-Conflict Mapping is used; and ARIZ functions as a possible extension (that needs "knowledge of advanced TRIZ") when normal steps are not sufficient.

8.2 Implementation

The TRIZ methodology in practise has some clear characteristics. Those ideas are generally found in the TRIZ methodology and with the appliance of TRIZ in for instance a company in the high-tech industry as Samsung [41] [42].

First of all, TRIZ is capable of generating a clear variety of alternative product ideas. With the prescribing approach noted before, TRIZ always aims to come up with a particular selection of innovation principles. Since those innovation principles are different, a distinction between the ideas generated with them will probably be clear too. Thereby, TRIZ uses a strong analysis with internal and external aspects to base the ideas in. Along with this, the task specification is seen as the starting point for achieving a specified goal.

Secondly, the evaluations and selections in TRIZ of the 'best' contradictions and ideas include the company's strategy and vision. Throughout the TRIZ methodology the arguments for selection are based upon this which is in line with the description in the innovation phase model.

Then the visual way in which problem analysis is being done. Hereby all arguments and reasoning is bundled in a visual representation. This provides an overview that can bring an unambiguous clarification among different disciplines. Showing the problem in depth to the engineers, managers and everyone else. Thereby, it is a uniform way that can be used by anyone with information relevant to the problem.

But there is also a downside of the practical implementation of TRIZ. This covers the large extent of knowledge and experience about the practise of TRIZ-tools that is needed and also the knowledge that keeping the product under budget is not the main aim of TRIZ. The methodology does not per definition aim for small changes that minimize the risk, but searches for an optimal solution which is eventually selected by the person who is applying TRIZ. However, this does mean TRIZ is always intended to aim for the bigger picture open for changes on the long-term. But even though there is a tendency to cover at least the best long-term possibility, the choice to pick a long-term or short-term development is not made by the methodology itself.

Altogether, TRIZ does provide a clear working structure that fits in perfectly with an exact and strong engineering perspective as found in GE Lighting. Besides that, the methodology combines this with

clear-cut stimulation for imagination and creativity. Especially, because it targets the area that is the most probable to contain the optimal solution.

Although all those aspects seem to be very useful in the current situation, they might not cover everything. The innovation phase model is a good base for this, and its part at Figure 8 shows that the search areas are defined via several other processes. Since the selected search area is like the task specification to apply the suggested steps of TRIZ, an addition seems to be needed.

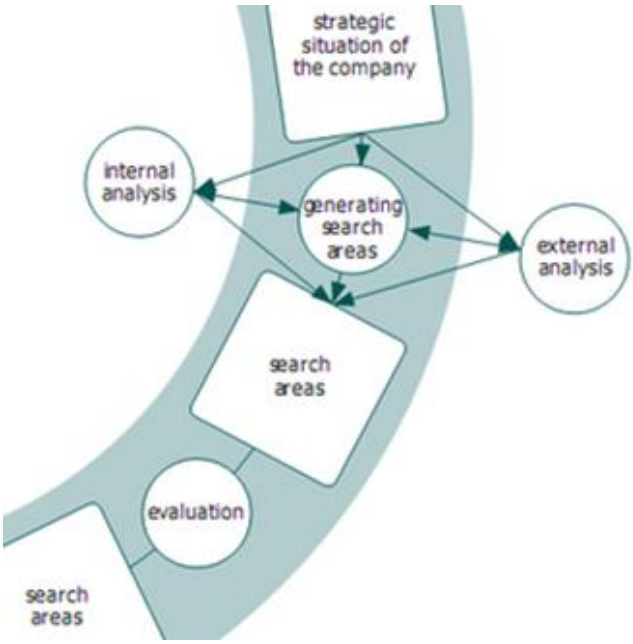


Figure 8: Zoomed selection of the innovation phase model of Buijs and Valkenburg (2005) [36].

Mainly the part from the strategic situation of the company towards search areas can be a logical step in this process. The fact that the evaluation of the strategic situation is generally viewed as the key starting point [37] emphasizes the targeted domain. In this part mainly the vision and goals of the company and the project should be leading.

Strategic situation		**Search areas**		**Search areas**
General strategy, Company's & Project vision, Long-term & ambitious goals	The reason why should lead to a project goal. The way to achieve.	Many things that should be achieved can be listed.	In addition with knowledge and experience	Top search area / thing / issue to solve as clear task of the project.

With this last aspect about the reflection of the company and project vision in mind, the coverage of the innovation process is reflected in Figure 9: Overview of methodologies and their coverage of the product innovation process in the innovation phase model . Referring to the innovation phase model as a base, and the Toll Gate NPI Process, marketing, (product) evaluation, the vision and goals and TRIZ together assist in all parts for clear specific guidance.

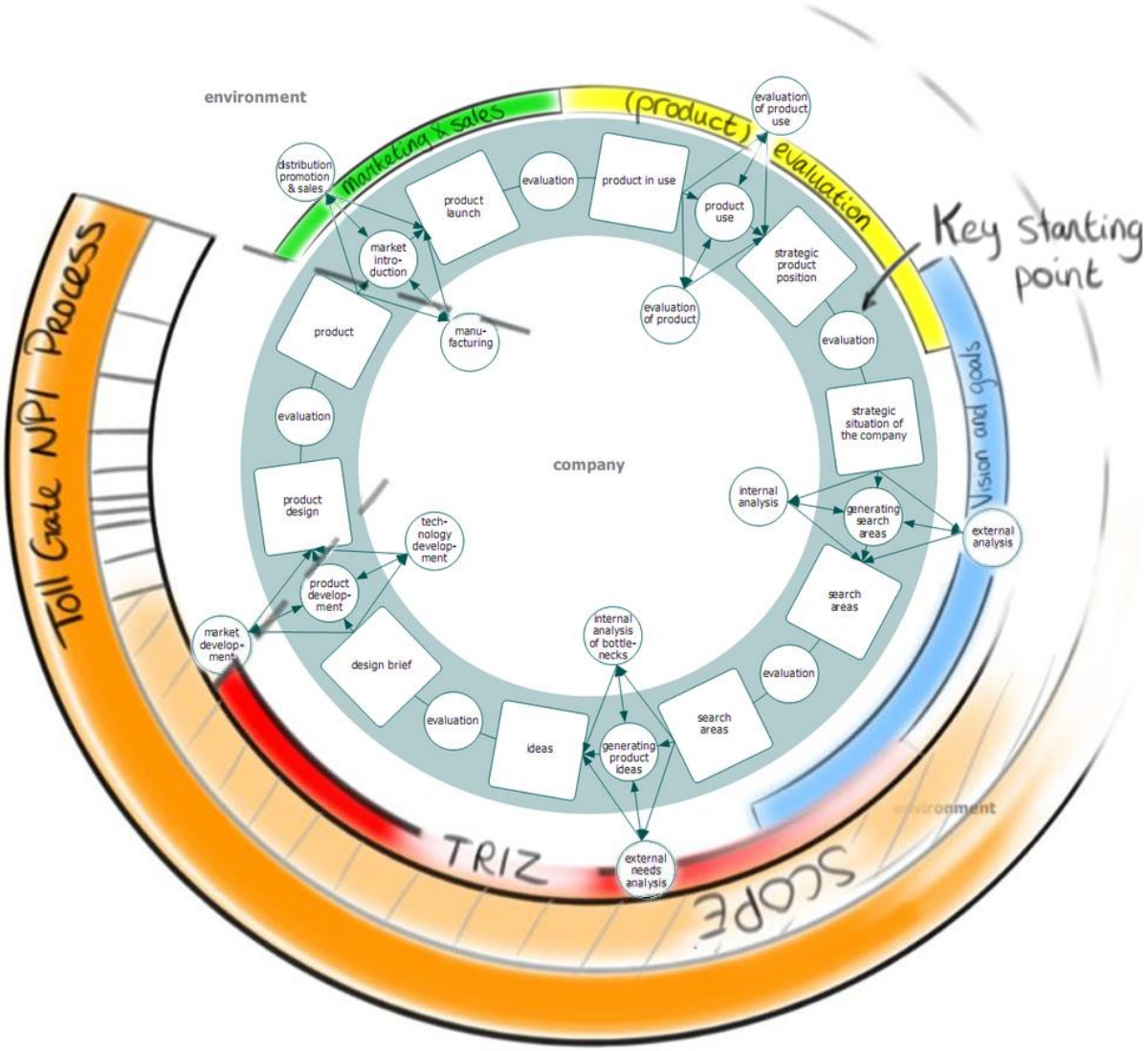


Figure 9: Overview of methodologies and their coverage of the product innovation process in the innovation phase model [43].

8.2.1 IDEF0-based variation description

IDEF0 is used to produce a function model. A function model is a structured representation of the functions, activities or processes within the modelled system. Figure 10 shows a variation made to show the enablers of a specific function. This term is used in different situations too and can focus at where, what and with whom the function is performed [44]. With this principle the script was visualised during the next chapter. Appendix 5 shows an example for this.

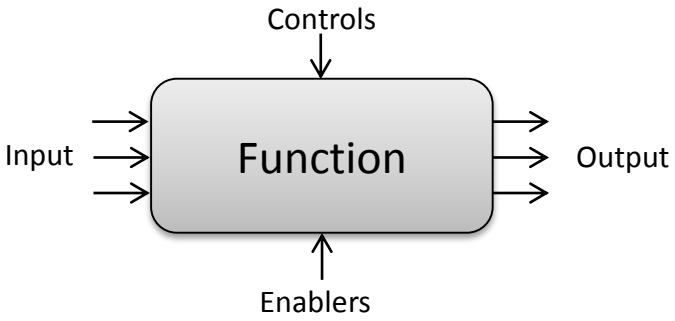


Figure 10: IDEF0-based variation for the general explanation of a function or process. In typical IDEF0 the location of 'Enablers' is for the 'Mechanisms' used. [54]

9 Final script

9.1 Construction of the script

The script is constructed of tree main components: first of all the criteria and its implications, secondly the existing design methodologies and last the applicability on the purposed case. In a few steps, the logic that follows by this information will lead to a skeleton for a script that should be capable of fulfilling the criteria and can be evaluated. Since there is a clear goal that should be targeted, the script should at least be applicable for a specific problem, therefore the problem definition is essential for the start of the case. All those aspects together construct the script.

9.1.1 xTRIZ-roadmap

This roadmap is used as the base for the implementation of TRIZ in a final script. It shows the possible starting positions and to target a specific problem the steps will be:

1. RCA+
2. Technical contradiction will be found,
3. Contradiction Matrix[1]
4. 40 inventive principles
5. Assessment and selection

9.1.2 "Basic TRIZ with RCA+"-extension

Based on the basic TRIZ Process with RCA+ a slightly further and more concrete overview can be achieved. This by adding several aspects (displayed in bold) to the list, making the script as follows:

1. **Problem study and documentation**
2. **Defining goals**
3. Problem Analysis: (RCA+ **/ Value Conflict Mapping**)
4. Selection process,
5. Contradiction Matrix = **Altshuller Matrix**[1]
6. 40 inventive principles
7. **Problem not solved? Possible extension to ARIZ if advanced TRIZ knowledge is available.**
8. **Evaluation and Portfolio building**
9. Assessment and selection

[1] The "Contradiction matrix" (also known as "Altshuller Matrix") relates two abstract-defined contradicting properties to a small selection of inventive principles. This selection of principles is very likely to overcome the targeted contradiction.

9.1.3 Reflection on the criteria

Assessing this methodology alongside with GE WorkOut shows still a lacking part for the criteria. This can be seen in Appendix 4: Assessment of methodologies and tools by the non-green areas under the TRIZ assessment. This aims mainly at the following non-fulfilled implications of the criteria:

1. Finds its basement in the search areas and strategic perspective of the company,
2. Bases the search areas heavily on the long-term ambitious vision, so that there will be plenty of space for future developments,
3. Creates an overview of the previous choices that have been made and the alternatives that are left behind. (This count for the alternative ideas as for the search areas.)
4. Keeping the product / development costs sharp,
5. Limiting the risks of a new product.

The last two points, number 4 and 5, can be seen as non-primary problem. This due to the fact that GE Workout already seems to be a quite sufficient and successful alternative at the moment. And that the TRIZ methodology definitely can be used to focus mainly at limiting the risks, but therefore it should be incorporated in the problem statement. It is just not a functionality of the method itself. The extension that is still needed should therefore focus at points 1, 2 and 3. Since those implications cover only the subjective area of vision and goals, the describing innovation phase model might show a better look at this part of the process. The focus point in this model is shown in Figure 11.

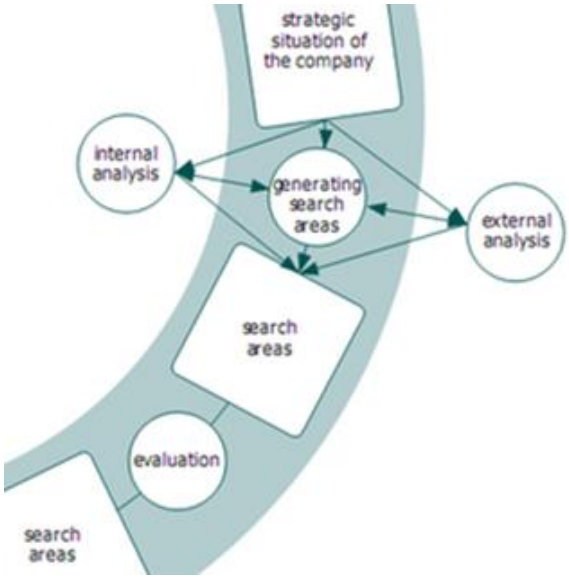


Figure 11: Part of the Innovation Phase Model that shows how the strategic situation of the company can result in targeted search areas.

The strategic situation will be based in the same material as the vision of the company. Whereby the generation of search areas heavily relates to the way (how) the vision is going to be achieved with the current internal and external situations.

That understanding should define and select the search areas / the concrete goals that should be targeted in this project. From there, the needed input for a sufficient base for TRIZ can be achieved. Included with this, the package for the script now becomes:

1. A clear expression towards the strategic situation of the company.
2. How to achieve the vision with the current internal and external situation taken into account.
3. The selected search areas with their goals that are to be targeted
4. Problem study and documentation
5. Defining goals The goal will already be defined in our case
6. Problem Analysis: (RCA+ / Value Conflict Mapping)
7. Selection process
8. Contradiction Matrix = Altshuller Matrix
9. 40 inventive principles
10. Problem not solved? Possible extension to ARIZ if advanced TRIZ knowledge is available.
11. Evaluation and Portfolio building
12. Assessment and selection

The stages around point 2, 3, 4 and 5 are overlapping for a big part, although both of them have a unique perspective to it. This will have to be subject to restructuring if maximal efficiency is wanted.

10 Evaluation on generating alternatives for the modularity of the R250-product family

Figure 12: One example of the R250 road luminaire.

Now that the script is developed it needs some reflection. Since large testing is not possible due to time constraints, there will be a small case in which the use of it is illustrated by generat alternatives for the modularity of the R25C Figure 12 shows an example of the luminai possibility to show at one hand the use an script and at the other hand, give the possi problem that is available and requested on the side from the first moment, results will be able to be valuable and GE can be helped with their current questions. Therefore, this part will not only function as an evaluation, but also for the creation of the resulted ideas. All those factors together result in the following scope.

10.1 Objective of the case

The case will cover one part of the development process guided by the script purposed in the chapter before, to illustrate the way this script would work. The starting point will be the task delivered by GE "generate alternatives for the modularity of the R250 Road Luminaire product family". The end point will be a variety of generated ideas listed in combination with currently existing patents that are in line with those ideas. The coverage from start to end includes only a part of the proposed script, the rest of the script is kept out of evaluation. This is due to the subjective character and indirect relevance for improving the generated results. Reflection on the script will happen based on the problems during the process and the extent to which the criteria and its implications listed in the Elaborate analysis of the design process are fulfilled.

10.2 Current concept: The R250 Road luminaire product family

This product family consists of several varying luminaires based on differences in setup. Together they cover a lighting power range from 39W to 237W in steps of 19/20W. This is achieved by two different types of LED light engines (one of 39W with a lamp that contains 32 LEDs and one of 57W with a lamp that contains 48 LEDs) that are incorporated in a modular design. Hereby one to four LED light engines can be installed in the luminaire, giving the possibility for combinations with up to two 39W and up to four 57W modules. The whole set of LED light engines will be powered by one driver

that can be customized according to the situation. To place this different amount of modules in the luminaire, its housing also consists of modular parts that can be put together for the belonged size. Besides the variations in power, there are also several colour temperatures available, those are 3000K, 4300K[2] and 6000K [45]. The product family is able to target one to 4 lanes and should be extendable for special / specific situations (like cycling paths), currently side entry and post top mounting of the luminaire are already possible for poles with a diameter of 60mm. Its height can vary between 4 and 12 meters. Besides that its optical efficiency is a very important feature; by horizontal and vertical uniformity and steering the light only where it is needed. This is currently provided by a variety of light distributions. Furthermore, their design efficiency (including the heat management), the application efficiency (the long-term efficiency of applying this LED solution) and its environmental efficiency are stated as important aspects for giving this luminaire the value it has [46]. Other restrictions are found in energy efficiency [46], operating temperature [45], weight [46] and certification standards.

10.3 Problem definition

The first thing to do is to get a clear problem definition. The information in the previous chapters helped for getting insight in the current situation and opening the way to a clear problem definition and model.

To identify the problem or the insufficient performance behind the given task of finding alternatives, the target was discussed, “why do alternatives have to be generated in the first place?” There were two main results, first of all to broaden the current view on future possibilities in general, but mainly for getting a grip on how a product line could be delivered on the most cost effective way. The goods that currently are being kept on stock were seen as a direct indication for the existence of better options than modularity as it is currently applied.

Due to this, the case would from mainly on focus on the costs of stock, seeing insufficient inventory cost as the main issue / problem to solve. From now on, the problem was defined as “the inventory costs are too high” and to see how this relates to the stocked goods, the next tool had to be used.

10.4 Problem analysis

The problem analysis can either focus at an analysis for the root cause of the problem or by mapping contradicting values that should be delivered. In this example a specific problem is needs to be solved and therefore Root Conflict Analysis (RCA+) is applied.

[2] The 4300K module actually does have a slightly higher Wattage than the 3000K and the 6000K modules.

10.4.1 Root Conflict Analysis

To get a grip on the causes of the now defined problem, a cause and effect tree gets generated as part of the Root Conflict Analysis. Via this diagram, a clear insight in the causing factors can be traced. The step by step construction of this overview can be found in appendix 14.6; the result is shown in Figure 13:

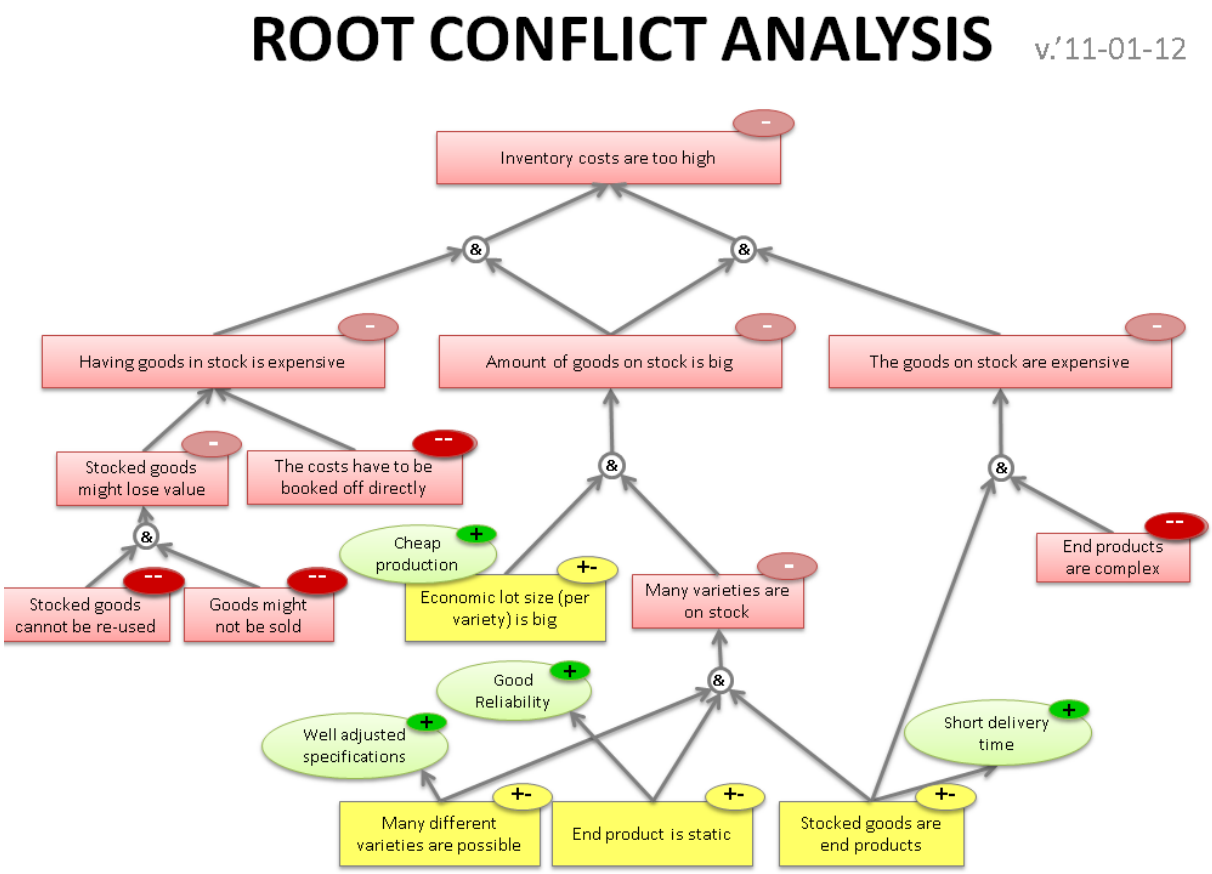


Figure 13: Root Conflict Analysis based in xTRIZ of the problem defined as the "inventory costs are too high". The red box at the top shows this main problem, the red and yellow boxes in the layers below the negative effects that causes this (sometimes indirectly via another box). The green boxes are the positive effects that go along with the so called 'contradictions' shown in the yellow boxes. The arrows point in the direction from cause to effect and when indicating to an &-sign, it needs to be along with the other causes towards this sign to make the negative effect happen. The + or – within the small oval indicate if an effect is positive or negative, a combination shows that it has both aspects and a dubble minus means negative and not solveable.

With this overview, two important notes should be made that were decided together with GE. Firstly, the assumption that stocked goods cannot be re-used. Therefore, this cause got here a double minus, indicating that it is an aspect that cannot be overcome. The other assumption notes that a big economic lot size per variety will only cause a negative effect when there are many varieties on stock. Therefore, solving one of them will decrease the amount of goods on stock, such that inventory costs are no longer too high. Upon this assumption was agreed, making further continuation possible.

10.5 Environmental analysis

With the RCA+ still fresh in mind, a function analysis was done. With the help of some software -- in this case TechOptimizer as shown in Figure 14 -- a quick overview was made with the (inter)actions of and between components. This is not only useful for a better understanding of the problem, but also for reviewing the consequences of a change or even to see aspects like trimming. In this example it might trigger the thought to integrate the isolation component with any of the other components since it does not provide a clear positive arrow in this situation. In Figure 15 and 16 can be seen how the parts of the (American) R250 are working together.

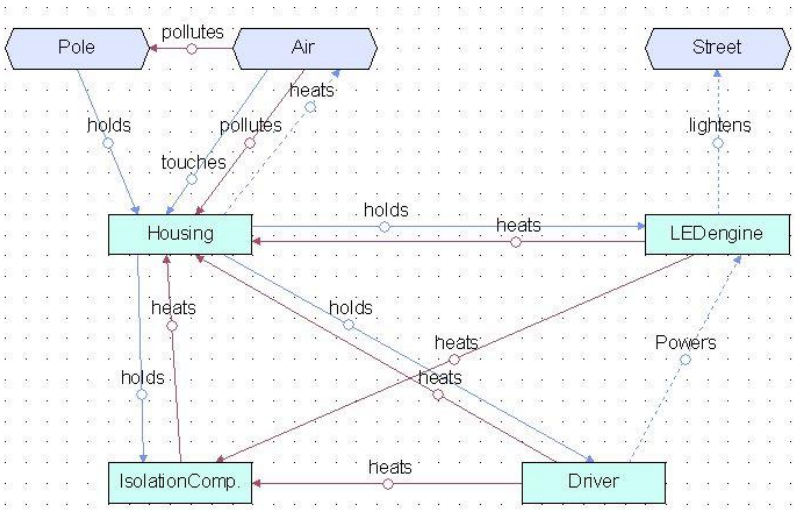


Figure 154: Functional scheme of the R250 Road luminaire's components and their interactions

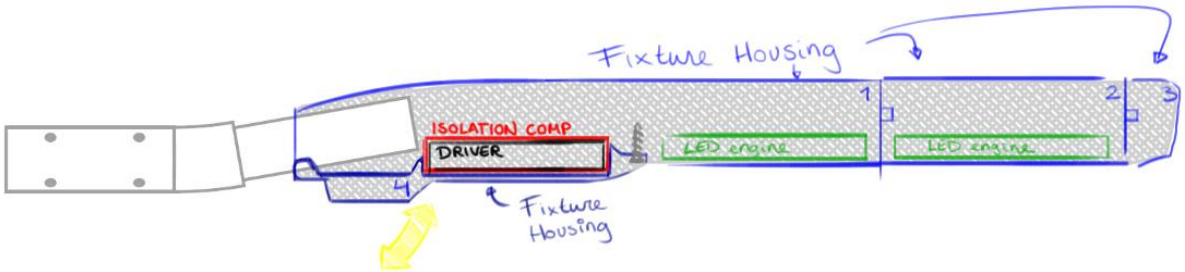


Figure 145: Side view with the components of the R250 road luminaire with two modules for the American market.

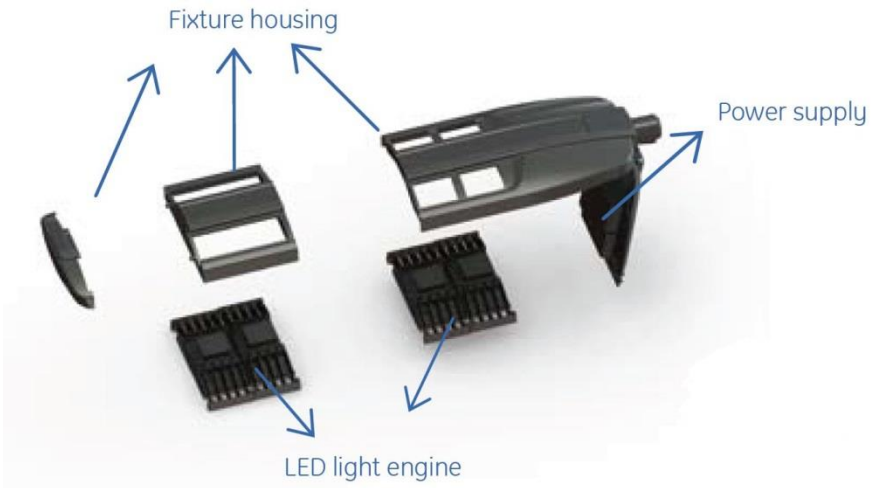


Figure 16: Exploded view of a version of the R250 luminaire with two LED light engines. [55]

Later on it seemed that the isolation compartment was not present in the European version of the R250 road luminaire, but represents the setup of the American model, showing that the side view was only like Figure 17, so that part was already trimmed!

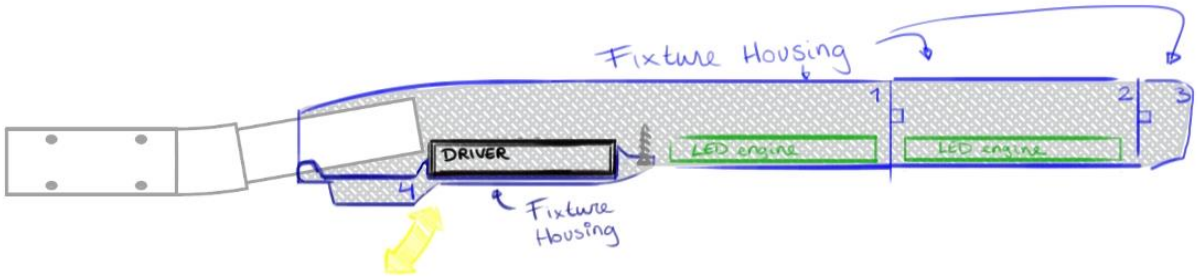


Figure 17: Side view with the components of the R250 road luminaire with two modules for the European market.

The environmental analysis can be extended a lot, identifying the available resources that can be used to solve a problem and the time and space properties of the problem are seen quite often.

10.6 Selection process

Based on the current knowledge, a specific focus has to be picked. This will be picked based on the overview of the RCA+. Out of the found contradictions (the properties in the RCA+ in the yellow boxes, with a good and a bad effect) a ranking can be made providing a framework for choosing.

10.6.1 Ranking

To gain the information for making a ranking, three questions are proposed in TRIZ:

1. Which contradiction involves the least number of (supersystem / external) components?
2. Which contradiction involves components we can change easily?
3. Which contradiction fits best with our strategy?

Answering those questions should in this example be based on comparative ranking, a way in which it is decided which of the contradictions is preferable for each aspect. This resulted in the table shown in Figure 18, indicating that ‘stocked goods are end products’ is the best option, quickly followed by ‘end product is static’.

RANKING

v.'12-12-10

1. Which contradiction involves the least number of (supersystem / external) components?
2. Which contradiction involves components we can change easily?
3. Which contradiction fits best with our strategy?

	Least number of (supersystem) components	Involves easily changeable components	Fits best with strategy	Total	Rank
Economic lot size (per variety) is big	4 (most)	3	4 (fits less good)	11	4
Many different varieties are possible	3	4 (hardest)	1 (fits best)	8	3
End product is static	2	2	2	6	2
Stocked goods are end products	1 (least)	1 (easiest)	3	5	1

This ranking is very subjective and mainly meant to give an insight, rather than showing the objective truth.
Therefore, not only the ranks should be checked, but also weights should be taken into account.

Figure 18: Ranking of the found contradictions.

10.6.2 Selection

Since selection of the best option is never perfectly objective, combining the ranking with the following suggestions is proposed too in TRIZ:

- The contradiction is the major cause of a problem (the degree of contribution to the problem is the highest).
- There are less constraints to produce system modifications.
- Solving a particular contradiction might result in extra benefits.

This results in the knowledge review that 'Stocked goods are end products' can be seen clearly, as the major cause of the problem. System modifications in the stock will probably have the fewest constraints. Solving the fact that the end product is static has the most potential for extra benefits. Combining all this knowledge, it seems that "Stocked goods are end products" is the best contradiction to solve. This has the focus task to have no end products stocked, while a short delivery time is maintained.

10.6.3 Ideal Final Result

Along with the selected contradiction comes the possibility to define the ideal final result (IFR), this formulation is heavily based on the contradiction itself and will function as a clear final target and

reference to keep in mind what eventually would be the ideal state of the system that should be improved.

In this case the IFR would be if: “Not a single end product is kept on stock, while delivery happens instantly.” As long as this stage is not reached, the possibility for improvement does still exist.

10.7 Contradiction Matrix (Altshuller Matrix)

10.7.1 Corresponding abstract parameter

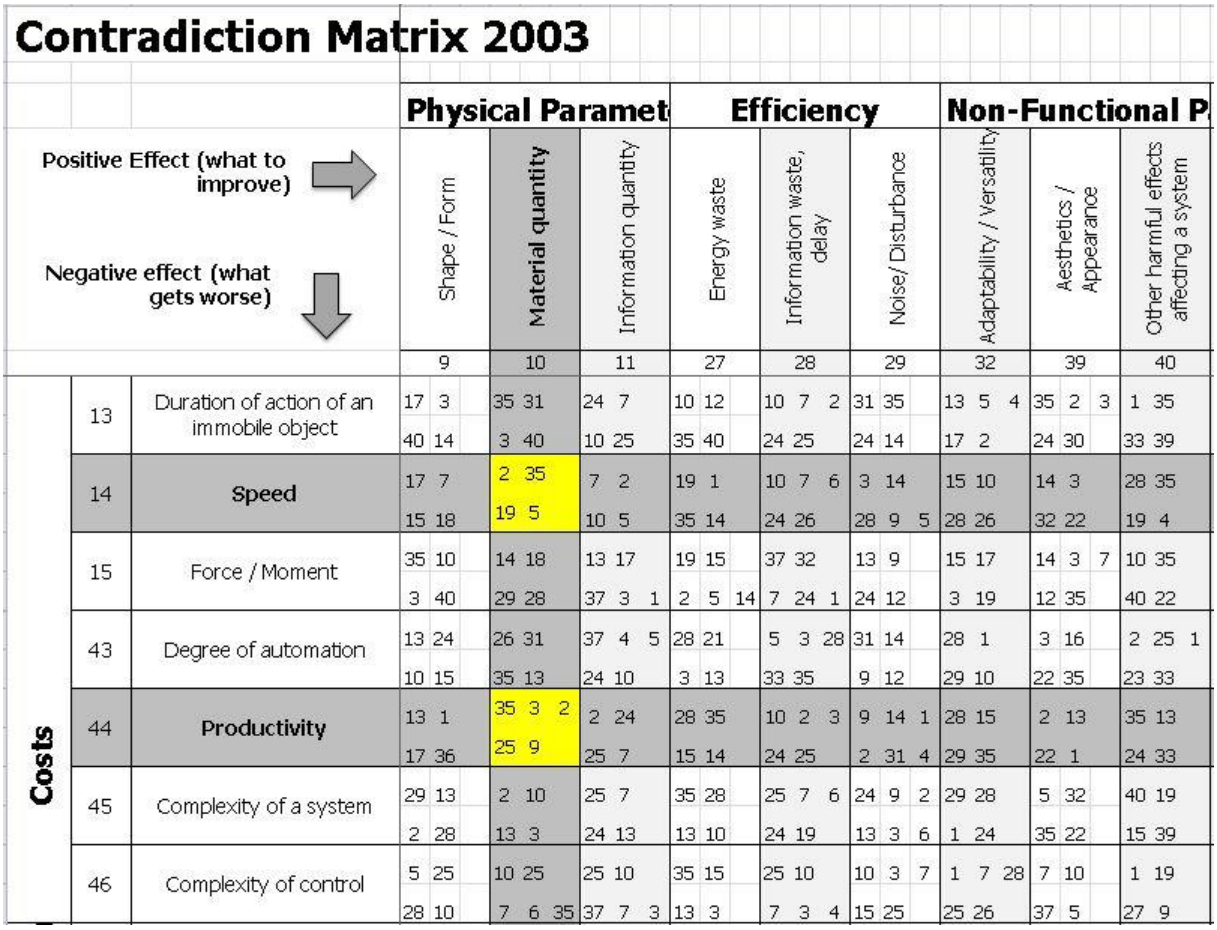
To find the corresponding abstract descriptions of those effects, each of them should be linked with one of the 39 parameters listed in this matrix. Not only the term is relevant, but also whether the parameter shows the positive or the negative effect.

The positive effect is the effect that should be improved and the negative one is the parameter that gets worse. In this case it is clear that the amount of ‘end products on stock’ is the effect that should be improved and the ‘short delivery time’ gets worse and is therefore the negative effect.

To get now the right suggestions for innovative principles out of the contradiction matrix, our parameters have to be matched with each other. This part is easy for making mistakes, but when looked at it very carefully this would be the result:

‘Short delivery time’ would become the abstract parameter ‘speed’ or ‘productivity’ and

‘Stocked goods are end products’ could become the abstract parameter ‘material quantity’.



Contradiction Matrix 2003

			Physical Paramet			Efficiency			Non-Functional P		
Positive Effect (what to improve) → / Negative effect (what gets worse) ↓			Shape / Form	Material quantity	Information quantity	Energy waste	Information waste, delay	Noise/ Disturbance	Adaptability / Versatility	Aesthetics / Appearance	Other harmful effects affecting a system
			9	10	11	27	28	29	32	39	40
Costs	13	Duration of action of an immobile object	17 3 40 14	35 31 3 40	24 7 10 25	10 12 35 40	10 7 2 24 25	31 35 24 14	13 5 4 17 2	35 2 3 24 30	1 35 33 39
	14	**Speed**	17 7 15 18	2 35 19 5	7 2 10 5	19 1 35 14	10 7 6 24 26	3 14 28 9 5	15 10 28 26	14 3 32 22	28 35 19 4
	15	Force / Moment	35 10 3 40	14 18 29 28	13 17 37 3 1	19 15 2 5 14	37 32 7 24 1	13 9 24 12	15 17 3 19	14 3 7 12 35	10 35 40 22
	43	Degree of automation	13 24 10 15	26 31 35 13	37 4 5 24 10	28 21 3 13	5 3 28 33 35	31 14 9 12	28 1 29 10	3 16 22 35	2 25 1 23 33
	44	**Productivity**	13 1 17 36	35 3 2 25 9	2 24 25 7	28 35 15 14	10 2 3 24 25	9 14 1 2 31 4	28 15 29 35	2 13 22 1	35 13 24 33
	45	Complexity of a system	29 13 2 28	2 10 13 3	25 7 24 13	35 28 13 10	25 7 6 24 19	24 9 2 13 3 6	29 28 1 24	5 32 35 22	40 19 15 39
	46	Complexity of control	5 25 28 10	10 25 7 6 35	25 10 37 7 3	35 15 13 3	25 10 7 3 4	10 3 7 15 25	1 7 28 25 26	7 10 37 5	1 19 27 9

Figure 19: Overview of the contradiction matrix 2003[3] with speed, productivity and material quantity selected.

[3] The contradiction matrix combines contradicting parameters with a set of inventive principles. There are several versions made, in this case the 2003 version is selected.

10.8 Evaluation and Portfolio building

This section will mainly consist of verification of the solution areas by the existing patents. The activities are in line with 'Evaluation and Portfolio building'. The ideas are ordered by their principle relevance as seen in the Altshuller matrix. Each principle will be guided with a citation of the specific part of '40 Inventive Principles' as described in Souchkov's bundle. This citation is interrupted by a direct suggested idea to emphasize its direct link.

10.8.1 Principle 2: Taking away

- "If some part of an object interferes with other parts or creates negative or undesired effects, "take away" (remove) an interfering part of your object by separating it from the object, or isolating it from the object." [47].

Suggestion: Separation of the LED light engine from its object (as long as the object is in stock).

Patent example: LED based street lighting module [48]. The design of the LED light engine as a separate module in the luminaire;

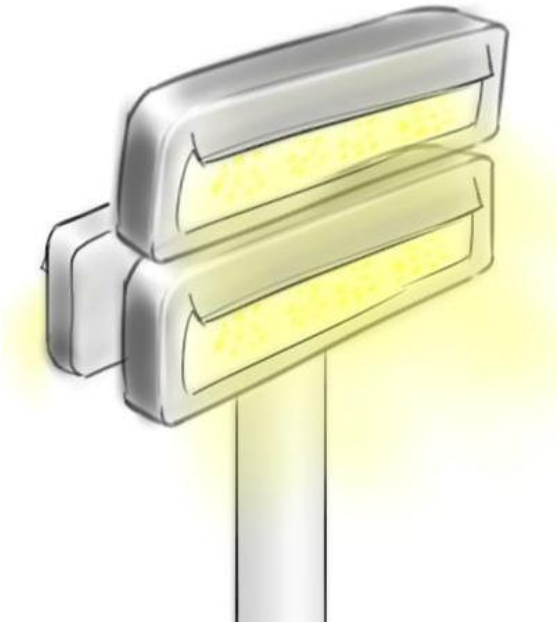
Comment: This is a solution possibility, since modular design can enable installation of a later-to-choose specific luminaire.

- "If some property of an object interferes with delivering the needed functionality, find out what part of the object is a carrier of this property and separate the property from the object by creating another object, or transferring the property to some other already existing part of the object.
- "Single out" the only necessary property of an object by creating another object which has the required property only." [47].

Suggestion: "Single out" the lighting part (the LED light engine) of the luminaire by creating a lighting box / light boxes next to a separate (central) driver.

Patent example: Flexible LED lighting systems, fixtures and method of installation [49]. This patent is about at least one LED lighting fixture, a remotely-located power driver and their interconnections.

Comment: This patent is supposed to be for mounting fixtures on ceilings but might also apply as principle for outdoor lighting.



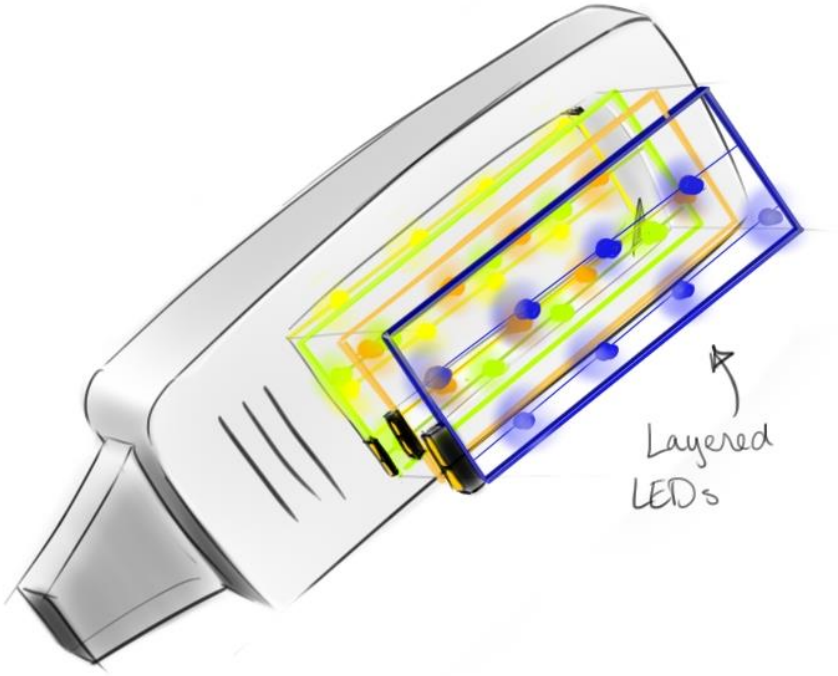
10.8.2 Principle 35: Parameter change

- "Change an object's aggregate state: instead of solid objects use liquids and gases, and vice versa.
- Change concentration or consistency of solid objects, gases or liquids." [47].

Suggestion: Change the concentration of LEDs in the module with the LED light engine.

Patent example: Luminaires using multiple quasi-point sources for unified radially distributed illumination [50]. Combining separate (groups of) LEDs by stacking them above each other to regulate the light emitted to a specific area.

Comment: The patent is focussing at how to optimize the result for several quasi-point sources. But assembling or delivering extra layers can also be used for quick improvement of the luminaires specifications when the wanted result was not known on forehand.



- “Change the degree of flexibility of objects.” [47].

Suggestion: Change the flexibility of the fixture housing.

Patent example: not seen yet

Comment: This solution would improve the insertion of a module.

Suggestion: Change the flexibility of the LED’s board.

Patent example: Conductive nanoparticle inks and pastes and applications using the same related applications [51] and conductive elastomer and method of applying a conductive coating to elastomeric substrate [52]. Showing the possibilities of flexible wires on or covered in silicon.

Comment: Those patents show possibilities of flexible circuitry in gel like structures like silicon. Although silicon can also be used strictly to keep the current LED (module)s with their heat sinks in place. Usage of gel like solutions for flexible shrinking of the board will thicken the ‘board’ with the amount of modules inserted.

- “Change the temperature.
- Change pressure.
- Vary parameters of your system adaptively.
- Change sensory parameters.” [47].

This overview can be increased with the other principles listed in the contradiction matrix. A quick overview of basic possible ideas that have been generated can be found in Appendix 3: Full list of ideas.

10.9 Assessment and selection

Based on the above approach the assessment and selection of ideas can provide a structured framework. The assessment and selection of the ideas can be schematic too. Therefore minimum criteria can guide on one hand and a definition of an ideal final result on the other. However, in practice this is still a very precious job where the existence of patents are coming into play. This might be very limiting for a company like GE, since it needs to make sure that it is legally allowed to develop a specific product. Seen the fact that many of the suggested ideas can be linked with patents developed by small companies, open innovation might be needed to develop an optimal idea. With open innovation new entrants could really trigger a market to make a change and big companies have more freedom to target an optimal idea and make a leap forward. However even if there is freedom to choose any idea, a proper portfolio with several alternative ideas is wanted to provide an overview for picking the wanted solution.

Based on the defined IFR, it looks as if the best suggestion would be: “Single out” the lighting part (the LED light engine) of the luminaire by creating a lighting box / light boxes next to a separate (central) driver. In this case the end product can be ‘assembled’ on-location. Hence, one doesn’t need any full end products on stock, while one still can have instant delivery. This refers strongly to the ideal final result that was defined in 10.6.3.

11 Conclusion

"How can the generation of possible design solutions become more successful in GE Lighting by using the knowledge in the field of Industrial Design Engineering?"

In the current moment, adaptation with the market is really essential. But this adaptation process is facing challenges. Based on the external factors those challenges in the lighting industry seem to be mainly focussing at three points: cost pressure, speed to the market and the increasing quality and warranty requirements. To cope with those challenges, the design process is challenged to be increasingly effective.

To increase this efficiency, industrial design engineering-knowledge might well possibly help. First of all, by setting up a prescribing approach that will be in line with a broad innovation perspective and secondly by effectively generating new design concepts, where several applicable principles can offer a variety of alternatives.

This project finally showed those aspects clearly via a case study in which new clearly varying design concepts were successfully generated via an IDE-knowledge-based methodology that contains the basic properties to work in the context of GE Lighting. Thereby, this knowledge clearly showed the possibility to stimulate the generation of possible design solutions.

However, to select and develop a specific idea or concept, a company like GE needs to make sure that they are allowed to develop it. The patents in the new areas are mainly from small companies that can be new entrants of the market. This indicates that open innovation might well be beneficial to large companies. With the application of IDE-knowledge and open innovation new possibilities for the market can clearly be stimulated.

12 Evaluation

During this project, many things went according to or better than expectations, many were harder than expected and even more were not expected to begin with. Although meeting all ambitions was not possible in the end, the bottom line is positive.

First of all, the subject itself, often felt as a hard and risky way to have a subject quite different than the standard setup. Although the start was all according to plan, but was not going to something concrete. Therefore, the contact with General Electric stimulated the project to focus towards more clearly targeted results. The ambitious mission to really make a concrete change within the way of working of GE seemed to be harder to reach within such a short time then hope was pushing into our minds and along with some obstacles within such a big company that turned out to be quite hard to overcome, expectations had to become more realistic again. Due to the fact that courses had to be followed in parallel with the project, the full amount of time could not be invested. Something that turned out to be key in the depth that can be reached and is clearly a point for consideration in future plans, since milestones were sometimes hard to make.

However all the support and feedback I got did made me learn a lot and showed the difficulties and opportunities that can be found between theory and commercial environments. Also it showed that expertise comes with time and it is clear that that progress has been stimulated strongly due to this project.

13 Bibliography

[1] GE Lighting Solutions, LLC., "Roadway Lighting: Case Studies for Roadway Applications | GE Lighting North America," 2011. [Online]. Available: http://www.gelighting.com/LightingWeb/na/images/GE_Evolve_LED_Outdoor_Lighting_Systems_Munincipalites_Brochure_tcm201-22136.pdf. [Accessed 21 Jan. 2013].

[2] A. Menon, J. Chowdhury and B. Lukas, "Antecedents and outcomes of new product development speed. An interdisciplinary conceptual framework.," *Industrial Marketing Management,* vol. 31, pp. 317-328, 2002.

[3] S. Lohr, "I.B.M. squeezes out a profit as its revenue declines," The New York Times, 16 October 2012. [Online]. Available: http://www.nytimes.com/2012/10/17/technology/ibms-results-are-mixed.html?_r=0. [Accessed 18 January 2013].

[4] A. N. Smith, "Yale Insights," Yale School of Management, November 2009. [Online]. Available: http://qn.som.yale.edu/content/what-was-polaroid-thinking. [Accessed 18 January 2013].

[5] BBC News, "Polaroid files for bankruptcy.," BBC News, 12 October 2001. [Online]. Available: http://news.bbc.co.uk/2/hi/business/1596340.stm. [Accessed 18 January 2013].

[6] Philips, "Annual Report 2009. Driving Transformation," Philips, 2010. [Online]. Available: http://www.annualreport2009.philips.com/pages/our_sector_performance/lighting/driving_transformation.asp. [Accessed 2013].

[7] R. Wensley, L. Hong, L. Roos and R. Wensley, "The dynamics of business orientation: the case of the Volvo Car Corporation," *Industrial Marketing Management,* vol. 33, no. 4, pp. 333-344, May 2004.

[8] GE Lighting Asia Pacific, "New Global Alliance of Lighting Industry Formation," GE Lighting Asia Pacific, 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/apac/news-and-media/press-room/press-releases/2012/lighting_alliance.jsp. [Accessed 19 January 2013].

[9] OSRAM GmbH, “Sustainability at OSRAM - Global Care,” 2013. [Online]. Available: http://www.osram.com/osram_com/sustainability/index.jsp. [Accessed 24 Jan. 2013].

[10] Philips, “Sustainability,” Philips, 20 September 2009. [Online]. Available: http://www.philips.co.uk/about/sustainability/index.page. [Accessed 19 January 2013].

[11] GE Lighting Europe, “Energy-efficient lighting solutions for indoors and outdoors at LME,” GE Lighting Europe, 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/news-and-media/press-room/press-releases/2012/lme-energy-efficient-lighting-solutions.jsp. [Accessed 19 January 2013].

[12] “GE Lighting is not just about LEDs,” GE Lighting, 15 December 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/news-and-media/press-room/press-releases/2012/not-just-about-leds.jsp. [Accessed 19 January 2013].

[13] General Electric Lighting, “Highlight strategies in Light 2012,” GE Lighting, 5 December 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/news-and-media/news/sil-2012-highlights.jsp. [Accessed 14 January 2013].

[14] GE Lighting Europe, “Michel Quicheron at Strategies in Light.,” GE Lighting Europe, 21 September 2012. [Online]. Available: http://www.youtube.com/watch?v=TTGZOor6vAs. [Accessed 14 January 2013].

[15] GE Lightning Europe, “Strategies in Light Europe 2012,” GE Lightning Europe, 4 October 2013. [Online]. Available: http://www.youtube.com/watch?feature=player_embedded&v=QGbwJTFqMg0. [Accessed 14 January 2013].

[16] GE Lighting Europe, “Jürgen Sturm at Strategies in Light Europe,” GE Lighting Europe, 26 September 2012. [Online]. Available: http://www.youtube.com/watch?v=U1878OghaUc&list=PLr2r-rz3d6p2dKAE4KUK0TDk3jeSci_Rv&index=2. [Accessed 14 January 2013].

[17] GE Lighting Europe, “Andras Toth at Strategies in Light Europe,” GE Lighting Europe, 18 10 2013. [Online]. Available:

http://www.gelighting.com/LightingWeb/emea/images/GE_Lighting_at_Light_and_Building_2012_Press_release_EN_tcm181-18317.pdf. [Accessed 15 January 2013].

[18] IMS Research, "IMS Research Releases Most Detailed Lamp Forecast in 2012 Lighting Report," IMS Research, 16 October 2012. [Online]. Available: http://www.ledmarketresearch.com/press_release/IMS_Research_Releases_Most_Detailed_Lamp_Forecast_in_2012_Lighting_Report. [Accessed 14 January 2013].

[19] GE Lighting Europe, "Andrew Davies at Strategies in Light Europe," GE Lighting Europe, 26 September 2012. [Online]. Available: http://www.youtube.com/watch?v=i2_VkuWr60M&list=PLr2r-rz3d6p2dKAE4KUK0TDk3jeSci_Rv. [Accessed 14 January 2013].

[20] GE Lighting Europe, "GE Debuts Landmark LED Modules," GE Lighting Europe, 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/news-and-media/press-room/press-releases/2012/ge-debuts-landmark-led-modules-at-lb.jsp. [Accessed 15 January 2013].

[21] GE Lighting Europe, "Lorenzo Dini at Strategies in Light Europe 2012.," GE Lighting Europe, 26 September 2012. [Online]. Available: http://www.youtube.com/watch?v=88xnUU9q3dk&list=PLr2r-rz3d6p2dKAE4KUK0TDk3jeSci_Rv&t=15s. [Accessed 14 January 2013].

[22] General Electric Lighting, "Stick T4 Sensor 6,000 hours. Compact Fluoresecent Lamps Integrated 15W.," General Electric Lighting, December 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/images/CFL_Integrated_Stick_T4_Sensor_Lamps_Data_sheet_EN_tcm181-12662.pdf. [Accessed 14 January 2013].

[23] GE Lighting Europe, "GE Lighting's great outdoor white light," GE Lighting Europe, 05 December 2012. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/news-and-media/press-room/press-releases/2012/outdoor-white-light.jsp. [Accessed 19 January 2013].

[24] C.A. Schiffmann and Company, "GE Workout," [Online]. Available: http://www.developingpeople-business.com/workout.html. [Accessed 21 Jan. 2013].

[25] A. Dasgupta, J. Dembani, A. Dhadda, I. A. Dhar, D. Ravishankar and D. Fernandes, “SlideShare,” Sept. 2007. [Online]. Available: http://www.slideshare.net/raviji/ge-workout. [Accessed 21 Jan. 2013].

[26] C.A. Schifman and Company, “GE Workout. WorkOut2008-1.ppt,” [Online]. Available: http://www.developingpeople-business.com/docs/WorkOut2008-1.ppt. [Accessed 21 Jan. 2013].

[27] GE Europe, “GE in Europe,” General Electric Company, 2013. [Online]. Available: http://www.ge.com/europe/. [Accessed 22 Jan. 2013].

[28] M. Van Dusen and J. Rennie, “GE Ecomagination. Portfolio,” General Electric Company, 2013. [Online]. Available: http://www.ecomagination.com/portfolio. [Accessed 22 Jan. 2013].

[29] M. Mascioni, “Open Innovation at GE,” MIT Techonology Review. , 7 Februari 2011. [Online]. Available: http://www.technologyreview.com/news/422626/open-innovation-at-ge/. [Accessed 22 Jan. 2013].

[30] Philips, “Open innovation - Philips Research,” Koninklijke Philips Electronics N.V., [Online]. Available: http://www.research.philips.com/open-innovation/index.html. [Accessed 22 Jan. 2013].

[31] European Commission, “Colloquium on state aid for innovation.,” 7 Nov. 2005. [Online]. Available: http://ec.europa.eu/competition/state_aid/reform/archive_docs/007.pdf. [Accessed 22 Jan. 2013].

[32] OSRAM GmbH, “Company Profile,” OSRAM GmbH, 20 January 2011. [Online]. Available: http://www.osram.co.za/osram_za/About_Us/The_Company/Company_Profile/index.html. [Accessed 20 January 2013].

[33] Royal Philips Electronics, “Company Profile,” Royal Philips Electronics, 2012. [Online]. Available: http://www.philips.com/about/company/companyprofile.page. [Accessed 20 January 2013].

[34] TU Delft, “Delft Design Guide,” TU Delft, 2011. [Online]. Available: http://wikid.eu/index.php/Product_innovation_process . [Accessed 20 December 2012].

[35] N. Roozenburg and J. Eekels, in *Productontwerpen: Structuur en Methoden*, Utrecht, Lemma, 1998, pp. 11-32.

[36] J. Buijs and R. Valkenburg, Integrale Productontwikkeling, 3rd ed., Utrecht: Lemma, 2005.

[37] A. Eger, M. Bonnema, D. Lutters and M. v. d. Voort, "Innovatiestappenmodel," in *Productontwerpen*, Den Haag, LEMMA, 2008, pp. 24-26.

[38] General Electric Company, "GE Works, 2011 Annual Report," March 2012. [Online]. Available: http://www.ge.com/ar2011/pdf/GE_AR11_EntireReport.pdf. [Accessed 16 10 2012].

[39] A. Reinders, *Sources of Innovation,* Enschede: University of Twente, 2011.

[40] V. Souchkov, "TwoWeeks_UT_TRIZ_Course_Technology_July_2012_Slides.pdf," ICG Training & Consulting, Enschede, 2012.

[41] V. Krasnoslobodtsev, "APPLIED TRIZ IN HIGH-TECH INDUSTRY," [Online]. Available: http://www.aitriz.org/articles/TRIZFeatures/6B7261736E6F736C6F626F64747365762D31323033.pdf. [Accessed 16 Dec 2012].

[42] S. Cheong, "TRIZ experiences at SMD - Samsung," 5 March 2010. [Online]. Available: http://www.koreatrizcon.kr/files/O-5%28Full%29.pdf. [Accessed 16 Jan 2013].

[43] R. Stroek, "Overview of design methodologies and their coverage of the innovation model," University of Twente, 2012.

[44] K. Long, "What is an IGOE?," *Business Rules Journal,* vol. 13, Jan. 2012.

[45] General Electric Company, "GE | Luminaires & Systems | Outdoor Luminaires | Road & Tunnel | R250 LED," 1997-2013. [Online]. Available: http://catalog.gelighting.com/system/outdoor-luminaires/road-tunnel/f=r250-led. [Accessed 24 Jan. 2013].

[46] General Electric Company, "LED Road R250 | GE Lighting Europe," 1997-2013. [Online]. Available: http://www.gelighting.com/LightingWeb/emea/products/highlights/led-road-r250/overview/index.jsp. [Accessed 24 Jan. 2013].

[47] V. Souchkov, “40 Inventive Principles,” in *TRIZ & Systematic innovation. Guides to TRIZ and xTRIZ Techniques and References*, 1993-2011, pp. 49-68.

[48] L. Domján, G. Szarvas, A. Sághy, S. Kautny, A. Molnár and I. Hoffman, “LED based street lighting module”. Patent WO/2011/033330, 17 September 2010.

[49] I. Ruud Lighting, “Flexible LED lighting systems, fixtures and method of installation”. U.S. Patent US8197079B2, 18 July 2007.

[50] “Luminaires using multiple quasi-point sources for unified radially distributed illumination.”. U.S. Patent US 2010/0091492 A1, 5 October 2009.

[51] I. NanoMas Technologies, “Conductive nanoparticle inks and pastes and applications using the same”. Patent US 2009/0159121 A1, 9 October 2007.

[52] I. John Mezzalingua Associates, “Conductive elastomer and method of applying a conductive coating to elastomeric substrate”. Patent US 8334048 B2, 27 April 2011.

[53] GE Consumer & Industrial, “U.S. Department of Energy. Energy efficiency & Renewable Energy,” July 2009. [Online]. Available: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/briggs_chicago09.pdf. [Accessed 16 December 2012].

[54] Knowledge Based Systems, Inc., “IDEF Integrated DEFinition Methods,” 2010. [Online]. Available: http://www.idef.com/pdf/idef0.pdf. [Accessed 12 Jan 2013].

[55] MidWest Green LED Lighting, “LED Outdoor Catalogue,” MidWest Green, 2011. [Online]. Available: http://www.mw-green.com/pdf/outdoor/Outdoor_Catalogue.pdf. [Accessed 16 Feb 2013].

14 Appendix

This is the additional or background material to provide further information where needed.

14.1 Appendix 1: Original project plan

Although the project plan was subjected to many and sometimes quite big changes, this is the project plan as it was when things got started with GE.

Project Plan

for the bachelor assignment of Roy Stroek, version 2012/10/25

Introduction

This document will describe the project from Roy Stroek for the bachelor's final assignment in Industrial Design Engineering (IDE). This will be a research-based assignment for the University of Twente (UT), within an Erasmus exchange project at the Budapest University of Technology and Economics (BME) under supervision of Dr. József Váncza (active in MTA SZTAKI and BME) and with collaboration of a division of General Electric (GE), GE Lighting in Budapest.

Nowadays, it seems to be that design processes are a key aspect in a product's life cycle. Information from many different areas comes together to set the lines about where and how to develop according to the current needs, possibilities and vision. At the moment that all this information is needed, some methodological approaches might help to cover all of the wanted aspects.

During the years, several design theories and methodologies have been described to stimulate the design process. All with their specific focuses and typical aspects, searching for the right way to let information come together at the right moments. The focus of those methodologies is traditionally on optimizing the exact specifications of the design. However, since this knowledge - in the area of optimisation of exact product specifications - is widely spread and relatively well covered (also in profit-based organisations like GE), the new challenges seem to appear in optimisation of less exact areas of the design process.

A big area in this is the generation of new ideas. Although there are several design methodologies and tools available to stimulate this, the practical application of them doesn't seem to have found its optimal implementation in profit-based organisations yet.

This project will try to bring the implementation of the state-of-the-art IDE-knowledge in this area one step further. In the first place by clarifying the possibilities given by the state-of-the-art knowledge about design methodologies and tools. Secondly by suggesting a way for implementing some of those possibilities in future use and in the third place, by strengthening this approach with an example for the role of a similar approach in which to come up with new ideas for a (product mix-) concept which is able to deliver different amounts of light for different areas.

Acting parties

- General Electric Lighting in Budapest
  This is the headquarter of GE's division 'GE Lighting' in Europe, Middle East and Africa [1]. GE is a publicly traded company with a wide variety of investors [2]. Thereby can be concluded that GE Lighting in Budapest functions in a profit-based way within GE Lighting and GE as a whole. Therefore, the final goal of this project for GE Lighting in Budapest is profit. In this project, the main way to achieve this is by keeping a long-term vision towards the possible developments of the products they produce. Although, due to the organization-structure, GE Lighting in Budapest usually the main principles and design gets from their American colleagues, the further design is done at the design teams in Budapest. The company GE as a whole considers itself "mission-based.", in their annual report of 2011 stated as: "It starts by being "mission-based." We have a relentless drive to invent things that matter: innovations that build, power, move and help cure the world. We make things that very few in the world can, but that everyone needs." [3]. The core competences of GE seem to be at the development of every detail in their product and production focuses at the actual part which produces the light and the assembling of the products.

- University of Twente
  This is a university in Enschede (the Netherlands) which offers research and degree programs. The university itself wants to keep an image of entrepreneurial research university with a special focus on the development of innovative technologies and the way in which those can be applied, so called 'high tech, human touch' [4]. The assignment will be part of the bachelor program called 'Industrial Design Engineering' (IDE), one of the UT's Technical and Engineering Sciences.

- Budapest University of Technology and Economics
  This is a university in Budapest (Hungary) which considers its role as to develop international relations in favour of improvement of expertise, knowledge and international reputation of professors, researchers and students. The university aspires to develop co-operations promoting research and education in the field of international relations [5].

- Dr. József Váncza
  Current deputy head of the Research Laboratory of Engineering and Management Intelligence, SZTAKI, scientific adviser for the Fraunhofer Project Centre for Production Management and Informatics and associate professor at BME in the Faculty of Mechanical Engineering [6].

- Me as a student
  An IDE-student, with mainly theoretical knowledge of design methodologies and processes. This knowledge will be expanded with further information in the area of software engineering via BME parallel to the project.

Project framework

The project aims to improve the competence of generating new design possibilities. Since there is already a lot of knowledge for optimizing solutions, the generation of possible concepts is mainly interesting to Budapest's office of GE Lighting. At the moment this generation is especially relevant, since there seem to be several transitions in or around the company.

First of all this can be seen in the delivered products, for instance the focus on indoor products is being extended with outdoor, there is a shift towards experience (e.g. an desire to adapt to local markets and usability aspects) and towards the delivery of product-service combinations. Besides that, the biggest transition is the more and more rapidly changing market. This brings very challenging transitions for manufacturing, after GE's implementation of Six Sigma, GE Lighting is now stimulated to move towards Lean Manufacturing. This stimulates the outsourcing of components and the attraction towards standardisation of the used components. For the basic concept it means that it must be possible to deliver a well-adapted range of products, while keeping the costs and risks relatively low. Therefore, the technique of modularity has been chosen, which seem to have quite some impact on the system as a whole. The application of this modularity principle is already implemented in several products.

However this is a nice way to deliver the basic concept in a well-adapted range, the question is if there were alternatives and even more, how it is possible to come up with those alternatives. The R250 Road Luminaire is a current example of a product in which modularity is applied, therefore it can lighten now a variety of lanes and situations, by using different combinations of modules. Therefore, this product is a very good possibility for a concrete case which shows how and what alternatives for its modularity could have been generated.

Goals

The project aims at an suggestion for the 'way to generate basic principles' for designs in the future. With this as the main goal, its result will heavily depend on its basement, the insights in the current process and needs. In this way, it can become clear how and why a certain methodology would work for GE Lighting. Mainly this, a clear insight in the criteria, will define the relevance of the project in the long-term. Therefore, it will be one of the most important and first-to-achieve goals.

After getting this improved insight in the as-is development process and its transformation into specific criteria, the possibilities for improvements can be relatively easy and clearly assessed. However, the main goal here will be to transform those possibilities into a clear, well-applicable script. Whether this covers the use of tools or complete methodologies, the script will aim at making clear what and how the tools / methodologies can be used best to meet the earlier noted criteria, resulting in an overview of the top-possibilities.

The last goal can be seen in line with all this, evaluation of the 'best' possibility. This means that the case will be mainly focused at testing the methodology, whereby insight can be achieved for e.g. the optimal use, possible errors and the concrete output delivered.

In comparison with the goals noticed above, the real output of the case is a short-term goal. Although, it is very important that the underlying methodology is solid. In that case, it will better emphasize the importance of knowledge-based improvements in the early conceiving of products.

Research Questions

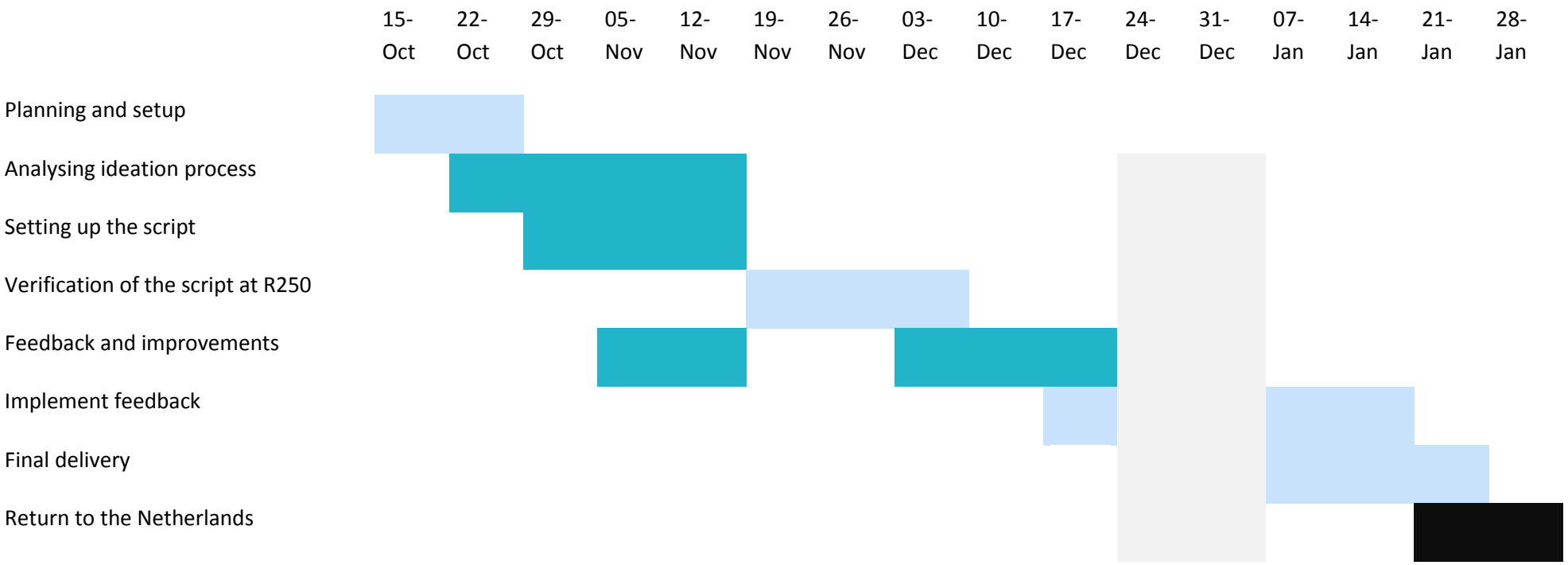
1. How can the generation of possible design solutions become more successful in GE Lighting by using the knowledge in the field of Industrial Design Engineering?
    a. What is the context in which the improvements have to take place?
        i. What are GE Lighting's goals and vision towards improving their designs?
        ii. What 'internal' factors influence the possible changes in the design process? *(e.g. Traceability, milestones, time constraints, motivation, capabilities, availability of people, risks.)*
        iii. What 'external' factors (outside the design process itself) influence the design process? *(e.g. Legal aspects, business strategy, demanded quantities, manufacturing possibilities)*
    b. What kind of improvements are needed in the current situation?
        i. What aspects of a successful implementation are lacking in the current situation?
        ii. What are the criteria for a methodology (or tool) to successfully improving the current process of generating possible design solutions?
    c. Which improvements (in the field of IDE) are the best to make the generation of possible design solutions become more successful in GE?
        i. What design methodologies and tools are available for improving similar situations?
        ii. How will the criteria be weighted and used? (now and in the future)
        iii. Which design methodologies and tools come out as the most sufficient to make the possible design solutions more successful.
    d. How will the suggested improvement concrete work and behave in a real case?
        i. Test case: "What alternatives exist for modularity in a product like the R250 Road Luminaire regarding its functionality to optimally cover a variety of lanes?"

Deliverables

1. In-depth analysis of the as-is ideation process,
2. Script for an adapted ideation process,
3. Evaluation on the selected product.

Project phases

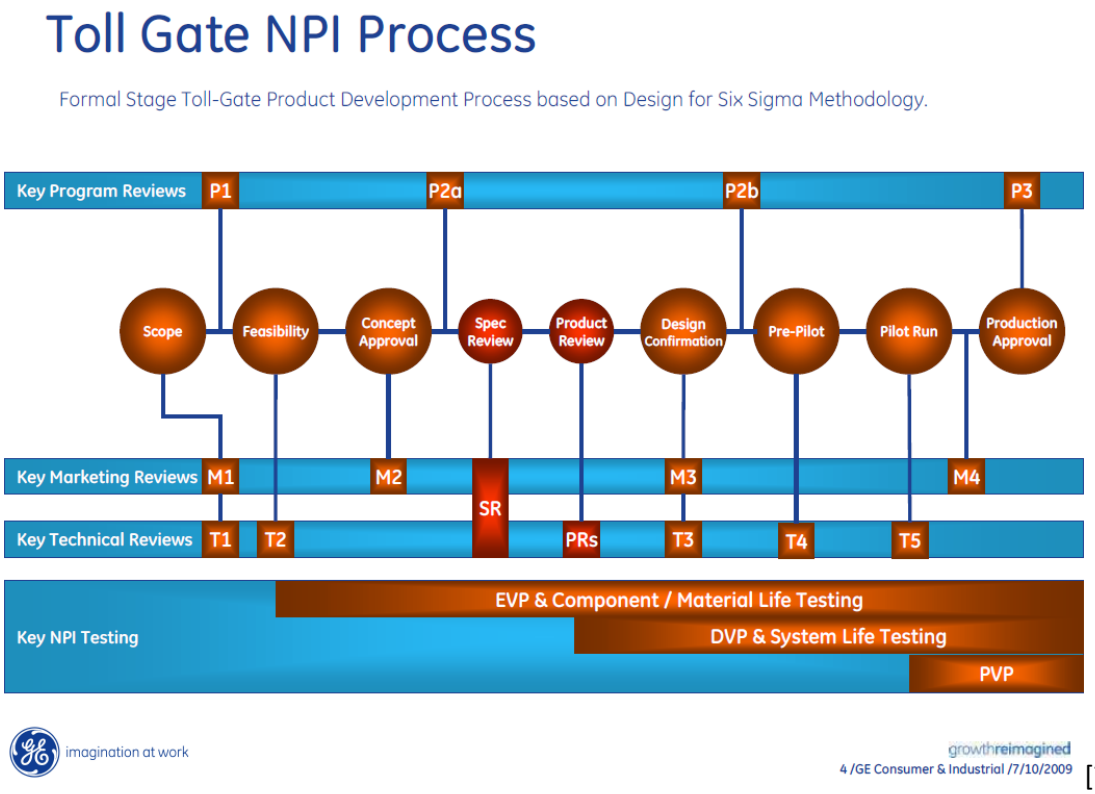
Gantt Chart:



Resources

To improve the process, by getting clear answers on the question, quite some information and views from within the company are needed, for instance:

- GE's goals and vision (e.g. mission statement, long-term plan, market penetration),
- Short contact about the design process (incl. a response to the image below) and about the role for implementing new the design concepts,
- Resource for insight in the needed improvements, preferably an interview and if possible, attendance of design meeting. (like a plant)
- Short contact for the weighting of the criteria for selecting the best improvement.



[7].

References

[1] General Electric Lighting (2012) *GE Lighting EMEA, Contact us | GE Lighting Europe.* (last visited on 16/10/2012) In: http://www.gelighting.com/LightingWeb/emea/contact-us/

[2] General Electric Lighting (2012) *GE Major Holders | General Electric Common Stock – Yahoo! Finance.* (last visited on 16/10/2012) In: http://finance.yahoo.com/q/mh?s=GE+Major+Holders

[3] General Electric Company (2012) *GE Works, 2011 Annual Report.* (last visited on 16/10/2012) In: http://www.ge.com/ar2011/pdf/GE_AR11_EntireReport.pdf

[4] University of Twente (2012) *Jaarverslag 2011.* (last visited on 16/10/2012) In: http://www.utwente.nl/jaarverslag/nieuws/jarverslag-ut-2011.pdf

[5] Budapest University of Technology and Economics *BME CSO Office of International Education.* (last visited on 16/10/2012) In: http://icepe.bme.hu/

[6] Váncza, J. (06/03/2012) *Dr. József Váncza.* (last visited on 16/10/2012) In: http://www.sztaki.hu/~vancza/

[7] GE Consumer & Industrial (07/10/2009) *GE Luminaire, Reliability*. (last visited on 17/10/2012) In: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/briggs_chicago09.pdf

14.2 Appendix 2: Questionnaire

This is the questionnaire that has been made in order to come up with some objective findings as a base for the criteria of a successful methodology. This questionnaire is eventually never been filled in.

Development during Scope-phase

A questionnaire for reviewing the process of generating product concepts in GE Lighting's Toll Gate NPI Process

Introduction

This questionnaire will aim to broaden the basement for suggestion of possible developments in the generation of working principles. In other words, the basement for picking something, that stimulates to come up with valuable ideas for the working principles of a product. Since those ideas will improve the insight in the possible developments, they will become more important, along with the evolvement of the market. However, the application of those ideas and possible developments should not be overlooked, since it could actually be one of the key aspects for a relevant development. Therefore, getting a grip on this relevance, heavily relies on the ways engineering from within the company would apply suggested developments. This questionnaire aims to get this information early, so that it can be integrated in the basement for suggestion possibilities. Therefore, your input is very important. Please note that, the more input provided from within General Electric, the more relevance can be achieved by suggesting possibilities.

Thanks in advance,

Roy Stroek

Student at University of Twente,

Currently researching for GE Lighting Budapest.

r.l.stroek@student.utwente.nl

Questionnaire

1. How would you describe / call your role within the Toll Gate NPI Process?

……
……

Please assume that we are strictly talking about the scope-phase of the NPI Toll Gate Process.

2. In which product developments have you been involved during the scope-phase? Please include a short description of one or two recent examples if possible.

……
……
……
……

3. Were there aspects of the scope-phase that did not feel optimal and therefore should be open for new possibilities? If so, what aspects?
You might want to relate this to your previous answer.

……
……
……
……

4. Have you ever thought about specific changes in this part of the process (the scope-phase)? If so, please describe them with a few words and the main reason why they might be useful.

……
……
……
……

5. What do you consider as the most important aspects for a good design process during the scope-phase?
Please rank the aspects you see in your given example together with the given aspects. Adding additional aspects is more than welcome.

Importance: Grade (or range) between 1 and 20. Fill in this column first!

Order: With the grading being done (!), nuance the priorities by putting the aspects in their order. Give each aspect a number, starting with a 1 for the most important aspect. Try not to use a number twice.

No.	Aspect	Importance	Order
1	Approach possibilities from different viewpoints		
2	Analyse issues in current products		
3	Analyse customer requirements		
4	Analyse the way the product will be used		
5	Have informal conversations with colleagues		
6	Generate high variety of alternatives		
7	Shorten time to pick the next development		
8	Set performance specifications early		
9	Visualize product concept for communication		
10	Analyse business properties (needed)		
11	Analyse marketing potential		
12	Analyse ways for manufacturing		
13	Use of pre-generated results and insights		
14	Documentation of current process		
15	Reflection on actions and choices during the process		
16	…		
17	…		
18	…		
19	…		
20	…		

6. How would you describe the influence of new possibilities for product developments in the company?

……
……

7. Which part of the methods or tools used in the current process do you consider to be the most valuable for coming up with new possible developments?

……
……

8. What do you consider to be the biggest trap for additions or changes in this process?

……
……

9. If you have any other thoughts, suggestions or remarks according to this topic please note them here.

……
……
……

Thanks!

This is the end of the questionnaire.

Thank you for your input, let's hope that we will keep track of the opportunities which are passing by. With those answers, the response to them might become a little better.

Thank you!

Roy

Appendix A

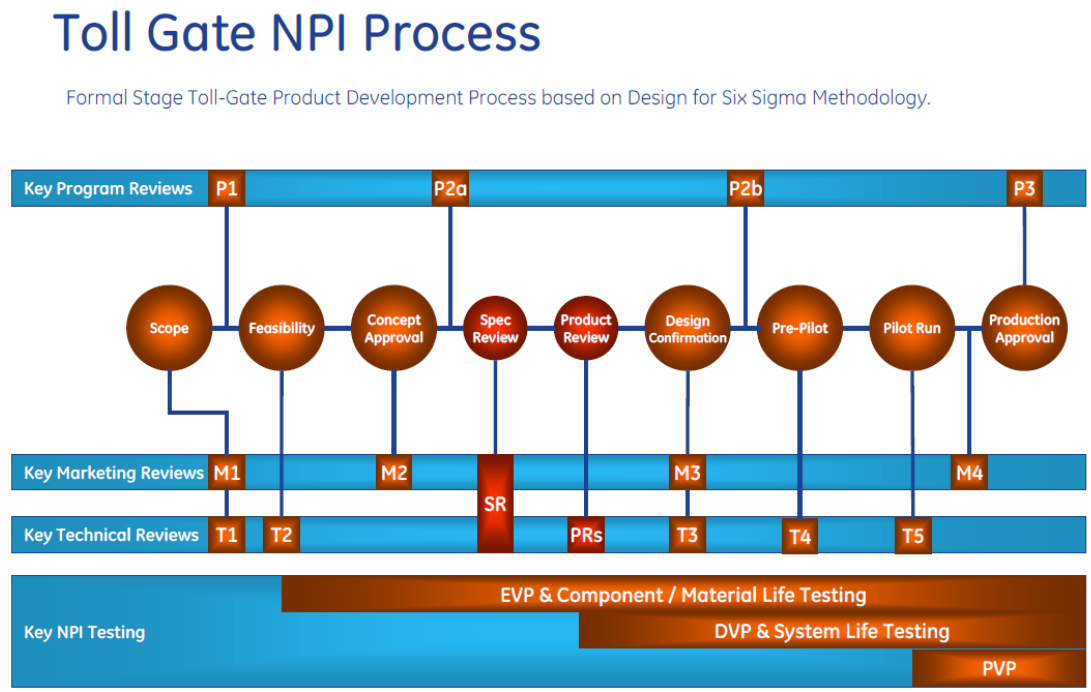


Figure 1: Model of the Toll Gate NPI Process, full fulfilment of respectively Marketing review 1 (M1), and Technical review 1 (T1) can be seen as changing point from 'scope' to 'feasibility'.

14.3 Appendix 3: Full list of ideas

14.3.1 #35: Parameter change

1. Increase LED density from stocked goods by adding layers over the existing LED engine.
2. Increase adaptation from the stocked goods by making the LED engines flexible.
3. Make the housing flexible.
4. Vary intensity based on the frequency or time it is switched on/off within a second.
5. Sense where the environment needs light and adapt the intensity (and thereby area) to it.

14.3.2 #2: Taking away

6. Keep the LED engines separate from the product itself, in such a way that they can installed really quickly for delivery.
7. Sell the LED engines as separate products.
8. Make multiple luminaires attachable at a single pole.

14.3.3 #3: Local quality

9. Make the transparent lens cap like a lens adapting the available amount of light to the needed direction.
10. Separate the LED's from its board so that they can be aimed freely.
11. Change the height and ending point of the pole according to the area that needs to be covered / intensity.

14.3.4 #25: Self-service

12. Use the light emitted by cars / bicycles itself to notice where the lanes are and what to light.

14.3.5 #19: Periodic action

13. Only start producing stock after the first talk about a project.
14. Use pauses in light emitting via the LED's to get rid of heat.
15. Use pauses to drop the perceived intensity.
16. Use pauses to sense the light in the environment.
17. Use a pulse of LED emitting for every lane from the same source.
18. Aim for non-continuous stock levels.

14.3.6 #9: Prior anti-action

19. Place all the extensions for the product at the beginning and make the given parts really easily removable (and reusable).

14.3.7 #5: Merging

20. Merge the LED engine and (a part of) the housing in such a way that they become directly attachable.
21. Merge the driver and the LED engine in such a way that you can put them directly on their place without the need to update parameters.
22. Merge the current modules together.

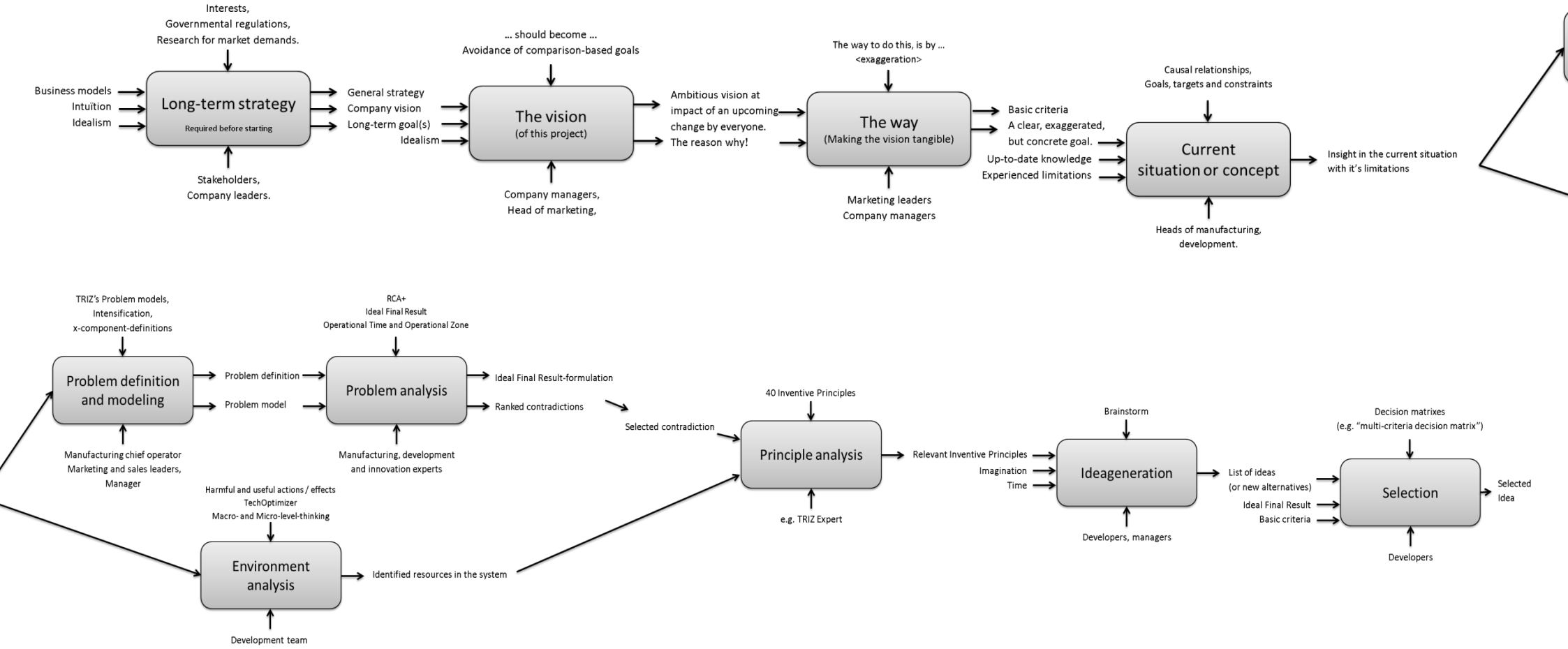
14.4 Appendix 4: Assessment of methodologies and tools

Assessment of methodologies and tools						
based on the criteria and its implications for a successful improvement						
Criteria	Implication	sub-implication	TRIZ	GE Workout		
Generates a variety of alternative product ideas,			**1**	**2**		
	Provides a structured prescribing approach to come up with clearly varying product ideas,					
	Includes the analysis of internal and external aspects,					
	Has results based on a well defined search area,					
	Finds its basement in the search areas and strategic perspective of the company,					
Shortens the time to pick the next development,			**1**	**2**		
	Bases the search areas heavily on the long-term ambitious vision, so that there will be plenty of space for future developments,					
	Creates an overview of the previous choices that have been made and the alternatives that are left behind. (This count for the alternative ideas as for the search areas.)					
Improves communication among different disciplines,			**1**	**2**		
	Uses clear communication about what and why something have to be done and has been done.					
Fits in the context of the current situation			**2**	**1**		
	Is not counteractive with a strong engineering		1	1		
		Provides a clear working structure,				
	Shows 'imagination at work'		1	2		
		Stimulates imagination and creativity,				
	Is applicable in a quick developing market,		1	2		
		Is open for the bigger picture and long-term changes,				
	Fits in a market with many new entrants,		-	1		
		Is capable of keeping the product / development costs sharp,				
	Can cope with increasing quality and warranty		2	1		
		Limits the risks of a new product.				

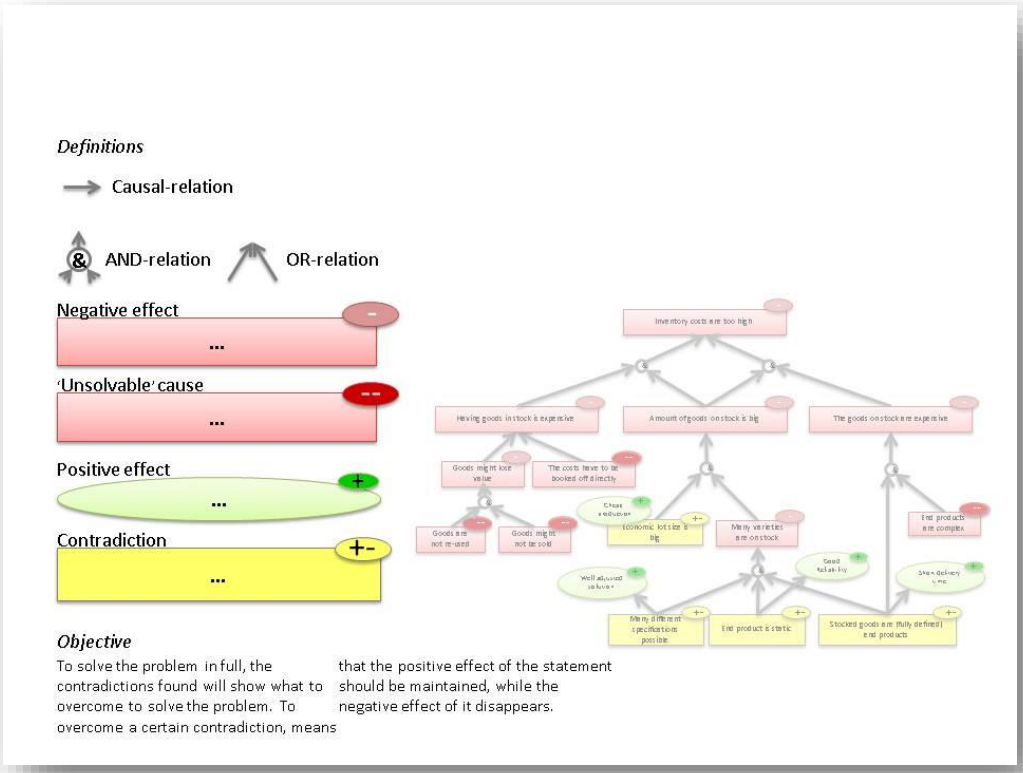
Legenda

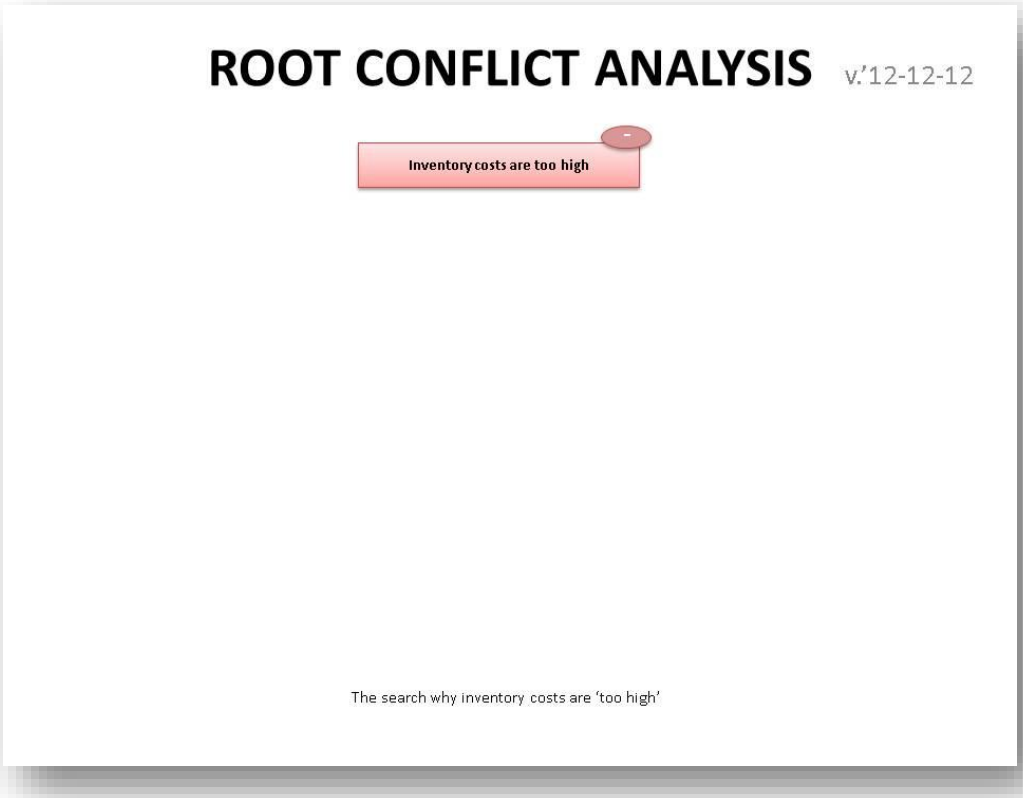
- well suitable
- somewhat suitable
- not really suitable
- not suitable
- unknown

14.5 Appendix 5: Early draft of the script

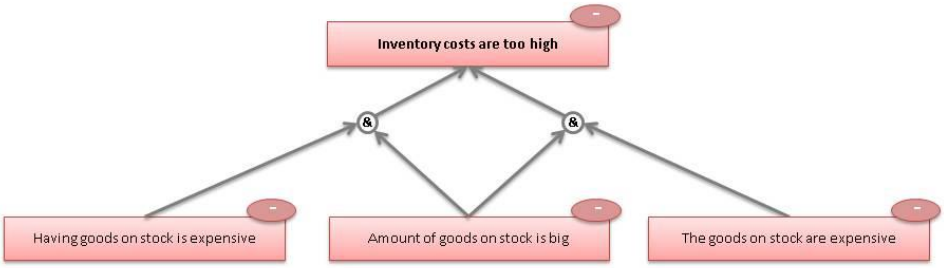


14.6 Appendix 6: Step-by-step construction of the RCA+





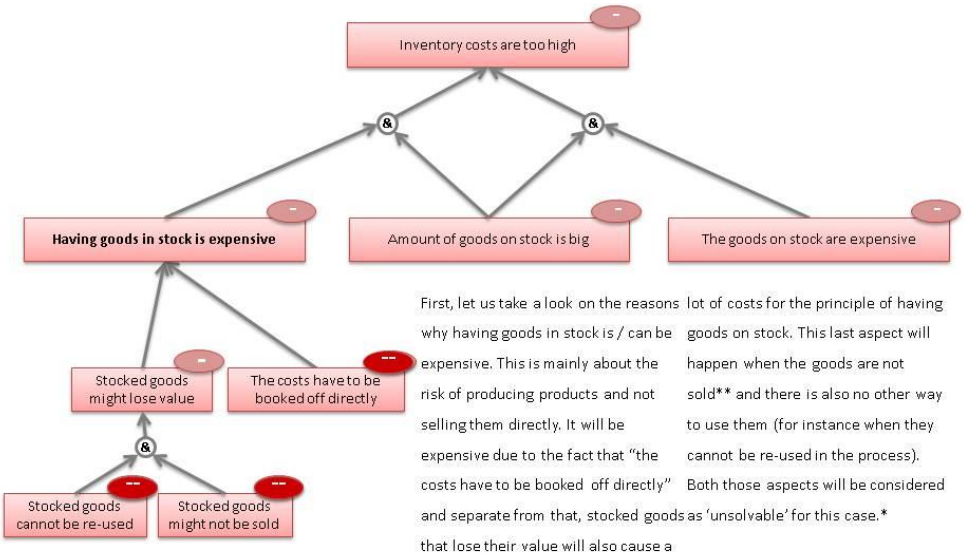
RCA+ v.'12-12-12



That the "Inventory cost are too high", can be caused by the following combinations:
Large amount of goods & expensive goods, or
Large amount of goods & having goods on stock is expensive.

So even when the goods on stock are not costing anything or when the principle of having goods on stock does not cost any money, there are still possibilities that the inventory costs are too high. However, having no goods on stock would solve the problem in full. Since it would eliminate both situations.
All the three aspects listed above, are seen as fully negative aspects, without any **direct** positive effects (discussion about this will be afterwards) and able to eliminate. Therefore, we can call them 'negative effects' and we can continue to search for the cause of those effects.

RCA+ v.'12-12-12

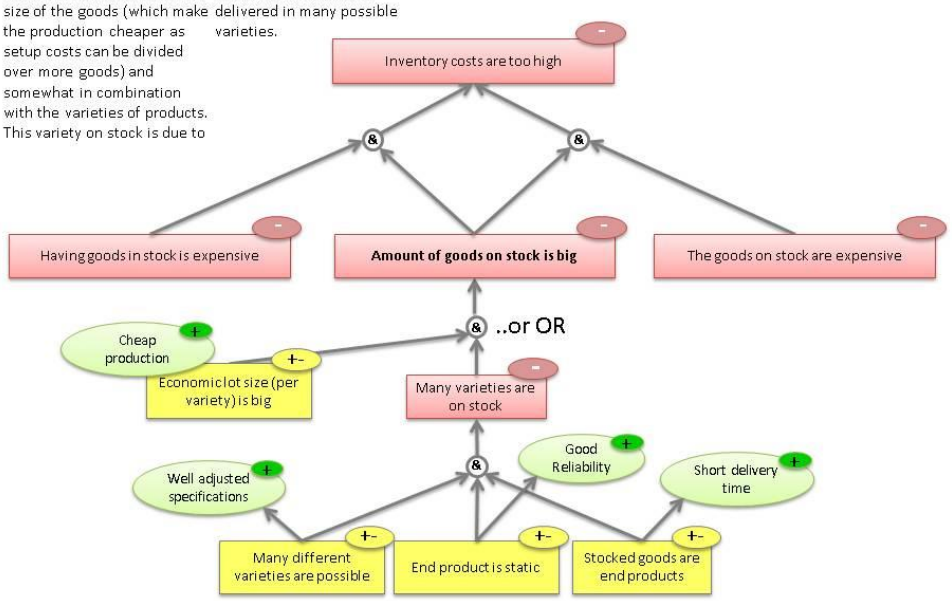


First, let us take a look on the reasons why having goods in stock is / can be expensive. This is mainly about the risk of producing products and not selling them directly. It will be expensive due to the fact that "the costs have to be booked off directly" and separate from that, stocked goods that lose their value will also cause a lot of costs for the principle of having goods on stock. This last aspect will happen when the goods are not sold** and there is also no other way to use them (for instance when they cannot be re-used in the process). Both those aspects will be considered as 'unsolvable' for this case.*

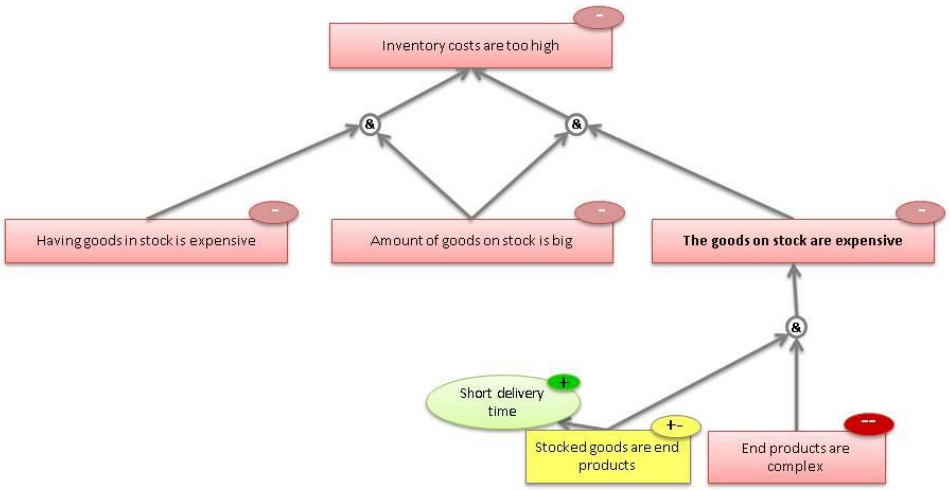
* Re-using products is also explainable in a way different than being 'unsolvable'.
** 'not being sold' can cover aspects like: overproduction, buffer or becoming outdated.

Now let's see the reason why there would be many goods on stock. This is first of all a result of the big economic lot size of the goods (which make the production cheaper as setup costs can be divided over more goods) and somewhat in combination with the varieties of products. This variety on stock is due to the fact that it are static, fully defined end products, which cover the whole range of specifications by being delivered in many possible varieties.

RCA+ v.'12-12-12

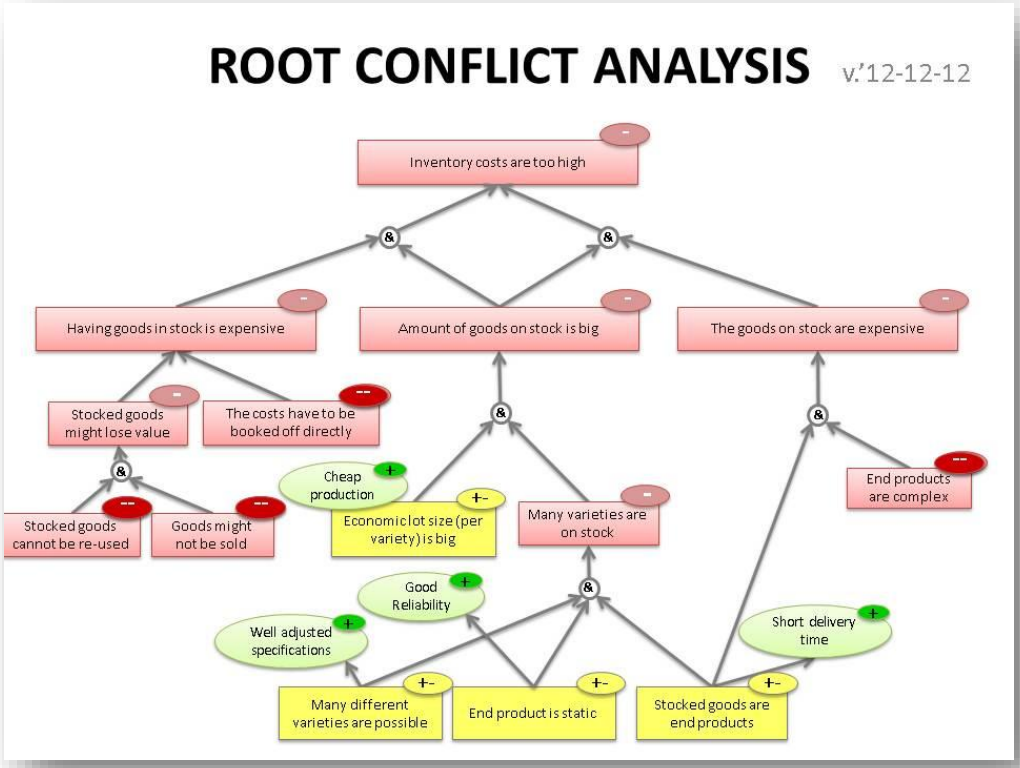


RCA+ v.'12-12-12



Finally the third aspect will be covered, the price of the goods themselves. This was said to be caused simply by the fact that the end products are stored, which of course are complex goods.

Now, the final step is combining those separate views...


ROOT CONFLICT ANALYSIS
v.'12-12-12
Inventory costs are too high
&
&
Having goods in stock is expensive
Amount of goods on stock is big
The goods on stock are expensive
Stocked goods might lose value
The costs have to be booked off directly
&
&
&
Stocked goods cannot be re-used
Goods might not be sold
Cheap production
Economic lot size (per variety) is big
Many varieties are on stock
End products are complex
Good Reliability
&
Well adjusted specifications
Short delivery time
Many different varieties are possible
End product is static
Stocked goods are end products