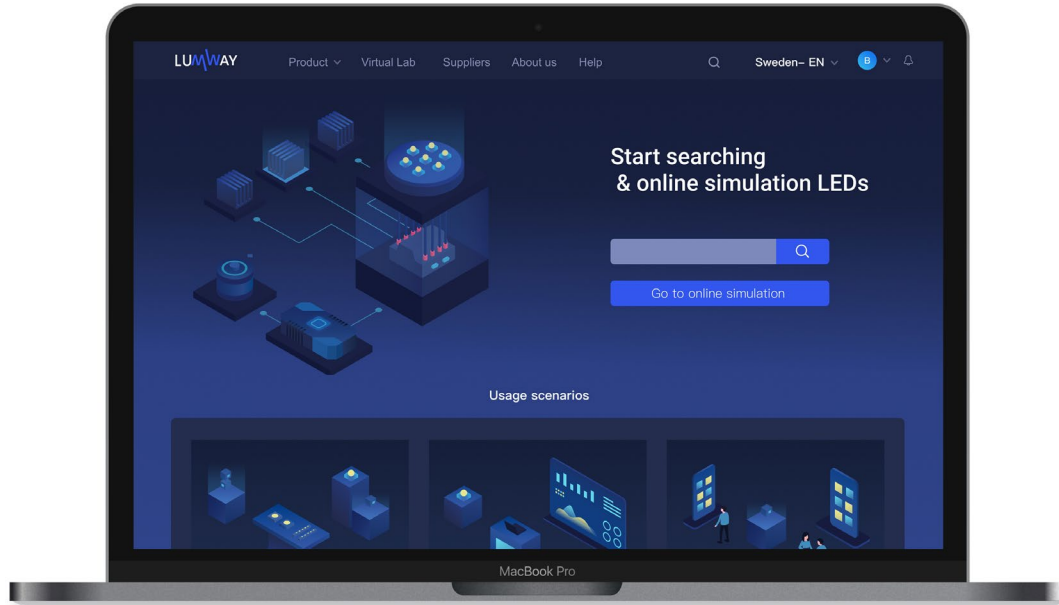




CHALMERS
UNIVERSITY OF TECHNOLOGY



Enhancing UX design to support organizational buying behaviour on a B2B website

The case of a LED purchasing website

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

MASTER's THESIS 2021

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Cover illustration: Beibei Zheng & Haining Liu

Gothenburg, Sweden 2021

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Abstract

The purpose of this thesis was to research important UX factors that can impact the B2B website to have a convenient UX. Therefore, the approach Research through design was applied, where a B2B website was designed and used in the research to extract important UX factors for creating a convenient user experience. In order to create the B2B website to extract design factors, a design process was conducted, which followed the double diamond model and utilized Garrett's five-plane model of UX to structure all elements. In this process, the domain research in the field of study, the user research of target website users, the design of the web prototype, and the design evaluations with stakeholders were conducted. And finally, the design factors were extracted based on the analysis of all findings throughout the process.

The thesis resulted in a web prototype for the buyer organizations to purchase LEDs online, as well as important factors to consider in the design of B2B websites to achieve a convenient UX. The created design can be regarded as an example of how the design factors could be applied in a design and provide a visual reference for designing similar websites. The proposed design factors suggest how to fit the factors on each UX plane to design the whole convenient UX, which can be used by others who conduct work in this context.

Keywords: user experience, B2B, organizational buying, website design.

Acknowledgements

We would like to thank our supervisor Bijan Aryana for guiding us, sharing expertise in user experience design, providing feedback on our progress, and answering our questions throughout the project. We also want to thank the people from Lumway company for bringing this interesting topic and helping us in this project. Furthermore, we want to thank all people who participated in the user research and design evaluations. We appreciate that you could take your valuable time to provide insights and feedback to the design, which helped us to improve the design and accomplish the research.

Beibei Zheng, Haining Liu. Gothenburg, June 2021

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1. Introduction

The significant growth of internet use promotes online e-commerce which means transactions between trading partners through digital platforms (Alsaad, et al., 2018; Meier, et al., 2010). Those digital solutions enable selling and buying firms to quickly and conveniently access each other at lower transaction costs. The statistical office of the European Union (EU), Eurostat (2020) shows, 82 % of individuals aged 16 to 74 within Sweden used the internet for ordering goods or services in 2019. The number increased from 49% to 63% in the whole EU in the last 5 years. While it is common for individual people to buy goods and services through an online channel, the e-commerce sale between businesses (B2B) is not many buyer company's priorities when they need to do purchasing behaviour. The study from McKinsey Company (2017) shows that consumer companies overshadowed B2B companies in terms of their overall digital maturity, which has helped them grow more sales. Around 50% of companies all over the world that provided organizational transactions service only started implementing a digital strategy in the last five years (Accenture Interactive, 2018).

During the COVID-19 disruptions, digitalization became the most important business strategy for many B2B companies as well as a crucial role in adapting the longer-term need for new safety measures. Forward-looking B2B enterprises have to think about how to create a new form of digital solution rather than staying on the defence and simply react to the user demands on the digital front (Benjamin, et al., 2020). To compete beyond price and accessibility, more and more companies have perceived the user experience as a strategy to help with product innovation as competitive advantages in market differentiation (Vääätäjä, et al., 2012). As a concept, user experience (UX) refers to "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" (ISO, 2010). A good user experience can attract and establish a trust relationship with users and improve the conversion rate to result in higher business revenue (Garrett, 2011). Jakob Nielsen's (2011) study shows that the task completion rate increased from 56% to 72% after improving user experience in 507 e-commerce website redesign projects. Even only improving the searching function which was the main problem for the user when they shop online, the success rate increased from 74% to 92% (Moran, 2018). Other research also showed how emotional components and affective bonds affect B2B customer's repeat purchase intention (Ferguson & Mohan, 2019; Pedeliento, et al., 2016). However, some research mentioned that B2B organizations are not influenced by sentimental elements like individual feeling (Veloutsou & Taylor, 2012). The different transaction process and decision-making mechanism (see Section 2.1) distinguished B2B from B2C that might also affect the UX design results. How to apply the benefits of good UX on B2B e-commerce appropriately needs further research based

on the B2B buying behaviour.

This thesis includes a case study that helps the start-up company Lumway to build their vertical e-commerce B2B website in the LED industry. Furthermore, the thesis aimed to explore the abstract part as UX factors within the UX designers' work that can contribute to the results especially in B2B context. In Lumway's website project, traditional LED organizational transactions mainly use paper documents for information transfer. According to the buyer's request, the supplier provides paper data sheets and examples as proposals. Although there are some existing websites that support those processes with online service (see Section 2.2.3), Lumway still believes a website with appropriate UX design can be an innovation for this industry to promote online buying behaviour. The core business idea of Lumway is to attract manufacturers or suppliers to sell LEDs through their platform by providing an online simulation technology, which helps the customers efficiently find the LEDs and suppliers they need for their projects. However, it was not enough for this concept to satisfy users having only the function of LED testing and simulation. Therefore, Lumway decided on doing user research and considered the workflow of the whole buying process. The goal of this website is to enable the preparation work of transactions before the final offline purchase phase. Lumway wants to design the web with a good user experience to support e-commerce behaviour. This thesis will research the issues presented by Lumway and find UX factors that support online user behaviour in B2B e-commerce context.

1.1. Aim

The thesis aims to explore the multidisciplinary relationship between UX and B2B e-commerce online buying behaviour, which includes how a *Convenient UX level* (see Section 3.3.1) impacts B2B online buying behaviour and what UX factors need to be considered to build the B2B website results with a Convenient UX level. The approach to this is mainly by applying *Research through design* (see Section 3.1). The design output needs to be evaluated to further explore and verify UX factors as the research answer. Those UX factors came from both the user research on users' goals from the user research held by Lumway and the user evaluation feedback based on the design prototype. Since Lumway only had the interactable demo of the simulation and testing tool, the whole website needs to start from scratch, and the team will be involved in the idea evaluation based on their perspective. Furthermore, Lumway proposed the challenge of this project, so they are potential actors using the results of this thesis. The research question will be answered by both a textual narrative with a set of web design interfaces. Additionally, the final results will help the team to improve the user experience in future design iterations and it can be an example for other similar websites that want to consider UX during the

development of their B2B e-commerce products.

To better achieve the design goals and apply the existing experience in this research context, reviewing has been made in several B2B e-commerce designs that have already been launched. This involves literature review and existing product investigation on B2B buying behaviours and how the existing platforms support the user's workflow. Thereafter, to verify whether the collected experience has the potential for success, these experiences will be considered in the design prototype for testing and evaluation with the user.

In conclusion, this research aims to use the design website as an artefact to explore the research question as:

1.2. Research questions

RQ1: How does convenient UX impact the B2B purchasing process?

RQ2: What are UX design factors that should be considered when designing the B2B website to have a convenient experience?

1.3. Stakeholders

It is vital to identify the stakeholders and consider their demands and goals through the whole project process. There are three main stakeholders involved in this project. The first one is the end-users of Lumway website. Since this thesis only considers the buyer side, the target users are lighting manufacturing practitioners whose companies want to purchase LED components online. They can be managers, lighting engineers, purchasers or other relevant roles in the business procurement process.

Another important stakeholder is Lumway that provides the opportunity to study the defined research question. The company has two main interests in the project, one is providing great experiences to their customers through the e-commerce B2B website, and another is making strategies for future design iterations to keep improving the UX.

The last stakeholder is Chalmers University of Technology that is responsible for the academic work. It includes the researchers, supervisors and examiners of this thesis. The aim is to yield useful results as well as satisfy the academic requirements.

1.4. Delimitations

As an intermediary firm, Lumway serves two interdependent customer groups of sellers and buyers through the B2B website. Because of the availability of sellers (suppliers), this thesis only focuses on demands and website interfaces of the buyer side.

In terms of the visual design reference created, this will only be a conceptual digital design, and should not be mistaken with the functional online website. The technical aspects of the website were outside the scope of this study, like coding and programme testing.

The final generated design will provide suggestions for how to take into account important UX factors to support consumer workflow in B2B context. However, it will not make sure that those UX factors can work in the real transactions process. This is because the time limit of this thesis does not allow for evaluating the UX factors through control variable experiments. But the research that will be made will aim to strengthen the claim of potentially being able to support B2B consumer behaviour.

1.5. Ethical issues

The project will develop a B2B website for the buyers to accomplish tasks during the LED purchasing process, therefore it is important to consider ethical issues regarding different stakeholders in the business collaboration.

Since the website deals with the procurement between enterprises, it will collect lots of customer information during the usage, such as registration forms, procurement lists and the message system. This privacy data is valuable for the sellers to understand the buyers and make better selling strategies to serve them. Although many customers benefit from the service based on privacy data, they may be unwilling to provide these data if they doubt their privacy might be invaded or threatened. Thus, privacy concerns are an important issue in B2B e-commerce when it is difficult or impossible to complete a transaction without revealing personal data (Liu, et al., 2005; Ackerman, et al., 1999). In this project, the issue is how the private information will be stored and who will have access to it. From the perspective of HCI, a series of questions need to be considered during the design process. For example, how do we inform users about possible privacy risks and available technical protections for privacy (Friedman & Kahn, 2002)? Should the default on the system be toward greater privacy protection or greater access to the

information? Privacy will also affect user's trust in the platform, which can be important for their purchasing decision (Hajli, et al., 2017).

Furthermore, privacy data of the target users will be collected when the project group needs to conduct user research and evaluation, like personal information, attitudes and feedback. It is vital to consider users' rights and hand these data with respect to their integrity when involving them in the research. In this study, informed consent will be designed based on general design principles for informed consent (Friedman & Kahn, 2002). Participants will be informed of the purpose and procedure of the study, potential risks and benefits before engaging in the whole process. In addition, participants should not be compromised. They have the right to leave the research or deny the recording of data.

Finally, the website will be used by distinct user types with differences in professional knowledge, technological skills and capability. It should be designed with great usability so that everyone can easily achieve task goals in the business collaboration. Although usability is one of the key points of the user experience with the website (Vu & Proctor, 2011), the final design result can only satisfy most of the users and ensure good usability in most cases due to the considerations of commercial cost. But the website will provide some helping functions to assist users in different contexts and try to achieve universal usability.

1.6. Project process

By applying *Research through design* (see Section 3.1), this project aimed at “making the right thing” (Frayling, 1993) in B2B LED purchasing contexts. The design result website intends to help the target users transform the current online working state to a better state with fluent using experience. The project results should include both generating the website for the user to test and the conclusion on what UX factors should be considered for B2B e-commerce website design.

To explore the website's capability and how it can impact users, a website prototype needs to be made by designers. The design process follows the *double diamond model* (see Section 4.2.1) process and Garrett's five-plane model of UX was applied to build the website UX from abstract to concrete during this design process.

The project was initiated with the domain research where the background research was conducted of the intended market and competitive websites (see Chapter 2) and the theoretical research of organizational buying behaviours and website UX (see Chapter 3).

After the exploration and domain research in the context of this thesis, the design work started with field and user research from a design perspective in the Discover phase (see Section 5.2). The user research aimed to collect insights of the users, their desire and typical workflows in the organizational purchasing process that will be carried out on the website, which was conducted by semi-structured interviews. Those collected data will mainly be used to inspire the insights belonging to the UX strategy plane and the scope plane.

The second phase of design was Define which aimed to extract the user needs on the strategy plane and transfer them into specific design requirements on the scope plane. To analyze the interview results, the affinity diagram was used to sort user data into different groups. To better summary the characteristics of users and understand their needs in a specific context, personas and context scenarios were used to model different user types and their typical usage scenarios of the website, and then analyzed to extract the user needs on the strategy plane. Then the ideas of design requirements were generated with both the user needs and the theory as support, which described what the website should provide on the scope plane to fulfil user needs.

In the third phase Develop, the website concept was constructed at a high level and then refined to more details based on the evaluation results. In the brainstorming session, two ideas of the website were sketched to explore possible design solutions on the structure plane where the interactions of functions were focused on. To validate these design ideas, and evaluation session was held to gather the initial reactions from the Lumway team and the target users. The collected feedback contributed to a more detailed definition of the scope plane, which aimed to clarify the functions of the website in further development.

Based on the paper sketches and the evaluation results, a set of wireframes was created to refine the website structure and identify different aspects of the interface on the skeleton plane. Then the wireframes were developed to a high-fidelity prototype with the focus on the visual design on the surface plane. After creating the high-fidelity prototype, heuristic evaluations were conducted with interaction designers to inspect and then fix usability problems before evaluating with end-users. The improved web prototype could be seen as the outcome of the design work.

In the Deliver phase, the outcome of the design was used for both design evaluation and research. Target end-users were involved in the usability testing to evaluate the prototype and provide thoughts and feelings for the research. Both qualitative data and quantitative data were collected during the evaluation. At the end of the usability testing, users were required to evaluate their overall experience with the prototype by filling in the UX questionnaire. To gather more user feedback and make the resulting representative, the online UX questionnaires were sent out to the target user group.

At the end of the project, the design result and the feedback from the evaluation will be analysed to reflect and disseminate as part of the research output. The research question specifically asked for finding out what important factors are for the B2B e-commerce website UX design to support buying behaviour in the transaction process will be present at this phase. How the outcome of this project will contribute to others will be mentioned as well in the end.

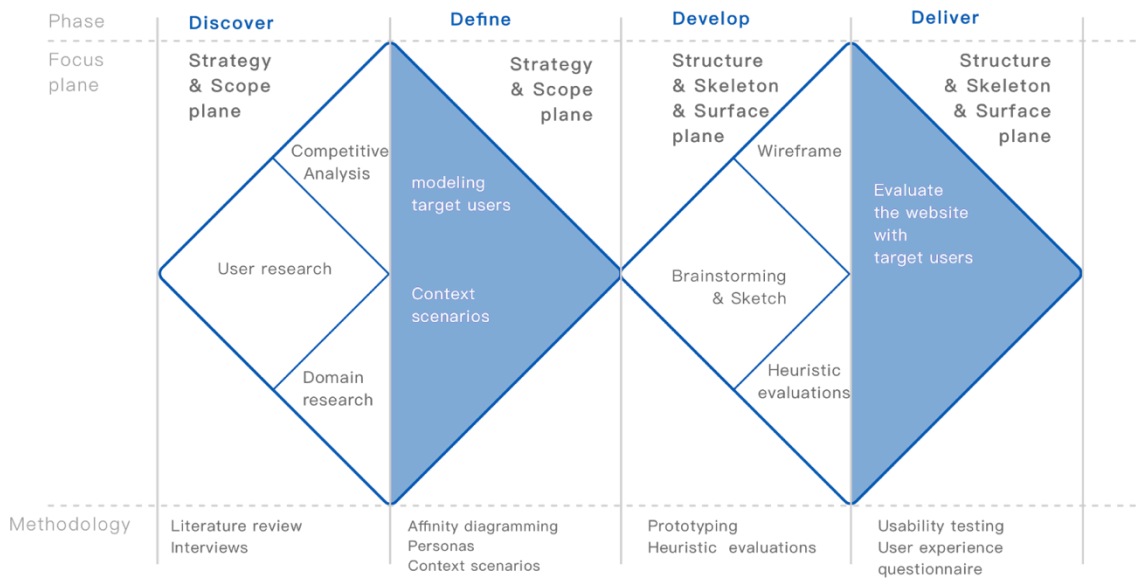


Figure 1.1 The project process

2. Background

To better explain the project background, more detailed background information about the market and technical aspects related to the thesis research will be presented. This information shows how B2B e-commerce and the LED purchase process are involved in the research. Thereafter, Lumway and the simulation tool are being introduced and how they relate to this thesis.

2.1 B2B online marketplace

Many companies such as Amazon or Alibaba are expanding their B2B operations following either the direct model or the marketplace model. An online marketplace is a platform where multiple vendors can offer products or services alongside their competitors (Boulaye, et al., 2019). By using this kind of B2B website, buyers can gain more choice, value, and greater efficiency, while sellers gain access to a broader pool of buyers—without the burden of marketing or technology of operating a standalone site (Boulaye, et al., 2019; EcommerceDB, 2019). The self-service, digitally sourced environments created by B2B marketplace websites can eradicate most of the weaknesses of SMEs and make it easier to improve the customer experience by making transactions simpler and more transparent (Boulaye, et al., 2019).

2.1.1. Concerns for B2B online marketplace website

Many buyer companies prefer traditional offline transaction models mainly because they need to take into account the complex legacy technology environments, organizational structures and surrounding information security before they turn to digital platforms (EcommerceDB, 2019). The offline meeting is more often for most buyer companies when they need to collect the supplier proposals and make negotiations (Kotler et al., 2017). Many buyer organizations and suppliers prefer the offline models even though they have an online website to display the connection information.

However, the conservative attitudes to the online platform have changed recently. Accenture's study (2018) shows that 61% of B2B transactions globally have a digital presence even if the actual purchase ends up offline. Considering the new and easier form of integration brought by the application platform in the cloud that has been most tested in B2C, B2B companies are focusing on applying the same digital solution that can benefit from those advanced technologies. The demographic change in the business environment shows impacts on purchasing procedures as well, which is caused by

younger people that prefer service through the internet have taken more positions in their companies (Pawłowski & Pastuszak, 2017). These digitalization trends will lead more B2B companies to put their online business as their heart of strategy and expand the global B2B e-commerce market size at a compound annual growth rate of 17.5% to reach USD 20.9 trillion by 2027 (Grandviewresearch, 2021).

2.1.2 Different buying behaviour between B2B and B2C

With the buyer companies' expectation that they want to have a similar shopping experience as Amazon B2C platform, a flexible and interoperable B2B shopping service architecture can be primarily important (Pawłowski & Pastuszak, 2017). Since buyer companies use the customer experience in B2C as a benchmark before they use B2B online service, there is a need to clarify the difference between B2B and B2C to see what can be improved.

Generally, the differences between the buying behaviour of the individual consumer and organization can be characterized by the following features according to the research of Pawłowski and Pastuszak (2017):

1. More research and negotiation on both companies and products before the purchase decision.
2. Testing technical specifications before the formal purchase procedures.
3. Focusing more on product functionality.
4. Increasing the number of people participating in the procurement process, as well as requirements about the sales representatives of the company offering solutions.

When those buying behaviours happen in internet environments, there are needs for different approaches to support the buyer's goal based on the scenario and the website strategies. More detailed theory about B2B buying behaviours and how they helped this project will be presented in chapter3.

2.2. LED B2B marketplace

A light-emitting diode (LED) is a two-lead semiconductor light source that can directly transfer electronic energy into light (Nair & Dhoble, 2021). For lighting use, the LED needs to be solid as a LED package to focus its light for use. The LED package consists of external contact pads for electrical and thermal connection to the die (Nair & Dhoble, 2021). Figure 2.1MCPCB package is an example of construction for a metal core

printed circuit board (MCPCB) package which means the LED die is directly mounted on a ceramic or a metal core printed circuit board. On one hand, those qualities of the components that formed the LED package decide the luminaire quality. On the other hand, the design of the fixture also affects the final performance of illumination produced, thermal management, low cost, and the long lifespan. For LED customization, the lighting engineer selects the appropriate parts according to the use scene to ensure the stable work of the equipment.

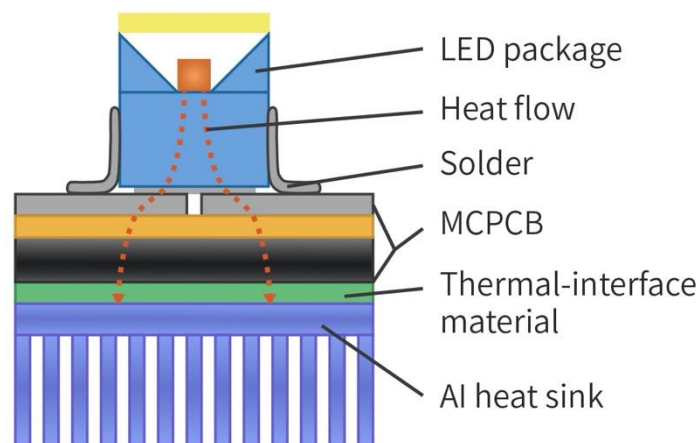


Figure 2.1 MCPCB package (Nair & Dhoble, 2021)

2.2.1. LED Industry Background

Compared to other lighting devices, LEDs have loads of merits in different aspects, such as their luminous performance which shows more lumens per watt than incandescent bulbs can do. For lighting use, a LED lamp can have a 10 times longer useful life compared to a fluorescent lamp or an incandescent lamp (Nair & Dhoble, 2021). The extensive feasibility of LEDs has been used in multiple categories which are visual indicators and signs, measuring and interacting with processes involving no human vision, machine vision systems, biological detection, lighting etc. In those use categories, commercial LED Lighting emerged as the largest segment and accounted for 52.7% share of the market revenue (Grandviewresearch, 2021). With the advent of the production of semiconductor wafers with higher purity and uniformity technologies, the improvement in the brightness and efficiency of LED will further help in boosting the LED market (Nair & Dhoble, 2021).

2.2.2. Challenges of LED B2B marketplace website

In the manufacturing section, the e-Marketplaces combine the search methodology and unique tools to the manufacturing buying cycle and it can help the procurement activities with less time spent vetting vendors, chasing down transactions, coping with paperwork, reining in rogue spend, and ensuring compliance. Buyers will be able to devote more of their energies to higher-value work, such as researching new and better materials and unearthing promising marketplaces (Boulaye, et al., 2019). Even though many e-marketplace websites have functions to search for products and communicate with suppliers online to support the buying behaviour, many of them simply extend the ERP system's solutions to enable e-business (EcommerceDB, 2019). There is a need to solve those usability problems for a better user experience as well as increasing conversion. More specifically, usability research on one site called RS that sells LED has been presented by Ben Davis that can be an example to show the problem for those electronic components e-marketplace website:

RS supplies around 500,000 products from 2,500 suppliers to over 1 million engineers worldwide (end-users and purchasing managers) and receives millions of visits per month and 100's of millions per year, with a large amount of traffic from search engines. The biggest problem they want to solve is that millions of customers were leaving the RS sites with the top customer frustration being site search and product information (Davis, 2015). This searching problem can be found in Herschlag's research in 1998 and it is still a big problem for most e-commerce websites now (Herschlag, 1998).

For the RS site, the design team tried many strategies to support user's searching activity such as predictive search, improving search filtering, extensive sort functionality and adding a compare function. After the design improvement, RS Components hit a 41-month high for e-commerce sales (Davis, 2015).

2.2.3. Examples of LED B2B marketplace website

There are currently many online product-focused marketplace websites for selling LED and related components, where many of them are very mature and have made considerable profits through online models. Table 2.1 shows last year's sales ranking.






		Company	2019 North American sales million\$	% of total sales
1		Arrow	11511	72
2		Avnet	4966	77
3		Digi-Key	1765	41
4		Mouser	879	43
5		Fusion Worldwide	347	73

Table 2.1: Last year's sales ranking

In this section, several LED marketplace websites have been reviewed and will be presented with information on what they are capable of using Garrett's five-plane model of UX. Three websites have been chosen to be analysed for competitive analysis: Arrow electronics, Fusion Worldwide and Future electronics.

The strategy plane

Although all those B2B e-commerce companies aimed at promoting the transaction, they choose different online strategies. Among the three websites chosen, Arrow electronics and Future electronics aimed to support users to find the component they need and go to the final purchase phase by providing several functions, as well as establish a connection with those users. However, Fusion Worldwide only used their website as a platform to show what they are capable of with contact information. No actual function user can access before they contact the company for further meetings.

The scope plane

The different website strategy decided the different functions they had for each website. Arrow Electronics and Future electronics have a similar goal to support users' online buying behaviour, they have similar functions to support the workflow. While Fusion Worldwide created its website as an information platform with limited functions to use. They did not show the items list to users. Instead, they allow users to send them what they need and maybe contact them later in other ways.

The following table (see Table 2.2) will show the specific functionalities that the reviewed websites provide according to the descriptions following.




			
Products list	✓	✗	✓
Manufactures list	✓	✗	✓
BOM	✓	✓	✓
LED	✓	✓	✓
Simulation	✓	✗	✗
Technical Resource	✓	✓	✓
Help	✓	✓	✓
Shopping carts	✓	✓	✓

Table 2.2: Functionalities of reviewed LED marketplace websites

The products list: It is an online category that allows users to see all products available on the website. This is the main entrance for the user to find the products by themselves. By applying filters or the search tool, users can locate the products they need.

Manufacturers list: It is another online category that shows the manufacturers on this marketplace first before users go to the product provided by this manufacturer. This function usually also shows the information about the manufacturers in a consistent form. By viewing this list, the user should also find a way to contact the manufacturer in some way.

BOM: Bill of materials is usually the file that shows quantities of each needed on products. All those websites provided functions to upload the BOM file without fulfilling it again. By using this function, the buyer can easily send their needs and allow providers to estimate the prices or even create orders online.

Technical resource: This function usually means the article or report that shows the industry trends or new technology news.

Help and support: This function usually involves customer service online to help users when they have a problem using the website or purchasing.

Shopping carts: This function allows the user to temporarily save products they need to order before they pay for them.

How each function works to support the workflow can be seen in the following illustration:

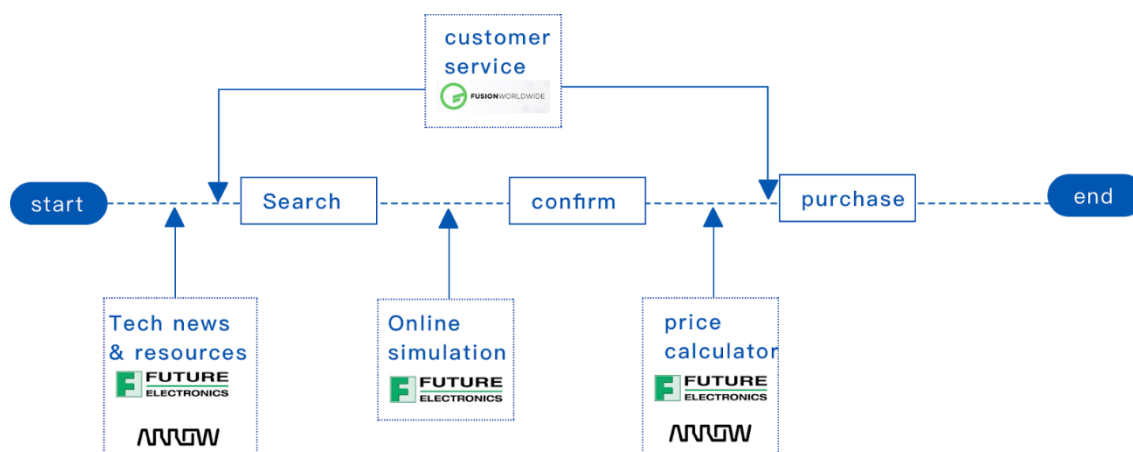


Figure 2.2 Simulation tools for Fusion Worldwide

The structure plane

Arrow Electronics and Future electronics websites have a similar information structure on each page as well as workflow. For example, the way of searching items in Arrow electronics and Future electronics websites is quite similar. In order to help users achieve their ultimate goal using the search-related function ——find the LED they need—— both those two sites implement the same workflow and the information structure: users either search the key word directly or use filters to find the LEDs they need (Figure 2.3). Since Fusion Worldwide has fewer and simpler functions, the workflow and information structure for the whole website is also very simple.

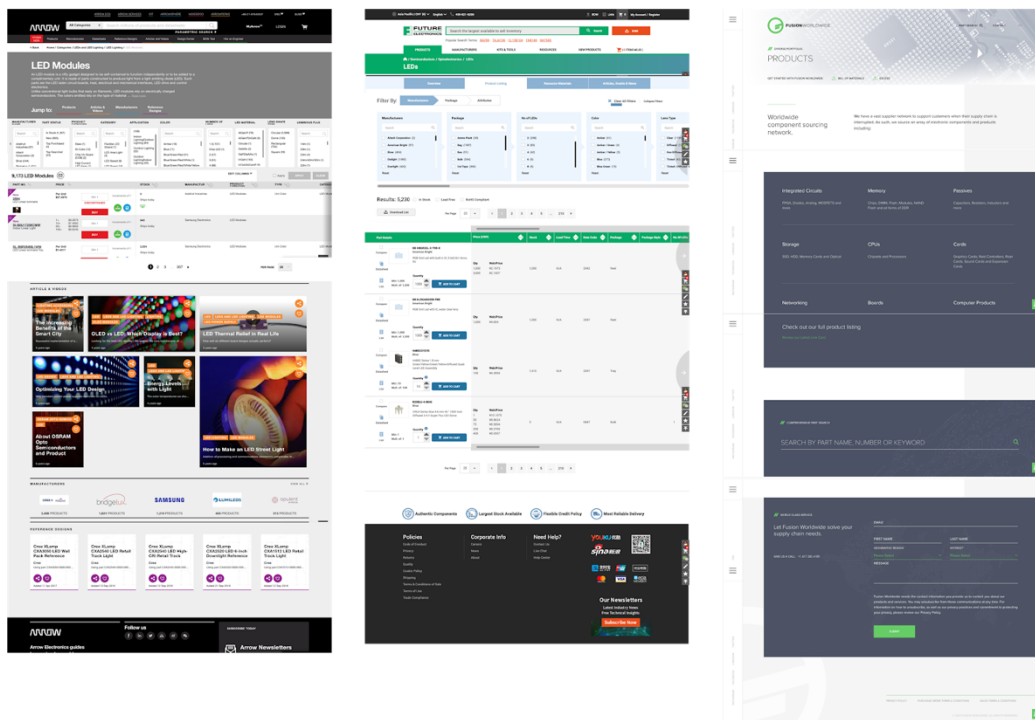


Figure 2.3 Searching page for Arrow electronics and Future electronics

The skeleton plane

Arrow electronics and Fusion Worldwide website has the most consistent design on interaction. While Future electronics lack consistency in interaction especially for the simulation tool page they had. Future electronics did not provide a very clear navigation system which made it hard to follow where the user is.

The surface plane

The visual design of all three websites follows the rule of reducing visual exercise. And Fusion Worldwide had the most styling visual design that evokes a feeling of simplicity. However, the page for the simulation tool in the Future electronics site was completely different from the other part of the site (see Figure 2.4). The lack of consistency in visual style may be confusing for users.

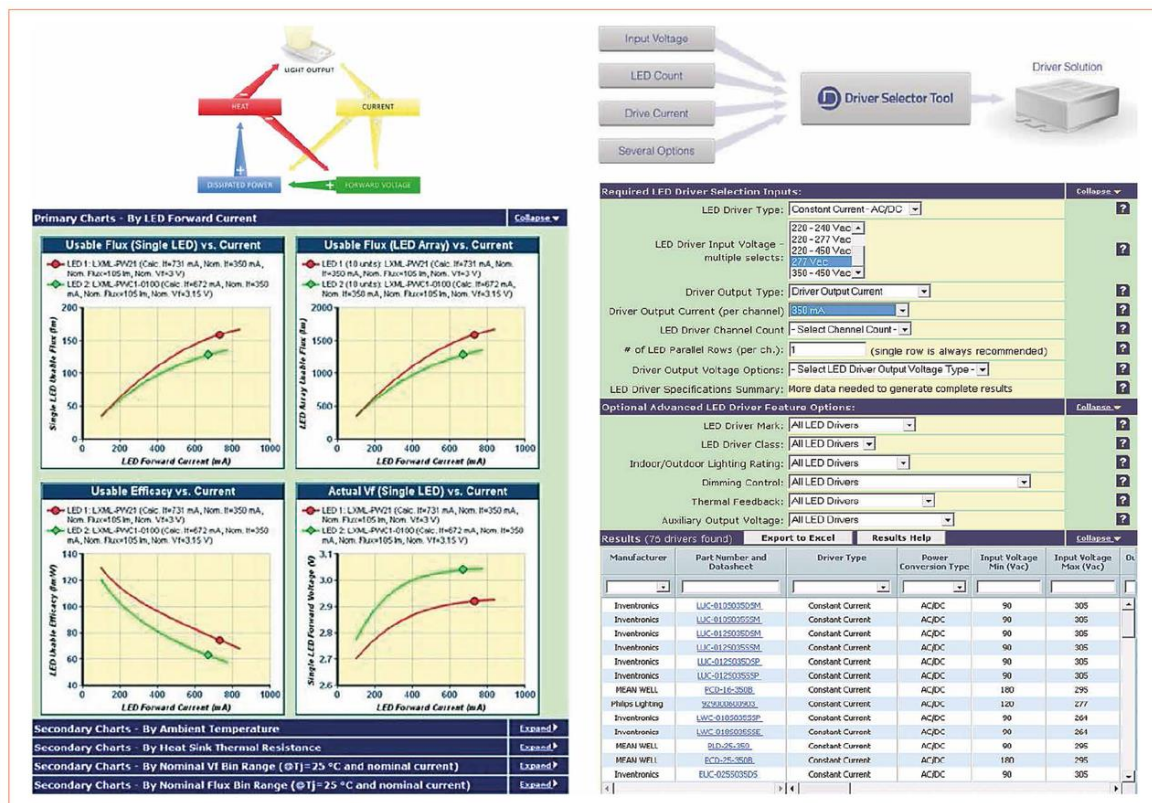


Figure 2.4: Simulation tools page for Fusion Worldwide

2.3. Lumway's simulation tool

In the Introduction (see Chapter 1), Lumway and their business idea were introduced, where it was emphasized that Lumway wanted to extend functions within their website that would better support users' online buying behaviour more than using the simulation tool. Before the design work starts, more detailed information about how this LED simulation tool works according to the demo they built will be presented. This can help the future design work to better focus on the core idea of Lumway as well as keep the innovative idea in mind. The simulation tool specifically involves the following three main features; setting inputs, showing results graphic, and comparing. The goals of the tool are what Lumway have emphasized in supporting people to find the LED they need.

Input setting: The simulation process starts with setting input parameters. To set the input, users need to select the LED they want to test with quantities they designed to work together by filling in each input box manually. There is a drop-down menu with a searching box that lets the users search for the LED. After the LED is selected, they also need to set the parameters for the rest of the LED packages like PCB, TIM and heat sink.

All those sections allowed the user to search the component based on their name.

Results graphic: After setting the input parameters, the system will start to calculate the optical performance changes of the set LED package following environmental changes. This tool allowed the user to see the optic losses and luminous flux based on the environmental changes. The result will be presented as data and graphics. The example of results can be seen in Figure 2.3.

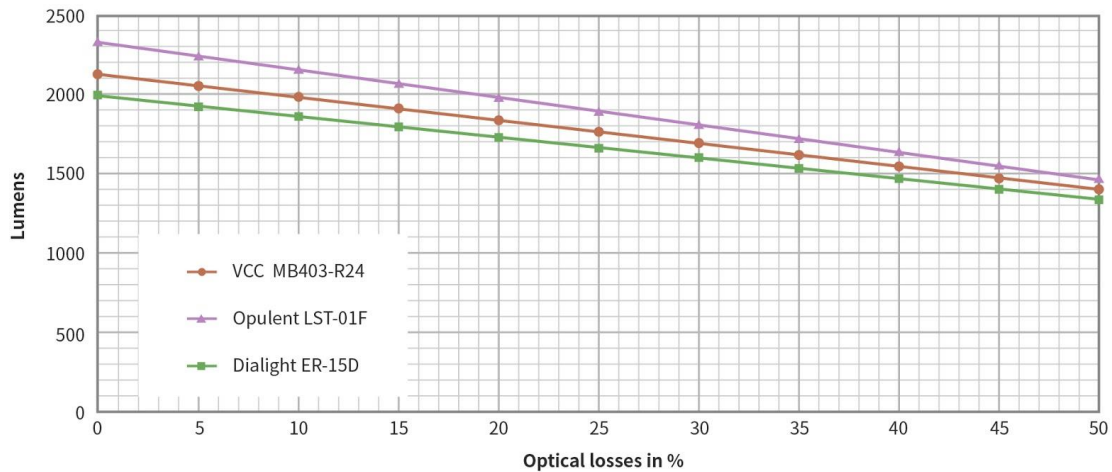


Figure 2.5 Simulation result for 3 LED

Compare function: After the simulations on each LED, the user can select the generated test results for comparison. The system will merge the results and generate new visualization graphics for a more intuitive performance comparison. More specifically, this tool helps the engineer compare the optic performance on different design ideas even if they used different LEDs with different quantities.

2.3.1. Failure in using a simulation tool to support online buying behaviour

Using the tool Lumway developed can help the engineer easier to see the visualization of the LED performance without professional software. However, to use the demo Lumway built, users need to first decide the LED they want to test in other marketplace websites before they use this tool. Thereafter, they need to copy and paste some of the parameters in order to make the simulation tool work. The lack of shopping context during the use of this tool might not help the business goal Lumway wants to achieve and users might turn into other online B2B websites after gaining the result because there is no support function for purchasing. Instead of improving this website to a more professional tool

with accurate results, Lumway thought of investing in the UX of this website. Therefore improving the functions to support the buying behaviour with this tool is what Lumway emphasizes, thus inspiring this thesis' aim in finding answers for the research question.

3. Theory

In this chapter, the theory supporting this thesis will be presented, including the core practice method this thesis relies on, called *Research through design*. After that, the related concepts and research theory of organizational buying behaviour and web UX mentioned in this project were presented.

3.1. Research through design

Research through design is an approach of researching by integrating theories and methods with technical knowledge in the design process (Zimmerman, et al., 2007). The output of research through design can take the form of artefacts and systems, as well as recommended methods and theories for dealing with similar problems (Gaver, 2012). Compared with conventional science and engineering methods, research through design provides a better chance to produce provisional, contingent, and aspirational theories (Gaver, 2012). Furthermore, this research method benefits designers to make research contributions that utilize their skills to reframe problems through a process of making the right thing (Zimmerman, et al., 2007).

To conduct research through design in this thesis, background research was first carried out by literature review to study the domain of the topic, like B2B online marketplace, LED B2B marketplace websites and Lumway's stimulation tool (see Chapter 2). Meanwhile, relevant theories and methods were collected and analysed to provide a theoretical foundation for the design process (see Chapter 3 and Chapter 4). Research questions were then formulated based on the results of background research. To answer the research questions, a design process of creating the Lumway website was conducted, where the design activity was performed iteratively to achieve a better solution. By analysing the design result and process, the research questions were answered in the end.

3.2. Organizational buying behaviour

To make succeed in B2B markets, organizational buying behaviour that included potential customers and the factors influencing their adoption decision must be considered in the marketing strategy (Sincic Coric, et al., 2017; Frambach & Schillewaert, 2002). To understand the structure of organizational buying behaviour and how internal and external factors affect each other, Several models have been reviewed in this research.

Since most organizational buying behaviour models in specific industries are created based on the classical model like Wesley and Jeffrey’s model in 1996. This model shows the combination of the other 3 similar models created by Robinson, Faris, and Wind (1967), Webster and Wind (1972), and Sheth (1973)’s theory. According to Robinson, three types of buying situations can be defined for business buyers: the straight rebuy, the modified rebuy, and the new task. Those different situations need the different departments to make the purchase decision, for example, purchasing agents are influential in straight-rebuy and modified rebuy situations, whereas engineering personnel carry the most influence in selecting products (Jackson Jr, et al., 1984). This decision-making unit of a buying organization is called the buying centre (Webster. Jr & Wind, 1972). The buying centre needs to respond to many influences for decision making. Those factors that influence the purchase decisions can be divided into 4 parts, like Figure 3.1 Major Influences on Business Buying Behavior shows:

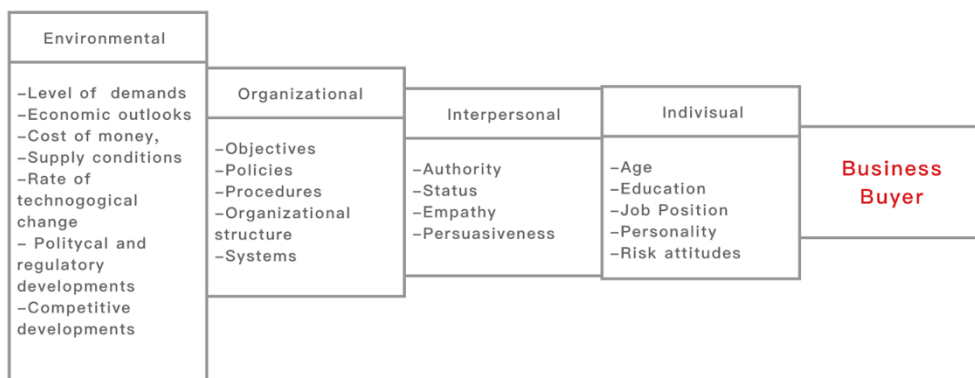


Figure 3.1 Major Influences on Business Buying Behavior (Kotler, et al., 2017)

However, the buying behaviour model like what Wesley and Jeffrey described lack specificity and are highly general. It might not directly help with predicting what buyers might do and what will be the influences during the process in this research.

Iyer and K.R (2021) described a model that explained how the organizational buying behaviour process works with radical software to show the technological environment impacts on the buying process as Figure 3.2 Organizational buying process with radical software shows (Iyer & K.R., 2021).

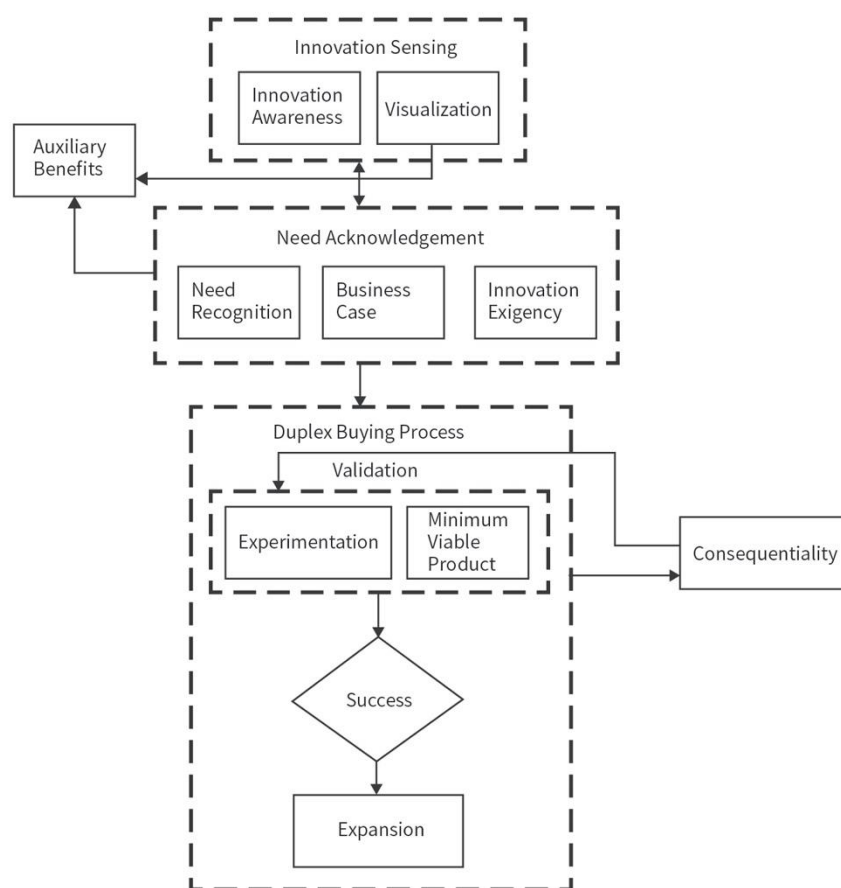


Figure 3.2 Organizational buying process with radical software (Iyer & K.R., 2021)

This model mainly explains what attracts the buyer group to use radical software before they turn into a general buying process (see Section 3.2.1).

Innovation awareness, which means the fame reported by specific media (Iyer & K.R., 2021). It will first decide the interest of the potential users together with visualization of the software. Thereafter, if the software can meet the need that helps users to achieve a certain goal, users will use it for their formal buying process. Except for directly showing the usage of certain software, visualization can be a key factor to attract buyers to using the software as a tool and lead them to find auxiliary benefits that might not be mentioned in the main workflow (Iyer & K.R., 2021).

3.2.1. The general buying process

Although the different factors will affect the purchase decision, the overall process can still be similar. Even with radical software to help with the buying process, it might only change how people receive the information instead of reducing the basic steps a purchase

needs to go through. Knowing the general buying process can be fundamental to understand what buyers will do in the specific context.

In the field of research of organizational buying behaviour, most of the researchers agree that organizational buying behaviour is best described as a process that includes 8 phases (Kotler, et al., 2017). The final decision can be influenced in each buying phase, suppliers need to consider the competitiveness in each phase to increase the chance that they will be selected and, ultimately, build a long-term relationship with their customers.

1. Recognition of the problem and need

The first phase in the organizational buying process is the recognition of a problem or a need in the company that can be met by purchasing a good or service, both internally and externally, i.e., when the company wants to use a new product for internal needs or external trade (Kotler, et al., 2017).

2. General Need Description

After recognizing the problem or needs that exist, the buyers have to describe the general characteristics and the required quantity of that item to make sure that everyone understands the need. For complex items, the organization might need to work with engineers, users, purchasing agents, and others to define and prioritize important product characteristics. Armed with knowledge, those people should understand virtually all the product-related concerns of a typical customer (Kotler, et al., 2017).

3. Product Specification

Once the general need description is ready, the buyer needs to develop the item's technical specifications. Usually, a product value analysis (PVA) engineering team will serve for this phase. The PVA team designs several alternatives for cost reduction that try to redesign or standardize or make cheaper methods of production then decide on the optimal product characteristics. This phase can help the buyer to refuse components that are too expensive or that fail to meet the specified standards (Kotler, et al., 2017).

4. Supplier Search

After specific the product item's characteristics, the buyer organization will try to identify the most appropriate suppliers. The buyer organization will conduct a search to identify which providers offer the best item on both price and quality through the online searching approach or the offline searching approach, i.e., examining trade directories, phoning other firms for recommendations, scanning trade advertisements, and attending trade shows. This phase can be important for suppliers to stand out. Developing online catalogues or service can be helpful to reach buyers in this phase. A shortlist of qualified suppliers will be created when the buyer has done their evaluation of each supplier (Kotler, et al., 2017).

5. Proposal Solicitation

Before the buyer makes their decision on choosing the supplier, qualified suppliers will be invited to submit detailed proposals including both technical documents and marketing documents. However, some suppliers might only send a catalogue depending on the nature of the purchase. After evaluating the proposals, the buyer will invite a few suppliers to make formal presentations that inspire confidence, positioning their company's capabilities and resources so that they stand out from the competition. At this phase, the supplier should not only present their advantage on both technical and marketing but it should also be qualified or even become certified, i.e., meet ISO 9000 international quality standards and can qualify for certification (Kotler, et al., 2017).

6. Supplier Selection

To make their decision on choosing the supplier, the buying centre will list the characteristics that describe desired supplier attributes (such as reliability of both product and service) and indicate their relative importance to identify the most appropriate one. The buyer may also try to negotiate with preferred suppliers for better prices and terms at this phase to make the final selection. The buyer organization usually pays more attention and time to negotiate the price at this phase as a key criterion for supplier selection (Minahan, 1991). Instead of lower prices, the supplier can also consider showing the "life-cycle cost" lower than other competitors and cite the value of the services the buyer now receives. As part of the supplier selection process, buying centres must decide how many suppliers to use. In the past, many companies preferred a large supplier base to ensure adequate supplies and to obtain price concessions. However, companies are reducing the number of suppliers they considered even using one supplier (Kotler, et al., 2017).

7. Order-Routine Specification

When it comes to the final order phase, the buyer lists the technical specifications, the quantity needed, the delivery schedule, and so on. There are generally two kinds of contracts, one is the periodic purchase order and the other one is called MRO blanket contracts that buyers are moving toward contracts that the supplier promises to resupply the buyer as needed at agreed-upon prices over a specified period. During the period for blanket contracts, once the buyer needs stock, the supplier will deliver products according to the blanket contract (Kotler, et al., 2017).

8. Performance Review

After the order, the buyer organization will periodically review the performance of the chosen supplier(s) that lead to continue, modify, or end the relationship with the supplier. The buyer can evaluate the supplier by contacting the end-users. Or the buyer may rate the supplier on several criteria using a weighted score method. Or the buyer might aggregate the cost of poor supplier performance to come up with adjusted costs of

purchase, including price (Kotler, et al., 2017).

3.2.2. Business behaviour online

Using the digital platform to support the transaction activity with products, services and information over the internet is known as online transaction behaviour. For organizational buying behaviour online, it might only contain part of the transaction process, like supplier searching and proposal solicitation and go through the rest of the transaction process offline. Those online processes and factors affecting that buying behaviour and the final decision can still be similar to the same offline phases model, therefore the frameworks of offline or general buying behaviour need alteration to be applicable for online buying behaviour.

The buyer organization go through a decision-making process also online and the process is similar, but not identical, to the general 8 steps decision-making model of recognition of the problem and need, general need description, product specification, supplier search, proposal solicitation, supplier selection, order-routine specification and performance review; the online process may as well go back and forth between these steps or completely skip some step and do it offline. There are factors beneath these general steps affecting online buying behaviour and decision-making. Chakraborty (2002) did research in construction industry websites that tried to explain factors that influence the organizational buying behaviour online for power tool companies. The results show that among the 8 factors considered (see Figure 3.3), informativeness, organization of the information structure in the website, transaction-related interactivity, and personalization are significant predictors of Website effectiveness. While there is no direct relationship between the other factors (non-transaction-related interactivity, privacy/security, accessibility, and entertainment) and Website effectiveness (Chakraborty, et al., 2002).

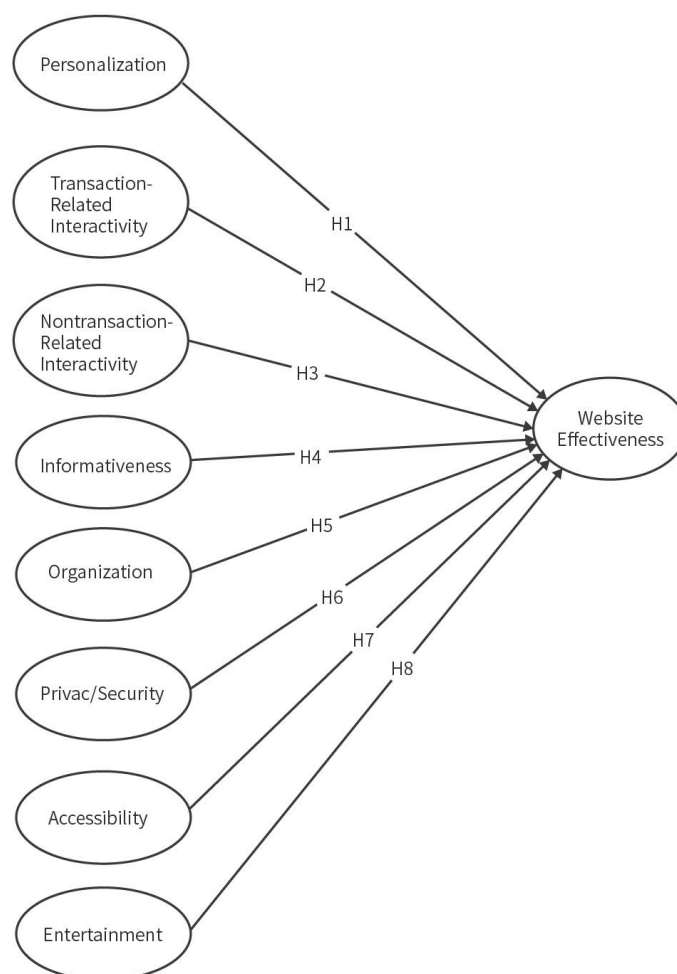


Figure 3.3 Factors that work on website effectiveness (Chakraborty, et al., 2002)

3.3. Web user experience

When it comes to the digitalization strategy in the business context, the value of user experience has been seen and adopted by more and more companies. The field of user experience (UX) has emerged as a comprehensive concept that goes beyond the task-oriented approach of traditional HCI and focuses on the user and the subjective side of product use (Hassenzahl & Tractinsky, 2006). User experience provides a holistic perspective on users' interaction with the product, which concerns not only usability and task completion but also emotional reactions. Depending on different users' attitudes, skills, personality, and context of use, the user experiences vary between users and situations and can change over time (Hassenzahl, 2003). Within the domain and aims of this thesis, the website user experience is focused on and can be defined as the experience created by a user's interactions with a website.

In the early days of the website, the key to success was being the first to realize ideas and launch on the market (Garrett, 2011). Therefore, companies compete to build websites and neglect user experience in the development process. To gain market share and compete against the first-movers, companies stress features of the web and add more and more functions and content to attract new customers. However, this strategy brings short-term competitive advantages but results in a worse user experience when the website becomes increasingly clumsy and difficult to use. Once the users have a bad experience, the possibility of repeat visits to the websites will decrease. Nowadays, more and more companies realize that providing a great user experience is an important and sustainable competitive advantage (Garrett, 2011; Väättäjä, et al., 2012). Positive user experience helps companies to stand out from competitors, attract and establish a trust relationship with consumers. Apart from customer loyalty, a positive user experience can improve the conversion rate by converting more browsers to buyers and finally results in an increase in revenue (Garrett, 2011).

To raise the awareness of UX and embed it in companies, Rohn (2007) suggests several strategies and tactics that have proven successful to apply. The first is to understand the business, culture, and stakeholders within the company so that the UX team can support the business goals in addition to user goals. The second is to integrate UX activities both in the formal and informal processes of the company to utilize UX. The third is to build close relationships with both internal and external customers to increase the influence of UX within the company. Finally, the organizational models should maximize the effectiveness of the UX team, e.g., position the UX team to report to a high enough level within the organization, centralize the UX team in the model of organizing the work, and choose the funding model of the UX work.

3.3.1. Levels to success in website UX

Due to the broad and subjective nature of the UX (user experience) concept, it can be quite challenging for researchers and companies to find ways to benchmark the prosperity of UX. Ralph (2017) introduces the UX pyramid based on Maslow's hierarchy of needs, which proposes a good framework to classify and track the UX development and effort. As shown in Figure 3.5, the UX Pyramid consists of six levels with the most fundamental UX elements at the bottom and more advanced ones at the top. The three levels at the bottom are more measurable and concentrate on the user's capability to accomplish a certain task or goal when the upper three ones are more abstract and focus on the user's subjective feelings during the experience with a product or service. Take the e-commerce website as an example, all the six levels and their specific characteristics will be described below:

1. **Functional:** The foundation level focuses on the functional ability of the website. It is constituted by several factors such as: does the website provide essential functions to support certain online buying behaviour? Does the function work in the desired manner, and are there programming faults or errors occurring.
2. **Reliable:** The second level concentrates on the availability and accuracy of the website; Does the website provide current and accurate information of the product and market for consumers, is the product information reliable and are customers questions answered in time to eliminate confusions.
3. **Usable:** This level stresses the usability of the website; can consumers use the website without difficulties, do they easily find the desired content without distraction or confusion, and is the website designed based on basic UX heuristics or guidelines.
4. **Convenient:** At this stage, the emphasis is the easiness of use. Compared with the previous level, convenience is more related to finding the most natural way for users to accomplish their tasks. It means that the website should align with users' mental model and work exactly how the users want it to. If this level is achieved, the users will actively seek situations and reasons to use the website more frequently.
5. **Pleasurable:** This level aims to provide an enjoyable experience for consumers. Consumers invest time in the website experience and incorporate the website into their daily routines and interactions. Moreover, they promote and share the experience with their social network.
6. **Meaningful:** At the highest level, the consumers form a personal relationship with the website which creates personal and social significance.

In the UX Pyramid, there is a space called “The convenient chasm” between the bottom three and the upper three levels, where a few websites can rise above this point. Many budget-focused companies only see the value of the first three levels when these levels enable users to perform tasks without any difficulties. However, companies will miss many precious benefits of the upper levels if they stop here, such as improved customer loyalty and customer spending (Ralph, 2017; Korkishko, 2018). Considering the development costs and time limitation, the effort on user experience design will aim to achieve the convenient level by fulfilling the requirements of usability and provide a natural way for users to easily find desired LEDs to accomplish purchases on the Lumway website.

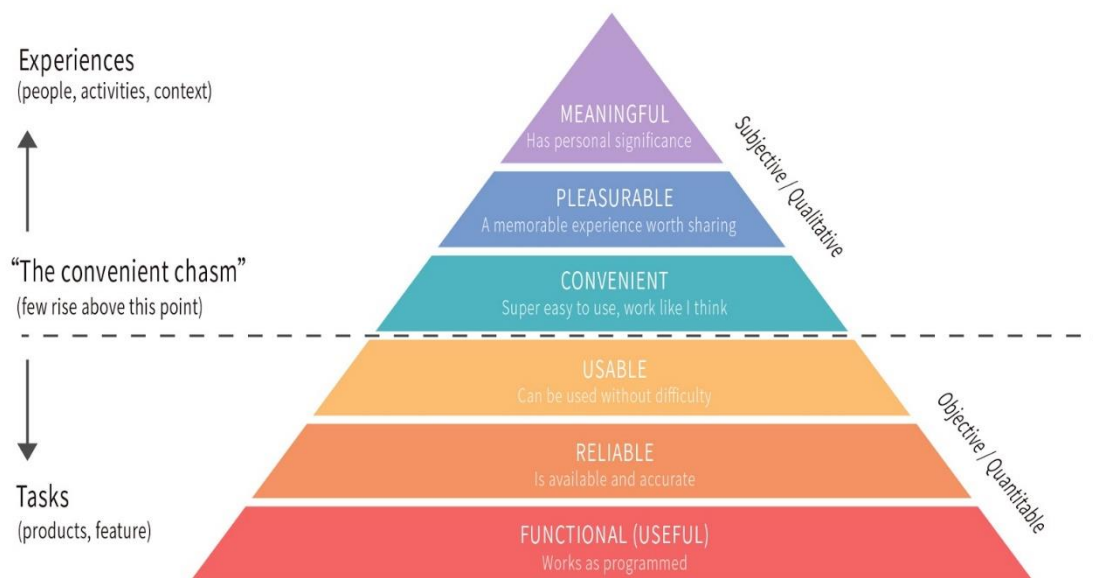


Figure 3.4 The UX Pyramid (Ralph, 2017)

3.3.1.1. Website usability

Usability is the most fundamental quality attribute that evaluates how easy to interact with a product (Vu & Proctor, 2011). Because website usability is part of the general domain of computer software usability, many issues relevant to software usability are applicable to website usability. Therefore, website usability is typically defined by the following five quality components (Lazar, 2006; Nielsen, 2012):

1. **Learnability:** How easily can novice users learn to perform basic tasks through the website?
2. **Efficiency:** How quickly can users accomplish tasks once they have learned how to use the website?
3. **Memorability:** How easily can users reestablish proficiency to use the website when they haven't used it for a period of time?
4. **Errors:** How many errors do users make, how serious are these errors, and how easily can users make appropriate corrections?
5. **Satisfaction:** How pleasant is it to use the website?

There are two major reasons why it is important to incorporate usability into the design life cycle for e-commerce websites. First, usability determines whether users will use a website and establish long-term customer loyalty (Vu & Proctor, 2011; Najjar, 2005). Regarding B2B e-commerce the website plays a significant role in the process of online

transaction, which supports a series of buying behaviours by aiding, guiding, and convincing consumers to successfully complete a purchase. During the buying process described in Section 3.2.1, users assess the website usability and decide whether to continue using the website's services or to abandon it. Given that many competing websites provide similar products or services, users do not hesitate to use an alternative website that delivers better usability. Second, usability influences the return on investment (ROI) which is rather important for e-commerce business. Conversion rate is one common way to measure ROI and the effectiveness of a user experience, which refers to the percentage of users that take the desired action (Garrett, 2011). Nielsen (2003) reported that spending about 10% of the development budget on usability could improve ease-of-use by 135%, increase conversion rates by 100% and increase user productivity by 161% on average. For example, after improving usability, IBM.com increased sales by 400% (Battey, 1999), and Liz Claiborne's Elisabeth.com tripled the rate at which visitors became buyers (Tedeschi, 2002).

To ensure good usability on the website, it requires the design team to apply a user-centred design process and carry out evaluations early and throughout the whole process. By identifying and then fixing usability problems, the website UX can be improved iteratively. When evaluating website usability, there are three things that should be taken into consideration: the purpose, target audience and core user tasks of the website (Vu & Proctor, 2011). The purpose of the website reflects the goals of relevant stakeholders, e.g., the company and the users. An explicit purpose statement can be transformed into specific and measurable values in the implementation of the evaluation. The target audience describes what types of users will actually use the website and participate in the evaluation. Personas are one way to summarize the characteristics of real users and help designers tailor the website to specific user groups (see Section 4.3.2). Based on the defined purpose and target audience, the core user tasks can be constructed and then used to test participants during the evaluation, which are typical and high-frequency tasks performed by the target audience.

The methods for testing and evaluating the usability of the website can be divided into two categories according to the types of evaluators: inspection-based evaluations and user-based evaluations. Inspection-based evaluations are analytical evaluation methods where experts often role-play typical users, analyze aspects of interfaces and identify potential usability problems by using a set of guidelines, e.g., heuristic evaluation and cognitive walkthrough (Preece, et al., 2015). These inspection methods are low-cost to apply at any stage of a design project and can be used to complement user testing. User-based evaluations are approaches to involve intended end-users in the evaluation and find usability problems based on user's actions and feedback, e.g., usability testing and field studies. When involving real users to test usability, the design solution should be detailed enough to give them something concrete to respond to (Cooper, et al., 2014). In this thesis,

heuristic evaluation (see Section 4.4.2) and usability testing (see Section 4.5.1) were applied to evaluate the usability of the designed website.

3.3.2. Build website UX according to the five-plane model

To create a convenient UX described in Section 3.3.1, it is particularly crucial to find appropriate approaches to break down the job of crafting the UX and design the UX in a clear and understandable manner. Garrett (2011) suggests the Five Planes build the website UX from bottom to top. As shown in Figure 3.4, each plane is dependent on the planes below it and the issues that need to be dealt with have become more concrete with the rise of the plane. Below are descriptions of what component elements are contained in each plane and how all pieces fit together to design the whole user experience.

1. The strategy plane

The foundation of a successful user experience is an explicit strategy that incorporates both product objectives and user needs (Garrett, 2011). The product objectives describe what the organization wants to get out from the website, involving the business goals, brand identity and success metrics. On the other hand, the user needs to answer who the target users are and what they desire by using the website. To identify user needs, user research can be conducted by various methods and tools. Some research methods and tools are devoted to collecting information about the general attitudes and perception of users, such as interviews, questionnaires and focus groups (Preece, et al., 2015). And others are more suited for understanding specific user behaviours and interactions with the website, e.g., user tests and field studies. As the beginning of the UX design process, the strategy plane sets the goals to achieve and influences every decision made in the later design stages.

2. The scope plane

The scope plane defines specific requirements for what content and functionality the website will offer to fulfil product objectives and user needs, which can be divided into three general categories (Garrett, 2011). First are the features that people directly say they want and provide clear good ideas for the final website. However, people sometimes only address the symptom and what they express is not their actual requirements. It needs to analyze the underlying cause of the problem and come up with completely distinct requirements that solve the real problem. The last type of requirement is the feature people don't know they want. These often come out from the brainstorming session when participants explore inventive solutions to problems. After collecting ideas for possible requirements, it is vital to take into account the feasibility to implement, e.g., technical feasibility and time limitation. By prioritizing the requirements according to different

considerations, we can sort out what features of the website are more important and will be included in the design scope.

3. The structure plane

On the structure plane, how the website will work is defined by creating the conceptual structure for the website from the perspective of interaction design and information architecture (Garrett, 2011). In terms of the functionality side, it focuses on the interaction design of the conceptual model which considers possible user behaviours to perform certain tasks and corresponding website responses. The designed interactions with the website should match users' implicit expectations. Then in content development, it concentrates on the information architecture which deals with classifying data elements and creating navigational schemes. A well-organized information architecture enables users to efficiently move through the website content (Cooper, et al., 2014). Both the interaction design and information architecture deals with the patterns and sequences in which options will be presented to users.

4. The skeleton plane

The skeleton plane defines what form that the website will take by refining the conceptual structure to detail from three aspects: interface, navigation and information design (Garrett, 2011). On the functionality side, the skeleton is defined through interface design which deals with selecting and arranging interface components to enable interactions, e.g., buttons, fields and other interface components. Then on the information side, it focuses on the navigation design which concerns the arrangement of navigation options to enable movement through pages. Finally, crossing both sides, the consideration of information design arises, which decides the placement and prioritization of informational elements. To integrate all three aspects of the skeleton plane, wireframes of the website can be developed to describe how different page components fit together to fulfil requirements (Garrett, 2011).

5. The surface plane

At the top of the five-plane model, attention is turned to the sensory design which deals with how the design will manifest to people's senses (Garrett, 2011). In terms of the five senses, vision is the most salient to the users when they interact with the website. Therefore, the visual design of the website is stressed on the surface plane, which improves the website's aesthetic appeal with suitable visual elements, e.g., colour palette, typography and images (Tidwell, 2010). By manipulating the visual elements of the website interfaces, it is possible to induce target emotions and further fluence intended buying behaviours, e.g., trustworthiness (Kim & Moon, 2000). In addition, aesthetics can contribute significantly to usability by influencing emotions. The websites are perceived as more usable when people enjoy them (Tidwell, 2010). The reasons are that positive emotions improve creative, breadth-first thinking and enable people to better tolerate

minor difficulties and become more flexible and creative in finding solutions (Norman, 2002).

In this thesis, the five-plane model of UX will be applied in the design process of the Lumway website. On the one hand, it helps us to gain insights of how to build the desired website UX from abstract to concrete by dividing the UX elements into neat boxes and planes. And on the other hand, it provides a clear framework to consider user experience problems and find tools to solve them. By using the five-plane model to design the website and analyze user feedback from evaluations, we can research what design factors can influence the UX elements in each plane and further impact the whole UX.

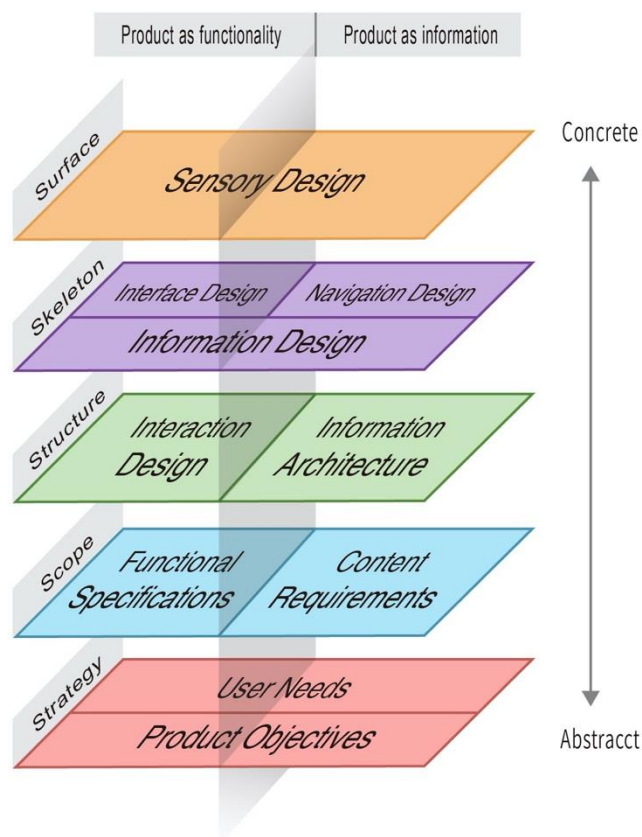


Figure 3.5 The five-plane model of UX (Garrett, 2011)

3.3.3. Evaluate website UX as a whole

The UX describes the users' subjective perceptions, responses and emotional reactions that occur from the use (Law, et al., 2009). Positive user experience is positively associated with customer satisfaction, which in turn increases the probability of repeat

purchase (Porat & Tractinsky, 2008). Therefore, e-commerce websites should aim to provide a positive experience to enhance purchase probability by fulfilling psychological needs. To achieve this objective, it is necessary to assess the UX in the early phase of the user-centred design process and to monitor it throughout the whole development process.

Besides the traditional methods to evaluate usability as mentioned in Section 3.3.1.1, it requires measuring the UX as comprehensively as possible since the UX is a complex construct that concerns beyond usability. In order to assess the UX as a whole, the researchers mainly utilize the self-reported measures that depend on introspection, the users' ability to access their own mental states and verbalize recently gained experiences with a product (Pollmann, et al., 2018). For example, measuring the users' attitudes through the tools like Thurstone scales, Likert scales, and semantic differentials. A common method to measure UX based on the self-reported measures and gather qualitative data is using questionnaires, e.g., the AttrakDiff (see Section 4.5.2), the User Experience Questionnaire (UEQ), and the MeCUE questionnaire. To achieve a standardized and lean UX measurement, the questionnaires should fulfil five basic requirements (Minge & Thüring, 2018). First, all aspects that are characteristic for experiencing a product should be included in the questionnaire, for instance, perceived particular product qualities, emotional reactions, behavioural sequences, and overall opinions about the product. Second, under the premise of not neglecting relevant UX aspects, the questionnaire should comprise as few items as possible to ensure assessment efficiency. Third, the items of the questionnaire should be short, explicit and easy to understand. Fourth, the questionnaire should fulfil the central psychometric quality criteria. At last, it should be possible to adapt the content of the questionnaire to different research contexts and types of applications.

4. Methodology

To better describe the design process with the method used in the project, this chapter will mainly mention how the method should be used theoretically. How those methods are implemented in the project will be presented in the project process sections (see Chapter 5). Considering the process continuity, how those methods related in the next chapter sections as shown in the following table:

Phase	Methodology	Process chapter
Discover phase	4.2.1 Literature review	5.1 Domain research
	4.2.2 Competitive analysis	5.1 Domain research
	4.2.3 Interviews	5.2.1-5.2.3 User research
Discover phase	4.3.1 Affinity diagramming	5.2.2 Analyzing the interview results 5.4.3 Conducting heuristic evaluations to find usability problems 5.5.1 Evaluate the website with target users
	4.3.2 Personas	5.2.4 Persona for modelling the target users
	4.3.3 Context scenarios	5.2.5 Context scenarios for describing ideal user experience
Develop phase	4.4.1 Prototyping	5.3 Brainstorming and elaborating the ideas by sketching 5.4 Website prototyping
	4.4.2 Heuristic evaluation	5.4.3 Conducting heuristic evaluations to find usability problems
Deliver phase	4.5.1 Usability testing	5.5.1 Evaluate the website with target users

	4.5.2 User experience questionnaire	5.5.2 Evaluate the website UX by using UX questionnaires
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Table 4.3: Methods in the process

4.1. The design process

The design process was divided into four main phases based on the *double diamond model*, namely, Discover, Define, Develop and Deliver (Design Council, 2015). The diamond shape represents the creative process of divergent and convergent thinking. In this case, the model contains two diamond shapes, where the first diamond helps to define the UX strategy plane and the scope plane and the second two phases aim to create insights that help with the higher UX plane including the structure plane, the skeleton plane and the surface plane.

4.2. Discover phase

In this section, the intended methods to use for collecting insights will be presented. This involves the method to research the context of the project in order to get a better understanding of the field, followed by the user research method to gather firsthand data about user needs and the method to identify potential competitive advantages.

4.2.1. Literature review

The literature review can distil information from published sources, capturing the essence of previous research or projects as they might inform the current project (Hanington & Martin, 2012). The Internet can be used as a tool for finding literature since it allows for accessing online libraries around the world. However, one critical factor that Martin and Hanington (2012) point out is that the sources must be selected with caution, both in terms of irrelevance and credibility. Within this context, Martin and Hanington (2012) also mention a method called secondary research or desk research, where it not only emphasizes literature review but also previous related work. Researching and reviewing related work can provide a better understanding of what has already been done, which can help define the scope of the project better and thus make it unique. The related work can additionally provide inspiration to your own design, such as visual guidelines on how to approach different design problems. In this study, the literature review was done to

understand the context of designing B2B websites. It focused on the three main topics: B2B e-commerce, organization purchase behaviour and e-commerce web UX.

4.2.2. Competitive analysis

To identify potential opportunities to establish a competitive advantage and guarantee success, it is vital for organizations to perform the competitive analysis where competitive information is gathered and analyzed, e.g., key business financials, company size, product, and service mix on an ongoing basis (Hanington & Martin, 2012). In this thesis, the competitive analysis will concentrate on assessing the competitors' products from the end user's perspective. Specifically, usability tests will be conducted to evaluate the usability and learnability of several competitive products. Besides identifying similar features to test between competitive products, it is equally important to isolate and test the features of competitive products that are different from yours. The result of the competitive analysis will provide insights into future market differentiation or specification for organizations.

4.2.3. Interviews

Interview is a fundamental method to gather qualitative data of users' experiences, perceptions, attitudes and opinions (Hanington & Martin, 2012). There are three main types of interviews according to how much control is imposed on the conversation: unstructured, semi-structured, and structured interviews. In this project, semi-structured interviews were conducted to gain user insights in the Discover phase. Stakeholders who had experience in the lighting manufacturing industry were invited to participate, e.g., lighting engineers and purchasers. During the interview, prepared open questions were asked to probe the interviewee to say more about the topics. Qualitative data from the interviews were recorded and analyzed by affinity diagramming.

4.3. Define phase

This section will present the intended methods to use for translating design requirements based on gathered insights from the Discover phase. This involves the method to analyze the gathered user data, as well as the methods to model typical user types and use scenarios.

4.3.1. Affinity diagramming

Affinity diagram is a qualitative analysis technique, which is used to organize large amounts of data into groups and result in research-based themes (Preece, et al., 2015). The design team records observations and insights from research on individual sticky notes and then clusters them based on affinity. The work of grouping is done from the bottom up instead of predefining groups at the start. The specific and small details are first clustered into groups, which then give the inspiration to form more general and overarching themes (Hanington & Martin, 2012).

4.3.2. Personas

Persona is a way of synthesising all previously gathered research data about real users into model users, which make it convenient and precise to communicate users' needs, motivations and behaviours when making decisions in the design process (Cooper, et al., 2014). The personas are typically written in a narrative way that abstract various attributes and relationships collected from the user research. The use of persona helps to identify and prioritize different types of users that will influence the design's eventual form and behaviour in different ways. To manage the design focus and avoid targeting extreme outliers, Martin and Hanington (2012) suggest creating a reasonable number of personas, which is between three and five.

4.3.3. Context scenarios

A context scenario is a written narrative that describes the broad context in which the persona will use the design in the future (Cooper, et al., 2014). The description of the context scenarios should focus on high-level actions from the perspective of personas rather than the details of the product or interaction. It represents a typical way of how users use the future product with their motivations and goals. Generally, the context scenarios are created before performing any design sketching and establish the primary touchpoints that each persona has with the system over a meaningful length of time. By creating the context scenarios, the design team has the most leverage to imagine an ideal user experience and focus on how the product can best serve the personas to achieve their goals.

4.4. Develop phase

This section will present the intended methods to apply for designing and evaluating the website, which in turn will provide potential improvements for the website design. This includes the method to create prototypes of different fidelities and the method to inspect usability problems of the web prototype from the experts' perspective.

4.4.1. Prototyping

Prototyping is the tangible creation of the design concept produced from ideation, which is used to test the concept with the design team and the stakeholders (Hanington & Martin, 2012). It helps the design team to gather user feedback to validate and improve the design solution. As a result of prototyping, prototypes can take many different forms depending on their level of fidelity, from low-fidelity prototypes and high-fidelity prototypes.

Low-fidelity prototypes are simple, cheap and rapid to produce with various materials. They are good for the early design phase that requires the design team to rapidly explore alternative designs and ideas. Common methods for creating low-fidelity prototypes are sketches and paper prototypes. High-fidelity prototypes on the other hand are much more refined and represent the final product in functionality and appearance (Hanington & Martin, 2012). They are suitable to produce in later stages of the design process, where evaluation is carried out to gather feedback from stakeholders on different aspects of the prototypes, e.g., usability, aesthetics, form and interaction. In terms of websites, one way of producing high-fidelity prototypes is to use the software which allows for creating interactive prototypes that look like the final products.

4.4.2. Heuristic evaluation

Heuristic evaluation is a usability inspection method where experts are guided by a set of heuristics to evaluate the design (Nielsen & Mohlich, 1990). Nielsen (1995) proposed ten usability heuristics for HCI evaluation. Aspects of the interface will be judged against these heuristics to see if they fulfil the principles. Given that the general heuristics might be inappropriate to evaluate a specific class of product in this project, we developed 26 sub heuristics as a supplement to the general heuristics. These sub heuristics incorporated other design guidelines collected from the literature review and the design brief. The heuristic checklist can be found in Appendix 8. This method was applied to identify possible usability problems from the expert's perspective when the high-fidelity

prototype had been designed.

4.5. Deliver phase

In this section, the intended methods to evaluate the design outcome will be presented. This involves the method to evaluate the web prototype with users and the method to evaluate the UX as a whole. Target end-users will be highly involved in these methods.

4.5.1. Usability testing

Usability testing is a way to validate the design with representative users, in which data about users' performance on predefined tasks are collected and analyzed (Cooper, et al., 2014; Preece, et al., 2015). During the evaluation session, participants are encouraged to think aloud while carrying out tasks, to reveal what they are thinking and planning. The number of errors and task completion is two common performance measures (Preece, et al., 2015). These quantitative data are recorded as well as qualitative data like feelings and suggestions for improvements. In terms of the number of participants for the usability testing, five to twelve participants will provide the best result of the evaluation (Preece, et al., 2015). This method was applied to identify usability problems based on users' actions and feedback when the high-fidelity prototype was improved after the heuristic evaluation.

4.5.2. User experience questionnaire

As discussed in Section 3.3.3, the self-reported measures are suitable to assess UX as a whole. In this thesis, the AttrakDiff was used to evaluate the website UX, which is a questionnaire containing 28 bipolar adjective pairs that measure UX from four dimensions: pragmatic quality, hedonic quality-identity, hedonic quality-stimulation, and attractiveness (Hassenzahl, et al., 2008). Considering that parts of the questionnaire are not adequate for the e-commerce website and the defined UX goals (see section 5.4.3), only ten adjective pairs that match the intended UX value remained and formulated the new UX questionnaire. For instance, the words "predictable" and "undemanding" were chosen to assess the value of simplicity. Each adjective pair is presented on a scale of -3-3 and rated by users. The UX questionnaire was applied in and after the usability testing to evaluate the overall UX and verify whether or not the defined UX goals were achieved.

5. Process

In this chapter, the process of the research execution will be presented in chronological order. The process includes both design and analysis of the findings from the design evaluations. Each section will describe in detail how different methods from Chapter 4 have been used to achieve the result that the research questions asked for.

5.1. Domain research

To better understand the area of research, relevant academic literature was reviewed. In terms of the academic papers that we selected to study, they were mainly within the area of organizational buying behaviour, E-commerce website and methodology in user experience design. In order to find relevant papers to read, Google Scholar (Google, n.d.) was used to search the previously mentioned terms.

After gaining a throughout understanding of background and theory in the field of research, the execution plan and research direction for this thesis project were created. In this plan, all important phases of the project process described in Section 1.6 were carefully considered, where the goal was to answer the research questions of this thesis with reflection and dissemination based on the analysis in the end.

Except for the literature review in this phase, the competitive analysis among several websites was conducted as well, which aimed to assess whether the initial idea would be feasible as well as enhance the strength of this website. By analysing those competitive websites' relative strengths and weaknesses, the team could see how they solve the same design problem and find what should be designed to support the buying behaviour in their website. The competitive analysis was done by conducting competitive usability evaluations with the team members. The results described in Section 2.2.3 helped discover potential chances for this project.

5.2. User research

After conducting the domain research to understand the project context, there was a need for research on the actual users. The user research was carried out at the beginning of the design process to gain insights from target users, the current buying process of LEDs and the users' attitudes towards the website vision. The findings from the user research provided a basis for modelling typical user types and use scenarios to extract user needs on the strategy plane, as well as defining specific design requirements of the website on

the scope plane.

5.2.1. Interviewing target users

The user research was done by conducting semi-structured interviews. In total, sixteen interviews were performed with thirteen different lighting manufacturing practitioners: two chief executive officers, three production managers working on purchasing, and eight lighting engineers. All of them had the experience as a buying centre in their previous buying process. An interview script was developed to guide the interviews, involving various topics of the participants, project cycles, difficulties and expectations, product selection and purchase, and their opinions on Lumway's ideas of the website. The questions in the interview script were adjusted a little when different roles of users were interviewed. All the questions can be found in Appendix 1.

5.2.2. Analyzing the interview results

To analyse the data collected from the interviews, the affinity diagram was used to sort the data into different theme groups. These themes were then discussed and summarized to answer the interview questions. In addition, they could provide important concrete insights of users in defining personas and context scenarios, as well as ideating design requirements. The full result of the affinity diagram can be found in Appendix 2.

5.2.3. Result of the user research

The result of the affinity diagramming will be presented below as summaries based on the full result. Furthermore, since the research of this thesis focused on the aspect of LED online buying behaviour, the focus point of the following results will be on the buying process online, even though the full result covers other parts of organizational buying behaviour.

5.2.3.1. The buying process of online LED purchasing

Interviewees worked in companies that provide customized lighting solutions for various areas, such as the automotive industry, highways, public environments and retail. The lighting solutions were usually delivered in the form of LED modules, luminaires, and

complete products. Roughly, the lighting project procedure can be divided into 8 distinct steps: recognition of the luminaires needs, general need description, LED parameters specification, supplier search, proposal solicitation with an offline lighting performance test, supplier selection, order-routine specification, and performance review. This step was similar to what Kotler et al. (2017) described as a general organizational purchasing process with LED industry background.

At the beginning of the lighting project, the lighting engineer needs to start with recognition of the luminaire's needs and make a general need description for luminaires and consider how the lighting product will be used, according to the requirements of customers. Ideas are drawn on the paper and evaluated by customers. Thereafter, LED parameters need to be specified, lots of product parameters are determined, for example, technical performance, mechanical performance, lens system, spreading angles, colour rendering qualities and so on. When parameters of the LEDs are specified, the lighting engineer starts to search for suitable LEDs from the reliable supplier on the market.

Generally, there are two ways to search for existing LEDs. If the company has collaborated with specific suppliers, the lighting engineer would visit their official websites or directly contact them to obtain information about LEDs. Most interviewees trust the big suppliers, such as, Cree, LumiLED, OSRAM and Samsung, because they can provide accurate and comprehensive datasheets and ray-files which are necessary to do optical simulations. But switching between different suppliers' websites to find satisfied LEDs is inefficient and sometimes can't promise to offer the best choice. Thus, some interviewees like to search on distributors' websites to look for LEDs in a larger range of suppliers, for example, Future Electronics and Mouser Electronics. By setting different kinds of parameter filters and comparing search results, LEDs that meet the demands of design specifications are selected out and waiting for further test verification.

The lighting engineer can use tools on the suppliers' or distributors' websites to quickly test the optical performances of LEDs. These online tools are used in a similar way: set the inputs of the LED system which includes energy, LED, printed circuit boards, thermal interface material and heat sink, and then check the calculated results which are presented by charts. The results of different LED systems are compared to find out energy-efficient products. Luminous flux, power consumption, temperature and optical loss are the main factors to consider in the comparison. To get more detailed data of illumination under real-world operating conditions, the whole luminaire is prototyped and simulated in professional software, such as Ansys SPEOS, Lighttools and LucidShapes. Besides testing by themselves, some lighting engineers would select RISE or Secom as a third-party testing institute to test LEDs. Some interviewees mentioned that it could take quite a long time in the whole process of comparing and choosing LEDs. Once optimal products are decided after the tests, the sourcing department will buy them if the

availability and pricing match the needs.

In terms of purchasing LEDs, the procurement department will negotiate with them and confirm information about price, stock, lead time, minimum order quantity and product samples when suppliers are decided. After reaching the agreements, contracts will be signed, and orders will be created. Then products will be delivered and used in production. After the contracts are made, the changes of LED parameters will be notified by suppliers as part of the services included.

5.2.3.2. Factors for decision making

From the interview results, we found the factors that affect decision making are similar to the offline buying process. The buyer centre cares more about the quality of the LED and the trustworthiness of the supplier. Most interviewees prefer to choose big suppliers and establish long-term cooperation with them because they view that big companies are reliable and have the capacity to produce in large volumes. However, they would like to try excellent products that appear from other suppliers sometimes if they want to start a relationship with a new supplier. This usually takes a lot of time to investigate and assess the supplier to establish trustworthiness.

The factors related to the online platform that they care about are the service and information provided by suppliers through the online platform which belongs to the scope plane as well as the structure plane. Because updates and changes of parameters in LEDs occur often. Thus, it is vital for customers to get notifications of product changes. They think the internet has an advantage on this updated information service. The functions such as an interface showing compared with the same tolerances can help engineers save time and will be considered as auxiliary benefits in the service.

5.2.4. Persona for modelling the target users

According to the interview findings presented above, we concluded that there were more user needs remaining to be satisfied beyond the test function of the current simulation tool. There were many possible users' needs that could be met by this design. To promote the design as well as conclude the interview finding, it required clarifying typical user types and use scenarios of the website based on the data from the interviews. Although the purchasing decision was made by the buying centre instead of the individual person, it was still helpful to analyse the individual role inside the buying centre to help understand the structure and the needs.

To understand and visualize the salient aspects of the users' characteristics and their relationships with each other in the buying centre, three personas were developed to model and prioritize distinct user types of the website that form the buying centre: Thomas, Jessie and Morga. Those three personas form the basic buying centre to evaluate the LED as well as make decisions. They can be considered as the approvers, the influencers as primary users to use the website and the secondary user who had a different position than technical personnel according to the user research result. They are described below with representative attributes collected during the user research, involving job responsibilities, attitudes, behaviours, pain points, goals and motivations. More details of personas can be seen in Appendix 3.

1) The approvers - 'technical manager' needs statement

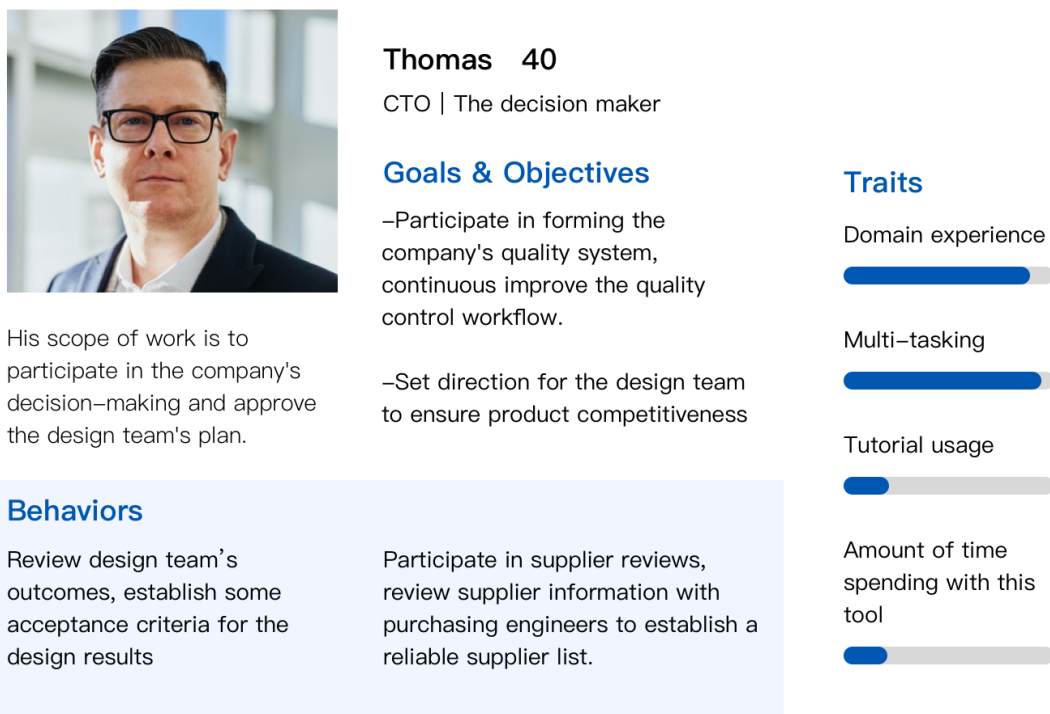


Figure 5.1: The persona: Thomas

Thomas, who is an expert in lighting solutions, needs to efficiently review ideas created by the engineering team in order to promote the project.

2) The influencer - primary user 'Lighting engineer' need statement

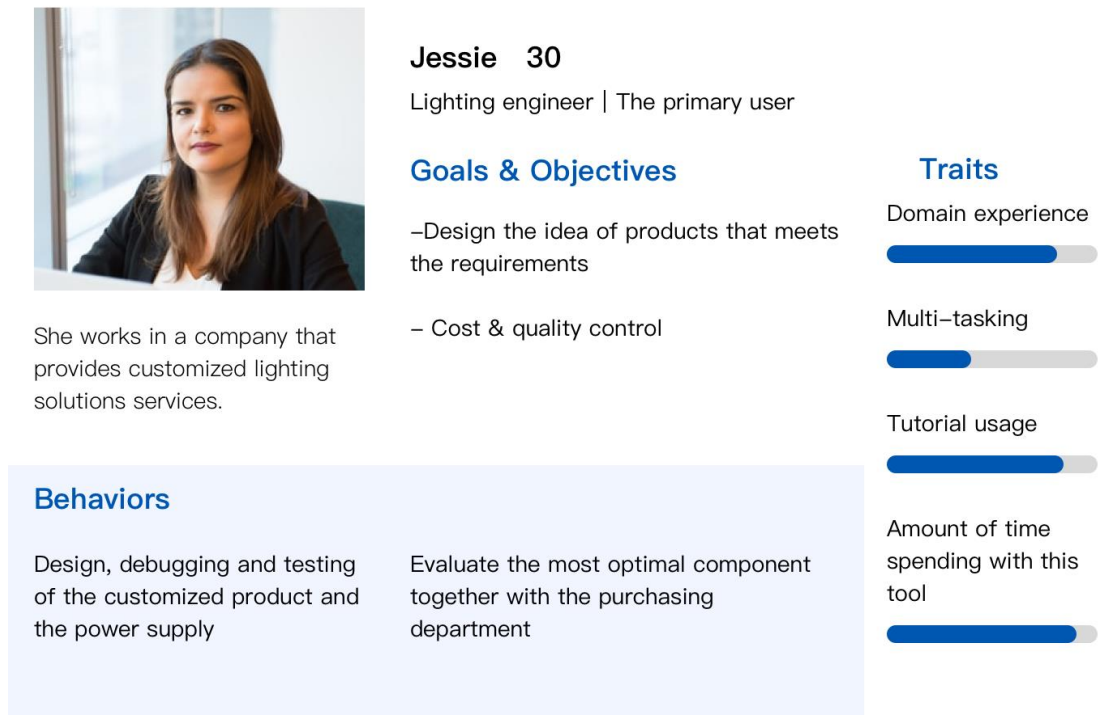


Figure 5.2: The persona: Jessie

Jessie, who is a creative lighting engineer, needs to explore as many ideas as possible for the lighting solution and then evaluate them in order to find the best solution to meet the customer's needs.

3) The influencer - the secondary user 'Purchasing engineer' need statement

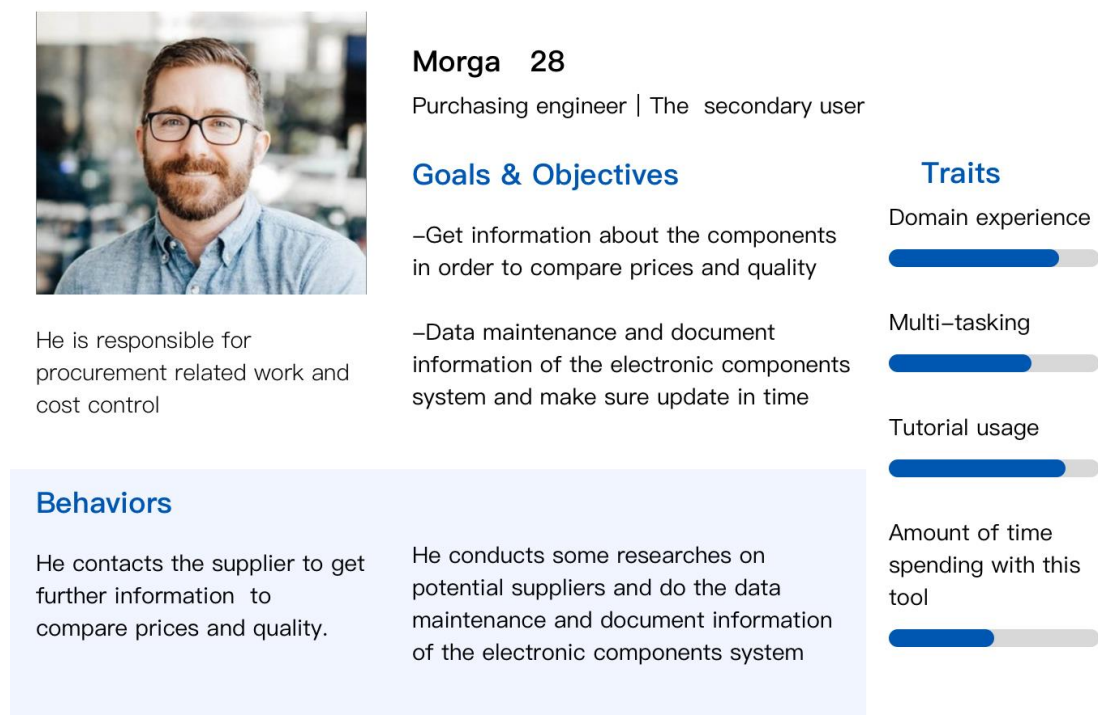


Figure 5.3The persona: Morga

Morga, who is a communicative and conscientious purchasing engineer, needs to keep in contact with collaborating suppliers in order to ensure the procurement process is fluent and safe.

5.2.5. Context scenarios for describing ideal user experience

Except for personas, context scenarios were also used at this phase which allowed a typical working situation to be presented for different personas. From the modelling on the typical scenarios, how the product will help personas to reach their goal in their work can be more concrete.

Thomas:

1. Thomas learned that Jessie was in the stage of selecting LEDs for the new project through her weekly report. Jessie sent him a brief report with screenshots showing the current work progress. Through the screenshots, Thomas had a general understanding of the direction Jessie was currently working on. Thomas contacted Jessie and proposed a meeting so that the purchasing engineer Morga can also participate to help with the selection to work as a business centre.

2. During the meeting, Jessie introduced 3 LEDs that had perspective parameters to Thomas and Morga:

LED A had been used in their previous product. The risk was that there was more optic loss with temperature increasing, which could barely meet the customization needs. LED B was found by Jessie online. It seemed to perform better than LED A in various environments and the price of it was reasonable. The only risk for this LED at this moment was that it was from a supplier that had not cooperated with before. LED C was also unused, but Jessie found it from a manufacturer that had worked before. The price of this LED was the most expensive of those three.

Thomas checked the simulation result from graphs that showed the optic loss under different temperatures and how other parameters changed according to the temperature. The interactive graphs helped him to quickly know the performances of each LED. Based on his experience, he suggested Jessie and Morga contact those suppliers to get a datasheet before they decided on it.

3. After further research made by Jessie and Morga, they choose LED B, which was affordable and met the technical requirements. Thomas received the final purchase decision from Morga and a more detailed simulation report from Jessie. Thomas asked Morga to evaluate whether this new supplier could be trusted in the future.
4. By using the website that we designed, Thomas could Intuitively view the simulation results and the engineer did not need to spend too much time on information visualization. This website could help them shorten the time of communication and improve the efficiency of communication. So, Thomas decided to let the team continue to use this website.

Jessie

1. Jessie designed a customized led solution that was planned to use in extreme temperature environments. This led Jessie to use some LEDs supporting the stable optic performance under the temperature change. This was Jessie 's first time designing such a product so she needed to find LEDs that could work under the special ambient temperature. She first checked the LED mentioned in related research or competitive products. At the same time, she also checked on the website of some manufacturers that they ordered LEDs before to see if they provided LEDs that could meet the requirements.

2. Through research and design, Jessie roughly identified 10 kinds of LEDs that might be able to be used in the product. At this time, seeing the different optic loss under dynamic temperature change was important for Jessi's decision. So, Jessie conducted a preliminary performance simulation and comparison through the website that we designed. She entered various environment parameters on the website and other related data to obtain the performance form graphs of these 10 LEDs. By visually comparing the charts, she eliminated 7 kinds of LEDs that could not meet the dynamic environment changing requirement.
3. Jessie sorted out those alternative LEDs' information and sent it to Thomas and Morga before the meeting. The intuitive data graphs provided by the website could help Jessie quickly make a visualization, which was convenient for communication and improved communication efficiency. At the meeting, Thomas suggested that Jessie and Morga contact the supplier to obtain further data for simulation before going to the final decision. At the same time, Morga needed to contact suppliers to compare pricing and risks as well.
4. Jessie performed more accurate simulations after gaining the detailed datasheet from suppliers through the website. After that, Jessie applied to the supplier for the test sample of LED B to perform the test in the real environment. In the end, Jessie and Morga reached a consensus on the selection of LED B, and shared their decision with Thomas to obtain the final agreement.

Morga

1. Morga learned that Jessie's current project needed to find a new LED, so Morga sent Jessie a list of suppliers and manufacturers that the company had worked with before. If Jessie could directly select LEDs from the manufacturers or suppliers that had already cooperated with, not only could they get discounts, but more importantly, it could reduce the risk of dealing with unknown suppliers.
2. In the project report meeting with Jessie and Thomas, Morga went through those graphs about 3 kinds of LEDs selected by Jessie. Thomas suggested Jessie further investigate these alternatives to make the decision. Morga planned to first contact those suppliers to obtain more detailed datasheets that can help Jessie's work.
3. After Morga contacted the supplier, he hoped that they could provide test samples and further detailed datasheets. Those suppliers asked Morga to provide some of their requirements with target parameters so that they can selectively provide part of LEDs 'parameters. Morga found the environment's parameters saved by Jessie directly from

the website. Morga knewed that these parameters were what Jessie also agreed that could be shared with suppliers. So Morga sent the data to the supplier and waited for their update on LEDs' datasheet.

4. At the same time, Morga also contacted suppliers who had not cooperated with them before. First, he checked the supplier's information through the official website and then obtained their contact information on the official website. Morga had conducted some investigations on the supplier and believed that the supplier was reliable. So, Morga contacted the supplier via email.
5. After further discussions with Jessie, Morga and Jessie reached an agreement on the selection of LEDs. They sorted out the selected LED, quotations, and some technical parameters and sent those files to Thomas for final confirmation.
6. After the transaction was completed, both Morga and Jessie would receive supplier update reminders on our website if there were any updates for the LEDs.

After clarifying the persona and context scenarios based on the interview data, we collected from user research, the overall need and expectation on the website can be summarized in the strategy plane:

To provide a convenient UX during the use, the design of the website should align with users' mental model and work exactly how the users want it. To be more specific, this website should support the buying centre team's buying behaviour, especially helping the influencer to efficiently find the LEDs and suppliers they need. To summarize the expectation of the buying centre team on the website, the overall impression after using this website can be perceived as simple, efficient and appealing at the convenient UX level.

Simple: The website should be simple to understand and use. It should align with the users' mental model so that they could predict how to use the website without any challenges.

Efficient: The users could perform their tasks efficiently when they use the website. It means that they could clearly navigate to the desired content as well as save the effort and time spent on the tasks.

Appealing: The website should attract the users to try the website and bring a pleasant experience during usage. It aims to motivate the long-term usage and transfer the users into loyal users.

5.2.6. Design requirements conclusion

After using personas and context scenarios for summarizing, we transferred the user needs into the design requirements that described what the website should provide on the scope plane. Those requirements can be separated into data and functional categories that can guide the later design work on the scope plane and the structure plane.

5.2.6.1. Data requirements

From the personas and context scenarios, we can conclude that this website will mainly help with LED parameters specification, supplier searching and proposal solicitation online phases among the whole LED purchasing process. To support those phases, the following data kinds should be provided to the user as below:

1. LED's detail datasheet
2. LED's available quantity and prices
3. Supplier/manufacturer information including location
4. The environment data for testing
5. Simulation test result
6. Supplier/manufacturer contact information
7. Privacy and other help documentation

5.2.6.2. Functional requirements

From the persona and context scenarios, we can conclude the following different functions that the system should provide to users in order to support their online buying behaviour:

1. Search LEDs:

This function can help users find the specific LED as well as view the available quantity and technical datasheet of the LED. At the same time, this function should also lead users to the test and simulation function. Users can start their whole testing and simulation workflow from this search function.

2. Detail datasheet

Detailed datasheet displaying pages of LEDs are directly connected to the search function. It shows the data related to a specific LED and some related functions such as download and price calculator.

3. Test and simulation LEDs:

When engineers need to further view the parameters change of the LED in a dynamic environment, they can choose online simulation and test tools as this function provided. The final outputs of this function are visual graphs that can be compared and help users make their purchase decision.

4. List to record LEDs

When engineers need to share their selected LEDs with other departments, there should be a function to record the findings on the website and simplify the communication process between various members. This list is not only a collection of product names but should also be a collection of project information that can be used in different phases of the development of the project. This function should also allow users to start other functions of the website on the interface.

5. Communication and proposal sharing

Taking into account the general process of LEDs' procurement, the information directly available on the website is only some basic information. If the users want to obtain a more detailed technical datasheet or negotiate with suppliers, they need a function to communicate online.

6. Price calculator

This function allows the users to view estimated prices on the website. This will help users make their purchase decisions. This function can be simple and only related to the order quantity. It can also require the users to enter more information to estimate a more accurate price.

7. Help system

This system should not only help the users to learn how to use the website and its functions, but also be the tool to support users back to their workflow when errors and problems stop users.

8. Terms and rules

This function allowed the user to check those related terms details information during their procurement.

5.3. Brainstorming and elaborating the ideas by sketching

The brainstorming session was carried out to explore the possible solutions for the design requirements on the structure plane. During this session, the needs we analysed from

personas and context scenarios were kept in mind and the design effort was focused on the structure plane where suitable interactions of the functions were explored. To quickly design and evaluate design solutions with the stakeholders, two ideas of the website were generated in the form of paper sketches. All the sketches for Idea A and Idea B can be seen in Appendix 4.

5.3.1. Paper sketches — Idea A

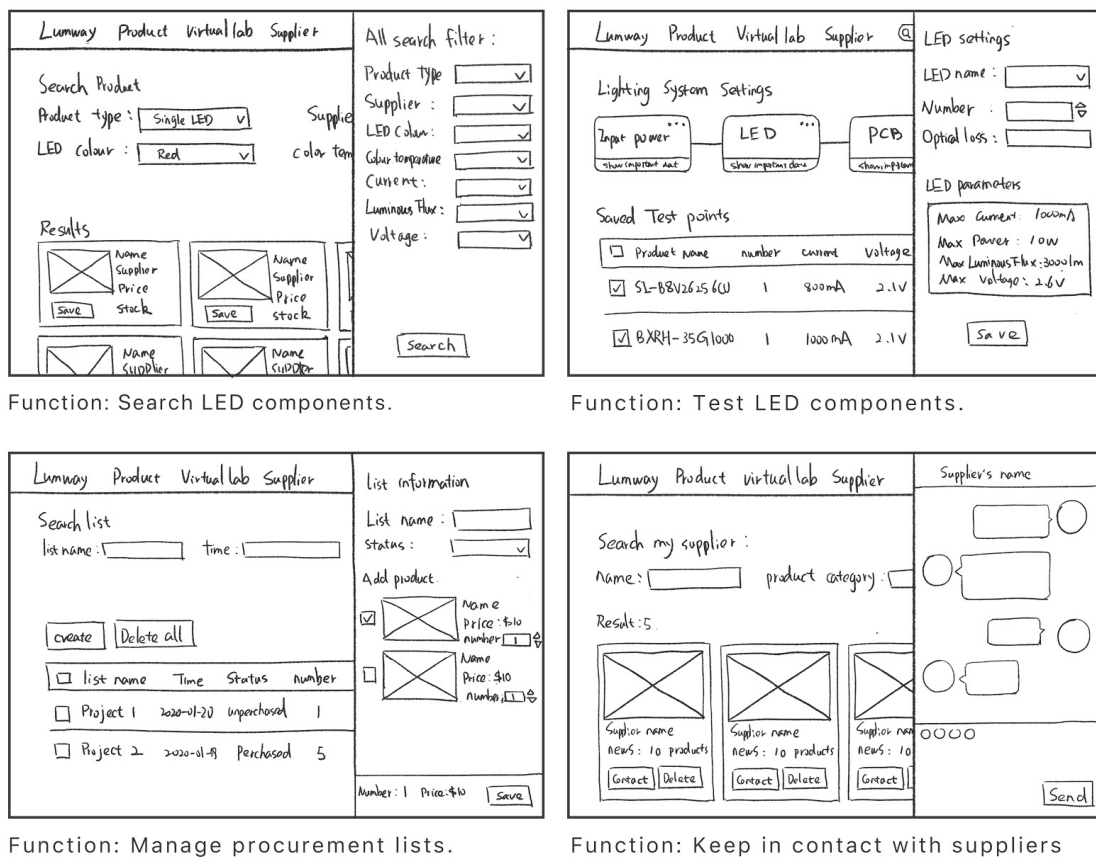


Figure 5.4 Sketches for Idea A

As shown in Figure 5.4, Idea A presents each function page through an interactive main page with a side drawer. Through the use of similar layouts and interactions to maintain the consistency of the whole site. The page first shows the users an interactive operation area, and the results of the operation that are placed below the operation area. When the users click the corresponding result item, the drawer on the right will display more information.

The idea puts various functional entrances on the top navigation bar to switch. There are the homepage, product page (search function), virtual lab (test and simulation function)

and supplier page. And like most other websites, this idea puts user-related functions in the drop-down menu of the top user avatar, which contains user information, the user's LEDs list and other setting functions.

For the search function, the aim of using this function is to help users find the LED they need. Since each optical LED contains a variety of parameters, e.g. supplier, luminous flux and colour temperature, etc. The search filters should have the ability to filter all those different kinds of parameters. However, displaying all those filters will make this search page confusing and reduce the efficiency of use. Therefore, Idea A refers to the similar design of the general customer-faced shopping website where the interface only displays necessary filters and hides those filters that are not frequently used. If the users want to use all filters, they can click the "More" button to use those remaining filters in the drawer. After clicking the search button to apply the filter, the results will be displayed below the operation area in the form of cards. The abstract information of the LED is displayed on the card, including product name, supplier, price and the parameter user used to filtrate. After clicking the item card, the website will jump to the product details page.

The virtual lab function intends to provide a clear and efficient process of creating, saving, viewing results and comparing the test points of LED systems. For idea A, there are four interactable modules in the upper area of the page, which allow the users to fill in the information of the led testing environment system that includes input power, PCB, TIM and heat sink. To fill in each part, the users click the module with abstract information, and it will activate the right drawer to fill in the information. After the users complete the setting of the environment system and click the save button, the LED that can be used to test will be listed below. By clicking the LED name in the table, the system will show the user the simulation results on a new page. If the users want to compare different LEDs' results, they could choose multiple items and click the "compare" button to access the comparison page of results.

The list function can be accessed both from the LED item detail page and the drop-down menu "my list" under the avatar on the top navigation bar. The main page for this function consists of filters for searching lists, control buttons for managing lists, and a table of saved lists. The users could click the "create" button and fill in the form in the pop-up drawer to create a new list. When the list is completed, it could be sent to the suppliers through the right message drawer.

The supplier homepage provides an overview of accessible suppliers, where the users can search for a specific supplier or click the supplier image to access the details page. On the details page, the users can learn about the supplier and provided products, as well as contact or follow the supplier. If the users have followed the supplier, its latest news can be found on the "my supplier" page which is accessed by clicking the drop-down menu

of my profile. There is a "contact" button on the supplier card and the details page, which enables the users to chat with the supplier in the pop-up message drawer.

5.3.2. Paper sketches—— Idea B

Search Products

① ————— ② ————— ③

Product Parameters Supply Information Check Results

Product type: LED Colour:

Colour temperature: Luminous Flux:

Show more filters ^

current: Voltage:

Power: CRI:

Function: Search LED components.

Test Products

① ————— ② ————— ③

Lighting system Settings Test result Comparison

Name	number	Current	Temperature	Power	lumination
<input type="checkbox"/> Product A	1	300mA	50 °C	10 W	100lm
<input type="checkbox"/> Product B	1	300mA	45 °C	8 W	80lm

Function: Test LED components.

Create a list

① ————— ② ————— ③

Basic information Add products confirm and send

List name: Project one status: unperched

Description: lamp design

Recipient: Anna Address: Hangzhou City Zhejiang Province

Product	Supplier	number	Price
Product A	Sanjiang Electric	1	\$ 10
Product B	Diligite	1	\$ 25

total number: 2 total price: \$35

Function: Manage procurement lists.

Keep in contact with suppliers

Function: Keep in contact with suppliers

Figure 5.5 Sketches for Idea B

Idea B shows another possible way to organize the interaction framework (see Figure 5.5). This set of design ideas follow the concept of guiding users to achieve their task goal step by step. It divides a long workflow into several steps which are displayed in sequence to guide users to accomplish the task gradually. For instance, on the function pages of search, test and create the list, there is a sequence map on the top of the interface. By clicking the number of a previously completed step in the map or the bottom “previous” button, the users can go back to that step and reset the controls.

The idea uses the left-side navigation bar to display various functional entrances vertically, e.g. product page (search function), virtual lab (test and simulation function), supplier page, list and contact. It enables the website to show more important navigation items in the vertical space in the future and users can scroll the content of the left-side navigation bar to select, which is not supported by the top navigation bar.

For the search function, the searching process is divided into three steps to achieve the searching goal: set parameters for a target product, set supply requirements and check the search result. Different from Idea A, advanced filters are put into a collapsible panel that can be opened and closed by the user. Because the filters and search results are displayed on separate pages, the users need to click the “previous” and “next” buttons or the sequence map to navigate between different pages. The search results are shown in the form of a table that shows the key information of the products.

The workflow of testing LEDs reverses the sequence of saving the test point and checking the result in Idea A. Firstly, the users set the inputs of the LED system, and then click the next button to jump to the test result page. If the users are satisfied with the test result and want to save this test point for further comparison, they could press the "import" button to go to the comparison step. On the comparison page, saved test points will be shown in the top table. When the users tick the checkboxes of the test points, the test result of selected test points will be displayed in the graphs below.

The list function page is similar to Idea A. By clicking the “create” button above the list table, the users enter the creating process and fill in the form step by step. Starting with writing the basic information of the list, the users then add and set the quantity of desired products. At last, the users need to confirm all the information on the list. If there is no problem with the list, the users can save the list or send it to the suppliers by clicking the corresponding button at the bottom.

On the supplier page, the content of website suppliers and “my suppliers” are put into two modules that can be brought to the top by clicking corresponding tabs. Compared with jumping to different pages in Idea A, the users can quickly switch between the modules to see the content of website suppliers and favourite suppliers in Idea B. Because concept B puts the entry point of contact on the left-side navigation bar, it is convenient for the users to access the chat interface when they want to communicate with the suppliers.

5.3.3. Idea evaluation with Lumway and users

After creating the two sketches that explored possible interactions, the evaluation on them was needed to see whether the sketches were suitable for going forward, and which idea should be further developed. To gather initial reactions to concepts and stimulate new experience opportunities, the evaluation session was carried out to collect feedback on stakeholders’ attitudes, expectations and suggestions. After the review of design ideas, the team also worked together to prioritize what to further develop in the next phase.

The evaluation discussion was held twice first with three Lumway team members face-to-face and then with three target users remotely. Each session lasted for one hour and a half. At the beginning of the session, the participants were introduced to four context scenarios and asked to imagine that they were under described working context. Thereafter, two sets of paper sketches created in brainstorming were demonstrated to the participants. They were encouraged to express their spontaneous reactions, feelings, and thoughts about different ideas. The session then ended with a discussion about which concept they preferred and why in each scenario. The key findings will be presented below.

Result and insights from idea evaluation

In general, the participants agreed that the website extended the simulation and teasing tool that made it more helpful in the actual workplace to support LED buying behaviour. However, there were still some parts that can be improved or modified. When it came to the global navigation manner, most participants preferred the top navigation bar in concept A because it was a superior approach in most cases and saves more screen space to show the main content. The basic layout of Idea A was preferred. It was agreed that setting the controls and checking the results should take place on the same screen rather than separate screens because the two actions were interconnected. Another reason was that the workflow of Idea B was too linear to compile several tasks efficiently because of the sequence map layout. By contrast, showing the results below the controls could provide users with a good overview of the whole operations and improve efficiency by reducing the jumps between different screens.

For the search function, the participants thought it made sense to hide infrequently used filters by default and preferred to use the collapsible panel to control the visibility. Most of the participants would like to check the results in the form of a table rather than cards because they could rapidly scan and compare the parameters of the products in the table. It was suggested that the table header was customizable so that users could focus on the product parameters that they were concerned about. And on the product details page, it was better to provide a test button for users to conveniently activate the test process.

The biggest challenge of the virtual lab was dealing with the workflows of a testing single LED and comparing multiple LEDs. In Idea B, the interfaces of creating, viewing test results, saving and comparing test points are shown in sequence. But in the actual usage scenario, the tasks are not always performed in this order. Some participants expressed that if they merely wanted to compare saved test points, they had to skip two steps to check the saved results. It was inefficient and inflexible to organize the workflow in such a strictly linear way. While in Idea A, relevant controls for managing test points were shown on the homepage of the virtual lab, e.g., creating, comparing and editing. This

framework provided a good overview of functions and allowed users to rapidly access desired functions. In terms of creating the test point, the participant would like to set inputs of the LED system on the same page rather than four different modules in Idea A. The participants mentioned that they would compare LEDs under the same system environment. In this case, the current ideas took users more time to repeatedly set the environment. It gave the inspiration to provide a save function for setting so that users could reuse the saved environment settings to quickly create the test point.

Neither of the ideas provided a satisfying experience of creating the list. The participants pointed out that it was cramped to fill in the form in the pop-up drawer, especially when the list contained lots of products. It was suggested to show the complete form of the list on a full screen rather than separated screens. Because the content of the list was not complicated, there was no need to divide the form into several steps like Idea B. It was considered to be good to fill in and inspect the list on the same screen.

None of the participants had any trouble with the workflows of keeping in contact with suppliers in two concepts. But they thought that Idea A represented a more common way of following and contacting the suppliers. Most commercial websites put personal collections in the drop-down menu of the profile. It is natural for the users to look for "my supplier" under the profile in the upper-right corner of the navigation bar. The participants wanted to have the entry point of "contact" on the global navigation bar like Idea B, which brought the benefit of fewer actions to access the chat function. Because the messages would not belong in most cases, there was no need to display the chat content on a full screen. It was comfortable to read the messages in the pop-up drawer which had a similar size to the mobile phone. To make it easier for the users to interact with the message drawer, it was suggested to provide similar functions and layout of those mobile chatting applications.

Based on the feedback from the evaluation session, the team reached an agreement on what should be further developed in the later digital prototype phases as well as what worked at this phase. To better clarify the design effort that the team made as well as the design direction for later phase, we explain the functions on the scope plane with more details.

Functions that should be provided for users to use in the scope plan can be roughly divided into 3 parts: searching, testing or simulation, contact. Except for those basic functions, the website should also provide the information and connected workflow for user to use the function. To be more specific, details of each function with the information and workflow as elements in structure plane were shown as below:

1. Search LEDs:

This function can not only help users find the specific LED and view the available quantity and technical datasheet of the LED. At the same time, this function should also lead users to the test and simulation function. Users can start their whole testing and simulation workflow from this search function.

The general workflow of the use case is presented in Figure 5.6 below.

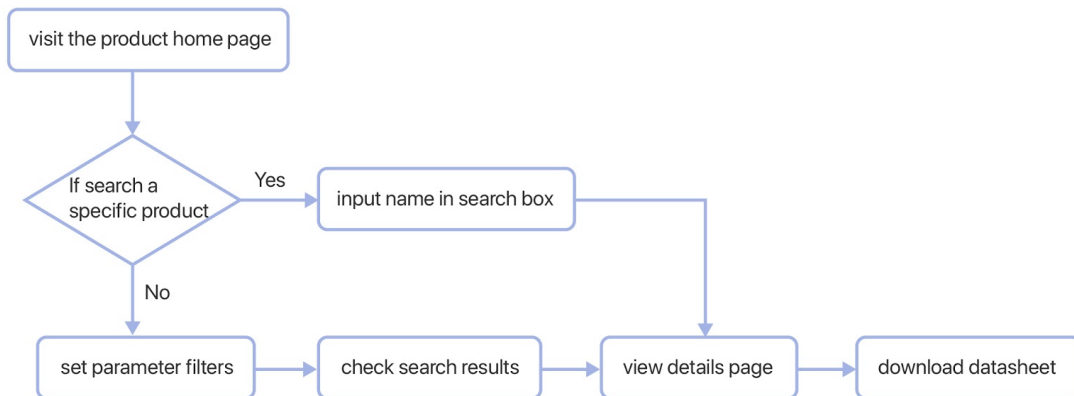


Figure 5.6 General workflow of the search function

2. Test and simulation LEDs:

When engineers need to further view the parameters change of the LED in a dynamic environment, they can choose to use online simulation and test tools. The final outputs of this function are visual charts that can be compared and help users make their purchase decision.

To perform the test, the user should set the inputs of the whole system and then check the analysis result. After creating the test point for each LED system, the user could compare the output results to find the best one. This function values the efficiency of testing as well as the simplicity of result visualization. The general workflow of this function is presented in Figure 5.7 below.

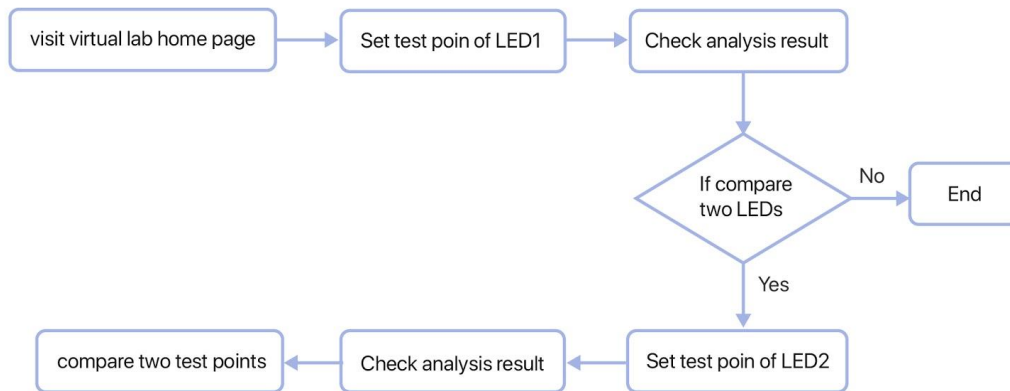


Figure 5.7 General workflow of test and simulation function

3. Manage list for recording

When engineers need to share their selected LEDs with other departments, there should be a function to record the finds on the website and simplify the communication process between various members. This list is not only a collection of product names but should also be a collection of project information that can be used in different phases of the development of the project. This function should also allow users to start other functions of the website inside the interface.

To create a complete list, the user has to fill in the form of different kinds of information related to the project. The list was not only used inside the team, but also the user can send it to the supplier and communicate via a chat function on the website. The general workflow of the function is presented in Figure 5.8 below.



Figure 5.8 General workflow of the list function

4. Online communication function

Taking into account the general process of LEDs' procurement, the information directly available on the website is only some basic information. If users want to obtain a more detailed technical datasheet or negotiate with suppliers, they need a function to communicate online. This will include both the online communication tools and updating functions that show the updated information for users in other function 's interfaces.

5. Price calculator

This function allows users to view estimated prices on the website. This will help users make their purchase decisions. This function can be simple and only related to the order quantity. It can also require the user to enter more information to estimate a more accurate

price.

6. Terms and rules

This function allowed the user to see those related terms details during their procurement.

5.4. Website prototyping

After reaching agreements on which idea to implement, the wireframes and the high-fidelity prototype that aimed to transform the design requirements and initial ideas were created. During the prototype making, the group mainly focused on developing the elements belonging to the structure plane, the skeleton plane and the surface plane. The heuristic evaluation was conducted to verify whether the concept worked well before we used the website to evaluate with end users.

5.4.1. Wireframe in Figma

As shown in Figure 5.9, a set of wireframes was created in Figma, which incorporated the positive aspects extracted from each idea in brainstorming as well as refined paper sketches to detail based on requirements on the scope plane. These Wireframes aimed to refine the website structure as well as identify specific aspects of the interface to enable interactions on the skeleton plane. The following will present the main features of the website with some key interfaces. For all the interfaces, see Appendix 5.

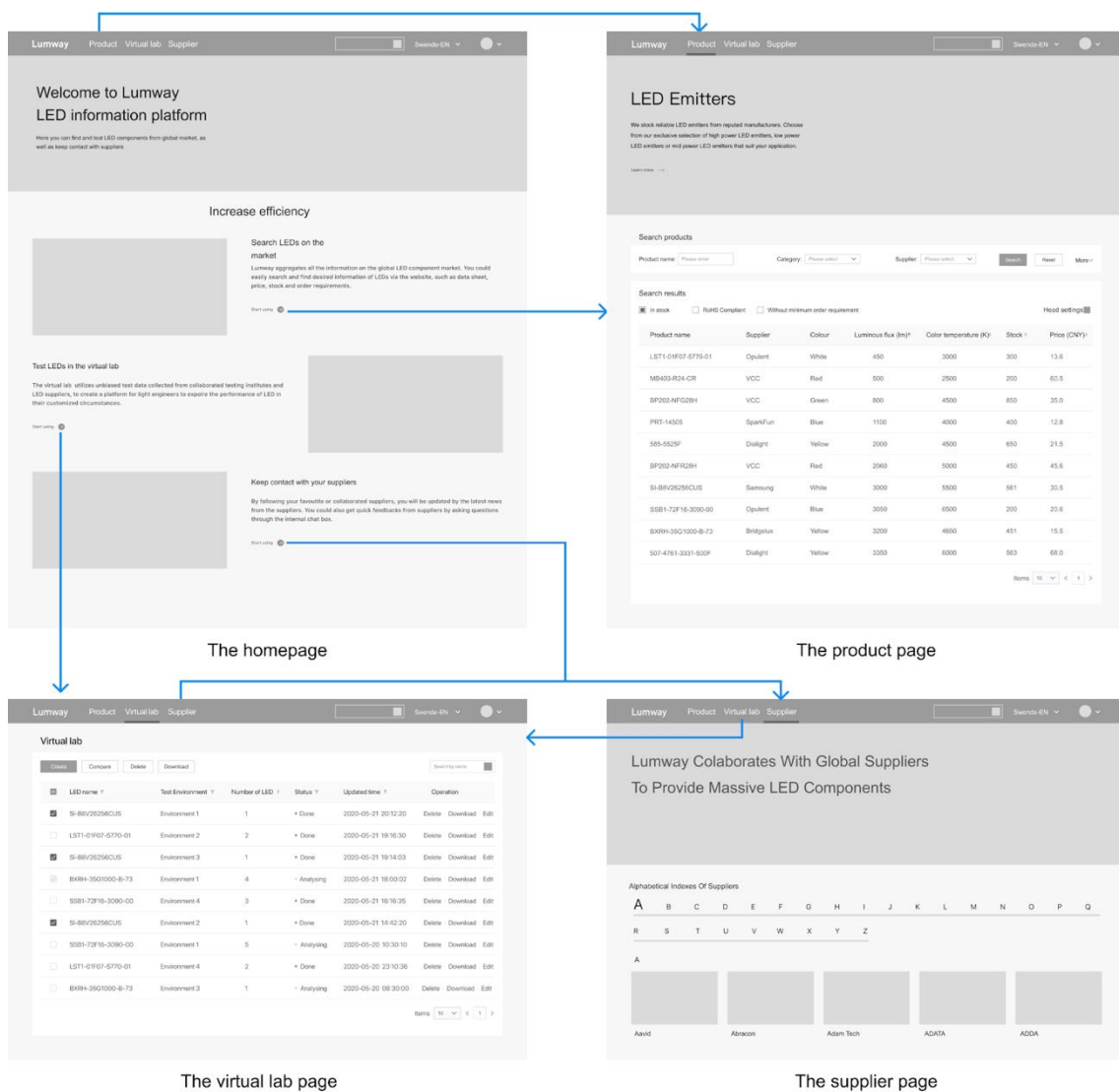


Figure 5.9 Wireframe

The website adopts a top navigation bar which enables main features to be accessed at all times. When users visit the website, they will firstly land on the homepage that shows short introductions of the three main features: product, virtual lab and supplier. The users can click the entry point in each feature-titled section on the homepage or the label on the navigation bar to access the corresponding feature page. There is a search box on the navigation bar, where users can search products, suppliers, promotions and other website contents. To enable users to communicate with suppliers at any given moment, the entry point of the message drawer is added into the drop-down menu of the profile. After logging in, users can use the navigations of “my suppliers”, “my lists” and “messages” by clicking the profile.

The product page is mainly divided into three parts from top to bottom: the banner area that displays promotion information, a collapsible search panel where the users can set

desired product parameters, and a product table that shows the search results. At the top-right of the table, there is a button for users to set the product parameters shown in the table header. By setting the table header, the users can rapidly compare the key parameters of the products to find out the suitable one and check its details. On the product details page, the users can check the information of price, supply and parameters, download the datasheet and add products to the list.

After finding suitable products, the users can test and compare the optical performances of products in the virtual lab. On the virtual lab page, there is a button group that includes four important action buttons, a search box, and a table of saved test points. By clicking the create button, the users access the test point setting page that structures the content into two sections: environment settings and LED settings. The users can save the environment settings and reuse them by clicking the list at the left of the environment setting section. After setting the test point and clicking the “analyze” button at the bottom, the test point will be added to the table shown on the virtual lab page. The users can click the LED name of the test point to check its test result or tick several test points and then click the “compare” button to check the comparison results.

If the users want to record selected LEDs during the buying process, they could create a list and share it with other stakeholders. By clicking “my list” in the drop-down menu of the profile, the users can access the list page that has a similar layout to the virtual lab. To create a new list, the users can click the “create” button above the table and then fill in the form on a new page. After creating the list, the users need to select products and add them to the list from the product details page. When the list is completed, the users can click the “send” button on the details page and the list will be sent to suppliers through the pop-up message drawer.

The information of suppliers that collaborated with Lumway is shown on the website. The users can use the alphabetical index to check suppliers on the supplier page and follow the supplier on its details page. If the users want to keep track of the latest news of suppliers, they can access the “my suppliers” page which displays the information of available products, promotions and samples. Communication with the supplier is done through the pop-up message drawer by clicking the “contact” button beside the supplier’s name or the “messages” navigation in the profile. On the primary interface of the drawer, there are two labels on the top, which show the list of messages and the list of followed suppliers separately. By clicking the message or supplier on the list, the users access the secondary interface that displays the chat details.

5.4.2. High-fidelity prototype

To make the concept identical to a final website in terms of look and feel, the wireframes were developed further in Figma with the focus on the visual design on the surface plane. All the interfaces for the website prototype can be found in Appendix 7. The overall visual design follows the principles of simple and minimal to communicate information efficiently. Considering that the brand colour is dark and it is more comfortable for the users to deal with numbers and graphs for a long time in the dark mode, the interfaces adopt the dark style to embody the brand impression and create a nice reading experience (see Figure 5.10). To make the visual interface more compelling and easier to use, three aspects were concentrated on and developed: visual hierarchy, icons and visual information design.

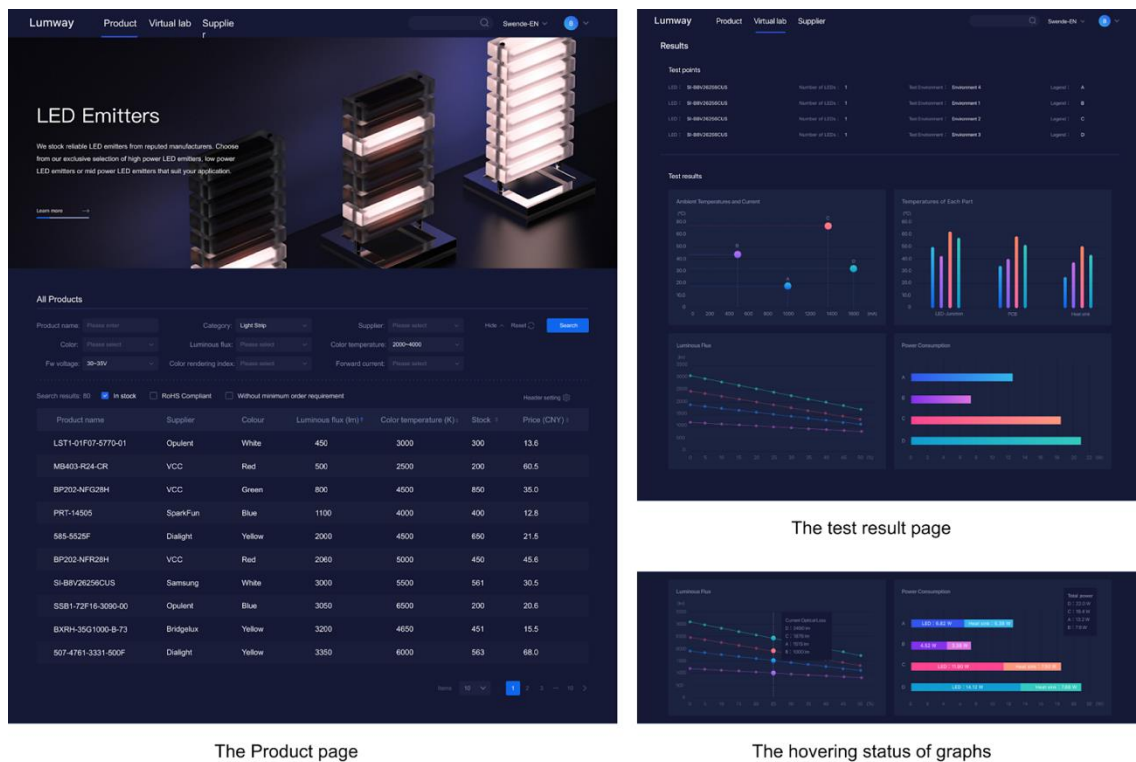


Figure 5.10 The web prototype

To give the users clues about the relative importance of page elements and draw attention to the important ones, the basic visual elements are used to distinguish levels of hierarchy, such as colour, size and position. For example, on the product homepage, the search button has a bigger size and greater contrast in hue and saturation against the background than other controls, to attract the users to notice and try the search button. The important data elements are shown in the white colour while the less important one is less saturated.

By establishing a clear visual hierarchy, the interface can lead the visual flow in an intended manner.

Part of the controls is signalled by icons to quickly represent functions and convey the desired brand attributes. For example, in the table of test points, the operations of delete, download and edit are visualized by icons instead of text in the interaction framework. The images of these operations are common in the usage scenarios of websites and mobile applications, thus they can be quickly recognized and understood by the users. These icons have a consistent style that uses simple geometric forms and the same less-saturated blue colour, to satisfy the usability requirements and match the aesthetic tastes of the target group.

The information of test results is visualized to help the users easily learn about and compare the optical performances of LEDs. Each test point is coloured with different high-saturated colours so that the users can distinguish the test points in different graphs. To show dense information in the limited screen space, the interactivity of the visual interface is taken into account. For example, in the graph of power consumption, the users can quickly find which test point is most power consuming by comparing the length of columns. If the users want to learn about the power consumed separately by LED and the heat sink in the test point, they can hover the mouse on the graph, and then detailed data will appear on the columns and the upper-right corner of the graph.

5.4.3. Conducting heuristic evaluations to find usability problems

The method heuristic evaluation (see Section 4.4.1) was applied to detect usability problems of the website prototype from the expert's perspective. By conducting heuristic evaluations in the middle phase of the design process, we could find and then fix identified usability problems before involving actual end-users, which made the usability testing more effective.

Considering that the website was domain-dependent, and the participants were fairly naive with respect to the optical knowledge, it was better to provide a series of tasks to assist the participants to use the interfaces. In total, nine tasks were developed based on the defined context scenarios, which helped the participants to focus on the important interface elements during the evaluation session.

Five user experience designers from different companies participated in heuristic evaluations. Each evaluation session lasted for roughly 90 minutes and was guided with a script (see Appendix 7). The evaluation was executed remotely by sharing the link of

the prototype with the participants and inviting them to share their screens and think aloud when inspecting the prototype. In the evaluation session, the participants were asked to take two passes through the interfaces. The first pass gave a general feel for the website scope. The second pass asked the participants to perform specified tasks by assuming the role of the target user and identify possible usability problems based on the provided heuristics.

After conducting all evaluation sessions, an internal debriefing session was held to discuss and synthesize the recorded problems into one list, so that similar problems could be merged to avoid redundancy. In order to prioritize the problems and focus on the critical problematic aspects of the design, each problem was ranked with the severity rating scale, where 1 represents “cosmetic problem only” and 4 represents “usability catastrophe”. The full list of usability problems and their ratings can be found in appendix 9. Then possible solutions for problems were discussed according to the recommendations from the participants, which provided input for improving the website prototype. The key findings from the heuristic evaluation are presented below.

In general, the prototype received positive feedback and helpful suggestions in the heuristic evaluation. The participants thought the overall experience with the website was pleasant, which was intuitive and easy to use. The prototype performed well in the heuristics “aesthetic and minimalist design” as well as “flexibility and efficiency of use”. The problems of the heuristic “Help and documentation” were prominent because of the undeveloped help system of the website. In total, 23 usability problems were identified in the debriefing session. These usability problems were divided into four problem areas according to the upper four planes in Garrett’s five-plane model of UX.

The scope plane

There were fewer instructions or help functions for new users to learn about how to use the website. It might cause confusion or frustration during the interaction with the website. For example, when the users visited the virtual lab for the first time, it would take a certain time to observe the controls on the interface and guess their functions. If the users had any problems during the usage, they did not know how to get instant help from the website. Another problem was about the function of sending the list. Since LEDs made by different suppliers were shown in the same table on the list details page where only one “send” button was placed, users had to send the list to all the suppliers without selecting particular ones. It was pointed out that the interaction might not match the actual usage scenarios where users were used to negotiating with one supplier rather than several ones at the same time.

The structure plane

Some interactions were difficult for users to learn and use for the first time, for example,

setting the table header and saving the environment settings. Some dialog boxes interfered with the user's original workflows, which aimed to provide system feedback to users' manipulations. Users had to first deal with the dialog box and then continue their task. For instance, a dialog box of saving reminders would pop up when users completed settings and clicked the "analyze" button without saving the environment settings. Such a dialog box might annoy the users when they did not want to save them. It was suggested to provide modeless feedback and avoid stopping the normal flow of activities and interaction. Participants also recommended providing more ways to accomplish the goal efficiently, e.g., allowing users to add products to the list on the virtual lab page as well as the product details page.

The skeleton plane

Some important navigation options were hidden, which decreased the efficiency to access corresponding interfaces, e.g., the message function hidden in my profile. In addition, there lacked in-page navigation to guide people to move between the interfaces that have different levels of hierarchy. When users browsed the tertiary interfaces by taking several page jumps, e.g., the product details page, they could not move back to the previous pages. It could be difficult for the users to figure out where they were if the interface hierarchy was too deep. And at last, the website did not provide helpful but low-frequently used navigation options for users to learn more about the website, e.g., promotions, terms and support.

The surface plane

There were three main problems with the visual design. First, the visual hierarchy of the interfaces was weak, which caused the failure to attract attention to the important parts. And the visual flow of the test point setting page was disordered. The section of LED settings was more important for the users to focus on and should be located above the section of environment settings. The analyze button was put at the bottom left corner. It increased the visual route to find the button, which was guided to move from right to left. Second, some clickable objects did not provide obvious visual clues to indicate clickability and current status. For example, the "follow" icon did not provide visual feedback after clicking, thus users did not know if they had successfully followed the supplier. It was suggested to use colour or underline to distinguish the different status of these clickable objects, such as normal, hover, active, loading and disabled. At last, some icons were hard to recognize and should be redesigned in a more understandable and familiar manner.

5.4.4. Improvements for the web prototype

Based on the feedback from heuristic evaluations, the high-fidelity prototype was further developed and added with new features to improve the user experience. The improved web prototype can be seen as the outcome of the design process and details about how to use the main features of the web prototype will be presented in Chapter 6. This section merely presents the design thoughts of how to solve the identified problems in heuristic evaluations and the most important design changes of the website prototype.

The scope plane

In order to reduce confusion aroused during the usage of the website, a help system is developed to provide comprehensive assistance when and where the users need them. Considering the concept of the virtual lab would be difficult for the new users to understand, the virtual lab page is redesigned to introduce the features of the virtual lab and provide help documents (see Figure 5.11). By clicking the “start” button on the banner area, the users can access the test point page to start testing, which has a similar layout to the previous virtual lab page. Furthermore, a guided tour was designed for first-time users to learn about how to use the main functions of the virtual lab step by step. To make the icons and buttons more understandable, Tooltips are used to provide interactive help for the users. When the users feel confused about the control of the icon or button, they can hover the mouse cursor on the item and a text label will appear around the item, which shows a short phrase to explain the control. Another significant change is the list details page where products are shown in separated tables according to the differences of the suppliers and users can select a particular supplier to send the list.

The structure plane

The interactions of the website are simplified to make the functions easier and efficient for users to use. For example, when the users are setting the test point, the input of the environment settings can be automatically saved in the “history” tab (see Figure 5.12). The users can choose to permanently save the current environment settings in the “my environment” tab by clicking the “save” button or continue their common flow of creating the test point without being annoyed by the save reminder. When the users visit the test point page for a second time, they can reuse or save the environment settings in the list of history. The simplified interaction of saving provides a more natural way for users to save the environment settings.

The skeleton plane

In terms of navigation, the top global navigation bar displays more useful navigations than the previous prototype, e.g., about us, help centre and messages. By clicking the message icon at the right, the users can quickly access the message drawer. It is also easier

for the users to notice the red dot that appears on the icon when there are new messages. To better guide the users to explore the website, the breadcrumb is added on the upper-left corner of each secondary and tertiary interface, which indicates the current level of hierarchy and navigates the users to the parent interface. At last, a sitemap footer is added to the end of each page to complement the top global navigation and make the complex website more discoverable. When the users scroll to the end of the interface, they can learn more content of the website and effectively find relevant links to subpages.

In addition, part of the system feedback was displayed on toasts instead of dialog boxes. By providing the modeless feedback through toasts, the users' normal flow of interactions will not be stopped by the annoying dialog boxes. For instance, when the users have successfully added the products to the list on the test point page, a blue toast of operation feedback will appear at the top of the interface (see Figure 5.13).

The surface plane

The visual hierarchy of interfaces is designed more prominent by colouring the important sections' background with a lighter blue. And the visual flow of some interfaces is reorganized to lead users through a logical path to accomplish certain tasks or goals. For example, the section of LED settings and the section of the environment list were coloured with light blue to stand out from the background. The visual flow was attracted to start from the top LED settings, to the left environment list, to the right environment details, and end with the buttons at the bottom right corner. As suggested by the participants in heuristic evaluations, the clickable objects provide visual feedback to provide clues of current status or feedback of users' operations. And finally, the appearances of some icons are redesigned to make them easier to recognize and understand.

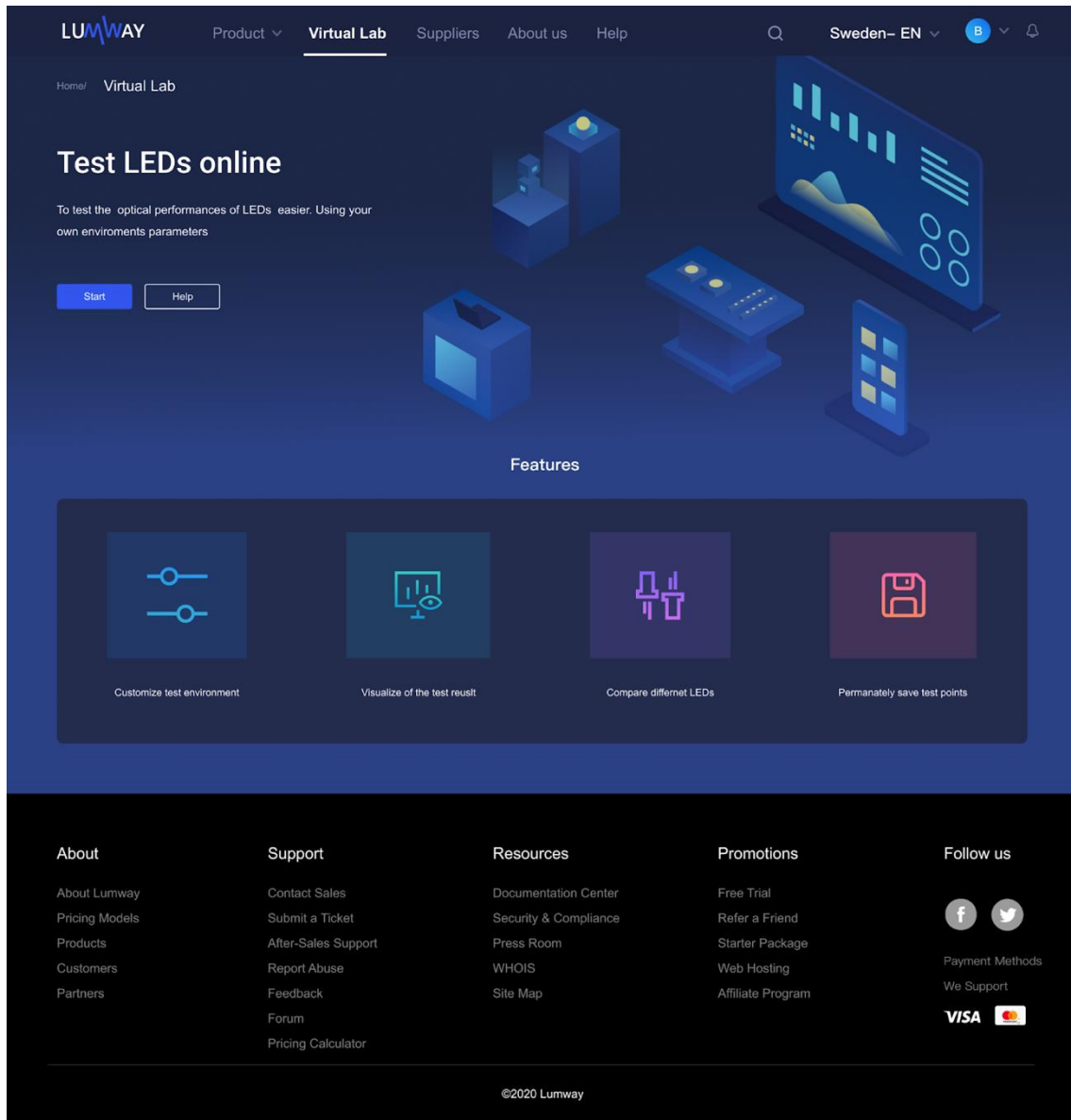


Figure 5.11: The virtual lab page

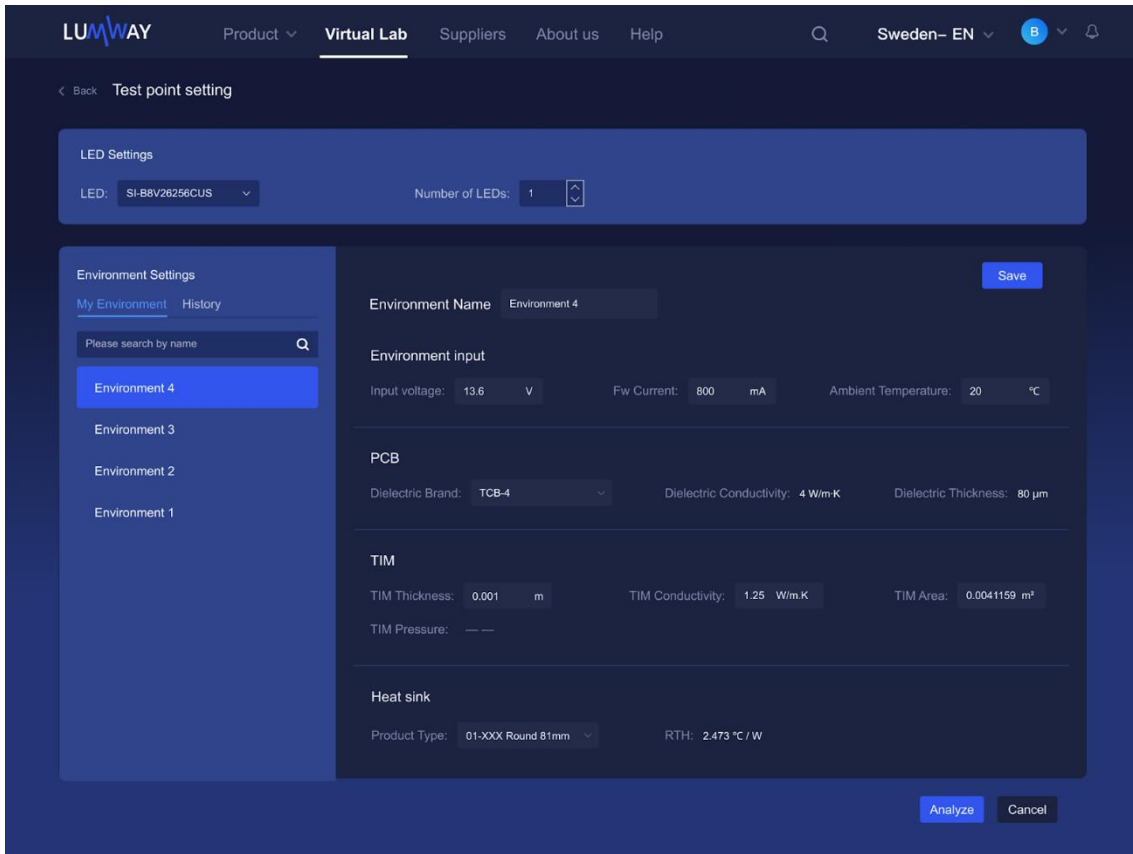


Figure 5.12: Test point setting page

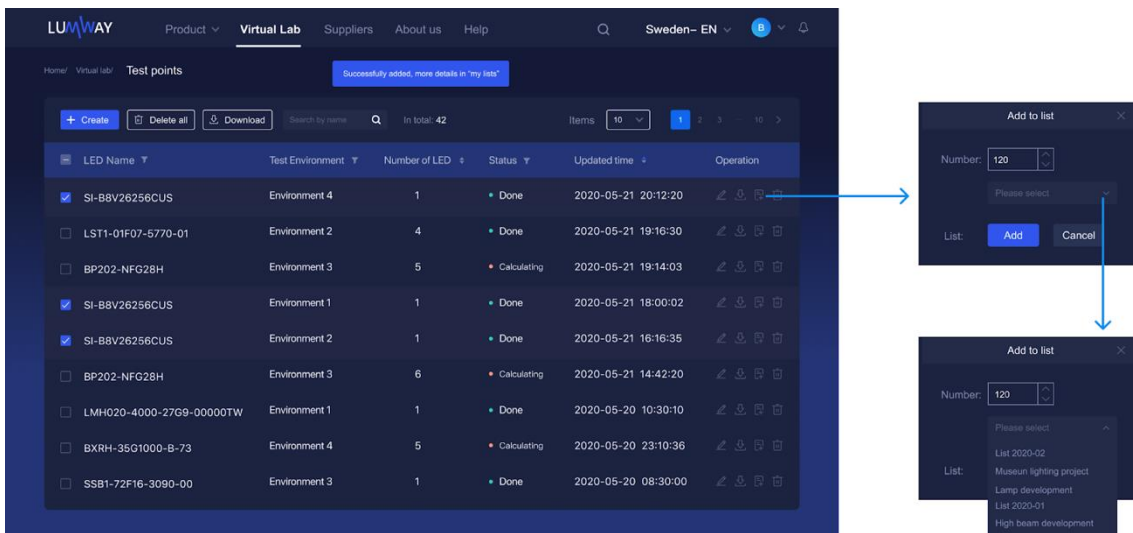


Figure 5.13: Add products to the list

5.5. Evaluate the design outcome

The evaluation took the method of usability test and UX questionnaire. The feedback on the design from users can both provide the suggestion on improving the design as well as information for generating the research answer.

After the evaluation, the affinity diagram was used to sort the data into different theme groups to help analyze the result. These themes were then discussed and summarized to answer the research questions which will be presented in chapter 6.

5.5.1. Evaluate the website with target users

The improved web prototype was evaluated by usability testing with typical end-users. The purpose was to find usability problems from the users' perspective and investigate how they feel about the prototype.

The usability test was executed with five users who had an education or occupation background related to optics and electricity. Because of availability, the usability test was conducted remotely as well. Each participant received the link to the prototype and was guided to perform the same tasks in the heuristic evaluation. The only difference was in task7 where the participants were required to add products to the list from both the product details page and the test point page. During the tasks, the participants were encouraged to think aloud about their impressions and suggestions for improvements. Notes of the use errors and task completion were also taken. After the nine tasks were completed, the participants were required to evaluate their overall experience with the website by filling in the UX questionnaires. The detailed description and results of the UX questionnaires will be presented in Section 5.6.2.

In general, the participants thought the website is helpful to find suitable LEDs. "easy to use", "concise and appealing interface", and "understandable" are some of the comments expressed during the usability test. In terms of the tasks, 88.9% were completed successfully by the participants. The number indicates that the website's represented model closely follows users' mental model. It is worth noting that some factors would bring both positive and negative influences on the task completion rate. For example, the prototype was not developed as well as a real website so that the users cannot click anywhere to explore, and the prototype would highlight the hotspots when the participants clicked the mouse, which helped the users to know where to click. However, according to the observation of users' interactions with the prototype from the shared screen and the communication during the test, it was agreed that the website provided a cognitive

framework that made it evident to the users how to perform the tasks.

Compared with the result of heuristic evaluations, the number of identified usability problems

and the percentage of problems with rating 4 and 3 decreases, which means that design improvement is effective to improve the website usability. The most important findings will be presented below.

The scope plane

Based on the participants' comments, the website covered the main functionality of their commonly used optical website and met their needs in the actual workplace. It was appreciated that the virtual lab enabled the users to rapidly test and compare the optical performances of LEDs. The function of saving environment settings is helpful to improve the efficiency of setting the test point. When the users selected a saved environment from “my environment” list and changed its parameters in the right setting area, the updates would automatically replace the old settings. However, some users pointed out that they would prefer to decide to replace or save as another new environment by themselves. Because sometimes they wanted to compare the differences of the test points under two similar environments and needed to save both of them.

It was pleasant to find that the help system has positive impacts on the task performance during the test. When the users accessed the virtual lab home page for the first time, the raised questions about the virtual lab were less than in heuristic evaluations. The users were attracted by the introductions on the virtual lab page and would like to try the test functions. Most users thought that the guided tours were helpful to guide them rapidly go through the important functions of the virtual lab. But some users expressed that it took time and patience to follow the guided tour and they preferred to explore the functions by themselves. All the users highly liked the ToolTips that could exactly explain the control for them. When they felt confused by the icons or the buttons, they could get instant help from the ToolTips. It largely contributed to the task completion rate when the users could find the right control to perform the task.

The structure plane

Overall, the interactions of the tasks were deemed easy and efficient by the users. The users expressed that some functions were useful to save time to achieve the task goals, e.g., setting the table header and saving the test environment. It was also noted that the website had good compatibility with different flows of interactions. It enabled the users to browse the website in a natural and explorative manner without interruption. For example, in this round of user testing, the negative emotion aroused by the conflict of creating the test point and saving the environment was decreased. The users thought it was nice to have the freedom to decide when to permanently save the environment

settings from the list of history.

The skeleton plane

When observing the users interacting with the website, it was evident that all the users could successfully access the pages of various main functions by using the global navigation bar. One user mentioned that he would carefully check all the labels on the navigation bar to learn about the major functions when visiting a new website. The fact that the navigation bar displayed the necessary entry points of functions and highlighted the selected navigation label was helpful to this user, as he could efficiently navigate the website and clearly know where he landed. Regarding the in-page navigation, it was perceived necessary to have the breadcrumb on the secondary and tertiary interfaces. When the users needed to return to the previous interface during the task, it was natural for them to look for and click the breadcrumb on the upper-right corner.

The surface plane

The users were impressed by the visual design of the prototype. It was pointed out that the interface elements were organized in a clear and understandable layout. Some users stated that the visual experience of the website was better than their current software and tools, which was enjoyable and visually efficient. However, some problems were identified as critical in visual perception. Two users pointed out that the operation icons in the table were not obvious enough to catch attention because of the low contrast in saturation against the background. One user expressed that the dark mode benefited dealing with data in the virtual lab but might not appropriate in other situations. It was suggested to provide the light mode for use to choose from and allow the users to change the colour mode according to their preferences. Although the aesthetics were deemed appealing to the users, some users addressed that they cared more about whether the website was useful and easy to use in their work routine rather than the aesthetics. If the website could not fulfil their needs or be difficult to use, they would not make a repeat visit.

5.5.2. Evaluate the website UX by using UX questionnaires

The UX questionnaire was applied to evaluate the user experience and gather quantitative data (see Section 4.5.2). By analyzing the result of questionnaires, we could evaluate the overall user experience with the website as well as verify if the UX goals were achieved.

Besides the five users from the usability testing, the link of the UX questionnaire was sent to the target user group to gather more user feedback in August. Because the users could not interact with the prototype in this method, they might not understand how the

prototype works when they only observe the limited website images in the questionnaire. Therefore, the animations of the task operations were generated and put into the UX questionnaire together with some key interfaces. The users were instructed to observe the animations and images and then rate the scales according to their impressions of the website. In total, twenty-one users participated in the questionnaire, who have an education or occupational background related to optics and electricity.

To analyze the result of the questionnaires, the mean value of the scores for the twenty-one responses was calculated (see Table 5.1). Most of the mean scores were around 2 points, which indicated that the overall user experience of the website was positive and the UX goals were achieved to some extent. It should be noted that the negative polar in the semantic scale ““undemanding and challenging” is the desired user experience value. And the mean value of -0.1 showed that users could understand how to use the new website but still have certain challenges. It was most likely due to the difficulty of using professional functions for the first time, e.g., testing and comparing LEDs in the virtual lab. The score of the words “professional” and “pleasant” were relatively high. It indicated that the website performed well in supporting the professional needs during the buying process and evoking pleasant emotions.

UX goals	Adjective pairs	Average rating
Simple	Unpredictable - Predictable	2.19
	Undemanding - Challenging	-0.1
Efficient	Unruly - Manageable	1.95
	Confusing - Clearly structured	2.24
	Impractical - Practical	2.1
	Unprofessional - Professional	2.43
Appealing	Conventional - Inventive	2.29
	Dull- Captivating	1.9

	Unpleasant - Pleasant	2.38
	Discouraging - Motivating	2.05

Table 5.1: The result of the UX questionnaires

6. Results

This chapter will present the final result of both design outcomes and analysis as a set of UX design factors from the whole research process. Since the research question specifically asked for important UX factors that need to be considered for the B2B e-commerce website to support buying behaviour in the transaction process. To find such UX design factors, *Research through design* was applied, where a prototype was created to find and extract the factors throughout the process presented in Chapter 5. The following sections will first present an overview of the created prototype, with key interfaces and complementary descriptions. Thereafter, the analysis of design factors for answering the research question will be presented.

6.1. The design outcome - the web prototype

In this section, the web prototype created in this thesis will be presented, which was the result of applying the *double diamond model*. Based on theoretical findings in the domain research, the web prototype was created according to the design process described in Section 1.6, where the complete process of how it was created is presented in Chapter 5. The creation of this web prototype aimed to find the UX factors to answer the research question. Meanwhile, the web prototype itself can provide a visual design reference for external research that has similar purposes as this thesis. At last, part of the number, text and images shown in the prototype merely imply the information categories, which should not be perceived as real as the launched LED e-commerce websites.

The Lumway website can be regarded as an information platform that enables both seller organizations and buyer organizations for LED transactions online. As mentioned in the delimitations, the created prototype mainly focused on the buyer side, e.g., how to fulfil the needs of the buyers, and how to support the buying behaviours through the website. The following sections will present the web prototype based on its main features.

6.1.1. Searching LEDs

After the phase of general need description (see section 3.2.1), the buying centre team has specified the parameters of desired LEDs within different stakeholders. Then the buying centre team needs to search and select suitable LEDs in the phase of product specification. To rapidly find several products that meet general needs to further compare, the users can use the search function of the website. The users will first land on the homepage by

accessing the website address, which introduces the most important features namely product, virtual lab and supplier (see Figure 6.1). For the purchasing engineers, they can directly search the product name through the search box on the homepage or the top navigation bar. For the lighting engineers, they can set the parameter filters to search LEDs. To do this, the users need to visit the product page by clicking the “learn more” button on the homepage or the “product” label on the top navigation bar. The users can find a collapsible search panel on the product page, where they set the filters to input LED requirements. After clicking the “search” button to apply those filters, the result will be shown in the product table below the search panel. If the users want to focus on several key parameters of LEDs and rapidly find suitable LEDs from the search result, they can use the set function to select the parameters shown on the table header. When there are too many parameters displayed on the table header, the users can scroll horizontally to check the full product table.

When the users find a suitable LED and want to check details of it, they can click the link of the product name and access the product details page which shows fundamental information about the LED, for instance, the data sheet, supply information, price references and product parameters. In addition, the users can select the quantity of LEDs and add them to the list from the product details page. Since the unit price of the LED usually changes depending on the order quantity, the current unit price and quantity are displayed in a brilliant blue rectangular to stand out from the background and attract attention. If the users want to learn more about optical performances of the LED before making purchase decisions, they can click the “test” button below the product image and use the online simulation tool provided by the website.

The website homepage

The product page

The product details page

The screenshots show the LUMWAY website interface. The first screenshot is the homepage, featuring a search bar and navigation links. The second screenshot shows a search results page for 'LED Emitters' with a table of products. The third screenshot shows the detailed product page for the 'SL-BRV1N603AWW' LED emitter, including supply information, price references, and product parameters.

Product name	Supplier	Stock	Price (CNY)	Colour	Luminous Flux (lm)	Power
LST1-41P07-5770-C1	Opulent	300	13.6	White	450	3000
MB403-R24-CR	VCC	200	60.5	Red	500	2500
BP202-AP02BH	VCC	850	35.0	Green	800	4000
PRT-14505	SpunFun	400	12.8	Blue	1100	4000
585-503P	Dialight	690	21.5	Yellow	2000	4500
BP202-APR0BH	VCC	490	45.6	Red	2000	5000
SL-BRV2626GUS	Samsung	561	30.5	White	3000	5000
SSB1-72P16-3000-00	Opulent	200	20.6	Blue	3500	6000
BXRH-3501000-0-73	BridgeLux	431	15.5	Yellow	3200	4650
507-4781-3331-500P	Dialight	563	68.0	Yellow	3300	6000

Unit Price	Quantity	Price
2.83	1-99	
2.75	100-99	
2.63	100-999	
2.58	1000+	

Parameter	Value
Color	Brown
Color Temperature	3000K
Luminous Flux	2000 lm
Power	33-33.1 W
Operating Temperature	-20 ~ 80°C
Forward Voltage	33-35.4 V
Package	Tray
Storage Temperature	-40~80°C
Forward Current	1~1.5 A
RoHS	Compliant
Color Rendering Index	90 CRI
Test current	1435 mA
Life Cycle	Unlimited
Number of LEDs	44

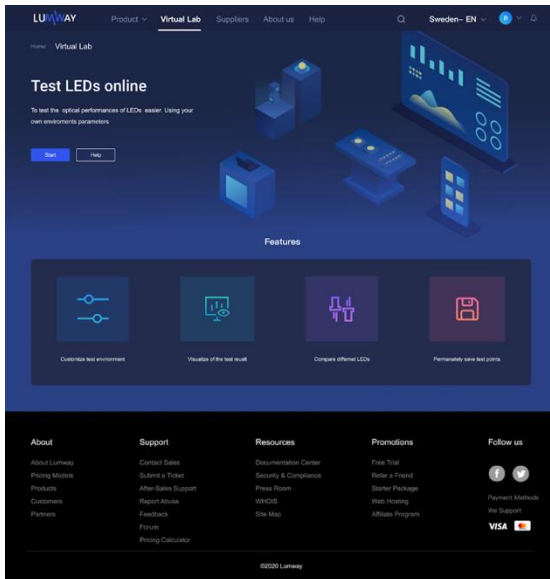
Figure 6.1 Searching LEDs

6.1.2. Testing and comparing LEDs

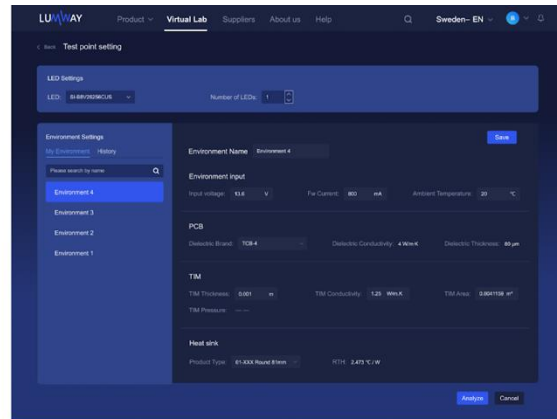
If the buying centre team wants to learn more about the technical aspects of LEDs, the virtual lab on the website can be used, which is an online simulation tool that enables the users to test and compare the optical performances of LEDs in dynamic environments. As shown in Figure 6.2, the virtual lab page provides feature introductions and helps

documents for the users to better learn about the virtual lab. The users can click the “start” button in the banner area to initiate the test workflow. Since the virtual lab is an advanced feature that contains privacy data, it requires the users to register and log in to their account before using the test functions. After that, the users can access the test point page where they can manage the test points of LEDs. If it is the first time for the user to land on the test point page, there will be a first-time guide to introduce the test functions. To test the LED, the lighting engineers need to create a test point by clicking the “create” button in the button group and then input LED settings and environment settings on the test point setting page. In terms of the environment settings, the users can save the current environment or reuse it in the left “my environment” list to improve the efficiency of the setting. When the users complete the setting and click the “analysis” button at the bottom, the test point will be added to the table shown on the test point page.

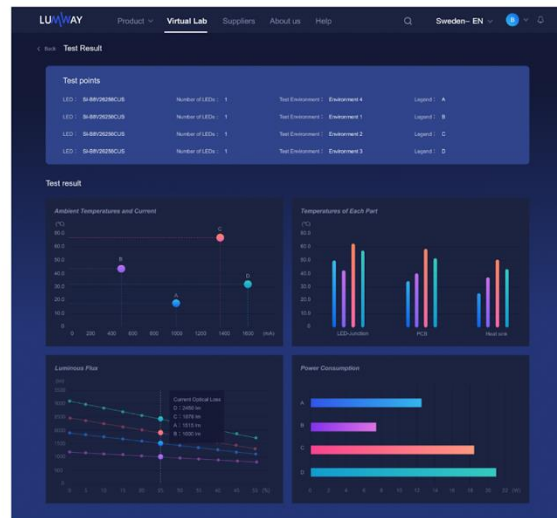
To check the test result of a single test point, the users can click the LED name and access the test result page which visualizes data in graphs. If the users want to compare several test points to find out the optimal LED, they can tick the checkbox of the test point. Selected test points will be shown in the top rectangular area and the “compare” button will appear at the right as well (see Figure 6.3). By clicking the “compare” button, the users jump to the test result page which shows the comparison result of selected test points. Each test point is coloured with distinct high-saturated colours and the users can easily distinguish and compare them in graphs. Some graphs are designed with both normal and hover states that display more information when the users have hovered the mouse cursor on the graph. The test result can be download by other team members, e.g., the purchasing engineer and the manager. By clicking the “download” button on the test point page, the users can download results to conveniently discuss test results with other people.



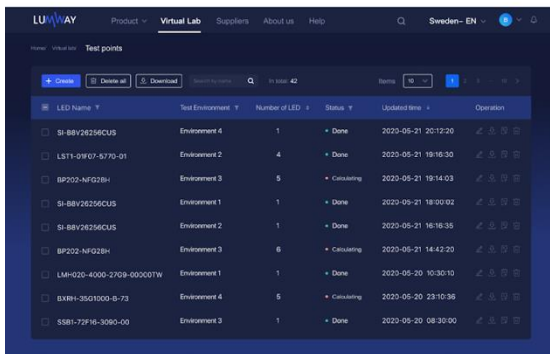
The virtual lab page



The test point setting page



The test result page



The test point page

Figure 6.2 The virtual lab

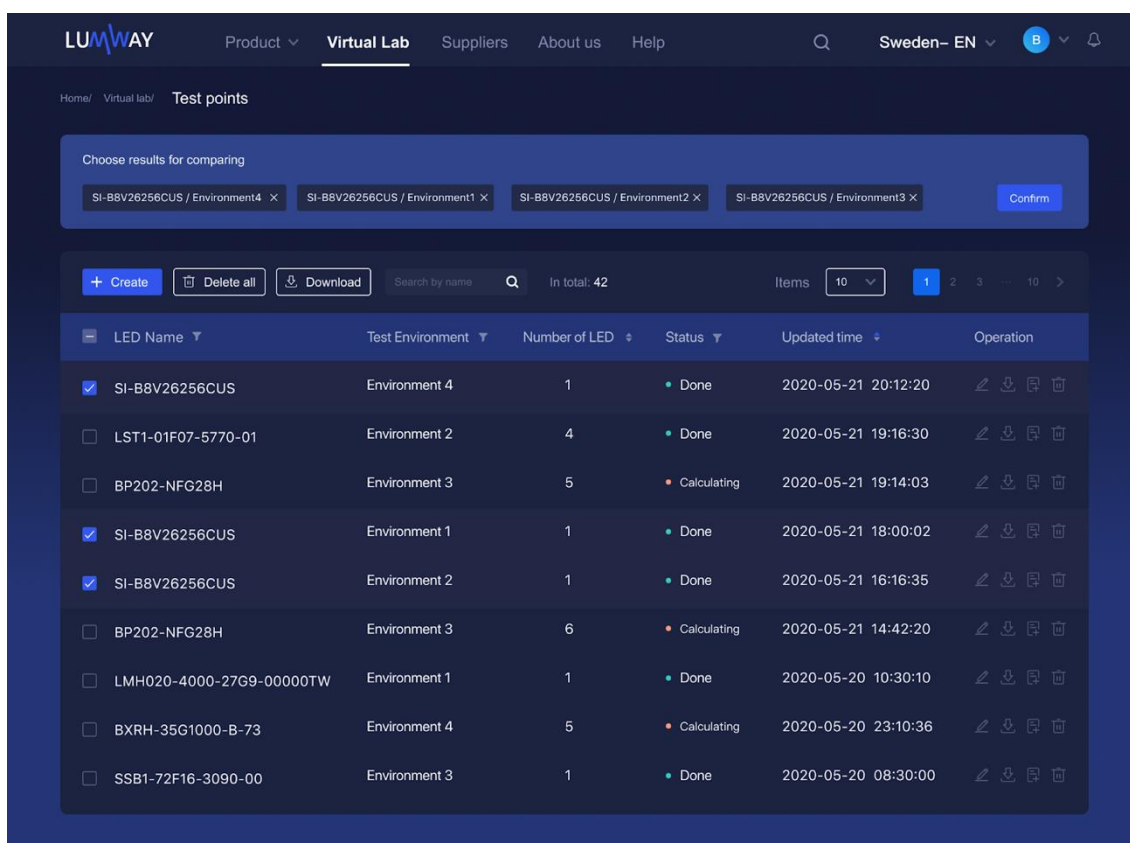


Figure 6.3 Select and compare test points

6.1.3. Recording LEDs

During the product specification phase, the buying centre team can use the list function to record and share selected LEDs with both internal and external stakeholders. The list is not only the collection of product names but also a collection of project information that can be used in other project development phases. To create a list, the users can access the list page by clicking “my list” navigation in the menu of the profile and then click the “create” button on the page (see figure 6.4). On the list details page, the users fill in the form under the editing status and save the list to convert to the viewing status. There are two ways to add products to the list: adding from the product details page and adding from the test point page. Despite different entry points, both adding ways follow the same workflow which needs users to select the quantity of products and then choose the list to add. When users want to negotiate the purchase with suppliers online, they can click the “send” button on the list details page to send the list to the corresponding supplier through the pop-up message drawer at the right. In addition, the users can download the list by clicking the “download” button and then send it through other communication channels.

My lists

List Name: Created time: Procurement status:

In total: 25

List Name	Created Time	Procurement status	Number of Products	Total Price(CNY)	Operation
<input checked="" type="checkbox"/> Lamp Development	2020-05-21	Unpurchased	3654	36000.32	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> List of June	2020-05-16	Purchased	46	654.00	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input checked="" type="checkbox"/> New Lighting System	2020-05-03	Unpurchased	513	5200.51	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> Car Lighting Solution	2020-04-25	Purchased	8123	12623.30	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> Museum Lighting System	2020-04-18	Purchased	36954	652300.01	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> Library Lighting System	2020-04-12	Unpurchased	630	8800.65	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> Lamp Redesign Project	2020-03-01	Purchased	1302	19870.23	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> List of May	2020-02-12	Unpurchased	530	5694.00	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>
<input type="checkbox"/> Important Project	2020-01-20	Purchased	13	725.36	<input type="button" value="Delete"/> <input type="button" value="Download"/> <input type="button" value="Change status"/>

Items

Figure 6.4: The list page

List details

List Information

List name: Procurement status: Created Time: 2020-05-03

Description:

Recipient Information

User Name: Telephone Number: Company:

Address: Warehouse: Note:

Products

Supplier:

Product Name	Unit price (CNY)	Number	Price	Tax Fee	Delivery Fee	Total price	Operation
PRT-14505	8.50	<input type="text" value="100"/>	850.00	315.00	86.55	3801.55	<input type="button" value="Delete"/>
SL-BBY1NGLAWW	13.25	<input type="text" value="200"/>	2650.00				<input type="button" value="Delete"/>

Supplier:

Product Name	Unit price (CNY)	Number	Price	Tax Fee	Delivery Fee	Total price	Operation
SI-BBY2026UCUS	5.23	<input type="text" value="1000"/>	5230.00	470.70	221.15	5921.85	<input type="button" value="Delete"/>

Total Quality: 1300 Total Price: ¥ 9633.40

The list details page - editing status

List details

List Information

List name: Procurement status: Created Time: 2020-05-03

Description:

Recipient Information

User Name: Telephone Number: Company:

Address: Warehouse: Note:

Products

Supplier:

Product Name	Unit price (CNY)	Number	Price	Tax Fee	Delivery Fee	Total price	Operation
PRT-14505	8.50	100	850.00	315.00	86.55	3801.55	<input type="button" value="Select list"/>
SL-BBY1NGLAWW	13.25	200	2650.00				<input type="button" value="Select list"/>

Supplier:

Product Name	Unit price (CNY)	Number	Price	Tax Fee	Delivery Fee	Total price	Operation
SI-BBY2026UCUS	5.23	1000	5230.00	470.70	221.15	5921.85	<input type="button" value="Select list"/>

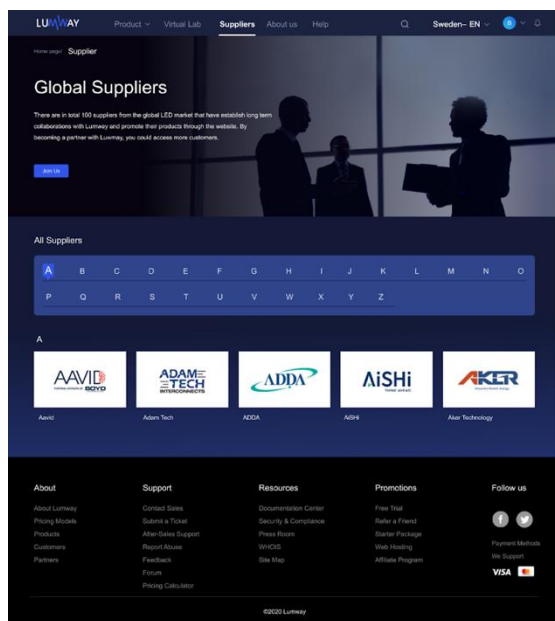
Total Quality: 1300 Total Price: ¥ 9633.40

The list details page - viewing status

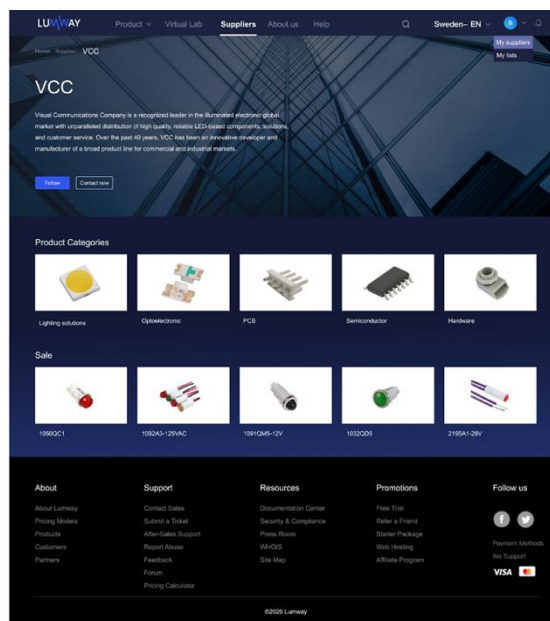
Figure 6.5: The list details page

6.1.4. Communicating with suppliers

When the buying centre team decides on the product's characteristics, they will try to identify the most appropriate suppliers in the phase of supplier search. By using the website, the purchasing engineers can conduct a search to identify which suppliers offer the best item on both price and quality. The website provides useful information about suppliers that collaborated with Lumway, which helps the buying centre team assess the suppliers and their products before making purchase decisions. By clicking the “supplier” label on the global navigation bar, the users can access the supplier page which displays the list of available suppliers according to the alphabetic index (see Figure 6.6). To learn more details, the users can click the image of the supplier logo and link to the supplier details page where they can find provided products. If the users want to keep track of the supplier and establish long-term collaboration, they can click the “follow” button in the banner area. To check the suppliers that the users have followed, they can click the “my suppliers” navigation in the menu of the profile. On my supplier page, the latest information of suppliers is shown in the table, e.g., new products and samples (see figure 6.7). The website provides the chat function to enable the users to efficiently communicate with the suppliers in the proposal solicitation phase and the supplier selection phase. To do this, the users can click the “contact” icon on the page or the “message” icon on the navigation bar to activate the message drawer. There are two module tabs at the top of the message drawer. One is the “message” tab which displays the list of messages and links to the secondary chat interface with the supplier. Another is the “contact” tab that shows the list of suppliers that the users have followed.



The supplier page



The supplier details page

Figure 6.6 Search the suppliers

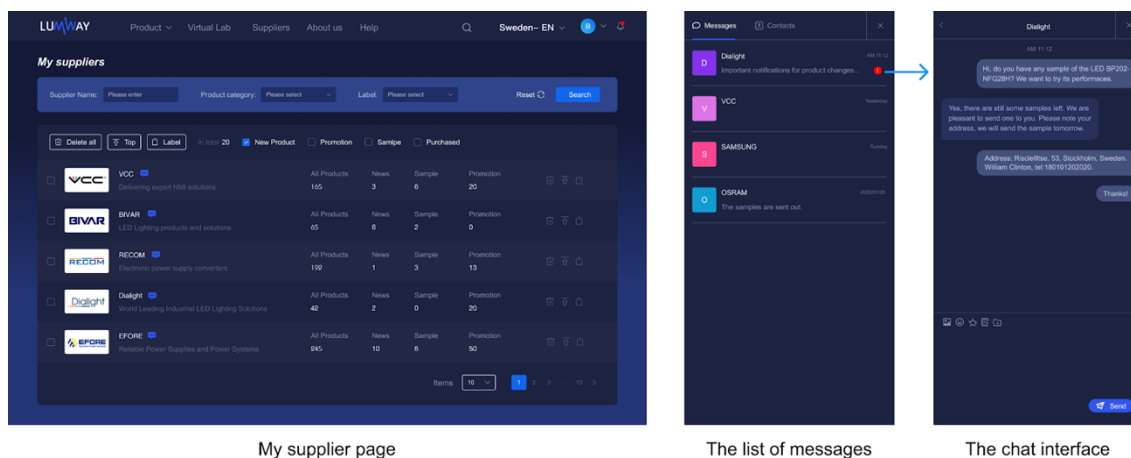


Figure 6.7 Communicate with the supplier

6.2. UX design factors for supporting e-commerce behaviour

This section will present the analysis results based on user research and design evaluation results, which will focus on factors that should be considered in UX design for a B2B website to support the organizational buyer in their purchasing process to have a convenient user experience. The factors are essentially based on reviewing theory within the field of study, exploring design solutions, and at last, evaluating the design solutions with people who work in the LED industry and have a need for online B2B activities.

In this context, the convenient UX influence the product specification phase and supplier search phase in the buying process (see Section 3.2.1), which enables the buying centre team in the organization to easily find suitable LEDs and suppliers to make a purchase decision. In terms of individual experience, the convenient UX enables different roles of users to efficiently perform individual tasks as well as effectively collaborate with each other. The details of how the convenient UX can influence a specific behaviour of an individual during the buying process will be presented in the description of each design factor.

The following sections will present the design factors in a structure that represents Garrett's Five Planes model (see Section 3.3.2) which describes how website UX should be designed in a specific framework to cover all aspects.

6.2.1. The strategy plane

As fundamental for the design concept, having a clear strategy that balance product

objectives and user needs can help to make decisions about other aspects of user experience in the latter design phases. In the business context, the strategy that the company make for the product tends to concentrate on the side of product objectives, which take into account the business elements, e.g., marketing, revenue, and brand identity. However, creating a successful user experience of the product requires paying attention to the user needs from the perspective of user experience design as well. This means considering the design of the website to align with the users' mental model and work exactly how the users want it. To be more specific, the B2B website should have a clear aim of supporting the buying centre team's buying behaviour to have a convenient UX. In this project, the consideration of user needs on the strategy plane showed a positive effect for the final design. The users from the design evaluation viewed that the created website was more attractive and helpful than the initial website concept that only provided the simulation function.

Although in the strategy plane, there are no concrete design factors that can be generated to support the B2B buying process, the following questions can be used as criteria to examine whether user needs are sufficiently considered on the strategy plane:

Who are the target users and what characteristics do they have?

How will the users use the product to fulfil their needs in a typical scenario?

What kind of experience of the website is expected from the users?

When these questions can be explicitly answered, the company can make an appropriate strategy from the perspective of user experience design.

6.2.2. The scope plane

For functions that should be provided for users to use will decide the capability of the website. Having a completed function system that can meet users' actual needs can be the most important on the scope plane. However, by applying the UX design process, we found several functions that not every B2B e-commerce website have but users would like to have from the evaluation. The following will go through the important functions that support users during the buying process.

6.2.2.1. Develop the help system to teach and introduce the web

It is always challenging for first-time users to understand and explore how to use digital products, especially when they use professional functions of LED simulation tools that require a certain knowledge of terminologies. Questions regarding "What does this

product do?” and “How can I start the main workflow?” are usually raised by new users. According to the results of heuristic evaluations and usability tests, lack of assistance is a common pain point of the user experience. In this project, a help system is developed to facilitate interactions and provide assistance for users in different contexts.

In the product specification phase, problems usually happen when the user needs to test and compare the optical performances of LEDs in the virtual lab. To solve the problem of initial learnability, guided tours can be used to provide brief introductions of features and interactions when the users visit the test point page for the first time. As shown in Figure 6.8, there is an example of the test function in the virtual lab. The guided tour includes a sequential set of text cards that take the user through a typical workflow: create the test point, check the result, and compare test points. Each text card displays the current step name, description of the function and a next button. By clicking the next button, users advance to the next text card in the tour. Such step-by-step guidance helps new users to rapidly understand the most important functions and interface behaviours in the typical testing scenario. If users want to get straight to work without visiting each guided interface, they can click on the background to skip the guided tour.

In addition to guided tours, a ToolTip is an effective pattern to provide interactive help on desktop applications. When the users have hovered the mouse cursor on a button or icon for a second, a text label that displays explanatory information will appear near the item. The textual hints provided by the ToolTip communicate exactly what the control is for. In terms of icons that are difficult to decipher with certainty at first glance, ToolTips can help novice users recognize the icons with little effort. Meanwhile, intermediate and advanced users can use ToolTips to recall the functionality when they want to use a rarely used icon.

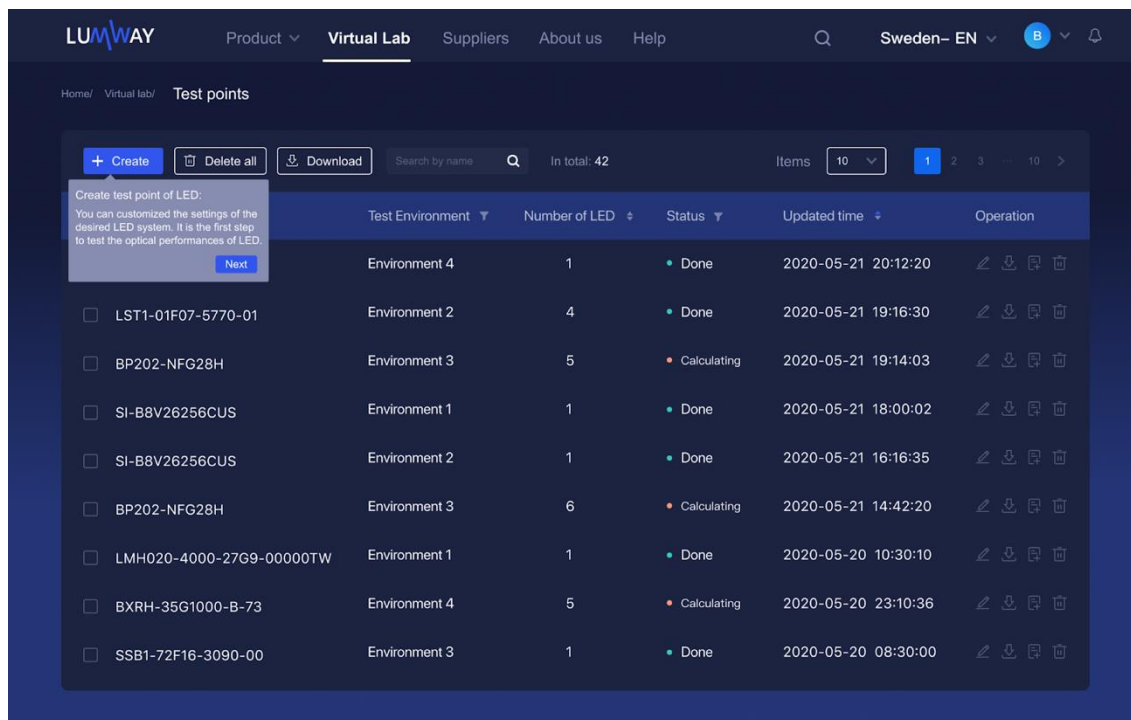


Figure 6.8 The first time guide of the test function

6.2.2.2. Use the simulation function as a tool to support showing technical capabilities

To further understand the characteristics of the product, users need to apply for more information to help their evaluation (see Section 3.2.1). In the LED purchasing context, the simulated product performance is used as a tool to help users quickly understand the product performance in the product specification phase, which can effectively display the product's capabilities. By allowing users to input data for simulation, they can view the technical performance of the product according to their needs as easily and comfortably as possible. Users who evaluated the prototype said that online simulation may be an important factor to help them make a purchase decision and choose to use this website because more technical information will be displayed visually. They also mean that by updating LED product information, they are likely to be able to communicate more easily with suppliers directly through the updated test results.

Furthermore, some users in the evaluation stated that the simulation function was not necessary for them, so this factor does not apply to the target group of users who do not trust the results of online simulations. The argument put forward is that using other unverified test tools outside of their testing software or institutions may not only obtain inaccurate results but also risk exposure of their internal design information. The

conclusion is that it is important to understand the target user group when trying to apply this factor because if people don't trust the simulation feature, this tool might be escaped during usage.

6.2.3. The structure plane

On the structure plane, the main issue is to construct the website structure at a high level, which describes how the functions defined in the scope plane will work. According to the user evaluations of the prototype, the efficiency of task completion is highly valued by the users. In this context of purchasing on B2B websites, the efficiency is related to how fast the users find desired functions, and how easy they use the functions to accomplish their tasks on the website. The following are two design factors of creating an efficient website structure in terms of interaction design.

6.2.3.1. Progressively disclose controls

To enable users to quickly find desired controls to perform tasks, it is suggested to show frequently used controls on the interface and progressively disclose the rest of the controls during the use. As mentioned before in the LED industry background (See Section 2.2), there are many parameters to describe a LED item. During the product search process, the users might use different parameter filters to search and find desired LEDs. If displaying all the parameter filters on the interface, it will make the interface crowded and reduce the efficiency of search. In the design, to make users deal with parameters as few as possible before visiting the product details page, the website hides advanced or less frequently used filters in the collapsible panel by default. When the users visit the product page, they can rapidly start the search by using the displayed high-frequency filters. If the users need to use advanced filters, they can click the "show" button on the upper-right corner of the collapsible panel to check more filters. Furthermore, the website provides the function of setting the table header, which allows users to set the parameters shown on the table header. By using this function, the users can focus on the parameters that they care about and rapidly select out LEDs that meet their intended parameter specifications. From the evaluations, feedback shows that the users felt more efficient with less information they needed to go through during such a search process.

6.2.3.2. Simplify the interactions of controls

The simplicity of interactions contributes to low costs for users to learn about how to use

the website and efficiently accomplish tasks during the buying process. If the interactions with the website are too complex and challenging to understand and use, the risks of giving up during the use will increase. Therefore the designers should simplify the interactions of operations and make the website easy to use for most users. Generally, users have already accumulated a generic mental model of the way a website is supposed to work, based on their experience on other digital products. To help users achieve better understanding, it is suggested to follow users' mental model when designing interactions of operations, which makes the interface evident to users how to perform tasks to achieve their goals. The closer the designed interactions come to the users' mental model, the easier they will find the website to understand and use. For example, the users from the evaluations expressed that it was easy to chat through the message drawer due to the similar interactions with the common chat applications on the mobile phone.

Another way to simplify the interactions is shortening the workflow to accomplish a task. By taking advantage of the website's abilities to automatically save and calculate, the users can take fewer actions to complete the task and improve efficiency. For instance, the website provides the same function for users to save and reuse the environment settings when they are creating the test point of the LED. In the user evaluations, the users highly liked this function because it helped them rapidly create test points and compare different LEDs under the same environment. Similarly, Amazon's "one-click" feature to buy things motivates users to buy things due to the simplicity to do so. Once the users have successfully purchased on the Amazon website, the information of the receiver's address and credit accounts will be automatically saved on the website. When the users make a repeat purchase on Amazon, the website will accomplish the rest process for users after the users click the product.

6.2.4. The skeleton plane

On the skeleton plane, the website structure from the structure plane is further refined to details from different aspects, which make the structure more concrete to enable users' interactions. Although there are many detailed interface elements that can influence the website UX in the design of the skeleton plane, two factors are considered most important when designing the detailed interfaces according to the evaluations: navigation system and modeless feedback.

6.2.4.1. Establish an efficient and intuitive navigation system

To enable the users to rapidly get to the desired content from numerous diverse pages, an

efficient and intuitive navigation system should be established to provide users clues about where they are on the website and where else they can go. In this project, the website used three navigation patterns to organize the navigations in a logical way: the top navigation bar, sitemap footer, and breadcrumbs.

The top navigation bar can be the first thing that users see when they arrive at the website for the first time. Therefore, the top navigation bar should be task-oriented designed to provide useful and persistent navigation. It should try to answer users' immediate questions regarding "What is this website about?" and "Where can I find specific functions or content instantly?". In this project, the top navigation bar includes global navigation options for the major sections that most visitors look for, a search box that allows users to directly search the desired content, as well as sign-in tools like personal messages, my list and my supplier. No matter where the users are, they can access the top navigation bar and rapidly jump to the frequently visited interfaces at all times.

The sitemap footer can be seen as complementary to the top navigation bar, which covers less important levels on the website hierarchy without overloading the header navigation. When the users have viewed all the content on the page and scrolled to the bottom of the page, they can see the sitemap and access related content by clicking the links. Generally, the sitemap footer deals with secondary tasks that are less important or rarely visited areas of the website, e.g., customer support, resources, and social media. Since B2B e-commerce users are very concerned about providing private data online, the website can provide links to the privacy and security terms on the sitemap footer to reduce this concern and increase customer trust.

If the website has a complex hierarchical structure that consists of multi-levels of interfaces, it should provide clear navigation for users to keep track of where they currently are in the deep website structure. An effective way is to apply breadcrumbs on the upper-left corner of each secondary and tertiary interface, which are composed of a sequence of links that indicates the user's path through the website hierarchy. The links of each interface should be named by the page titles so that users can quickly recognize what the pages are about. Besides helping users to figure out where they are, the breadcrumbs enable users to easily retrace previous interfaces by clicking the links.

6.2.4.2. Provide modeless feedback to users' manipulations

When users are interacting with the website by clicking various controls on the interfaces, e.g., buttons, icons or sliders, it is necessary to provide immediate system feedback to users' manipulations. According to users from evaluations, they would feel confused

about if they had taken the right actions to perform the tasks when they did not receive any feedback that presented the current status and effect of their manipulations. For instance, when the users clicked the “follow” button on the supplier details page in the heuristic evaluations, there was not a visual style change in the button appearance or textual notification. Lack of system feedback caused that the users did not know if they had successfully followed the selected supplier. Besides providing immediate system feedback, it is also necessary to consider how to use appropriate interface components to convey such information on the skeleton plane. In the heuristic evaluations, the dialog boxes were used to present system feedback to users. However, the users stated that it was quite annoying to deal with these dialog boxes before they could continue their task. Therefore, a better way to inform users was tested in the usability tests, which provided modeless feedback by toasts without interfering with the users' original flow of interaction. The toast will stay at the top of the interface for several seconds to display information and then disappear. The users from the evaluations addressed that they preferred toasts to convey feedback because they were not interrupted by dialog boxes.

6.2.5. The surface plane

The surface plane decides the look and feel of the website. Although the aesthetics of the website might not motivate users to finish the whole process, it can influence users' pre-purchase expectations, initial experiences of the product and decisions of repeated use. In general, the visual design of the website should be appealing and motivating to its intended market, as well as communicate the information efficiently to users. To achieve these objectives, the following two design factors should be taken into account on the surface plane.

6.2.5.1. Keep the visual interface minimal

As mentioned earlier, the users of the B2B website care about the efficiency of performing tasks. If there are many visual elements on the interface, it will be difficult for users to rapidly process the overwhelming amount of visual information in their brains. In addition to increasing the cognitive load, superfluous visual elements can distract users from tasks and cause errors. Therefore, keeping the visual interface minimal benefits the user to concentrate on the core information or functions and perform tasks efficiently. One way is to get rid of the visual noises that do not convey meaningful information. For example, the icons on the website were designed in simple geometric forms instead of 3D rendering styles that did not add extra information. From the evaluations, feedback shows that the interface of this LED website attracts users to try the website for its simple visual

style. However, the simplified visual interfaces should still retain clarity and guarantee usability. The evaluation results of the website show that if there are other factors that hinder their use, such as unable to meet their functional requirements or inaccurate data, users will not change their idea of giving up this website even if visual related factors attracted them to try the website.

Another way is to decrease the unnecessary variation of the visual elements. The differences in visual property of every visual element should be designed reasonably. For example, the website applies a restricted colour palette which consists of three kinds of blue colours. The background of titled sections is coloured with dark blue to divide the website background. The neutral blue is used to display less important visual elements or information while a few brilliant blues is used to emphasize important ones. By using the same colour palette to deal with the visual hierarchy on different pages, the website can convey the feeling of balance and coherence.

6.2.5.2. Design a clear visual hierarchy and lead the visual flow

When users are looking at a visual interface, they go through an unconscious process of evaluating the relative importance of interface elements and their relationships. Therefore, it is necessary to design a clear visual hierarchy to attract users' attention to important interface elements. To distinguish levels of visual hierarchy, some basic visual elements can be used to make a contrast, like size, colour, and position. In general, the most important interface elements could be larger or have a greater contrast in hue or saturation than less important ones. After utilizing the visual hierarchy to set up focal points, it requires to arrange these interface elements to create a fluent and efficient visual flow. By comparing the results of heuristic evaluations and usability tests, a prominent finding with the visual design was that users could better recognize the visual patterns and understand the website content when they used the improved web prototype. For example, the visual flow of the product details page follows the natural reading order that moves from top to bottom and left to right. When users scan the page, they start with the large product image at the left, then move to the right supply information section that has an outstanding background colour and learn more about price and parameter information below. The key elements are coloured with brilliant blue to attract attention, e.g., the contact button, the unit price and quantity, the add button and the datasheet download button. By establishing such a clear visual hierarchy, the users can rapidly find desired information or functions on the product details page.

7. Discussion

In this Chapter, the discussions on different aspects of this thesis will be presented. This involves the final result that includes the web prototype and the UX design factors, the process of implementation, and lastly, suggestions of potential future work for this thesis.

7.1. The final result

By applying *Research through design*, the thesis has succeeded in creating the web prototype that provides a convenient online transaction UX for the target users, as well as using the web prototype to extract a set of UX factors that LED e-commerce websites need to concern when creating the website supporting users' online buying behaviour. More details of the web prototype and UX factors can be seen in Chapter 6. The following sections will present discussions about how results are correlated with literature review findings and how results can be interpreted to answer the research question.

7.1.1. The web prototype

In this thesis, the web prototype played the role of a medium to evaluate the design solutions and contributed to the generation of UX factors in the end. Specifically, it was mainly used to evaluate whether the website concept had provided a convenient experience in supporting organizational buying behaviours. By providing such a concrete web prototype to the target end-users, they could gain a better understanding of the website features and then evaluate their experience with the website. This argument can apply to each design solution created in different design stages. If there is not the web prototype as a medium, users involved in the evaluations would not have a concrete concept to respond to, which would cause the failures to collect data of user experience and answer the research question in the end.

Since the Lumway website was not an existing website, the design was started from scratch in this project. In the design of the web prototype, Garrett's five-plane model of UX (see Section 3.3.1) was used to break down the UX elements and concentrate on certain elements in the prototypes with different fidelities, which helped to design the website UX from abstract to concrete. Although the five-plane model divides UX elements into different planes, it does not mean that the work of a lower plan must be accomplished before the plan above it can be addressed. This was because it was difficult to make decisions in the lower planes when designing a complex website from the

beginning. In this project, the scope plane was reevaluated and defined after the structure plane. By creating and evaluating two sets of paper sketches, we could rapidly gather user feedback of initial design solutions and prioritize the functions of the website, which helped to figure out functions that were more feasible to develop in the later design phase.

Through user research and design practice, we have produced a set of design output that is different from competitive websites (see Section 5.3). The competitive websites provide comprehensive features regarding online LED transactions while the created web prototype focuses on limited features to support the core user workflows and considers how to enable collaborations between different user types. This was due to time constraints and the design effort aimed to create a testable prototype that could contribute to the research rather than designing a mature website like competitive websites. Some features that did not influence the core workflows were purposefully remained undeveloped or left out of the web prototype, e.g., the help centre page, the price calculator and commenting on the suppliers. Another reason was that the business objectives and target user groups of the Lumway website were different from the competitive websites. The Lumway website serves as an information platform that excludes the payment features provided by competitive websites and aims to support different roles in the buying centre to efficiently complete online transactions, e.g., managers, lighting engineers, and purchasers. And at last, the design process only took into account design factors as far as possible to exclude technical and other factors.

In terms of the UX of the created web prototype, it was deemed convenient for the users to perform tasks during the buying process. However, this evaluation result can be argued due to the limited web prototype and test conditions. The web prototype provides functions defined in the scope plane, which merely supports limited phases of the whole organizational buying process. Furthermore, the web prototype is unprogrammed and cannot allow the users to explore the website in a free manner. The limited capability of the web prototype cannot ensure the evaluated UX will be the same as the website that will be actually launched in the future. On the other hand, the participants did not perform the tasks under the real work environment with pressure or time limitation during the evaluations. The evaluated website UX was mainly influenced by the predefined task. Other possible factors that might influence the UX were excluded during the evaluations, e.g., time pressure and company regulations. But with the aim of the thesis and all evaluations made on the web prototype, it can be acknowledged that the web prototype has provided a convenient UX in the intended research scope.

7.1.2. The UX design factors

By using the approach *Research through design*, the UX design factors have been extracted successfully after analyzing the entire design process and design results. Compared with the factors that affect online organizational buying behaviour mentioned in the literature review (see Section 3.2), the UX design factors presented in this thesis show the knowledge in the academic field of UX. At the same time, UX factors presented using UX five planes structure to show what the target users cared about and what they might ignore.

The UX factors found in this research are obviously different from the common UX factors applied for all kinds of websites. The distinctiveness of the results shows the meaning of this research. There may be many reasons behind this situation. Most importantly, the organizational structure can be a key reason for the difference. To be more specific, the decision on purchasing was made by the buying centre as a team which provided a structural impact within the team on members. For example, an individual person might only care about the final results as well as the simplicity of the process to reach the result. However, people under this organizational structure might accept the more complex process in order to share the progress with others and follow the organization rules. Meanwhile, this organization changed user's expectations on the platform to be less professional. If the website aimed at target users included people in different positions, the multidisciplinary professional requirements might be hard to balance with the system consistency.

Although this thesis has divided UX factors into different planes of UX for external researchers and designers to sort out different factors as well as showing the relationship between each other, it should be noted that the lines between these areas are not always clearly drawn under the real circumstance. Commonly, it can be difficult to identify which design factor is best to be concerned with to solve a particular user pain point. Some pain point needs to pay attention to several design factors on the same plane at once, and some seem to be correlated with factors in different planes. Furthermore, it is very difficult to evaluate the effect of one design factor by separating other ones when all factors work together to accomplish the UX goals. Therefore, it is suggested to carefully analyze the underlying cause of the problem and consider the interplay of design factors when taking into account the proposed design factors during the design.

7.2. The process

The approach *Research through design* was applied in this thesis to extract design factors

to answer the research questions generated in the domain research. To create the web prototype used in research, Garrett's five-plane model of UX was used in the design process following the *double diamond model* and integrated the methods presented in the methodology chapter. Regarding the whole process and methods used, all methods were deemed significant in producing the final result. However, some changes would have been made to improve the project process if we had the opportunity to retake the project.

The UX questionnaire was adapted from the AttrakDiff and consisted of ten semantic differential scales that aimed to evaluate the intended UX values. This tailored questionnaire made the UX evaluation more efficient and adequate in our research context. Although the AttrakDiff correlated each semantic differential scale with different aspects of UX, we still did not know the underlying reasons for each rating score when the UX questionnaire was used to merely collect quantitative data. If more time was given in this thesis, the qualitative data of the users' attitudes and expectations could have been collected to deeply research the reasons for forming the user experience. One way is to add some open questions at the end of the questionnaire. However, this has the disadvantage that people might not be willing to type answers and the responses will be few. Another way is to hold interviews or focus groups with some users involved in the questionnaires, which require more time to investigate the users. Furthermore, the UX questionnaires were filled by users who learned about the Lumway website for the first time. This only evaluated the initial user experiences with the website. As the users gradually incorporate the website into their work routine, the users will become intermediates and their experiences will also change over time. Thus, the evaluation of long-term user experiences should be carried out in future development.

It was beneficial to apply the heuristic evaluations before testing with the end users. By identifying and then fixing the usability problems of the web prototype, the users could have a better experience with the improved prototype, which made the usability tests more effective. To make the heuristics more appropriate to evaluate the specific class of websites in this project, Nielsen's ten heuristics were expanded into 26 sub heuristics according to the literature review. However, it caused the participants to spend more time reviewing and understanding these heuristics before they started the tasks in the evaluation. Moreover, it increased the difficulties to inspect the interfaces when they required keeping all heuristics in mind. Therefore, the heuristics used in the evaluation should be reduced to a reasonable number and improve the efficiency of inspecting.

In terms of the user involvement in the usability tests and the UX questionnaires, it should have involved more users who better matched the characteristics of the defined personas. Because of availability, participants of the evaluations might only work with small organizations. Although these participants had experience in purchasing LEDs on competitive websites, they might only have had experience in collaborating with limited

colleagues in the actual B2B purchase environment. Since the different organization size might have an influence on decision making stress or organization rules, the results on how people act on the website and how they feel may be different due to this. In addition, although the preliminary work of this project was carried out in Sweden and the website was aimed to serve the global LED market, all the design evaluation work was carried out with Chinese participants. The possible influence of different cultures on the results was not discussed in this study but may become an influencing factor. In an ideal scenario, involving users from several different countries in the design evaluations would be desired. In this way, it would be possible to gather feedback from users who had different cultural backgrounds, and in the end, result in design factors that depend on cultural differences.

When it comes to the ethical issues in this project, privacy and trust are rather important in the B2B e-commerce context. Since the website needs to collect some privacy data from the customers to provide services during the buying process, it is necessary to consider how to protect these privacy data and increase the trust from the customers during the design. In the final design, the website provides the links to the privacy and security items on the sitemap footers for users to learn more about how their privacy security can be ensured. However, due to the time limitation, the website does not explore other approaches to protect privacy in more usage scenarios, which should be further developed in the future. In terms of usability in the ethical issues, the created website has successfully provided a convenient UX where the usability issues are sufficiently concerned. Since the B2B website serves the buyer organizations, it is necessary to fully take into account different roles of users in the buying centre and ensure good usability for different user types. To make the website easier to understand and use, the help system of the website can be further developed to offer more useful assistance in diverse usage scenarios.

7.3. Future work

As mentioned earlier, due to time constraints, the created website only supports a small part of the workflow in the entire organizational buying process. Therefore, the future work of this thesis research can be carried out to develop a completed function system to support the whole buying process. The extension might include more functions as well as more requirements like connection to the user's own ERP system. This will include more people in different positions to see the impact in B2B context, which requires conducting more user research to investigate the actual needs of different user types in the buying centre of the organization. However, with more functions added to the website, the workflows and interaction with the website will become complex. This will bring

challenges for designers on how to balance the complexity of function structure with the simplicity of interaction and learning to keep the convenient UX for B2B websites in future development.

Except for website iteration in the future, the research on UX factors in B2B context also have possibilities to further polished. Some UX factors that might have influences on the user's buying process were not fully discussed in the thesis, for example, the accessibility of the website and how the homepage supports the user has not yet been evaluated. Since we gave the participants some specific tasks, it might not show how users who do not have a clear goal like that use the website. During the evaluation, the user has informed the website as a saved link. However, there might be many ways for them to access the website, for example, searching via Google or opening the link shared on social media. The current homepage merely displays the banner with a search box and the entry points to three main features. Other kinds of information that helps to encourage purchases are excluded on the homepage, e.g., promotions for products and customer comments. Those impacts of how they first visit the website and what the website should show to them when they first visit have not been discussed in the research. Another factor that might have an influence on their using process is personalization. By collecting and utilizing the information of user's registration forms, purchase history and browsing history, the website can be tailored for each user, which leads to a more convenient user experience and higher conversion rates. In order to realize personalization, users need to at least visit the website twice to let the system use cookies to provide service based on individual behaviours. However, since the prototype created in the design process was not a programmed website, it could not record the data or any cookies. Without showing users what personalization in design means, the related topic was not fully discussed during the evaluation session. Some suggestions given by the users on expected changes of the website can be seen as a need for personalization, like changing the colour or changing the search results order.

As mentioned in the previous section, the website will serve the global buying organizations and website UX might be influenced by cultural differences. Therefore, users that have different cultural backgrounds should be involved in the design evaluation. This might result in design factors that are correlated with cultural differences and a strategy to apply different design factors to better serve different countries. Besides the cultural differences, the feasibility of more assumptions and design factors can be further verified on the basis of the current design modification. If other buying processes are considered in the research in the future, more influencing factors can be discussed and verified, such as the influence of geographic location on buying behaviour during the order delivery process.

8. Conclusion

This thesis aimed to answer the research question:

RQ1: How does convenient UX impact the B2B purchasing process?

RQ2: What are UX design factors that should be considered when designing the B2B website to have a convenient experience?

To be able to answer these questions, *Research through design* was applied, where a B2B website was created and used in the evaluations to research the answers for Research Questions. To create such a website, a design process was carried out, which followed the *double diamond model* with suitable methods and utilized Garrett's five-plane model of UX to build the website UX from abstract to concrete. Based on domain research, user research, design development, and design evaluation with the users, the final design and answer to the research questions were generated in the end.

In conclusion, for RQ1, the convenient UX is perceived as simple, efficient and appealing from the user perspective, which enables the buying centre to easily accomplish product specification and supplier search in the buying process. In terms of individual experience, the convenient UX enables different users to efficiently perform tasks as well as effectively collaborate with each other. To conclude, the convenient UX can attract users to try the website, enable users to efficiently perform tasks during the purchasing process, motivate users to make repeat visits due to simplicity, and result in higher customer satisfaction and conversion rates.

The final answer for RQ2 is a set of UX factors, which are considered in the design process of the B2B website that support the organizational buying behaviour. In this case, it is necessary to fully consider all type of users in the buying centre in order to provide support. As part of the result, the created design can provide a visual design reference to understand how a convenient website would look like when the proposed design factors are used. What are design factors and how they support B2B organizational buying process by creating a convenient experience are summarized as follows:

- **Develop the help system to teach and introduce the web**
By solving the learnability problems of how the website can work to support users using the B2B website during the whole buying process
- **Use the simulation function as a tool to support showing technical capabilities**

Enable users to quickly evaluate and learn about the product performance in the product specification phase

- **Progressively disclose controls**
Hide the advanced or less frequently used controls on the interface by default and allow users to rapidly find desired controls to perform the task
- **Simplify the interactions of controls**
Make the interactions of controls as simple as possible to improve the efficiency of tasks
- **Establish an efficient and intuitive navigation system**
Users can efficiently move through the website to get to the desired content
- **Provide modeless feedback to users' manipulations**
The users are informed by the system immediately without interruptions when they take actions to perform the task
- **Keep the visual interface minimal**
Design the visual elements in a simple style so that users will not be distracted from their tasks
- **Design a clear visual hierarchy and lead the visual flow**
Attract users' attention to important interface elements and ensure visually efficient

Even though the result was successfully accomplished in the end, it has to be noted that those results are not the only UX factors for designing B2B online websites. When user groups and background industries change, users' mental model and needs may change as well. When applying the results of this research, it needs to consider the similarity to see the possibility of using the results as a reference.

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Appendices

Appendix 1: Interview script

Appendix 2: Affinity diagram for interviews

Appendix 3: Personas

Appendix 4: Brainstorming

Appendix 5: Wireframes in Figma

Appendix 6: High-fidelity prototype for heuristic evaluation

Appendix 7: Heuristic evaluation script

Appendix 8: Heuristic evaluation checklist

Appendix 9: Heuristic evaluation result

Appendix 10: Usability testing result

Appendix 11: UX questionnaire

Appendix 1: Interview script

The interview script was used with small changes when different kinds of users were interviewed, such as the chief executive officer, the production manager, and the lighting engineers.

Introduction

Thanks for attending the interview. We are two master students from Chalmers and now developing the web portal of Lumway. To learn more about our consumers, we would like to ask you some questions about your daily workflow and your opinions on our ideas. Your feedback today will help us to improve the design.

General questions

1. Which company are you working for and How long have you worked here?
2. What is your position in the company? Main responsibility?
3. Who is your customer? What kind of company?
4. What makes your products stand out from the competitors? Where would have better information that helps you create a better product?
5. How do you keep track of your competitors?

Workflow

1. Could you guide me through a project cycle of yours?
2. What is the most difficult/challenging part of the project?
3. What different solutions to this problem have you tried?
4. What would you like to do your job better?

Select LEDs

1. How do you choose an LED for a product? How do you get the information about the desired LED?
2. Do you trust the datasheet you get from the suppliers?
3. How do you ensure the quality of an LED's various parameters?
4. Do you use any tools to test? What are the main limitations of using the tools you are using?
5. Would you compare different LEDs before choosing one for a design? How do you compare one LED with another?
6. What percentage of all suppliers in the market do you think you have “gone through” when comparing different LED components?
7. How much time do you spend comparing different LEDs to a particular application?
8. Do you have access to all options on the market? How do you know that you have made a good choice for it?

Purchase LEDs

1. What part of the LED does your company buy (chip, package, module, luminaire)?
2. What is most important when buying the LED part?
3. Who is making the decision of what product to purchase?
4. Do you always look into several suppliers when it is time to do a new order? How many suppliers do you compare? Who is mainly doing the supplier research/evaluation?
5. Do you have established partnerships with your suppliers?
6. How do you stay up to date regarding all suppliers' new products?

Ideas of Lumway website

Supposing that there is a web-based platform with a database of global suppliers and their products. All products are tested by a third party so that the database is verified. You could be able to search for solution alternatives by filling in the technical parameters that your application requires, and then use a virtual lab where you can change different parameters to see how it affects other parameters and compare LEDs to find the best one. How do you feel about the ideas?

Appendix 2: Affinity diagram for interviews

The users			
From companies that provide lighting solutions to different industry		Take different work routines depending on their roles in projects	
<p>U7-1 Lighting design is our largest customer. Museums, churches, public environments.</p> <p>U8-1 A small organization offering lighting solutions to caravan and camping cars mostly (and yacht a bit)</p>	<p>U8-2 Buying the flexstrips and customizing them based on customer wishes.</p> <p>U10-8 Receive specific lists of electronics that companies in Sweden need and do the logistics for them. They contact all distributors that have those components and negotiate the price and availability of those components.</p>	<p>U2-1 Tailors everything that is produced to the customer. Parameters are set together with the customer. Then a designer draws proposals for a module or luminaire.</p> <p>U2-5 Check the email. Production meeting. Purchasing and production planning. To-do list.</p> <p>U13-4 Understanding application, specify parameters of LEDs, consider other hardware around LEDs</p> <p>U12-1 Industrial and thermal design from the products.</p> <p>U3-4 When working on an LED project, both the administrative and the technical that takes time.</p> <p>U3-2 I want to understand what the customer needs faster and easier, so that it becomes clearer. Simply makes everything faster and easier for all parties.</p>	<p>U8-3 Project management to clients based on customer needs. The organization is a project/purchase/supply chain management.</p> <p>U11-1 I am involved in the development process, I light measure and heat measure our products, light meters on entire luminaires and on modules before they go out.</p> <p>U3-3 Works a lot with customers. It's a lot about understanding what the customer wants. then I will specify the customer's "product dream" to more technical parameters.</p> <p>U2-4 Wish to not work so much for the customer. But generally structure how you work. Use checklists. Have everything raked out to be able to do as good a job as possible.</p>
Make strategies to be competitive			
<p>U3-5 We are more fast-paced and work customarily. Can be faster on site and provide better support.</p> <p>U4-3 It is necessary to constantly check what the market offers in order to stay ahead of the competition</p>	<p>U5-5 You are more competitive if you have better LEDs.</p>		

Select LEDs			
Use different tools to test and compare LEDs		Tend to trust large suppliers' datasheet and ask suppliers for details	
<p>U1-13 Tests are performed to guarantee the quality. Lifespan testing under different temperatures is incredibly important in car production</p> <p>U2-3 To compare different parameters at the level of detail, we use SP / RISE to do tests.</p> <p>U4-2 Use the simulation programme: SPEOS, ANSYS, Catia, Lighttools, Lucidshapes</p> <p>U6-2 Use dialux, selects luminaires, tests sound levels, picks everything from manufacturers' databases online.</p> <p>U7-3 I have my own tool - an excel sheet where I can enter parameters.</p>	<p>U1-3 It would be interesting for the company to have more LED testing, with more suppliers</p> <p>U4-9 Goniophotometer (or Sphere) measurement to get the data for greenhouse simulation</p> <p>U5-7 Sometimes test the LED into own facility, Would be nice to test the parameters in-house.</p> <p>U5-8 Get details from Lamp characterization in order to do simulation. Test the lamp in a Goniophotometer. Put the data you get from this test into the simulation. The whole luminaires.</p>	<p>U1-1 I trust the data from the big actors</p> <p>U3-1 Trust the datasheets for the LEDs. In combination with years of experience it is enough.</p> <p>U6-1 Gets data through the use of online catalogs/datasheets that the lighting producers have</p> <p>U12-5 Gets the data from the datasheet from suppliers and add the info from our side such as heat sink efficiency, driver outputs etc.</p>	<p>U1-12 I trust smaller companies' datasheets. I am trying to build up information about suppliers, by asking for more data sheets.</p> <p>U4-1 I trust the big companies datasheets, Mostly we still have to process the available data available on the datasheet, usually by asking the specifications to the supplier</p> <p>U8-11 Have datasheets which we ask directly to the suppliers. Then, the suppliers fill up the datasheet based on our product's performance.</p>

<p>U5-10 Test the lamp in a Goniophotometer. Put the data you get from this test into the simulation. The whole luminaries.</p> <p>U11-7 Use own testing equipment or use an already established testing institute.</p> <p>U13-1 Use tools provided by distributors or suppliers to select LEDs. These tools are very similar. They provided limited feedback.</p> <p>U9-10 What I have noticed over the years working with lighttools, there are a number of suitable software for ray tracing, but for us its lighttools, others are ASAP, tracepro, photopia, c-max, half a dozen packages that can be used for illumination.</p>	<p>U6-5 In dialux: draws a whole room. When taking in ldt / luminaire file: you get the right image of the light, but not so high resolution image of geometry.</p> <p>U12-4 Works with SCFD to simulate thermal and fluid flow</p> <p>U12-3 Excel spreadsheet tool - calculate the thermal flux and lumen output from the combination driver + LED + heat sink</p> <p>U11-8 I feel it is easy enough to compare suppliers using existing tools (like LED calculators)</p> <p>U11-9 We have had test equipment for chips before as well.</p>	<p>U1-18 If ask the major players about their performance, you will receive a report. They must have a basis for how their products perform. The reports they have are confidential. They do not share these voluntarily.</p>
Use graphs to analyze LEDs		
	<p>U12-6 Needs to make the graphs digital and it is quite time consuming. He uploads an image of the graph and set points on the curve and get a function that matches it,</p>	<p>U9-4 Basically we need to rely on the graphs we get from the data sheets today.</p>
Look for information about LEDs through different channels		
	<p>U1-10 Initially, start using something used in a previous project. Otherwise, turn to a supplier with whom I have contact or have a good brand or have easily accessible information about what I want to know about.</p>	<p>U1-6 I spend the least amount of time in the LED selection step as I only use the data I have available from the largest producers.</p>
Characteristics of LEDs that users tend to focus on during selection		
<p>U1-20 Electricity consumption, color, effect, spreading angle, production capacity are important</p> <p>U4-8 Determine the desired Spectrum, necessary energy efficiency, and Choose the LEDs to get the desired outcome</p> <p>U5-1 Specify spectrum, energy efficiency, efficiency photon.</p> <p>U9-8 the data on the colour coordinates is necessary.</p>	<p>U1-5 I need to know that the lifespan of the LEDs are good</p> <p>U6-4 We look at the type of joint, sound quality, color reproduction, light image</p> <p>U8-10 Care about legal requirements, lifetime, colour temperature, tolerance of the white, apparent differences, dimension tolerances.</p> <p>U11-4 It is a lengthy process - and a very important parameter</p>	<p>U6-3 Light scattering, everything comes from online catalogs. Manufacturers have catalogs</p> <p>U10-3 SCHC and ROHS check if the components have contaminants against regulation</p> <p>U12-2 From selecting the LED type, selecting the materials for the heat sink and the heat management from the interaction of the system: Driver+LED+Heat sink+PCB.</p> <p>U13-3 Always use the future electronics website to find LEDs and uses its tool.</p>
	<p>U10-4 Octopart.com - database with several components, showing their specifications, and prices, where I search with the part number where which distributors have such a product</p> <p>U5-4 It is important to know about what is happening in the for front.</p>	
Problems in searching LEDs		
<p>U13-2 It is inefficiency to gather different information of LEDs from different LEDs on the market.</p> <p>U1-8 Lots of benchmarking on cars is available through a company called A2MAC1.com - but not for LEDs at a detailed level</p>	<p>U10-1 High end products are more difficult to come by (less availability). Ceramic capacitors (relays, connectors, inductors as well) are also very difficult, sometimes having lead times up to 6 months</p>	

Purchase LEDs	
Prefer to buy products from large suppliers	Buy components from different suppliers
<p>U4-7 We are approached by big companies (5-8), Cree, Osram, Lumileds, Nichia, Samsung</p> <p>U11-3 We try to stick to the big, well-known brands, the companies.</p> <p>U4-5 Usually do not research better opportunities outside the big companies</p> <p>U5-3 The big ones are more reliable. Horticulture market. OSRAM, Cree, LumiLED, Nichia, Samsung</p> <p>U7-12 The supplier brand plays a bigger role in sales than the possibility of a better fitted component</p>	<p>U7-10 I prefer not to go to someone unknown. It might be less accurate if it was a really good price.</p> <p>U11-6 We think mostly of well-known manufacturers. The supplier brand plays a bigger role in sales than the possibility of a better fitted component</p> <p>U12-7 Mostly use well known suppliers because these are companies that already have the components we know and that matches our need.</p> <p>U1-2 The big actors have everything you need related to simulation data, but the smaller ones only have PDFs - then I have to do it manually.</p>
	<p>U11-2 we evaluate all different modules from different manufacturers. So that they are within tolerance.</p> <p>U1-21 Choose the supplier, ZKW, HELLA, VALEO, Automotive Lighting, ESOV</p>
	<p>U8-5 Buy plastic from Germany, metal stripes from China, manufacturing in China. They give the material to subcontractor and they put it together.</p>
	Value the long-term collaboration with suppliers
	<p>U7-2 We use the brands we are used to. Sometimes, of course, something exciting appears from another supplier, or something else is speculated by the customer - from, for example, Cree - then you have to run on it.</p> <p>U12-10 Relationship plays a large part. Sourcing is constantly chasing better suppliers, especially for high volume products</p>
	<p>U7-13 Relationship with the supplier is the most important. There is no point in verifying different suppliers since the partnership with them is more valuable than the possible gains of changing</p> <p>U8-5 Established partnerships: Btop, Coolight, Elektra</p>
Factors influence the trust on suppliers	Access and evaluate suppliers
<p>U1-4 The small actors don't have ray-files, but the first step to trusting them is to get ray-files. But we would also need to know the capacity they have to produce large volumes of LEDs - but these are not questions that I work with.</p> <p>U9-1 One reason we avoid the Asian manufacturers is because they have too little information. We can't rely on them because no test data, are they a reliable supplier etc.</p>	<p>U9-7 In order to trust a supplier it is necessary to have at least one company that has used their product before and has a good feedback</p> <p>U9-9 Trust issues with past suppliers seemed more related to the inability to supply the product (discontinuation of a product that is still listed in the website or being "sold" by salespeople and lack of availability of product) or changes in the product (updates) with no prior warning.</p>
	<p>U1-19 Most suppliers report what they are good at but perhaps hide what they are not as good at.</p> <p>U8-6 Always benchmarking with other companies and it is possible to get half price flexstrips. Compare the raw data on the company: turnover, personnel, technology, where they operate.</p> <p>U8-12 going to fairs to meet suppliers, recommendations from customers, Also potential new suppliers contact us. We basically try to reduce the number of suppliers to reduce the logistic prices.</p>
	<p>U1-9 Compare About 3-4 suppliers. I build my own library. OSRAM is huge. There are many players.</p> <p>U8-7 15 to 20 suppliers are checked. But it is not a one time benchmark. Whenever something new appears, we start testing to see if it is better than our current supplier.</p> <p>U10-2 IHS Markit, a place where you can verify if suppliers are compliant with European laws (standards and certificates)</p>
Negotiate with suppliers	
<p>U1-15 Get in touch with purchases and then have a price negotiation.</p> <p>U8-13 We have one supplier which are supplying them always with good quality and small volumes - that supplier I never negotiate with. We negotiate when they have to pick the best match</p>	<p>U1-11 It is always possible to negotiate the price. Often about 30%</p>
	Different roles participant in making purchase decisions
	<p>U1-14 Make a prototype and show it to their managers and explain which LEDs it is in. A person from purchasing is also usually involved. Reports what I use by compiling everything in a presentation. Compare the one used in the prototype with 3-4 other suppliers.</p> <p>U1-17 Engineering - Design - Purchasing / Finance ("a triangle"). Always a compromise between these three parties. Always initiated from the Purchasing Department.</p>

Sometimes changes would be made to the LEDs during production		<u>U1-16</u> The person who is the assignment leader is responsible for the total cost of the project.		<u>U13-5</u> Compare different aspects of LEDs to find the most cost-efficiency one.	
<u>U5-2</u> Some companies have adjusted their datasheets to plant LEDs.	<u>U9-6</u> It has happened that a provider just sent out a new spec for an LED. So same model, reduced performance - probably due to bad performance of the first products in the field, lead the company to update the specs in the datasheet.	<u>U13-6</u> Buying decisions depends on the customers and the appliance.	<u>U10-7</u> The clients determine the specifications and components to be used	<u>U13-7</u> Sometimes a company will change their datasheet (probably because it was not complying with the actual performance) and not warn customers about it	
Change LEDs in a product would cost much		<u>U4-4</u> Need to know the pricing in addition to other parameters as it is always a compromise.	<u>U9-3</u> Usually different sections and people in the company investigate different parts (electrical, thermal, optical). Then it goes to sourcing department and in case the availability and pricing matches the needs, they purchase it.		
<u>U4-6</u> Changing LEDs have a high opportunity cost. It usually means changing the whole product, so it would likely mean a new project development.	<u>U5-6</u> It is not easy to switch LEDs.	Large volume of products is common in the transactions			
Establish a network for purchase work		<u>U7-4</u> Many Asian manufacturers that have appeared in recent years have been a bit clumsy with this with volumes - they like large volumes and demand it before they release	<u>U8-8</u> Chinese suppliers are interested on high volumes, so they only take suppliers willing to offer low volumes with competitive price.		
<u>U8-9</u> Have a purchasing network, so that's where I reports it. Every month we conclude all data. We bundle all the necessary orders with Siego (software) and it is shared with everyone in the purchasing operations.	<u>U10-6</u> The procurement department do a lot of manual work to see which distributors have which part, by going to each website and typing the part number	<u>U9-2</u> We produce big volumes, therefore price is important.	<u>U8-4</u> Minimum order varies 500 pieces for China for most of the companies		
Keep in contact with suppliers					
		<u>U7-5</u> I value very much personal contacts. The ones we trade with are the ones we know very well.	<u>U7-14</u> If you have started a contact with a supplier and take technical support from them, then you use them. On the other hand, you may sometimes want a second source as a fallback if something happens to your main supplier.		
		<u>U1-7</u> I can get a lot of stuff for free from different suppliers, e.g. leds, plastics, prisms, because they know that I am a prospective large volume buyer			

Feedback to Lumway's simulation tool			
The test function is useful		Willingness to pay for the platform	
<p>U7-6</p> <p>The virtual lab is useful for me as a electronics-engineer for selection and comparison</p>	<p>U12-8</p> <p>It would be very helpful to have a same baseline</p>	<p>U7-7</p> <p>I could see us paying a yearly fee for access" / "It would not ruin trust if suppliers paid to be on platform"</p>	<p>U12-9</p> <p>Definitely would pay for this platform.</p>
<p>U7-8</p> <p>I would trust RISE or Semco as a third party testing institute.</p>			
More information should be provided to users		Wishes to the platform	
<p>U12-11</p> <p>Of course the LED is a part of this tool, but it is more than just an LED selection tool, it is something you use for designing LED.</p>	<p>U9-5</p> <p>A platform like what you suggest should keep track on updates of chipsets, end of life.</p>	<p>U7-11</p> <p>This would simplify things for us and it would be constantly updated -perhaps a push notice that there is now new stuff from OSRAM.</p>	<p>U10-5</p> <p>I am interested in finding the suppliers by simply typing the part number</p>
<p>U7-9</p> <p>Except for having verified parameters for the product - it is important that the new supplier is available, e.g. can provide samples, deliver whenever the customer wants to purchase a new order etc.</p>	<p>U11-5</p> <p>Factors such as how much a supplier can deliver, that they take responsibility for problems, consistency, client list, logistics and other things which you do not show on the current platform are much more important</p>		

Appendix 3: Personas

1. The approvers



Thomas 40

CTO | The decision maker

Goals & Objectives

–Participate in forming the company's quality system, continuous improve the quality control workflow.

–Set direction for the design team to ensure product competitiveness

His scope of work is to participate in the company's decision-making and approve the design team's plan.

Behaviors

Review design team's outcomes, establish some acceptance criteria for the design results

Participate in supplier reviews, review supplier information with purchasing engineers to establish a reliable supplier list.

Traits

Domain experience



Multi-tasking



Tutorial usage



Amount of time spending with this tool



Thomas is 40 years old and works as the CTO of a lighting manufacturing company (see Figure 6.7). His scope of work is to participate in the company's decision-making and approve the design team's plan. Working as a member in the buying centre, He can use his own experience to identify the risks from the product designed by the team. Although he does not directly work with the engineering team to design the product, he will establish some acceptance criteria for the design results. After the products get approved, he still needs to collect project-related data and conduct qualitative analysis.

For quality evaluation, he also needs to participate in the supplier selection phase, which requires him to review supplier information and proposal with purchasing engineers to establish a reliable supplier list. Because choosing the cheaper LEDs from the supplier that is out of the list can be risky. Therefore, when the price gap is not big, he would suggest the team adopt the strategy of establishing long-term cooperative relations with some well-known large suppliers. Because large quantities of orders can also get certain discounts.

As a team manager, he values the efficiency of teamwork and hopes to simplify the project process. If the tool can improve the working efficiency within the team and increase the speed of product development, he is willing to try and pay for this new digital solution.

2) The influencer - primary user



Jessie 30

Lighting engineer | The primary user

Goals & Objectives

- Design the idea of products that meets the requirements
- Cost & quality control

Traits

Domain experience



Multi-tasking



Tutorial usage



Amount of time spending with this tool



She works in a company that provides customized lighting solutions services.

Behaviors

Design, debugging and testing of the customized product and the power supply

Evaluate the most optimal component together with the purchasing department

Jessie is a 30 years old lighting engineer working in a medium company that provides customized lighting solutions services (see Figure 6.8).

During the project, She is mainly responsible for the design, debugging and testing of the customized product and the power supply. After she gets the requirements or needs of customized lighting products from customers, she will start to design the product according to the product goals and working environment. She will also initially determine the range of available electronic LEDs based on parameters. Then the lighting engineers team will have a discussion on the selection of those alternative LEDs. After reaching an agreement on the LED that the product will use, Jessie will start to evaluate the most optimal LED supplier together with the purchasing department. Usually, she will visit several large suppliers or manufacturers' websites to compare the quality and the price of the LED. Then she will contact the supplier to gain further related data files as part of the supplier proposal before they order the LED. At this phase, the lack of completed and verified data files will affect Jessie's decision on purchasing.

As the primary user who might go through most functions of the website we plan to design, she wants to have fluent experience when she uses it, like other apps or websites she uses in daily life.

3) The influencer - the secondary user



Morga 28

Purchasing engineer | The secondary user

Goals & Objectives

–Get information about the components in order to compare prices and quality

–Data maintenance and document information of the electronic components system and make sure update in time

He is responsible for procurement related work and cost control

Traits

Domain experience



Multi-tasking



Tutorial usage



Amount of time spending with this tool



Behaviors

He contacts the supplier to get further information to compare prices and quality.

He conducts some researches on potential suppliers and do the data maintenance and document information of the electronic components system

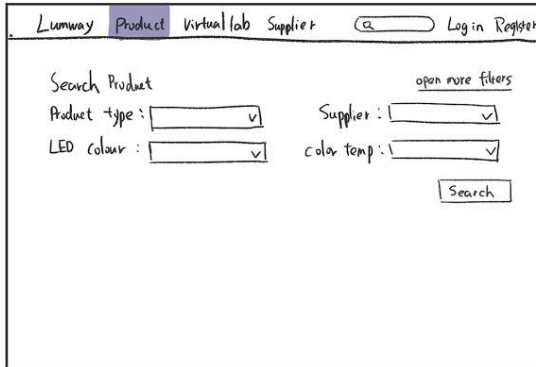
Morga is a 28-year-old man working in a luminaire company (see Figure 6.9). He is a purchasing engineer who is responsible for procurement related work during the supplier search, proposal solicitation with offline lighting performance test, supplier selection, order-routine specification phases to control the cost. Usually, he will conduct some research on potential suppliers and then share the reliable supplier list with lighting engineers to help with the supplier selection. After the evaluation of the LEDs with the lighting engineer, Morga will contact the supplier to get further information about the LEDs in order to compare prices and quality. When the need is to purchase products from new suppliers, Morga will spend a lot of time evaluating potential suppliers before making decisions.

After the procurement work, Morga needs to do the data maintenance and document information of the system of the electronic LED, which requires him to keep in contact with collaborated suppliers. In some cases, there might be a change of the LEDs, it is important to get the notifications in time.

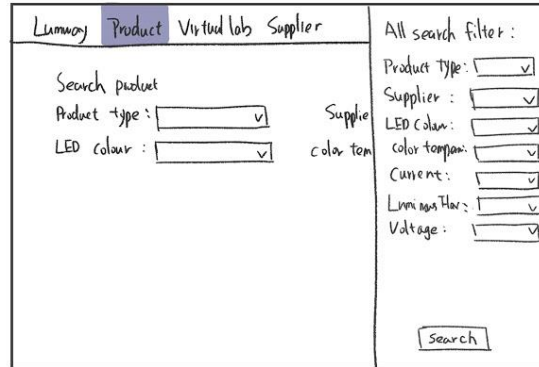
As the secondary user of the designed website, Morga might not always need to go through all features of the website while he is using it. A simple handover is important for him.

Appendix 4: Brainstorming

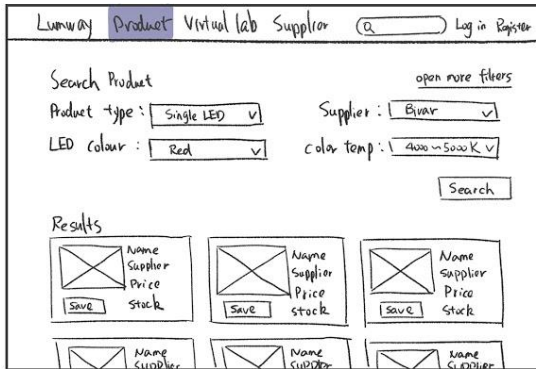
Prototype A: "Search LED components".



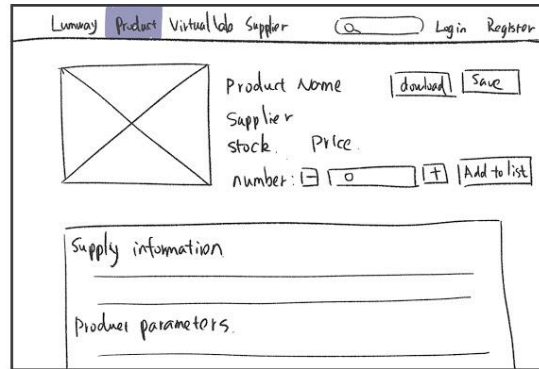
01. On the home page of "product", set the frequently used filters to search products.



02. Click "open more filters" to use more filters (if needed) in the pop-up drawer.

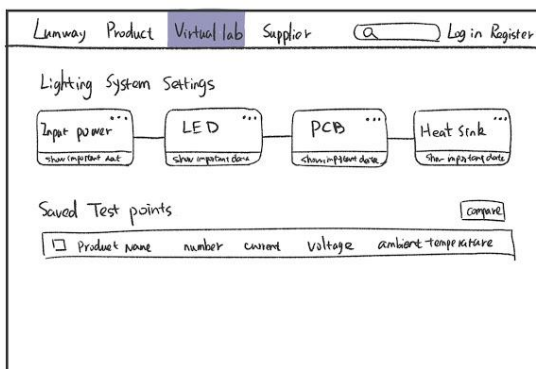


03. Click "search" to apply filters and see the results in the below.

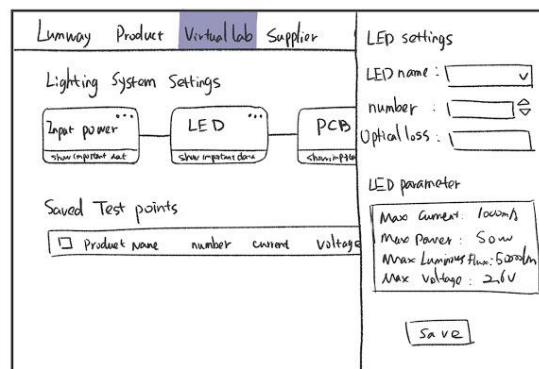


04. Check the details of one product.

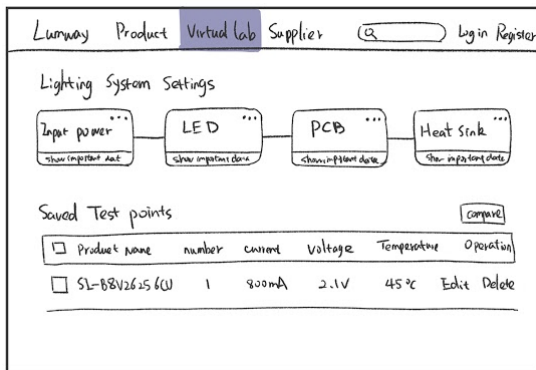
Prototype A: "Test LED components".



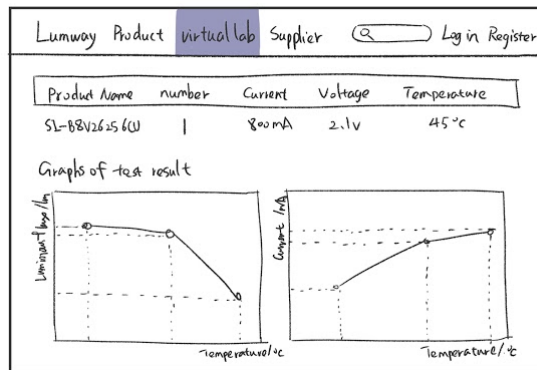
01. Click the four modules above to create a new test point.



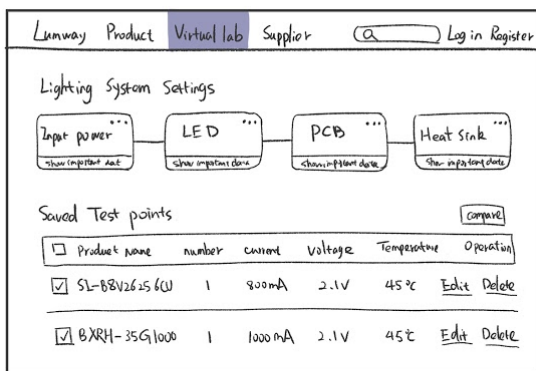
02. Finish settings in the pop-up drawer for each module and click "save".



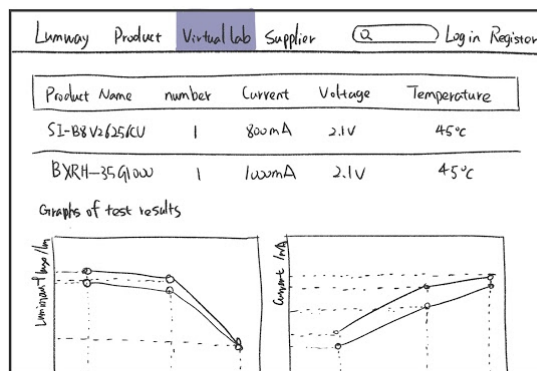
03. A new test point will be generated in the table below.



04. Click the name of the product and check the test result.

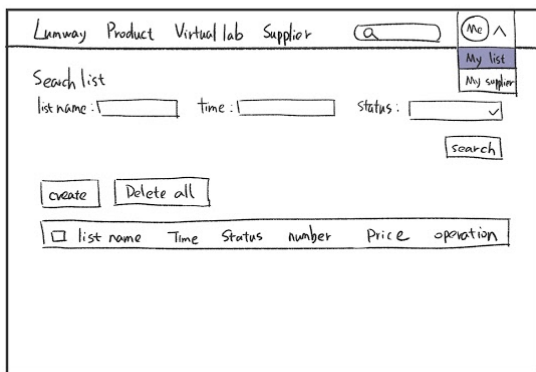


05. Select two saved test points and click the "compare" button.

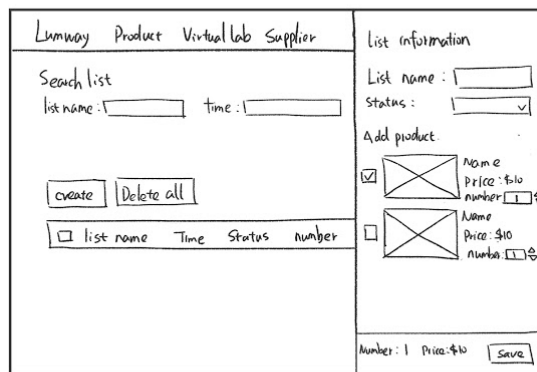


06. Compare the test results of two test point to see which has the best lighting performance.

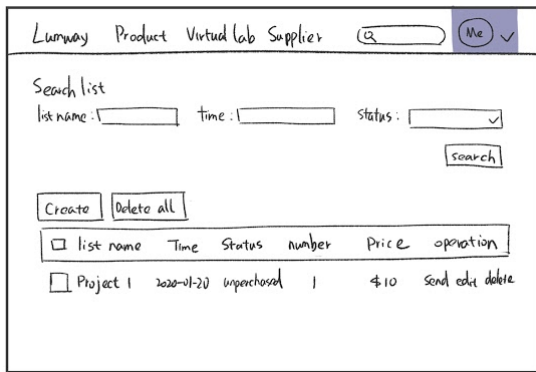
Prototype A: "Manage procurement lists".



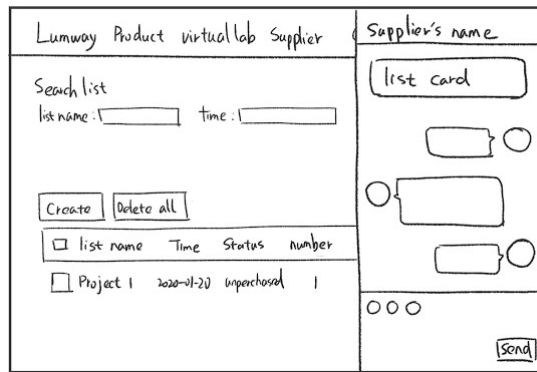
01. After login, click "my list" to access the home page of list management. Then click "create"



02. Fill in the information in the pop-up drawer and click "save"

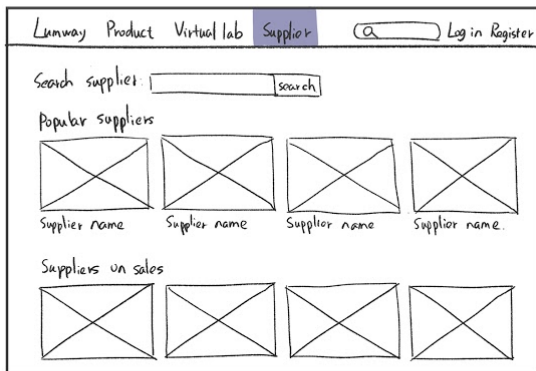


03. The new list will be added in the table and click the text button "send" on the right.

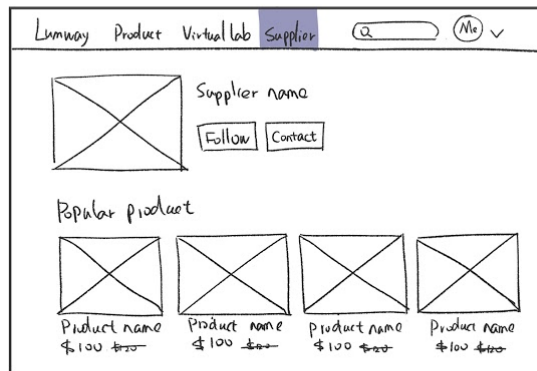


04. Ask the supplier questions about the list in the pop-up drawer.

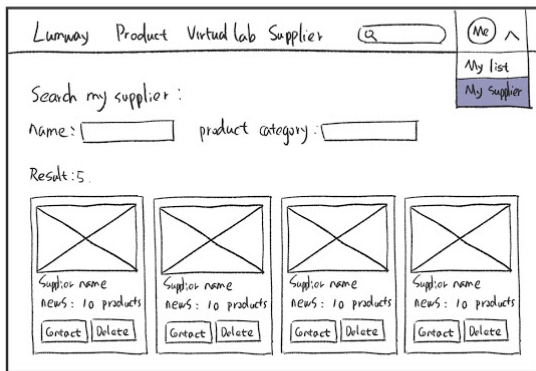
Prototype A: "Keep contact with suppliers".



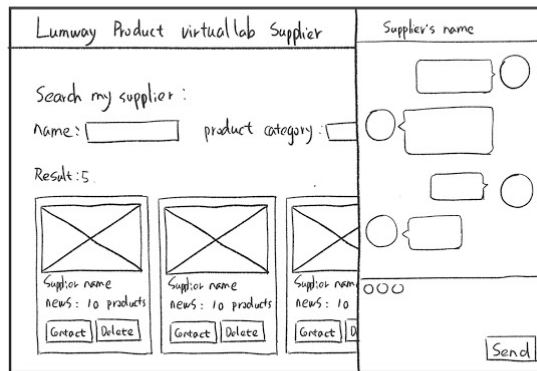
01. On the home page of supplier, find and check an interested supplier.



02. On the detail page of the supplier, follow the interested supplier after login.

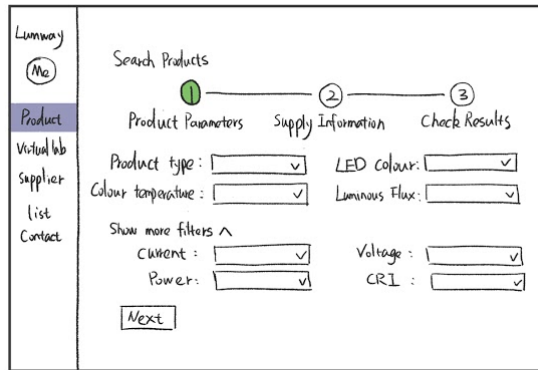


03. Open "my list" collection, keep updated with followed suppliers' news.

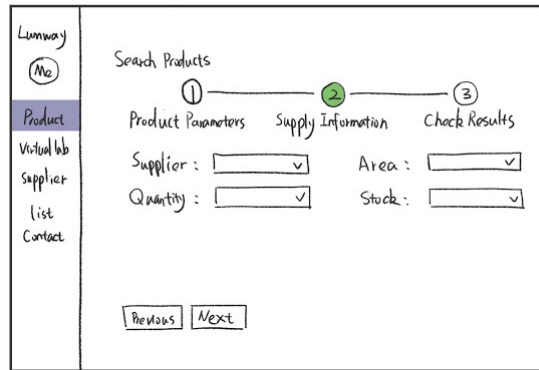


04. Click "contact" to chat with the supplier in the pop-up drawer.

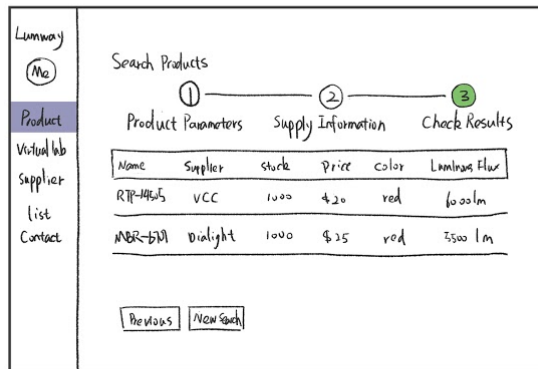
Prototype B: "Search LED components".



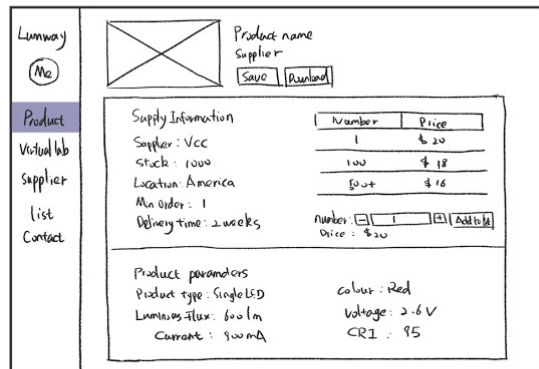
01. Set the filters of product parameters and click the "next" button to next step.



02. Set the filters of supply information and click the "next" button to next step.

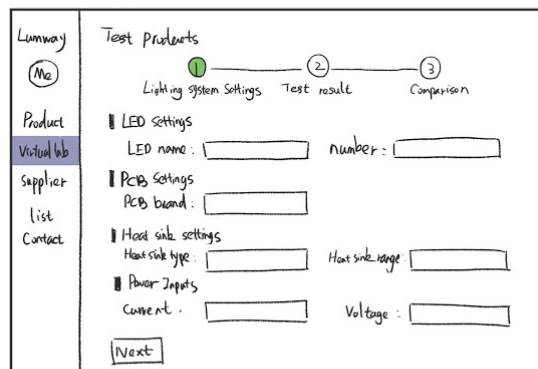


03. Results that meet needs are shown in the table. Select one product to learn more.

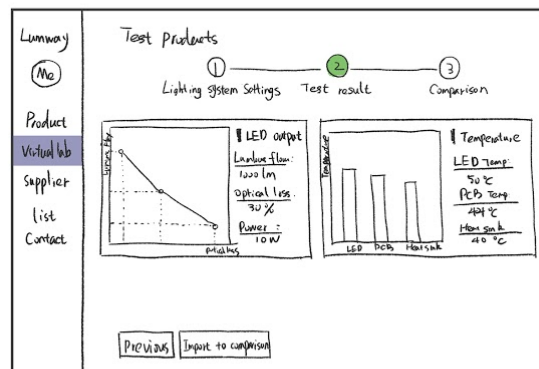


04. In the detailed page of the selected product, users can save this product or add to list.

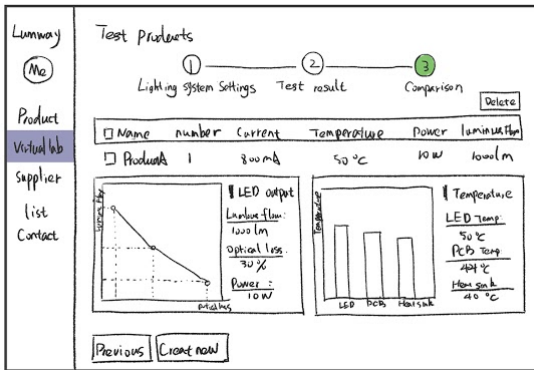
Prototype B: "Test LED components".



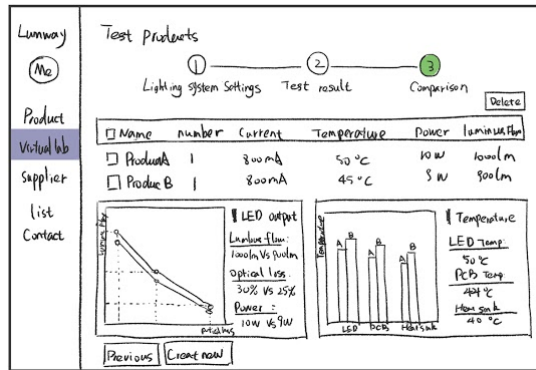
01. Set the inputs of LED, PCB, Heat sink and power respectively.



02. Check test results of the LED in the whole lighting system. Then import to comparison.

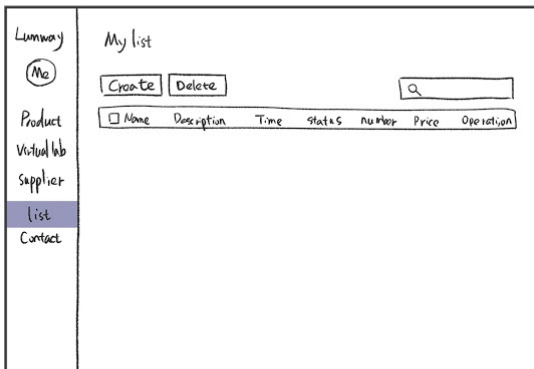


03. The test point is added to comparison table. Repeat previous steps to add more test points.

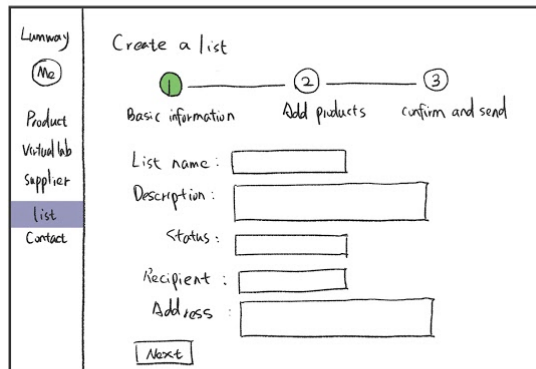


04. Select to test points to compare their lighting performances in different graphs.

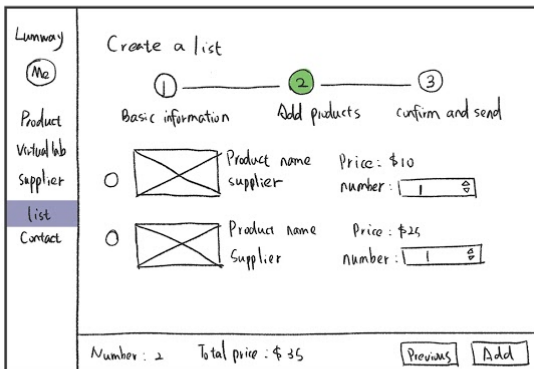
Prototype B: "Manage procurement lists".



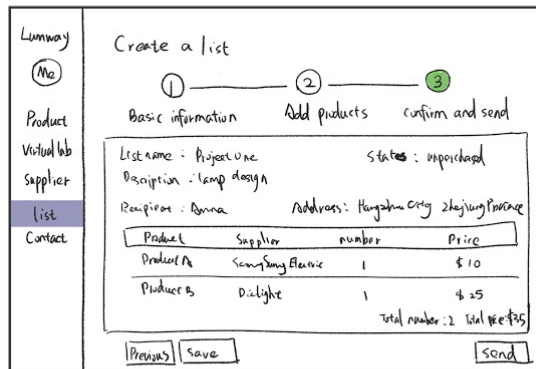
01. Click "create" button to start the process of creating a new procurement list.



02. Fill in the basic information of the list and click "next"

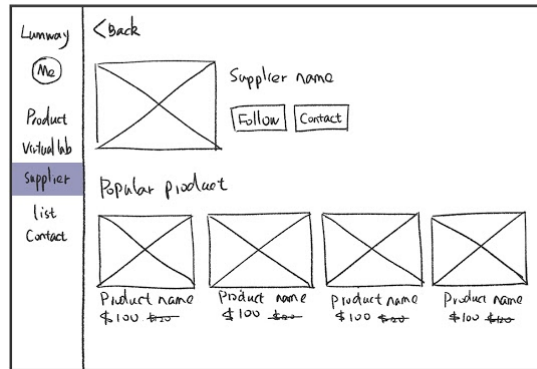
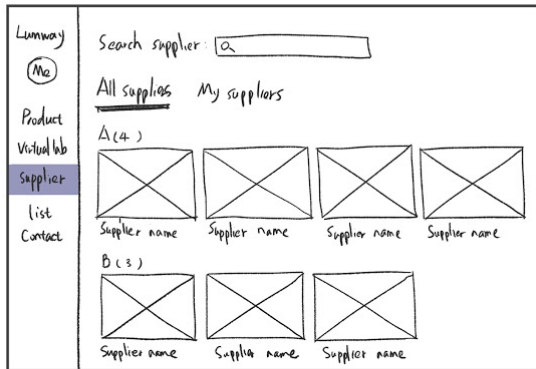


03. select products from personal collection and add to the list.



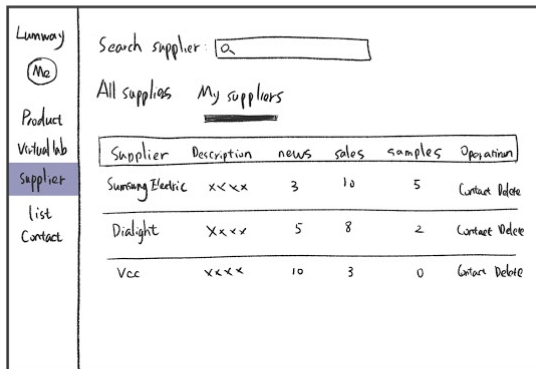
04. Confirm that all the information on the list is right, then save the list or send to suppliers.

Prototype B: "Keep contact with suppliers".

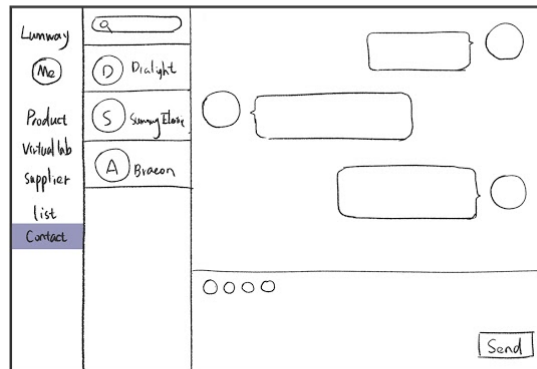


01. Select "All suppliers" label, and find an interested suppliers.

02. On the detail page of the supplier, follow the interested supplier after login.



03. Select "my supplier" label, and check the news of followed suppliers. Click "contact"

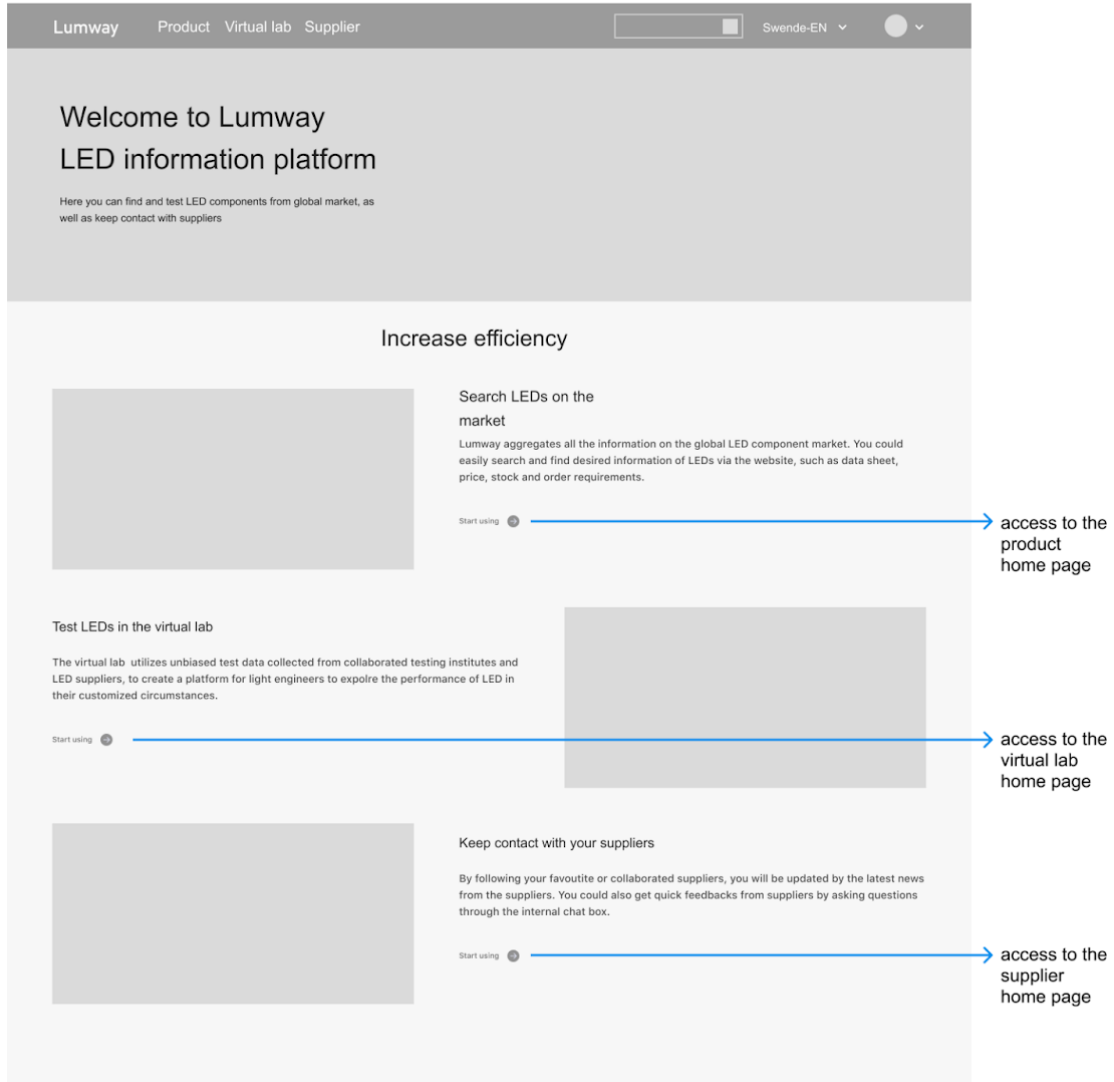


04. Access to the "contact" page and chat with the selected supplier.

Appendix 5: Wireframes in Figma

Lumway 1.0 Website homepage

1 Homepage



Lumway 1.0 Search LEDs

1 Product page

Search Box

Search products

Product name: Category: Supplier:

Search results

In stock RoHS Compliant Without minimum order requirement Head settings

Product name	Supplier	Colour	Luminous flux (lm)	Color temperature (K)	Stock	Price (CNY)
LST1-01F07-5770-01	Opulent	White	450	3000	300	13.6
MB403-R24-CR	VCC	Red	500	2500	200	60.5
BP202-NFG28H	VCC	Green	800	4500	850	35.0
PRT-14505	SparkFun	Blue	1100	4000	400	12.8
585-5525F	Dialight	Yellow	2000	4500	650	21.5
BP202-NFR28H	VCC	Red	2060	5000	450	45.6
SI-B8V26256CUS	Samsung	White	3000	5500	561	30.5
SSB1-72F16-3090-00	Opulent	Blue	3050	6500	200	20.6
BXRH-35G1000-B-73	Bridgelux	Yellow	3200	4650	451	15.5
507-4761-3331-500F	Dialight	Yellow	3350	6000	563	68.0

Items

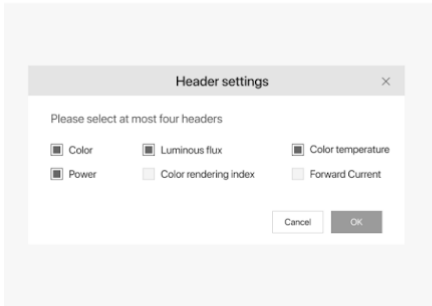
1.1 Collapsible search panel

Product name: Category: Supplier: Luminous flux: Color temperature:

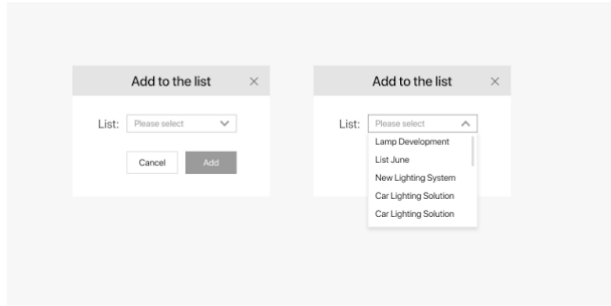
Power: Color rendering index: Forward Current:

Lumway 1.0 Search LEDs

1.2 Header setting dialog



2.1 Adding dialog



2 Product details page

Price References

Unit Price:	¥2.83	¥2.75	¥2.63	¥2.58	More prices please contact the supplier
Quantity:	1-199	100-299	300-999	≥1000	

Multiples Of: 1
In Stock: 200
Quantity: → Add to the list
Total Price: ¥330 (13% VAT included)

Supply Information

Supplier: Samsung Electronics Contact Follow → Contact or follow the supplier
Delivery: Sweden
Lead Time: 1 week
Delivery Time: 1 week
In Stock: 200
On Order: 400
Completion Time: 2020-07-30

Product Parameters

Color:	Brown	Color Temperature:	3000K	Luminous Flux:	2820 lm
Power:	33-53.1 W	Operating Temperature:	-30 - 50°C	Forward Voltage:	33-35.4 V
Packaging:	Tray	Storage Temperature:	-40-80°C	Forward Current:	1-1.5 A
RoHS:	Compliant	Color Rendering Index:	90 CRI	Test current:	1430 mA
Life Cycle:	Unconfirmed	Number of LEDs:	44		

Recommendations

- FP14997_FLORENTINA-HLD-W
Supplier : LEDIL
Price : ¥2.56
- SS81-72F16-3090-00
Supplier : Opulent
Price : ¥3.45

Download datasheet or Test in virtual lab →

Lumway 1.0 Test LEDs

1 Virtual lab page

Batch operations

Create a new test point

Search box

Table of created test points

Operations of single test point

Click the name of LED to view its test result

LED name	Test Environment	Number of LED	Status	Updated time	Operation
<input checked="" type="checkbox"/> SI-B8V26256CUS	Environment 1	1	Done	2020-05-21 20:12:20	Delete Download Edit
<input type="checkbox"/> LST1-01F07-5770-01	Environment 2	2	Done	2020-05-21 19:16:30	Delete Download Edit
<input checked="" type="checkbox"/> SI-B8V26256CUS	Environment 3	1	Done	2020-05-21 19:14:03	Delete Download Edit
<input checked="" type="checkbox"/> BXRH-35G1000-B-73	Environment 1	4	Analysing	2020-05-21 18:00:02	Delete Download Edit
<input type="checkbox"/> SSB1-72F16-3090-00	Environment 4	3	Done	2020-05-21 16:16:35	Delete Download Edit
<input checked="" type="checkbox"/> SI-B8V26256CUS	Environment 2	1	Done	2020-05-21 14:42:20	Delete Download Edit
<input type="checkbox"/> SSB1-72F16-3090-00	Environment 1	5	Analysing	2020-05-20 10:30:10	Delete Download Edit
<input type="checkbox"/> LST1-01F07-5770-01	Environment 4	2	Done	2020-05-20 23:10:36	Delete Download Edit
<input type="checkbox"/> BXRH-35G1000-B-73	Environment 3	1	Analysing	2020-05-20 08:30:00	Delete Download Edit

Select 2~4 test points and click "Compare" button to compare test results

1.1 Status dialog

Under analysis

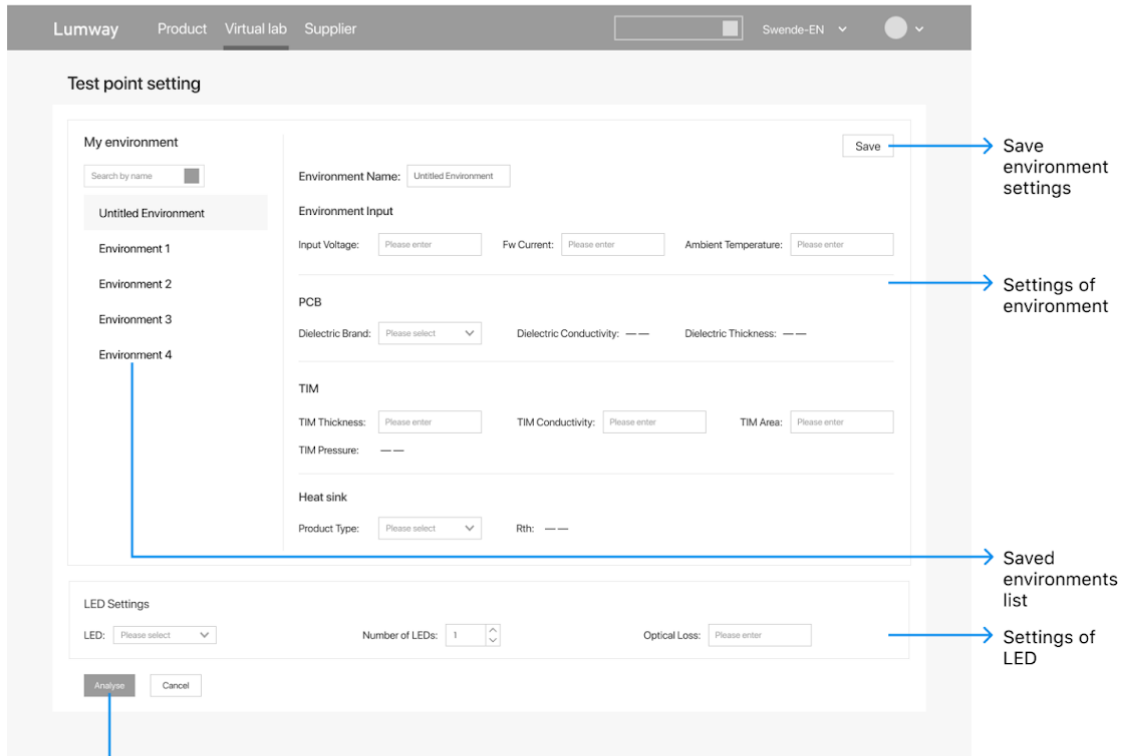
The selected test point is still under analysis
Please check results when the status shows done

OK

When new test point is created and shown in the list, the status dialog will pop up to notice user wait for a while to view the test result

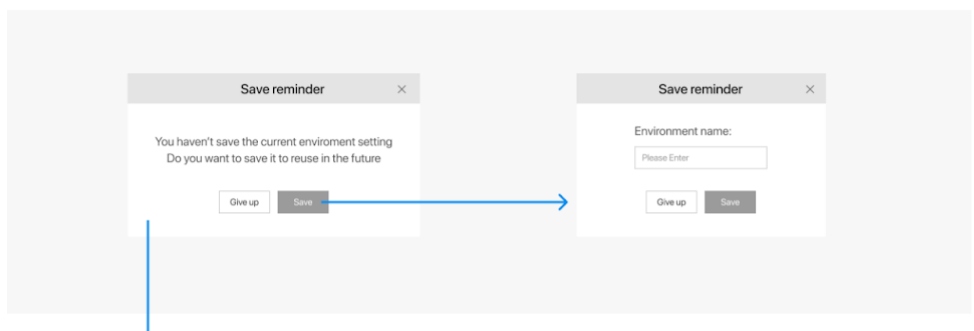
Lumway 1.0 Test LEDs

2 Test point setting page



Add to the test point table and the web sarts to analyse the result in the backstage

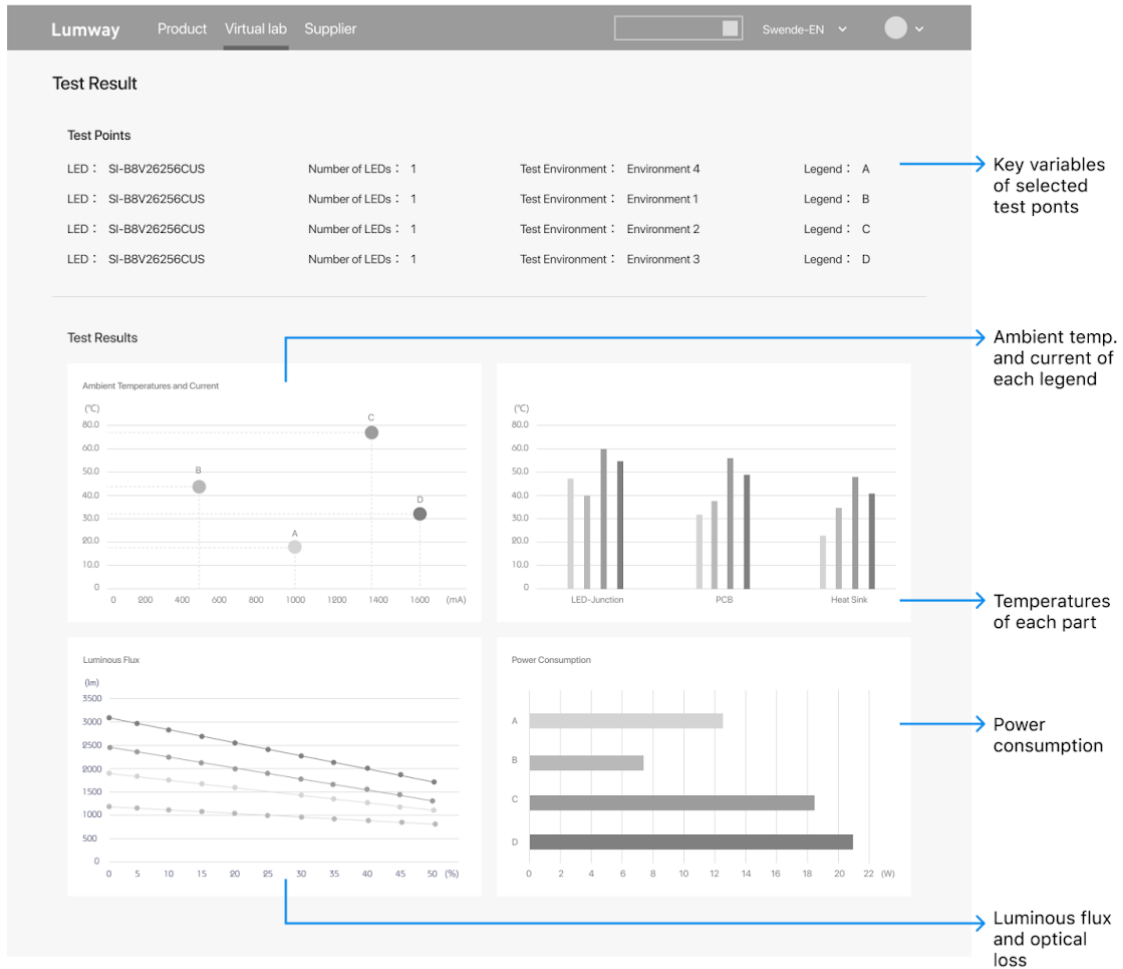
2.1 Save dialog



If users don't save the environment setting and press "Analyse" button, the dialog will pop up to ask if they want to save the settings

Lumway 1.0 Test LEDs

3 Test point result page

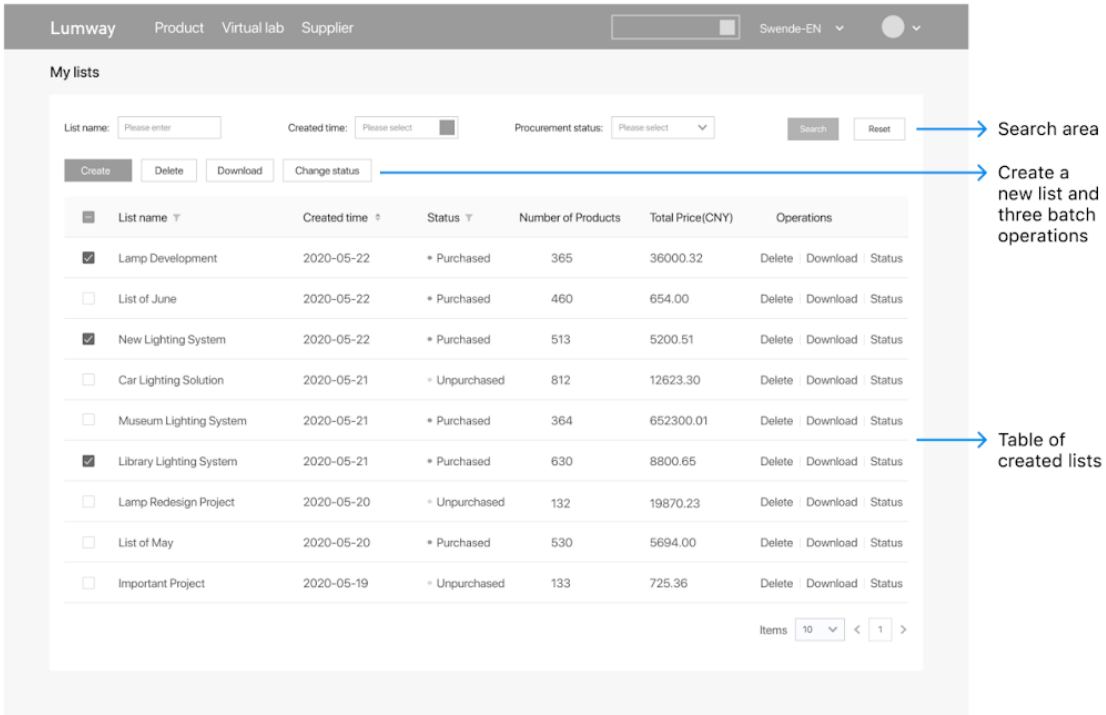


Lumway 1.0 Record LEDs in lists

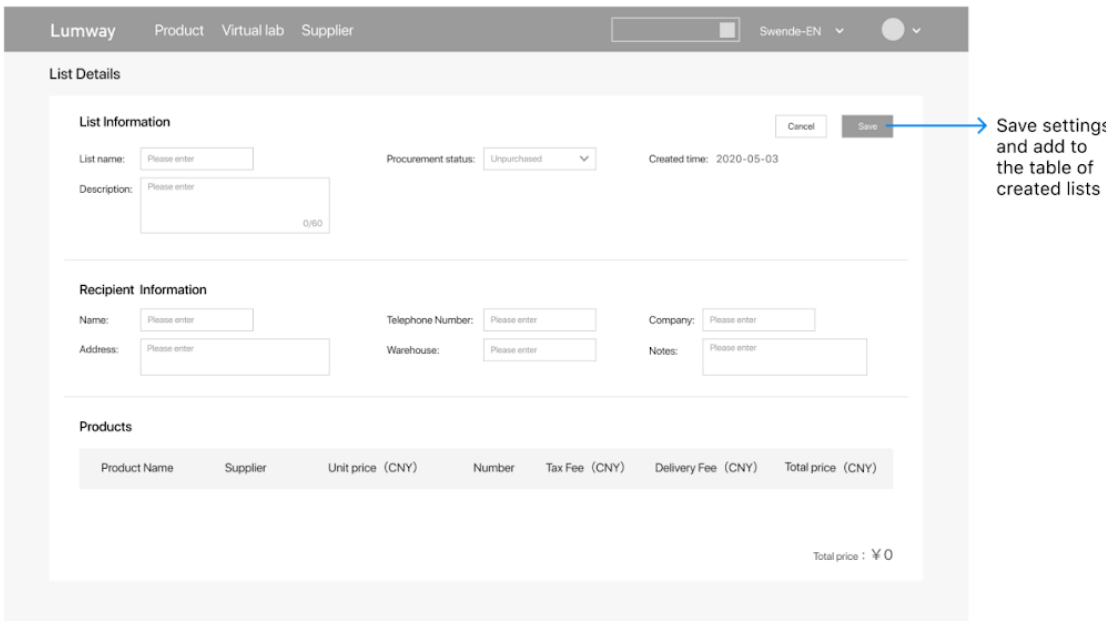
1.1 Drop down menu



1 List page



2 List details page - Editing status



Lumway 1.0 Record LEDs in lists

2.1 List details page - Viewing status

List Information

List name: Lamp Development Procurement status: Unpurchased Created time: 2020-05-03

Description: A urgent project and needs to complete the relevant procurement work by the end of August.

Recipient Information

Address: William Clinton Telephone Number: +46 788336468 Company: Alous Light International AB

Address: Risclelltse, 53, Stockholm, Sweden Warehouse: Central Warehouse Notes: -

Products

Product Name	Supplier	Unit price (CNY)	Number	Tax Fee (CNY)	Delivery Fee (CNY)	Total price (CNY)
SL-BBV1N60LAWW	Samsung Electronics	350	1	20	10	380
507-4761-3331-500F	Dialight	210	2	30	20	470

Total price : ¥ 850

Buttons: Delete, Edit, Download, Send

Annotations:

- Change to editing status (points to Edit button)
- Send lists to suppliers. The chat drawer will pop up (points to Send button)

2.2 Messages drawer

Messages

- Dialight: List Confirmation (AM 11:12)
- SAMSUNG: List Confirmation (AM 11:12)
- VCC: Thanks for choosing VCC and wish to collaborate in ... (Sunday)
- OSRAM: Currently, we can't provide samples for you. (2020/05/20)

Annotation: Label: Messages show the table of messages

Chatting interface (Dialight)

List Confirmation

List name : Lamp Development ¥ 470

The current inventory of the product RAY1102W-745-TR in your order is not enough for your quantitative requirement. The new source is expected to be replenished at the end of this month. The specifications of the product BHA-1517 have been revised, and the new samples can be shipped tomorrow.

Got it

We will give you priority to arrange your orders when new goods are arrived in the warehouse.

Thanks!

Enter text

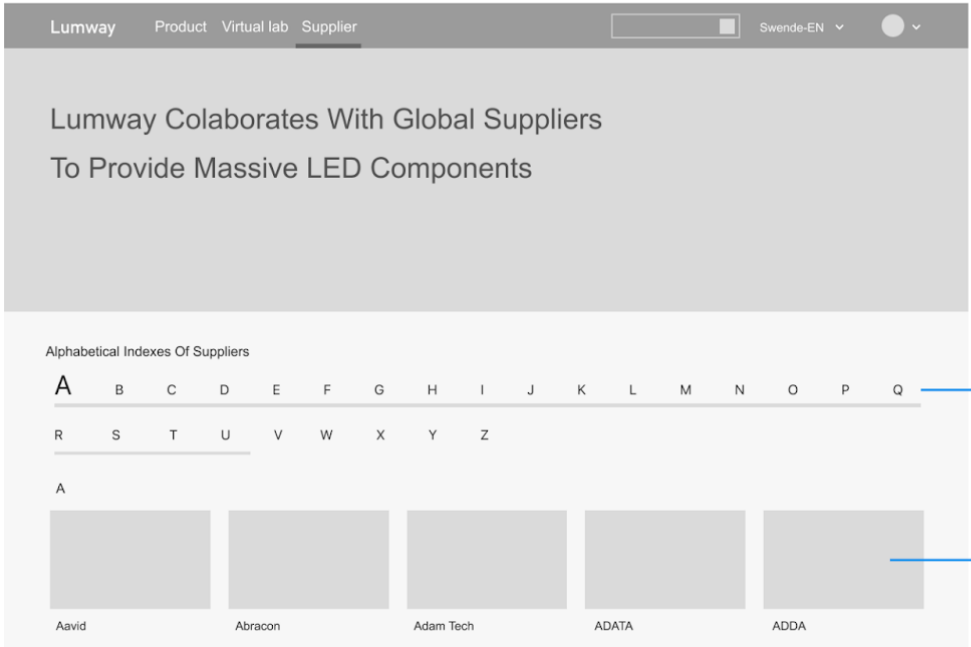
Send

Annotations:

- Chatting interface (points to the chat window)
- Sent list (points to the list name in the chat message)

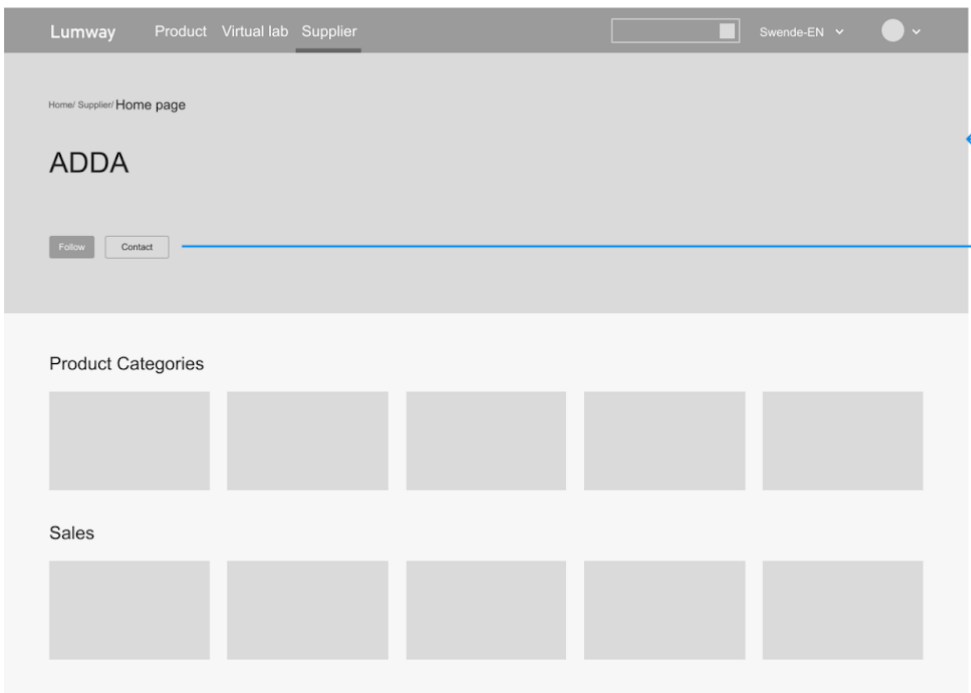
Lumway 1.0 Online communication

1 Supplier page



Navigation of suppliers

2.2 Supplier details page



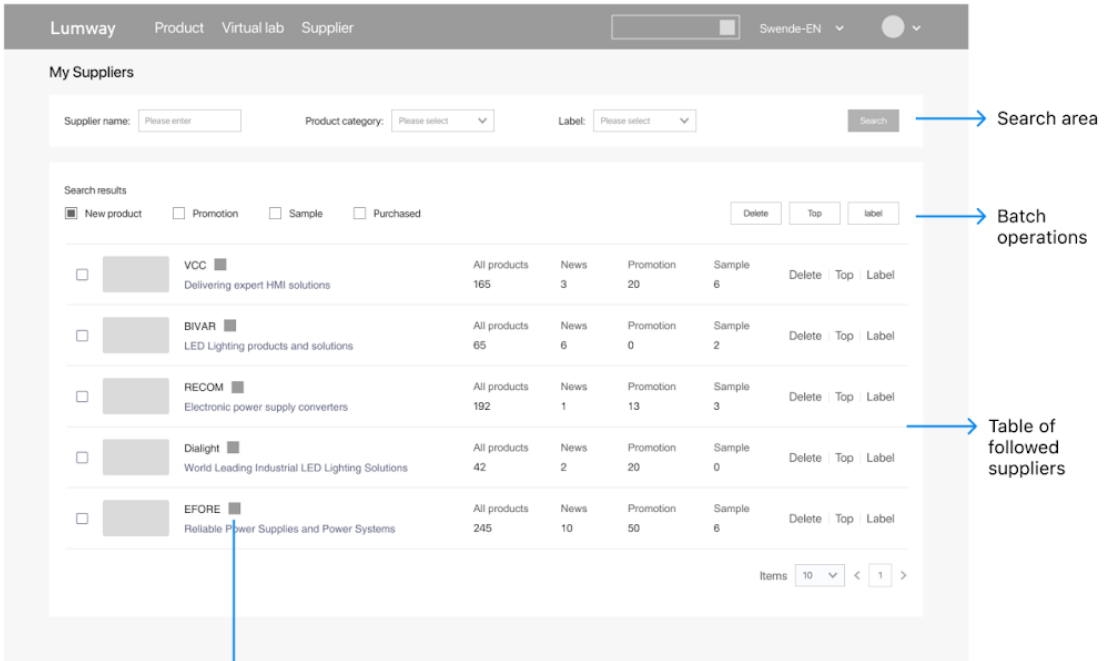
Follow and contact the supplier

Lumway 1.0 Online communication

1.1 Drop down menu

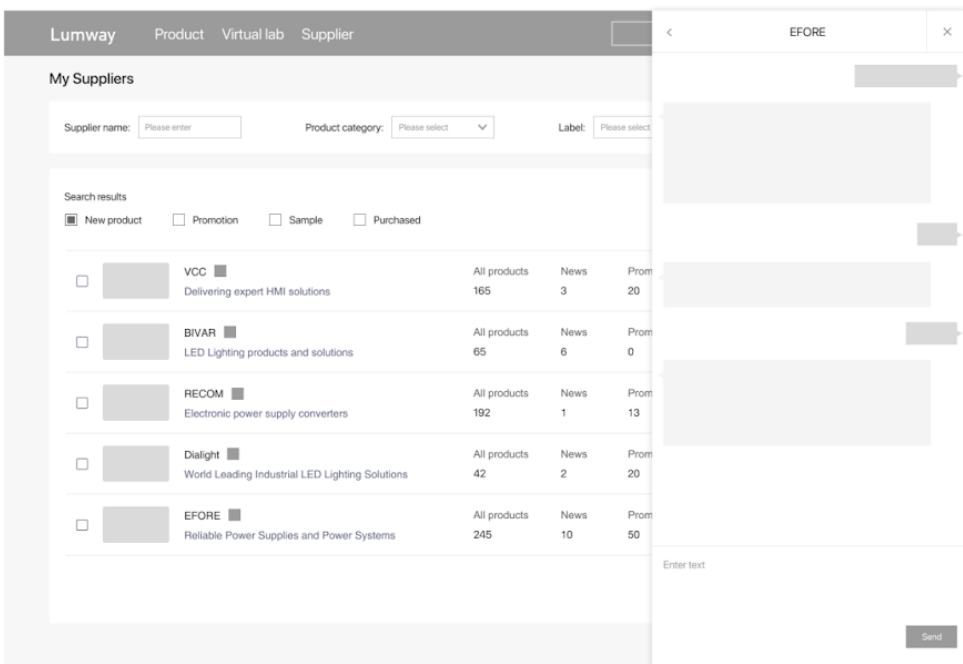


1 My supplier page



Click the contact button or the message navigation in the drop down menu, the message drawer will pop up

2 Message drawer



Appendix 6: High-fidelity prototype for heuristic evaluation

Lumway 2.0 Search LEDs

1 Product page

LED Emitters

We stock reliable LED emitters from reputed manufacturers. Choose from our exclusive selection of high power LED emitters, low power LED emitters or mid power LED emitters that suit your application.

[Learn more](#)

All Products

Product name: Please enter Category: Light Strip Supplier: Please select Hide Reset

Color: Please select Luminous flux: Please select Color temperature: 2000-4000

Fw voltage: 30-35V Color rendering index: Please select Forward current: Please select

Search results: 80 In stock RoHS Compliant Without minimum order requirement Header setting

Product name	Supplier	Colour	Luminous flux (lm)	Color temperature (K)	Stock	Price (CNY)
LST1-01F07-5770-01	Opulent	White	450	3000	300	13.6
MB403-R24-CR	VCC	Red	500	2500	200	60.5
BP202-NFG28H	VCC	Green	800	4500	850	35.0
PRT-14505	SparkFun	Blue	1100	4000	400	12.8
585-5525F	Dialight	Yellow	2000	4500	650	21.5
BP202-NFR28H	VCC	Red	2060	5000	450	45.6
SI-B8V26256CUS	Samsung	White	3000	5500	561	30.5
SSB1-72F16-3090-00	Opulent	Blue	3050	6500	200	20.6
BXRH-35G1000-B-73	Bridgelux	Yellow	3200	4650	451	15.5
507-4761-3331-500F	Dialight	Yellow	3350	6000	563	68.0

Items 10 1 2 3 ... 10

Lumway 2.0 Search LEDs

2 Product details page

The screenshot shows the product details page for 'SL-B8V1N60LAWW' LED Modules. The page is divided into several sections:

- Product Image:** Shows two LED modules.
- Price References:**

Unit Price	€2.83	€2.75	€2.63	€2.58
Quantity	1-199	100-299	300-999	≥1000

More prices please contact the supplier

Multiples Of: 1

In Stock: 200

Quantity: [Add to list](#)

Total Price: €330 (13% VAT included)
- Supply Information:**

Supplier: Samsung Electronics [Contact](#) [Follow](#)

Delivery: Sweden Lead Time: 1 week Delivery Time: 1 week

In Stock: 200 On Order: 400 Completion Time: 2020-07-30
- Product Parameters:**

Color: Brown	Color Temperature: 3000K	Luminous Flux: 2820 lm
Power: 33-53.1 W	Operating Temperature: -30 ~ 50°C	Forward Voltage: 33-35.4 V
Packaging: Tray	Storage Temperature: -40-80°C	Forward Current: 1-1.5 A
RoHS: Compliant	Color Rendering Index: 90 CRI	Test current: 1430 mA
Life Cycle: Unconfirmed	Number of LEDs: 44	
- Recommendations:**
 - FP4897_FLORENTINA-HLD-WSupplier - LEDL Price: €2.58
 - FP4897_FLORENTINA-HLD-WSupplier - LEDL Price: €2.58

3 Message drawer

The screenshot shows the 'Message drawer' overlay on the product page. The drawer contains a list of messages:

- Dialight:** Important notifications for product changes... (481 11:12)
- VCC:** Thanks for choosing VCC and wish to collaborate in ... (Yesterday)
- SAMSUNG:** Currently, we can't provide samples for you. (Sunday)
- OSRAM:** The samples are sent out. (2020/6/10)

The background shows the 'LED Emitters' section of the product page, including a 'Learn more' link and a search filter for 'All Products' with fields for Product name, Category (Light Strip), Supplier, Color, Luminous flux, and Color temperature (2000-4000).

Lumway 2.0 Test LEDs

1 Virtual lab page

The screenshot shows the 'Virtual lab' page in the Lumway application. At the top, there are navigation tabs for 'Product', 'Virtual lab', and 'Supplier'. Below the tabs, there are action buttons: '+ Create', 'Compare', 'Delete', and 'Download'. A search bar labeled 'Search by name' is also present. The main content is a table with the following columns: 'LED Name', 'Test Environment', 'Number of LED', 'Status', 'Updated time', and 'Operation'. The table contains 10 rows of data, with some rows selected (checked boxes). At the bottom right, there is a pagination control showing 'Items: 10' and page numbers '1', '2', '3', and '10'.

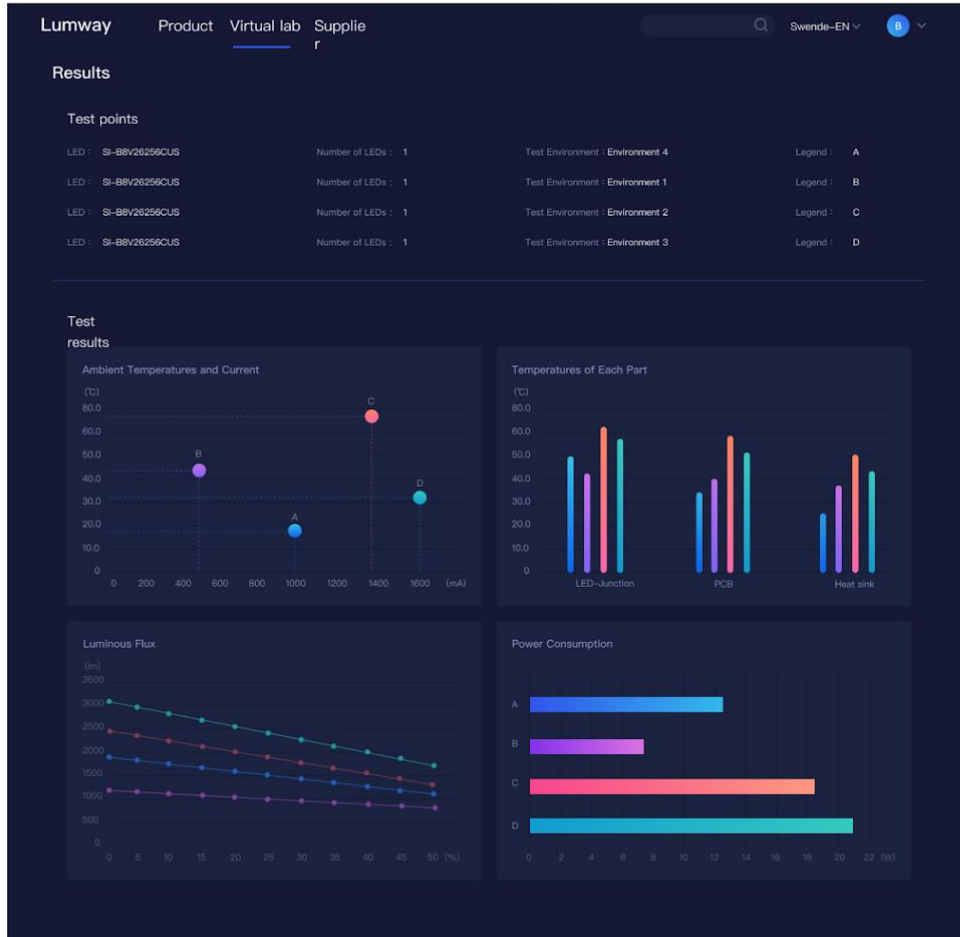
LED Name	Test Environment	Number of LED	Status	Updated time	Operation
<input checked="" type="checkbox"/> SI-B8V26256CUS	Environment 1	3	Analyzing	2020-05-21 20:12:20	[Icons]
<input type="checkbox"/> LST1-01F07-5770-01	Environment 2	4	Done	2020-05-21 19:16:30	[Icons]
<input checked="" type="checkbox"/> BP202-NFG28H	Environment 3	5	Analyzing	2020-05-21 19:14:03	[Icons]
<input type="checkbox"/> SI-B8V26256CUS	Environment 1	4	Done	2020-05-21 18:00:02	[Icons]
<input type="checkbox"/> SI-B8V26256CUS	Environment 4	3	Done	2020-05-21 16:16:35	[Icons]
<input checked="" type="checkbox"/> SI-B8V26256CUS	Environment 2	6	Analyzing	2020-05-21 14:42:20	[Icons]
<input type="checkbox"/> LMH020-4000-27G9-00000TW	Environment 1	1	Done	2020-05-20 10:30:10	[Icons]
<input type="checkbox"/> BXRH-35G1000-B-73	Environment 4	5	Analyzing	2020-05-20 23:10:36	[Icons]
<input type="checkbox"/> SSB1-72F16-3090-00	Environment 3	1	Done	2020-05-20 08:30:00	[Icons]

2 Test point setting page

The screenshot shows the 'Test Point Setting' page in the Lumway application. It features a sidebar on the left titled 'My Environment' with a search bar and a list of environment names: 'Untitled Environment', 'Environment 1', 'Environment 2', 'Environment 3', and 'Environment 4'. The main area is titled 'Environment Name' and 'Untitled Environment' with a 'Save' button. Below this, there are several configuration sections: 'Environment input' with fields for 'Input voltage: 13.6 V', 'Fw Current: 800 mA', and 'Ambient Temperature: 20 °C'; 'PCB' with 'Dielectric Brand: TCB-4', 'Dielectric Conductivity: 4 W/m.K', and 'Dielectric Thickness: 80 μm'; 'TIM' with 'TIM Thickness: 0.001 m', 'TIM Conductivity: 1.25 W/m.K', and 'TIM Area: 0.0041159 m²'; and 'Heat sink' with 'Product Type: 01-XXX Round 81mm' and 'Rth: 2.473 °C / W'. At the bottom, there is an 'LED Settings' section with 'LED: SI-B8V26256CUS' and 'Number of LEDs: 1'. 'Analyze' and 'Cancel' buttons are located at the very bottom.

Lumway 2.0 Test LEDs

3 Test point result page



3.1 Hovering Status



Lumway 2.0 Record LEDs in lists

1 The list page

The screenshot shows the 'My lists' page in the Lumway application. At the top, there are navigation tabs for 'Product', 'Virtual lab', and 'Supplier'. Below the navigation, there are search filters for 'List Name', 'Created time', and 'Procurement status'. A '+ Create' button and 'Delete', 'Download', and 'Change Status' icons are visible. The main content is a table with the following data:

List Name	Created Time	Procurement status	Number of Products	Total Price(CNY)	Operation
<input checked="" type="checkbox"/> Lamp Development	2020-05-21	Unpurchased	3654	36000.32	
<input type="checkbox"/> List of June	2020-05-16	Purchased	46	654.00	
<input checked="" type="checkbox"/> New Lighting System	2020-05-03	Unpurchased	513	5200.51	
<input type="checkbox"/> Car Lighting Solution	2020-04-25	Purchased	8123	12623.30	
<input type="checkbox"/> Museum Lighting System	2020-04-18	Purchased	36954	652300.01	
<input type="checkbox"/> Library Lighting System	2020-04-12	Unpurchased	630	8800.65	
<input type="checkbox"/> Lamp Redesign Project	2020-03-01	Purchased	1302	19870.23	
<input type="checkbox"/> List of May	2020-02-12	Unpurchased	530	5694.00	
<input type="checkbox"/> Important Project	2020-01-20	Purchased	13	725.36	

2 List details page – Viewing status

The screenshot shows the 'List details' page for the 'Lamp Development' list. It includes 'Delete' and 'Edit' buttons at the top right. The page is divided into three main sections:

- List Information:**
 - List name: Lamp Development
 - Procurement status: Unpurchased
 - Created Time: 2020-05-03
 - Description: A urgent project and needs to complete the relevant procurement work by the end of August.
- Recipient Information:**
 - User Name: William Clinton
 - Telephone Number: 18100000000
 - Company: Alos Light International AB
 - Address: Risdellitsee, 53, Stockholm, Sweden
 - Warehouse: Central Warehouse
 - Notes: -
- Products:**

Product Name	Supplier	Unit price (CNY)	Number	Tax Fee (CNY)	Delivery Fee (CNY)	Total price (CNY)
SL-B8V1N60LAWW	Samsung Electronics	350	1	20	10	380
507-4761-3331-500F	Dialight	210	2	30	20	470

Total price: ¥ 850

Lumway 2.0 Online communication

1 My supplier page

The screenshot displays the 'My suppliers' page in the Lumway 2.0 interface. At the top, there are navigation tabs for 'Product', 'Virtual lab', and 'Supplier'. Below the navigation, there are search filters for 'Supplier Name', 'Product category', and 'Label', along with a 'Search' button. The main content area shows a list of suppliers with the following data:

Supplier	All Products	News	Sample	Promotion
VCC	165	3	6	20
BIVAR	65	6	2	0
RECOM	192	1	3	13
Dialight	42	2	0	20
EFORE	245	10	6	50

At the bottom of the page, there is a pagination control showing 'Items 10' and a page indicator '1'.

Appendix 7: Heuristic evaluation script

Thanks for participating in the heuristic evaluation that will last around 90 minutes. The aim is to identify usability problems of the Lumway website according to the 26 heuristics in the checklist, which will provide meaningful inputs for us to improve our design.

Steps:

1. Please carefully read the heuristic checklist that we sent to you.
2. Open the prototype link and quickly go through all the interfaces.
3. Return to the first interface and perform the following tasks. In each task, please diagnose usability problems of the interfaces based on the provided heuristics
4. Please fill in the UX questionnaire

Tasks

Task 1: Supposing that you are a lighting engineer who is designing a high beam of the car. After reading related literature, you decide to use a LED component in your design, which is named SL-B8V1N60LAWW. Thus you visit the Lumway website to search this product and download its datasheet.

use the search box, download datasheet

Task 2: You want to find such a LED component that meets the following requirements: color temperature:2000~4000K, forward voltage:30~35V, and provide the highest CRI. Please find this product by using the website.

set advanced filters, set the table header, use the rank icon on the table header

Task 3: You have heard about there is a powerful new product named SI-B8V26256CUS and want to know how it would perform under the desired environment. Therefore you open the website and test it in the virtual lab with a set of environment settings: input voltage: 13.6V, Forward current: 900mA, Ambient temperature: 20°C, Heat sink: 01-xxx Round 81mm, TIM thickness: 0.001m, TIM conductivity:1.25w/m.k, TIM area:0.0041159m², PCB brand:TCB-4.

create a new test point, check the test result

Task 4: You are not satisfied with the optical performances of LED: SI-B8V26256CUS in such an environment, thus you want to change the environment settings (reduce the forward current to 800mA) and test how it would perform in the new environment. Tips: please save the new environment as “environment 2”.

edit the created test point, save the new environment, check the new test result

Task 5: You are satisfied with the optical performances of LED: SI-B8V26256CUS in

“environment 2”. But you have another alternative named BXRH-35G1000-B-73, and you want to test LED: BXRH-35G1000-B-73 in “environment 2”.

create a new test point, reuse the saved environment, check the new test result

Task 6: Provided that you have created the test points of LED: BP202-NFG28H under four different environments: “environment 1”, “environment 2”, “environment 3”, “environment 4”. Now you want to compare their performances and see which is the best. search the four test points, and compare the result of created test points

Task 7: After testing, you have decided to purchase 1000 LED:SI-B8V26256CUS made by Samsung Electronics, 200 LED:SL-B8V1N60LAWW, and 100 LED:PRT-14505 from SparkFun. You need to create a procurement list for these products and named “list 2020”. Then contact the suppliers to inquire about the stock and negotiate a lower price.

create a new list, add product to the list, sent the list to the suppliers

Task 8: You once purchased products from VCC. You feel that the products have good quality and could establish long-term collaboration with the supplier. So you follow VCC on the website. One day, you want to know if VCC has provided free product samples. If VCC has provided, please ask if VCC could send some samples to you.

search the supplier, follow the supplier, open my supplier page and check data, contact the supplier

Task 9: Your company is used to purchase a particular LED component from BIVAR to produce lamps. But BVAR has decided to stop producing this component for some reasons. How do you want the website to notice you about this news in time?

check the new message in the message drawer

Appendix 8: Heuristic evaluation checklist

Nielson's ten Heuristics	Sub Heuristics
H1: Visibility of system status	The menu or dialog boxes are titled and accurately convey the information included.
	There is some form of system feedback for every operator's action.
	Clickable objects are recognizable and have visual feedback to indicate the current status.
H2: Match between system and the real world	The icons are concrete and familiar.
	The graphs are understandable and visualized in common forms.
	The language is clear, concise, and accurate
H3: User control and freedom	when a user's task is complete, the system wait for a signal from the user before processing
	The users can move forward and backward between fields and dialog box options
	The users can easily reverse their actions.
H4: Consistency and standards	Established industry standards are applied consistently on all interfaces of the website.
	There is a consistent icon design scheme.
	System objects and user actions are named consistently across all prompts in the system.
H5: Error prevention	The system warns users if they are about to make a potentially serious error.
	Indications appear when there are requirements of the inputs in the fields.
	Fields in data entry screens and dialog boxes contain default values when appropriate
H6: Recognition rather than recall	Relevant controls for performing the task are grouped and put in the order of actions.

	<p>The relative importance of different interface elements is distinguished by Size, boldface, underlining, color, shading, or typography.</p> <p>Dependent fields are displayed on data entry screens and dialog boxes only when necessary</p>
H7: Flexibility and efficiency of use	<p>The new user can use the data recommended by the system while the expert user can add and set parameters by themself.</p> <p>The users can save commonly used data.</p> <p>The users can customize the information and settings</p>
H8: Aesthetic and minimalist design	<p>The visual interfaces are visually efficient and avoid visual noise.</p>
H9: Help users recognize, diagnose, and recover from errors	<p>Error messages should be expressed in plain and precise language.</p> <p>To signal an input error in a form, mark the textbox which needs to be changed.</p> <p>Error messages should constructively suggest a solution.</p>
H10: Help and documentation	<p>The help system is organized to follow the sequence of user actions.</p> <p>It is easy to access and return from the help system.</p>

Appendix 9: Heuristic evaluation result

Number	Problem Description	Problem areas	Severity rating
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1	There are less instructions or help functions for the new users to learn about how to use the website, especially for the test function.	The scope plane	4
2	The users have to send the procurement list to all the suppliers and can not choose particular suppliers to send.	The scope plane	4
3	The users can't directly add the product in the virtual lab. They have to search and then add products on the product details page, which is time-wasting.	The structure plane	4
4	The dialog box of inquiring saving the environment settings abrupts the workflow of creating the test point. It annoys the users when they don't want to save the environment settings	The structure plane	4
5	The navigation between the main interface, the secondary interface and the tertiary interface is missed.	The skeleton plane	4
6	It is inconvenient to click the top action buttons when the users are browsing the list details page, especially when the list is long, the users have to scroll through the interface to find the button.	The scope plane	3
7	Because the selected test points aren't shown somewhere separately, the users might forget which test points they have selected when they select the test points in several different page numbers.	The scope plane	3
8	The website uses dialog boxes to convey system feedback to user operations, which might abrupt the original workflow and require an extra step to close it every time, e.g. notification of analyzing test result.	The structure plane	3
9	When the users click the following icon, the visual style of the icon doesn't change. The users don't know if they have successfully followed the supplier.	The surface plane	3
10	In the table of search results, the text of product name and supplier don't provide visual feedback to indicate that they are clickable.	The surface plane	3

11	The visual hierarchy of the test point setting page is disordered. The sections of environment settings and LED settings are inverted. The bottom left buttons increase the visual route.	The surface plane	3
12	When the users set the table header, it limits the number of parameters to choose. The website should allow the users to select all the parameters. Considering the limited size of the table header, it should allow the users to scroll horizontally to check the data when they choose lots of parameters.	The scope plane	3
13	The delete icon in the operation choices of the table is put in the first place. It is easier to cause the misoperation because in most cases the first choice is frequently used.	The scope plane	2
14	When the users search the products, they can't freely set the range of some product parameters, for example, color temperature.	The scope plane	2
15	The entry point of messages is hidden in the drop-down menu of the profile. It takes two steps to open the message drawer and does not provide obvious notification of new messages.	The skeleton plane	2
16	On the homepage, the users have to scroll through the screen to see the three entry points below. These important entry points should be displayed on the first screen and make sure the users can quickly access them without scrolling down.	The skeleton plane	2
17	When the users create a new procurement list, its status should be "non purchased" by default.	The structure plane	2
18	The visual hierarchy of some interfaces is not prominent, the relatively important section should be more outstanding from the background.	The surface plane	2
19	Some icons are difficult for the users to understand their functions, e.g. the icon for activating the test in the virtual lab, and the icon for changing the status of the procurement lis	The surface plane	2
20	There should be the contact button for each supplier on the list details page so that the users can conveniently start the communication.	The scope plane	1

21	The contact icon is designed in line and hard to be noticed by the users. It took some time for the users to find the advanced parameters. In the table header, the icons of ranking or filtering data are not obvious.	The surface plane	1
22	The icon of the setting function is not obvious and the users might be confused of this function for the first time	The surface plane	1
23	When the users check the test results of a single test point, there is no need to use the hovering mode because the data is little. It is better to directly show the data in the blank space of the graphs.	The surface plane	1

Appendix 10: Usability testing result

Number	Problem Description	Problem areas	Severity rating
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1	It is inconvenient to select or remove the test points during the comparison. the users have to go backwards to tick or cancel the checkboxes in the test point list page.	The structure plane	3
2	It is inefficient to change the settings of the test point when the users are comparing the results. The users need to go backwards to the test point list page and then click the edit icon of the test point.	The structure plane	3
3	If the users change the settings of a saved environment, the update will automatically replace the old one. The users thought it should allow the users to decide to replace or save as another new environment.	The scope plane	2
4	The function of table header setting is a little hard for the users to find and understand for the first time.	The scope plane	2
5	Some users can't find the entry point to the test result page. They firstly try to find it from the icons in the operation area. Then they realize they should click the name of the test point.	The structure plane	2
6	The overall process of managing the list is a little complex	The structure plane	2
7	There is only one entry point of the list. It's better to provide more ways to access the list page.	The structure plane	1
8	It is a liitle hard to identify the operation icons in the table due to the color	The surface plane	2
9	On my supplier page, one user thought the contact icon should be put in the operation area together with other action icons.	The surface plane	1
10	The dark mode is suitable in the virtual lab but prefer to view other content in the light mode. The website should provide the light mode for users to choose	The surface plane	1

Appendix 11: UX questionnaire

Please rate the scale for each emotional word pair according to the whole experience of using the web.

Unpleasant	-3	-2	-1	0	1	2	3	Pleasant
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Conventional	-3	-2	-1	0	1	2	3	Inventive
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Unprofessional	-3	-2	-1	0	1	2	3	Professional
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Dull	-3	-2	-1	0	1	2	3	Captivating
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Undemanding	-3	-2	-1	0	1	2	3	Challenging
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Unruly	-3	-2	-1	0	1	2	3	Manageable
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Impractical	-3	-2	-1	0	1	2	3	Practical
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Confusing	-3	-2	-1	0	1	2	3	Clearly structured
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Unpredictable	-3	-2	-1	0	1	2	3	Predictable
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Discouraging	-3	-2	-1	0	1	2	3	Motivating
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	