



RESEARCH BOOK

HOW TO INTEGRATE ENERGY-SAVING
ARCHITECTURAL INSTRUMENTS TOWARDS A
HOLISTIC ENERGY NEUTRAL ICE RINK DESIGN

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Cover & backside

Microscopic photograph of artificial kagome spin ice, an atomic structure with the same spatial characteristics as H₂O ice, but due to its size it is able to be photographed (Braun e.a., 2012). As a symbol to where it all started.

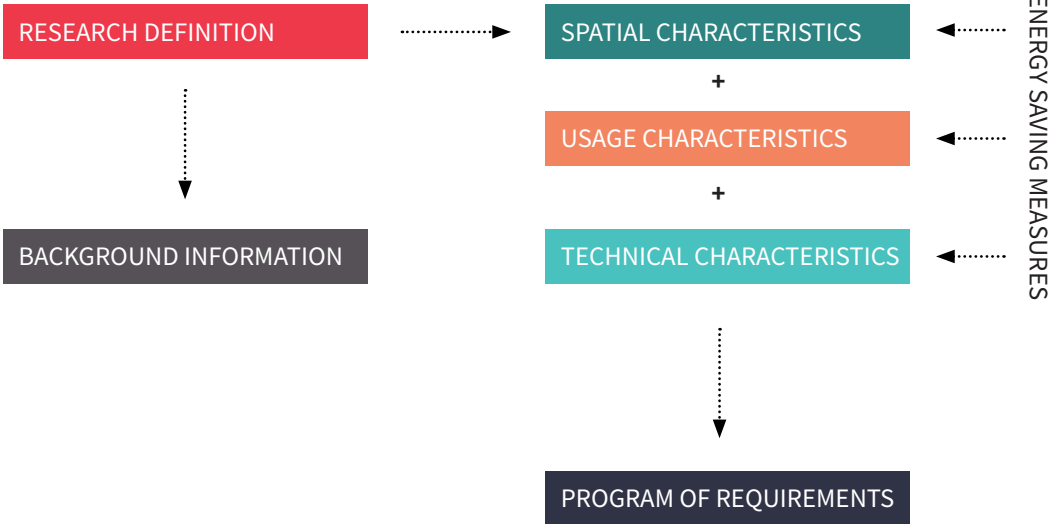
Energy neutrality
in our building designs
shouldn't be a choice,
it should be the norm.

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CONTENTS SCHEME



An ice rink building can be described as an **active machine**. It needs electric energy to fulfill its purpose: to provide artificial ice to - initially - extend the ice skating season.

Nowadays the need of artificial ice has increased, since the opportunity to practice the ice skating sport outside with natural circumstances ceased to exist. The main cause of this development is the increasing annual temperature, which has been a result of global warming.

Due to this climate change, an ice rink building will soon be the only means to practice the sport.

Another development is the increasing demands of the ice skaters to have the right circumstances to enhance their sporting performance.

The architectural typology of the ice rink had been initiated in the 1980's, before that speed skating on artificial ice had mainly been practiced outdoors. This newly introduced architecture merely played a role as a shell of protection, but is low performing in controlling the right circumstances for high-quality ice and comfort of the sporter.

The ice rink building nowadays is still generally challenged in providing a controllable environment and the typology is still associated with being occupied in winter, and vacated in summer. The ice rink typology can be described as unsustainable.

The directive of the research is to find architectural means to improve an ice rink in its sustainable characteristics. This is mainly focussed on lowering the energy demand by application of architectural solutions, and compensating this energy demand by integrating energy producing elements.

For this research, mainly the usage/operation stage will be taken into account. For the construction stage (choice of materials and their embodied energy) only assumptions will be made to improve the buildings energy sustainability. The result will be an energy neutral ice rink.

To gain insight in the building requirements, **case studies** of ice rink predecessors and **questionnaires** on larger potential user groups were necessary. To go into depth of the building characteristics and usefull feedback on how to design an ice rink, **specialists in the ice rink field were interviewed**. Where needed the research was expanded with **literature studies**.

Outcomes of the research are, among others, a roof and a double facade acting as an climatic buffer, insulation in the building envelope, avoidance of heat radiation by the sun or surrounding materials, strong climate regulation devices, and a hermetically sealed sport area as protection from its outer environment. **In the end the building design will provide an ice sport venue in winter and multifunctional venue in summer with its own fully controllable micro climate.**

These solutions will be applied in a program of requirements for a design proposal of the ice rink of the future.

2: INTRODUCTION

The ice skating sport has experienced huge alternations over the last decades. It was previously practiced outdoors, but in during the 1980's, there was a major shift towards indoor ice facilities.

Climate change was the largest contributing factor, since ice speed skating requires ice and therefore freezing temperatures in winter. Another reason was that sporters appreciated the opportunity to practice their sport without “battling the elements”.

Because the sport is nowadays mostly practiced within a more controllable environment, the sport now includes an architectural influence. The ice rink building is generally known as a protective layer for the icesheet and the skater from the outside circumstances. Wind and rain are from all times, but a new factor in this newly introduced architecture is a higher outdoor temperature.

When one would summarize the main function of an ice rink building, it would be:

A building which houses a frozen sheet of ice, which makes it possible to continue our ice skating season in our soft winter.

Producing ice means, to extract heat from a surface or area, which leaves the surface being colder than before.

In this way, ice rinks are actually huge heat producers, which releases their heat towards the outer air.

This process contributes in an elevation of outer temperature.

We made a solution for ice skating in soft winters, but with this solution we indirectly make our winters even softer.

Therefore an ice rink indirectly works against itself, but improves its reason to exist. We need artificial ice more than ever, if we want to continue practicing the ice skating sport with warmer temperatures.

For this reason, there has been some discussion about the ethical question whether we should continue this sport. Has it had its glory in our (c)old days? Is it now time to continue with a similar discipline, but for example inline (roller) skating on asphalt roads?

Within this scenario there is no need for technical buildings

which produce artificial ice with a lot of operating costs and climatic problems.

But the enthusiasm for the sport is still very present in several countries. Still new ice rinks are build, and several disciplines of ice skating are being practiced during the Winter Olympics, unlike inline skating.

The ice rinks are buildings which have to fight for their existence, during summer they're mostly unused and their energy bills are not compensated without governmental influence every year. This combination of insufficient operation management and a high demand in electric energy results in an unprofitable building.

With this project I will prove that there is a way to improve the ice rink in its energy and operation performance, resulting in a building which can exist by its own, without being influenced or dependant by other sources.

It is my opinion that within the building environment, we can only strive towards sustainable building, it shouldn't be a choice. It should be the norm.



Im. 1: Skating education on the Jaap Eden rink in Amsterdam, age 8 in 2001.

3: FASCINATION

To start a graduation project is to find something which can keep you occupied and interested for a long period of time. To combine your hobby with your study is an outcome more students have applied. For me, choosing to design an ice rink was not coming randomly.

Since my youth I have been on the ice on a weekly basis during the entire winter. I used to go on trips to frozen lakes and fences when Dutch winters were still cold enough, and had skating education at the Jaap Eden rink in Amsterdam.

Ice speed skating to me is a very elegant sport. Though perhaps the word elegance wouldn't be used when one sees a professional skater. For me the beauty and elegance is in the slow movement in which can result in a high speed, when the technique is right. The sport is extremely technical, with high precision and subtle motions. Especially in the beginning your brain will try to avoid all the unnatural movements, since you have to move sideways to go forwards, and the gravity point of your body passes over your feet, which can feel uncomfortable, but when mastered you will

immediately feel the progress in your self-produced velocity.

This constant process of self-evolving progress is a great motivator, the competitions are also done one against one, but mostly you skate against time, which stimulates the individualism even more. Probably it sounds contradictory, but the sport is most entertaining when practiced in groups, it is a social sport and highly entertaining when attending a competition, it is something which can be endlessly discussed by people who share this excitement.

As an ice speed-skater, who sometimes joins a competition, I have the privilege to visit a lot of ice rinks throughout the Netherlands. For my hobby I have also joined several trips abroad to make use of the ice skating facilities in Baselga di Piné and Collalbo (Italy), Hamar and Trondheim (Norway), Inzell and Berlin (Germany), and Innsbruck (Austria) or skate on natural ice in Finland, Sweden and Norway.

Some of the rinks abroad showed me that an ice speed skating rink doesn't necessarily have to be unappealing, a standard which I was used to

when practicing in any rink in the Netherlands.

Among skaters it was a given fact that our indoor sport was just not attractive in terms of direct surroundings. Usually this was a cause for jokes or complaints which were part of every training.

My aim in architecture has always been leaning more towards environmental friendly buildings. Working with low carbon materials, energy efficiency and passive solutions to improve a building in its sustainability performance was the big directive in most design projects I did. Our building stock shouldn't be our biggest energy consumer. It should be able to sustain itself.

I always had the feeling that I had to defend myself to make use of a building, an ice rink, which is so environmentally unfriendly. By practicing my sport I intentionally contribute to humans' bad influence towards our environment. By doing this project I can use my expertise in both ice skating and architecture to explore if an ice rink can indeed be made more environment friendly.

4: TERMINOLOGY AND DEFINITIONS

The premise of this project is **Energy Neutrality in the building environment**. In this chapter energy related definitions are explained.

Energy neutral building

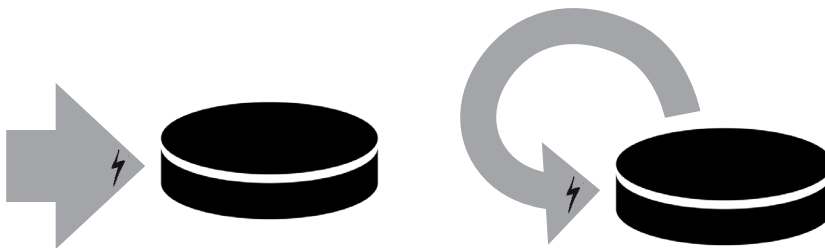
Since this term will be used throughout the report, and it is one of the main goals which should be achieved in this research, a complete definition of my perspective on energy neutral building is required. The definition for energy neutral, used by the designer, may also affect the result in assessing if the project has a positive result or not.

“The way the zero energy goal is defined affects the choices designers make to achieve this goal and whether they can claim success.” (Torcellini et al., 2006).

The term mostly used in the architecture field is **Zero Energy Building (ZEB)**. Which is defined as:

“A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.” (Torcellini et al., 2006).

In short, it means the energy consumption of the building is compromised by energy-producing/renewable energy sources. This mostly applies to the usage stage of the building. Zero Energy Building is also including the energy investment which is needed to produce the materials, and their transport to the site.



To present the environmental damage of material production or the building process, the calculation of this investment can be presented in two different units: **Electric energy, kWh**, or the amount of carbon dioxide produced, usually measured in **grams of CO₂**. For ZEB the first unit is mostly used. When Carbon is involved as calculating unit, one speaks of **Carbon Neutral Building**.

Creating a building will always include an investment in energy, one can reduce this investment by applying efficient energy saving measures. But to make it completely **energy neutral** one has to achieve as much energy production **during the life time of the building**. So when the building is demolished, it will leave no environmental damage.

TERMINOLOGY & DEFINITIONS

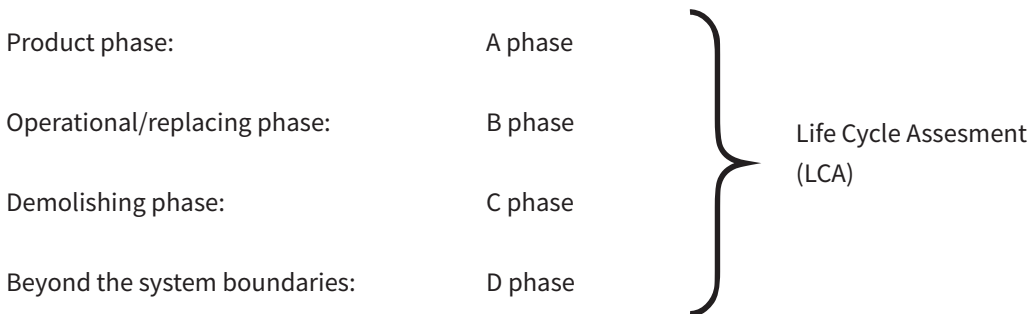
As mentioned, to achieve full transparency from both sides, energy production and energy consumption, the full life time of the building needs to be taken into consideration. Which is why a Life Cycle Assessment is necessary.

Life Cycle Assessment (LCA)

LCA is defined as:

“Comprehensive ecological assessment that identifies the energy, material, and waste flows of a product, and their impact on the environment. This cradle to grave evaluation begins with the design of the product and progresses through the extraction and use of its raw materials, manufacturing or processing with associated waste stream, storage, distribution, use, and its disposal or recycling. The objective is to identify changes, at every stage of the life cycle, that can lead to environmental benefits and overall cost savings. Also called life cycle impact assessment” (Businessdictionary.com, 2017)

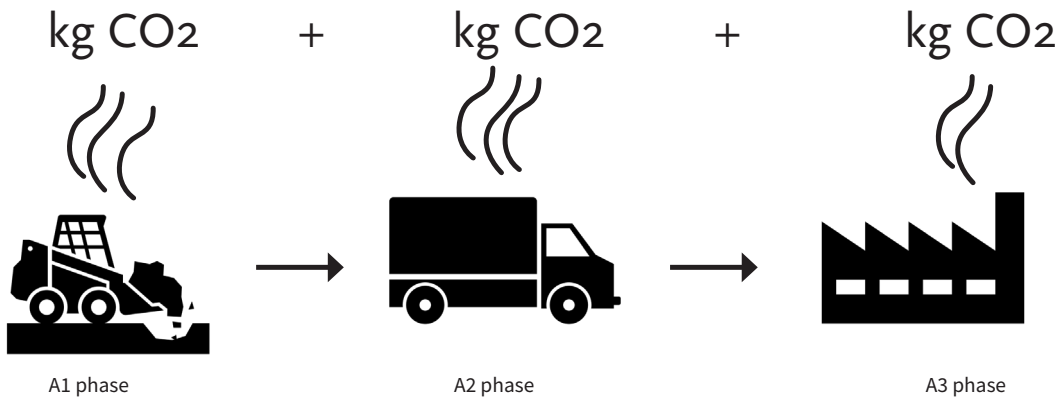
This definition talks about “stages”, or “phases” of a buildings life cycle. In the construction field four phases of a building life cycle are defined:



Product phase (A phase)

This means the manufacturing of the product, and mostly includes :

- The harvesting raw material at the source site (A1 phase)
- Transporting it to a factory (A2 phase)
- The manufacturing at the factory (A3 phase)
- Transporting it to the building site (A4 phase)
- Assembly at the building site (A5 phase)



Operational phase (B phase)

This includes the period when the building is completed and functions properly. Which includes:

- Use of the building (B1 phase)
- Maintenance (B2 phase)
- Repair of the materials (B3 phase)
- Replacement of the material (B4 phase)
- Refurbishment (B5 phase)
- Operational energy use (B6 phase)
- Operational water use (B7 phase)

Demolishing phase (C phase)

Disassembling the building parts and transport it to a disposal site, to leave no footprint behind on the previous building site.

- Deconstruction demolition (C1 phase)
- Transport to disposal (C2 phase)
- Waste processing (C3 phase)
- Disposal (C4 phase)

Beyond the system boundaries (D phase)

In this phase includes the Reuse/Recovery/Recycling potential.

Embodied Energy

“the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service” (Cleveland & Morris, 2009).

When raw materials are manufactured and brought to the building site, an investment in energy is done to make this transformation for the material happen. If a steel beam is produced, it will require labor in heating, rolling and shaping the material. The energy needed to produce a certain amount of building material is called Embodied Energy. This is not literally put into the material, but it is defined as kWh used to produce one kg/tonne/m²/m³ building material.

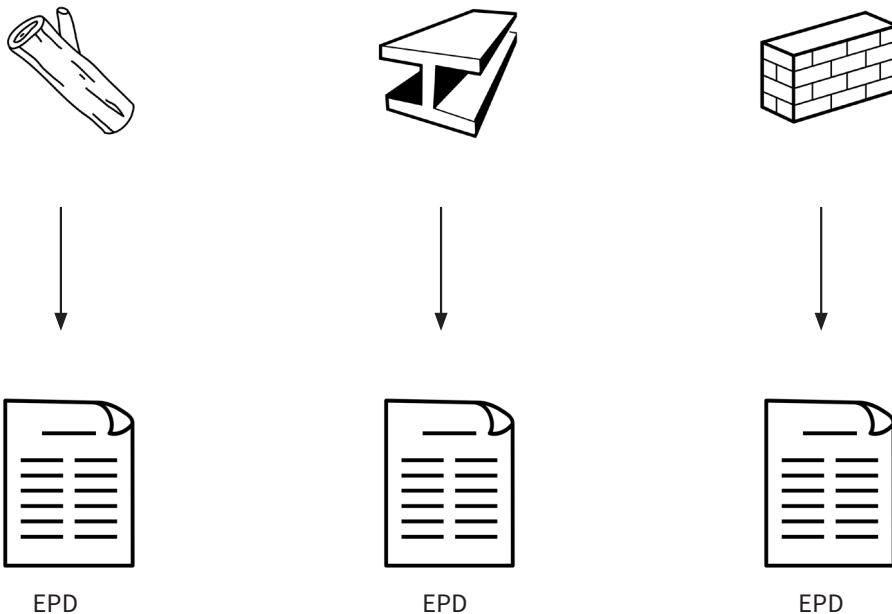
TERMINOLOGY & DEFINITIONS

Embodied Emissions

By producing building materials, the manufacturing and transporting can also be expressed in the amount of Carbon Dioxide which is evaporated into the air during the production processes. The term “embodied” suggests that this carbon is stored inside the material, however it is only to show the link between the amount of grams of CO₂ produced during the production of the product.

Environmental Product Declaration (EPD)

The documentation about how much CO₂ is produced per Life Cycle Phase of the material, is documented in an EPD. This is an overview, produced by a manufacturer, which shows transparency in the production process of the product. It tells the life cycle story of a product. And it shows which phases of the life cycle are included, and if so, what the specific amount of CO₂ production is during this phase.



Country Grid Mix

To calculate CO₂ or energy amounts in the production process of a building material, some EPD’s work with kWh used during a particular Life Cycle Phase. Sometimes the EPD is more accurate on the production of CO₂ evaporation. Sometimes these two units need to be translated to one another. How much CO₂ is produced to get one kWh depends on the country and where it gets its electric energy from. This is explained in a Grid Mix, which is usually documented and updated every few years. There is no general database where all gridmixes are found. But the European Union keeps track of all European countries.

Ice rink

“An ice rink is a level area of ice, usually inside a building, that has been made artificially and kept frozen so that people can skate on it.” (collinsdictionary.com, 2017)

Circularity

In the most simple definition circularity means “reasoning or arguing in a circle.” To apply the word in the architecture field it compares to the definition used in **Circular Economy (CE)**:

“CE takes the reusability of products and materials and the protection of natural resources as a starting point and pursues value at every stage of the system” (Prins et al., 2015).

In more daily terms, circularity in the building environment means to close production loops. This means that certain production flows in the building process or during the existence of the building, there should be more attention to close these production cycles.

In this project the term reusability is important, ice rinks are highly overproducing waste heat. Reusing this heat will enhance the circularity of the building.

RESEARCH DEFINITION

RESEARCH DEFINITION

- 5.1. Problem statement
- 5.2. Research directive
- 5.3. Research questions
- 5.4. Methodology

RESEARCH DEFINITION

5.1. PROBLEM STATEMENT

In a world where sustainability and durability is being integrated into several scientific fields, the architectural field plays a highly contributing role. Approximately 30% of the emissions produced by human kind is by the building process/building usage. A durable/sustainable building has a minimal impact on the environment, has a low energy consumption, so financially independent and can last with minimal maintenance.

These requirements are not met by the ice rinks currently available in the building stock. An ice rink is forced into its

existence because the sport can no longer be practiced outdoors. This relatively new building typology is struggling on several levels.

The architectural challenge

An ice rink, a building containing an artificial ice floor, is a building typology which is undermining nature. When nature doesn't provide natural ice, the ice production has to come from another source. The way artificial ice is made, is an energy consuming process, which involves dangerous chemicals and machines with, still, a low efficiency. The building surrounding this

ice layer has a large role in the poor energy performance. This poor performance is originated from several developments:

The necessity of an indoor ice skating facility

Ice skating is known for its heavy circumstances. It can be cold and snowy when this sport is practiced outdoors. As shown in image 5.3. In the 80's the Netherlands started building their first ice rinks. The initial reason these rinks were build was to extend the skating season, because during that time, the skating seasons grew shorter. The

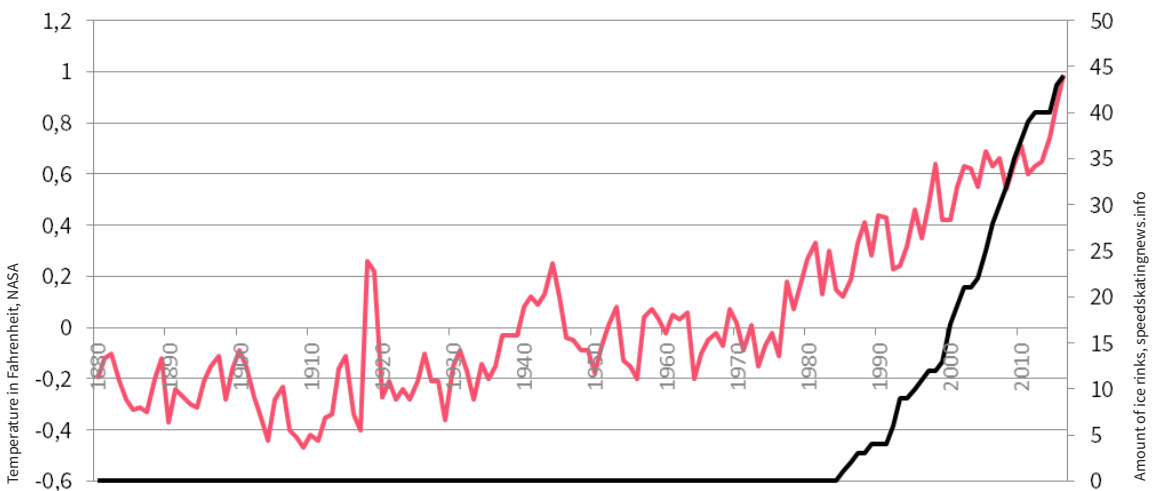


Figure 5.1: Indoor ice rinks build over the years, own illustration.

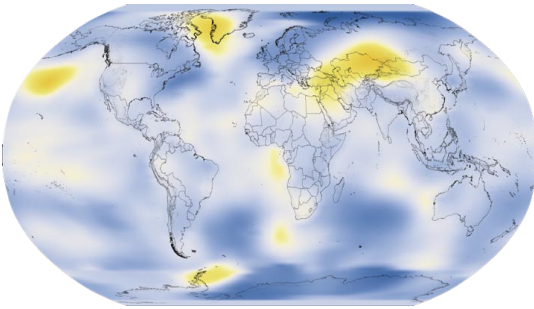
— Temperature change
 — Indoor ice rinks build

RESEARCH DEFINITION

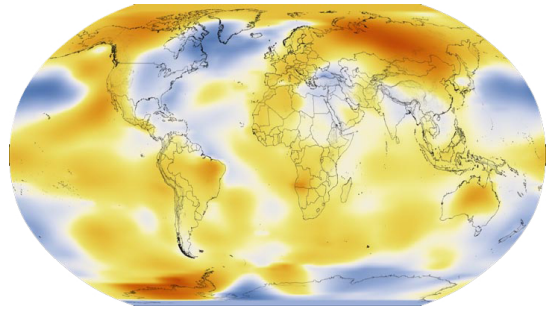


Figure 5.2: Global warming: temperature change

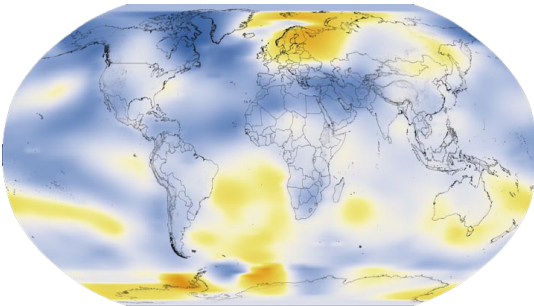
The five-year average variation of global surface temperatures in Fahrenheit (GISS/NASA, 2017).



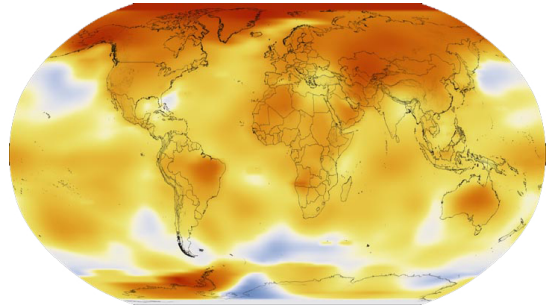
1966



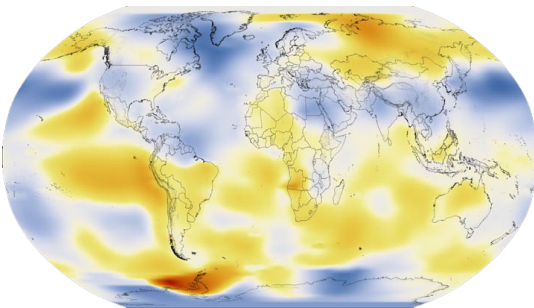
1996



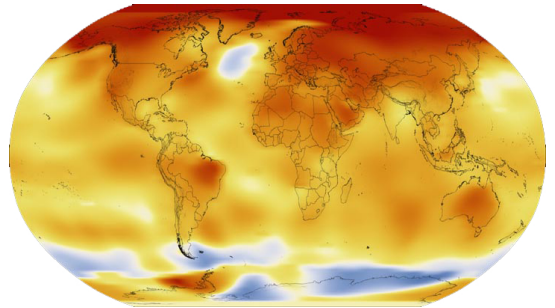
1976



2006



1986



2016



Image 5.3: Skaters during the Elfstedentocht in 1963, an ice skating tour, also called “The hell of 63”, known for its heavy natural circumstances (G-geschiedenis, 2013).

winters were still heavy enough to provide a steady period of below-zero temperatures. Only this period was growing shorter (Berends, 2015).

Nowadays our winters are so soft we can only practice skating on natural ice on rare moments. The annual temperature worldwide is increasing, as shown in figure 5.2.

In figure 5.1 the amount of indoor rinks with artificial ice build and the increase of temperature over the years are displayed. The relation between the two is visible,

they are connected positively, by an increased temperature the number of ice rinks grows. This increase of ice rink numbers has a small delay compared to the temperature increase. This can be explained by the fact that for some years, the smaller skating seasons were simply accepted. As well as it takes a couple of years from initiation to realisation when building an indoor ice rink.

Only in approximately the last 100 years an unusual increase in annual temperature is visible. This effect is happening worldwide, called global warming. This change in global

climate is caused by several reasons, in which the human role is leading.

Unsustainable architectural typology

The change of context in which the sport is practiced is reason for an unsustainable development:

“A transformation of recreational activities and ways of defining national identity may be required in the long term. However, current adaptations in the face of warming conditions appear to focus on preserving existing activities through “controlling” local environmental conditions

RESEARCH DEFINITION

in the short term in the face of changing weather conditions, often in ways that involve increased energy use” (Eriksen et al., 2016, p. 15).

The rush in producing these ice rink buildings and lack of budget resulted in ice rinks with a temporarily character.

The reason this energy use is increasing can be explained by the energy demand for the production of an artificial ice floor. “Energy costs are typically the largest bills for skating rinks, which use huge amounts of electricity to run the equipment that makes and maintains the ice” (Ring, 2016). The problem that these facilities use a lot of energy, and cost more in their investment and use than they will ever deliver back, is mainly not acknowledged by the public.

For every Olympic Winter Games more rinks are build, case studies showed that some rinks will only provide ice within the Olympic event itself, afterwards the building is used for another function in the best circumstances, for example the Richmond Oval in Vancouver. In some cases the buildings are never used again, which is the case for the Adler Arena in Sochi, and sometimes they are

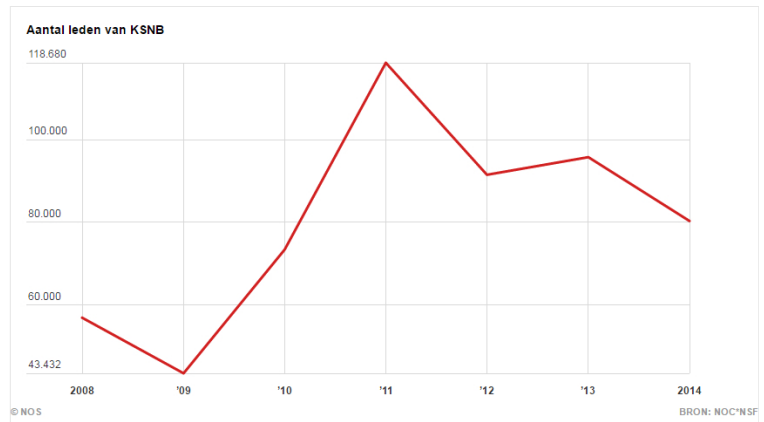


Figure 5.4: Amount of members at Dutch Ice skating Club in Longtrack ice skating (NOS, 2015).

demolished in just a couple of years after the Olympic games, like the ice rink used for the games in Turin. The question arises if buildings like these, existing for public interest, but not profitable in their life time, should be desired. Playing with laws of nature to make a building which will only consume energy and produce waste, can be described as unsustainable.

Demanding sport architecture

Sport buildings in general don't compromise when it comes to energy demands, they want the best lighting possibilities, the best climate and there will be no compromises to reach these goals. There has been thrown with energy when it comes to sport accommodations (Brink,

2004). Sport, which was in general initiated to provide us with a healthy lifestyle makes our world in a way unhealthy by making buildings which contribute to environmental damage.

Lack of interest

This shift from outside skating to inside skating is tending to change the skating experience. As stated in the questionnaires which were executed for this research, the skaters perception of the skating image is changed and that the appreciation for skating in nature is almost vanished. “The production of artificial ... ice can only support skating ... in isolated areas, while the loss of natural winter conditions and associated recreational activities could

damage cultural and emotional attachment to the winter landscape, and potentially lead to a loss of values around national identity” (Eriksen et al., 2016, p. 15).

The sport has suffered losses in participation. This loss consists especially of youth, but in general from recreational skaters, whose numbers were higher when the sport was still practiced on natural ice (NOS, 2015). This natural ice experience is preferred by this target group, the scenery and social gathering is important to them. The group tends to grow when there are colder winters, in a graph provided by NOS (Figure 5.4) one can see the decrease in members of the KNSB, the Royal Dutch Skating Federation, after a cold year: 2011.

Materialisation

“In many cases the buildings are simple in plan and pre-manufactures metal buildings” (Straube, 2006, p. 1). Because of this cheap fabrication, a lot of rinks comb with indoor climate problems, mostly related to moist. The choice of materials does have a high contribution to a better- or worse - indoor climate. Materials can radiate heat



Im. 5.5: Bad ice conditions in Optisport ijsbaan Breda due to warm temperatures.



Im. 5.6: A humid indoor climate is bad for the sporter's comfort and performance (Ijsbaan De Scheg in Deventer).



Im. 5.7: Dark interior during daytime at De Uithof, the ice rink of The Hague (Den Haag Direct, 2014).

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towards the ice, cause condensation or, in case of bad detailing, let hot humid air into the ice sheet area, which is bad for the ice quality and air quality.

Comfort of the sporter

Another reason the sport was shifting indoors is that these building could provide comfort and protection form heavy weather circumstances. During rainy days or heavy wind skaters could choose to practice their sport indoors. Sporters complain a lot about these circumstances, their performance is dependent on good circumstances, within ice hockey the ice needs to be extremely hard, which means the surface temperature needs to be cold. Within longtrack speedskating the ice needs to be even and as low resistance as possible , around -7 degrees the optimum is achieved. An ice rink needs full control in its inner climate.

Other demands of the sporter, in case of architecture, are mostly about lighting. In all ice skating discipline a brighter inner sport facility is a better

facility (E. Berends, personal communication, 07-12-'16, Appendix 1).

Also air movement and air temperature are considered important for an ice skater. The air is not preferred to move with a high velocity, to improve comfort and performance.

A lot of rinks try to improve their comfort by heating their air, IJsbaan Twente invests more energy in this than the refrigeration plant (G. van Dam, personal communication, 30-11-2016, Appendix 1). In a lot of cases ice rink air is humid, because of the exchange of hot and cold air in the same space, also sporters contribute to a humid environment. An open ice rink has this problem often, due to its dependency on outer circumstances.

Unprofitable architecture

Due to the large consumption in electricity and loss of heat/ cold and the building is fighting to keep on existing.

Triavium in Nijmegen pays 2,7 million to electric energy and are still using 100.000

cubic meters gas to heat their building, and this is just one example. This overconsumption and large energy loss leads to large expenses. Rinks rely on subsidy of the local municipality or government (E. Berends, personal communication, 07-12-'16, Appendix 4).

Annual ice rink occupation

Ice rinks are occupied during the winter months, mostly the skating season stretches from the beginning of october to the end of march. The other six months these buildings are mainly unoccupied. Sometimes this is obligated, to prevent competition with other large sporting venues (G. van Dam, personal communication, 30-11-2016, Appendix 1). Case studies have shown that in most cases the architecture doesn't support another function to occupy the building in the summer months (Appendix 4).

To summarize all challenging developments of the ice rink building typology, a overview scheme is made.

Artificial ice rinks are, in these times, barely able to be maintained. This [Thialf] was a “leaking” box, the heat was disappearing everywhere. The energy expenses were sky-high.

3 DEVELOPMENTS INFLUENCING THE MODERN ICE SKATING PERCEPTION:

1.

2.

3.

GLOBAL WARMING

DEMANDING SPORTERS

LOW INTEREST

THE NECESSITY OF ARTIFICIAL INDOOR ICE RINKS

POOR BUILDING PERFORMANCE

UNPROFITABLE

LOW OCCUPATION

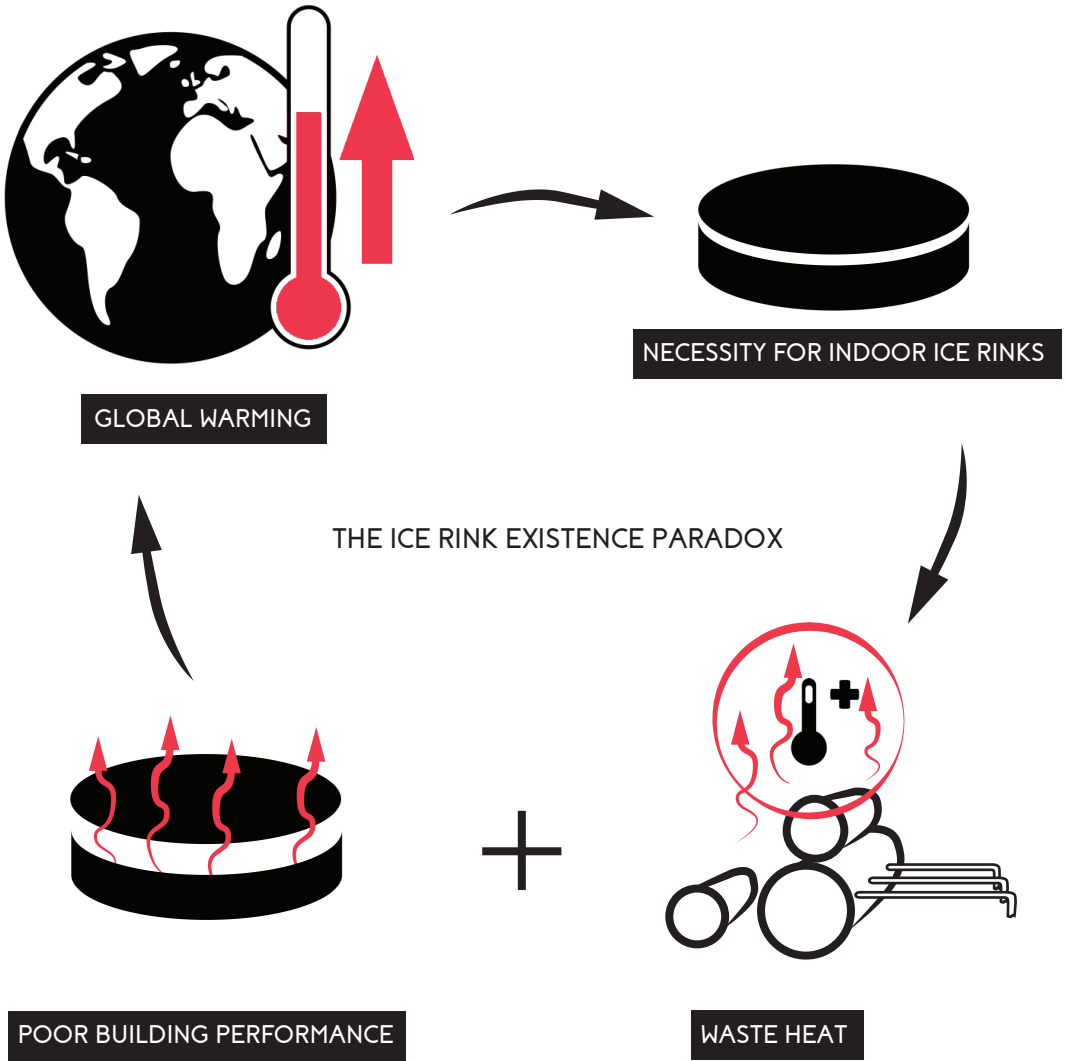
LOW COMFORT

LOW ENERGY EFF.

WASTE HEAT

THE FOCUS OF THIS RESEARCH

RESEARCH DEFINITION



5.2. RESEARCH DIRECTIVE

Energy neutrality in our building designs shouldn't be an option, it should be a standard.

Being an architect means that, as a designer, there is a responsibility towards the building stock in the future. The habit to design a building and add energy saving means later is an outdated way of designing.

Designing a building, with integrated energy concept, taken into account materialisation and operation scenarios, should be the norm. Energy neutrality in our designs shouldn't be an option, it should be a standard.

The main goal is to create a manual on how to build an **energy neutral** ice rink. This manual is used to create a

designproposal for an energy neutral 400 meter ice rink in a later to be defined location.

The manual will **rethink the technical design, operation system and spatial composition, of an ice rink.**

The next step is to design an ice rink, focus on the speedskating discipline, which means a 400 meter ice rink, an oval ice sheet surrounded by a smart building, supporting the ice skating environment and shaped recognizably for its large range of visitors.

The design will be a new proposition on "**How to integrate energy-saving**

rchitectural instruments towards a holistic energy neutral ice rink design".

Which will be further discussed in the Projectbook, a sequel to this Researchbook.

Apart from the operational/spatial/technical requirements, some **background information** is needed to fully understand the complexity of the project.

The final result will be a program of requirements. Which can be viewed as a conclusion to this research.

To summarize the goals of this project, the research is divided in three main chapters:



RESEARCH DEFINITION

A new performance and independent ice rink, for multiple ice sports, which operates in an environmentally friendly way and promotes the sport for a broad public.

Why new?

To make sure that all aspects can be considered, no concessions will be made for an existing structure, the building will be designed from scratch to achieve optimization of several fields. As well as having control when it comes to calculations of energy usage and financial expenses/incomes.

Why performance?

To attract professional ice skaters, which promote the ice rink and city. Also leisure ice skaters will be pleased with a comfortable inner climate and good ice quality. Making an ice rink energy neutral could be achieved by making concessions in ice quality, less cooling means fewer energy needed, but it also means a bad ice quality. The challenge is to integrate both goals: good ice quality and energy neutral building.

Why independent?

Ice rinks are mainly using electric energy “from the net” and require subsidies from the government/municipalities to exist. By taking a closer look at how the building can be managed and closing circuits the building could sustain itself without being dependent to other parties.

Why multiple sports?

The sports work together in training practices, by practicing one, one could improve their skills for the other. And to generate higher visitors numbers in both sporters and spectators. Also, the climatic challenges are the same, better to cluster them.

Why environmentally friendly?

By building a traditional ice rink, we deteriorate the climate change even more. The archetype of an ice rink needs to change, to anchor the reason of existence of an ice rink in the future.

Why promotion?

The monocultural success of one country can deteriorate the enthusiasm of the sport in other countries. There is a lack of facilities in countries with potential of success in the ice skating sport. By promoting the sport one can generate higher visitors numbers towards the ice rink, which will improve the financial sustainability of the building.

Why a broad public?

To generate higher visiting numbers, to improve the financial situation of the ice rink.

5.3. RESEARCH QUESTIONS

As described in the Research Directive, energy neutrality is the main focus. But the building should also generate high visiting numbers, in winter and summer, including all technical requirements designed in a logical spatial composition, to generate a **holistic energy neutral ice rink design**.

Main research question

How to integrate energy-saving architectural instruments towards a holistic energy neutral ice rink design.

Sub research questions

The 3 main focus subjects of this research are categorizing different questions. On which the chapter structure of this report is based. An overview of subquestions is shown below. In the next page more questions are displayed, connected to the main chapters of this research.



- Who are the users of the building and what do they require?
- How can the building be used to generate an optimal occupation density?
- What are the potential routes every user needs to make?
- Which spaces are required for winter and summer functions?
- Which construction features the best properties for usage and technical requirements?
- How can an ice rink be integrated in a city?
- Which climatic applications are necessary?
- Which materials are convenient to support an energy efficient ice rink design?
- How are water, heat and electric energy integrated in ice rink designs?
- Which architectural elements can be contributing to the production of the required electric energy?

RESEARCH DEFINITION

How is an artificial ice layer for ice skating produced?

How does the refrigeration process work?

How did the ice skating sport come into existence?

BACKGROUND INFORMATION

How did the ice rink building typology come into existence?

What are the different ways of ice skating?

Do different ice skating disciplines need different ice sheet dimensions?

In which countries are most ice skating disciplines practiced?

What is the financial situation of an ice rink, and how can this be improved?

What is the management structure of an ice rink?

ICE SKATING RINK

How will the ventilation be regulated to achieve optimal sport circumstances?

What are the climatic requirements in summer?

How is heat produced in the building?

How can energy producing elements be integrated in an ice rink design?

How can the inner climate of an ice rink be managed?

ENERGY PERFORMANCE QUESTIONS

What parts of the ice rink consume energy and how can this demand be reduced?

Which materials are to be chosen to improve the inner climate?

What materials are enhancing the buildings sustainability?

Is it possible to make closed loops in water use?

Is it possible to make closed loops in water use?

Can natural daylight be used inside an ice rink?

What is my definition of sustainable?

What does artificial ice mean?

TERMINOLOGY + DEFINITIONS

What does energy neutral mean?

What are embodied emissions?

How to optimize the annual use of an ice rink?

How will a winterbound building be used during summer?

OPERATIONAL QUESTIONS

Who will use the building during what time?

What are the requirements of the user?

Which spaces will the user occupy?

What is the order of space occupation per user?

How many people need to be able to spectate?

Who is the permanent staff?

How will logistic services enter the building?

Which spaces need to be in direct contact with the outdoors?

How should an ice rink be implemented into a city?

How can a large span construction be made?

SPATIAL QUESTIONS

Which spaces does an ice rink require?

How many square meters does every space need?

OF THE FUTURE

RESEARCH DEFINITION

Interviews and questionnaires

Technical staff



Gerwin van Dam



Jelle Van Beek



Frank Bongenaar

Architect



Engineers



Christian Potma



Ernst Berends

Manager



Johan van der Kooi

Skaters

Questionnaire in the Netherlands:
70 participants

Questionnaire in the United Kingdom:
83 participants

5.4. METHODOLOGY

By doing a smaller orienting research it became clear that scientific literature about the building typology, climatic requirements or financial problems are not highly present when it comes to investigating ice rinks.

Most information about the use of the building can be found within a small group of experts. Architects of recent new rinks, but also cooling/flow design technology experts, exploitants, but most importantly: **ice makers.**

This profession includes technical management of a building, and these are the people who have experience with climatic, financial and building physical problems within ice rinks.

My method will include interviews with the professionals mentioned above.

Most of the questions which will be asked to them will be about the **operation of an ice rink.**

Other research, like solutions for the **climatic demands** of an ice rink, and what these demands are, what the **building envelope** requires, but also how a **construction of a large span** like that of an ice rink can be build are subjects which needs to be addressed. Other aspects, like the **circulation of people** in spectator areas, **use of the rink in summer**, and the history of the sport and its housing cannot all be found in interviews.

Therefore, **literature** will be addressed.

On specific ice rink solutions on the subjects mentioned above, I will look into **case studies of existing rinks**, not only in the Netherlands, but a small selection of the international ice rink stock.

Goal is to find within these interviews, case studies and literature ways to lower the energy demand within ice rinks, for example types of insulation, programmatic

solutions, building physical aspects to improve the inner climate and lower energy loss.

These will be the requirements which will be implemented into a Program of Requirements. This program will be an overview of (if possible: measurable) goals which will be the spine of my design proposal.

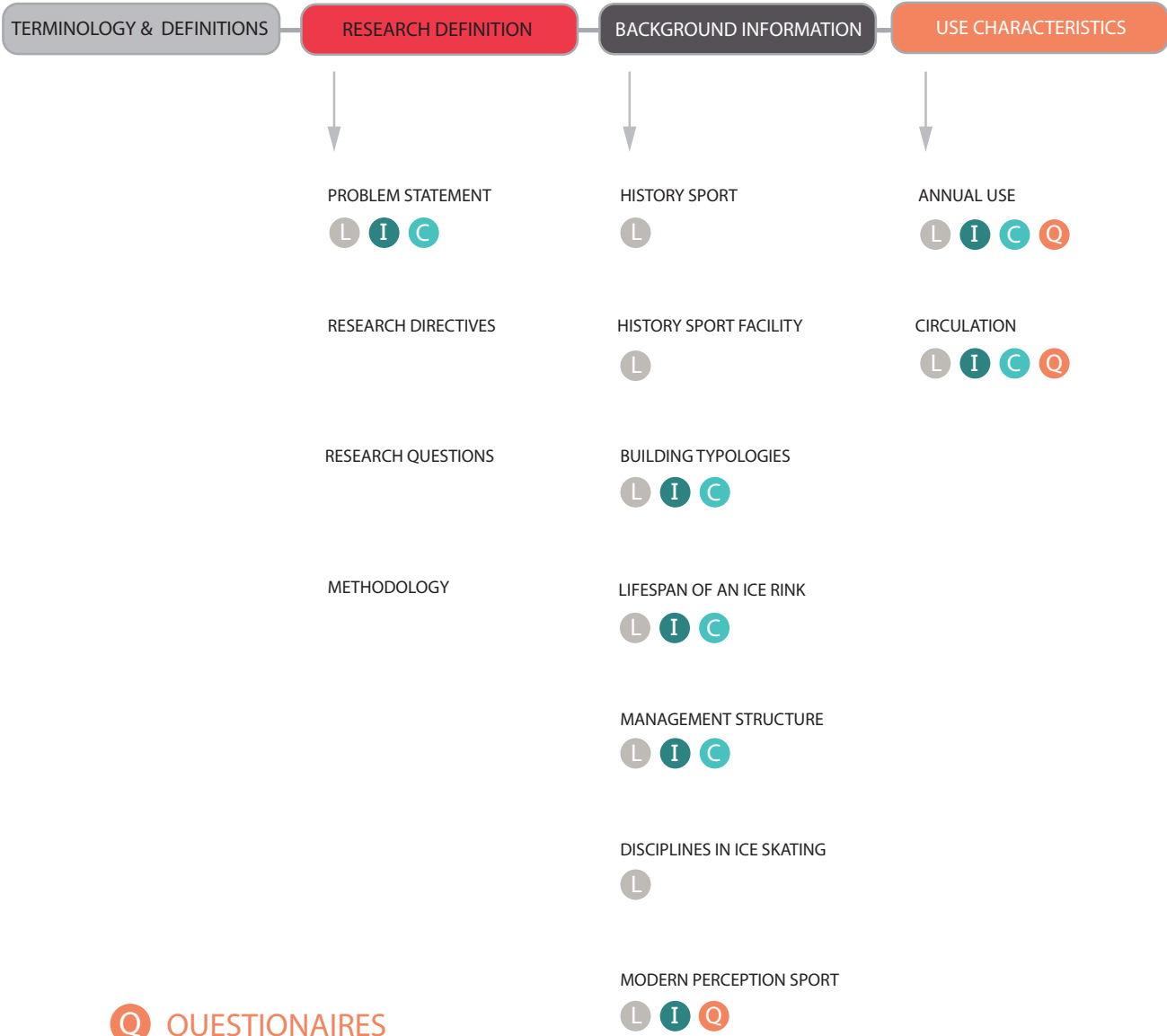
4 methods of research

So, in short, in this research 4 methods will be applied.

1. Interviews
2. Literature
3. Case studies
4. Questionnaires

It is not definite that one research method only matches one chapter. There will be overlap, some questions will be answered during interviews, some through questionnaires. An overview of what information is needed and where to get this, is shown on the next spread.

RESEARCH DEFINITION



- Q** QUESTIONNAIRES
- I** INTERVIEWS
- C** CASE STUDIES
- L** LITERATURE

SPATIAL CHARACTERISTICS



REQUIRED SPACES
L I C Q

CONSTRUCTION PRINCIPLES
L C

INSERTION IN CITY
L C Q

TECHNICAL CHARACTERISTICS



SUSTAINABLE MATERIALS
L I C

CLIMATE CONDITIONS
L I C

CIRCULARITY ENERGY
L I C

CIRCULARITY HEAT
L I C

CIRCULARITY WATER
L I C

USAGE OF LIGHT
L I C Q

ENERGY PRODUCTION
L I C

ENERGY BALANCE

PROGRAM OF REQUIREMENTS



SPATIAL REQUIREMENTS

SUSTAINABLE REQUIREMENTS

CONCLUDING



CONCLUSION

DISCUSSION

REFLECTION

BIBLIOGRAPHY

RESEARCH DEFINITION

Interviews

3 types of experts were interviewed during this research, an operator of an ice rink, who is responsible for managing the building. Ice experts, who produce and maintain ice skating surfaces. And engineers who have directly or indirectly knowledge about ice skating facilities and their technical requirements. In the end, 7 people were interviewed to gather information about the operation of an ice rink. One of these interviews was done confidentially, so the results are not shown in this report.

The other interviews are visible in Appendix 1-5, two people I interviewed at the same time, so in the end 5 interviews were done.

Dutch questionnaire

To find out the requirements of the biggest user group, the ice skaters, two questionnaires were done. One was for the Dutch ice skaters, in which I used my personal network. Being an ice skating student, there are a lot of ice skating

student clubs, which have regularly contact with each other. So most questionnaire responses were ice skating students. A positive aspect about this is that there is a good balance between experienced performance-driven students and students who start practicing the sport when they started studying. So there is a good recreational/performance distribution in this group. The downside of this questionnaire is that mostly longtrack skaters responded on the questionnaire. So there is less distribution in different ice skating disciplines.

British questionnaire

As will be clear in the Projectbook, my ice rink design will be designed for a British city. To make sure that there was enough interest and if the Dutch requirements were not that different from British ones, another questionnaire was made.

To reach as much British ice skaters as possible I had the privilege to use the network of Stephen Airey, Longtrack Development Manager of the

NISA, National Ice Skating Association of the UK. Being the person to promote the longtrack ice skating discipline in England he had a lot of contacts in several areas in England. Longtrack ice skaters in the UK have to practice their sport in the Netherlands. In this way, I was able to get a large response, not only from longtrack skaters, since this is not a popular sport, yet, in the UK. Among the responses were also shorttrackers, practitioners of figure skating and a small ice hockey players group.

Goal of both questionnaires was to have a demographic overview where skaters were situated, how long they were willing to travel for the nearest ice skating facility and what their requirements for an ice skating facility were.

Case studies

During my ice skating practices I had the chance to make use of all 17 Dutch ice rinks. I am familiar with all designs, and sometimes I could practice in international rinks as well.

By the choice of the case studies I chose some rinks because of curiosity. Some of the international ones I already had the chance to visit.

I chose the rinks which were well known in performance, meaning, having produced “fast track times” over the years.

Also, Olympic rinks are interesting to analyse, since their use can differ after the Olympic season and Olympic organisations mostly try to give

their buildings an attracting appeal, so most rinks which are considered beautiful are Olympic rinks.

Eventually the following list of rinks were chosen, to keep things clear for myself I named the rinks to the city they are placed in, since most names don't suggest their location:

- Heerenveen (NED)
- Leeuwarden (NED)
- Nijmegen (NED)
- Astana (KAZ)
- Vancouver (CAN)
- Sochi (RUS)

- Kolomna (RUS)
- Salt Lake City (USA)
- Calgary (CAN)
- Inzell (GER)
- Nagano (JAP)
- Hamar (NOR)

Conclusions in every chapter

To have a clear translation between the conclusions of this report and a framework for my graduation design, every chapter include design demands extracted from the text, as a conclusion at the end of each chapter.

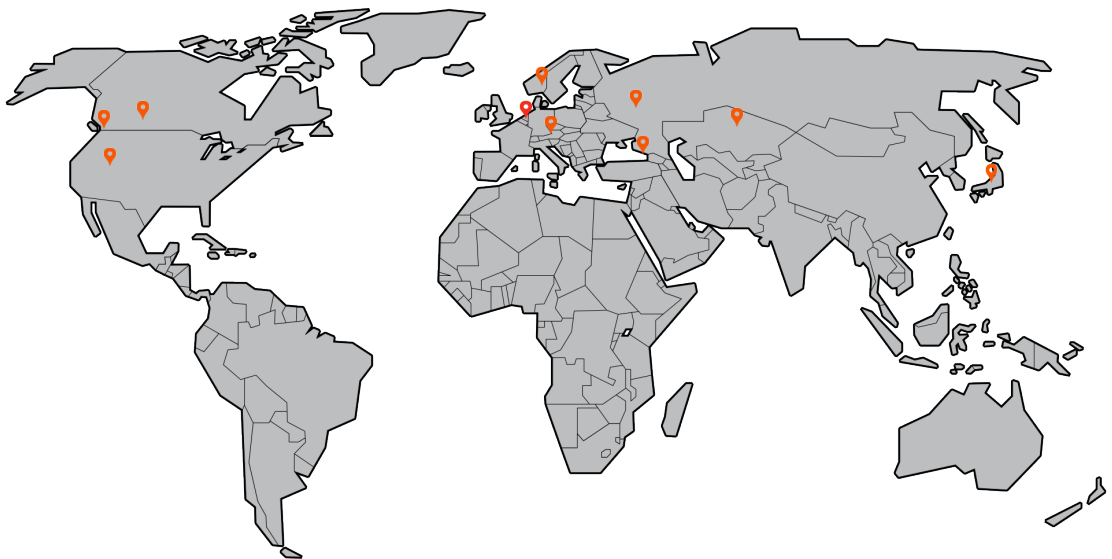


Figure 5.8: Overview of the locations of the investigated Case Studie Ice Rinks. Own illustration.

BACKGROUND INFORMATION

BACKGROUND INFORMATION

- 6.1. History of the sport
- 6.2. History of the sport facility
- 6.3. Different building typologies
- 6.4. Lifespan of an ice rink
- 6.5. Management structure /
Financial situation
- 6.6. Ice sheet production /
Refrigeration process
- 6.7. Four disciplines
of ice skating practice
- 6.8. The modern perception
of the ice skating practice

BACKGROUND INFORMATION

6.1. HISTORY OF THE SPORT

The beginning of the sport

An actual beginning or location of the skating sport is unknown, since evidence has been found in several places on earth. Though it is estimated that the sport found its origin about 5000 years ago in the Northern part of Europe. Countries which had a lot of surface covered by water were, not unexpected, also the countries where the evidence has been found. This evidence consists of skates made out of animal bones, mostly retrieved from horses, mostly from the lower leg bone, which is called the 'gliss', skates from this time are therefore called glissers (shown in image 6.2). These skates have been found in Norway, Sweden, the Netherlands and Germany. But Finland most of all, since the division in water and land in a higher rate than the other mentioned countries.

Back then skating was not considered as an actual sport or leisure. It was a means for transport, to hunt or to get to places for shelter. It has been known that these skates could



Im. 6.1: Painting called: Winterlandschap met schaatsers (winter landscape with skaters), Hendrick Avercamp, app. 1608, From: Rijksmuseum.nl.

“ease” the travelling by 10% on the same distance compared when you did it by foot. Also one could travel easier over ice and make short cuts. Though the technique had been believed to be very different from nowadays. In stead of

the sideways movement, the skaters used poles to push their way forward, more related to the cross-country ski movement. (Whipps, 2008)

The actual usage of metal blades dated back to the 13th

century (Russel-Ausley, 2015). Evidence of this has been found in Amsterdam and Dordrecht in the Netherlands, and because of the metal it was possible to change the technique into a movement sideways. These skates, made of wood and a metal plate were a Dutch invention, named “Houtjes”, or small woods (shown in image 6.3). Some other countries, mentioned earlier, continued on using bone structured skates for several more centuries. Because metal was a valuable resource the skating sport was only practiced by the elite in the Netherlands. During the Dutch golden century, around 1600 till 1700, people became wealthy, so the activity became also a leisure for common people (Boere, 2011). A scenery painters were fond of, like the painting of the winter landscape by Hendrick Avercamp, shown at Image 6.1 (rijksmuseum.nl).

In the Dutch culture skating was the most efficient conveyance till the 19th century. Another theory why the sport was popular, was the fact that the Netherlands was



Im. 6.2: To be believed the first type of ice skates, the gliss, made of horse bone. Found in several north European countries (Whipps, 2008)



Im. 6.3: Wooden skates with metal blade, houtjes, invented around 1300 (Lc.nl, 2012)

always struggling to keep the land secure from water. The time that the water freezes is also a time for celebration, that

the water has been temporarily conquered (Vos, 2014). Interesting fact is that during the Spanish Occupation, the 80

BACKGROUND INFORMATION

years war, in 1568-1648, Dutch cities could keep sustaining themselves since food would be brought to them by use of the frozen waters, something which could not be prevented since the Spanish soldiers didn't have the experience on the ice. Up till the 1800's skating was used as transport agent and leisure.

But two centuries ago it became more competitive, the first reports from competitions in the north of the Netherlands. Halfway the 19th century a lot of skating clubs were established, they were arranging the tracks to skate on, which was usually some water on a meadow, or a canal cleaned from the snow. Ten of these largest clubs erected a skating bond in 1882, which still exist today, the KNSB. Ten years later the International Skating Union was established, by name of ISU. The organisation of competitions became more professional, and the sport became popular among other countries, not directly on professional level, but for leisure purposes (KNSB, 2008).

Another interesting facts is that



Im. 6.4: Traditional ice skating, with sticks, is still practiced in Finland (Outdoorfinland, 2017)



Im. 6.5: Dutch soldiers using the ice in their defending mechanism during the second world war, Iceskatesmuseum.nl.

the ice skating skill was also used during later wars, like the second world war, Dutch soldiers made weak spots in the ice to set traps for the invaders, the Dutch soldier

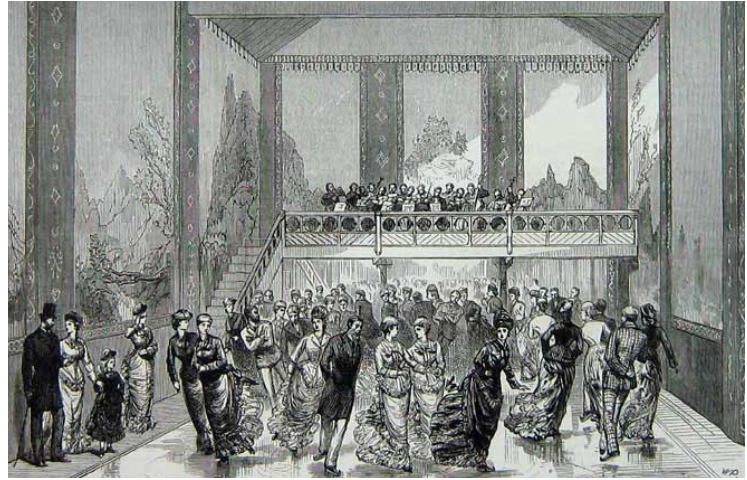
skaters knew where they were, in this way they had an advantage on enemy troops. Shown on the previous page (iceskatesmuseum.nl).

6.2. HISTORY OF THE SPORT FACILITY

Artificial ice rinks

Around the middle of the 19th century, international competitions were more common, organisers had to have a guarantee that the ice would be in good condition, they had to be responsible for the ice since there would be a lot of international competitors, travelling for long distance. The dependence of good ice, also during warmer winters, was gaining. Which resulted in the first artificial ice rinks in London around 1840, called London Ice Floor, shown on the right. Another rink of this type was made in New York in 1868, by the name of The Covered Rink. The artificial ice was made of chemical mixtures, mostly salt, alum or sulphur solutions, which “according to old books smelled awful, there was always fog and you should not fall!” (Berends, 2006, p. 1)

Around the year 1805 the refrigerator system was invented, but it was not commonly known and there was a natural resistance against this invention, since ammonia gas was used, which is poisonous. It took to at least

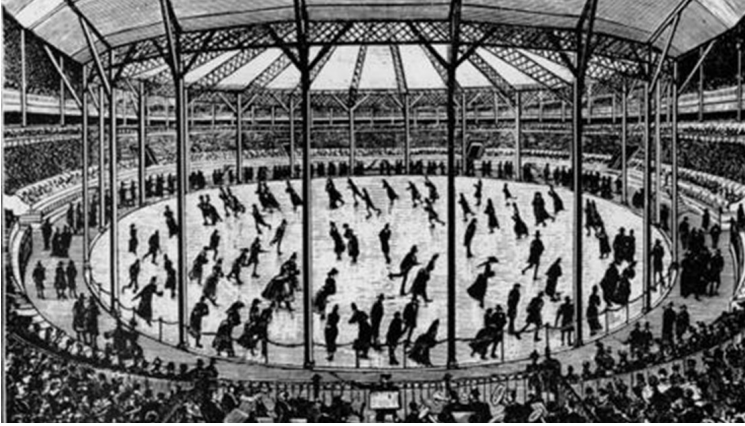


Im. 6.6: Glaciarium from 1876 in London, (hhhistory.nl, 2013)

the 1850's that refrigerators were used on a larger scale (Inventor Strategies Group, 2007). Because of its industrial revolution and its role in the invention process of the refrigerator England had the chance to make the first ice rink made of real ice. Though the term artificial ice rink is also used to describe this rink, it is actually wrong, because the system producing the ice is artificial, and the ice isn't. This first “artificial ice rink made of real ice” functioned by means of copper pipes, which contained a mix of glycerine and water to cool the surface, which was a very expensive system. In these systems the water was directly placed on

the same surface as the pipes, the pipes were in this way visible through the ice. This first “real ice” rink was placed in London in the year 1876, it was called the Glaciarium. Three years later the United States opened a indoor ice rink in New York (Russel-Ausley, 2015). The sport had gained interest, because of experts travelling from Europe to the US and the other way around to give demonstrations (Berends, 2006). All these rinks mentioned before were small rinks, made for ice hockey and figure skating. Until the 1950's there were no 400 meter rinks and the international competitions were until the 1980's most

BACKGROUND INFORMATION



Im. 6.7: London Ice Floor in 1840 (Snoep, 2011)



Im. 6.8: The first skating practice at Jaap Eden Baan Amsterdam, October 19th 1967, in the ice are visible pipes, (ANP Foundation)

common to be held on natural ice. Obviously the winter temperatures were more extreme during that period, compared to current times.

The first 400 meter rink was built in 1958, in Gothenburg, Sweden. This rink was a temporarily rink which would be removed in summer. The building was providing an

arena for the ice skating sport, but also a runway for athletes. Both tracks are 400 meters, but the radius of the athlete track is different from the ice track. Also, when one had to make a concrete slab underneath a running track, the gravel on top would be damaged by defrost and freezing. The third 400 meter rink was made in Amsterdam, in 1961.

This also was a removable rink, the piping system was able to be taken out and stored. But in practice this took a long time and a lot of effort, so the system was removed only once (Berends, 2006).

Since Amsterdam a lot of other artificial rinks were introduced in the Netherlands, the most recent one is realised last year: the Elfstedenhal in Leeuwarden. The count now is 20 ice rinks.

When Thialf was build in 1986 Heerenveen and with the one build in Berlin one year earlier, a new concept was introduced. These rinks were both completely indoor, and had a full span construction over the sporting area.

Performance ice rinks were the new trend. During Olympic games the competitions was not only between the skaters, but also within organizing countries to realise the fastest rink of the world. The ice quality is the main contributing factor to a rinks "fastness". The investment in these rinks are building up each games, from 27,7 million euros in Calgary, during the Olympics of '88, to 211,3 million in Sochi in 2014 (Appendix 10).

6.3. DIFFERENT BUILDING TYPOLOGIES

As mentioned in previous chapter, having a sheet of ice inside a building, is considered a relatively modern buildingtype.

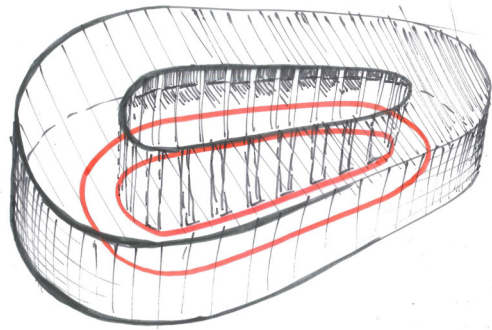
The sheets of artificial ice, which were used for skating were covered in the 19th century, but the bigger rinks, like the first 400 meter rinks, were outdoor.

Since the 80's, due to temperature elevation, protection of this layer of ice was required. From solar radiation, but also wind.

A relation between the annual temperatures elevation and built rinks is shown in the Problem Statement chapter.

Since the focus of this research is 400 meter ice rinks, the building which surrounds this particular ice sheet will be discussed in its different typologies.

The very first covered/indoor ice rinks was in Berlin, built in '85. Which was a completely open space,



Partly covered

In the 90's, most Dutch ice rinks were covered only above the ice sheet. Including bearing columns, which are placed within the inner circle of the ice skating sheet.

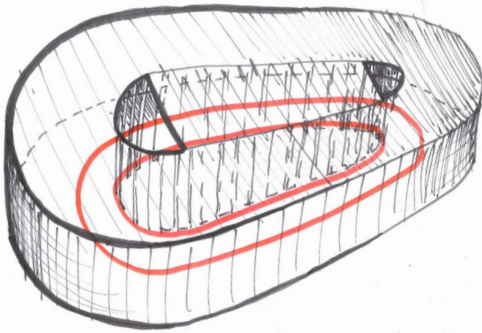


Im. 6.9: Ice rink in Eindhoven, Netherlands (Indebuurt.nl, 2017)



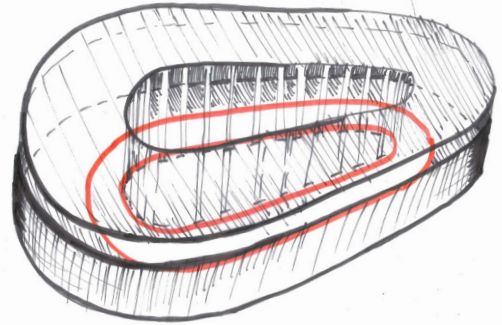
Im. 6.10: Aerial view of the rink in Eindhoven (Indebuurt.nl,2017)

BACKGROUND INFORMATION



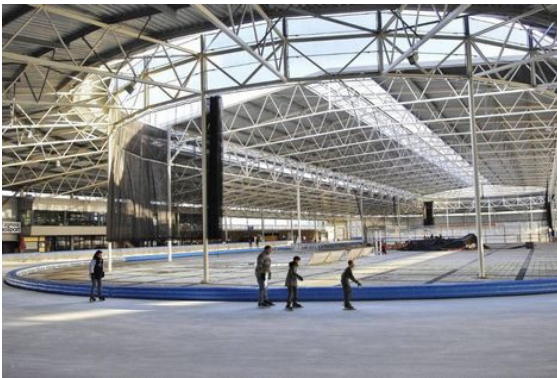
Partly covered, including inner area

Some ice rink contain smaller ice rinks in the inner area of the 400 meter rink. Mostly these areas need to be covered as well, to be more comfortable for the sporter. And to prevent wind access.



Partly covered, partly open surrounding walls

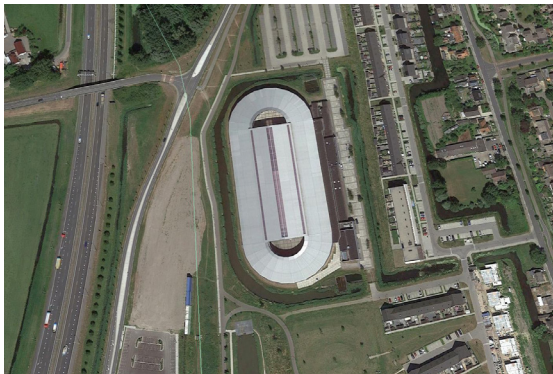
To stimulate natural airflow, some rinks have open parts in the walls, just underneath the roof (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).



Im. 6.11: Ice Rink Westfries (<https://www.optisport.nl/westfries>)



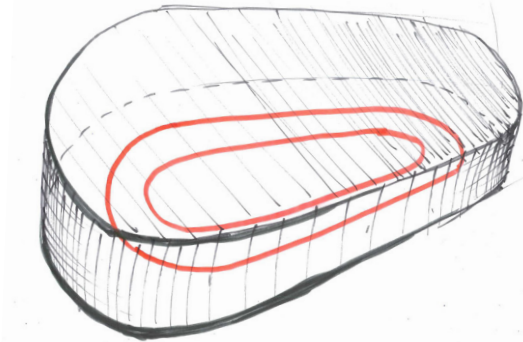
Im. 6.13: Ice Rink De Meent in Alkmaar (Demeentalkmaar.nl)



Im. 6.12: Ice rink De Westfries in Hoorn, the Netherlands (Google Earth)



Im. 6.14: Ice rink De Meent in Alkmaar, the Netherlands (Demeentalkmaar.nl)

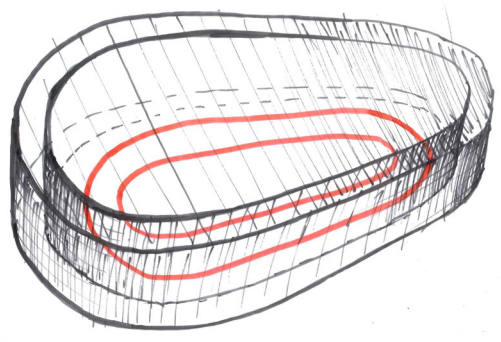


Indoor

To achieve more comfort and manageable circumstances, completely closed rinks are a solution. Though a ventilation system is needed to refresh the air (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).



Im. 6.15: Leisure World in Dronten (www.dnij.nl)



Double indoor

Indoors rinks mostly contain no insulation in the walls and roof. Which can harm the ice quality, because warm humid air can still enter the building. An extra boundary or layer can prevent this from happening and achieve a more manageable inner climate.



Im. 6.17: Interior Thialf (www.zja.nl)



Im. 6.16: Leisure World in Dronten (Google Earth)



Im. 6.18: Thialf in Heerenveen (www.syntess.nl)

BACKGROUND INFORMATION

6.4. LIFESPAN OF AN ICE RINK

The life span of an ice rink

An exact number of how long an ice rink should last is hard to find. A summary of my findings are shown here.

The starting date of ice rinks is sometimes hard to determine. Some rinks exist for many decades, the artificial ice sheet in Haarlem for example, exists since 1977, but it was already there in 1968 without any artificial cooling (IJsbaanhaarlem.nl). And Amsterdam was the first rink in the Netherlands, since 1961, and the first rink to have artificial ice from the start (Jaapeden.nl). The roof/building typology didn't exist by then, but the function itself is operating for at least 50 years in both cases and existing still. In plans from recent ice rinks, a certain notification is made about the future plan of the building, administrated in contracts. In an article about entrepreneurship in the

Netherlands it is said that the ice rink in Leeuwarden and the constructor firm, Dijkma Draisma, would have a contract for 25 years of exploitation of the ice rink (of.nl).

In another document the plans are explained for the renovation of the ice rink in Heerenveen, Thialf: Projectplan Realisatiefase Nieuw Thialf (Directie Thialf, 2013). Here there is explained that the rink is at the end of his lifespan, the document, written in 2013 contains a proposal for the restoration and renovation of the ice rink.

In the new projectplan, the document mentioned above, the aim for the renovated rink in Heerenveen to lasts is 20 years (Directie Thialf, 2013).

The rink is established in 1967 including cooling technology and 1980 a new cooling system was introduced. In 1986 it was provided with a roof(Thialf.nl).

The skating season of 2001-2002 the entire concrete slab was replaced, as well as the refrigerant and the cooling system.

To do a simple calculation, when you assume that these renovations were necessary because the system was reaching its end of life and that the building has been renovated in the year 2016, one can say that for the roof of an ice rink can last for 30 years and the cooling system for almost 21 years.

The rink in Heerenveen has been known for the fastest rink in the Netherlands. But a refrigerating system can still be functional in cooling, still it can be dangerous to let it exceed its lifespan. It could show leaks of ammonia, which can be poisonous in high amounts. To be more specific about the cooling equipment lifespan, all equipment will be listed here

BACKGROUND INFORMATION

with their recommended life span:

- Compressors: 40 years
- Chillers: 20 years
- Condensers: 15 years

Of other required equipment, like pipes and the concrete slabs, it is only mentioned that if they break the whole system will be dysfunctional. In case of steel pipes the brine water needs to contain an anti-rust chemical and in case of PCV's the pipes must be able to abide high pressure. Regular check ups could prevent this from happening, but a certain number of years of life is hard to give for this equipment (Hawes, 2016). Though it has been mentioned that the rink

in Amsterdam had replaced its piping system after 30 years (Berends, 2006).

To come to an actual amount of years to use as a life span property of the ice rink, for further LCA calculations, I decided that the source of the most recent realisation plans from the rink in Heerenveen and Leeuwarden are the most reliable. Also, the fact that ice rinks in general are buildings which have an image of being financially unstable, the popularity differs each year, and investors for longer life spans are hard to find. So I will aim for a lifespan period of 25 years.

The seasonal schedule

An ice rink will provide ice during the entire day, for a whole winter. Within Longtrack, an ice skating season generally exists from the beginning of October, in some cases even from September (E. Berends, personal communication, 07-12-'16, Appendix 1), until the end of march. In the Netherlands it happens that there are several ice rinks even providing ice during some months in summer. Thialf for example provided an ice skating possibility from the beginning of June till mid-July in 2017.

6.5. MANAGEMENT/FINANCING STRUCTURE

LCC

Buildings costs is mostly referred to as costs for realising the building. So the production of materials, labor costs or the costs of assembling the materials together.

Aspects which are mostly left out of the picture are the operation costs. And when one draws the line further: the transition costs into another function or demolishing costs. Making a financial independent building is the goal of all building clients. In case of an ice rink, this is challenging, and mostly accepted as impossible. In all Dutch cases these buildings are built with support

of the government (E. Berends, personal communication, 07-12-'16, Appendix 1).

The operator can be the municipality of the city where the rinks is build, or a separate operator who is renting from the municipality or a private owner and operator. But in all cases these initiation and building phase is initiated and financed mostly by the municipality.

These buildings are "Marktconform"(Interview Leeuwarden). Which is the Dutch word for market competitive. Which means that there has been a (government) measure to make sure these

buildings work according to the market mechanism. They are financially supported by the government, in case of Thialf in Heerenveen, or the local municipality. Which is another way of saying that these buildings cannot sustain themselves without financial support.

To include not only the building phase but also the operation and demolition phase into the finances and energy calculations is called: **Life Cycle Assessment (LCA)**. It is a type of analysis which I want to include in my research and design as well, when I make a design proposal for a new ice

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rink. This can give me insight in the finances over the full lifetime of the building, but also use it as a design driver.

This is also directly linked to calculate the produced emissions of the building, so in this way one can know if the building can have a positive

or negative effect on the environment.

The initiation of ice rinks

The standard procedure to initiate the building of an ice rink comes with an initiating party. Mostly this is a group of skaters who are under the impression that in their area

an ice rink will be a positive addition to their leisure facilities. They will approach their local municipality, this was the case with IJsbaan Twente (G. van Dam, personal communication, 30-11-2016, Appendix 1) and Ijsbaan De Westfries (Hoorn) (G. van Dam, personal communication, 30-

Side note 1: Ice rinks secrecy in their finances

Ice rinks turn out to be secretive about their finances, not only towards journalists or the users of their buildings, but also towards the municipalities who own these buildings.

The reasons for this withhold of information may differ. For Thialf, the ice rink in Heerenveen, it is said that they don't want any competing parties to know their solutions. So their rinks reputation, which is known as fast rink in the world ranking, can stay that way (E. Berends, personal communication, 07-12-'16, Appendix 1).

Another reason can be that the operators are simply not proud on the fact that their building is operating with high financial losses.

And in some cases, the operators cannot share their finances, because their company forbids them to speak publicly about it, which is the case in IJsbaan Twente (G. van Dam, personal communication, 30-11-2016, Appendix 1).

In last couple of years some attempts to extract financial information from the ice rink operators turned out to be unsuccessful. In 2010 the NOS, the Dutch Broadcasting Foundation, did a research on the finances of the Dutch ice rinks. Their journalists paid visits to the managing board of these buildings. Most operators were willing to give their visiting numbers, but only in rough estimations. The operator of the Jaap Eden rink in Amsterdam said to have an annual visiting amount of 600.000 skaters. Most Dutch rinks have a visitors amount around the 200.000 people.

According to some interview participants, there has to be mentioned that it is likely that rinks lie about their visitors attendance (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

11-2016, Appendix 1&Hoorn). In some cases, the municipality or province will take the initiative, in case of De Elfstedenhal (Leeuwarden) (J. van der Kooi , personal communication, 17-11-2016, Appendix 1).

The biggest challenge in this initiation phase is the financial feasibility. Mostly the municipality will invest in it, in some cases surrounding municipalities or the province itself will be contribute in the investment.

When the financial plans are confirmed the municipality will act as client. And will finance the realization of the ice rink. When it has been decided that an ice rink will be build and a piece of land has been reserved, the municipality will arrange a design competition.

Design competition consortia

Within ice rink building projects it is common that multiple design and consultancy parties merge together to offer their design as a consortium. In case of the Elfstedenhal in Leeuwarden, the architect was actually divided in 4

architectural firms who merged together as GEAR, an architectural firm which cooperated with an energy consultancy company called Ekwadraat. They worked together with a contractor and other smaller companies.

In case of the Elfstedenhal 5 of these “packages” had participated in the design competition.

The future operator was already decided by the municipality, called De Elfstedenhal Stichting, and could join the decision process which consortium to choose. But the final call was within the municipality (J. van der Kooi , personal communication, 17-11-2016, Appendix 1).

The decision proces is based on granting. In case of the Elfstedenhal a “granting matrix” (gunnings matrix) was made, in which every requirement, established by the municipality was carefully checked. The municipality already decided on a building sum. If parties were exceeding this amount, they must have a very good reason for it. In some

cases this plan still might be the winning plan, if it is really offering something extra for the extra investment.

Chairman Johan van der Kooi about the competition of the Elfstedenhal: “The client gets most likely the highest achievable market option. The market party (the consortium) have done their utmost effort to draw the Elfstedenhal. They go further than they initially want, because they don’t know what the competition will do. So as a client you completely wear out all parties. You are in a competition, but you don’t know how far the other one is”.

Building costs vs operation costs

The finances of a building in general can be divided in two phases. The building costs, consultancy costs included, are the first phase: the realisation phase. The second part considers the actual use of the building: the operation phase. Unfortunately, when ice rinks are already open about their financials, it is not always clear in their administration

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what costs do belong to the realisation phase and the operation phase (Bakker et al, 2013).

Privately owned vs. Publicly owned and market forces

In some cases an ice rink is privately owned. So the owner and the operator are the same party. These rinks have a slight disadvantage than the publicly owned rinks. Since the public ones will be relying on a certain cooperation with the government, they don't aim for the optimization of profit, but that their rink is accessible for everyone (Bakker et al, 2013). Privately owned rinks do aim for profit, and they have to function without substantial public funding. In some cases rinks are semi-private.

In a way the governmental influence in the initiation of ice rinks is one of the reasons the Netherlands have so many. When the initiation of ice rinks was only based on market forces, the amount of ice rinks would be far less (Bakker et al, 2013).

The consumer sees no difference in privately owned or publicly owned rinks, they offer, in eyes of the consumer an identical product. Since the

competition is quite high, the "private rinks" cannot ask for a higher entrance ticket, so their profit, if any, is not as high as they would wish.

But a perfect competition is not the case with Dutch ice rinks. The government has decided to support the skating sport. "The government grants this subsidy based on a political consideration that people underestimate the skating sport and/or give it a low priority in their consumption pattern" (Bakker et al, 2013, p. 10).

Government subsidies are mostly based on welfare considerations.

This is why most ice rinks in the Netherlands are publicly owned buildings. The government has decided to promote the sport and make the supply as high and accessible as possible. According to the report of the financial feasibility in of the renovation project of Thialf, it is unrealistic to manage an ice rink without governmental support (Bakker et al, 2013, p.12).

Most operation contracts of ice rinks last 20 to 25 years. In some cases, like the Elfstedenthal, some contracts

can be shorter: 5 years (J. van der Kooi, personal communication, 17-11-2016, Appendix 1). It depends on the type of contract.

The operation phase of an ice rink considers many contracts:

- Rent contract (in Leeuwarden for 5 years)
- Energy contract (in Leeuwarden for 25 years)
- Maintenance contract (in Leeuwarden for 25 years)

Operational expenses

The ice rink building typology has a reputation of being highly demanding in energy consumption. One can expect the energy bill to be the highest contributor to the annual costs of an ice rink. This is actually not the case. In several rinks, like the Elfstedenthal in Leeuwarden, IJbaan Twente in Enschede and De Westfries in Hoorn, the highest post in annual costs is the staff.

Roughly, the following aspects are integrated in the annual costs:

- Staff
- Energy
 - Electricity
 - Water
 - Gas
- Maintenance
 - Cleaning
 - Maintenance contracts
 - Small maintenance

- | | | |
|---|--|--|
| <ul style="list-style-type: none"> (daily) • Bigger maintenance (replacement of materials) • Purchases • Restaurant/Café • Shops • Business related <ul style="list-style-type: none"> • Insurances • Taxes • Consultancy | <ul style="list-style-type: none"> • IT • Promoting/advertising • Other finances <ul style="list-style-type: none"> • Interest/Bank • Rent • Depreciation <p>The actual expenses linked to these aspect were granted to me, but I may not publish them.</p> | <p>As said before the staff expenses are considered the highest post, this has been confirmed by the interviews of mr. Bongenaar, mr. Van Dam and mr. Van Der Kooi. This post takes approximately half of all annual expenses (F. Bongenaar, personal communication, 07-12-'16, Appendix 1, Enschede, Leeuwarden).</p> |
|---|--|--|

Side note 2: Contracts demotivate optimization

Mostly, in case of publicly owned rinks, the operator has an agreement with the municipality that they will rent the rink for a certain amount of years. In case of IJsbaan Twente it is 20 years. In the Elfstedenhal it is 5 years.

But there are other contracts as well, for example energy contracts. These are made with the energy company and the operator, which can be more or less years than the renting contract. In some cases, like the Elfstedenhal, this contract speaks of a fixed annual energy bill. Every year the operator will pay the same price for the energy used. This sum has been established by an appraiser, as well as the rent and maintenance sums.

Therefore the operator could invest in energy efficiency, but will still pay the same price. This means that every investment in energy decrease will result in a higher bill, which is why the investment is never made.

In some cases managers tend to care in lowering the energy demand of ice rinks. These are mostly the technical managers, a profession mostly combined with head ice making. Because these technical managers knows the more pragmatic insights of the machines in their rink, they know what measures to take to lower this their energy demand. Ice maker Frank Bongelaar, of IJsbaan de Westfries, said he has the impulse to lower their energy consumption, but his personal motivation is mostly not enough to convince higher parties, because most energy decreasing measures means a large investment, which most managing parties are not willing to risk (F. Bongenaar, personal communication, 07-12-'16, Appendix 1). The fixed character of these contracts therefore demotivates the operators to act innovative. Ice rinks are literally "frozen" from the moment they are build.

This is not something I can solve, the only lesson which can be taken from this is that the building needs to function energy/financially efficient from the moment it is build.

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6.6. REFRIGERATION PROCESS/ICE MAKING

Within an ice rink, the surface on which the ice sheet is made, is consisting of concrete with steel or plastic pipes inserted in it. Whether it is steel or plastic pipes in the concrete is depending on the cooling liquid: the refrigerant. This liquid has the ability to carry cold, or “produce” it by its evaporating properties (Berends, 2004). This evaporating ability is the reason a liquid can turn cold. It is comparable with perfume for example. When perfume is applied to the skin, the skin will feel colder. The liquid will evaporate, taking the heat of the skin with it. The same is happening to a cooling liquid (E. Berends, personal communication, 07-12-'16, Appendix 1).

In a refrigeration circuit the liquid is transforming into several different states, liquid and gas. In a direct system the evaporative liquid was transporting through the pipes and, because of the pressure, it would evaporate. Which needs heat, which is why the concrete in which the pipes are installed will turn colder. The amount of

pipes needed depends on the refrigerant, some rinks have more than 65 km pipes in their concrete (Berends, 2014).

In older ice rinks the pipes were carrying the refrigerant itself, it was cooled down in a machine chamber, and pumped into the pipes of the ice rink. This was the case when Ammoniac was the standard refrigerant. The substance was already used since the late 1800's, since refrigeration has been an invention, applied not only to produce ice, but also in ventilation and preserving food.

Recently a law is enforced that large amounts of ammoniac cannot be applied in areas which contain large amounts of people. Ice rinks are included in this criteria. Which is why most ice rinks in the Netherlands now switched to other refrigerants (Berends, 2004).

A lot of ice makers are disappointed in this law to prevent ammoniac to be the main refrigerant. The substance needs the lowest amount of energy to achieve a freezing

temperature. Also, the concrete slab is cooled more evenly and Ammoniac is the cheapest refrigerant available. And apart from what other might think, compared to other refrigerants it is a natural product. Which can be broken down before it is thrown away (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

All refrigerant which are applied nowadays have a lesser energy efficiency than ammoniac. Which is why the energy consumption of “cooling” has increased. But in the last decades the energy consumption and solutions to make this less extreme has been investigated. Solutions like thinner ice, thinner concrete, smaller pipes, so less refrigerant, are some of the outcomes of these investigations (Brink, 2004).

Direct vs indirect systems

Another development is the splitting of the refrigerant circuits. Ammoniac can still be applied in the machine room, it is only forbidden to apply it in the ice sheet pipes. Since ammoniac is still the best choice in energy/costs/

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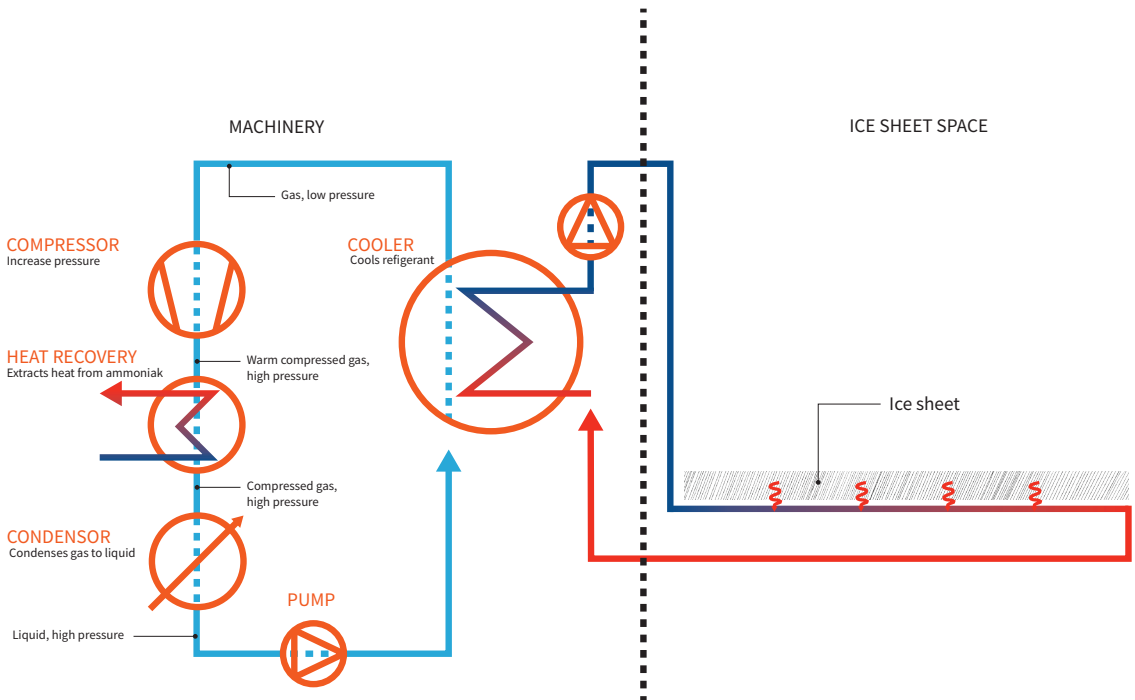


Figure 6.19: The refrigeration system. With two loops, called the indirect refrigeration, own illustration.

maintenance it is put into a combined system. On its own it would be a direct system, combined with another cooling liquid it is called an indirect system. The principle is the same. The cold temperature is provided by the ammoniak, the "cold" will be transported through the pipes with another "cold carrying" liquid. This system always costs more energy. When you want the liquid in the pipes to be -10 degrees, the temperature of the ammoniak needs to be -12 degrees.

Also the "carrier" will heat up in the transporting process

through the concrete slab. Ammoniak as transporting liquid doesn't heat up. It only changes slightly in consistency. Which is why the direct system will have a more even ice temperature. The indirect system will have a temperature difference of 2-3 degrees within the transporting liquid. So it will consume about 20-25% more energy. Carrier liquids can be brine water, alkali (ammoniak solved in water), glycol, freon and a new relatively new: CO2 (Berends, 2004).

In the next image the efficiency of different systems is shown,

ammoniak as a direct system, is considered the standard in this equation, and is set on 100%.

The refrigeration process

The order of machines in which the ammoniak is transported/ changed in state will be described below:

Because the refrigeration process is a circuit, so there is no actual beginning. Since in an indirect system the machine where both circuits meet is the heat exchanger (or Cooler), I will start there. This machine has ammoniak in a big tank, where pipes with the "cold carrying" liquid is flowing

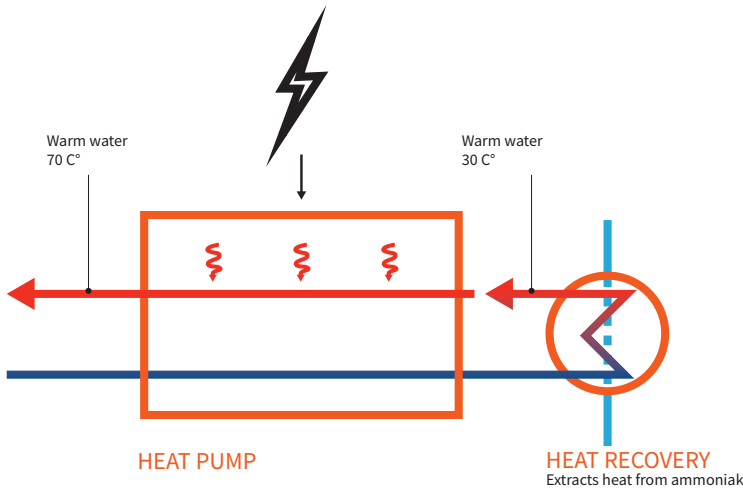


Figure 6.20: Heat recovery is recently more used, in combination with a heat pump, to increase the temperature slightly, own illustration.

be used for heating purposes (Berends, 2004, E. Berends, personal communication, 07-12-'16, Appendix 1).

After the condenser the high pressure liquid will be transported into the heat exchanger tank again, which will transform it again into “warm” gas.

CO₂ as “carrying liquid” is, as mentioned, a modern development. This is comparable to ammoniac, since it is, unlike the others, an evaporative liquid. In this way, the temperature of the ice will be more even. And research has proved that as a combined system with ammoniac in the machinery it is the most energy efficient. The only down part is, that in these high amounts, CO₂ can be stifling. Also, for it to be liquid, it needs to be pressed into 25 bar. Which is 10 times as high as a normal refrigerant. And it needs a higher investment, since CO₂ is more expensive and the equipment needed for it even more.

When it comes to ice rinks, one can optimize in several ways.

Refrigerant	Carrier	Percentage
Ammoniac	Ammoniac	100
Ammoniac	Brine	120
Ammoniac	Glycol	125
Ammoniac	CO ₂	108

through. In this way, this transport liquid will transport its heat towards the ammoniac, so the liquid cools down when it is transported, by means of pumps, towards the ice sheet. This is the “ice sheet circuit” shown in the image with the red-blue line.

The other circuit covers the ammoniac transport. After the heat exchanger is lead towards the compressor, the consistency of the ammoniac is warm gas, with low pressure, because it heated up inside the heat exchanger tank. The compressor, as the name says,

will compress the ammoniac, into a warm high pressure gas. Normally, the ammoniac would be lead directly towards the condenser, which makes it into high pressure liquid. Because the gas will be transformed into liquid, it will reject a lot of heat. Condensers, therefore, are placed outside to unleash the heat towards the air. At modern circuits the heat will be taken out by means of a heat recovery machine, before the condenser. This heat recovery machine transporting the heat within water pipes. In this way the waste heat of the refrigeration process can

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The ice floor in general has a lot of inventions which can make its energy use more efficient. For example by the placement of the pipes inside the concrete slab (Brink, 2004), when these are placed more to the surface, the transmittance of cold, or better said, the abduction of heath, is more efficient this way.

Waste heat

Because the principle of refrigeration is to extract heat, to leave the liquid colder, heat will be produced during this process. The heat recovery machine can produce heat in liquid form, about 30 degrees. Transport heat through water is a quite efficient way of transporting, and it can be used for several functions, for example to heat showers. Due to recent introduced regulations, the temperature of this water needs to be 70 degrees. Which is why a heat pump needs to be added in the circuit to push the temperature up. Unfortunately this requires electric energy, so the energy consumption has to increase again.



Im. 6.21: Refrigeration pipe system, which will be integrated in a concrete slab.

Conclusions:

- An indirect circuit is chosen for the ice rink design, CO₂ as carrier and ammoniac as refrigerant.
- The cooling liquid pipes need to be placed close to the concrete surface, to save unnecessary energy consumption by inefficient cooling.
- Waste heat of the refrigeration plant must be used for heat consumers inside the building.
- To use waste heat a heat pump needs to be installed, which carries heat in liquid form.

6.7. ICE SKATING PRACTICE

Ice skating, how does it work?

Why does gliding on a frozen surface evolve in a movement with a small resistance? The scientific explanation is that nature always want to have an energy level as low as possible. Big contrasts will be flattened and a balance will be made. A direct transition from ice (solid) to air (gas) is according to natural rules not possible. There will always be a transition zone in between, in which these two stages overlap (Russel-Ausley, 2015).

To explain this transition zone the actual structure of ice needs to be explained. Water is known to form a hexagonal structure when it freezes. An illustration of this is viewed on the right side of this page. When the temperature drops or the pressure increases, the molecules of water, which consists of two hydrogen atoms and one oxygen atom, are situating themselves making a circle of 6 water molecules. This structure is so rigid that the molecules in this structure

can hardly move, they are trapped in a way, the only movement they can make is vibrating. But where the ice meets the air, the molecules at the surface can actually move around a bit, since the structure is ending there. When a molecule can move around more, it is able to change of state. Gas is known to have molecules which can move independent on one another, liquid molecules can move past each other. The molecules on the surface of the ice are almost transforming into water, but not completely. This state is called: quasi-liquid-state.

This natural phenomenon will only occur in a certain temperature/pressure range. Since the pressure is almost constant (normal earth pressure) the temperature is of bigger influence here. This effect is efficient between 0 and -10 degrees Celsius. If the temperature drops more, the effect will be less, and in this way the ice will be less slippery

and build up resistance. Which is less desirable in ice rinks (Rossano, 2005). An overview of the resistance and the corresponding temperature is shown in a graph on the right (Berends, 2006).

The use of ice mostly involves skates. In this category 4 disciplines can be extracted:

- Figure skating
- Ice hockey
- Shorttrack
- Longtrack

An ice surface also hosts other sports, which are not related with skates:

- Curling
- Bob sledding
- Luge
- Ice speedway (motorbikes)

This research will be a blueprint for a design of an ice skating rink. The last mentioned disciplines practiced on ice will therefore not be taken into account in the research of this thesis.

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Discipline 1: Ice speed skating / longtrack

The goal of this thesis is to find energy saving ways of making a 400m ice rink. The reason a 400 meter oval of ice surface is chosen to be the main focus of this building is that this ice sheet is used for Olympic competitions, the distance of the rink is established by the ISU, the International Skating Union. Also the dimensions of an indoor ice rink with a 400m lap are enormous, which makes it an interesting design challenge. Goal of this discipline is to overlap a distance in the shortest time possible. A race consists of two skaters competing against each other. But there are other races as well, like team sprint (3 skaters in a team to cover 3 laps as fast as possible) and team pursuit (3 skaters in two teams, competing against each other. Or marathons in big pelotons.

- Participation all Olympics
- Participation last Olympics
- Medals last Olympics



Figure 6.22: Olympic participation in the Longtrack discipline, own illustration.



Discipline 2: Shorttrack

Shorttrack takes place on a shorter track of 111,12 meters long. As longtrack most competitions cover a distance, like 500/1000/1500 meter or more. The big difference is that within the race a shorttrackers competes against 4/5 others. Which makes the races quite dynamic. Since the diameter of the corner is much shorter, the shorttrackers needs to thrust themselves into the corner, which explains the small angle towards the ice. Other race-combinations are the relay, in which they switch within a team of skaters every 1,5 lap. Shorttrack requires much safety precautions, they wear more protection gear compared to longtrack and the ice rink needs to be surrounded by cushions for the skaters to fall into.

- Participation all Olympics
- Participation last Olympics
- Medals last Olympics

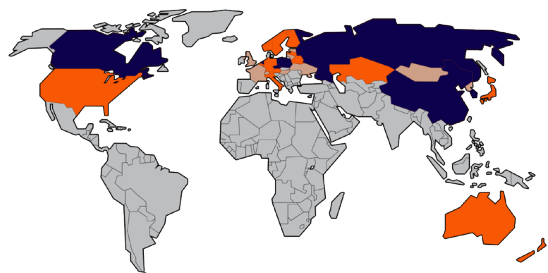


Figure 6.23: Olympic participation in the Shorttrack discipline, own illustration.



Discipline 3: Ice hockey

In the ice hockey discipline, speed isn't the main goal, being agile and a teamplayer are more important. The competitions consists of two teams of 6 players, including spare players a team may consist of 20 players in total.

The sport includes a lot of physical contact and collisions, so ice hockey players need a lot of protective gear. Because their speed isn't as high as speedskating, not protective cushions are needed around the rink. But a hard layer of transparent material surrounds the rink, to protect the spectators.

The sport is especially popular in Canada, Nordic countries, Russia in international championships and in Great Britain within student environments. The sport only seems to gain in popularity in the last few years.

- Participation all Olympics
- Participation last Olympics
- Medals last Olympics

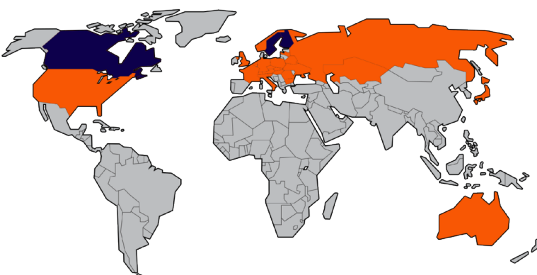


Figure 6.24: Olympic participation in the ice hockey discipline, own illustration.



Discipline 4: Figure skating

Figure skating can be an individual sport, or is practiced in pairs. In both cases their form of competitions consists of a jury who are rating them for their performance.

In case of global participation, figure skating is practiced in the highest number of countries, compared to other ice skating disciplines.

The interesting fact about figure skating that the distribution of participating countries is stretching also to a lot of southern countries. The discipline requires less space for practice and one can train for the sport only with a set of skates. Which makes it accessible for more people.

- Participation all Olympics
- Participation last Olympics
- Medals last Olympics

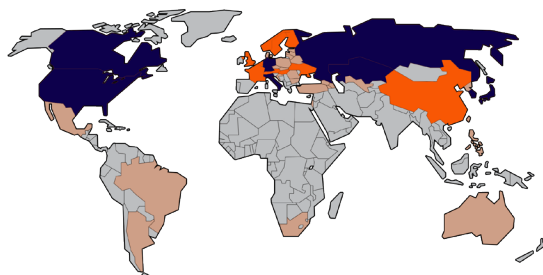


Figure 6.25: Olympic participation in the figure skating discipline, own illustration.

BACKGROUND INFORMATION

6.8. MODERN PERCEPTION OF ICE SKATING

Monopoly in success

If you compare inhabitant numbers with the amount of ice rinks, you can see that there is a big peak in the Netherlands, shown in Appendix 9. In total, the Netherlands contains 20 ice rinks with an artificial 400m ice sheet. 17 of these are completely indoors or at least have a roof. Then there are a lot of possibilities to make ice on flooded lands. Which is sometimes the case when the temperature drops for a longer time period. These natural rink are sometimes made in a 400m rink as well, and used for competitions.

The Netherlands and their investment in the ice skating sport

In the chapter Finances one can already conclude that the Netherlands has invested a lot in the ice skating sport, and by doing so, the Dutch position in international competitions is quite dominant. One can speak of a great monoculture in the ice skating sport. This is mainly explained by the high amount of supplied ice rinks inside the country, which the Dutch

government helped build. The relation between build rinks and won medals in the Olympic Winter games is shown on the next page.

Investment of the government in skating education

Throughout the country there are several possibilities in skate education. Schools are stimulated to let their students skate during sport class, some municipalities even provide subsidies to make this happen. IJsbaan Twente provides lessons for schoolchildren, who may enter at a lower price, thanks to the municipality who is paying 1 euro per child (G. van Dam, personal communication, 30-11-2016, Appendix 1).

Sponsor teams

Another reason the sport has booked success is the commercial character of the ice skating sport in the Netherlands. Most countries have a national selection, in which young skaters from all over the country are forced to train in the same location. From young age the skater is obliged

to invest all their time in this sport, and because there is just one educational facility for these young skaters, the group is small and not everyone can be accepted. When the young skater is performing well, they level up to the national team. Which again, stays quite small. In this way few skaters in those countries make it to the professional level. This happens for example in Norway and Germany.

In the Netherlands every "Gewest" (region) has its own youth selection. Who have their own rink to practice at. When they are performing well and are of an acceptable age to perform internationally, they are recruited by Sponsorteams. These teams are financed by big sponsors. These teams can finance their skaters in equipment, training hours, trainers, training weekends/holidays and clothing. Sometimes sponsorteams seize to exist if the sponsor quits. But when the skaters have a good reputation, perform well in the international field and gain publicity, they don't have much difficulty with getting

BACKGROUND INFORMATION

a new sponsor. Sometimes it happens that foreign skaters get recruited as well for these teams.

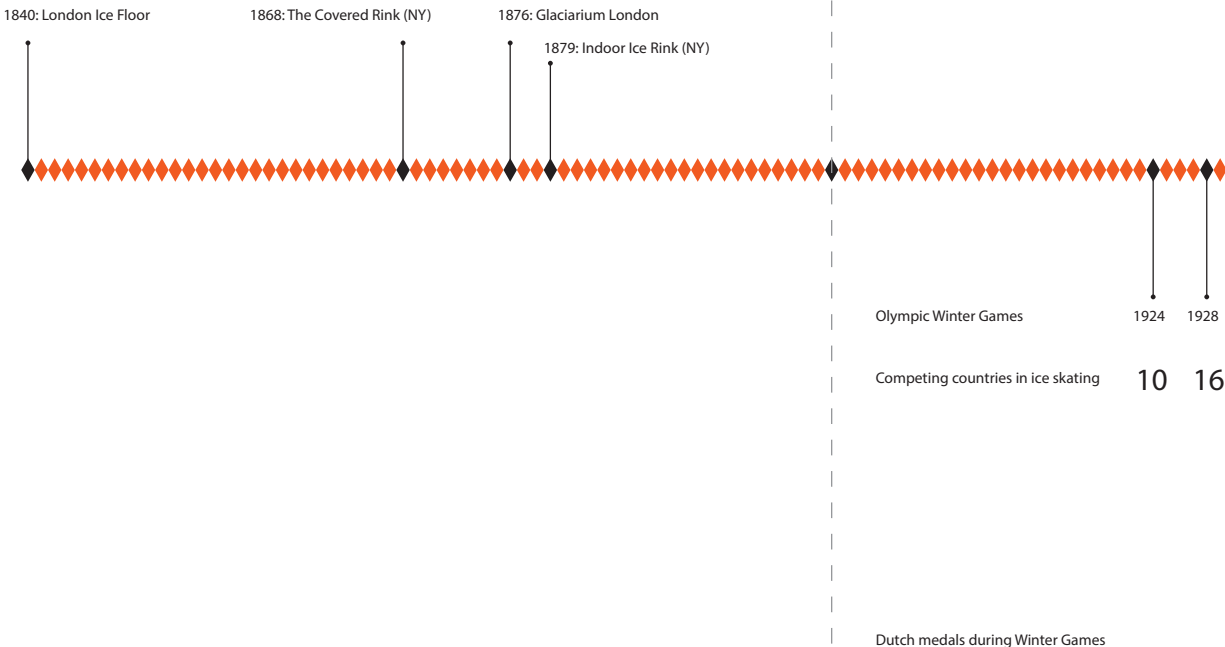
There are only a few spots available per country to join the international competitions. Because of the competition

between these sponsorteams, they are obliged to tilt themselves to a higher level if you want to get the spot in international competitions. Which is why large successes have been booked by the Dutch teams.

Public interest

The interest of the public in ice skating is highly present in the Netherlands. Not only because of the high amount of rinks and accessibility. But mainly because of the international success and publicity. One can say that due to Olympic

19th century



success and success in World-cups the country has interest for the sport.

Of course, there are some elements a government cannot control. But to have enough possibilities to train or to skate recreationally is a large contribution to a sports

popularity.

Initiation in another country

The monopoly in ice skating success, can be interfered by making more training possibilities in other countries. The design assignment which will follow from this research

will cover a design which is not located in the Netherlands. The specific location of this ice rink design will be further explored in the ProjectBook.

20th century

21st century

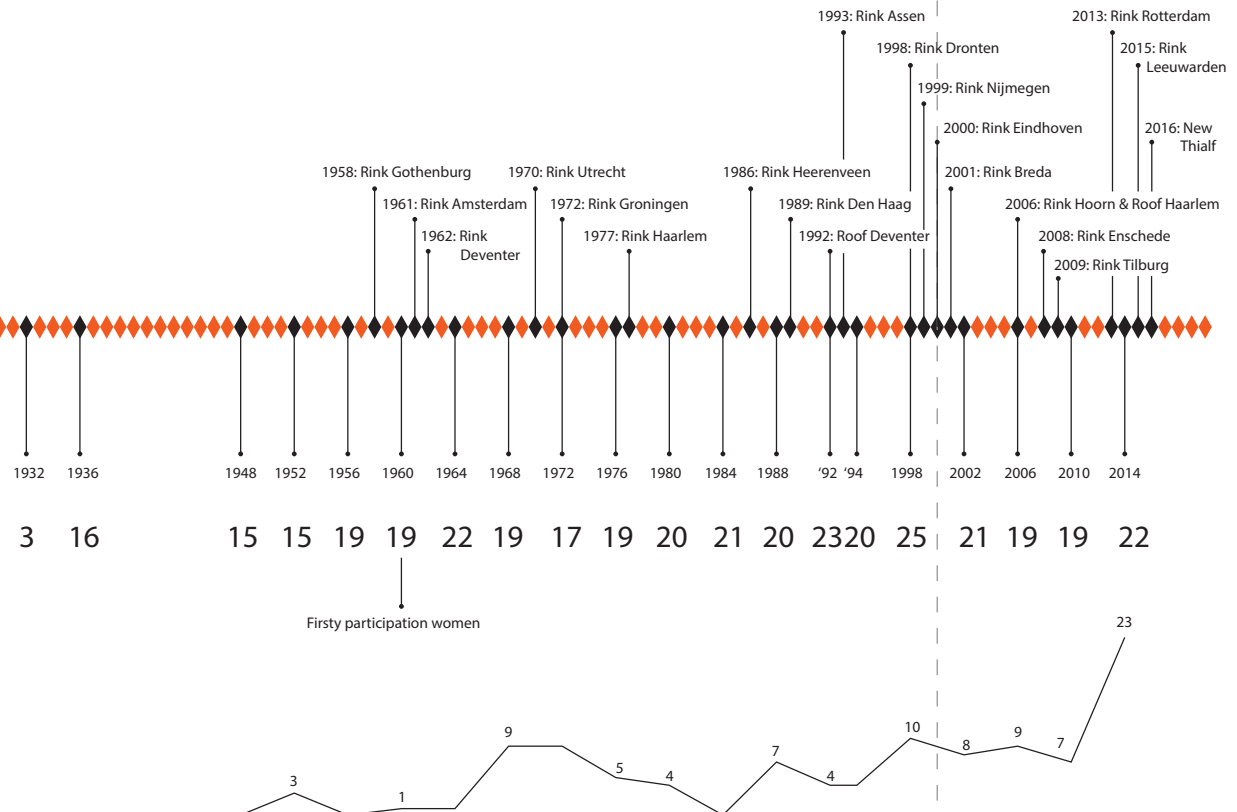


Figure 6.26: Relation between build rinks in the Netherlands and Dutch medals in the Olympic Games, own illustration.

USAGE CHARACTERISTICS

USAGE CHARACTERISTICS

- 7.1. Annual use
- 7.2. Description users
- 7.3. Human circulation

USAGE CHARACTERISTICS

7.1. ANNUAL USE

Summer use

Since the seasonal character of an ice rink, the question arises what to house during summer. In some cases, this is simply not possible. IJsbaan Twente had to sign a contract to only function as ice skating facility, since there was an event hall next to the rink (G. van Dam, personal communication, 30-11-2016, Appendix 1). Ice rinks are big empty halls in summer, a large covered area like that can be very flexible for other functions. To explore different functions, similar large spaces are investigated.

Olympic rinks

A lot of Olympic Ovals do not survive after the Olympic Games, they were made for one purpose, to grant an 400 m lap with space for an audience, of course in a building with a high quality in visual appearance, representing the local characteristics. Most of these buildings have a high price, Richmond Olympic Oval, of Vancouver 2010, was 120

million euros. Right now, 6 years after the Olympics, the 400 lap is gone. Already before these Olympics the plan to get rid of the 400 meter ice sheet was definite. It would be replaced by 2 ice rinks of 24x48 m and an 200m athletic track, 6 basketball fields and an indoor canoe centre. The concrete slab for the 400m rink has been preserved, so ice could be made when it is required in the future (Berends, 2010).

These added functions for

an Olympic rink, plus other known functions for a large open space are discussed in the following pages.

To organise a social event inside a venue can attract a lot of visitors and boost the publicity of the ice rink in summer. The origin or cause of the event can be different. But to have an overview of the different possibilities, several “summer functions” are taken into consideration in this chapter.

Side note 1: Like most ice rinks, mentioned in the “Background information” chapter, there is a secrecy in the information of the spatial set-up, financial structure and management system in big event venues. A simple reason is safety of the visitors. When a large event takes place, the knowledge of the floorplan is considered dangerous, since people with bad intentions could make use of this knowledge. For example for terrorism purposes. It has therefore proven difficult to get information on the floorplan and logistics of an event venue.

USAGE CHARACTERISTICS

Promotion event



RAI, Amsterdam, Netherlands.

Market



Vikingskipet, Hamar, Norway.

Shows/exhibitions



M-Wave, Nagano, Japan (Nagano-mwave.co.jp, 2017)

++

For symposia, fairs or other promotional purposes, where specific stands are built by an external organizing agency. This agency will rent the venue for this event, which will be the general income of the building.

++

A local market can mean a lot for a city or a community. The attendance can be high and the hosting building only needs to provide toilet facilities and comfortable inner climate. Stands and other equipment can be provided by external parties.

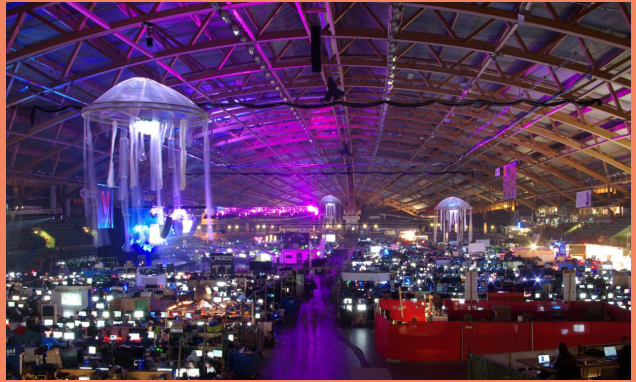
++

A big part of event halls, can be to show prototypes or inventions or house exhibitions. This function can be connected to a local society, like a school, university or sport facility. Shows could be compared to Dutch Design Week, Car Shows, new sport inventions, which can be organized by an external party.

Social event



The event shown in the picture is a large gaming event, taken place in Hamar, a small city in Norway. People from all over the country come to this event and stay in the city for multiple days, it could mean a large promotion for the building and the city. It should be able to be dark in the event area.



The Gathering Gaming Event, Vikingskipet, Hamar, Norway (Vikingskipet.com, 2017)

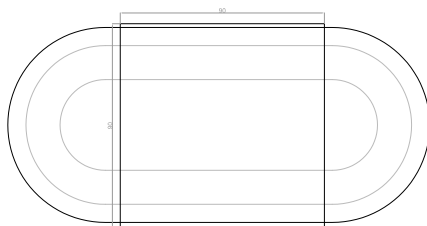
Concert



Having a large venue which is build for large visiting numbers, a concert could take place with relatively small effort. Logistic applications are already required for winter events. Concerts require an acoustic comfortable space, which is able to be made dark and have enough emergency exits. An ice skating hall can easily house to times the visitors of the Ziggo Dome:



Aarhus Jydsk Væddeløbsbane, Aarhus, Denmark.



Ziggo Dome
Amsterdam



For large lectures or a symposium the space of the 400 meter rink and the ice hockey rink are suitable. Extra seating possibilities may be required and may be provided by a third party.

Auditorium



Auditorium TU Delft, The Netherlands (PEEK, 2017)

USAGE CHARACTERISTICS

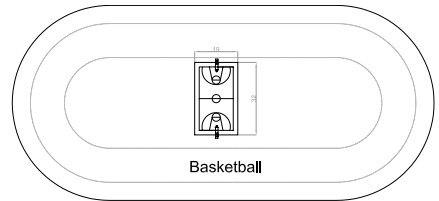
Basketball



Basketball courts, Orlando, Florida (Walton, 2014)

++

For training purposes, only a the marking on the floor are necessary, including baskets on both sides. The floor consistency is mostly preferred wood, but could also be PVC, PP or rubber and must contain some absorbance.



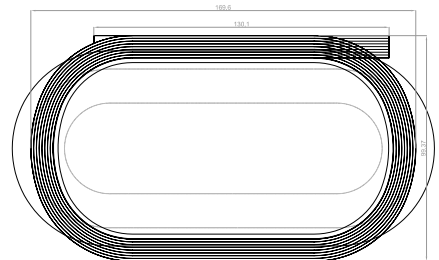
Running track



Utah Olympic Oval Running track (Utaholympiclegacy.org (2017)

-

For training purposes, only a the marking on the floor are necessary, including baskets on both sides. The floor consistency is mostly preferred wood, but could also be PVC, PP or rubber.



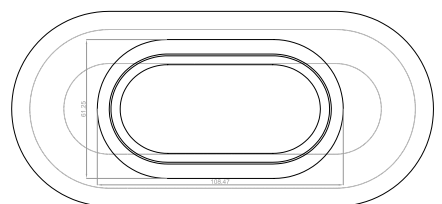
Keirin (cycling)



Velodrome in the London Olympics (Londonolympicphotoblog.nl, 2012)

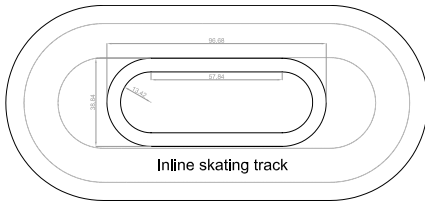
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A less achievable function, since the rink needed a velodrome needs to be elevated on the sides, so requires a whole separate construction.



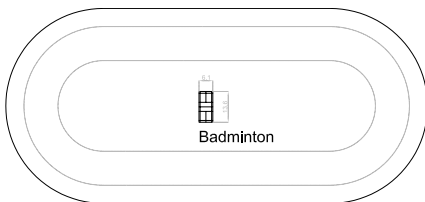
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An inline skating dome needs a 200 meter lap, with elevated corners. A separate construction is therefore necessary. Down part is that it takes a lot of space, and the sport is preferred to be practiced outdoors.



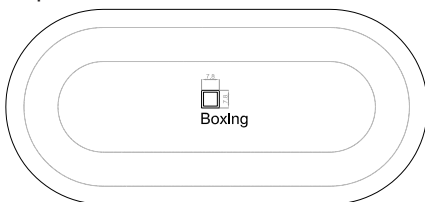
++

Badminton is a gentle sport to perform in multiple courts next to each other. The flooring can be compared to basketball fields. Only necessities are one net per court.



+ -

For most fighting sports is a elevated stage required, but the dimensions are small, which had logistical advantages, but is less visible from the spectatorstand required in winter.



Inline skating



Inline Skate Dome, Heerenveen, The Netherlands (Google Maps: Inline Skate Dome Heerenveen)

Badminton



Richmond Olympic Oval (Centaurproducts.com, 2017)

Fighting games



Sumo sport in the M-wave, Nagano, Japan (Nagano-mwave.co.jp, 2017)

USAGE CHARACTERISTICS

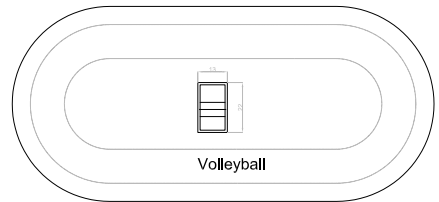
Volleyball



Valleyball hall (Ecc.cz, 2017).

++

The field required for a Volleyball practice requires a similar floor consistency to basketball, but is slightly smaller in its dimensions. Volleyball has a special requirement that the ceiling should be 12,5 meter high.



Summer functions

Social Event

Promotion event
Market
Shows
Social Event
Concert
Auditorium

Sports

Basketball
Running Track
Keirin (Cycling lap)
Inline skating
Badminton
Fighting games
Volleyball
Tennis

Beneficial as summer function

Large income

High attendance

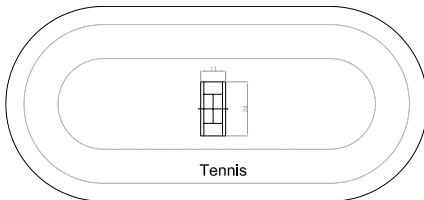
Small dimensions

	+++	+++	-
	+++	+++	-
	+++	+++	-
	+++	+++	-
	+++	+++	-
	+	+	+
	+	+	---
	+	+	-
	+	+	++
	+	+	+++
	+	+	+++
	+	+	++

Tennis

+ -

Although the ground consistency of tennis is mostly preferred with gravel or artificial grass. But they also consists in plastic variations, comparable to basketball and volleyball. An extra requirement is protection to other surrounding sports, for example with a net.



Ice Rink Kardinge in Groningen, The Netherlands (FocusGroningen , 2014)

Negative as summer function

High ceiling needed Logistic effort

Other

External organisation

Further remarks

-	---	yes
-	---	yes
-	---	yes
-	---	yes
---	---	yes
-	---	yes

Acoustic requirements could improve a lot of other functions

-	-	no
+	-	no
---	---	yes
--	---	yes
---	-	no
-	-	yes
---	-	no
---	-	no

The ice rink space needs to be made broader if a 400m

Needs an additional construction

Needs an additional construction

Needs 9m high ceilings (Neufert)

Needs an additional construction

12,5 meter high ceiling needed (Neufert)

Extra net required to prevent interfering with other functions

Choice matrix on summer functions, based on economical benefits and logistical efforts, own illustration.

USAGE CHARACTERISTICS

Organizing agencies

The main finding of this research is that all event venues have a small permanent staff. The events are mostly organized by external parties, event agencies. So to get an overview of investments or incomes these events will generate, is highly dependent on the organizing agency.

Chosen functions in summer

All the possible functions mentioned meant as social events, are suitable for the ice rink in summer. These functions involve an external organizer, which should be able to use storage in the building, make light adjustments, are able to fully darken the event area for gaming events, symposia, lectures, concerts, plays and shows. Furthermore, the acoustics in both event halls should be made that most sounds will be absorbed by surrounding constructions, which will prevent irregular

repeating of music or sound. For most events, catering and sanitary facilities should be present in high numbers and easy to reach.

To reach multi functionality the full floor area of the eventhalls should be columnless. Also, freedom in light and sound application is required, which the bearing construction should be calculated to.

Remark regarding concerts

During a conversation with the correspondents of Ziggo Dome, there was mentioned that in the warmest months of summer no concerts take place in indoor areas, since the festival season will demand all artists to perform outside. During these month other events need to be organized.

Also, during these performances an artist needs to be able to have a private area, or backstage area. So the

eventhall should make place for that as well as defining a backstage space behind the stage.

Winter use

As described in the Research Definition, the main focus is to design a 400 meter rink, but other ice skating disciplines should be housed as well, to achieve full coverage of the skating sport and to achieve high visiting numbers to the building.

All disciplines, Longtrack Speedskating, Shorttrack, Ice Hockey and Figure skating, should be able to practice in the ice rink at convenient times, to promote every sport. Furthermore, these disciplines should be able to have competitions, on recreative or professional level. Which will be further examined in the next chapter.

Winter One 400meter ice rink and (at least) one 30x60 meter ice rink.

Summer Multifunctional venue, for social events and summer sports.

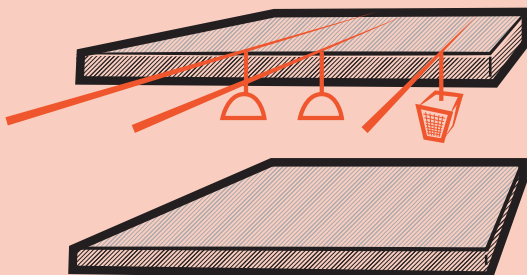
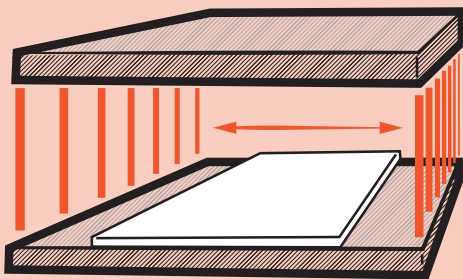
Functions in the winterseason

During winter the building will function as an ice rink, with a separate 400 meter rink, including a 30x60 ice slab on the inner area of the 400 meter rink.

The requirements of the users during winter are mentioned in the next chapter.

Requirements

- The building should be made suitable for a large group of spectators, to visit the building during competitions.
- In the sporting/event area there should be no columns deviding the space, to achieve multifunctionality.



Functions in the summerseason

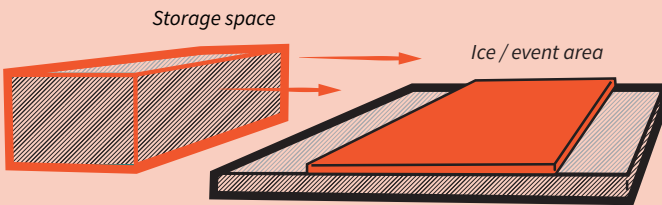
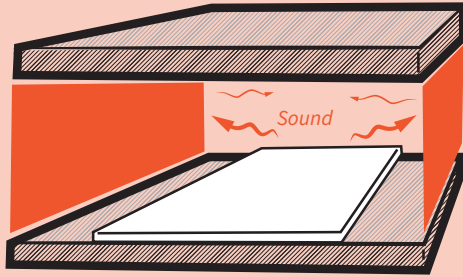
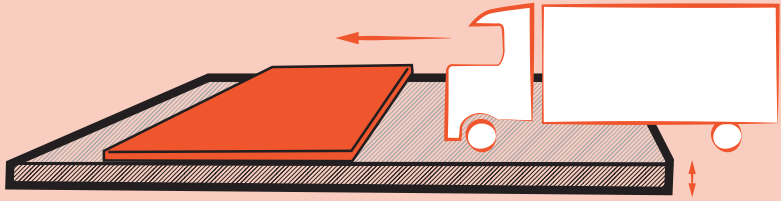
During summer the building will function as a multifunctional venue. With social events included, mostly organized by an external event agency.

Also, the concrete floorslabs have to be covered with a secondary floor, to prevent the concrete floor from getting damaged and to prevent dirt and stains.

Requirements

- There should be an option to completely darken the event area
- There should be storage space for extra seats, cleaning equipment, floors for sport purposes,
- There should be enough space to place catering industry facilities during big social events
- The surrounding construction should have acoustic absorbance to establish comfort of the visitor during the events.
- Catering and sanitary facilities should be present in high numbers and easy to reach.
- The secondary floors for summer should include absorbance which fits the requirements of ball sports.
- The social events should be easy in set up, so breaking down a secondary construction shouldn't take too much time.
- The eventspace should be divisible into smaller areas or a backstage area.
- The bearing construction should be calculated on freedom in light and sound applications.

USAGE CHARACTERISTICS



7.2. DESCRIPTION USERS

Established in previous chapter, the building should be made adaptable to multiple functions in summer. The extra function introduce new users to the building. To have a clear overview of who uses the building, a list of users, and their requirements is made in this chapter. The list of users is based on personal experience and the interview with Frank Bongenaar (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

WINTERUSERS

There are several user categories when the building is used in winter:

- **Skaters**
- Sport related staff, including coaches, physiotherapists and team support.
- Permanent staff, incl. the director of the building, receptionist and medical staff
- **Technical staff**, incl. ice maintainers, cleaners and security
- Competition related users, like the **spectators**, press,

jury, referee.

- Sales staff, for the rental shop and restaurant.

For this research the skaters and technical staff have priority, the building will be “shaped around the sporter”, and the technical staff is responsible for the energy efficiency of the ice rink.

The sporters are researched by means of a questionnaire, while the technical staff, and mostly the staff members who are responsible for ice maintenance and the refrigeration process, “ice makers”, who are represented by the interviews which are done for this research.

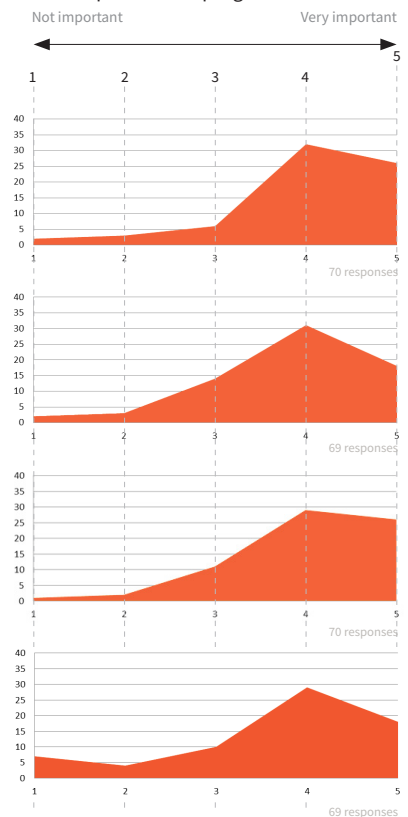
Figure 1: Level of importance of programmatic features

How important is having changing rooms close to the ice rink?

How important is a cosy café near the ice rink?

How important is the view on the other side of the rink from the ice area?

How important is view on the ice skating area from the café?



USAGE CHARACTERISTICS

WINTERUSERS

SKATERS

Longtrackers



Shorttrackers



Ice Hockeyers



Figure Skaters



SPORT RELATED

Trainers/coaches



Sport support



PERMANENT STAFF

Receptionist



Director



Medical personel



TECHNICAL STAFF

Ice maintainers



Security



Cleaners



Spectators



COMPETITION STAFF/VISITORS

Jury



Press/broadcasting



Starter



Volunteers



Referee



Waiters



Chef



SALES STAFF

Storekeeper



SUMMERUSERS

SPORTERS

Ball sporters



Gym users



Inline skaters



SPORT RELATED

Trainers/coaches



Sport support



PERMANENT STAFF

Director



Medical personnel



Event planner



Receptionist



TECHNICAL STAFF

Cleaners



Security



Light/climate expert



SALES STAFF

Waiters



Chef



OCCASIONAL EVENT STAFF

Spectators



Volunteers



Press/broadcasting



Artists



Producer/organizer



Builders



Service staff



USAGE CHARACTERISTICS

The skaters

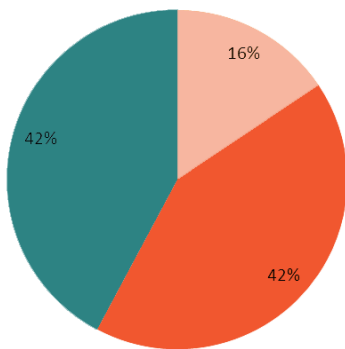
The questionnaire contains questions about the preference of the longtrackers, only this discipline is approached, since the goal of the project is to make a 400 meter rink, and most preferences for different ice skating disciplines overlap. In a selection of the questions, shown underneath, the participants had to share their sense of importance to particular spaces. One can

conclude that the changing rooms need to be closed to the ice, a restaurant with view on the ice is required, and there needs to be a complete overview on the sporting area, from all sides. 88% of all participants skate competitions, from which 43% more than 5 times a year, which shows the compositional ambitions of the skaters. Most skaters had to opinion that ice quality was highly important. Most longtrackers

are performance aimed, they value the perfect skating conditions.

Natural ice skating is less preferred when it comes to “training”. For recreational purposes it will suffice. 16% doesn’t define a perfect skating practice when skating on natural ice. 42% will go when there is the opportunity, but prefers to train on artificial ice. Also, the conditions preferred during training and

Figure 2: Natural vs. artificial ice
My perfect skating practice is on natural ice/artificial ice
69 responses



- Artificial ice
- Natural ice
- When there is natural ice I'll go, but I prefer practicing on artificial ice

Figure 3: Preferred temperature
What temperature do you prefer during training or competition?
69 responses

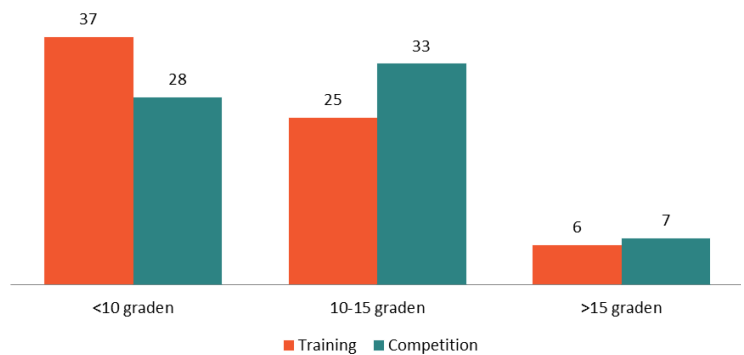
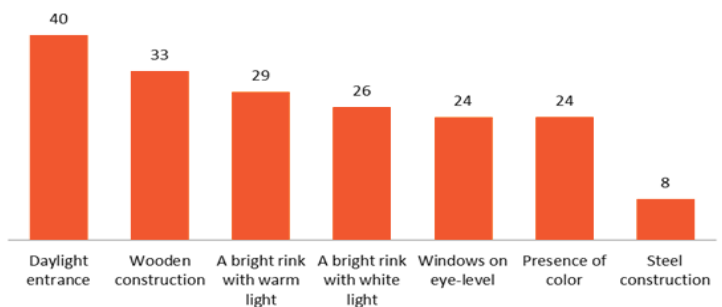


Figure 4: Attractive elements
Which elements make an ice rink attractive?
69 responses



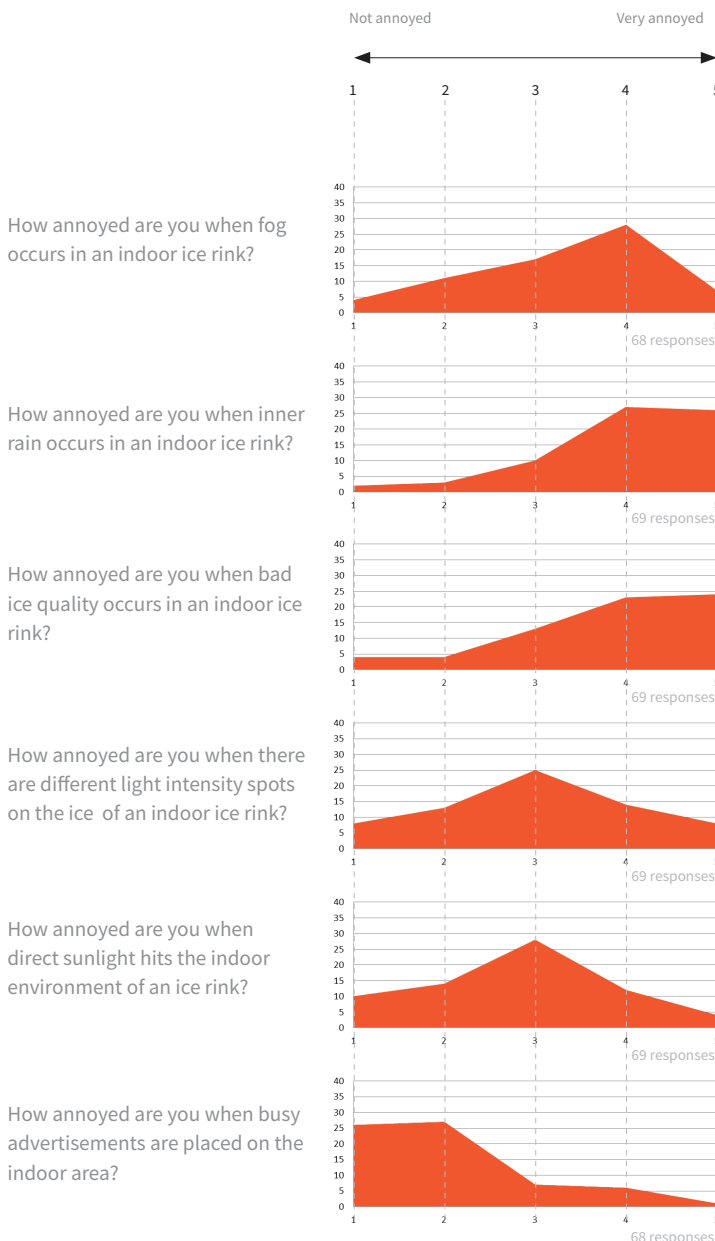
competitions differ. In all disciplines, competitions define themselves as peak moments, where the amount

of effort is high, but for short time. A sporter prefers the air temperature during these competitions warmer than

during practices.

A majority prefers minus 10 degrees for training sessions, and between 10-15 degrees during competitions. As shown in figure 3. A small amount of participant prefer a warmer climate, but since this research is about saving energy, and ice skating is considered a winter sport, the warmer temperatures will be kept out of consideration.

Figure 5: Level of annoyance climatic problems



Technical staff

During the interviews it became clear that most ice rink design don't take the convenience of the ice maker into consideration.

Bongenaar (F. Bongenaar, personal communication, 07-12-'16, Appendix 1) spoke about the drainage system for the ice resurfacers, which was lacking in several ice rink designs.

Employees of the technical staff need to be able to contact permanent staff, without having to cross the whole building. Since the dimensions of an ice rink are enormous, having all important technical equipment on one location is important.

Also, replacing climatic/

USAGE CHARACTERISTICS

refrigeration equipment can be a logistic challenge. In some cases, no entries are implemented in the design, while the dimensions of these machines can be several meters in length and width. This needs to be taken into account when replacing this equipment.

Spectators

During the research of the case studies, most performance rinks, like Olympic rinks and for example Thialf, have reserved relatively large proportions of their floorplan for spectators. Thialf can house 10.000 people, taken into account that seated stands are only available on the straight ends, in the corners the spectators are standing. Olympic rinks like the last rink in Sochi can generate 8000 seats. These seats are occupied

during the Olympics, or in case of Thialf, during large championships. But, knowing from personal experience, they are usually unoccupied, and even during popular championships not all seats are taken. This suggest that 10.000 available spots exceeds the demand for seats. Smaller rinks have an advantage that the span of the construction can be shortened, and that there is less volume which needs to have strict climate control. Therefore, less spectator stand will enhance the benefits mentioned above. For summer purposes the amount of seats can always be expanded on the previous ice floor area. For the design assignment spectator numbers between 3000 and 5000 are considered reachable. There should be some flexibility in the seating plan, so when the spectator

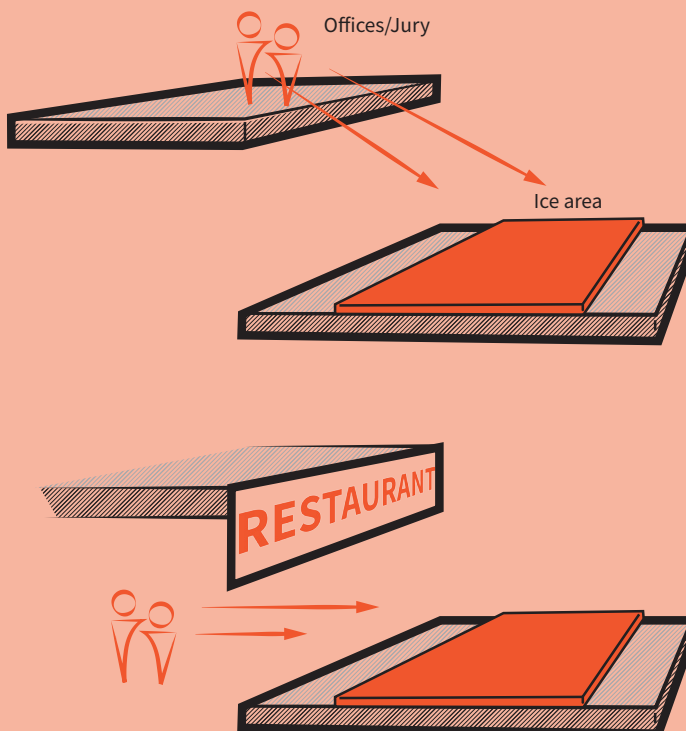
amounts need to be increased, there could be an architectural measure for that.

SUMMERUSERS

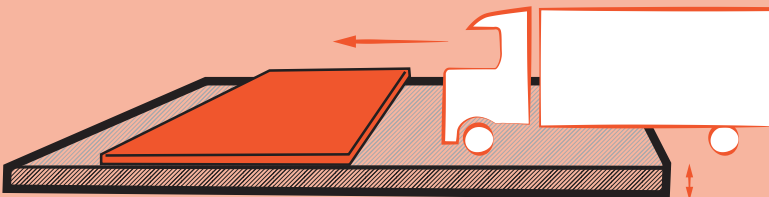
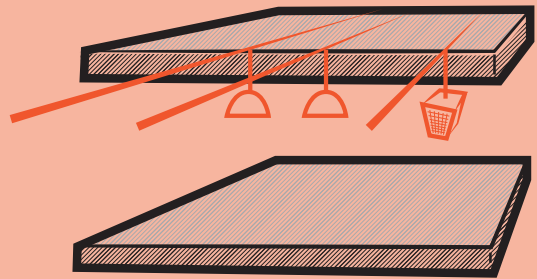
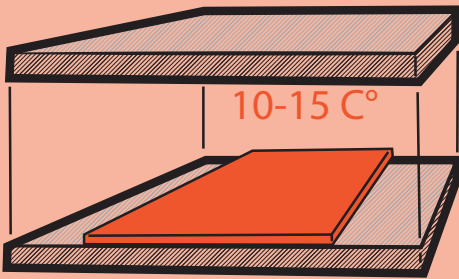
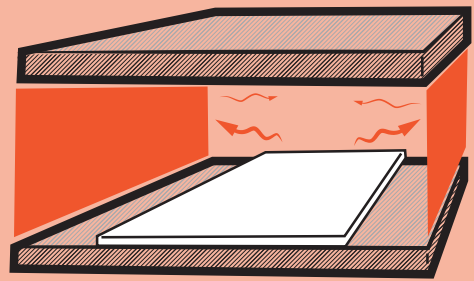
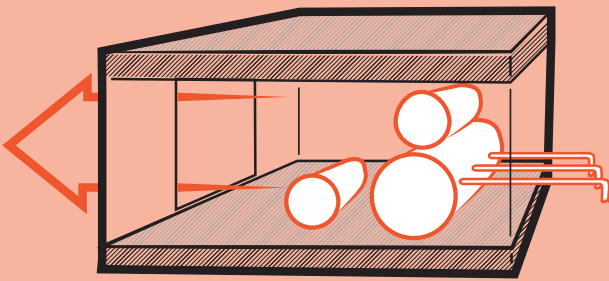
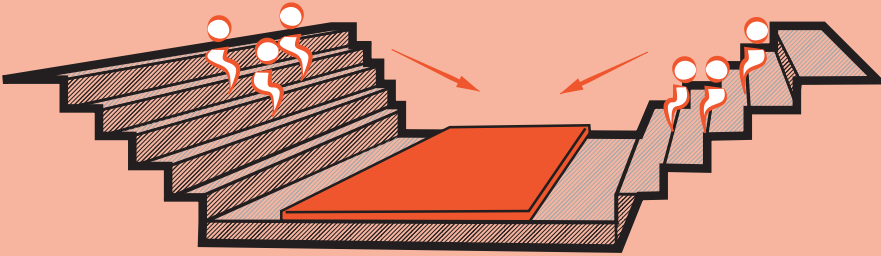
There are a few adjustments in the list of summer users compared to the winter version. The sporters have a different occupation, and there are no ice maintainers, who are usually responsible for the climate regulations. So another staff member is responsible for the climate control in summer. And in stead of an ice skating competition, in summer there will be events, which attract external parties to organize these events. Usually a multifunctional venue requires an extra staff member to manage these events, which in this perspective will be called the “event planner” in the permanent staff. Additionally during events, builders and of course artists are required.

Concluding about the users requirements

- The changing rooms need to be close to the ice.
- There needs to be a restaurant or café, with view on the ice skating area.
- The visitor and sporter need to be able to have full overview in the ice skating area.
- The ice quality needs to be suitable for performance training.
- During training the air temperature must be below 10 degrees
- During competitions the air temperature must be between 10 and 15 degrees.
- There should be a drainage system for melting ice and the ice resurfacing parking area.
- The technical spaces, climatic chamber and refrigeration room, should have a large entrance to assure that replacing machines and equipment can be possible.
- The offices of the technical staff should be placed close to the offices of the permanent staff.
- The rink should offer flexible spectator stands, with standing or seating option and the possibility to increase the number of visitors by architectural measures. It should house between 3000 and 5000 people.
- The building should be able to accomodate logistic vehicles.
- The construction should be able to bear multifunctional installations.
- The event area should be able to accomodate sound systems, and provide acoustic comfort.



USAGE CHARACTERISTICS



7.3. HUMAN CIRCULATION

Who will move through which space, during which time?

As shown in previous chapter, the list of users who occupy the building, during different times, in different spaces requires more investigation.

In the next pages infographics show the user types and the “route” they make throughout the building. In all schemes the route to the main occupation space is shown, which means that the route of the longtrack skater will eventually lead to the 400 meter ice sheet, the

road back has been taken out of the equation, since this will be the same route for every user.

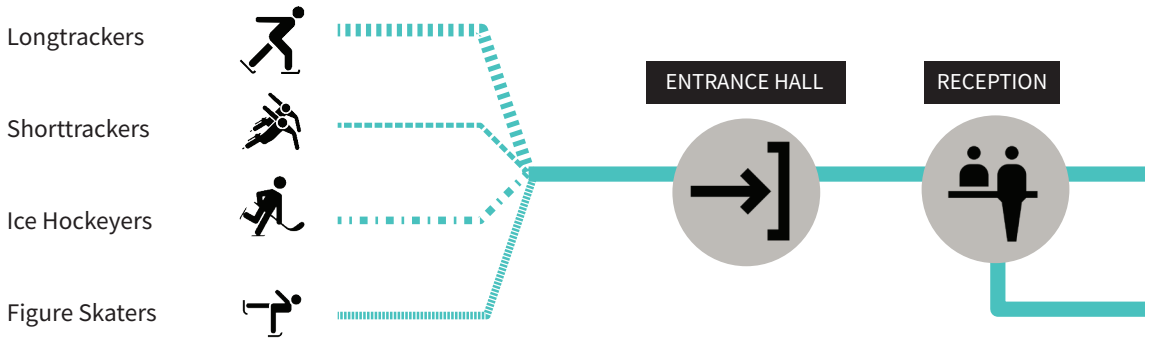
All infographics show which spaces are used by which user, during winter and summer.



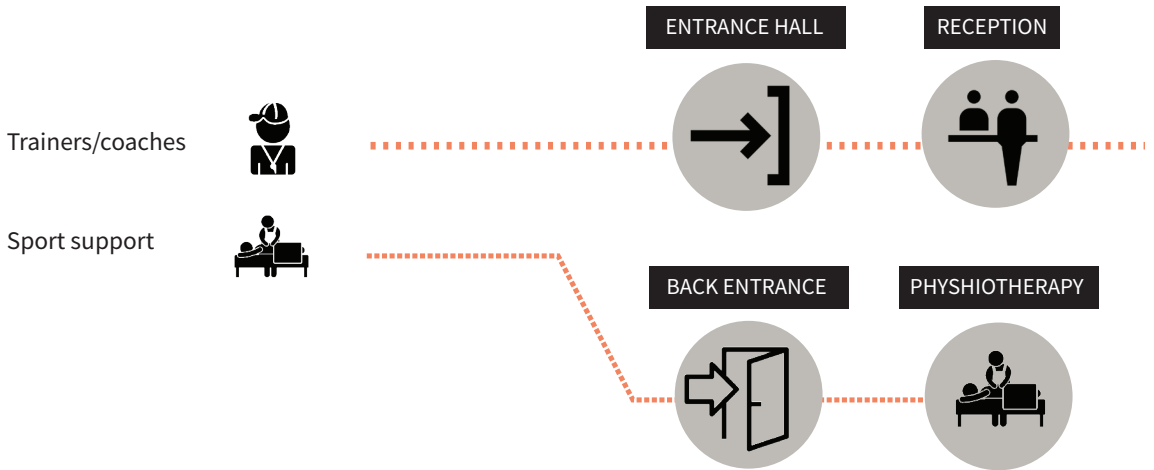
World Championships of Shorttrack in Dordrecht (Kuijf.nl, 2016).

WINTER: ORDER OF CIRCULATION 1

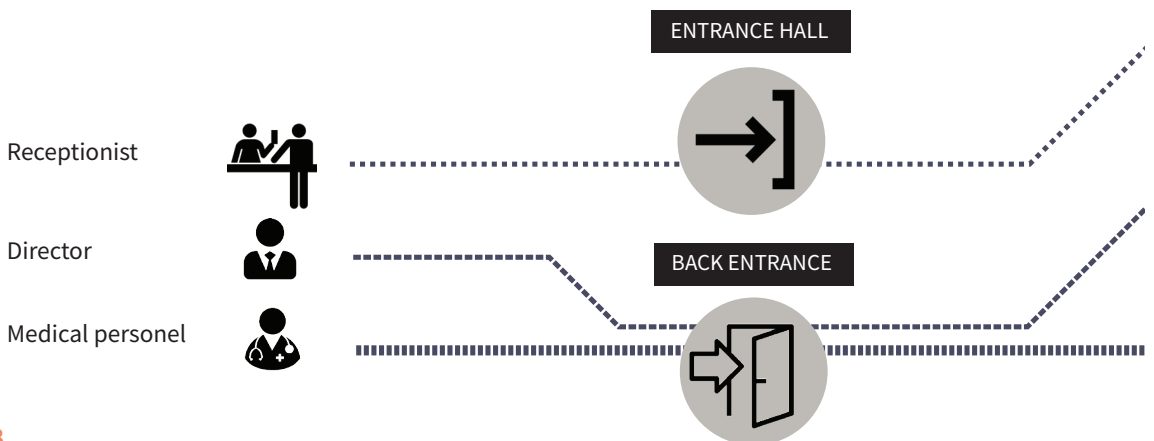
SKATERS

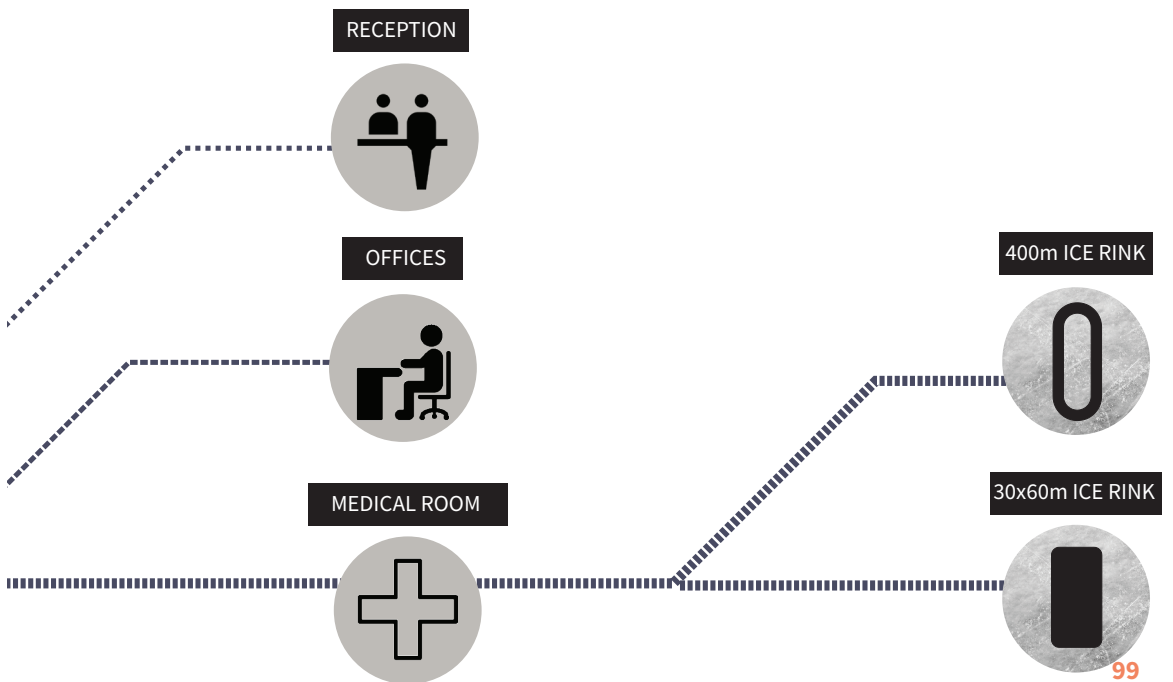
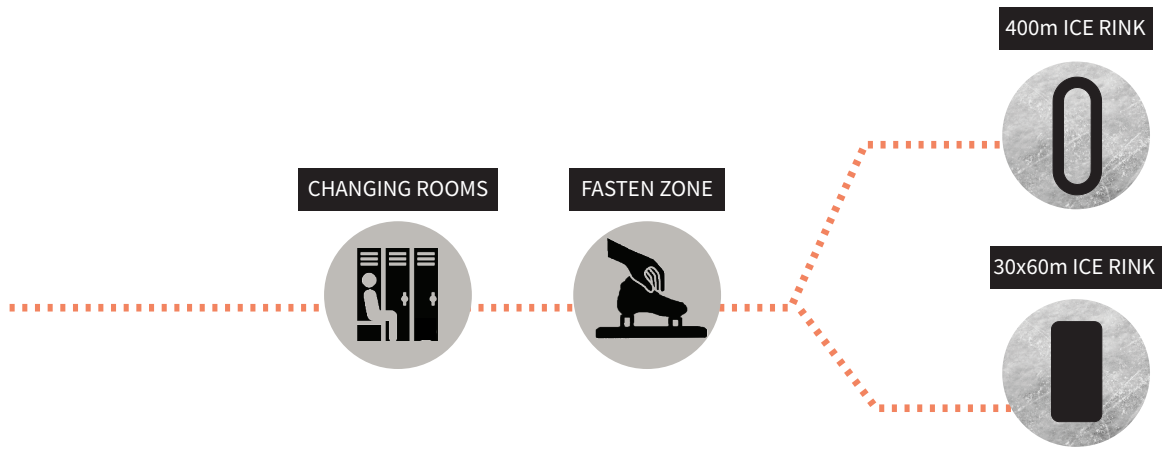
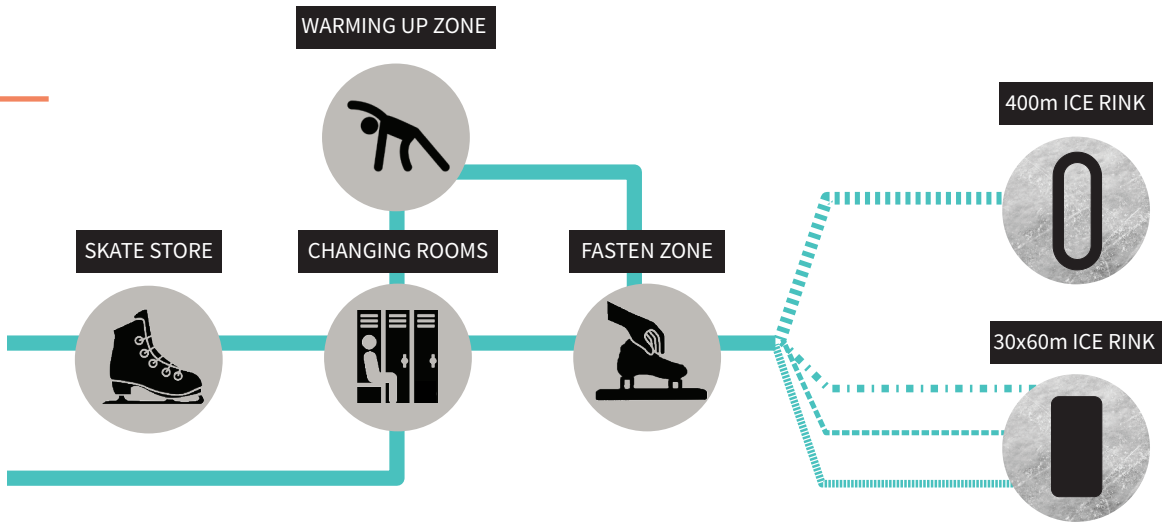


SPORT RELATED

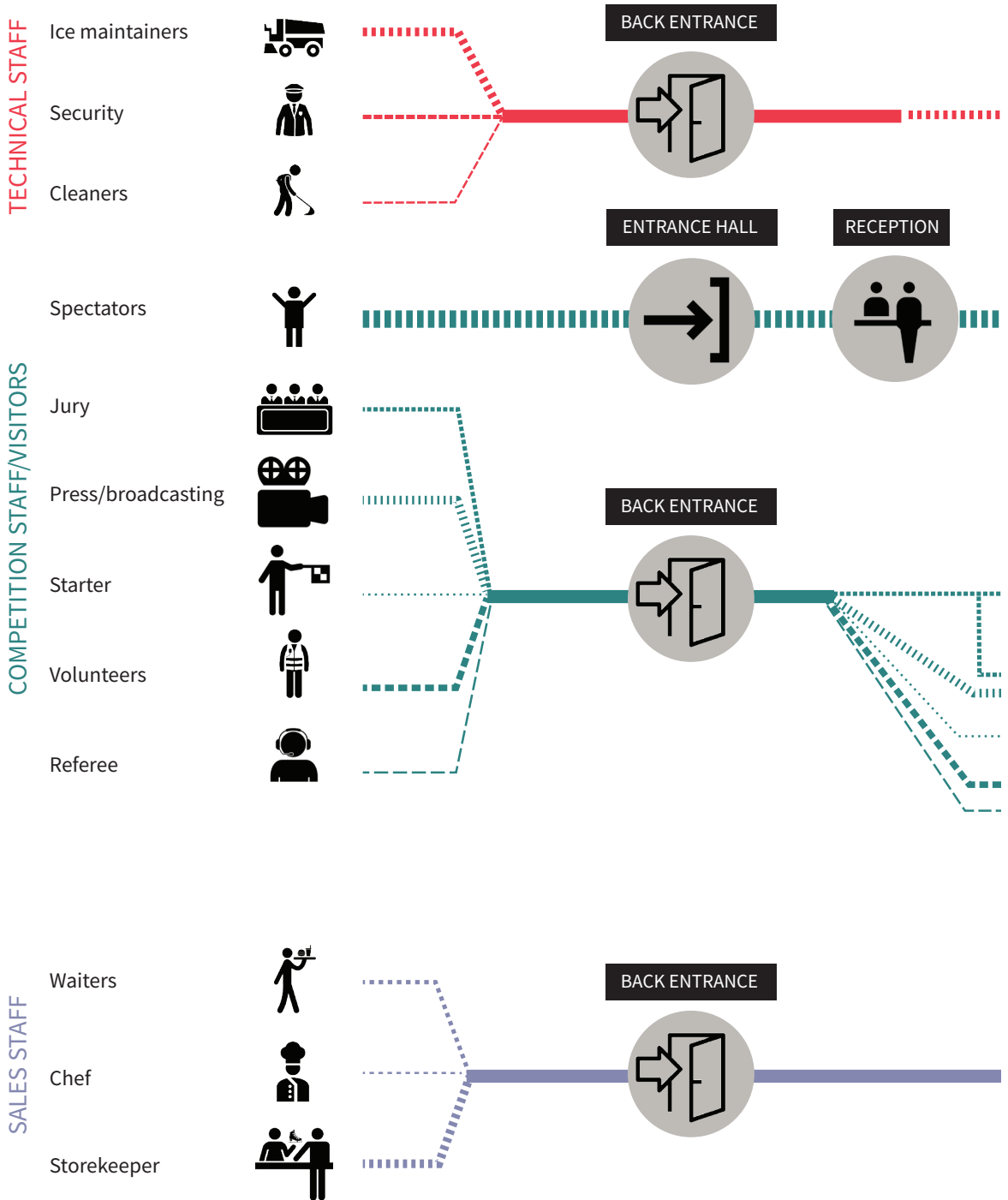


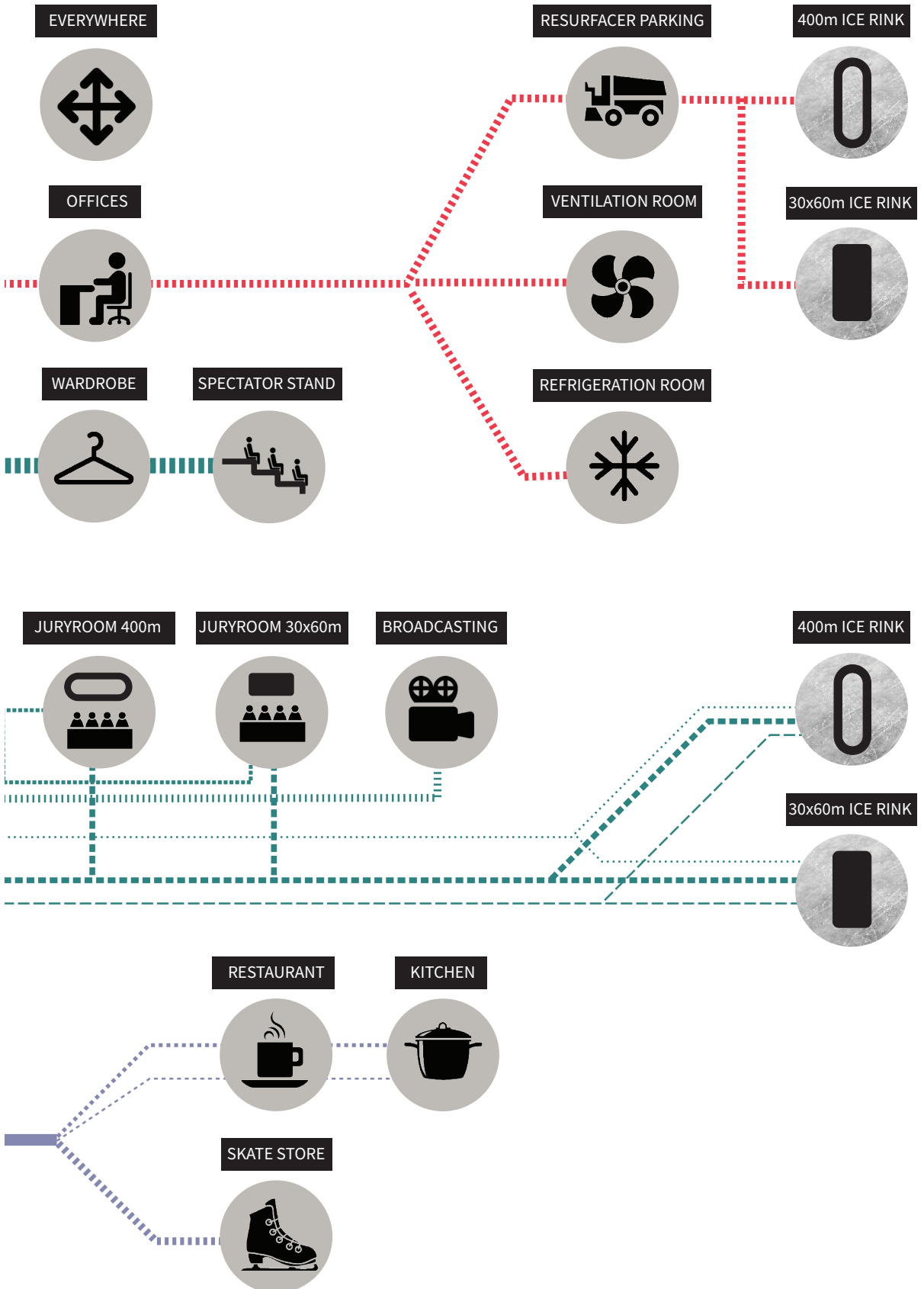
PERMANENT STAFF



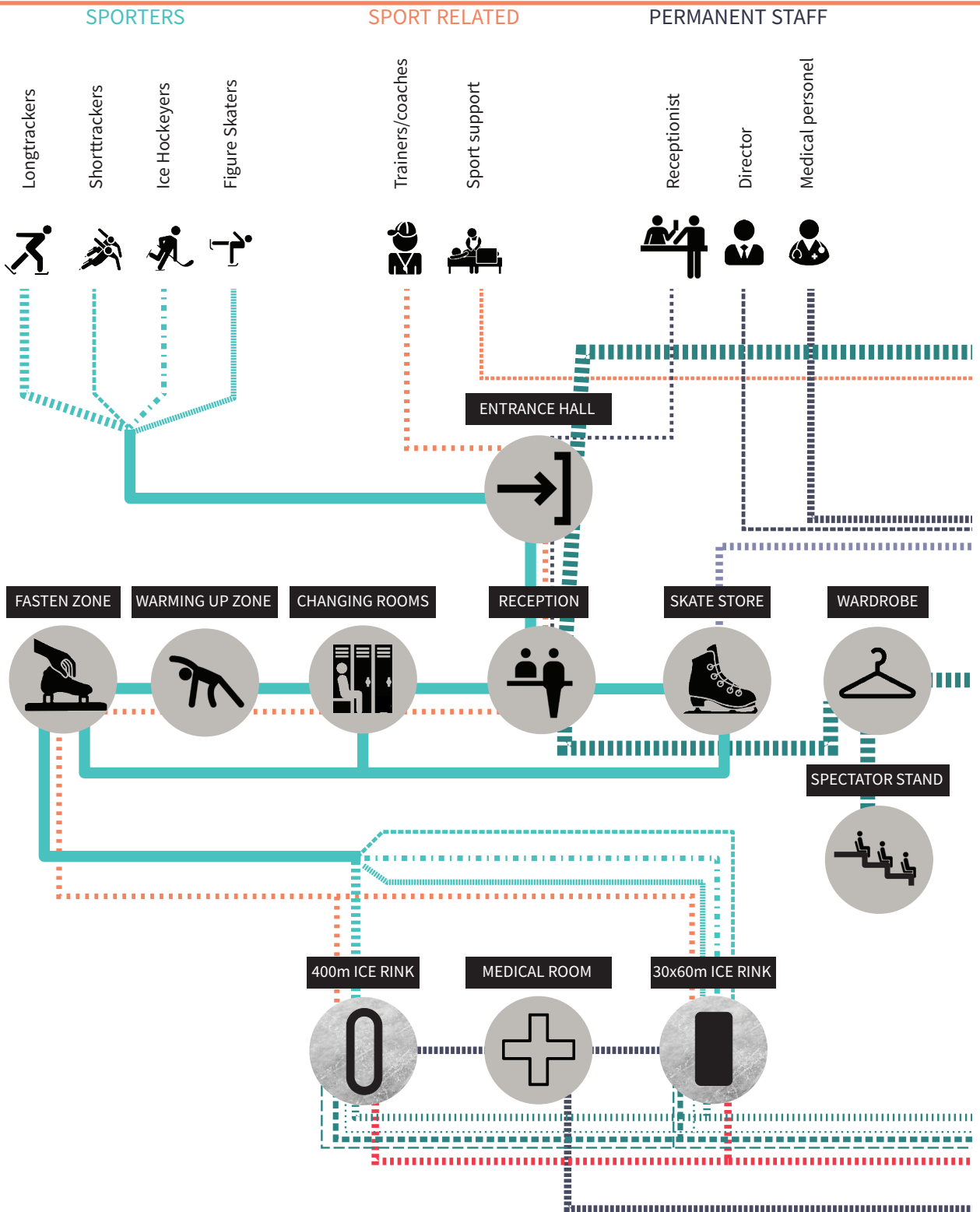


WINTER: ORDER OF CIRCULATION 2





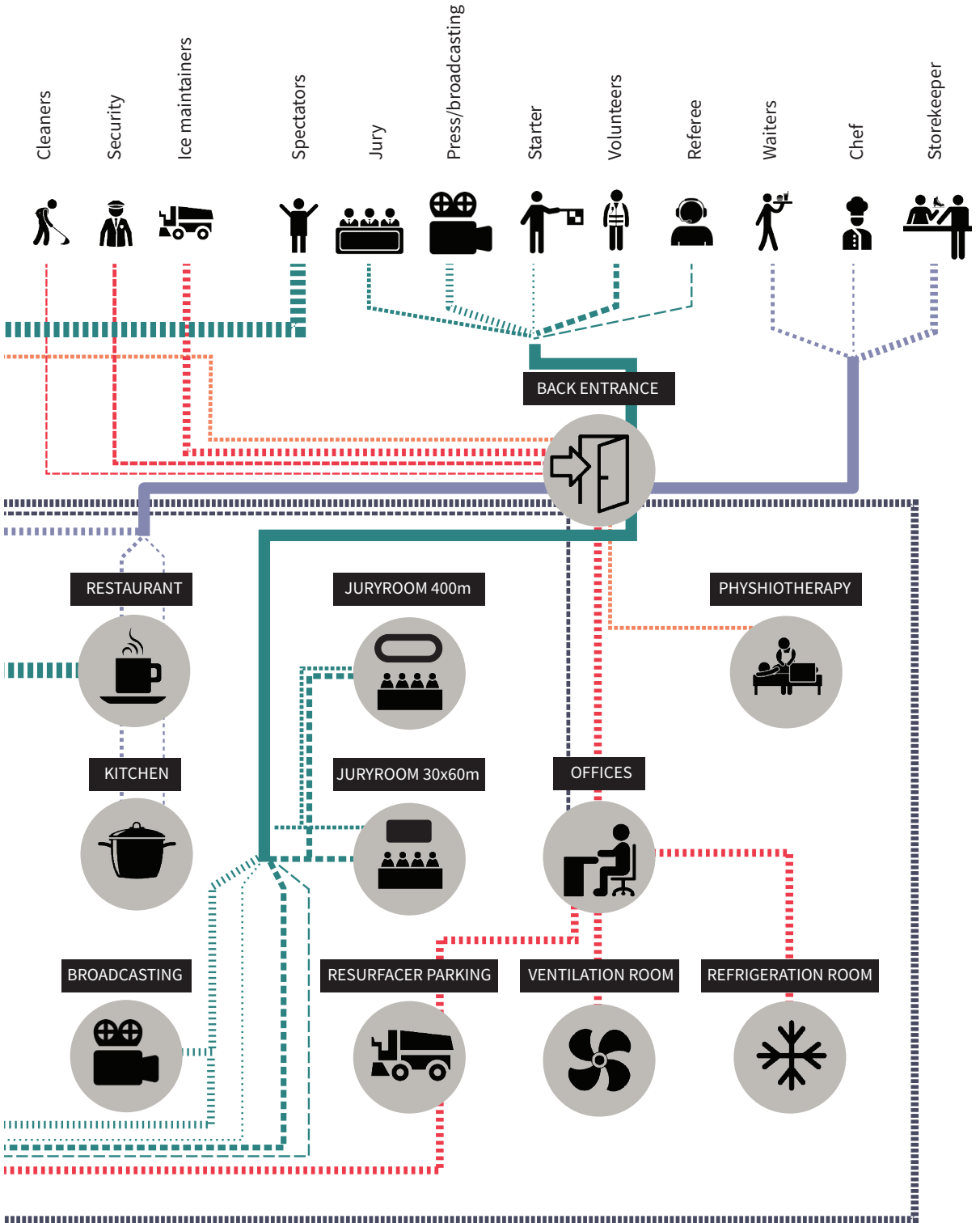
WINTER: ORDER OF ALL CIRCULATION



TECHNICAL STAFF

COMPETITION STAFF/VISITORS

SALES STAFF

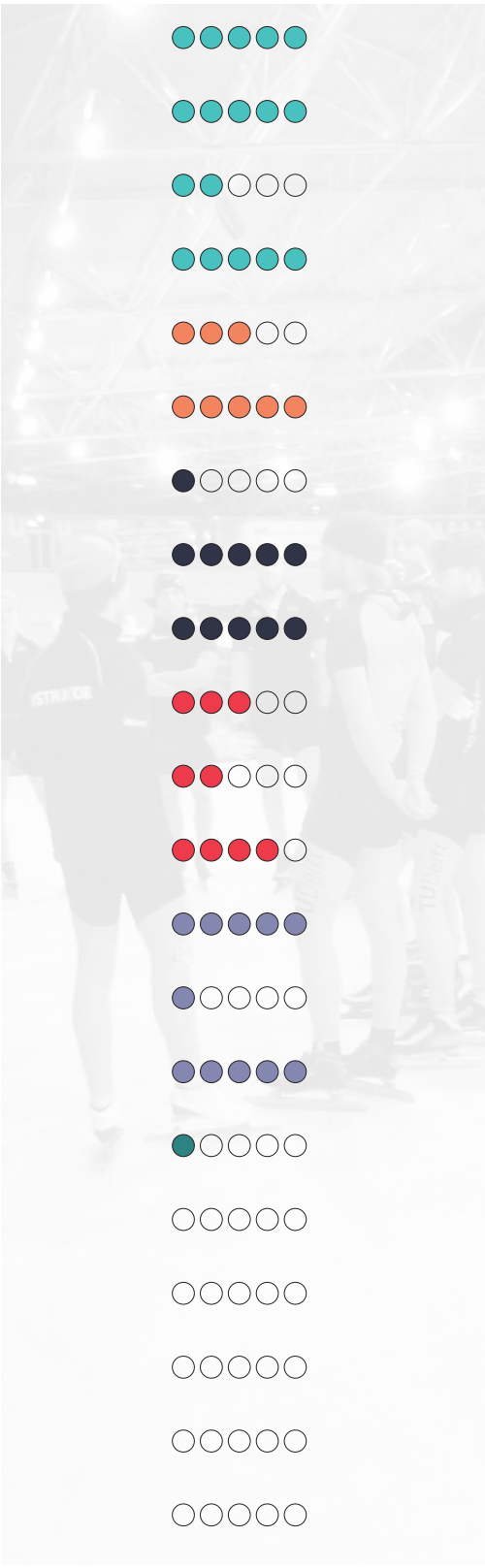
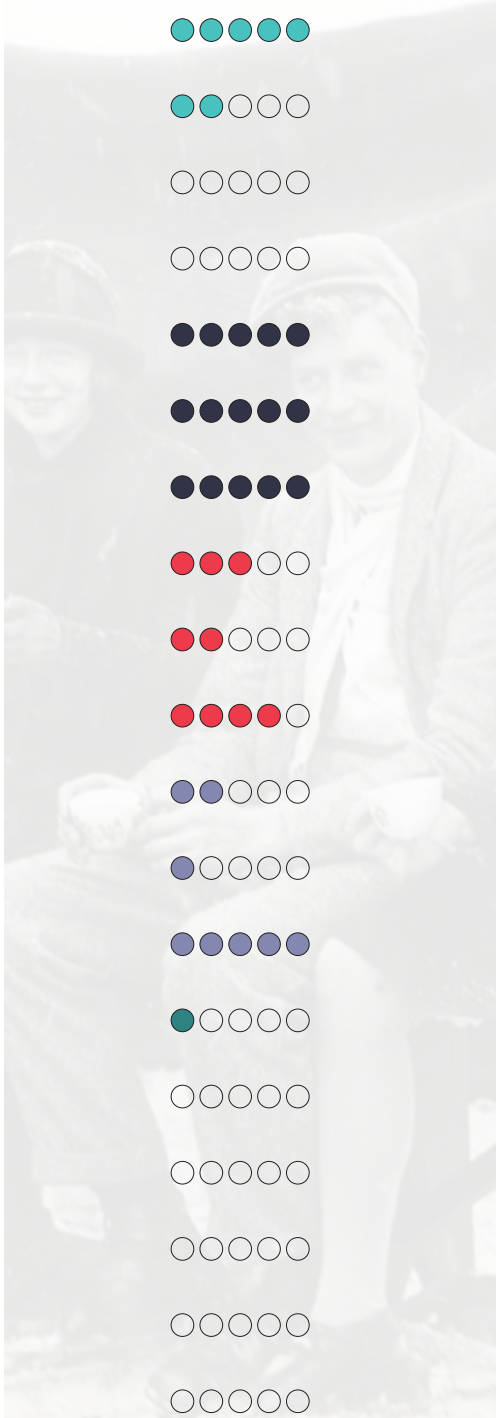
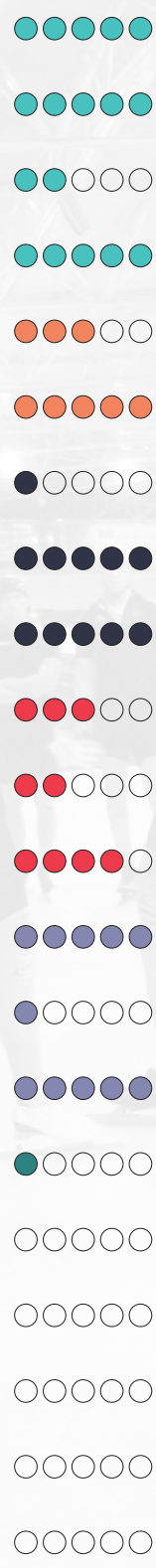
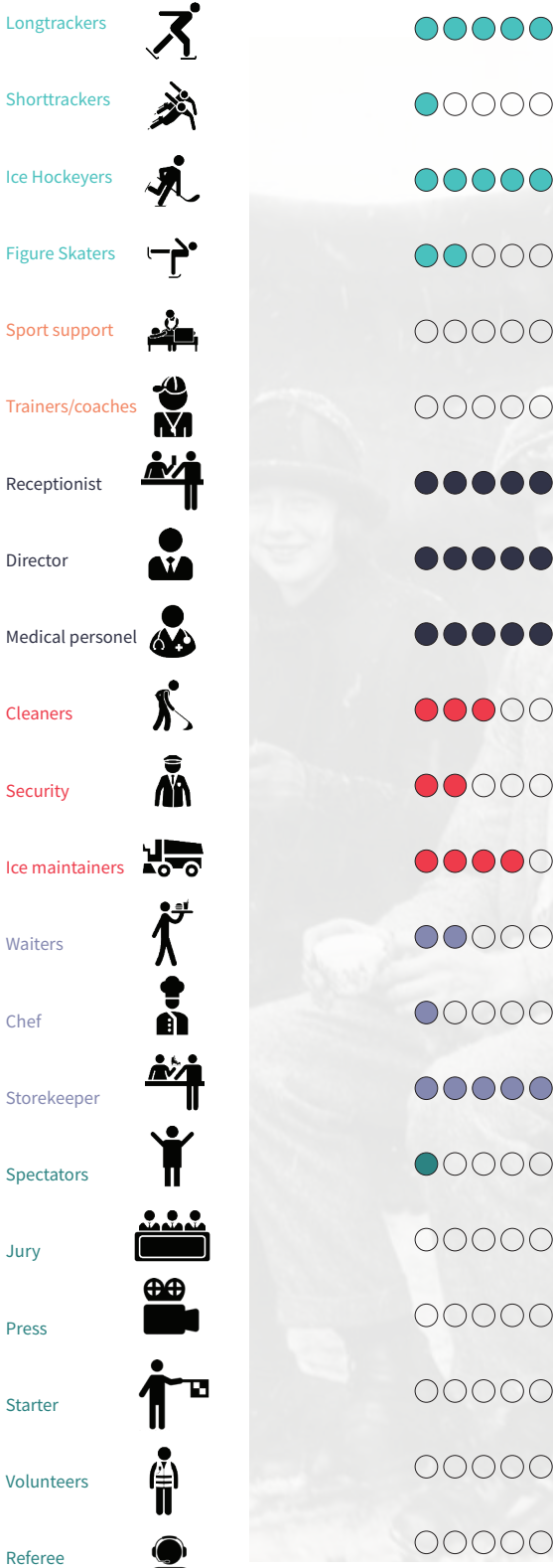


LEISURE

Recreational open hours of ice skating

TRAINING

Educational ice skating, limited acces

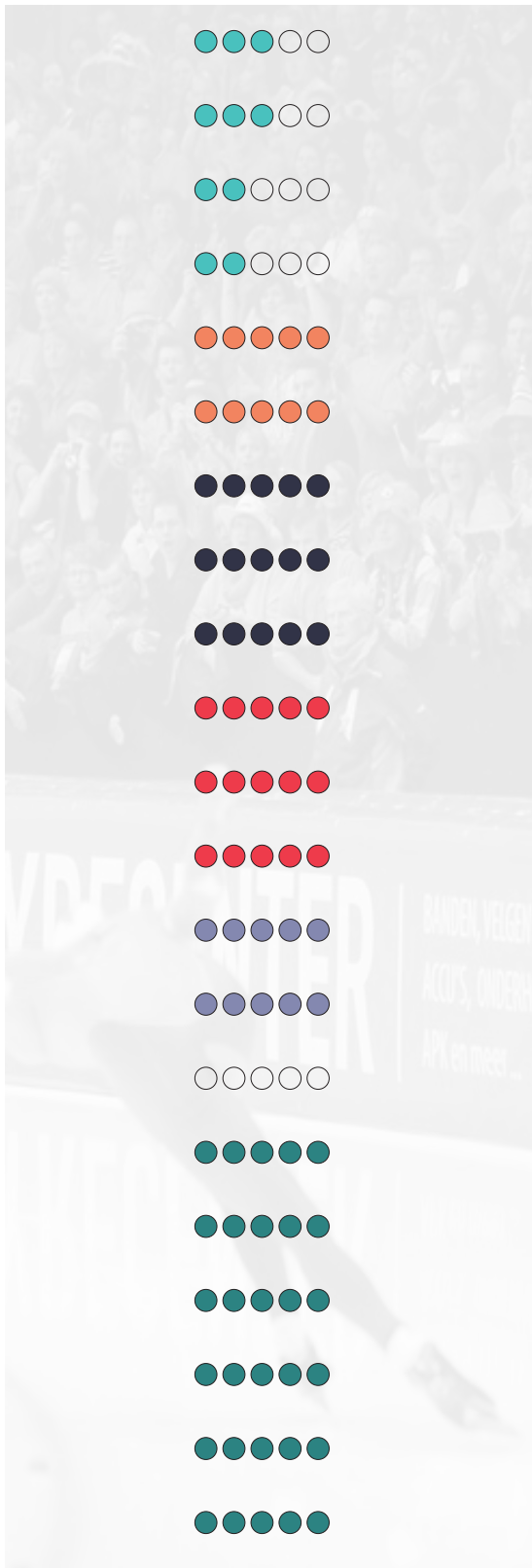
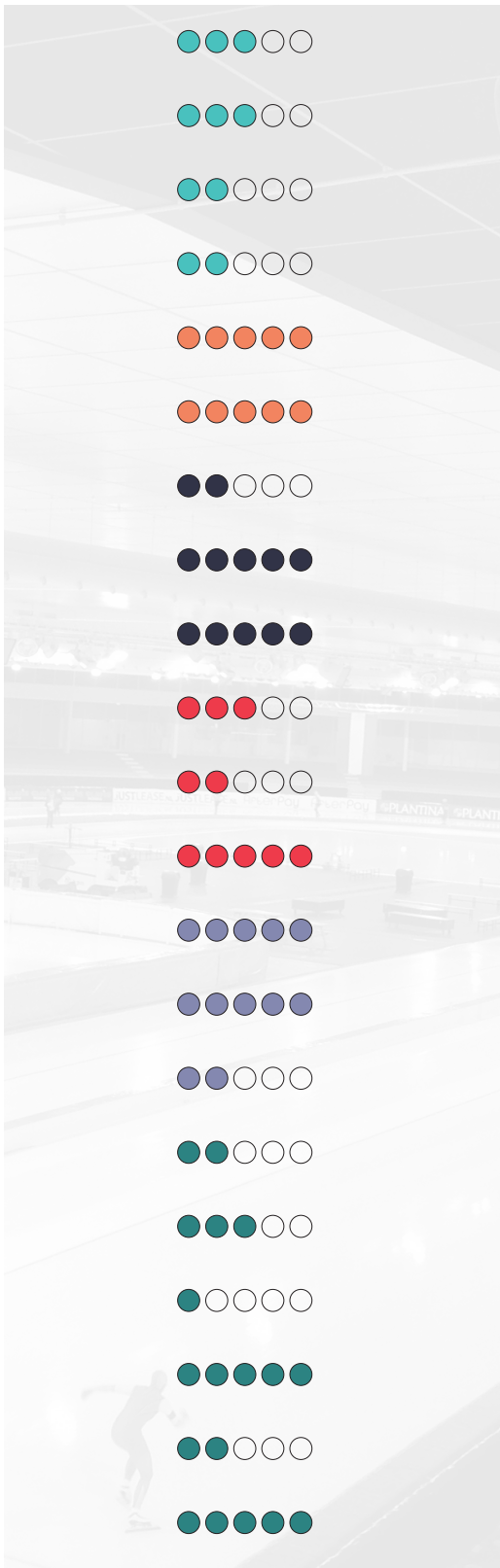


TRAINING COMPETITION

Competition with skating clubmembers

PROFESSIONAL COMPETITION

Competition with spectators & broadcasting

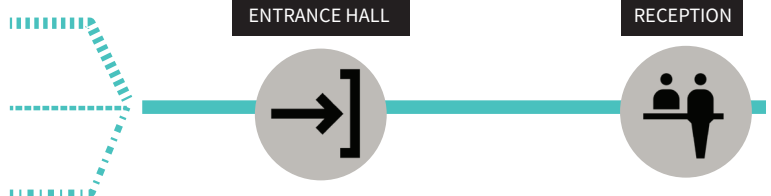


WINTER: USERS OCCUPANCY RATE PER SCENARIO

SUMMER: ORDER OF CIRCULATION 1

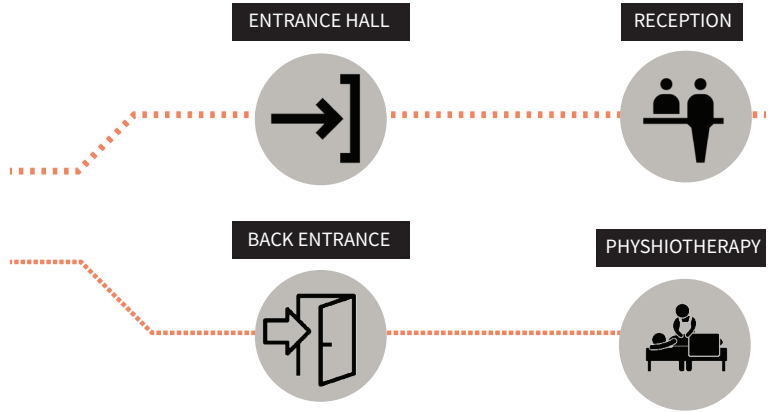
SPORTERS

- Ball sporters
- Gym users
- Inline skaters



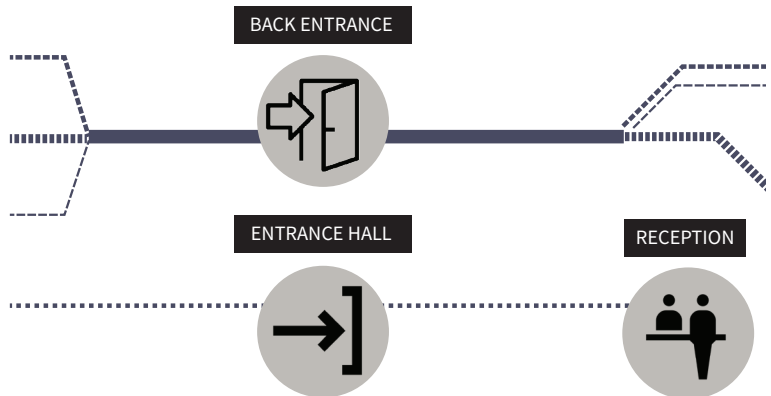
SPORT RELATED

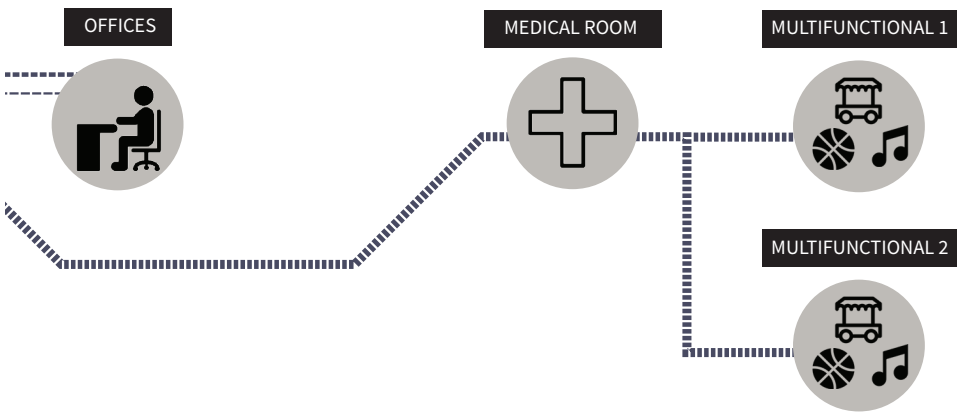
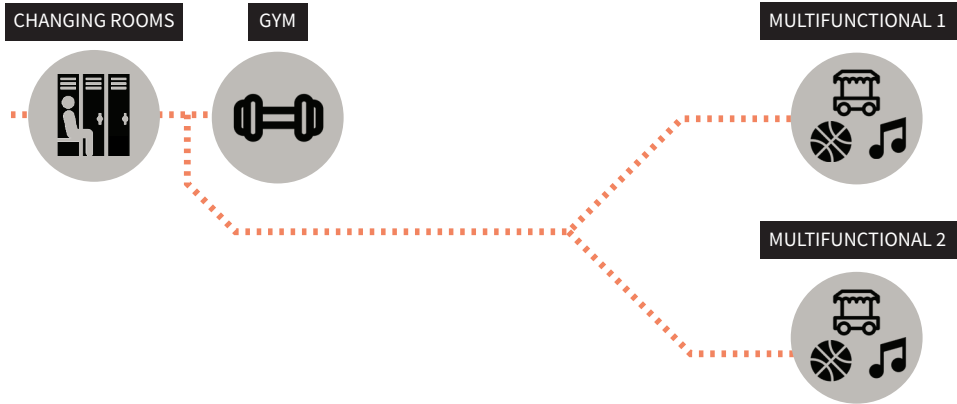
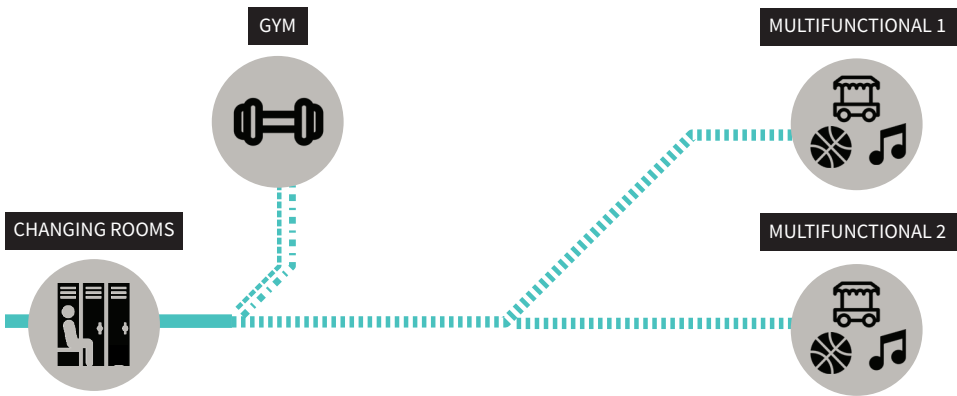
- Trainers/coaches
- Sport support



PERMANENT STAFF

- Director
- Medical personel
- Event planner
- Receptionist





SUMMER: ORDER OF CIRCULATION 2

TECHNICAL STAFF

Cleaners



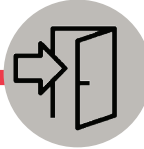
Security



Light/climate expert



BACK ENTRANCE



SALES STAFF

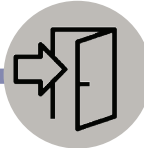
Waiters



Chef



BACK ENTRANCE



OCCASIONAL EVENT STAFF

Spectators



Volunteers



Press/broadcasting



Artists



Producer/organizer



Builders



Service staff



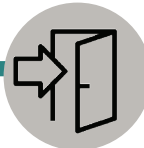
ENTRANCE HALL

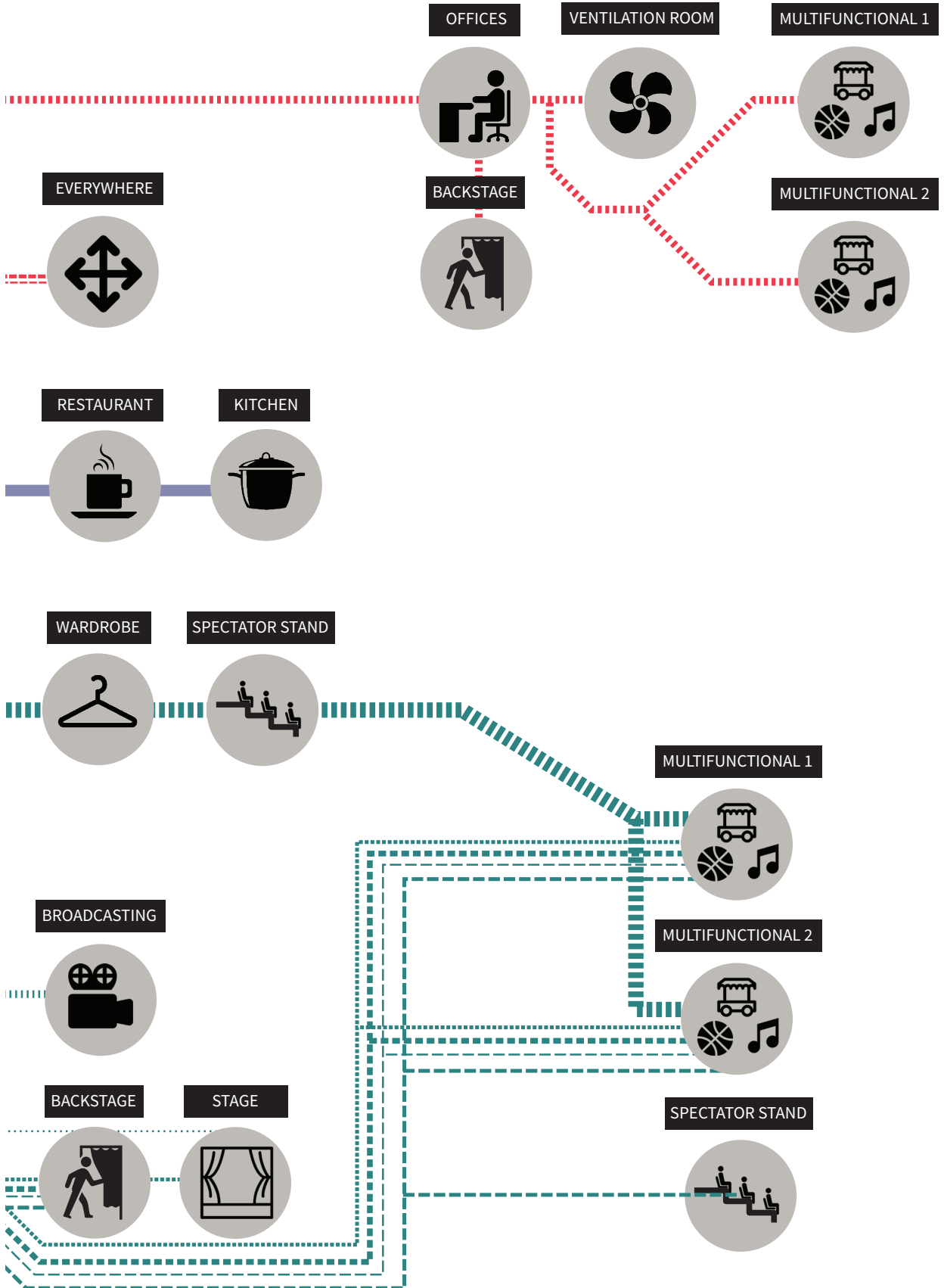


RECEPTION



BACK ENTRANCE



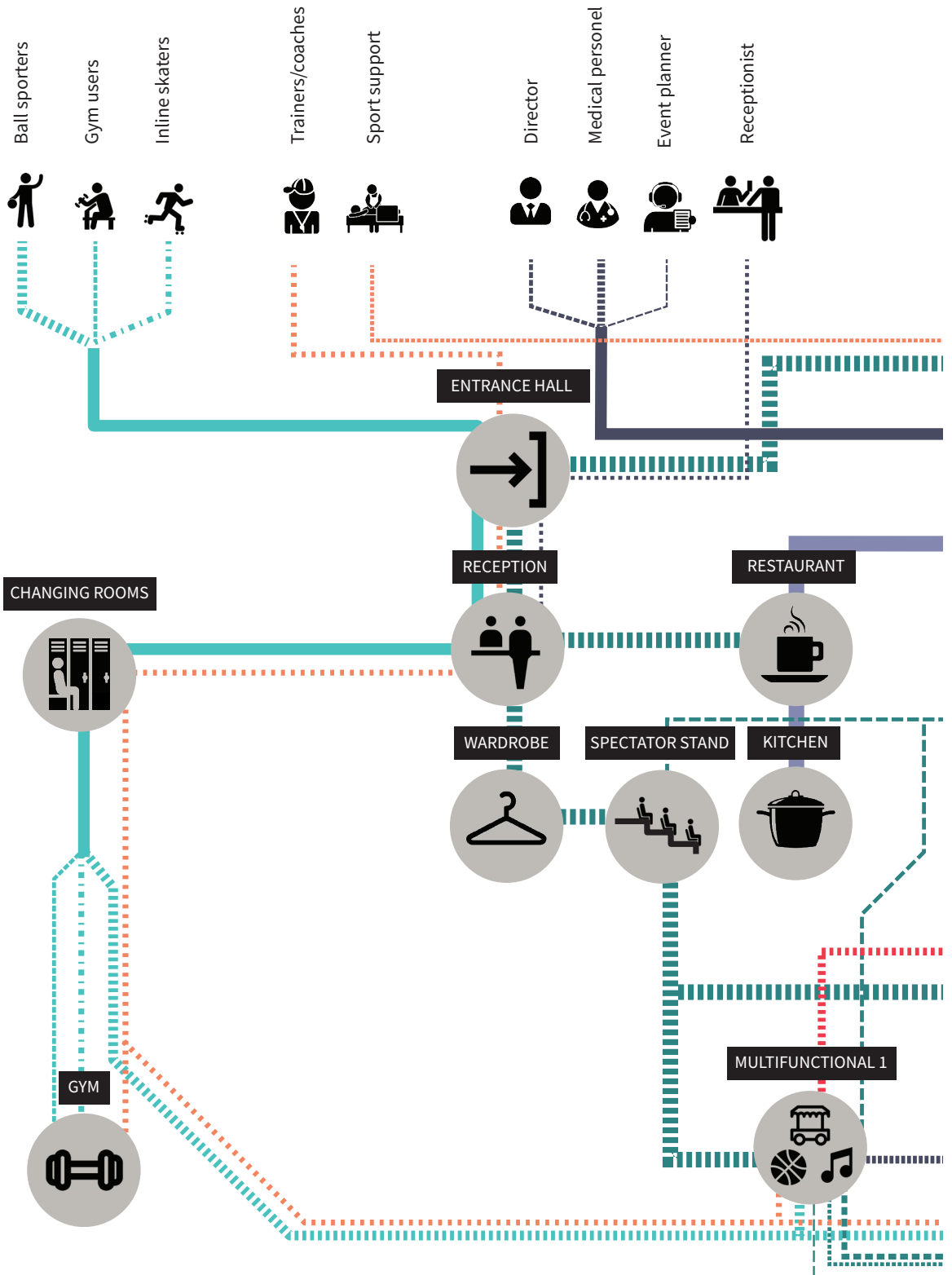


SUMMER: ORDER OF ALL CIRCULATION

SPORTERS

SPORT RELATED

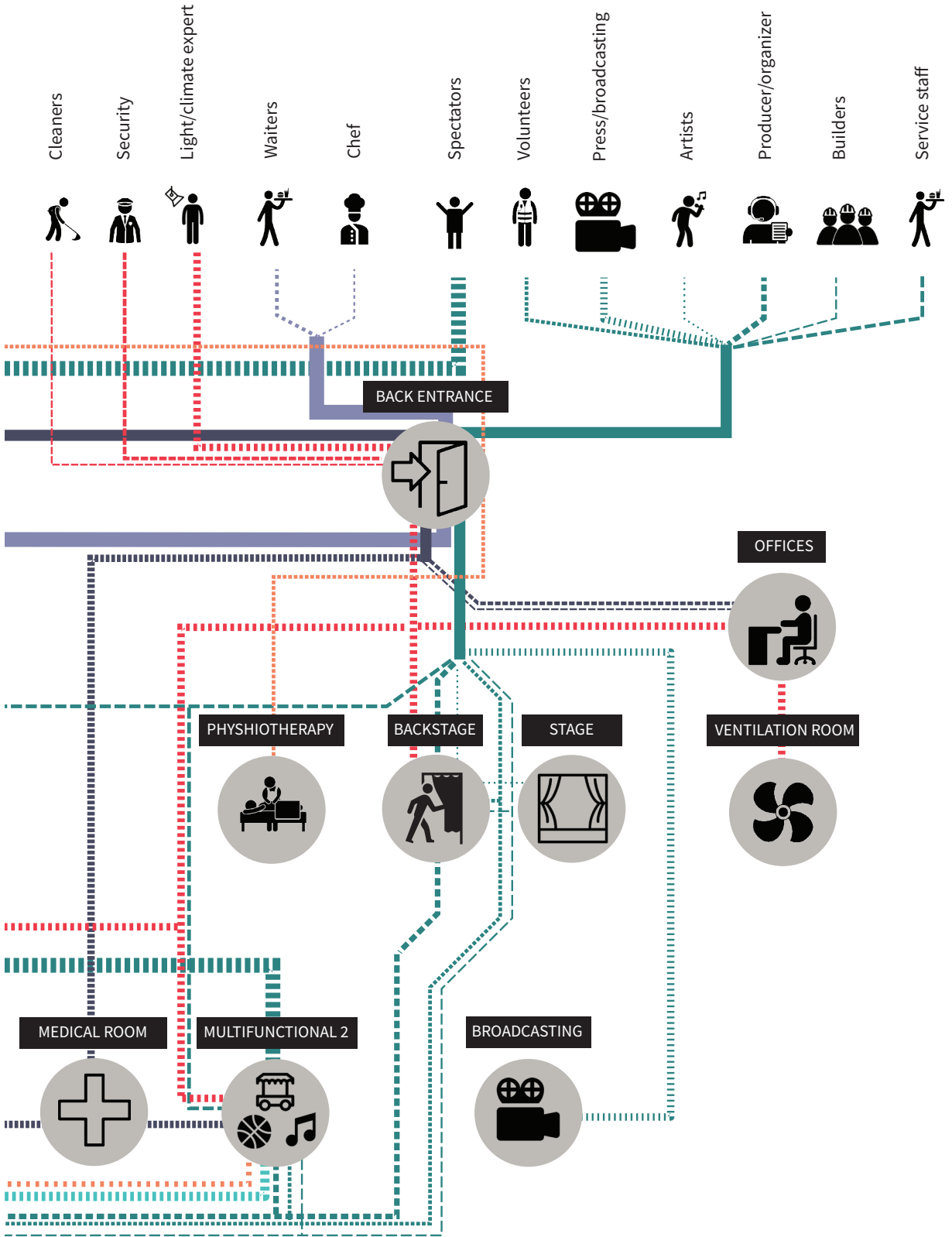
PERMANENT STAFF



TECHNICAL STAFF

SALES STAFF

OCCASIONAL EVENT STAFF



An aerial photograph of a forest with a grid overlay. The grid consists of thin, light-colored lines forming a rectangular pattern across the entire image. The forest below is dense and green, with some lighter patches indicating different types of vegetation or terrain. The overall image has a slightly grainy, high-resolution appearance.

SPATIAL CHARACTERISTICS

SPATIAL CHARACTERISTICS

- 8.1. Required spaces of 400m ice rinks
- 8.2. Construction principles of 400m ice rinks
- 8.3. Insertion of an ice rink into a city

SPATIAL CHARACTERISTICS

8.1. REQUIRED SPACES OF 400M ICE RINKS

As a frequent user of these typical buildings I have a general idea what type of spaces are needed to make an ice rink into an sufficient functioning building. This is viewed from the sporters perspective. So to get a complete overview of all rooms required several aspects will be investigated:

- A floorplan analysis of 3 existing ice rinks
- Interviews with users of this building type
- A questionnaire with the sporters using the building type

The requirements from

the interview and the questionnaire are being elaborated in the Usage Characteristics Chapter. But an exact amount of square meters cannot be extracted from this type of qualitative research.

3 floorplans: Requirements

So to get a better insight in how much space every function needs, 3 floorplans will be researched on their surface area.

The three rinks I chose are based on the following two requirements:

1. In the chapter "Ice rink typology" is described that

there are roughly 3 types of ice rinks, semi-open ice rinks, closed ones and ice rinks which have a double layer of façades, which houses more rooms. The chosen floorplans should cover these three types.

2. The floorplans should be readable, in a way that it is clear what space houses which function.

Floorplans were to be found of 3 rinks, which represented the 3 mentioned ice rink typologies from requirement 1:

- Ireen Wüst IJsbaan, Tilburg, Netherlands: Semi indoors.
- Max Aicher Arena, Inzell, Germany: Fully indoors.
- Thialf, Heerenveen, Netherlands: Indoors with extra façade layer.

In Appendix 10 all floorplans were analysed on their square meters per function.

Side note 1: In the end, requirement 2, happened to be the biggest challenge. It turned out to be difficult to find floorplans of ice rinks, since these buildings are mostly build a non-digital period, in the 80's and 90's and the drawings are not (yet) digitalised. Also, there is an assumption that floorplans, or technical drawings are sometimes not the presentable drawing architects want to show.

SPATIAL CHARACTERISTICS

Ireen Wüst IJsbaan

Architect: Van Hoogmoed architecten (nowadays PANplus architecten)
Building year: 2009

This Dutch ice rink was made in combination with a sport centre included under the same roof. The rink contains a fitness space next to the ice rink, which overviews in the length axis direction the ice speedskating field. Unlike most ice rinks, the entrance are in the length axis, accessing the ice sheet at the corner. Just a small strip of service functions were situated next to the ice rink on the longitudinal axis, containing changing rooms, a garderobe and toilet units. The technical spaces are on the other side of the entrance unit.

Max Aicher Arena

Architect: Behnisch architekten & Pohl architekten
Building year: 2011

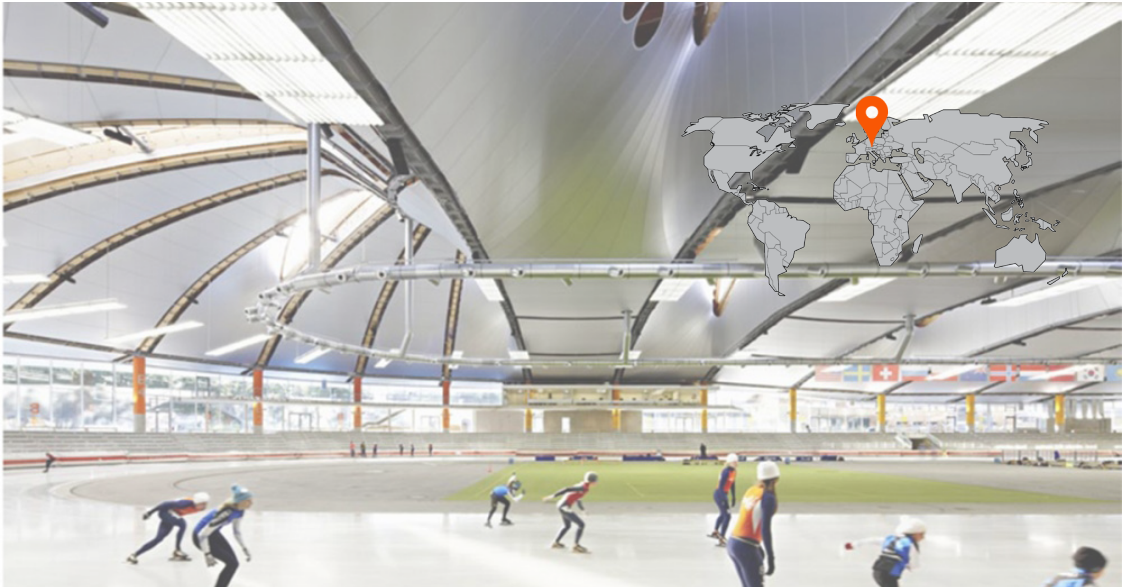
This rink is a renovation of an outdoor ice rink. Some old facilities are kept intact. The entrance zone, from the old days, is connecting the ice rink on the width axis. The public functions are kept on ground level, the changing rooms and technical spaces are placed underneath the ground level. Interesting fact is that the visitor enters the building to buy a ticket and than visits an outdoor-zone to enter the actual sport area.

Thialf

Architect: ZJA
Building year: 2016

Thialf has been renovated in to a buffer rink, which contains an extra layer of facade around the ice sport area. In this buffer zone, spectators can circulate, on the first floor there are rentable offices and a warming up gym. The general set up of the floorplan is a connecting zone between two ice halls, the 400 meter area and the ice hockey hall. Sporters come in from the other side of the 400 meter rink, to offer privacy and direct acces to the warming up gym. The spectators visit the connecting zone first, before the bufferzone towards the stands.





Max Aicher Arena in Inzell (Appendix 3)

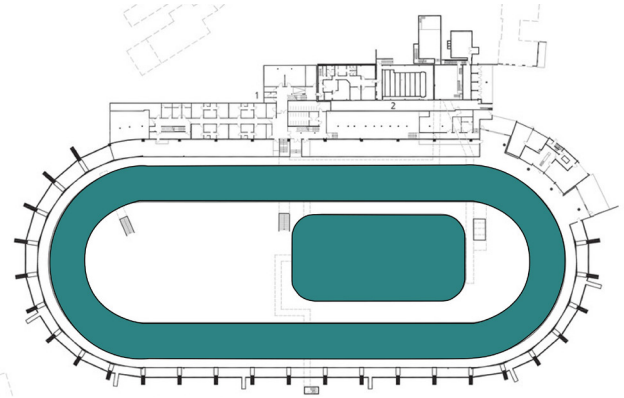
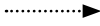


Thialf ice rink in Heerenveen (Appendix 3)

SPATIAL CHARACTERISTICS

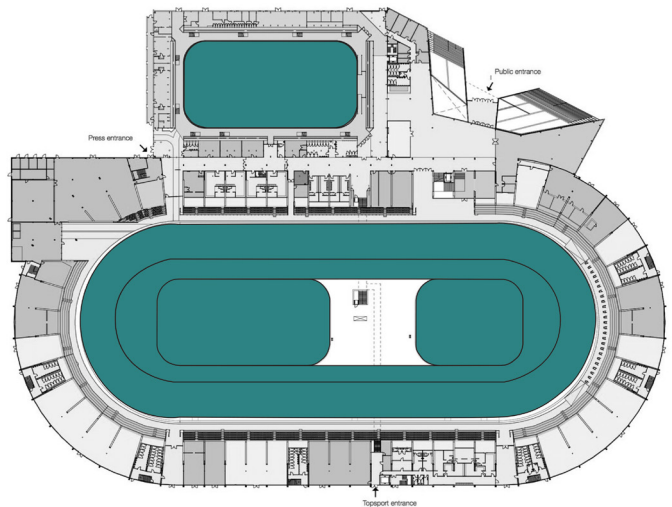
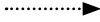
Ice sheets

Max Aicher Arena:
6639,0 m²



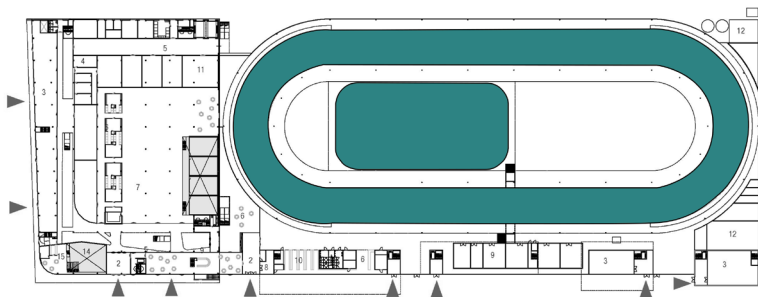
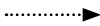
Max Aicher Arena, Inzell, Germany
Behnisch Architekten & Pohl Architekten

Thialf:
11899,0 m²



Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

Ireen Wüst IJsbaan:
6639,0 m²



Average:
8392,2 m²

Ireen Wüst IJsbaan (Sportcomplex T-Kwadrant), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Per case study there has been a surface calculation of all different spaces. The results are shown in Appendix 5, also an example of area calculation in the floorplans of the three case studies is shown on the left. In this case the surface which has been covered with ice.

Ice sheet dimensions

The measurements of an actual 400 meter ice rink, as mentioned before, were established in Gothenburg, at the first 400 meter ice rink of the world. Established in 1958. Since then no changes were made to the actual competition lanes. However the smaller lane on the inside of the rink, used for the skaters which are waiting for their turn in the competition, may differ for each rink. The regulation says it should be at least 3 meters. This also goes for the most outer line, which needs to be

at least 5 meters (Gewest Zuid Holland, 2014). Also shown in the illustration on the bottom of this page.

Missing functions

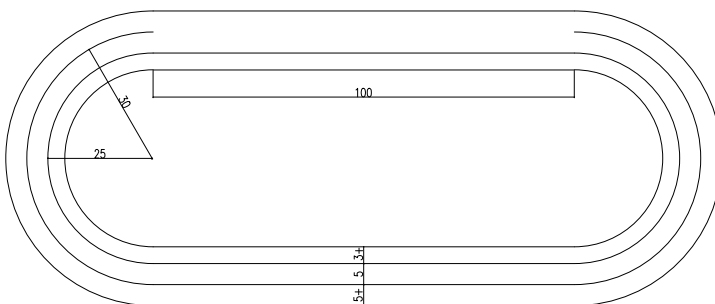
Within all analysed floorplans there were some functions missing. Since there is no existing program of demands to fall back to, I have to make use of the interviews I did and personal experience. These functions are mentioned at “functions extracted from personal experience”.

Within the Max Aicher Arena in Inzell, there was also a utility room, it is not specified what the room is used for.

Discussion aspects

The three floorplans which were used in this research were sometimes not complete. The Max Aicher Arena in Inzell had two floorplans, but failed

to name all spaces which were there, also, I can only conclude that several spaces were in reality somewhere else. The numbering system to indicate the spaces were wrongly placed. Inzell had only the ground floor and the basement included in the drawings, as Thialf had only the ground floor. The Ireen Wüst ice rink only presented the ground floor as well. So a lot of information is lost in other floors. Because the goal of this research was to find what functions were included in an ice rink, this results in an incomplete picture. Another goal was to find the number of square meters required for each function and to compare the rinks with each other whether these numbers are coherent with one another. The last goal was fortunately still possible.



Measurements of a standard 400 meter ice rink in meters, own illustration.



Warming up/cooling down space in Thialf, one can see the ice rink area at the left side, own picture.

SPATIAL CHARACTERISTICS

Conclusion: Functions extracted from the floorplans

According to this analysis all three ice rinks contained the following spaces:

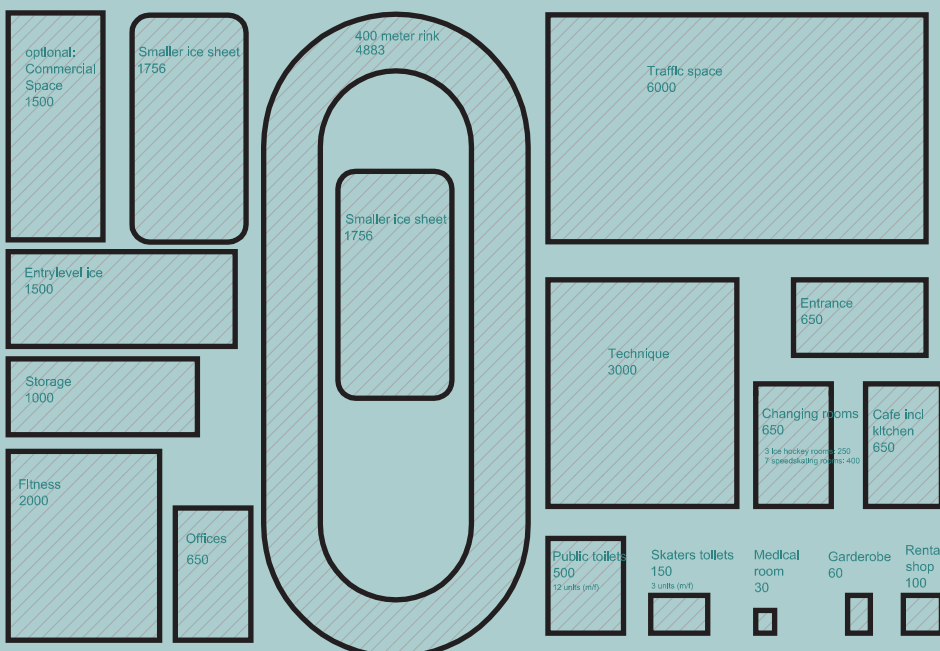
- Technical spaces
 - Cooling plant to provide the cooling refrigerant for the pipes underneath the ice surface
 - Climatic control rooms / air conditioning
 - Ice sheets
 - Most rinks contain one 400m lap and one 30x60 ice sheet. This can differ, which will be elaborated on in this chapter.
- Changing rooms (incl. toilet)
 - Sometimes only to serve the speedskaters using the 400m rink and ice hockey players combined. Sometimes to serve other functions as well, like a fitness space.
- Fitness spaces
 - Either for external users, or for the

ice skaters to warm up an cool down.

- Garderobe
- Separate toilet units
- Café
- Storage
- Commercial space
- Rentable spaces
- Traffic space
 - All corridors and movement between spaces taken into account
- Entrance
- Medical room
- Spectator stands
- Offices
- Multifunctional space
 - Usually the leftover space inside the 400m ice lap

Functions extracted from personal experience

- Jury room
- Additional leisure room for the jury
- Storage for time measurement instruments



8.2. CONSTRUCTION PRINCIPLES

By researching the case studies, the focus was to investigate ice rinks which showed a full span construction, covering the complete ice skating area. Direct sight to the other straight end of the 400 meter rink is considered desirable for broadcasting purposes, but also or spectators to have a clear overview. But most importantly the skaters themselves prefer a clear sight to the other side of the rink (questionnaire).

The construction span is, depending on the amount of spectator stands, around 90 meters in width. This case study research proves that there are several construction methods and materials which could achieve this prestigious large span.

Construction principles

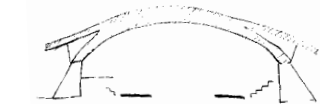
There are two construction methods which can be used to bear a roof with the additional loads (snow, rain and wind).

Tensile structure

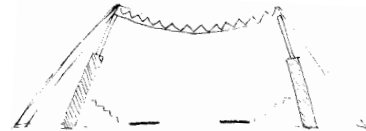
A tensile structure and a compression structure. From all case studies only two are based on the tensile bearing system, a construction method is comparable to a



Construction principle Max Aicher Arena, Inzell, Germany.



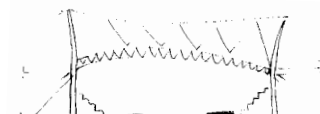
Construction principle Richmond Olympic Oval, Vancouver, Canada.



Construction principle M-Wave, Nagano, Japan.



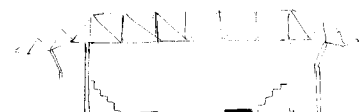
Construction principle Vikingskipet, Hamar, Norway.



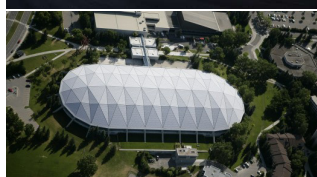
Construction principle Utah Olympic Oval, Salt Lake City, USA.



Construction principle Thialf, Heerenveen, Netherlands.



Construction principle Adler Arena, Sochi, Russia.



Construction principle Olympic Oval, Calgary, Canada.

SPATIAL CHARACTERISTICS

suspension bridge. The roof construction is “hanging” between columns, in this method, only tension is carried in the construction materials. The M-Wave in Nagano, Japan, is an example of this principle. The name also refers to the general shape the building possesses, the tensile structure is covered, so the construction elements are not visible. This structure is highly visible in the Utah Olympic Oval in Salt Lake City. Within this rink, the tensile structure is used as an eye catcher and defines the building in its appearance. Before the renovation, Thialf used to have a tensile construction as well, this has been changed into an compression construction, shown in the image below. A benefit of a tensile construction is the low costs, since the construction principle includes light weight materials, and economic advantages.

Compression structure

Most ice rinks bear the load through compression, which is also visible in their general shape. These rinks mostly have an upwards curved roof construction. This construction principle is, in case of Thialf and Max Aicher Arena combined with a lens construction, which is a spatial truss shaped like a lens, “floating above the ice”

Curved or rectangular

There has been a discussion if the outer shape of an ice rink necessarily has to follow the curve of the ice sheet. This is what is happening with all the semi covered ice rinks. A curved building design is more expensive than rectangular construction. It is even said that building a closed rectangular construction can be achieved for the same amount of money as for building an open curved construction (Berends, 2000). However, the ice rink building typology is frequently referred to an “oval” shape. Like the Olympic Ovals of Salt Lake City

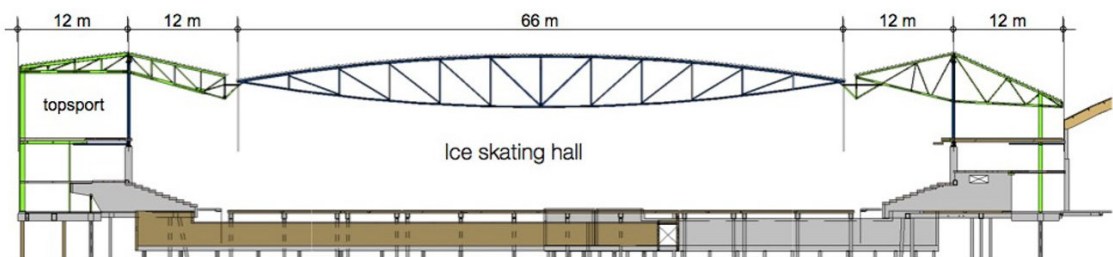
and Cargary. It is a recognizable feature of what houses inside. Since one of the design goals is to “sell and promote” the sport, the oval shape has a preference.

Integrated ventilation

Some construction trusses used for several ice rinks contain an integrated ventilation system, like the Richmond Olympic Oval (Berends, 2010) and Triavium in Nijmegen (E. Berends, personal communication, 07-12-'16, Appendix 1). Which is a aesthetic solution to a climate application.

Foundation

When the ground substance is other than swamp or clay it is possible to build the concrete slab, which supplies the ice sheet, directly on the ground surface. This mostly happens when the ground consists of rock or sand. In this case, the soil needs to be protected from permafrost



The new construction of Thialf, after the renovation (Staalmakers.nl, 2017).



Constructing the Jaap Eden Ice rink in Amsterdam in 1961 (Berends, 2003)



formation, so usually underneath the insulation layer, there is another concrete slab with floorheating (E. Berends, personal communication, 07-12-'16, Appendix 1).

In the Netherlands most rinks are build on piles, these are drilled into the ground. In the past this could cause trouble, since the concrete slab would experience expansion due to temperature differences. The slab could start moving from its foundation, with disastrous consequences. Some ice floors had to be replaced completely over the years. Thialf in Heerenveen experienced this in the 70's (E. Berends, personal communication, 07-12-'16, Appendix 1). Jaap Eden in Amsterdam was close to the point that they would lose their ice floor. Also this ice floor was slightly elevated above

ground, shown in the pictures above, to prevent the soil from freezing.

“Die baan was eind jaren zeventig van zijn sokkels gegleden” (Brink, 2004, p.20). Butter is talking about the fact that ice floors can “move” during their lifetime. Nowadays they are fixed on several flexible slider points. Some ice rinks have two of these fixation points, most modern rinks have four (F. Bongenaar, personal communication, 07-12-'16, Appendix 1). It says that every year an ice floor can move 4 centimeters, if you don't fix these points there will be problems, sometimes disastrous, when the whole construction moves from its foundation. Also, rinks abroad, like Richmond Olympic Oval, are build on poles (Berends, 2010).

Usually the foundation construction is leaving a space underneath the ice sheet construction, when the sheet is not directly build on the sand. This space underneath the ice is lightly ventilated to prevent condensation on the construction material. In all known cases the bearing construction underneath the ice sheet is made of concrete with flexible fixing points attaching the concrete slabs of the ice construction (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

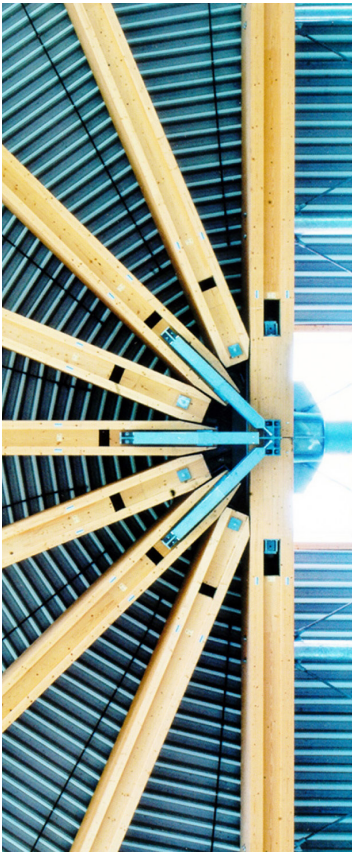
The elevated foundation principle is preferred over the direct placement on the soil. Since floorheating is required in the last solution. This is a large consumer of energy, which could be solved by elevating the ice sheet foundation and invest a smaller amount of energy in ventilation purposes.

Constructing materials

The large span is only possible with limited amount of material types. These are divided in different in 4 main “families”.

- Steel construction

SPATIAL CHARACTERISTICS



Detail of ice rink in Erfurt, wood as bearing structure, metal plating as finishing (Pohl Architekten, 2017)

- Wooden construction
- Reinforced concrete
- Mix material combinations

As will be described in the Energy Performance Chapter, materials which don't score high on the Embodied Emissions, don't radiate too much heat towards the ice, and perform well within temperature changing climates.

Steel had a high emissivity rate, which means it will radiate heat to its surroundings. It is defined as a cold material, which means that when the material is colder than its surroundings, it will easily attract condensation, when the relative humidity of the air is too high.

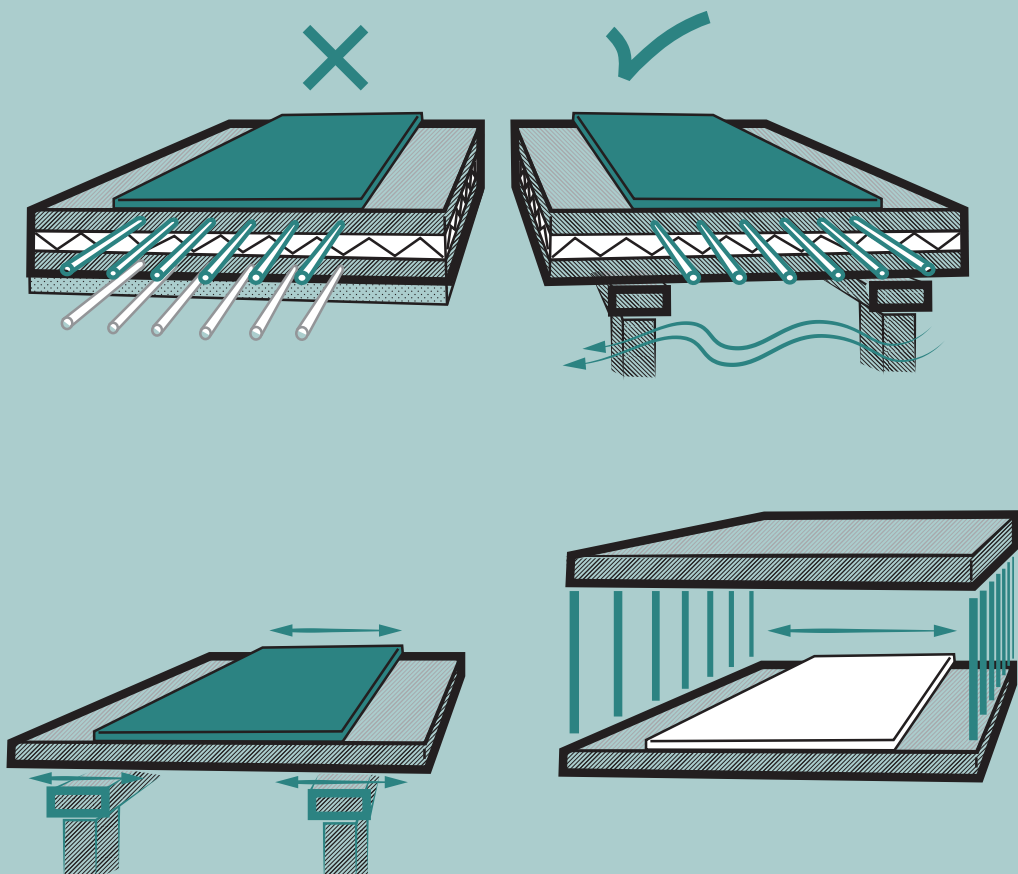
Ice rinks, comb with a humidity problems due to the open character of most rinks, but also bad material choices. When the bearing construction is wood, mostly the finishings

are done in metal, for economic reasons. This is applied in Erfurt, Germany and Haarlem, The Netherlands. In these open rinks, where warm humid air from outside can still penetrate the building, steel plates as finishing can result in condensation in the material, which leads to rust and eventually to the replacement of the material. Metal doesn't comb well in open ice rink environments (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

Materials which relative temperature is compared or equal to its surroundings are preferred in the ice skating situation (F. Bongenaar, personal communication, 07-12-'16, Appendix 1). To assure that the materials will exist as long as the life time of the building, materials should be chosen which survive well in the ice skating climate.

Conclusions about preferred construction

- The sport area for the 400 meter rink and the separate ice hockey rink should be an open space. To achieve multifunctionality. Which is why there should be no columns in this area, to achieve an open floorplan.
- The construction should be as light as possible, preferably made of timber.
- To improve the energy performance, the rink shouldn't apply floorheating as layer directly in contact with the soil. Instead, the foundation should be elevated from the ground, and ventilated slightly, to prevent condensation.
- The oval function inside must be visible in the outer form language.
- If possible the ventilation must be integrated with the bearing construction to generate an aesthetic appearance.
- The construction should be flexible in moving, especially in direct contact with the ice sheet. The foundation underneath must have flexible connecting points.



SPATIAL CHARACTERISTICS

8.3. INSERTION INTO A CITY

A 400 meter ice rink has dimensions of roughly 200 meter in length by 100 meter in width. A building with

these proportions need to be carefully placed in a city. Also, because it will house competitions, and other

audience attracting functions, it needs to be surrounded with enough parking space and road for supplies and logistics.



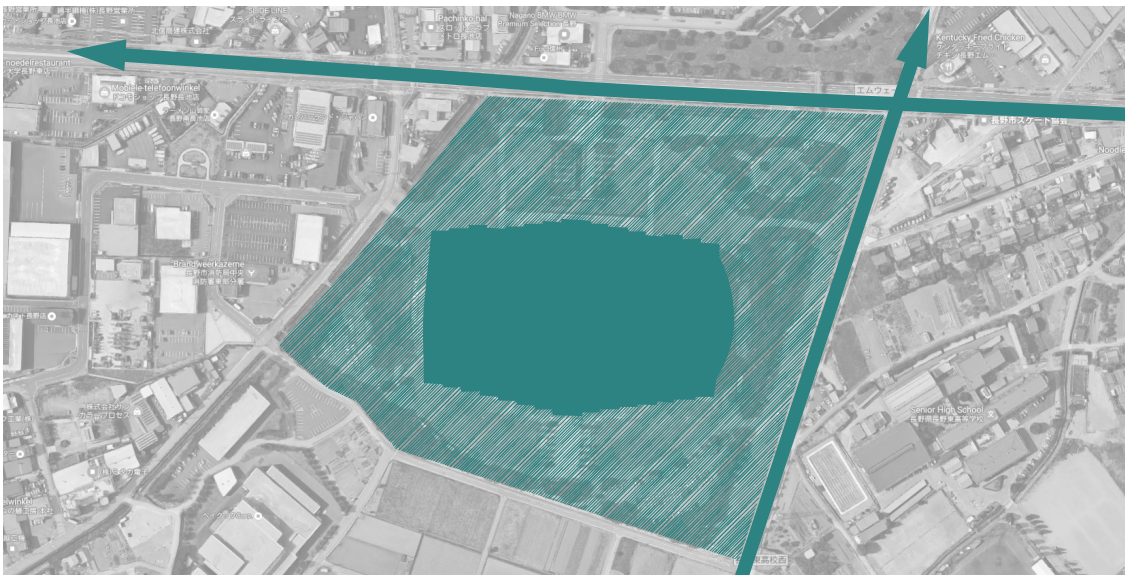
Insertion Vikingskipet ice rink in Hamar, Norway (Own illustration)

SPATIAL CHARACTERISTICS

Looked at the case studies of international and Dutch rinks, some similarities were found. As seen in the case study of the

Vikingskipet, the Olympic Oval in Hamar, the rink is located close to two main roads, as shown on the previous page.

The city of Hamar is small, but has the Vikingskipet as main attractor for foreign visitors and skaters from Norway. Its



M-Wave in Nagano, Japan (Own illustration)

location can be described as monumental, it is visible from many roads, among the lake and from the trains which pass by. The downpart is that the accessibility by public transport is poorly managed, spoken from personal experience. The nearest trainstation is 2 kilometers away.

The rink surrounds itself with parking space and hotels. The rink itself contains an entrance zone as a separate volume, at the side of the 400 meter ice sport area. This entrance zone cuts the public parking space and the logistic back entrance. Logistic traffic is managed at the north side of the building. Public parking at the south. The location is considered at “the side of the city”, where the city is opening up to nature and water.

In another case study, the M-Wave, Olympic Oval in Nagano, shown on the left, is placed in the middle of the city. Next to two main roads cutting through the city. The M-Wave surrounds itself with a designed monumental garden. The rink has a wide spread set up, where one big axis from the entrance leads to the big road. Most of the direct surrounding

ground is designed with a park appearance, the parking - park proportion is lower than in Hamar.

Several more case studies are viewed from above to

gain information about their placement in the city. This, including some personal experiences, leads to the requirements in light of the location choice which has to be made for the design project.



Entrance M-Wave, Nagano, Japan (Google Maps)

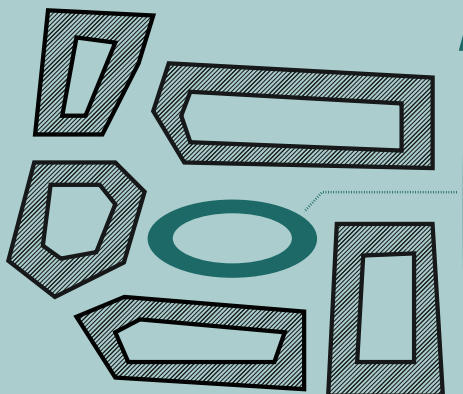
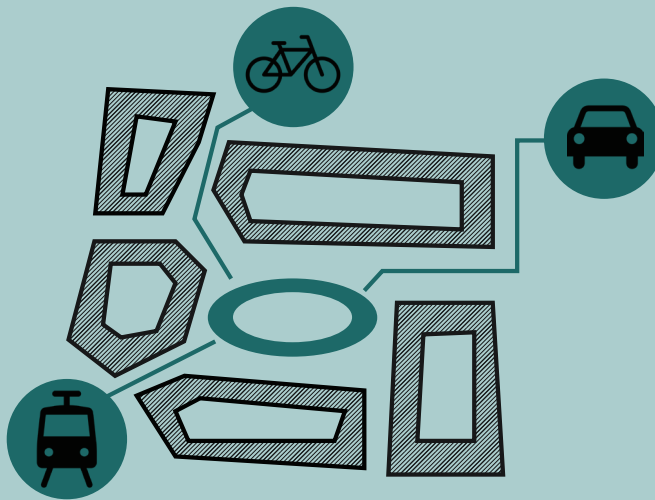


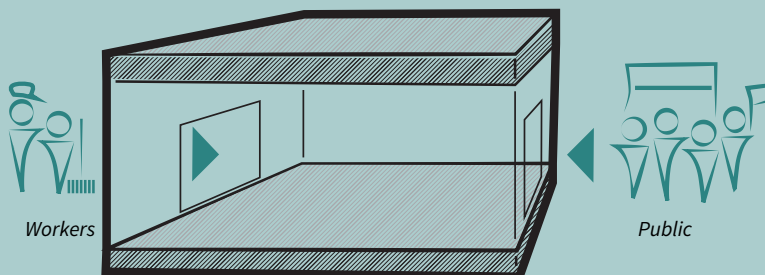
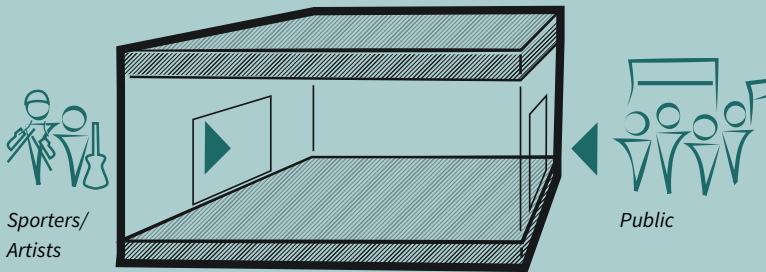
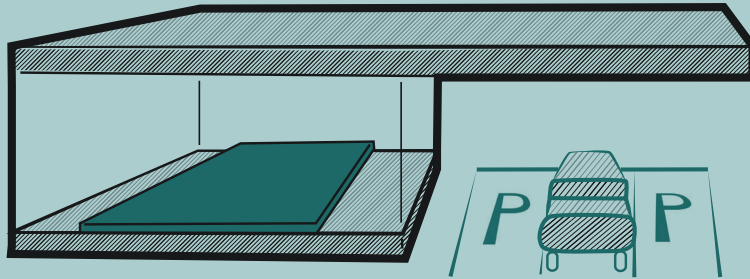
Vikingskipet, Hamar, Norway (Own picture)

SPATIAL CHARACTERISTICS

The chosen site should be:

- Close to a motorway
- Close to a public transport station
- Easy accessible by bike
- It should contain enough square meters to host parking spaces for public and private visitors.
- Logistic traffic should have its own entrance into the building and site.





TECHNICAL CHARACTERISTICS

TECHNICAL CHARACTERISTICS

- 9.1. Sustainable materials within ice rinks
 - 9.1.1. Embodied emissions in materials
- 9.2. Climate conditions
 - 9.2.1. Climatic processes in ice rinks
 - 9.2.2. Climatic demands of an ice sheet
- 9.3. Circularity in electric energy
- 9.4. Circularity in heat energy
- 9.5. Circularity in water usage
- 9.6. Light application in ice rinks
 - 9.6.1. Winter requirements
 - 9.6.2. Summer requirements
- 9.7. Summary: Energy consuming elements
- 9.8. Energy producing elements

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9.1. SUSTAINABLE MATERIALS

Envelope

To make sure that the inner climate of an ice rink is not influenced by weather conditions outside, the rink needs to be insulated. In this way, the materials in direct contact with the inner climate will have body temperature which will be more relatable to the inner temperature of the ice rinks. Too cold materials will result in condensation, shown in the picture on this pages. And warm materials will radiate their heat towards the ice, which is bad for the ice quality (Brink, 2004).

Insulation can also lower the energy bill, because the hall doesn't need extra heating or cooling to compensate for the outer conditions which would influence the inner rink. Also, it will have a positive effect on the acoustics inside the hall (IIHF, 2016).

Mostly sandwich panels are used, to guarantee the flexibility of the envelope. If one wants to add or remove a certain building part, it's necessary to make the building flexible.

Glazing

Also double/triple glazing



Condensated moisture drips from the ceiling onto the ice, which forms an ice stalagmite (Icerinksupply.com, 2017)

windows are, when daylight is desired, necessary. To guarantee the ice quality, the sun radiation has to be blocked. Infrared will heat up the ice surface, which will increase the ice resistance for the skater. Therefore, the glass needs to have a coating which block infrared. For example K-glass, or low-emission glass. Which is a designed to have a "high solar heat gain coefficient" (LEITAT, 2015, p.37). It is comparable to the low-e ceiling coating, only it will allow a maximum amount of sunlight into the interior. When daylight is required, but no direct sunbeams, it can be possible to apply shading possibilities, like sunshading exterior mullions, or

transparent screens (LEITAT, 2015). Other rinks only have window openings towards the north, to have diffuse, white daylight.

Ceiling finishing above ice

A development within ice rinks is the appliance of low emissivity foils. Or in short Low-e materials. By emissivity is meant: "A physical property of the surface of an object and is the ratio of the energy which is absorbed and emitted from its surface in the form of infrared radiation to the total energy hitting the object" (Thermal Design, 2004, p.1).

One of the highest heat loads towards the ice floor is

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coming from the radiation of the surrounding construction. The radiation of materials can be prevented by making the material emissivity as low as possible. A material is a perfect radiator with an emissivity of 1, materials that do not radiate at all have an emissivity of 0. Most rinks have emissivity of 0,9 in their applied materials (IIHF, 2016).

So for example, when sunlight hits the material, the material absorbs this energy and raises in temperature. Because of its high emissivity it emits infrared radiation. In ice rinks, “the amount of heat radiated to the ice is controlled by the temperatures of the walls and ceiling and by their emissivity” (Thermal Design, 2004, p.1).

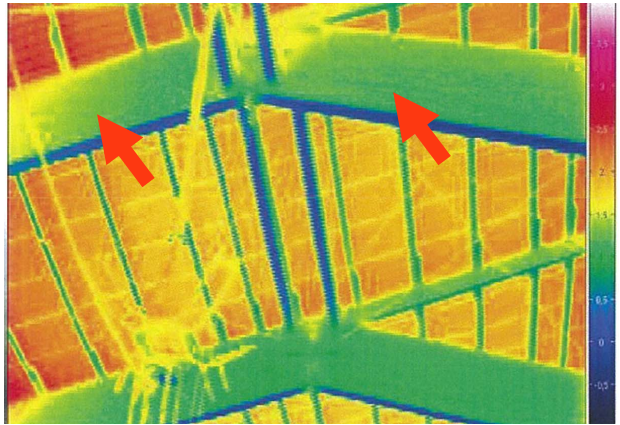
The material choice is highly influencing the radiation characteristics of the surrounding construction. The lower image it showing a sport hall which has steel coating applied, placed on timber beams. When the colour is red, it means the material is radiating heat. So steel would be a inconvenient choice as material in ice rinks, when heat radiation on the ice must be prevented.

Low-e foils could prevent this radiation from hitting the ice. It has been proven that the appliance of these foils could turn out positively for the energy balance of an ice rink. “Suspending a ceiling with low-e surface between the ice sheet and the hot upper ceiling surfaces causes some reduction

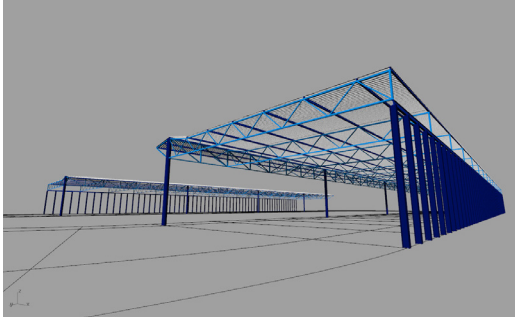
in refrigeration costs”(Thermal Design, 2004, p.1).

But at the same time, it’s only a necessity when the construction is actually radiating. When this radiation process is prevented, there is no need for the application of Low-e foils layers. This radiation process can be reduced by the appliance of insulation in the “skin” of the building.

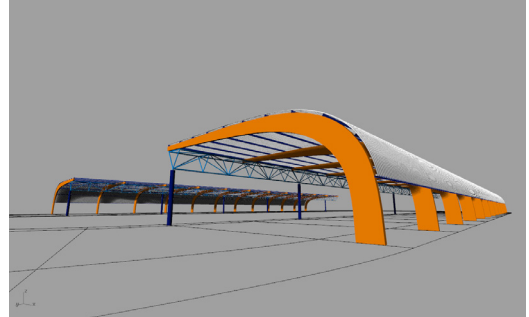
A combination of a Low-e ceiling with high performance insulation “will result in substantial energy savings because a well insulated ceiling assembly will in itself minimize heat transfer into the rink building from all three modes (conduction, convection, and radiation)” (Thermal Design,



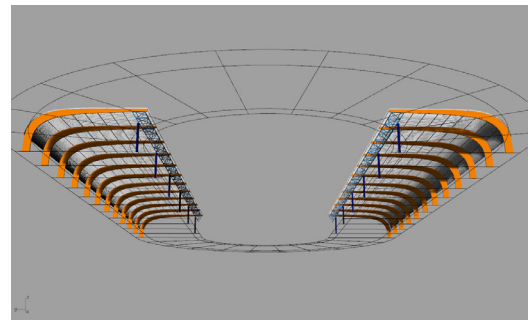
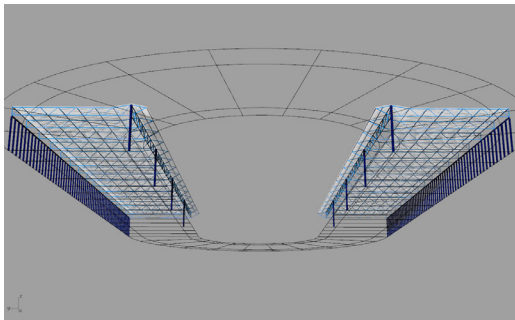
Heat radiation from different materials (Krawinkel Ingenieure GmbH, 2015, p.39)



Ice rink De Meern in Alkmaar in 3D model, own illustration.



Ice rink Kennemerland in Haarlem in 3D model, own illustration.



2004, p.1). Also, a Low-e layer needs to be maintained and loses its properties when it gets dirty or corroded, and it does not have any insulation value, so convectional heat can still easily pass through.

But there are positive sides. One argument is that it still supports the heat radiation from the ice towards the sky. The foil only blocks radiation on one side. It also is said that it will transfer the light more homogeneously. (Thermal Design, 2004).

Acoustics

Because of all the usually reflective materials inside

an ice rink, the sounds will be reflected multiple times, which makes the sound uncomfortable inside an ice rink. Insulation is therefore required also for acoustic purposes. It is recommended to use softer materials for the materialisation of the ceiling (Brink, 2004).

Embodied emissions

In an earlier study, two ice rinks with different construction materials were compared in their embodied emissions. Since buildings have different dimensions and life cycles, the unit to compare two projects together is grCO₂eq/sqm/yr.

During this small study two Dutch rinks were compared in embodied emissions. One rink with a full steel construction: De Meern in Alkmaar, and one with a hybrid construction, consisting of timber trusses and steel finishing. Both rinks spanned the same length and both models only involve the straight ends of the rink. Both rinks were made in digital 3D models calculate material volumes. Shown above.

The result was the that the rink in Haarlem contained 1,93 kgCO₂eq/sqm/yr in embodied emissions. The rink in Alkaar

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contained 3,35 kgCO₂eq/sqm/yr.

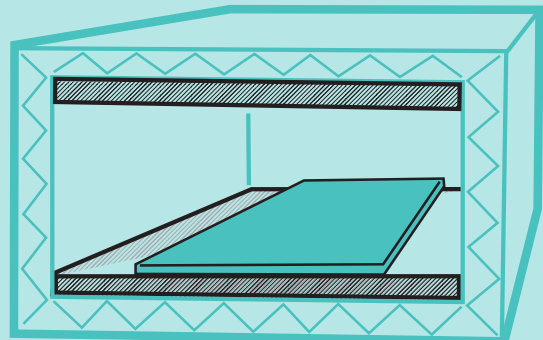
From which may be concluded that wood as primary construction had a large difference to the carbon footprint of the building and thus to the energy neutral character of the building.

During this study it became clear that all materials which are considered “natural”, are well performing in reducing the carbon footprint. Natural materials can be defined as raw material which doesn't require a lot of manufacturing to fulfil its purpose.

An increasing effort in manufacturing a material will result in high embodied emissions for that material. Therefore, materials with minimal manufacturing labour are preferred.

Requirements materials

- To achieve energy reduction, due to reduction of energy waste, Low-e materials should be applied.
- In the direct environment of the ice sheet, materials with a high emissivity must be avoided. Wood had been known as a low emissive material and is preferred in this situation.
- Low-e foil will be applied to the ceiling to prevent heat radiation from the surrounding construction.
- The materials in the direct environment of the ice sheet should have insulating properties. To protect the inner climate, but also for acoustic comfort.
- To lower the embodied emissions of the ice rink as a whole, natural materials are preferred.
- Materials with minimal manufacturing labor are preferred.



9.2. CLIMATE CONDITIONS

Butter said: “Half overdekken levert geen energiewinst op” (Brink, 2004, p. 21). Which roughly translates as: A halfly covered roof doesn’t provide energy gains.

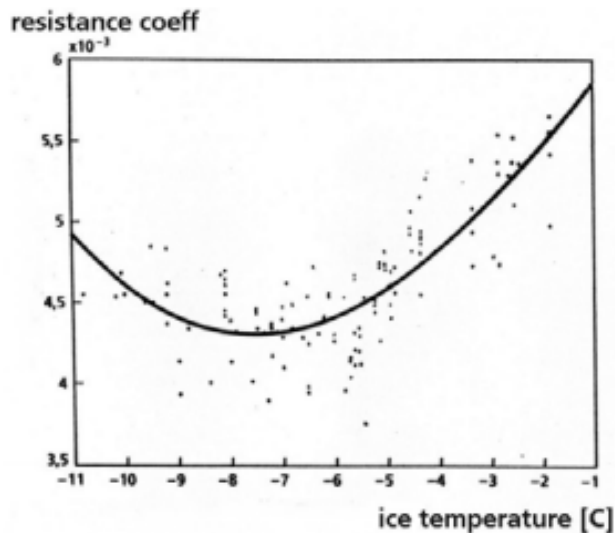
The quality of the ice is dependent on 4 aspects:

- Heat radiation
- The humidity of the air
- The movement of the air
- The temperature of the air

Within an open rink, these circumstances cannot be controlled. The ice is only as good as the worst part. So radiation and air conditioning are the two challenges, when it comes to perfect ice conditions.

What is perfect ice to skate?

According to Berends (E. Berends, personal communication, 07-12-’16, Appendix 1), to achieve the “fastest” ice is to have the perfect surface temperature of the ice, combined with perfect air conditions. The ice temperature has to be at least -4 at the surface, with -7 as optimal temperature. As shown in the figure above. Resistance of the ice is approximately



Resistance related to ice temperature (Berends, 2006)

20 percent, compared to 80 percent of air resistance. The surrounding conditions to achieving this will be described in this chapter.

Heat load on ice

To minimize the heat load on the ice, is to minimize the energy consumption of this ice sheet in the refrigeration process.

Some aspects which have influence on this heat load are shown below:

- Ceiling radiation
- Convective heat load of the air temperature
- Lighting

- Ice maintenance
- Ground heat
- Pump work of the cooling pipe network, because of the friction.

Ceiling radiation has been explained in the previous chapter.

Convective heat can also increase the radiation heat. Since the temperature of the air is also influencing the temperature of the materials surrounding it. “The most effective way to reduce convective heat load is to keep the ice temperature as high as possible and the air

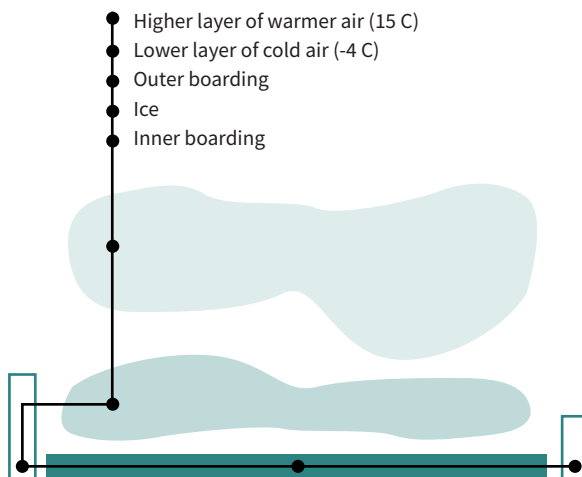
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temperature as low as possible. In other words, the difference between the two should be as minimal as possible.

Air layers

Both sides of an ice slab need to have a border which extends higher than the ice. In this way the air between both borders will be "captured". This layer of air will have to have a low humidity and a temperature. Ice makers talk about a temperature of -4 degrees (G. van Dam, personal communication, 30-11-2016, Appendix 1), experience shows that this layer is about 40 cm in height. The layer above that, which contributes more to the feeling temperature of the sporter, needs to be warmer. According to the questionnaire, elaborated in Usage Characteristics Chapter, most skaters prefer a temperature of 10 till 15 degrees.

During a previous renovation of Thialf, in 2004, an air sucking system was installed underneath the ceiling. Which catches the warm air, which could be 30 degrees up at the ceiling, this air will be treated and water will be taken out, afterwards it will be blown above the ice to provide the



Airlayers above ice sheet, supported by boarding, own illustration.

warm layer (Brink, 2004). It will only take an ice rink 15/20 minutes to warm up the air. Since that renovation many records have been broken in Thialf, so blowing in warm treated air can contribute to a high ice quality.

Relative Humidity Air

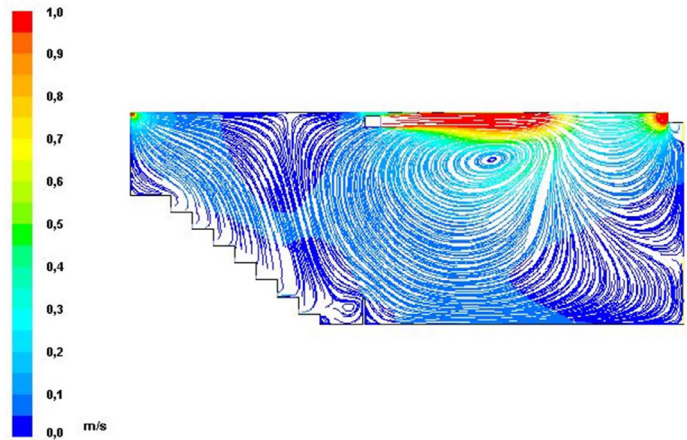
The relative humidity in an ice rink is always a cause for problems. With half-open constructions this can be problematic when warmer air from outside comes inside an ice rink hall. Warmer air can hold a higher amount of water, when this air cools down, its capability to hold water will decrease as well. The water in the air will condense on the coldest material available. When a construction is made of

metal, without any insulation from the sky, the radiation from the sun will decrease the material temperature when the emission coefficient of this material is high. In this way, the metal construction will be a target for condensation to attach. When the airflow in the rink will increase the construction will release water drops, which will fall on the ice and sporters. In both cases it decreases the sport performance (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

In Richmond Olympic Oval the choice of wood in its construction prevented this from happening. Wood has the ability to absorb a small amount of water, also the

temperature is higher than metal-like materials because it has a lower emission coefficient. In this way, wood will be a less obvious target for condense to form (Berends, 2010).

For the Richmond ice rink, they talk about a goal to keep the RH on <40%. With a temperature of 15 degrees Celsius (Berends, 2010).



Air flow simulation for new Design Max Aicher Arena, Inzell (Meyer, 2015, p.31)

Air movement

When there are a few hundred people skating on a 400 meter lap, they create an airflow in the skating direction. This can improve the speed of the skater, since there will be less resistance from the air. The resistance for the skater is mostly air, 80 % and 20% is coming from the ice (KE FIBERTEC, 2015). To improve the air resistance, surrounding circumstances can improve the performance of the skater. For this reason, ice rinks which are high above sea level, like Salt Lake City (Utah Olympic Oval) on 1425 meter above sea level or Calgary (Olympic Oval) on 1105 meter above sea level. Air becomes thinner when the position is higher, which results in a low air resistance. Some rinks try to improve their the air movements by steering the



Blowers in the Olympic Oval of Gangneung (Spekenbrink, 2016)

inlet of the ventilation towards the skating direction. This is said to be happening to the Olympic Oval in Gangneung, (Spekenbrink, 2016). Where blowers were installed to achieve wind in the same direction.

Aircurtains and audience

An ice rink which needs to show competitions has a need for a spectators stands. When this space is completely filled during a skating competition with people, the ice has a challenge. The humid hot air produced

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by the audience can make the surface of the ice turn dim. Which increases the resistance dramatically.

In the newest rinks, like Kolomna, Astana, Sochi and the renovated design of Thialf, the air is divided in two compartments, one for the audience and one for the sport environment. Between these two areas, a "veil" or curtain of air is applied. On the edge of the two zones air is blown in and heads "over" the audience, above the audience the air is sucked in at the ceiling. After this the air is treated and blown in again. In this way, the warm humid air from the audience is not making contact with the sporters (KE FIBERTEC, 2015).

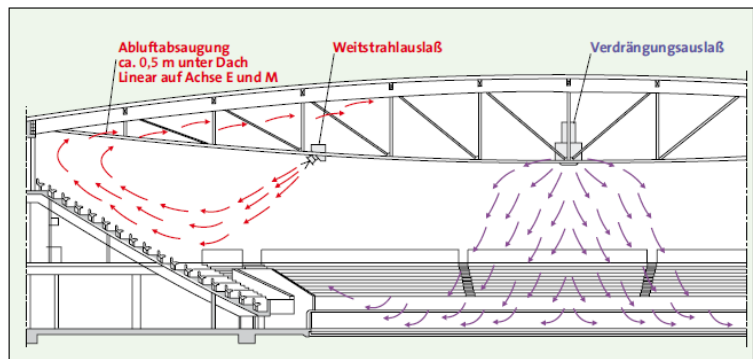
Every person produces 30 gr of moist every hour (Meyer, 2015). In a hall like Inzell, with a full capacity of 7000 spectators, it means that 210 kg of water needs to be extracted from the hour on a hourly basis. Thialf even speaks of 500L water per hour.

Direct daylight

Direct daylight has a bad influence on the quality of



The aircurtain outlets of Thialf, marked in blue, own picture.



Air flow simulation for new Design Max Aicher Arena, a different design for an "aircurtain" (Meyer, 2015, p.31)

the ice. The infrared radiation increases the ice temperature and makes the ice "soft". An ice rink, with a focus on competitions, needs to provide

a monotone light environment for broadcasting purposes, but also to create a stable environment for the sporter. Glass in the facade of the



Sunlight hits the ice in De Westfries, Hoorn, own picture.

building will be hard to apply in a good way to achieve high quality ice.

Some rinks, like Nijmegen, had to change their design afterwards, large strips of glass have been covered with dark curtains. These curtains are permanent, but the glass behind still results in a building which is not well insulated (E. Berends, personal communication, 07-12-'16, Appendix 1). The new design of Thialf has two layers of glass strips on both sides of a buffer zone. This zone consists of a transition zone for visitors, VIP spaces, offices and gyms. The

outer layer of glass strips can be easily darkened with a pull down shading system.

It is believed that sunlight is bad for the overall control of the building. "Vanuit het oogpunt van energiehuishouding wordt je gebouw een stuurloos schip" (Brink, 2004, p. 22). Which translates as: The building becomes uncontrollable. Also, because of the high amount of reflectivity, a lot of glass in the building is bad for the acoustics. During the Winter Olympics of Vancouver in 2010, the window area in the Richmond Olympic

Oval had to be covered. The sunlight was disturbing the broadcasting of the sports (Berends, 2010).

Ventilation

An ideal energy-neutral situation would be to provide the perfect indoor climate with natural ventilation. This would only be possible when the outside air would have the right humidity and temperature (Fiedler, 2007). But, since the requirements of the indoor climate is strict in the values on both humidity and temperature, the only way of ventilating an ice rink is mechanically. In this way one has complete control about the inner conditions. During competitions, and preferably training, the rink needs to provide a stable climate (IIHF, 2016).

In the hall there will be spectators at some events, also "sporting" in general needs a well working ventilation. For unpreferable scents, but also to create healthy air to increase the sport performance. To make sure that the climate control is optimally applied, the inner hall needs to be as

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airtight as possible (IIHF, 2016). There have been reports on open doors during competitions, which were disturbing the inner air flows (E. Berends, personal communication, 07-12-'16, Appendix 1).

Energy saving can be done by ventilating depending on the amount of people inside. So to say “demand-controlled” ventilation (IIHF, 2016). For every person 20 m³/h fresh air is needed (Krawinkel Ingenieure GmbH, 2015). The indoor sport area needs to be heated. The ice surface will constantly extract heat

from the air. So the air supply must be heated and then transported into the skating hall. In this process, energy can be saved due to heat recovery in this ventilation system. The air which is sucked out of the indoor area will transport its heat to fresh air, which is blown into the indoor sport area again (Straube, 2006).

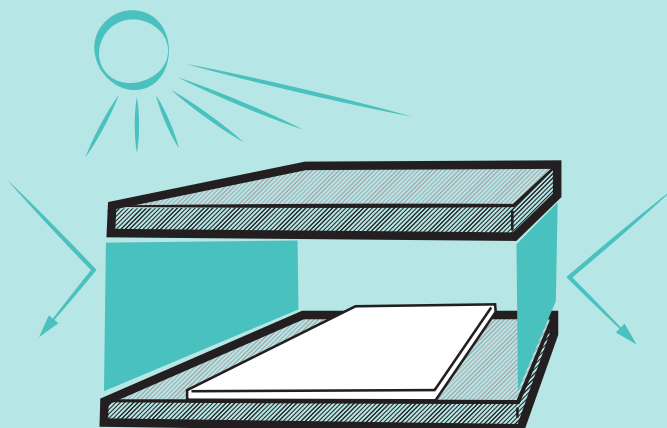
But not only the skating area needs heating. Some parts inside the hall need extra heating. Like the spectators tribune, when occupied. Also, offices, jury rooms, changing rooms and other necessary spaces need heating as well.

However, most of these rooms do require ventilation, in which the temperature is comfortable. But the actual heating of these spaces mostly happen due to floorheating (G. van Dam, personal communication, 30-11-2016, Appendix 1).

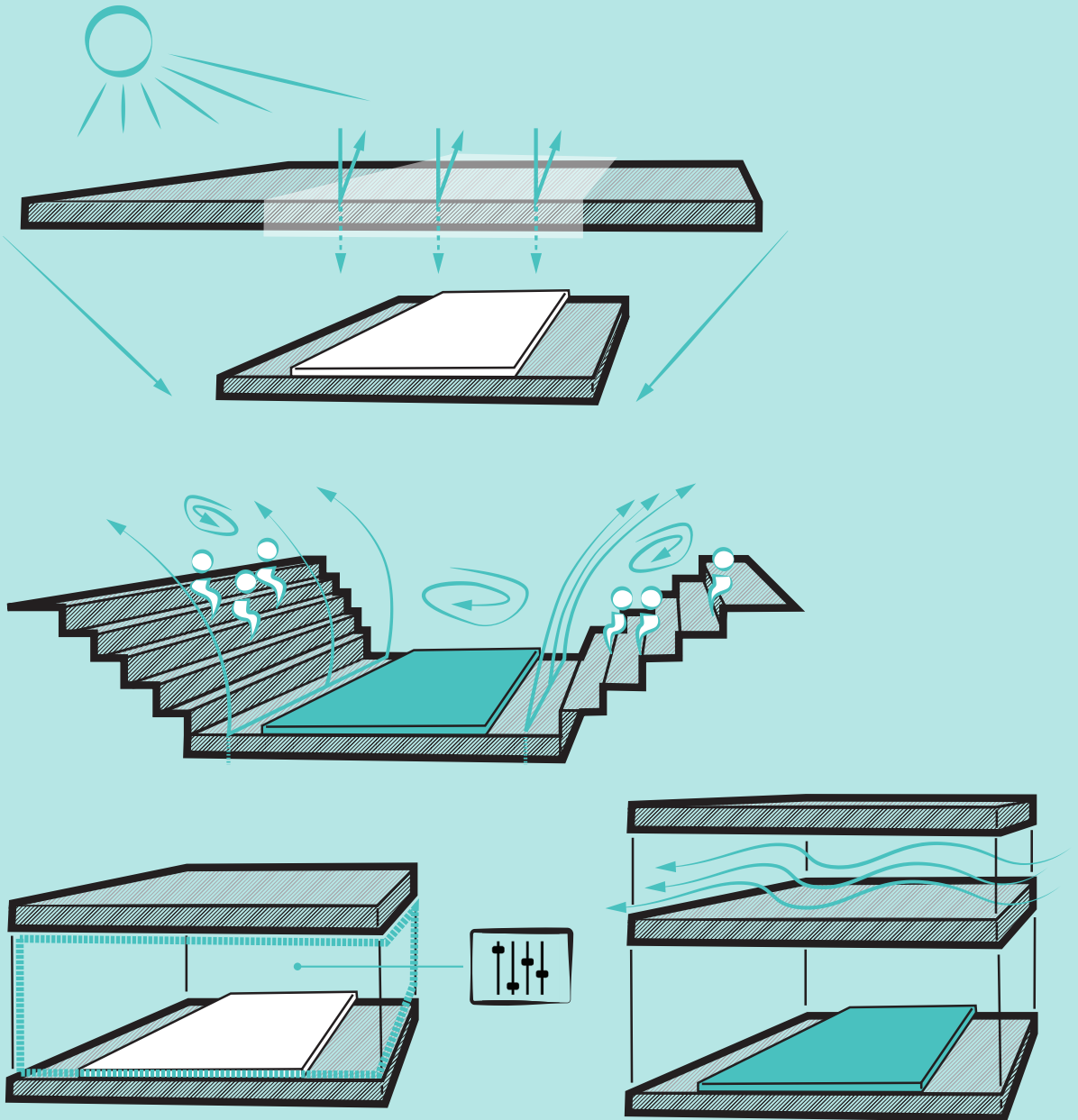
Energy can be saved when the heating of air isn't required. It is one of the biggest energy demands in an ice rink, since the air, which is constantly in contact with the ice is cooling down. The less heating the air requires, the less energy is required (Fiedler, 2007).

Climatic requirements

- The ceiling shape of the sport area needs to steer the air from the ice skating area to the spectator area, and needs to prevent the air from going the other way.
- Wood as construction material can prevent condensation on the material.
- The relative humidity in the ice rink sport area should be below 40%
- The boardings around the ice layer need to be as much closed as possible to achieve the colder layer of air between the two boundaries.
- To achieve a better air quality, an aircurtain will be applied, to split the audience from the skaters.
- During competitions, or large events in summer, the ventilation system needs to be able to extract 30 gram s of moist per person from the air. In case of 3000 spectators, it means that 90kg of water needs to be extracted from the air.
- When glass is applied in the facade of the building with direct solar entrance towards the ice area, infrared radiation should be avoided.
- When glass is applied, there should be a shading system to completely darken the indoor area, for broadcasting purposes.
- The ventilation of the sport area should be done mechanically, to provide stable humidity and temperature.
- The inner climate of the sporting area should be stable in temperature and humidity, and monotome in lighting.
- For full climate control, the indoor sport area should be detailed as airtight as possible.
- To save energy the ventilation system needs to be driven “demand-controlled”, adjusting to the amount of people inside.
- Every person visiting the building needs 20 m³/h fresh air.
- Heat recovery need to applied in the ventilation mechanism.



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9.3. CIRCULARITY ELECTRIC ENERGY

The main function of an ice rink is to produce a layer of ice, thick enough for ice skaters to use. Producing this layer of ice, even in the most efficient way possible, will ask for electric energy. An ice rink will, even with all low tech/passive solutions still ask for energy for the ice production.

As a general law, nature wants to keep everything balanced. Therefore nature strives to keep

material in approximately the same temperature as the surrounding air. In ice rinks, this natural process is countered, by using energy they make a difference in temperature in a certain material compared to its environment. In this case, a concrete slab which contains pipes which transport a refrigerant. The energy needed to fuel this process comes in all ice rinks mostly from “the

net”. Therefore, this stream of energy is still coming from elsewhere than the rink itself. So the rink is dependant on influences from outside. If an ice rink would provide its own energy, it would still be an active building, but it could sustain itself. The energy provided would be coming from a closed circuit. This is where circularity comes in.

Take-make-dispose

Side note 1: Secrecy in energy data

A general comment has to be made about the secrecy of this information. Most rinks don't want to share their electricity bill with the world, some don't even want to talk with external parties about it. This because it can be harmful for their image (E. Berends, personal communication, 07-12-'16, Appendix 1) or because their operator didn't allow it. This was the case in IJsbaan Twente, where the ice maker, Gerwin van Dam, said during an interview that he cannot say anything about the financial matters of his ice rink. Energy numbers he could maybe share, which he had to discuss with his employer first. The employer, PCH Groep, is a company, which has the right to keep certain information about the company hidden from public. During the building process this operator is sometimes the building client as well, in this case they can give the contractor, architect and other consulting parties restrictions about sharing information about the project. These are usually included in a contract. The architect of the Thialf renovation, which has been finished in 2016, agreed to talk to me, but I cannot share the information which he told me, because he signed a contract about secrecy.

Eventually mr. Van Dam could send me the energy consumption numbers of IJsbaan Twente, displayed at the end of Appendix 1.

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In our society we generally buy a product, use it, and, when it loses its value, we throw it away. This “take-make-dispose” model, has been known to us since the industrial revolution (Prins et al., 2015). Since that time it became easy and cheap to produce a product, so the effort of keeping or maintaining it was not required. But continuing this way, this wasting lifestyle resulted in scarcity of raw materials, and a huge overproduction of waste.

Energy in the Netherlands

In ice rinks this is mainly visible in the energy consumption. Electric energy in the Netherlands is still mainly produced by cogeneration plants, which use natural gas and oil to produce electric energy. CBS came with these numbers in 2012: 54% of the Dutch electric energy still comes from gas, 27% from coal, 3% from oil. About 4% comes from nuclear energy.

Sustainable energy sources

are wind energy and biomass energy, but this is a small amount: 12%, wind(46%) and biomass(48,7%) are the biggest contributors. Solar energy(4,2%) and hydroelectric power(0,9%) are relatively small (CBS, 2015).

Because an ice rink, in this way, indirectly uses a lot of natural gas and coal, it is contributing highly towards our “take-make-dispose” society, in this situation the product, gas/coal, evaporates in the air as, among others, CO₂. “This unsustainable development has resulted in ... global warming, environmental pollution, greenhouse gas and climate change” (Prins et al. 2015, p. 1).

Energy numbers of ice rinks

To have an insight in how much energy an ice rink consumes, a lot of different sources were consulted.

As noted in Side Note 1, this proved to be a challenge.

Eventually through literature and the interview contacts a general overview could be made.

The energy consumptions vary a lot for each rink, this is dependable on the amount of surfaces which had to be frozen. Some rinks have only a 400meter ice sheet, other include one or two ice hockey sheets. In case of Thialf there is even more surface covered in ice, shown in appendix 5.

Frank Bongenaar, icemaker of De Westfries, the ice rink of Hoorn, spoke about 180-250 W per m² ice sheet. This amount will be low when the ice sheet is thin (180W), Bongenaar spoke of 3-4 centimeter as ideal thickness, which had been confirmed by Ernst Berends as well (Appendix 1). A thicker layer of ice can be useful when the use is extensive in a short period of time, for example during a popular public training hour. But automatically the energy consumption for a thicker ice

layer will be comparable to 250 W per m² ice sheet.

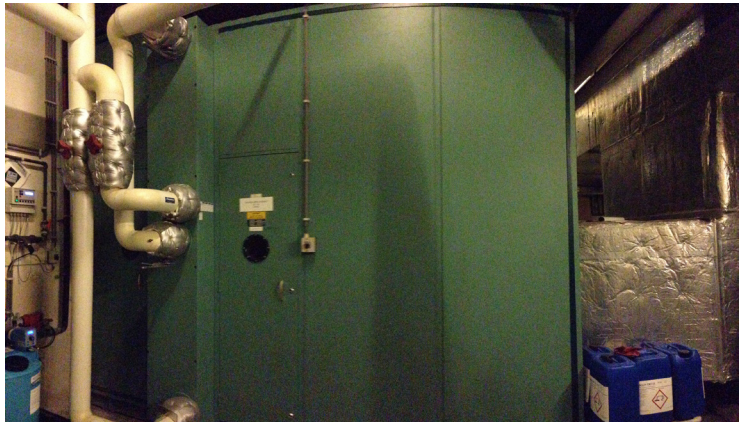
In the Program subchapter it has been described that the amount of ice needed for an archetype ice rink is: One 400 meter lap (4882 m² ice) and one ice hockey rink (1756 m²). With an average energy consumption of 215 W/m², this will result in 9075 m² * 215 W/m² = 1,951 MW for all ice production. Over one day (24 hours), this means a consumption of 46.827 kWh per day.

Other energy consumers

An overview of the other energy consumers are based on the interviews.

A list of energy consumers are:

- Lighting
- Sound systems
- Computers
- Floorheating
- Ventilation systems
- Dehumidifying systems
- Electric resurfacing vehicles
- Heat pump



Air conditioner cabinet in Triavium, Nijmegen, own picture.



Ice resurfacer parking and snow disposal well in Triavium, Nijmegen, own picture.

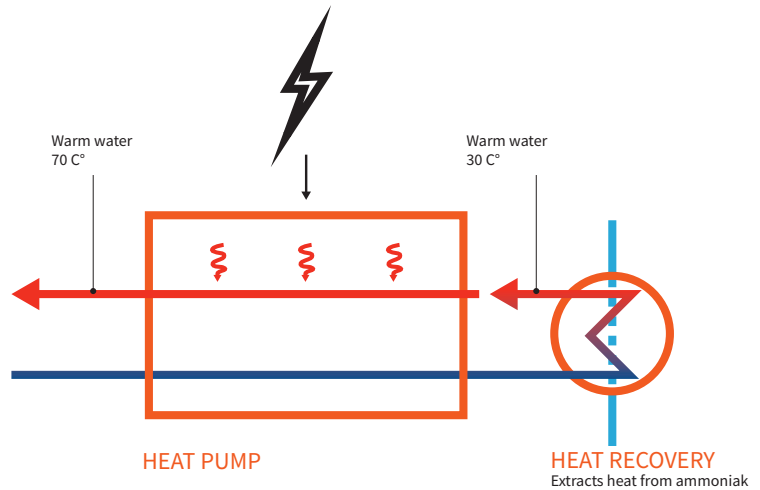
ENERGY PERFORMANCE

9.4. CIRCULARITY HEAT ENERGY

Heat production

As explained with the refrigeration process, cooling will produce heat. By means of a heat recovery machine this heat can be extracted. An ice rink, which has an average cooling capacity of 2,5 MW can produce 3 MW in heat (Berends, 2016), a household boiler can produce about 10-15 KW (E. Berends, personal communication, 07-12-'16, Appendix 1).

This waste heat can reach up to 60 degrees in water temperature, which comes from the heat recovery machine. Recent introduced laws require that the temperature is increased towards 70 degrees, to prevent legionella and other bacteria from settling. This increasing in temperature can be achieved by applying a heat pump. A heat pump has an efficiency of 560%, in which a gas boiler only has an efficiency of 100%. Disadvantage of applying a heat pump is the energy consumption. Energy is needed to increase the water temperature. Every heat pump consumes about 350W, according to Gerwin van



Heat recovery is recently more used, in combination with a heat pump, to increase the temperature slightly, own illustration.

Dam (G. van Dam, personal communication, 30-11-2016, Appendix 1).

Lately, in some Dutch ice rinks, a heat pump is replacing the gas boilers in ice rinks. In Den Bosch, at the Hockey Rink it saved €100.000, and 500.000 kg CO₂ per year. At Triavium in Nijmegen, the 333 meter ice rink, it saved half of the gas expenses (Berends, 2016). Richmond Olympic Oval can function on 40% of the waste heat, produced by the cooling machines (Berends, 2010). It is said that only during the last couple of years this

waste heat opportunity is researched into detail. Ice makers state that most companies are specialized in cooling techniques or heating techniques. But a combined technique and optimizing this doesn't happen within these companies. Most ice rinks therefore hire two different companies with their own specialism. Another problem is that when this heat is used for other purposes it is hard to control the heat flow. Stories of waste heat from ice rinks, used in swimming pools often stated that some of these pools had

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a temperature of 42 degrees, when 32 degrees was required. Controlling the temperature of the waste heat still requires some innovations in this field (E. Berends, personal communication, 07-12-'16, Appendix 1).

Preserving heat

A recent invention a buffer tank for hot water. Which is applied in some American ice hockey rinks already. In this way, the amount of hot water can be controlled, since not all waste heat- water needs to be used at once. These **stratified buffer tanks** use the properties of hot/colder water to preserve the heat inside the water, cold water remains at the bottom of the tank due to its higher density. "Stratification pipes are vertically installed inside a heat storage tank in order to prevent vertical heat transfer, creating a good stratification inside the tank" (LEITAT, 2015,

p. 47).

This could be a short term solution to store heat for later use, when there are several hours or days between the heat production and the use of the heat. For example when the showers are used.

But when a large amount of heat is produced in winter, and is required in summer, **geothermal heating** could be a solution. A side note for this system is that geothermal heating is usually applied to acquire warm stored temperatures in winter, in this particular design in heat is produced in winter and used in summer. So in further research the efficiency of this system should be investigated.

Heat consumption

Like other sport buildings, heat can be used for several purposes. Elements which

need heat in an ice rink are:

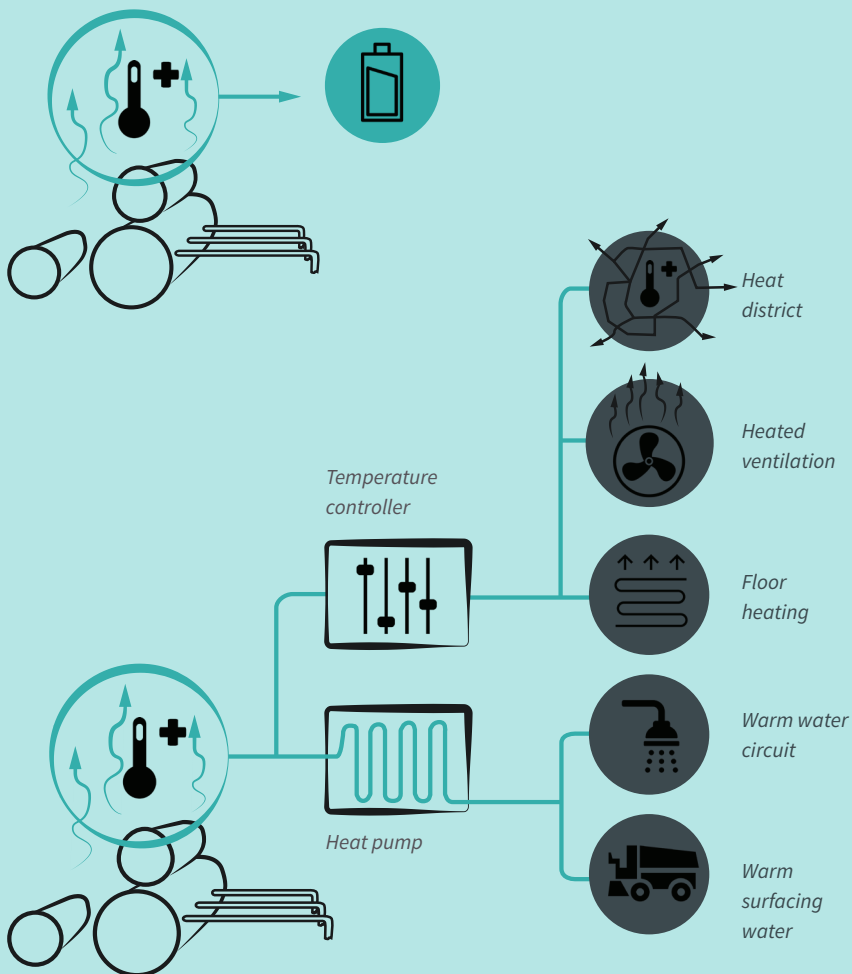
- Floorheating in several spaces:
 1. Offices
 2. Traffic spaces
 3. Commercial space
 4. Fitness
 5. Café
 6. Toilets
 7. Changing rooms
- Ventilation heating in the ice sport areas.
- Heating of the water used for resurfacing the ice, which goes from 30 - 60 C
- Showers

Floorheating

Floorheating carries the thermal energy by means of water running through pipes. Since waste heat is carried by water, and has a temperature towards 60 degrees, and doesn't need to be purified, this could directly be used for floorheating throughout the building.

Conclusion about heat circularity

- To make use of waste heat, a heat pump must be attached to the evaporator of the refrigeration plant, this engine consumes 350W, but will increase the water temperature so it is legitimate to use.
- Geothermal heating or a stratified buffer can be used to store heat.
- Floorheating is perfectly combinable with waste heat water, it could be applied in a direct system.



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9.5. CIRCULARITY WATER

Ice resurfacing

For the preparing of the ice, the resurfacing vehicles, mostly called zamboni's, referring to the brand mostly used for these devices, drive on the ice. They drag with them a flexible cloth which catches the snow produced on the ice during the skating. At the same time the cloth is humidified with warm water, the temperature of this can be 30-60 degrees (G. van Dam, personal communication, 30-11-2016, Appendix 1 EN HOORN). In this way a layer of warm water is applied on the ice, which flattens the irregular surfaces and freezes to become a solid layer of ice. The snow caught during the process is mostly thrown in a basin which slowly melts it into water again.

In several other rinks, the water obtained from melting the snow is used again for the resurfacing (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

Drainage system

Some rinks had the problem that the ground around the concrete slab was sinking, because the ground had to dissolve great amounts of

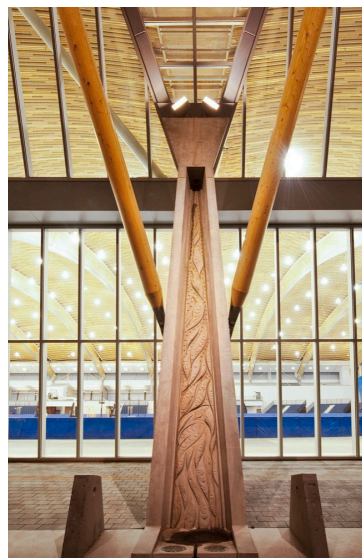


Parking place of the ice resurfer, behind the vehicle is a well to drop the scraped snow in from the ice (own picture).

water during the melting period, was sinking. Which made the ground directly surrounding the ice rink sometimes lower compared to the concrete slab. This happened at the Westfries in Hoorn and De Uithof in Den Haag (F. Bongenaar, personal communication, 07-12-'16, Appendix 1).

Rainwater

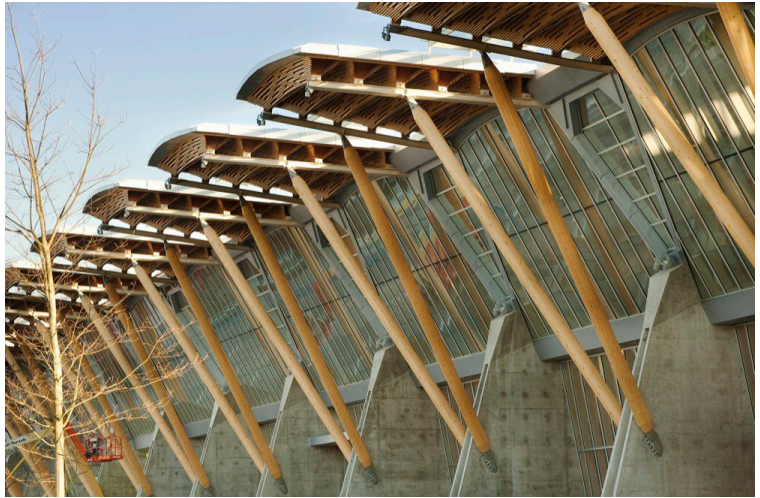
In Richmond Olympic Oval the rainwater was captured and used for toilets and irrigation of the nearby park (Berends, 2010). The architect made this visible in the outer appearance of the



Water drainage visible in outer columns of the Richmond Olympic Oval (Centaurproducts.com, 2017)

rink as well.

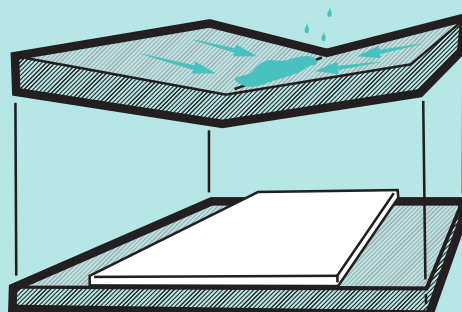
There have been attempts to use rainwater as well for resurfacing the ice in Haarlem and Assen (E. Berends, personal communication, 07-12-'16, Appendix 1). Both examples were not successful, due to the fact that rainwater needs to be purified first. Hard water is excellent to produce rigid ice, which is preferred for high ice quality, the disadvantage is that hard water damages pipes and leaves tarnish formation when the water is evaporated.



Water drainage visible in outer columns of the Richmond Olympic Oval (Centaurproducts.com, 2017)

Conclusion about water circularity

- Since the rink in the designproposal shall be completely indoors, there should be sufficient water drainage system. For the melting ice, but also for drainage in summer, during large cleaning activities.
- Rainwater could be used for grey water systems, or, if purified, to create the ice sheet.



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9.6. LIGHT APPLICATION

9.6.1. Winter requirements

Ice rinks have the reputation of having a dark sporting area, explained in the problem statement chapter. The light requirements of these sportbuildings have been different depending on the situation. When training hours are applied, the sportarea is illuminated with a lower intensity than when a competitions is at hand, since in the last case broadcasting parties, sporters and spectators want high lighting quality to achieve the best view.

In the renovation of 2016, Thialf, the ice rink in

Heerenveen, had their light intensity changed to 1600 lux (Nieuw Thialf, 2016a).

According to an Artificial Sport Lighting Guide there is a difference between outdoor rinks and indoor rinks. The requirements for indoor rinks are asking higher light intensities, compared to outdoor rinks.

For a 400 meter ice rink, the required light intensity is 500 lux for competition circumstances, for training circumstances it is only 200 lux (Sport England, 2012). So the latest update in Thialf is exceeding this requirement.

Other than that, in Thialf the ceiling covermaterial is aluminium, which reflects this light intensity even more.

Result can be seen in the lower picture. Thialf is known as a skating centre in which high quality broadcasting and important competitions are the main goal of the rink.

Since the focus of this research is also to analyse all performance - skating measurements are taken into account, the design of Thialf will in this context be taken as an example.



The light application in ice rink Thialf, Heerenveen, The Netherlands (Fila Newsmarket, 2017)



The ice rink in Dordrecht during the World Championships of Shorttrack (Kuijf.nl, 2016)

Function	Light intensity	
	Training	Competition
Winter		
Longtrack	300	500
Shorttrack	300	500
Ice hockey	500	750
Figure skating	500	750
Summer		
Ball games	500	750
Concerts		150*
Fairs		750
Markets		750

Needed light intensities in winter and summer (Sport England, 2012 & Devonbuy.com, 2013)

*150 lux in the spectator area, the stage requires higher intensities, depending on the performance.

Also, for the ice hockey discipline the rink is required to have a light intensity of at least 750 lux during competitions and 500 during training sessions.

A development of the last years is to make ice skating more into a spectacular show, according to ice maker Jelle van Beek. Some competitions like the shorttrack Worldcups and Ice Hockey work with light shows, or even projections on the ice, to entertain the crowds during a break (E. Berends, personal communication, 07-12-'16, Appendix 1).

9.6.2. Summer requirements

As told in the Usage Characteristics Chapter, the ice skating halls will be used in summer for summer sports. Most of these indoor sports will include ballgames, which have according to the Artificial Sport Lighting Guide similar requirements.

For competitions, most sports require 750 lux, for training purposes 500 lux is already sufficient (Sport England, 2012).

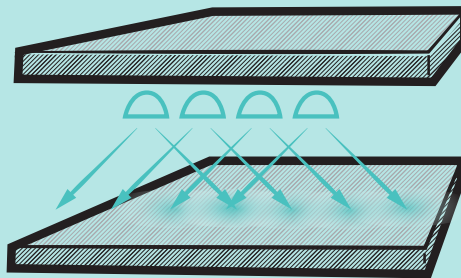
The other functions housed in summer, like fairs, markets and concerts all have different light requirements. For all

these multifunctional purposes an outer organizing party is involved. Who are allowed to bring their own lighting systems with them. Therefore, there should be a possibility for these parties to have luminaires or beams which can bear these light systems.

During the interview in the Triavium, the ice rink of Nijmegen, it was mentioned that the rink had attaching points which could carry another 1000kg, in case of a special event, for lighting and other purposes (E. Berends, personal communication, 07-12-'16, Appendix 1).

Concluding:

- The sport areas need to have a flexible light system which can project 150-1600 lux during multifunctional events.
- The ceiling beams need to be able to bear at least 1000 kg more per attaching point.
- The luminaires should spread the light homogeneously.



9.7. ENERGY PRODUCING ELEMENTS

The term energy production needs to be clarified. It implies that energy is able to be made from nothing. In this perspective “Energy production” means the transition from one energy source into another. In the situation of energy in the building technology field, the final product is electric energy, but it could also be transformed into heat energy.

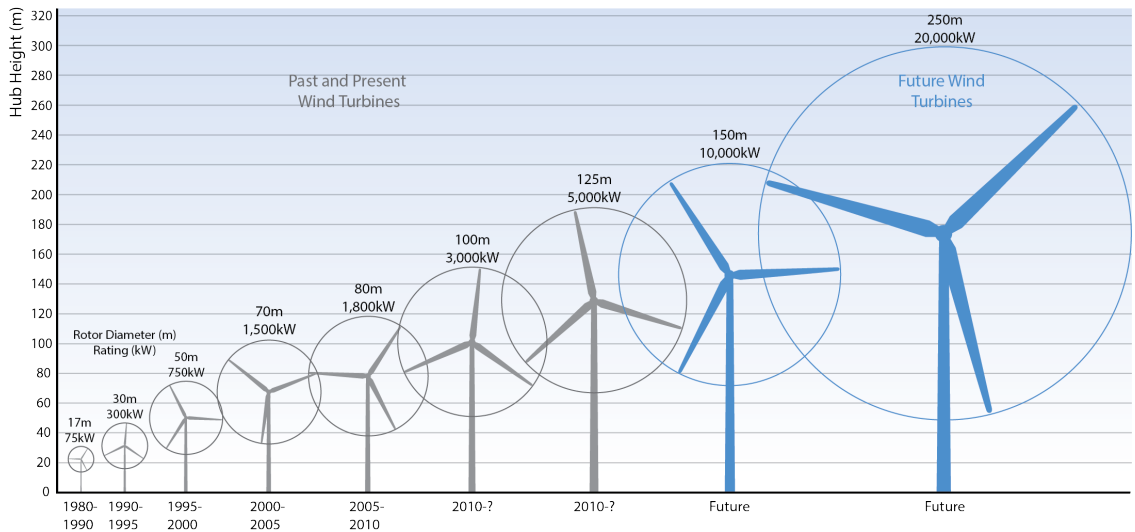
Sustainable sources which

could provide energy are called renewable energy, which is defined as a theoretically inexhaustible source of energy. Examples are:

Solar energy as producer

Thialf just installed solar panels on its roof, which can produce 3MW in electric energy. Side note 2 describes that solar energy can not completely compensate the energy consumption, due to its unpredictable character.

Solar energy can be transformed in two ways. Through solar panels, which results in electric energy, or solar collectors, which collect the heat of the solar radiation. Both carriers of energy can be useful to apply in a building. Both methods are applied in the general calculation at the end of this chapter. For this calculation a rough estimation of 30% coverage of the total 400 meter roof surface has



Diameter in combination with energy production with 6,5m/s as annual average on wind speed (Myfloridahomeenergy.com, 2017)

Side note 2: solar energy unpredictable character

Solar panels are being installed in several ice rinks. Utah Olympic oval, in Salt Lake City, covered their roof and parking lot to generate more energy to compensate for their own consumption. The panels contribute about 1 million kWh per year, which is about 20% of the energy Utah Oval needs, their annual energy consumption is about 6 million kWh, the ice rink is providing ice for a whole year. The 3108 panels produce 791 kW (Utah Olympic Legacy, 2017). But there is not always sun or an efficient solar angle. And a solar panel can only receive about 8 hours of sun a day at its maximum. So the annual energy production can not simply be calculated by saying $791 \times 8 \times 365$ equals to almost 7 million kWh per year. In this case it is “only” one million kWh expected. This unpredictable character of solar panels was also a challenge for Thialf in the Netherlands.

Thialf installed 5000 solar panels in 2016. This could produce about 1,35 MW in electric energy. But this says nothing about what it could produce on an annual basis. Since we do not know how efficient these solar panels are, because their angle differs and the Netherlands is not known for having a lot of solar exposure. Unfortunately nothing about the annual energy production has been shared by Thialf. So we can only guess. It is said that this 1,35MW contributes to a quarter of Thialf’s energy consumption (Energyvalley, 2015). But saying that Thialf’s energy consumption is $4 \times 1,35 = 5,4$ MW cannot be concluded. Since the refrigeration process which needs this energy is only working during winter, and there are several circumstances in which a solar panel is not functioning at 100%.

Thialf cannot store energy to be used later, the electric energy overflow will be given “back to the net”. Thialf made a service from this. A household can connect itself to the energy of Thialf, the over-production of Thialfs energy can be used by 1250 households. And Thialf increases its income by this (Powerpeers, 2017).

The yield of a solar panel, the percentage of the energyproduction which is actually produced, improves every year. But still solar panels are producing energy in various amounts. To say that an ice rink can compensate its energy consumption completely by applying solar panels, is therefore not possible.



Solar panels installed above parking lot at the Utah Olympic Oval in Salt Lake City (Utah Olympic Legacy, 2017)

been made, for every method. The solar collector's capacity is being established by assuming the "Ice rink of the future" is located in an average, temperate region, which applies to west Europe. The capacity of a solar collector in those circumstances are approximately 3,2 kWh/m². For the solar panels a value of 200 w/m² has been used, with an average of 7 hours of sun a day.

Wind energy as producer

The capacity of wind turbines depends on the wind strength. The turbines transform wind energy into mechanical energy and then into electric energy. The total production, in this calculation on an annual basis, depends on the radius of the turbine wings.

Another renewable energy

source is the application of **Biogas**, which is usually used directly for heat energy through combustion, a disadvantage is that there will still be greenhouse gases, which emit into the air. So unfortunately not the most sustainable source of energy.

Other application, but perhaps less applicable in the field of architecture are **hydropower** (use of waterforce) and **geothermal energy**.

Waste heat as a producer

Because ice is made by extracting heat, the ice rink "produces heat", at the moment a lot of ice rinks are starting to use this previously wasted heat. Some rinks connect their refrigeration plants to the heat producing plant for a swimming pool, in which both sport functions are in the same building cluster

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5000 solar panels applied on the roof of Thialf with a capacity of 1,3MW, during the renovation of 2016 (Nuon, 2016).

(Duurzaambedrijfsleven.nl, 2014). Other rinks, like the Elfstedenhal in Leeuwarden, use their waste heat for floor heating. But there are difficulties with extracting the heat from the refrigeration

plant in an efficient way, most of it is lost in air (E. Berends, personal communication, 07-12-'16, Appendix 1). Waste heat is generally transported with water as a carrier. Waste heat is therefore more efficiently

applicable in floorheating and is less effective for airheating, since the thermal energy needs to be transformed in a different state.

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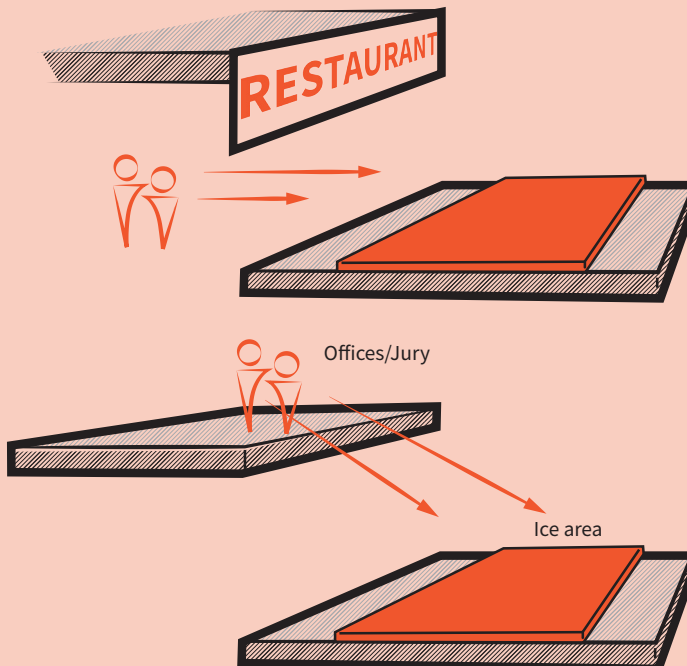
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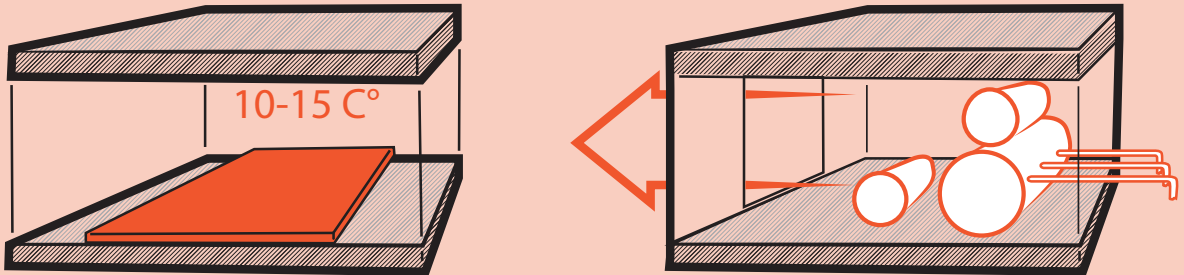
PROGRAM OF REQUIREMENTS

USAGE REQUIREMENTS

Users requirements

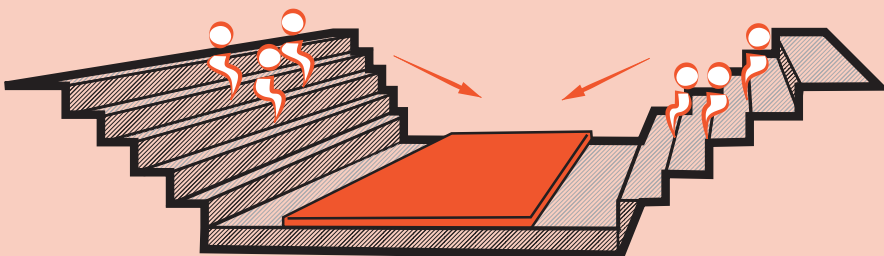
- The changing rooms need to be close to the ice.
- There needs to be a restaurant or café, with view on the ice skating area.
- One needs to be able to have full overview in the ice skating area.
- The ice quality needs to be suitable for performance training.
- During training the air temperature must be below 10 degrees
- During competitions the air temperature must be between 10 and 15 degrees.
- There should be a drainage system for melting ice and the ice resurfacing parking area.
- The technical spaces, climatic chamber and refrigeration room, should have a large entrance to assure that replacing machines and equipment can be possible.
- The offices of the technical staff should be placed close to the offices of the permanent staff.
- The rink should offer flexible spectator stands, with standing or seating option and the possibility to increase the number of visitors by architectural measures. It should house between 3000 and 5000 people.



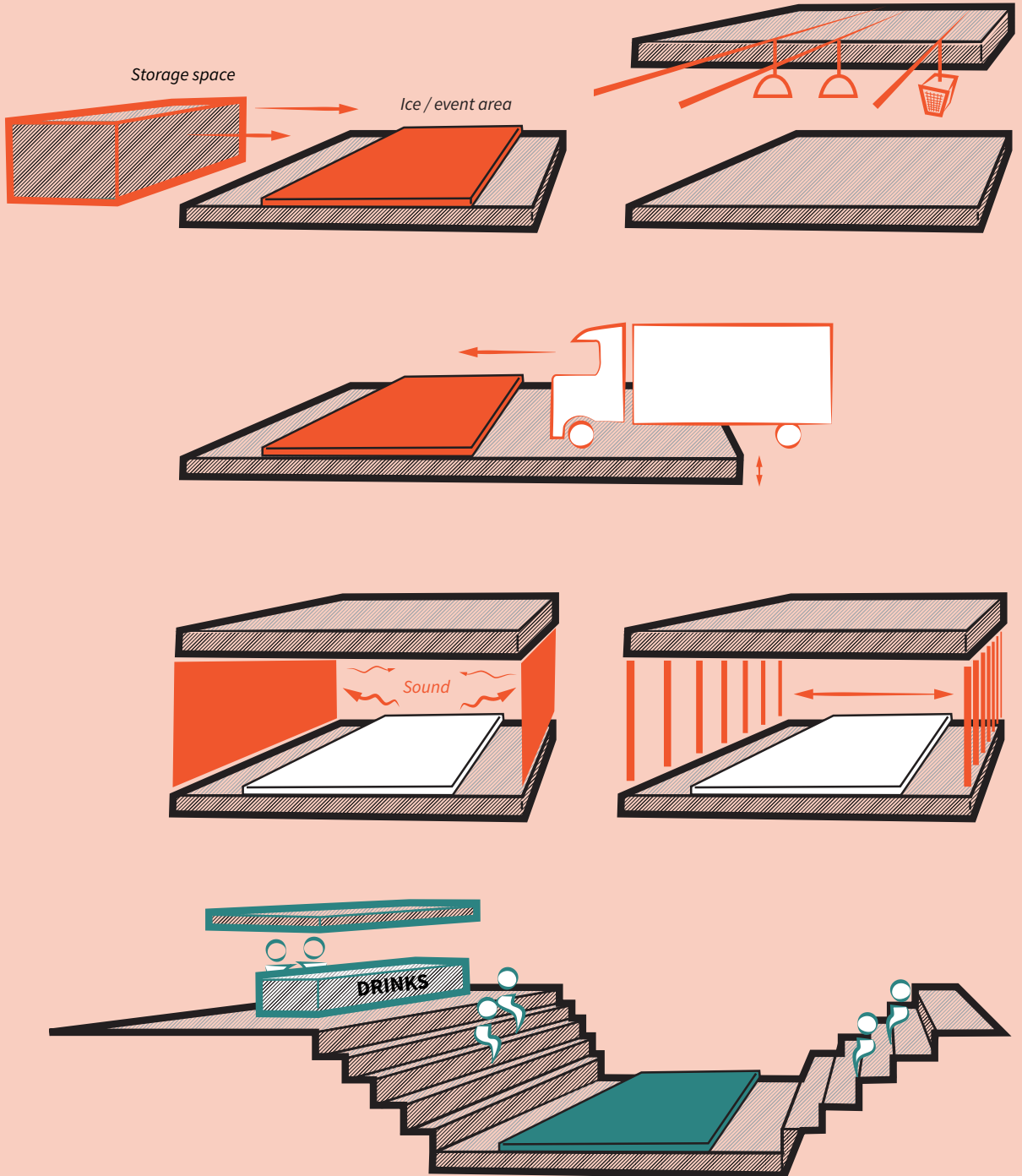


Multifunctionality

- The building should be made suitable for a large group of spectators, to visit the building during competitions.
- In the sporting/event area there should be no columns deviding the space, to achieve multifunctionality.
- There should be an option to completely darken the event area
- There should be storage space for extra seats, cleaning equipment, floors for sport purposes,
- There should be enough space to place catering industry facilities during big social events
- The surrounding construction should have acoustic absorbance to establish comfort of the visitor during the events.
- Catering and sanitary facilities should be present in high numbers and easy to reach.
- The secondary floors for summer should include absorbance which fits the requirements of ball sports.
- The building should contain large entrances for trucks, to reach the ice rink level.
- The summer events should be easy in set up, so breaking down a secondary construction shouldn't take too much time.
- The eventspace should be divisible into smaller areas or a backstage area.
- The bearing construction should be calculated on freedom in light and sound applications.



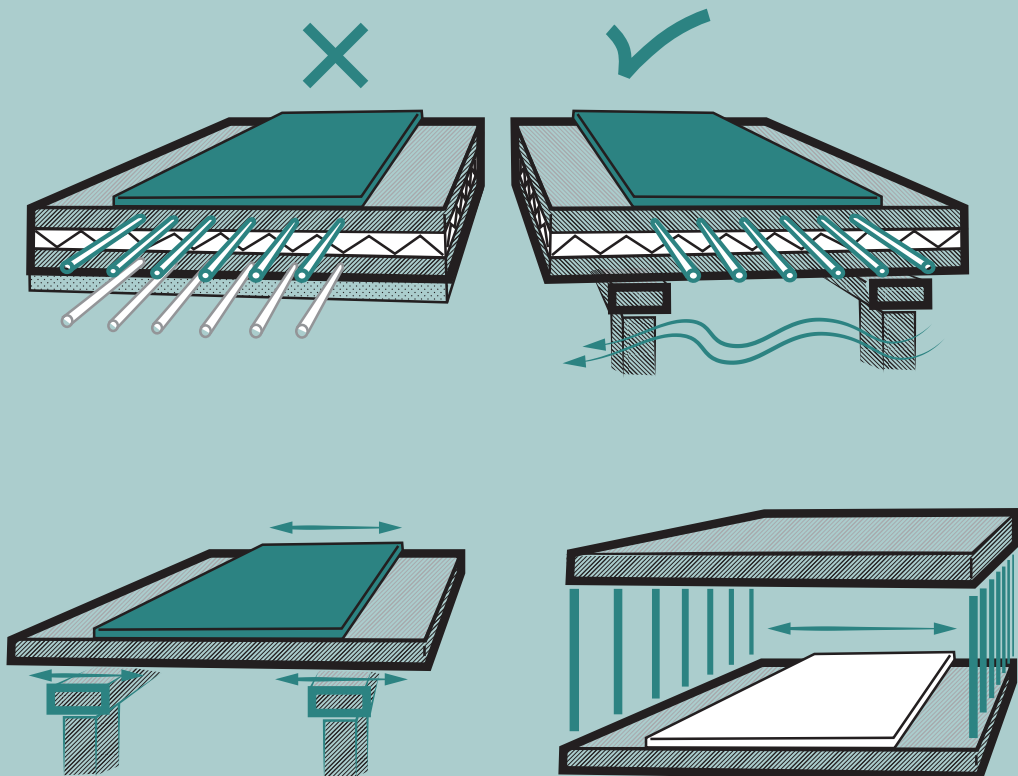
PROGRAM OF REQUIREMENTS



SPATIAL REQUIREMENTS

Requirement construction

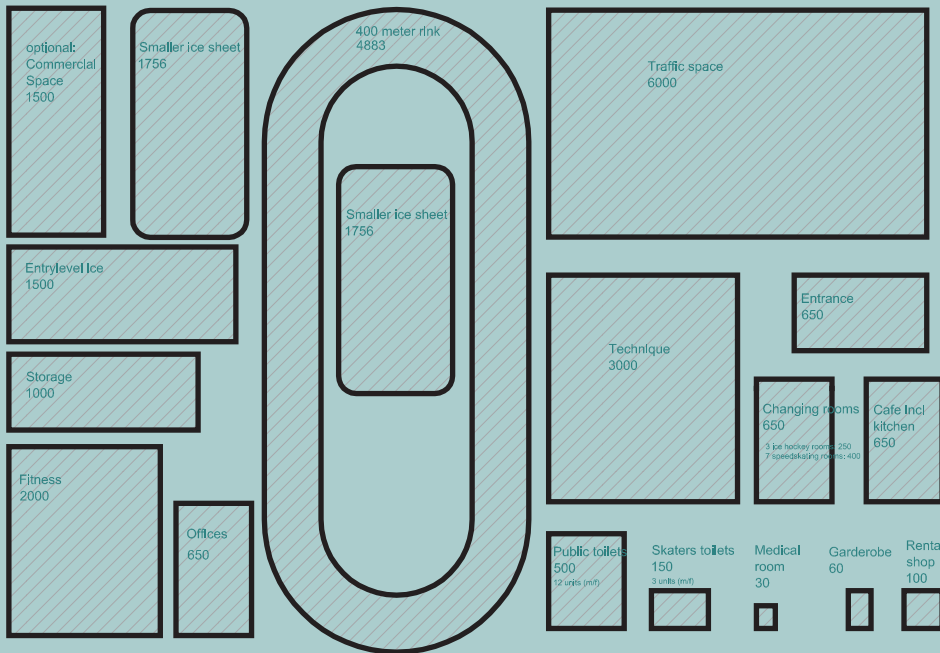
- The sport area for the 400 meter rink and the separate ice hockey rink should be an open space. To achieve multifunctionality. Which is why there should be no columns in this area, to achieve an open floorplan.
- The construction should be as light as possible, preferably made of timber.
- To improve the energy performance, the rink shouldn't apply floorheating as layer directly in contact with the soil. Instead, the foundation should be elevated from the ground, and ventilated slightly, to prevent condensation.
- The oval function inside must be visible in the outer form language.
- If possible the ventilation must be integrated with the bearing construction to generate an aesthetical appearance.
- The construction should be able in absorbing thermal expansions, especially in direct contact with the ice sheet. The foundation underneath must have flexible connecting points.



PROGRAM OF REQUIREMENTS

Required spaces

- Technical spaces
 - Cooling plant to provide the cooling refrigerant for the pipes underneath the ice surface
 - Climatic control rooms / air conditioning
 - One 400meter ice rink
 - One 30x60meter ice rink
- Changing rooms (incl. toilet)
 - Sometimes only to serve the speedskaters using the 400m rink and ice hockey players combined. Sometimes to serve other functions as well, like a fitness space.
- Fitness spaces
 - Either for external users, or for the ice skaters to warm up an cool down.
- Garderobe
- Separate toilet units
- Café
- Storage
- Commercial space
- Rentable and VIP spaces
- Traffic space
 - For large visiting numbers
- Entrance
 - Logistics
 - Sporters
 - Audience
- Medical room
- Spectator stands
- Offices
 - Technical staff
 - Chairman
 - Summer staff
- Multifunctional space
- Jury room
- Additional leisure room for the jury
- Storage for time measurement instrument

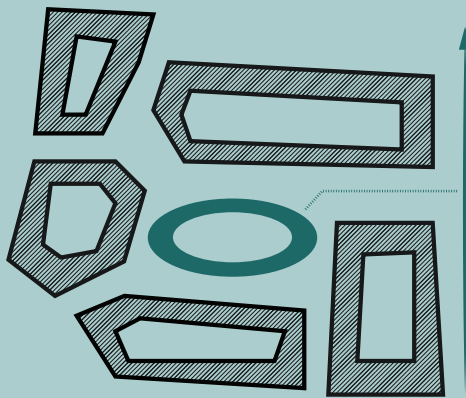
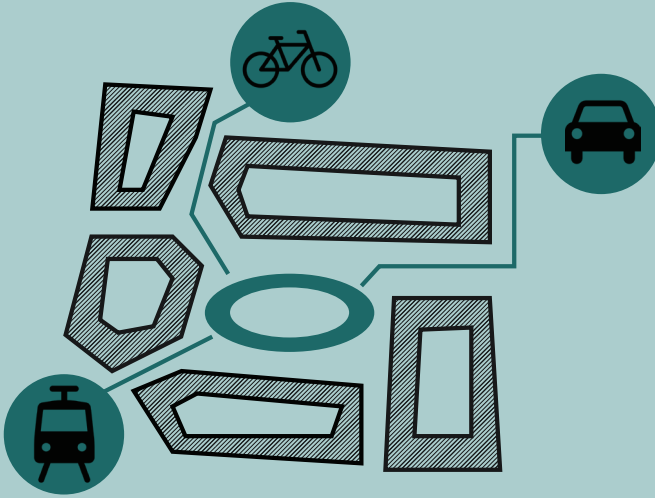


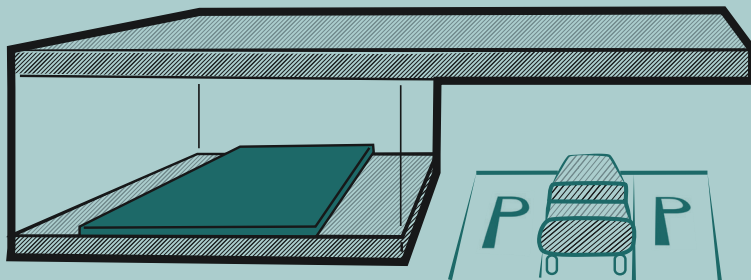
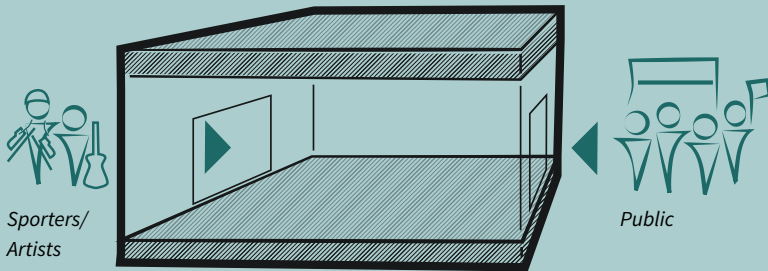
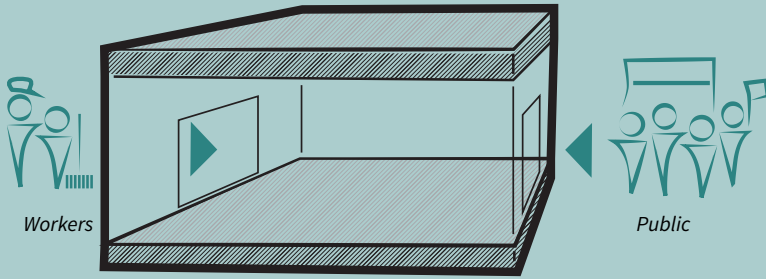
Area calculation from Appendix 5. 1 to 2000. Own illustration.

The chosen building site should be:

- Close to a motorway
- Close to a public transport station
- Easy accessible by bike
- It should contain enough square meters to host parking spaces for spectators and other building users.
- Logistic traffic should have its own entrance into the building and site
- The location of the newly designed ice rink should be outside of the Netherlands.

PROGRAM OF REQUIREMENTS





PROGRAM OF REQUIREMENTS

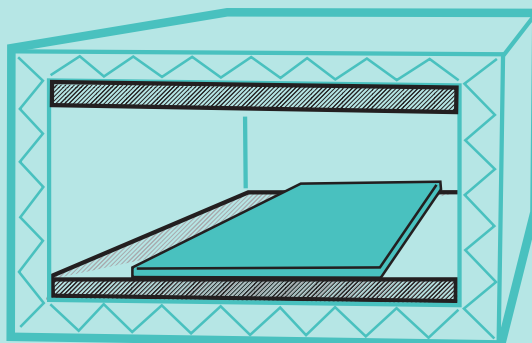
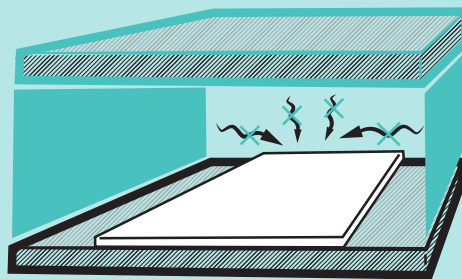
TECHNICAL REQUIREMENTS

Requirements materials

- To achieve energy reduction, due to reduction of energy waste, Low-e materials should be applied.
- In the direct building environment of the ice sheet, materials with a high emissivity must be avoided. Wood had been known as a low emissive material and is preferred in this situation.
- A low-e foil will be applied to the ceiling to prevent heat radiation from the surrounding construction.
- The materials in the direct environment of the ice sheet should have insulating properties. To protect the inner climate, but also for acoustic comfort.
- To lower the embodied emissions of the ice rink as a whole, natural materials are preferred.
- Materials with minimal manufacturing labor are preferred.
- The concrete of the ice sheet should have a high temperature conductivity.
- Constructive elements need to be able to be replaced

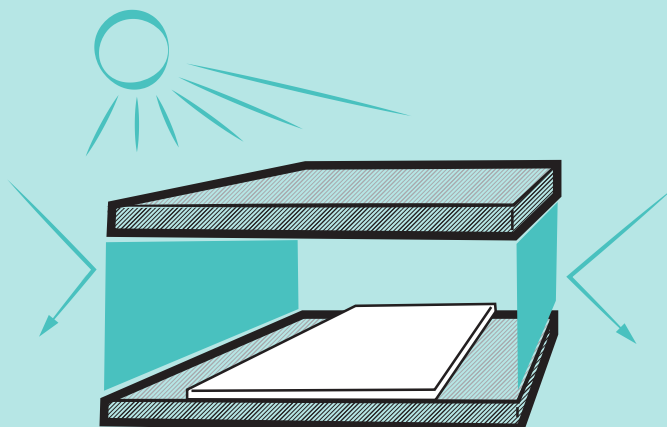
Refrigeration linked requirements

- An indirect circuit is chosen for the ice rink design, CO₂ as carrier and ammoniac as refrigerant.
- The cooling liquid pipes need to be placed close to the concrete surface, to save unnecessary energy consumption by inefficient cooling.
- Waste heat of the refrigeration plant must be used for heat consumers inside the building.
- To use waste heat a heat pump needs to be installed.

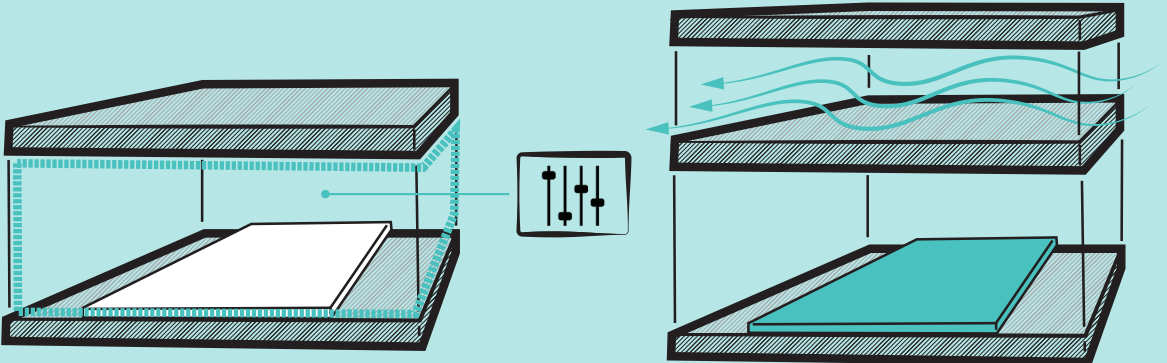
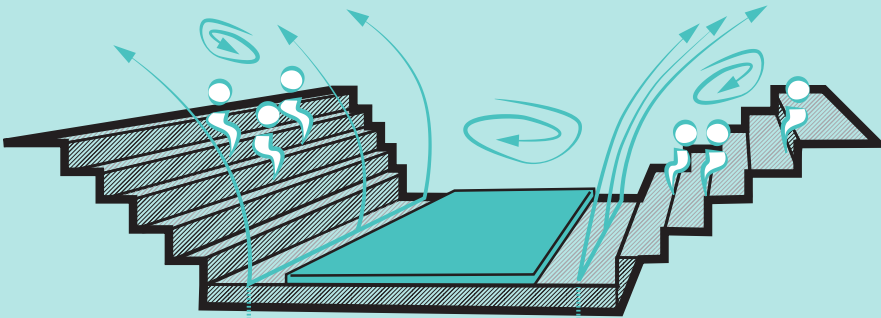
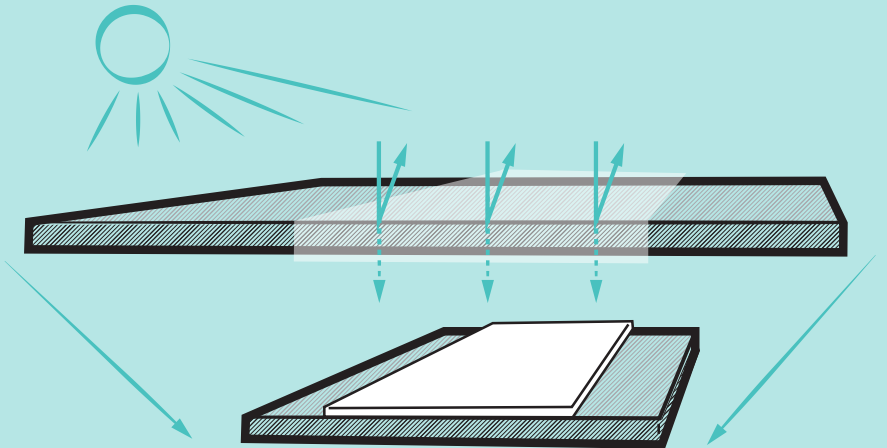


Climatic requirements

- The ceiling shape of the sport area needs to steer the air from the ice skating area to the spectator area, and needs to prevent the air from going the other way.
- Wood as construction material can prevent condensation on the material.
- The relative humidity in the ice rink sport area should be below 40%
- The boardings around the ice layer need to be as much closed as possible to achieve the colder layer of air between the two boundaries.
- To achieve a better air quality, an aircurtain will be applied, to split the audience from the skaters.
- During competitions, or large events in summer, the ventilation system needs to be able to extract 30 grams of moist per person from the air. In case of 3000 spectators, it means that 90kg of water needs to be extracted from the air.
- When glass is applied in the facade of the building with direct solar entrance towards the ice area, infrared radiation should be avoided.
- When glass is applied, there should be a shading system to completely darken the indoor area, for broadcasting purposes.
- The ventilation of the sport area should be done mechanically, to provide stable humidity and temperature.
- The inner climate of the sporting area should be stable in temperature and humidity, and monotone in lighting.
- For full climate control, the indoor sport area should be detailed as airtight as possible.
- To save energy the ventilation system needs to be driven “demand-controlled”, adjusting to the amount of people inside.
- Every person visiting the building needs 20 m³/h fresh air.
- Heat recovery need to be implemented in the ventilation mechanical system.

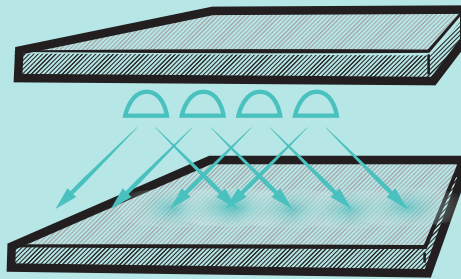


PROGRAM OF REQUIREMENTS



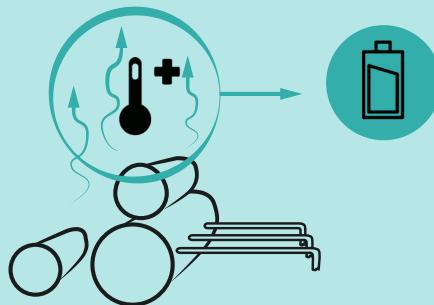
Light requirements

- The sport areas need to have a flexible light system which can project 150-1600 lux during multifunctional events.
- The ceiling beams need to be able to bear at least 1000 kg more per attaching point.
- The luminaires should spread the light homogeneously.

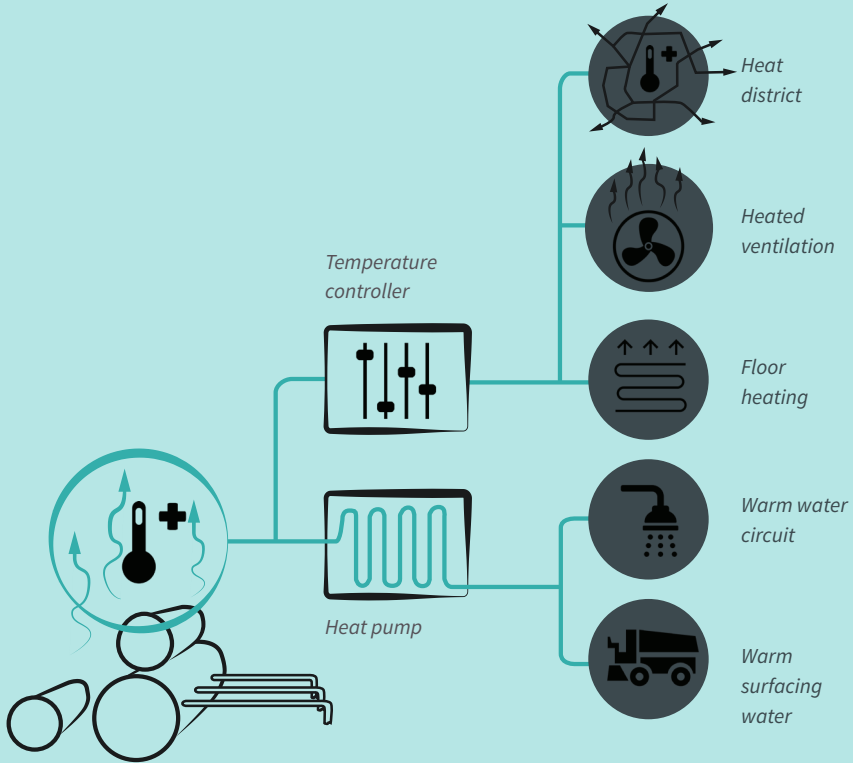


Requirements heat circularity

- To make use of waste heat, a heat pump must be attached to the evaporator of the refrigeration plant, this engine consumes 350W, but will increase the water temperature so it is legitimate to use.
- Geothermal heating or a stratified buffer can be used to store heat.
- Floorheating is perfectly combinable with waste heat water, it could be applied in a direct system.

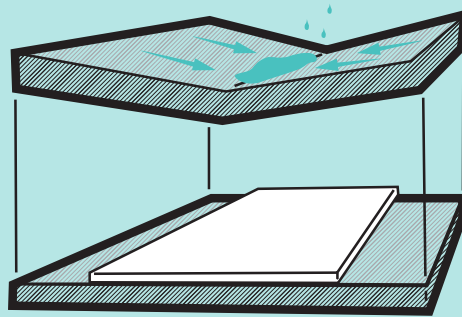


PROGRAM OF REQUIREMENTS



Requirements water circularity

- Since the rink in the designproposal shall be completely indoors, there should be sufficient water drainage system. For the melting ice, but also for drainage in summer, during large cleaning activities.
- Rainwater could be used for grey water systems, or, if purified, to create the ice sheet.



REFLECTION

REFLECTION

REFLECTION

How to integrate energy-saving architectural instruments towards a holistic energy neutral ice rink design.

This research question suggests a literal outcome, in form of a manual. Already at the start of this research the main goal was to get a list, a program of requirements on “How to make an ice rink energy neutral”. This had been proven that there was a need to change course. Already, when looking at the research question, the more simple question arises: “How to make an ice rink?”.

This already was a challenging subject. Before one could dig into energy efficiency / production / overview of energy consumption of ice rinks, the basics of defining boundaries on architectural level had to be taken into account. Finding out who the users are, including their requirements, what spaces are needed and their dimensions were subjects which had to be investigated first.

How can one make an assumption about the energy consumption, when the requirement of energy is depending on the tangible program and the requirements of the user. Which is why eventually energy performance is a subject which can be handled, when a certain base design has been produced.

Also, a literal answer on “how to make an energy neutral ice rink” doesn’t exist. There are influencing factors which makes alternative design outcomes. Like the chosen location, the local weather, the preference of the users in materials, the demands of the users in ice quality, the annual use of the building and also, the

specific method and style of the architect.

Lack of specific data

The original research plan was to have a long list of energy saving means and renewable energy means to achieve energy neutrality in the ice rink design proposal. Eventually, this became a challenge. Since most news or literature items were explaining innovations in making the refrigeration process more energy efficient. Most literature and people who were interviewed, were more informed about the refrigeration possibilities, than in actual architectural solutions to reducing the energy consumption.

Also “reducing energy consumption in ice rinks” specifically was not a subject which was well presented in the global academic literature. Most solutions had to be found by asking questions to the right people, or were integrated in flyers and unofficial reports of manufacturers.

A clear overview in energy consumption is, due to confidentiality in many fields, impossible to come by.

I tried to compensate for this data by gathering or producing this data myself, by organizing questionnaires and interviews. The required data is, for energy consumption, specific to the building design. Since no operators were willing to share this information, the data was

found by putting bits from different building projects together. Which leads to the image of the calculations being of a general character. But since this is a general manual before going in depth in a design assignment, the outcome is still useful.

Lack of information: rephrase design assignment

Although the gathered information was less in depth than expected, this research has still a convenient character. It shows that this particular subject, energy efficiency in ice rinks, is a relatively young research field, with no academic background.

The aim of the research transformed during the researchprocess. When it became clear that certain pieces of the data puzzle would continue to be missing, the research plan had to be adjusted. Instead of a dry list of energy saving means, the process itself had to be described as well. To gain full transparency in this process all decisions and challenges are described in this Research Book under “side notes”.

Eventually this book became more a summary of findings in this field, and what pieces are missing. This Research Book is a manual for a later design project. Because the research aim has been adjusted, this automatically means that the design approach will be different.

The goal of this research to have a dry list of requirements where the whole design can depend on, is simply not possible. To design a building which deals with energy efficiency, energy saving measures and renewable energy, constant calculations have to be made, on which the the designprocess needs to be steered. In other words, the design needs to be tested along the process, to reflect if it is indeed supporting energy efficiency.

Research book vs. Projectbook

The translation from research to design is a challenge for the simple fact that both are intertwined in each other.

To constantly switch between the two brought no structure to the research or to the general planning. Eventually the decision has been made to literally split both process stages, into two books.

One, the Researchbook, describes the general problem statement, background information, and answering main research questions. It can be treated as the “package” needed to make the design. The second book, the projectbook, will analyze the design assignment, location analysis and design decisions.

Fascination as research driver

This research is connected to the graduation Explore Lab of the Architecture faculty of the University of Technology in Delft. Goal of this graduation studio is for students to dive into a

REFLECTION

Energy efficiency in ice rinks, is a relatively young research field, with no academic background.

subject of fascination.

To have a fascination in a certain field, in my case the technology and architecture of ice skating rinks, can help in stimulating oneself in a project. But it can also mean that keeping a clear overview on the research process may be a challenge, since every sub study seems important and supporting your final results.

Personal recommendation

Looking back, my questions during the interview could have been more specific. And when an answer wasn't helpful, I could have asked for other sources, this was done a couple of times, but I could have been more specific in my intentions. The interviews were extensive, but still more in width than in depth.

If I would give myself a recommendation, it would have been to not only stick to ice rinks in the energy-performance research. Case studies could have been done from other sport buildings, or even concert halls, to generate sufficient comparable information.

Also the need to solve everything in a new field, with tools and methods which were new to me,

was ambitious. For further research initiations I would recommend to narrow the research angle, and to compare the research plan to others. So to summarize, keep it small and know when you did enough.

Recommendation in the research field

Confidentiality is an issue which occurs in more research fields, but in this specific research angle, it limits the results and the possibility to compare my findings with other sources. Also, if designers, constructors and consultants desire to collaborate in a future which provides energy neutral buildings, the distribution of information is crucial. The desired development to make energy neutral buildings, is diminishing because of the fact that parties are keeping important information to themselves. Ice rinks, but also designers and municipalities are competing with each other, but in this way they are preventing a required innovation in this field. This confidentiality serves a financial advantage. But if we want to continue practicing this beautiful sport, the importance of distributing energy-saving concepts must be addressed on a large scale.

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APPENDIX

APPENDIX

1 Interview Matrix

2 Questionnaire NL

3 Questionnaire UK

4 Case studies

5 Three floorplans analysis in square meters

APPENDIX 1: INTERVIEW MATRIX

	Ice makers	
	Frank Bongelaar	Gerwin van Dam
	Ice maker De Westfries, Hoorn	Ice maker IJsbaan Twente, Enschede
Who owns and exploits this rink?	Owned: Municipalities of West Friesland Exploited: Optisport (Company)	Owned: Municipality Enschede Exploited: VolkerWessels, PCH Groep (Company)
How much does the operator pay for rent?	140 to 150.000 euros	-
How much did it cost to build your ice rink?	9,5/10 million.	13 million, our rink is second in the dutch ranking, so fast times are possible on a rink with less means than Thialf.
How much do you pay annually in energy bills	-	That I may not say, I can only add that our incomes compensate the costs more or less.
How much annual income does this rink receive?	-	-
How much energy does an ice rink use?	We use 180/250 W per m ² , we use 2000 kW in total.	We use one fifth of the old energy consumption of Thialf (600 kW). They have more ice ofcourse. We try to let our machines work for 100% and as less operation time as possible, we make a buffer of cold. For the ice rink we use 9000 kWh per day.
Is the sport promoted in away?	-	We work together with municipalities, they add euro to every child which participates in skating lessons.
What materials are recommendable in indoor circumstances of an ice rink?	I always say: Natural materials, they have great acoustic/moist repelling properties	In this rink we have steel as construction, I never had problems with that.
What temperature do you make your refrigerant?		
How does the ventilation system work?	We don't have a ventilation system in the skating hall.	The air supply comes from above, and sucked back above as well. Downpart is the height, we never get hot air at the skating surface.

APPENDIX 1: INTERVIEW MATRIX

	Engineers		Exploitant
Jelle van Beek	Ernst Berends	Christian Potma	Johan van der Kooi
Ice maker Triavium, Nijmegen	Application Engineer	Airmovement flowmotion	Director Elfstedehal
Owned: Municipality Nijmegen Exploited: Municipality Nijmegen	-	-	Owned: Municipality Leeuwarden Exploited: Stichting Elfstedehal (Federation)
-	-	-	More than a tonne.
-	-	-	21,7 million euro's. 14,5 with advice and consultancy excluded.
-	Thialf had to pay 1 million a year, before their renovation, they wanted to reduce this by half.	-	About 240.000 euro's per year.
-	-	-	Around 2 million per year
-	Thialf uses 1800 kW for the 400m rink, 1200 kW for the other rinks so 3MW in cooling capacity, which is a lot.	-	For that you have to be at the energy providing company.
	-	-	-
Wood always is "warmer", which prevents condensation	Wood always needs to impregnated, but behaves better in cold climate	A smooth surface will stimulate airflow in the preferred direction	We get a lot of positive reactions from our visitors about the wooden construction
-10 or 9, the ice will be around -4 C.	-	-	
We have "blowers" at the ceiling and suck the air below. So the air generally moves towards the ground.	-	-	I can only tell you that we dehumidify the air with mechanical ventilation, and that we provide the hall with air from above.

APPENDIX 1: INTERVIEW MATRIX

	Ice makers	
	Frank Bongelaar	Gerwin van Dam
	Ice maker De Westfries, Hoor	Ice maker IJsbaan Twente, Enschede
Is direct sunlight a burden in an ice rink?	Yes	Yes
Why is sunlight a burden?	Both for comfort and radiation on the ice, which makes the resistance higher. My ice is melting with those sunbeams radiating on it!	Mostly comfort for the skaters, I don't think sunlight affects the ice in a high contributing way.
What measures do you do to prevent direct sunlight from coming in?	We have curtains on the upper gaps of the walls, and in the open part of our roof. These curtains also keep away dust and dirt.	The design of the rink prevents direct sunlight from coming in, the envelope is shaped in a way it cantilevers above the windows.
Are some building components strangely arranged in your rink?	In my rink it is well done, they learned from Breda, which is an older copy of this one. I only would like to add more program, like a gym.	The restaurant is quite high, unused space if you ask me. And my office is two floors higher than the machinery, I walk a lot.
Do you use waste heat?	Yes, for the floor heating in the offices and service spaces. For 2000 kW in cooling you can produce 2300/2400 kW in heat, But you only need to use the full 2000kW when you start the cooling process.	Yes, we used to heat air in the sport area with it, but it was not reacting fast enough, so we changed to gas, I am working on changing it back. We also use it for floor heating in the offices.
How much heat do you need to produce for an ice rink?	-	The heat from the heat pumps is 350 kW, they are producing heat for 13 hours a day.
Do you think a bufferzone around the ice rink can improve the innerclimate conditions?	Yes, but it is an enormous investment.	Yes, to make it more controllable. But if you ask me, it was a lot of money and effort. We yet have to find out if it works.

APPENDIX 1: INTERVIEW MATRIX

	Engineers		Exploitant
Jelle van Beek	Ernst Berends	Christian Potma	Johan van der Kooi
Ice maker Triavium, Nijmegen	Application Engineer	Airmovement flowmotion	Director Elfstedehal
Yes	Yes	Yes	Yes
-You cannot guarantee good light quality for broadcasting purposes. -Concerts and other sports require the possibility to play with light, it's not possible with sunlight	20% of the skating resistance is ice, this only increases when sunlight hits the ice.	Sun radiation can have influence on air temperature, and on the ice surface.	-
We darken some windows, permanently. And have curtains to close more windows when necessary.	-	-	Our windows are quite low, so only with very low wintersun there would be a small amount of light coming in. But the building is surrounded by objects which block sunlight.
The rental shop is blocking the circulation towards the ice sheet.	-	-	No, we did a lot of research on this, and are very content with the result.
Yes, to heat the sport area and the offices. When you have a closed rink, like we do, the waste heat can always be used in heating the sport area.	Sometimes the outer air is -10, so you don't need to cool your ice. So no waste heat is produced, you always need a boiler ofkettle to heat your building.	-	Yes, for the floorheating in the service area and around the 400m rink. The plan was to heat the local neighborhood, if that worked out you have to ask the energy company.
When we used gas it was 700/800 cubic meters of gas aday, and in winter 1700.	-	-	-
Yes, but it is a specific Thialf problem, no other rink receives a visiting number this high, and it makes it possible to make ice accurate in tenths of seconds.	-	-	-

APPENDIX 1: INTERVIEW MATRIX

	Ice makers	
	Frank Bongelaar	Gerwin van Dam
	Ice maker De Westfries, Hoorn	Ice maker IJsbaan Twente, Enschede
Statement: A fully closed ice rink is better for the ice quality	Yes, your ice becomes more stable and more predictable. Also, you have less wind, so the cold layer on the ice is more stable as well.	-
Statement: A fully closed ice rink is better for decreasing the energy consumption?	Not necessarily, you have to invest a lot more, your rink become a high performance rink with greater demands, some semi closed rinks do not have any ventilation applied, so ofcourse that means less energy, but also less comfort and ice quality.	-
Statement: Air conditioning is necessary to make high quality ice	No, with good circumstances I can make great ice. But it become more controllable and independent of what happens outside.	Yes, we can make fast ice here, I think that our ventilation system and indoor atmosphere are contributing to that.
Can air be fully controllable?	No, even in closed rinks, with potentially fully controllable inner climate, it can be hard to let the system do what you want. With this big investment it's not guaranteed.	-
Are there means in management to decrease costs?	-	We make use of sponsoring. Other parties can offer services or material/equipment if we share their names.

APPENDIX 1: INTERVIEW MATRIX

	Engineers		Exploitant
Jelle van Beek	Ernst Berends	Christian Potma	Johan van der Kooi
Ice maker Triavium, Nijmegen	Application Engineer	Airmovement flowmotion	Director Elfstedenhal
Yes, also to extend the skating season. You can control the innerclimate and have better ice quality, in this way you always win from semi-open structures.	-	-	-
You have the possibility to heat your hall, which can increase your energy use again. On the other side, you lose less of this heat. And the ice can be preserved better, so you need less cooling.	-	-	-
No, Utrecht, Deventer etc can make great ice, but are more depending on weather circumstances.	Yes, you can see that closed ice rinks, which have an AC system, have better ranking places, so they can provide fast an high quality ice.	Yes, you want to make the environment as controllable as possible. In the ice sport every tenth of a second counts.	-
No, you always have the skaters which influence air movement, this influences the ice more than direct sunlight, especially if the hall is warm.	No, but in Inzell for example they simulated a lot of air plans, also when the building already build, with smoke. In this case you can make it predictable.	No, simulations are the only way to control if the air behaves correctly. There are a lot of rules which can predict air movement, but testing it is the best way. And not even then you have a 100% certainty if air will behave that way.	-
-	-	-	We do everything ourselves. Selling/renting skates, café, skating school etc.

APPENDIX 1: INTERVIEW MATRIX

	Ice makers	
	Frank Bongelaar	Gerwin van Dam
	Ice maker De Westfries, Hoorn	Ice maker IJsbaan Twente, Enschede
Is it possible to have a second performance rink in the Netherlands	No, don't make a second Thialf, Thialf alone already has trouble attracting enough spectators and events. Focus on "breedte sport".	Yes, but not for the big events. IJsbaan Twente is nr. 2 in the Netherlands, and hosts some Dutch championships and training facilities for the professional teams, but that's it.
Why is a reflective ceiling preferable?	Yes, it has been proven to make the ice quality, air temperature and light more homogenous.	Yes, we don't have a layer like that. Our applied material is reflective in itself, but way too high. So the effect could be increased in this hall.
Do you think insulation will improve ice quality?	Yes, in my rink we don't have insulation anywhere, the materials are colder than the air, which is why I have condensation every day.	Yes, the walls (borstwering) isn't insulated, which costs us a lot of energy, we have to heat our building
Do you think insulation improves the indoor climate?	Yes, we don't have insulation here, but you can see that the cold materials are attracting condensation.	Yes, in this rink we don't have insulation in the walls, when it is cold outside, we need to heat up the skating area.
How is the ice sheet detailed to prevent leaking?	The pipes are directly attached to the concrete slab, after 10 years it still functions.	-
What kind of water is used in your ice rink, and how is it prepared?	-	We heat our water with the waste heat. Around 14 m3 per day to 40/50 degrees. When it is just a recreational skating hour, we use water of 30 degrees.

APPENDIX 1: INTERVIEW MATRIX

	Engineers		Exploitant
Jelle van Beek	Ernst Berends	Christian Potma	Johan van der Kooi
Ice maker Triavium, Nijmegen	Application Engineer	Airmovement flowmotion	Director Elfstedenhal
No, not when you want to attract more events, you will still have the same amount of events, divided over two rinks, which is financially bad for both	-	-	-
Yes, we were one of the first in the Netherlands who had it. Our energy consumption therefore has been better than other rinks on that matter.	It reflects the cold back to the ice. As well as reflect the light, which makes the atmosphere more	-	-
Yes, if you think about the sporter, you always have to seal your hall.	Yes, mostly it is suggested in the pre-building phase to use sustainable materials. In cost estimations it the design proposals will be tested for that.	-	-
Yes, take also the windows into account. Out windows don't stop any radiation from coming in, which badly influences skaters comfort	-	-	-
-	By the making of an ice sheet there is an expert involved, you make the pipes flexible, when they leave the concrete slab.	-	-
-	Thialf uses water sources on a depth of 100 meter, which makes it warmer. With reversed osmose and de ironing, membrane filtration and addition of minerals it will be heated to 60 degrees and used for ice preparation.	-	We reuse the snow which is produced by the scraping of the ice. What water we use to start with, you have to ask the ice maker.

APPENDIX 1: INTERVIEW MATRIX

	Ice makers	
	Frank Bongelaar	Gerwin van Dam
	Ice maker De Westfries, Hoorn	Ice maker IJsbaan Twente, Enschede
If ever a new ice rink is to be built in the Netherlands, where would you build it?	-	-

APPENDIX 1: INTERVIEW MATRIX

	Engineers		Exploitant
Jelle van Beek	Ernst Berends	Christian Potma	Johan van der Kooi
Ice maker Triavium, Nijmegen	Application Engineer	Airmovement flowmotion	Director Elfstedenhal
I would go for a nice environment, so it can be combined with sporting outside, cycling etc. It should have all facilities and materials and experts to help within the sport. Papendal in NL is an epicentre of this.	Look at possibilities of traffic jams and accessibilities.	-	-

Gerwin van Dam [gerwin.vandam@ijsbaan-twente.nl]

Aan:

[Eline Stubert](#)

vrijdag 2 december 2016 9:08

Goedemorgen Eline,

Ook hartelijk dank voor het leuke gesprek. Door deze gespreken bekijk we de ijsbaan soms ook eens van een ander perspectief dan dat we dat degelijks doen.. Ik zou dan ook graag op de hoogte gehouden worden over jouw vorderingen.

Als ik kijk naar het totale verbruik van de ijsbaan verbruiken wij per dag gemiddeld ongeveer 9000 kWh. De warmte die we eruit halen met warmtepompen om het gebouw weer te verwarmen is 350 kW en draaien ongeveer 13 uur per dag. Daarnaast verwarmen wij ons dweilwater met de warmte die we uit het systeem halen. Ongeveer 14 m3 per dag op 40 a 50 graden. Denk dat je zelf de rekensom wel kunt maken hoeveel we er weer uithalen ;). Hoop dat je zo voldoende info hebt? Als je meer moet weten hoor ik dat graag.

Nu vol aan de bak voor het NK Junioren, als je wil

volgen: <http://www.schaatsen.nl/nieuws/2016/kpn-nk-junioren-live-te-volgen-op-schaatsen-nl/>

Met vriendelijke groet,

Gerwin van Dam

Hoofd Technische Dienst

Ijsbaan Twente

Colosseum 90, 7521 PT Enschede

Factuuradres: inkoopfacturen@pch-dienstengroep.nl

T: +31 (0) 53 460 19 70(algemeen)

M: +31 (0) 6 10255162

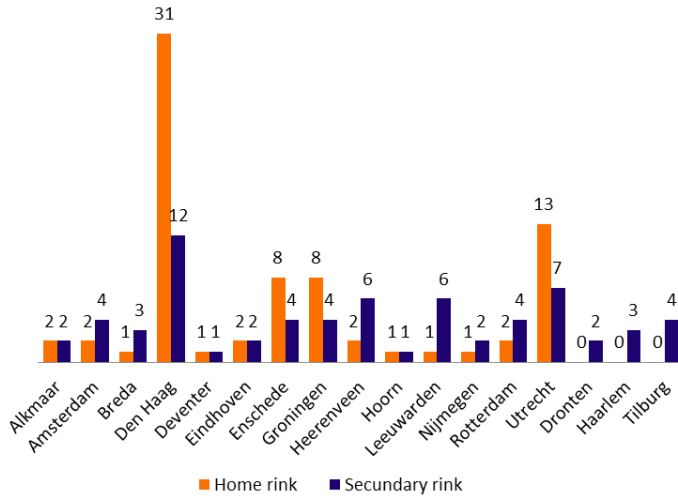
E: gerwin.vandam@ijsbaan-twente.nl | W: www.ijsbaan-twente.nl

APPENDIX 2: QUESTIONNAIRE NL

What is your “home rink” (where do you train the most?)

Home rink: 69 responses

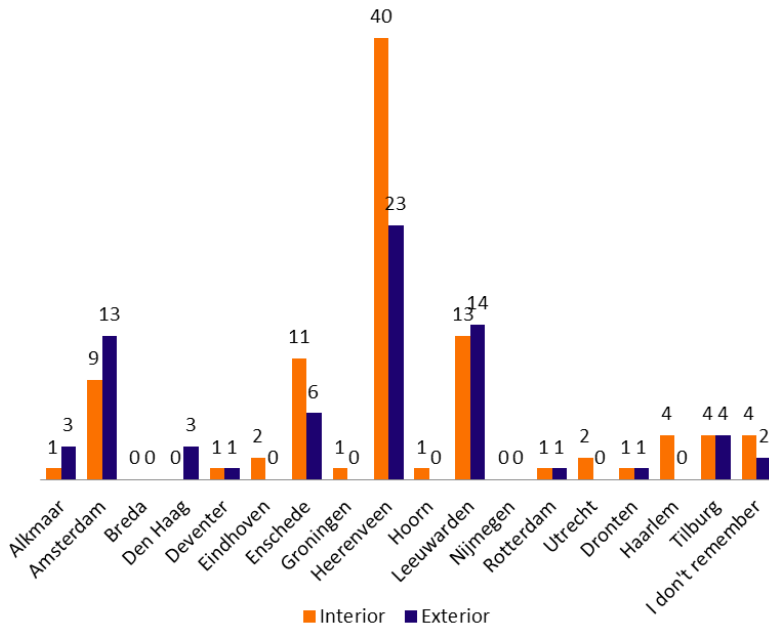
Secondary rink: 46 responses



Which rink do you like because of its interior/exterior?

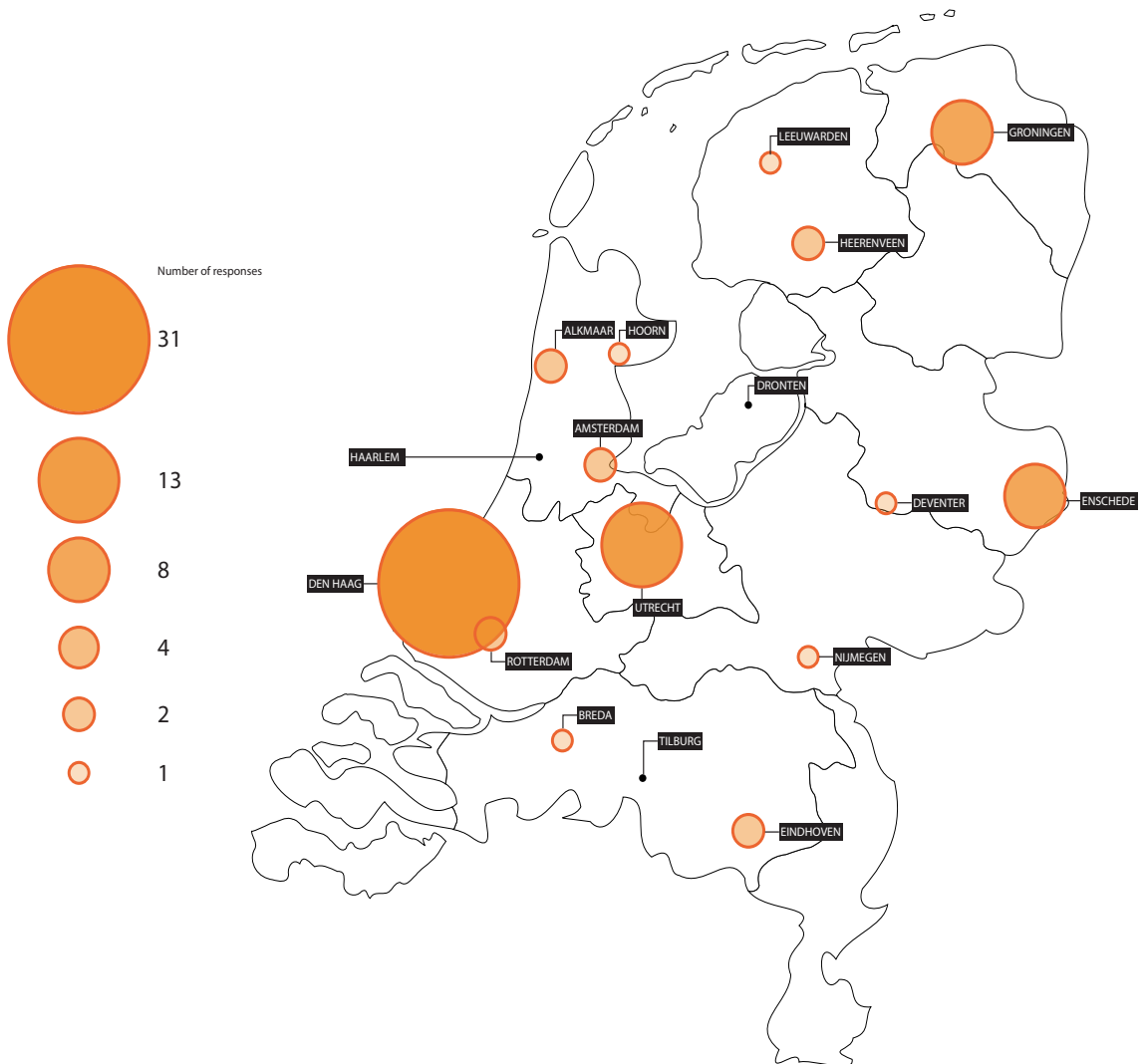
Interior: 66 responses

Exterior: 64 responses



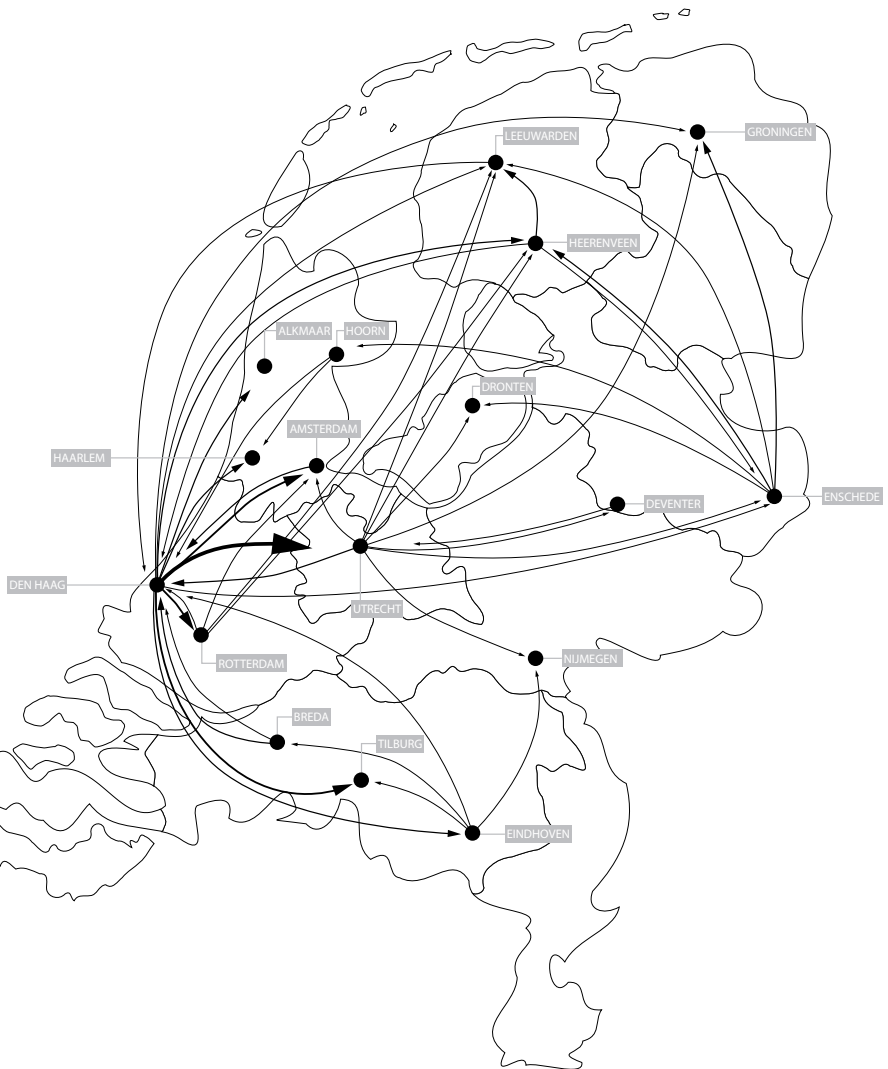
APPENDIX 2: QUESTIONNAIRE NL

Number of responses per rink



APPENDIX 2: QUESTIONNAIRE NL

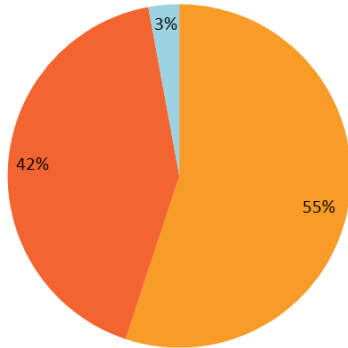
Used secondary rinks from “home rink”



APPENDIX 2: QUESTIONNAIRE NL

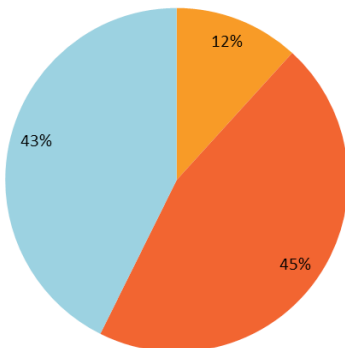
Are you a performance or a recreational skater? 70 responses

■ Performance skater ■ A bit of both ■ Recreational skater



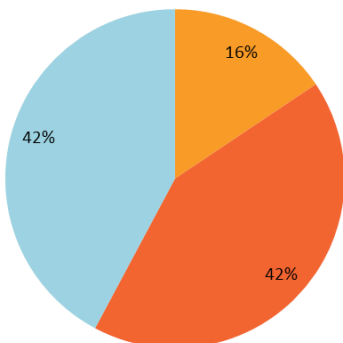
Do you skate competitions? 69 responses

■ I don't skate competitions ■ Sometimes ■ More than 5 times a ye



My perfect skating practice is on natural ice/artificial ice? 69 responses

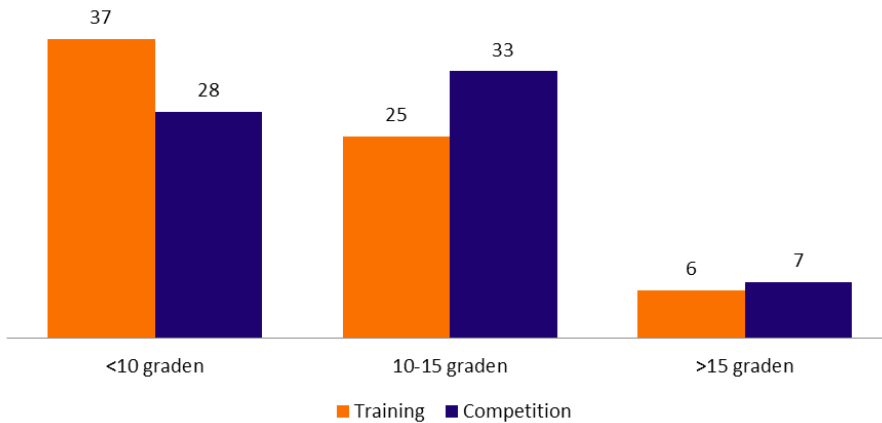
■ Artificial ice ■ Natural ice ■ When there is natural ice I'll go, but I prefer practicing on artificial ice



APPENDIX 2: QUESTIONNAIRE NL

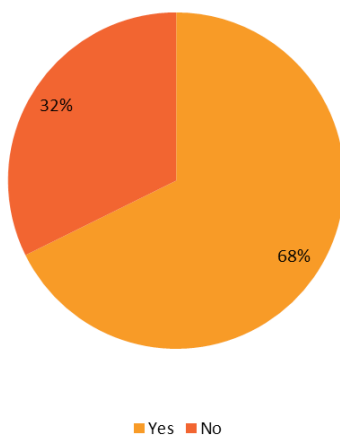
What temperature do you prefer during training or competition?

69 responses



Since the 90s many indoor rinks were build, skate practices which used to be outdoors, where moved inside. Do you think the image of the ice skating sport has changed since we skate indoors?

68 responses

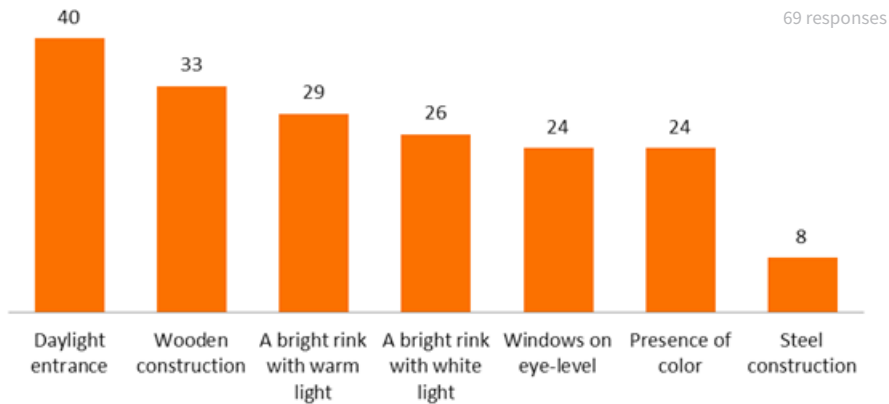


Open answers:

- Ja, maar denk niet dat overdekken de enige bijdrage is die de schaats sport veranderd heeft. Kijk ook naar de andere technologieën in pakken/schaatsen die hebben bijgedragen
- Het schaatsen is op deze manier iets geslotener geworden, echter is de kwaliteit van het schaatsen toegenomen.

APPENDIX 2: QUESTIONNAIRE NL

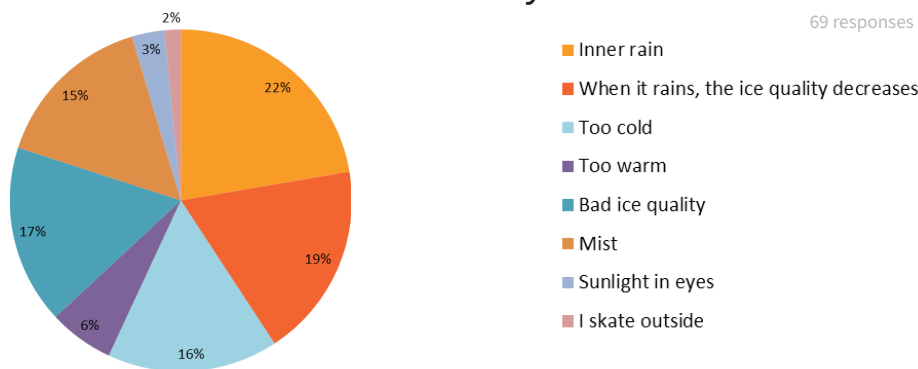
Which elements make an ice rink attractive?



Open answers:

- Neutrale kleuren (geen fel rood of groen maar licht groen of licht blauw)
- Overzicht
- Aantrekkelijke afwerking van matetialen en kleuren
- Goedkope kaartjes
- Staat van onderhoud, zicht naar natuur
- Goede muziek, en weinig galm als de speaker aan het speakeren is
- Natuur of (deels) open baan
- Goed ijs
- Ijskwaliteit / breedte baan

What climatic problems does your home rink endure?



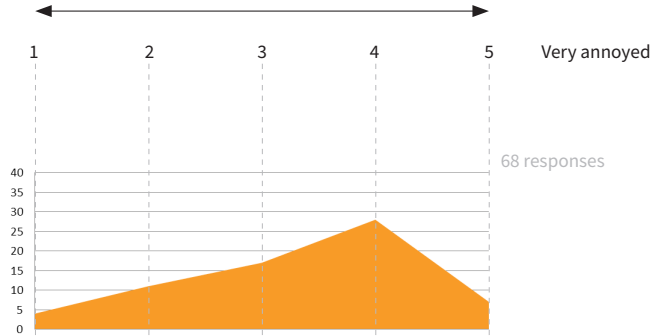
Open answers:

- Zacht ijs in de bochten
- Geen, prachtige baan
- Geen 400 meter baan
- Hobbeltjes, snel ruw worden van ijs in Den Haag
- Geen gladde ijsvloer, soms wakken als het buiten warm is, heuvels en bobbels aan de buitenkant van de baan (soms lijkt het net alsof je op natuur ijs schaatst, erg avontuurlijk!)
- Door kou te harde toplaag van ijs, daardoor minder grip en sneller uitbreken ijs
- Te druk dus snel uitgetrapt ijs
- IJs dat wegbreekt tijdens het rijden.
- Temperatuur niet constant. Heeft te maken met buitentemperatuur maar is geen eenduidige lijn op te trekken. Moeilijk om te bedenken wat aan te trekken tijdens de training
- De ijsvloer blijft nooit vlak
- Bocht snel uitgelopen en wordt snel slecht bij regen+wind (Uithof), Te koud (Rotterdam)

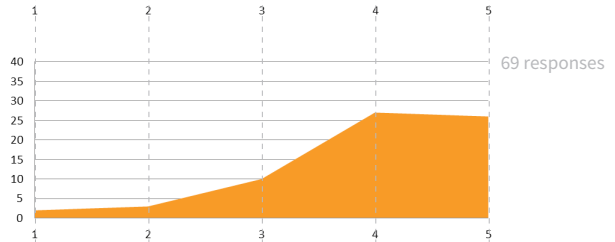
APPENDIX 2: QUESTIONNAIRE NL

ANNOYANCE INNER CLIMATE

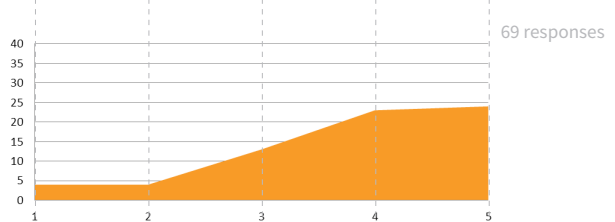
How annoyed are you when fog occurs in an indoor ice rink



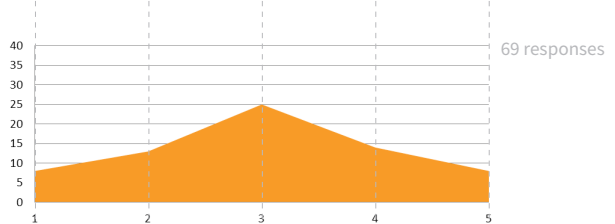
How annoyed are you when inner rain occurs in an indoor ice rink



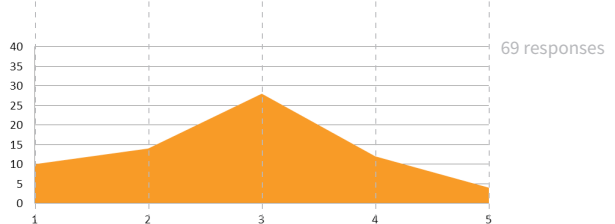
How annoyed are you when bad ice quality occurs in an indoor ice rink



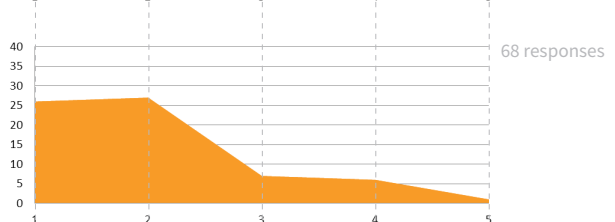
How annoyed are you when there are different light intensity spots on the ice of an indoor ice rink?



How annoyed are you when direct sunlight hits the indoor environment of an ice rink?



How annoyed are you when busy advertisements are placed on the indoor area?



APPENDIX 2: QUESTIONNAIRE NL

Are there other climatic problems you would like to add?

17 responses

- Putten in het ijs, zoals in Den Haag. Allergst.
- Wind en regen moeten geweerd worden op een kunstijsbaan. Hij moet dus voor het grootste gedeelte overdekt zijn.
- Weinig dweilen, veel mensen, mensen die altijd te laat zijn
- Een smalle inrijbaan, geen hometrainers langs de kant, slechte muziek en karige douches (!)
- Natte banken naast de baan door neergeslagen mist en druppels van plafond. Wind!
- Vies ijs doordat er geen goede route voor de zamboni's is
- langszazende treinen, grote trappen
- Wisselende omstandigheden
- Vuil op de baan, blaadjes op de baan.
- Slechte geluidsinstallatie
- Blaadjes/zand op t ijs
- Het niet kunnen horen van het omroepsysteem in de kleedkamers
- Te hoge binnenboarding, waardoor je niet de bocht door kunt kijken (Nijmegen)
- Wisselende ijskwaliteit in een baan die gewoon klimaatbeheersing heeft.
- Zand op de baan, daar waar de zamboni erop/af gaat
- Wind op de baan (Niet direct ergernis, wel hinderlijk voor bijv. wedstrijden)
- Drukte en uitgetrapte bochten. Golvend ijs als de dweilmachine niet genoeg tijd neemt om te dweilen

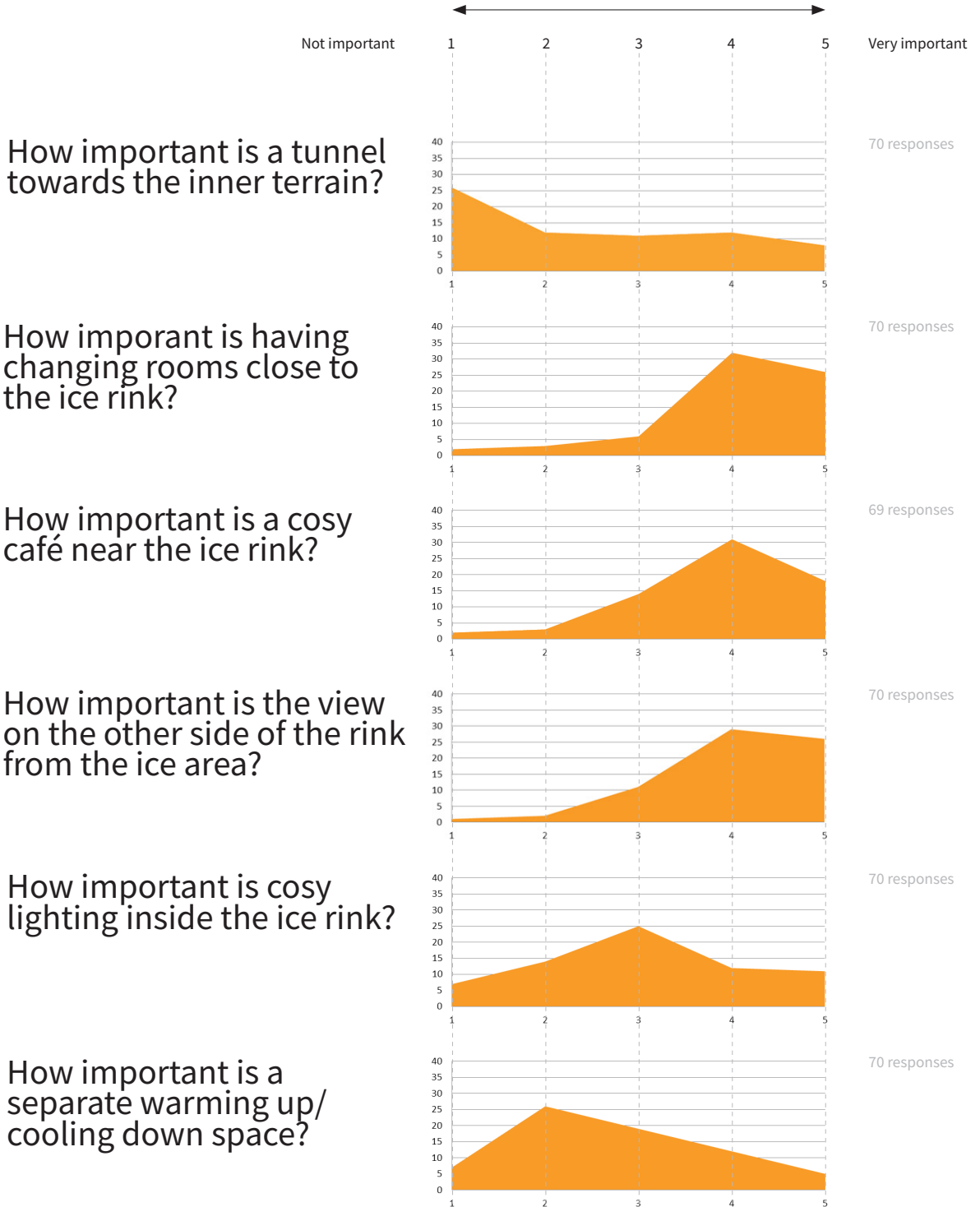
Are there any recommendations/tips for improvements of ice rinks which you would like to mention?

20 responses

- Kwaliteit van het ijs is het belangrijkste van alles, uiterlijk is in mijn ogen ondergeschikt
- Een goede ventilatie in kleedkamers, de meeste zijn heel klam als 1 iemand een douche heeft genomen
- Hoi Eline, komende jaren worden in China een paar honderd schaatsbanen gebouwd. Als je ambitie hebt om die kant op te gaan, dan zou ik een email sturen naar Peter Kolder. Wie weet wat daar uitkomt. <http://www.schaatsen.nl/nieuws/2016/peter-kolder-als-bondscoach-naar-china/> Verder denk ik dat je het cultureel aspect mee moet nemen in je ontwerp en dat is natuurlijk afhankelijk waar de schaatsbaan wordt gebouwd.
- Bij de ijsbanen waar ik vooral geweest ben is er weinig aandacht besteedt aan de kleedkamers en de uitstraling van de kleedkamers en daarbij vaak niet of niet mooi zijn afgewerkt. Hierin zijn nog verbeterpunten.
- Opvouwbaar dak. Buiten is chiller
- Ik zou meer stopcontacten bouwen in kleedkamers en op de tribunes zodat mensen hun telefoon kunnen opladen
- Entree is ook belangrijk, hoe makkelijk je bij de baan kunt komen en de kleedkamers en horeca. Vanuit horeca zicht op volledige baan en Veel plek voor publiek. Krabbelbaan zoals in Den Haag vind ik wel in Eindhoven ontbreken. Ideaal voor verzamelen van trainingsgroepjes. Mogelijkheid tot om de baan rondjes opwarmen. misschien iets doen met vergroten van een ruimte/opstelling om beschermers aan te doen, vaak erg druk an einde van trainingen.
- Onderhoud; zicht naar buiten, alsof je in de natuur schaatst; open constructie.
- Meer lampjes zoals op de Jaap edenbaan is leuk! Verder weet ik dat ik hout mooier vind maar net voor staal heb gekozen bij de plaatjes, blijkbaar spreek ik mezelf tegen.
- Geen witte tent in het midden op de baan zoals op de Uithof
- Beter licht, vooral op foto's wordt het duidelijk dat het vaak te donker is in een hal.
- Dat er geen goedkope horeca bij het krabbelbaantje zit in Den Haag. Zou graag na de training nog ff een biertje of theetje doen
- Veiligheid. Geen palen direct achter de boarding ivm er onderdoor schieten. Ook zijn te kleine kleedkamers vaak een ergernis. Tenslotte is het vaak het niet gebruik maken van de mogelijkheden die er wel zijn. Stukjes afsluiten die er wel zijn en dergelijke
- Fatsoenlijke ijsmeesters
- Ze echt indoor maken
- Een kleedkamer dicht bij het ijs is chill, tenzij je een ware hal hebt (Enschede, Herenveen) dan boeit het echt veel minder.
- Goed zicht over de hele baan. Geen obstakels op middenterrein. Watertappunt op middenterrein.
- Combifunctie zou mogen verbeteren, meer sporters onder 1 dak. bijv. wielervediept op middenterrein? atletiek train mogelijkheden onder tribunes?
Ik denk dat een ijsbaan een metertje breder ook weinig kwaad kan (meer ijs). "
- Geur. In sommige indoor ijsbanen (bijvoorbeeld Erfurt) hangt een nare lucht die op je longen slaat
- Uiteindelijk denk ik dat gezelligheid belangrijker is dan super goed ijs, omdat we het schaatsen moeten verkopen. En dat doe je m.i. beter door een gezellige sfeer op de ijsbaan dan hele snelle tijden.

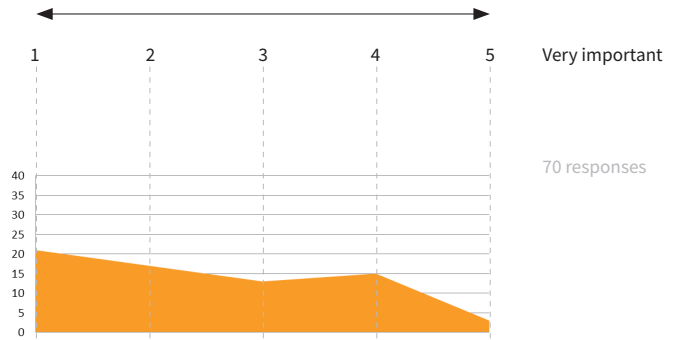
APPENDIX 2: QUESTIONNAIRE NL

IMPORTANCE OF CERTAIN ELEMENTS

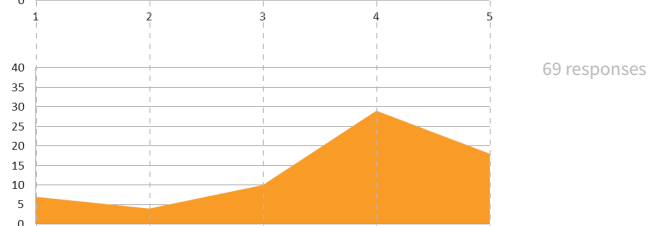


APPENDIX 2: QUESTIONNAIRE NL

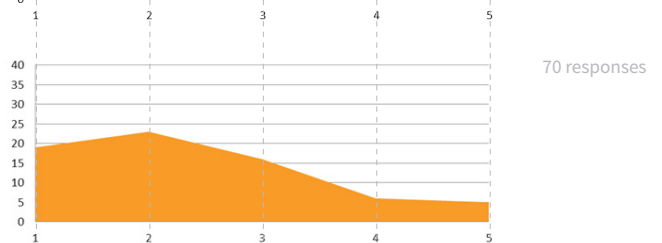
How important is the view on nature from the ice skating area?



How important is view on the ice skating area from the café?



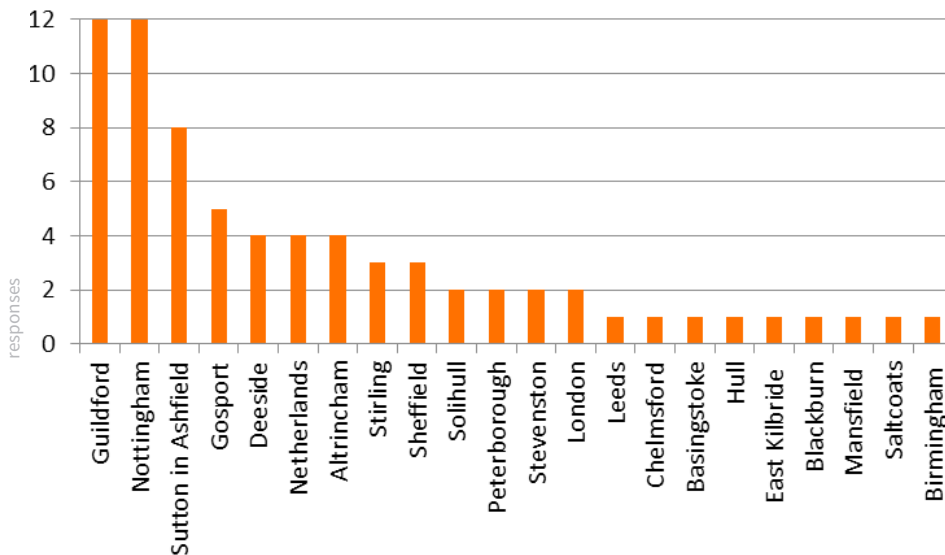
How important is the view from the café towards the outside?



APPENDIX 3: QUESTIONNAIRE UK

To get an overview of what the preferences are of British ice skaters a questionnaire was made by means of Google Forms. This form would be shared by means of the network of Stephen Phil Airey, the Development Manager of UK longtrack of NISA (National Ice Skating Association). For this, a sidenote has to be mentioned. Since we are using a network of a manager who is associated with the longtrack discipline, the distribution of answers would shift towards the longtrack practitioners inside the UK. Therefore, the outcomes of this questionnaire should be taken into perspective. For a lot of preferences of other skate disciplines are not highly represented.

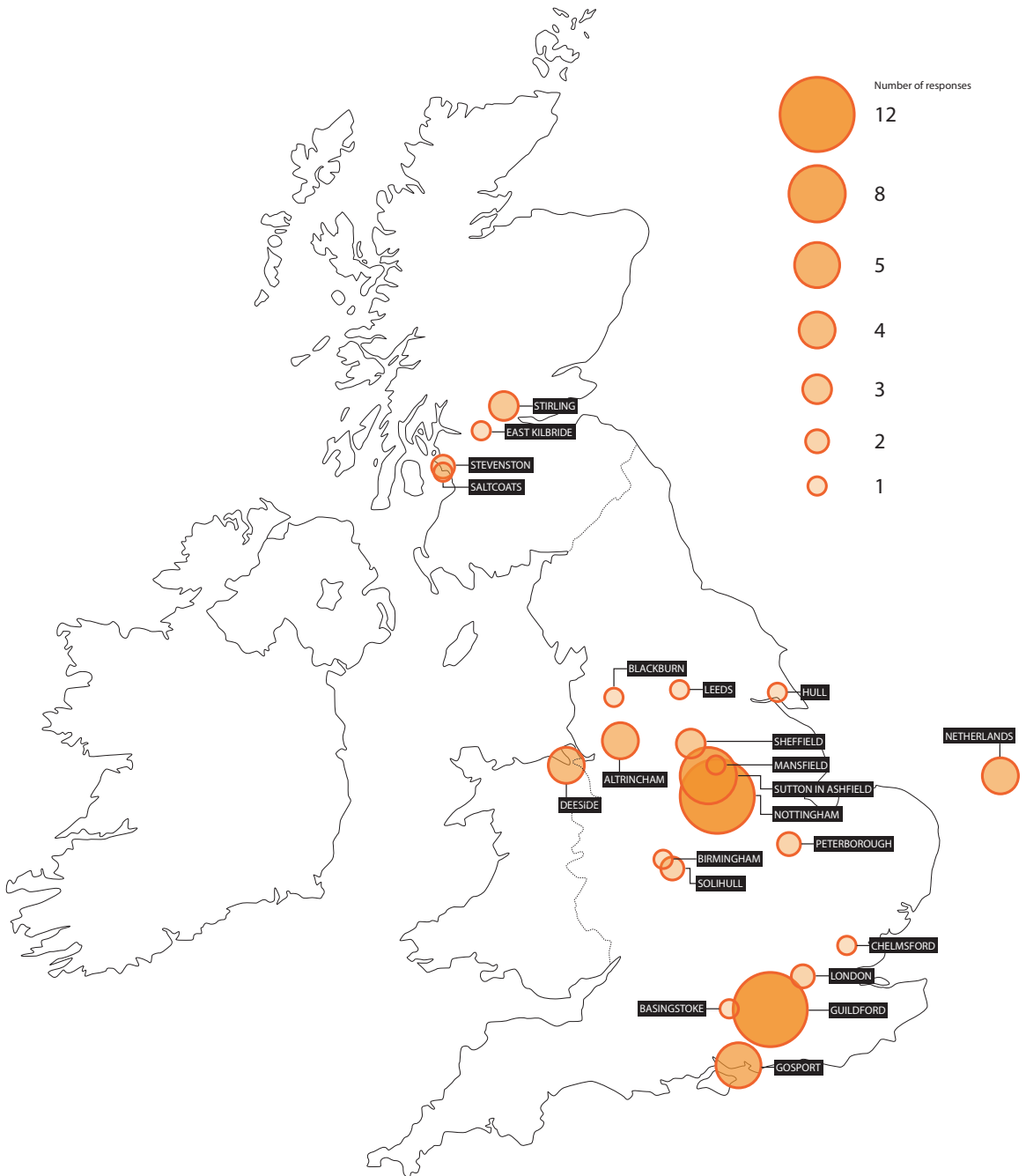
Which ice rink is closest to you? 83 responses



No 400m rink is available in the UK, so skate practice takes place in 30x60m ice rinks, feasible for ice hockey, figure skating and shorttrack. Since these are the only options, an overview of which rinks are used mostly is made.

The screenshot shows a Google Forms interface for a questionnaire titled "Ice skating in the UK". The header includes the TU Delft logo and the text "Ice skating in the UK". The form is currently in the "VRAGEN" (Questions) section, with 83 responses recorded. The first question is "What is the nearest ice rink to your hometown? (name of the city)". Below the question is a text input field labeled "Korte antwoordtekst". The interface also shows navigation icons and a "VERZENDEN" (Send) button.

APPENDIX 3: QUESTIONNAIRE UK



Based on the outcome of the questionnaire, one can say that Guildford, underneath London, and Nottingham are the biggest hotspots where ice skaters are situated.

APPENDIX 3: QUESTIONNAIRE UK

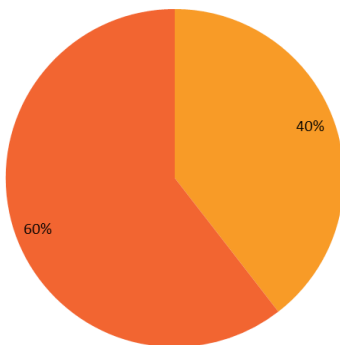
How long do you have to travel to the nearest ice rink?



Most rinks in the UK are accessible in one hour.

Do you recognize an ice rink by its architecture?

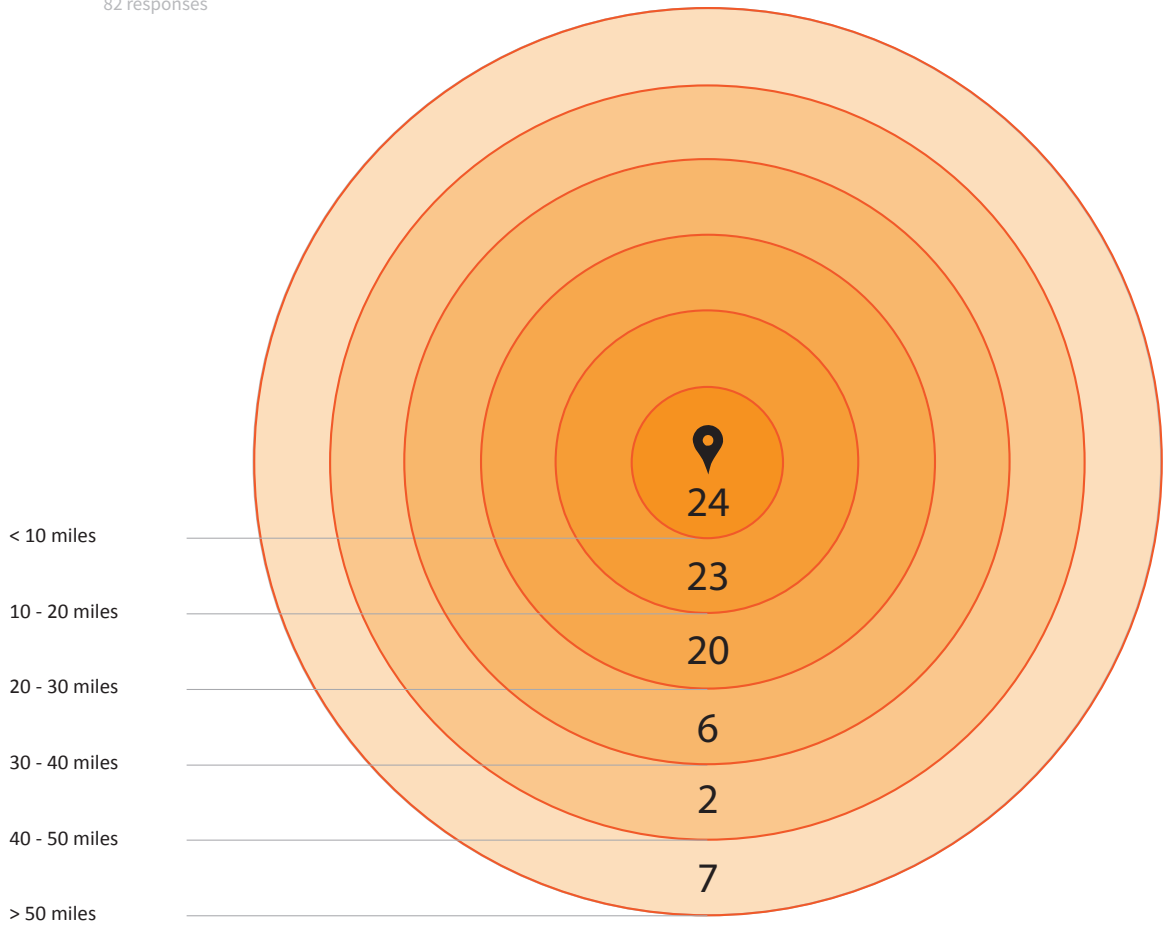
- 81 responses
- Yes, I can see from the outside what the purpose of the building is
 - No, on first sight you don't know what happens inside



APPENDIX 3: QUESTIONNAIRE UK

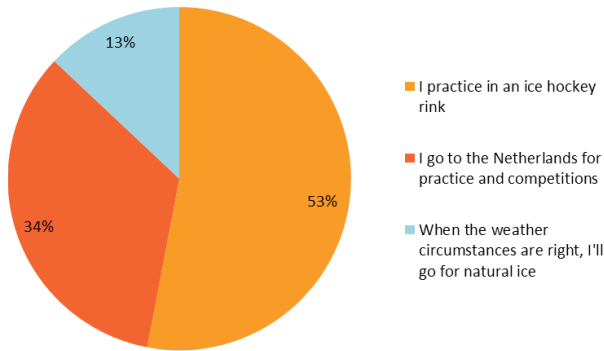
What is the distance you need to travel to this rink?

82 responses

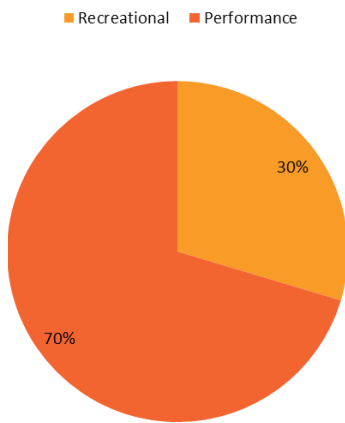


APPENDIX 3: QUESTIONNAIRE UK

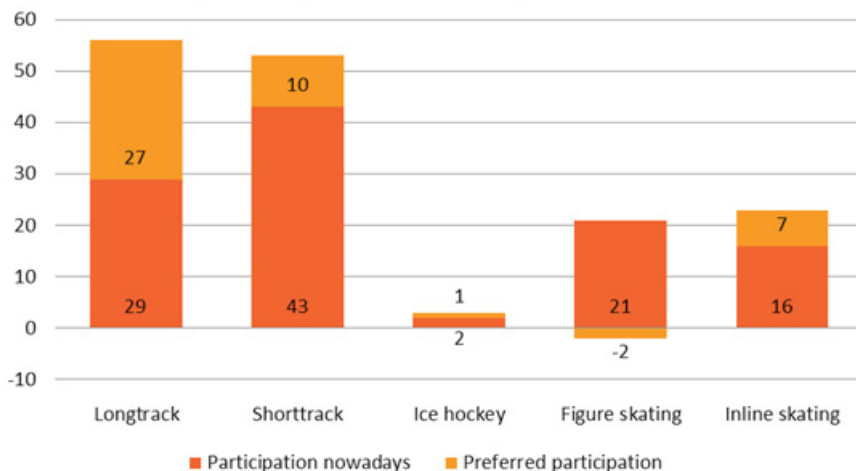
In what situation do you skate? 77 responses



Do you consider yourself a recreational or performance skater? 81 responses



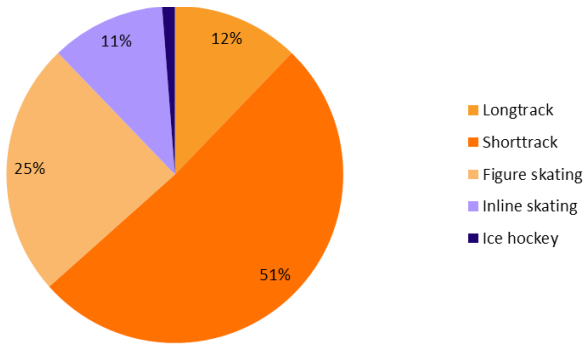
Participation in competitions 80 responses



APPENDIX 3: QUESTIONNAIRE UK

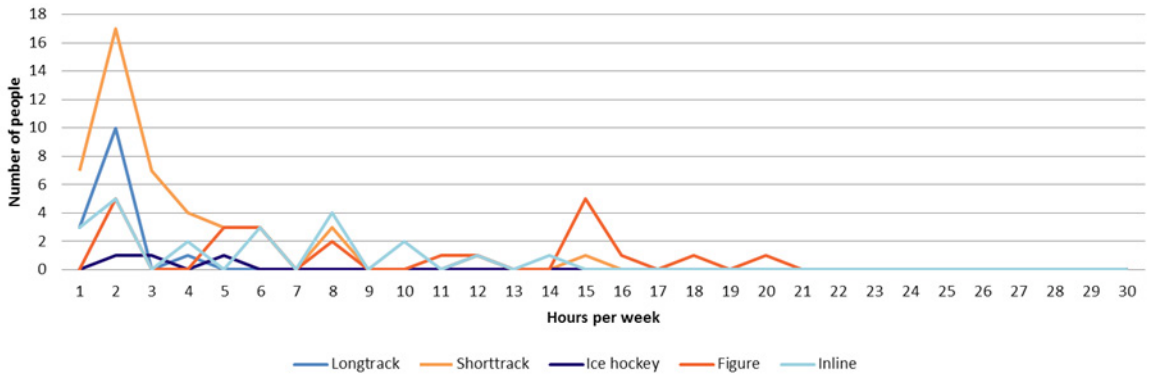
What discipline do you practice the most?

83 responses



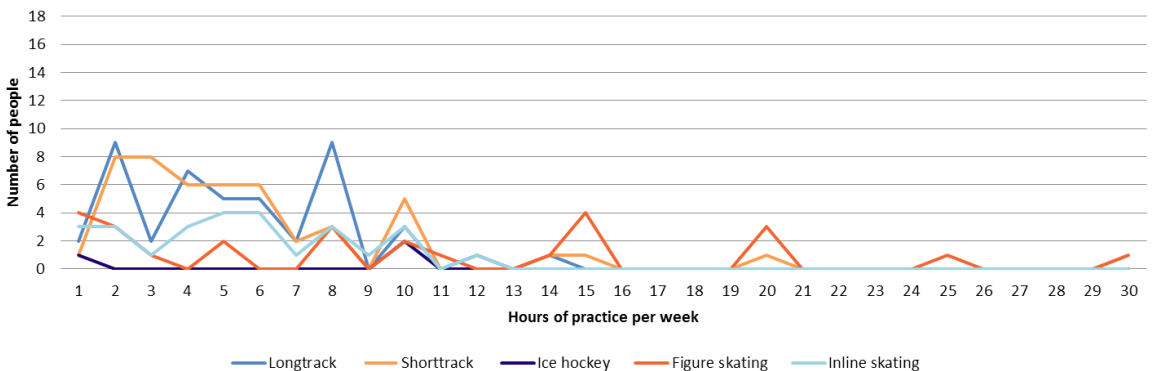
Practiced hours per discipline per week

83 responses



Preferred hours per discipline per week

83 responses

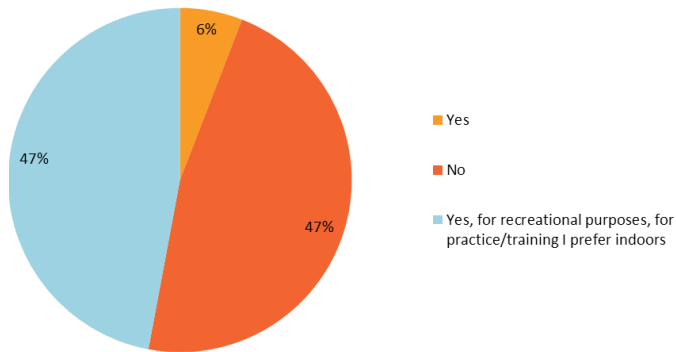


APPENDIX 3: QUESTIONNAIRE UK

PRACTICE ON NATURAL ICE

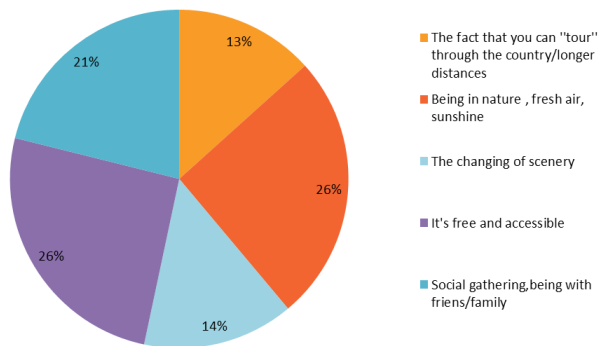
Statement: I prefer natural ice for my skating practice

77 responses



In case of practicing on natural ice, what attract you to these circumstances?

44 responses



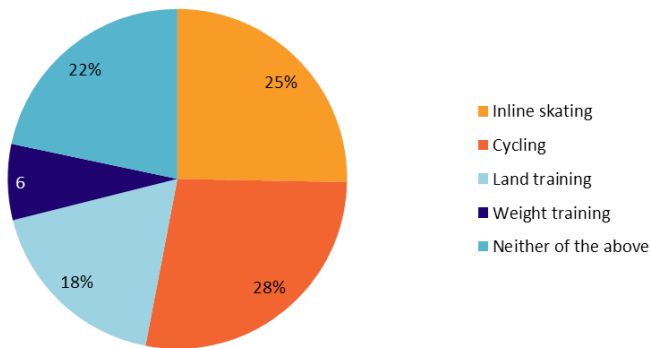
Open answers:

- Would love to try, but never had the conditions since starting longtrack
- i dont skate outside
- The view
- Not available
- I do not have close accessibility
- Social history of fen skating
- There hasn't been a natural ice rink near me
- I have never tried speed skating on ice but it is something i would love to get into if i had the facilities
- Never had the opportunity
- The historical side of what we call "Fen Skating"
- Not available

SUMMER SPORTS

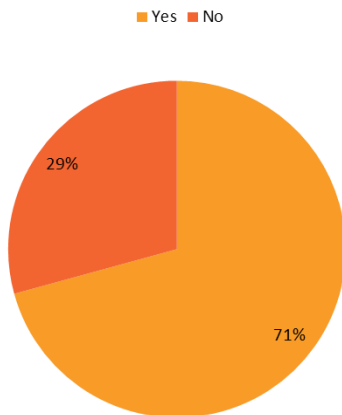
Which skate-related sports do you practice in summer?

83 responses



Would you like to practice these sports at the same place as the ice skating practice?

82 responses

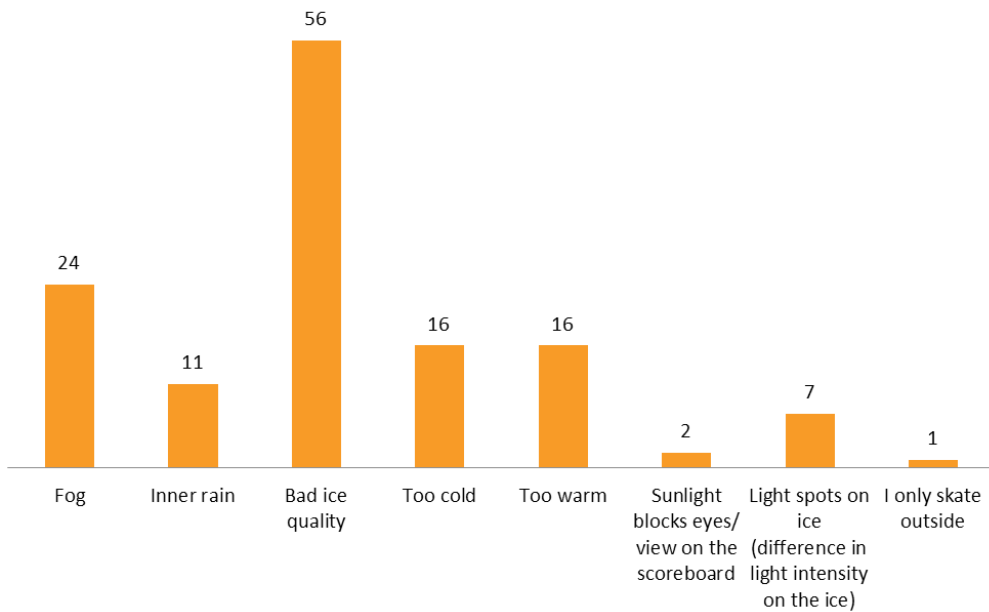


APPENDIX 3: QUESTIONNAIRE UK

INDOOR CIRCUMSTANCES

If you skate indoors, what climatic problems do occur in this facility?

70 responses



Open answers:

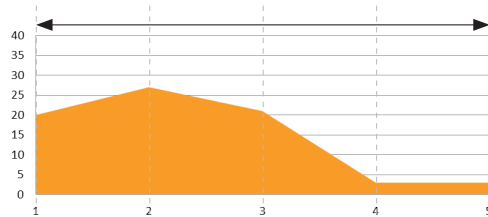
Scoreboard so small you can't see it

I have only skated in inline speed skating tracks

APPENDIX 3: QUESTIONNAIRE UK

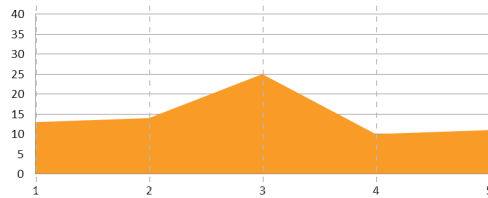
ANNOYANCE INNER CLIMATE

How annoyed are you when fog occurs in an indoor ice rink?



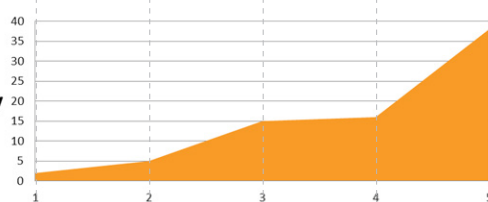
74 responses

How annoyed are you when inner rain occurs in an indoor ice rink?



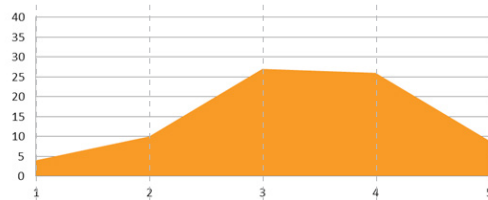
73 responses

How annoyed are you when bad ice quality occurs in an indoor ice rink?



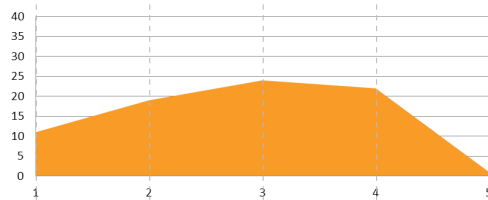
76 responses

How annoyed are you when inner temperature is too high?



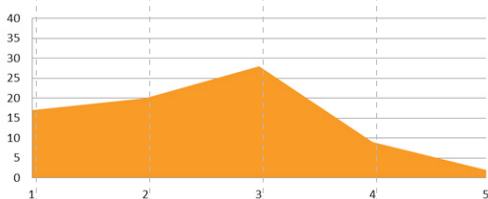
76 responses

How annoyed are you when inner temperature is too low?



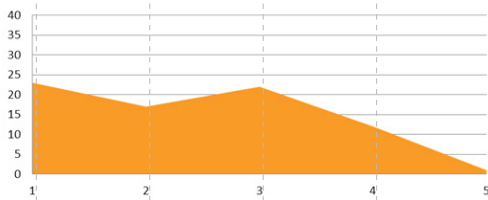
77 responses

How annoyed are you when there are different light intensity spots on the ice of an indoor ice rink?



76 responses

How annoyed are you when direct sunlight hits the indoor environment of an ice rink?



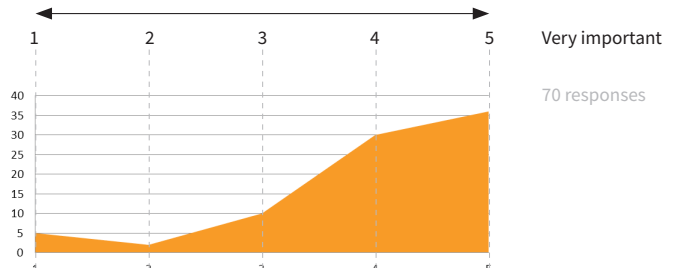
75 responses

APPENDIX 3: QUESTIONNAIRE UK

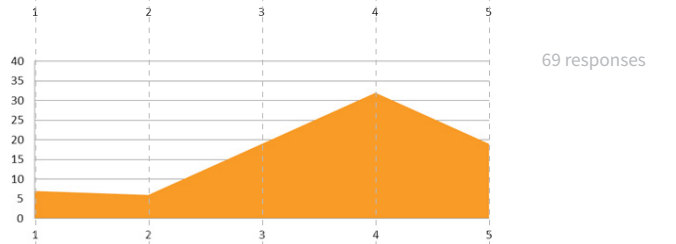
IMPORTANCE OF CERTAIN ELEMENTS

Not important ← 1 2 3 4 5 → Very important

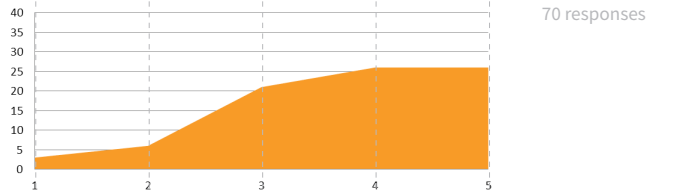
How important is having changing rooms close to the ice rink?



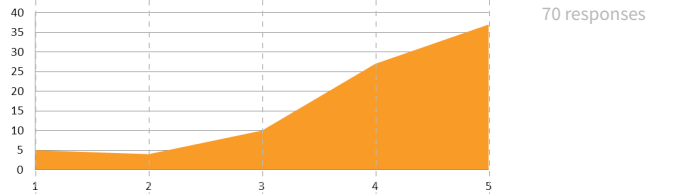
How important is a cosy café near the ice rink?



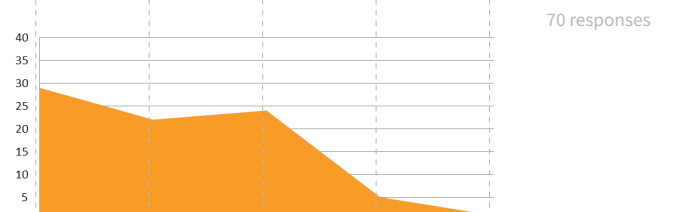
How important is the view on the other side of the rink from the ice area?



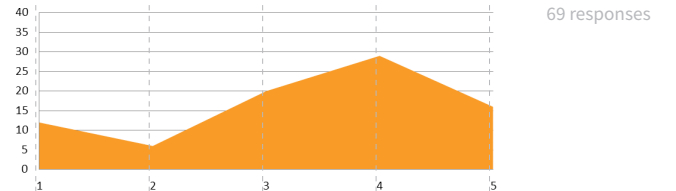
How important is a separate warming up/cooling down space?



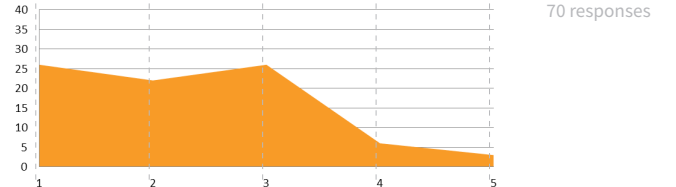
How important is the view on nature from the ice skating area?



How important is view on the ice skating area from the café?



How important is the view from the café towards the outside?

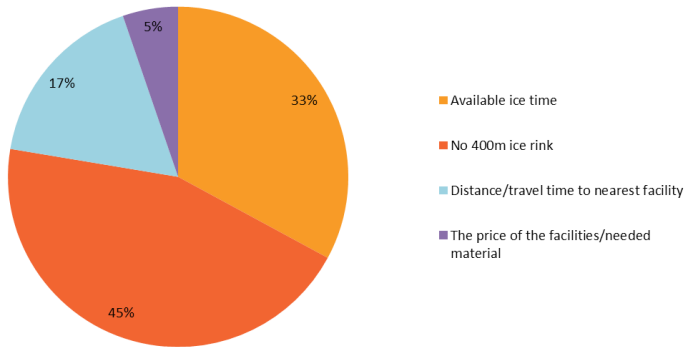


APPENDIX 3: QUESTIONNAIRE UK

PROMOTING THE SPORT

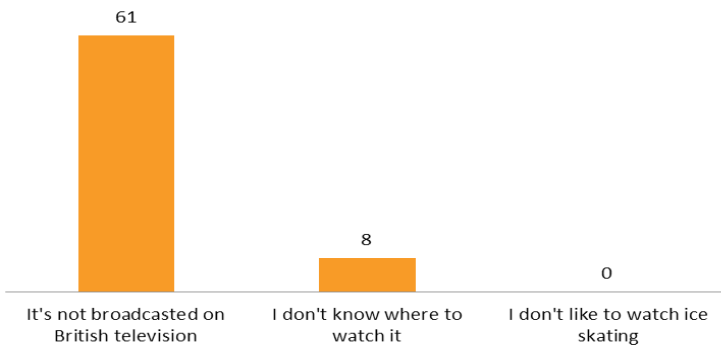
What limits you in practicing your skating?

81 responses



What limits you in watching the ice skating sport on television?

81 responses

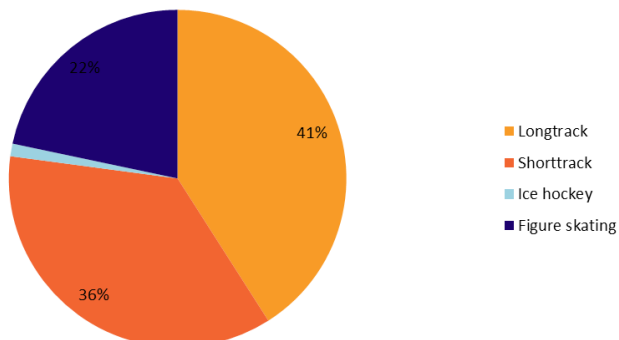


Open answers:

- Rights issues, content not available to geography
- very limited tv time
- No tv license
- It's not on often
- Don't watch television
- Time
- I watch through dutch tv from back home
- Dutch tv
- nthing limits me i watch on comput
- I don't watch TVs

If the possibility is there, in what discipline would you attend a competitions or watch on television?

81 responses



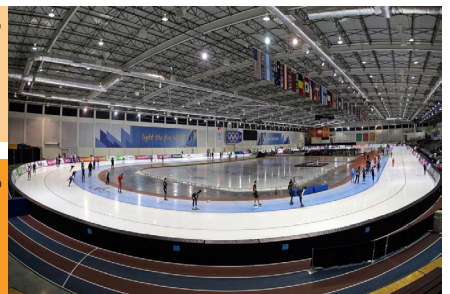
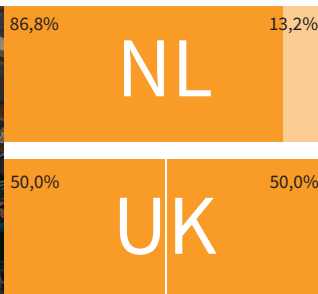
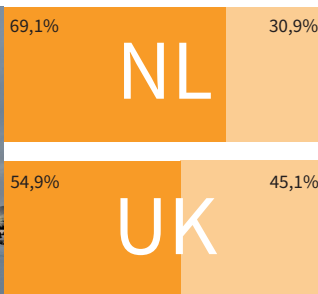
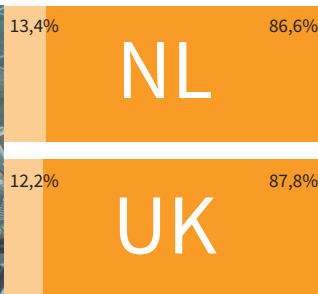
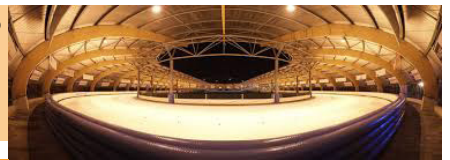
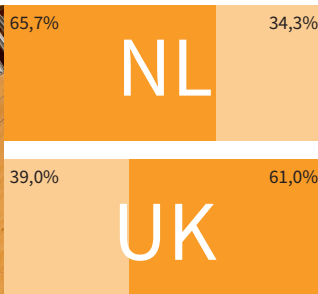
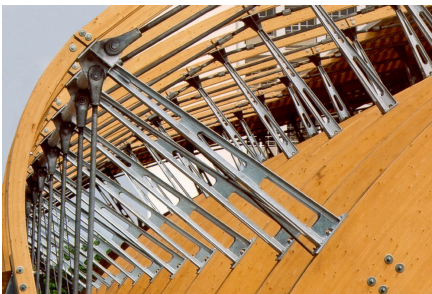
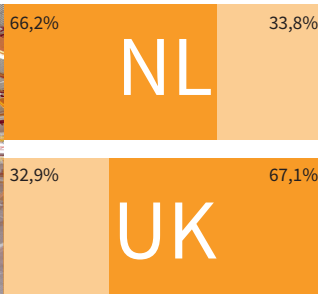
APPENDIX 3: QUESTIONNAIRE UK

What do you think will attract more people to start (ice) skating?

59 responses

- Accessible, sensibly priced skating
- Local rinks with low admission prices
- Promotion of the sport
- Accessibility, proximity to transport and promotion
- More facilities and better promotion with training times that are good for attracting kids (not late night)
- An 400m ice rink with well managed events
- Allowing people to see the sport and letting them know anyone can get involved and have a go. Advertise on competition days for the public to watch races, have training sessions on at the weekends before or after public sessions so people can see what they could do if they wanted.
- Knowledge of the sport and ice availability
- More availability to try it for themselves
- Getting people to see more people inline skating on the roads, streets, school sports grounds, athletic grounds and sport halls, more media exposure, long track ice rink available to public sessions.
- Advertising
- 400 meter track with family facilities
- More promotion
- Awareness of the sport...skating is awesome
- Accessibility, International results/ medals, media coverage/televised competition
- More facilities more coverage of the sport on tv
- Availability of facilities
- Speed skating presented as a fun experience (not so much a sport) for children. We did something like this in the 80's and televised it from the Oxford arena + the Skate Electric series raised the profile of the sport.
- More TV coverage
- More ice rinks
- Local facilities, good pricing
- More ice rinks !!
- The social event
- Availability of the sport
- Publicity of Olympic success
- Ease of access
- Promotion of long track as a fitness activity like running or cycling
- More and cheaper ice rinks. More publicity for the sports.
- More rinks
- Having a nice ice arena for all skating disciplines . And not being to expensive to skate .
- Tv
- Availability of lessons for beginners - there are often long waiting lists for introductory courses.
- Availability of facilities
- More TV coverage, especially the way the World Short Track was done from Rotterdam, a more interactive experience, people who already enjoy skating will watch it anyway, but new comers may need a more "jazzed up" version with a light show and music.
- More Ice rinks
- Team GB winning the world cup, maybe more promotions of clubs.
- more promotion of clubs, the uk being good at iceskating
- More ice time at suitable times of day
- More ice availability
- Tv programs & cheaper pricing
- The Christmas period
- More publicity, better times, reduced cost
- Tv shows
- TV shows ie- Dancing on Ice
- Tv programmes
- Lower cost and better availability
- TV coverage
- Better facilities and being able to do long track in the uk
- Yes
- Publicity of people like Elise Christie
- Availability of tracks
- Good results in comps good media coverage, "come and try times, meet the team"
- Better facilities and more media
- The winter olympics will be a big draw as people will watch the competition and want to get involved. Being able to watch the sport combined With easy access to good facilities will massively increase the number of interested people.
- Broadcasting it on television more
- More ice rinks.
- Long track would need a 400m rink, short track would need more clubs/ice time.
- A proper facility, dedicated time for speed skating and good coaching availability
- government funding and sponsorship and events and more faltcues

APPENDIX 3: QUESTIONNAIRE UK



APPENDIX 3: QUESTIONNAIRE UK

Are there other remarks or recommendations you have on the appearance of an ice rink? (on material or color choice for example)

15 responses

- Quality of and amount of facilities inside are much more important to me than the appearance
- Modern, futuristic, easily accessible good for the environment, self sustaining
- Having an area to stand inside the rink
- Convert a Tesco or similar hyper-market into the ice rink to reduce cost :)
- No, just want a 400m rink in the UK
- Ability to open and close blinds to prevent sun light melting the ice and blinding the skaters. ISU rules dictate that entrance to the ice cannot be over the track so a tunnel must be built; make the tunnel very wide. Calgary's tunnel is small and accidents have occurred. Richmond Oval in Canada is nice and wide ...but they no longer use the building as a long track facility - idiots!
- Modern architecture
- I really don't care what a rink looks like. Cost and longevity are far more important than aesthetics.
- Silly little things that make the whole experience more pleasant, in Hoorn, they have reeds printed on the barrier padding, to give impression of skating in nature, in Deventer they have a big childrens play area in the middle, many of the stadiums in Holland have something more than the 400m ice oval, making more use of the space, and potentially making it easier for families to enjoy spending time in the same building.
- Maybe inspiration from Thialf
- Mirrored sides for figure skaters practice
- Good seats
- Wood is good
- I'd rate quality of the facility than architecture in rinks, though I love Leewarden interior and Inzell generally. But any 400m rink even in an unattractive industrial shed in the UK would make me happy...
- Ice is most important

APPENDIX 3: QUESTIONNAIRE UK

APPENDIX 4: CASE STUDIES



HEERENVEEN

THE NETHERLANDS



THIALF

Building year:	1987
Altitude:	0
World ranking:	3
Architect:	ZJA
Prize:	€54 million (renovation)

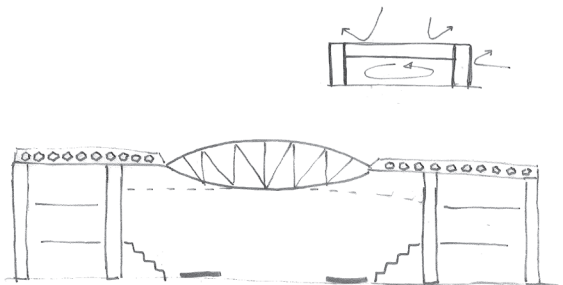
Thialf was the second ice rink worldwide which was provided with a roof in the '80's. Back then it had a comparable construction, which Utah Olympic Oval had 20 years later. It was built with tension rods, which were bearing a "belly shaped" steel truss. Thialf is still the only rink in the Netherland who has a full span construction, which provides full sight from one side to the other of the rink. In 2015-2016 it was renovated over two seasons, firstly the ice sheet and its machinery was replaced. In the second season they build a surrounding "ring" around the existing construction. Which acts like a bufferzone. This should make the inner climate conditions uninfluenced by

the outdoor conditions. The rink is provided with a low-e aluminium ceiling coating. Which lowers the ceiling and therefore lowers the air volume which needs to be heated. Thialf mostly has summer ice as well.

Program:
Ice hockey rink (2x), restaurant, shop/rental, gym/warm up space, physiotherapist, innovationlab.



Image 1: Outdoor appearance



Sketch 1: Construction Principle

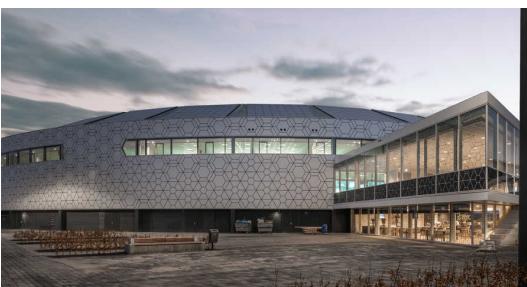
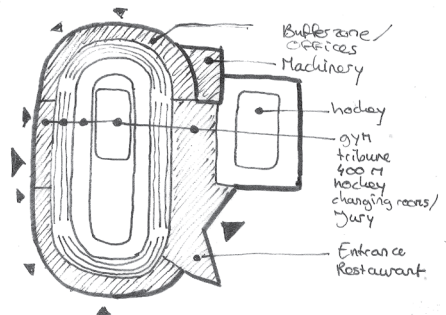
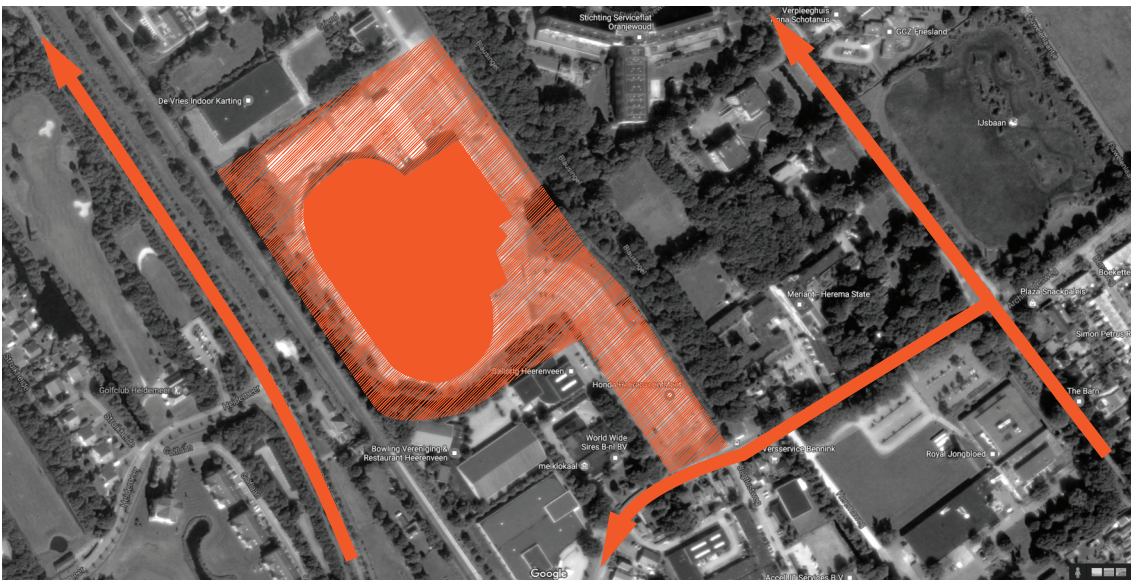


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



UTAH OLYMPIC OVAL



Building year:	2000 (Olympics 2002)
Altitude:	1425m
World ranking:	1
Architect:	GSBS Architects and Cannon Design
Prize:	€27,9 million
Audience places:	6500 (now: 3000)

Since it has been built in 2000, for the 2002 Olympics, Utah Olympic Oval holds all world records. It is the fastest rink, due to its high altitude. The rink is still a popular competition facility, because of its fast reputation.

With the construction design Salt Lake City saved a lot of energy, since they constructed as a suspension bridge. In this way, the dimensions of the materials needed were minimal. "Between twenty-four masts, twelve on each side of the building, steel cables nearly 400 feet (120 m) long and 3.5 inches (89 mm) in diameter were strung, suspending the roof above the oval".

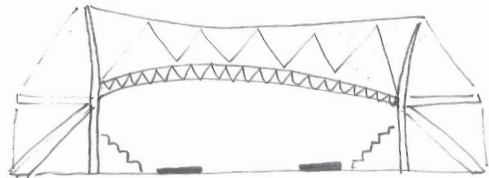
The tribunes used at the Olympics were later removed. They were replaced by a running track, completely surrounding the 400m ice rink.

The building is completely focused on the ice skating sport. During summer the ice is still provided.

Program:
Ice hockey rink, gym, shop/rental



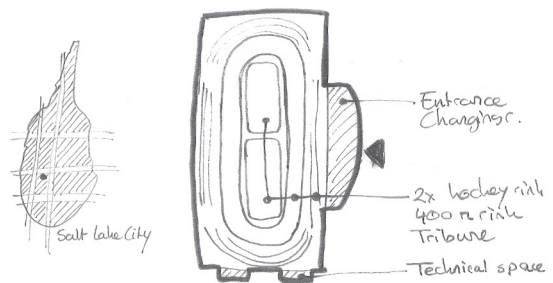
Image 1: Outdoor appearance



Sketch 1: Construction Principle

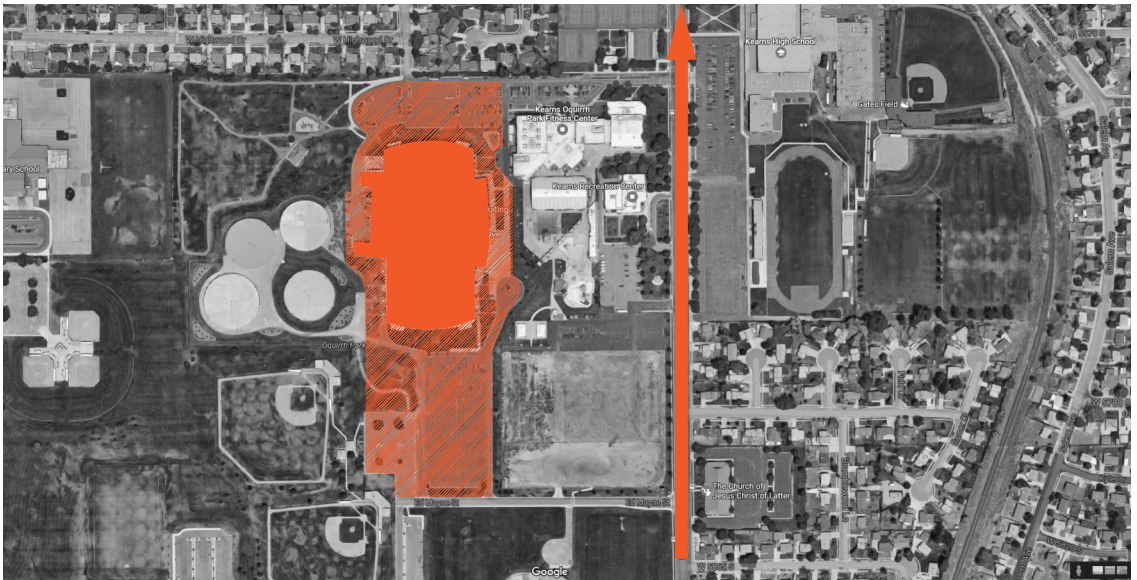
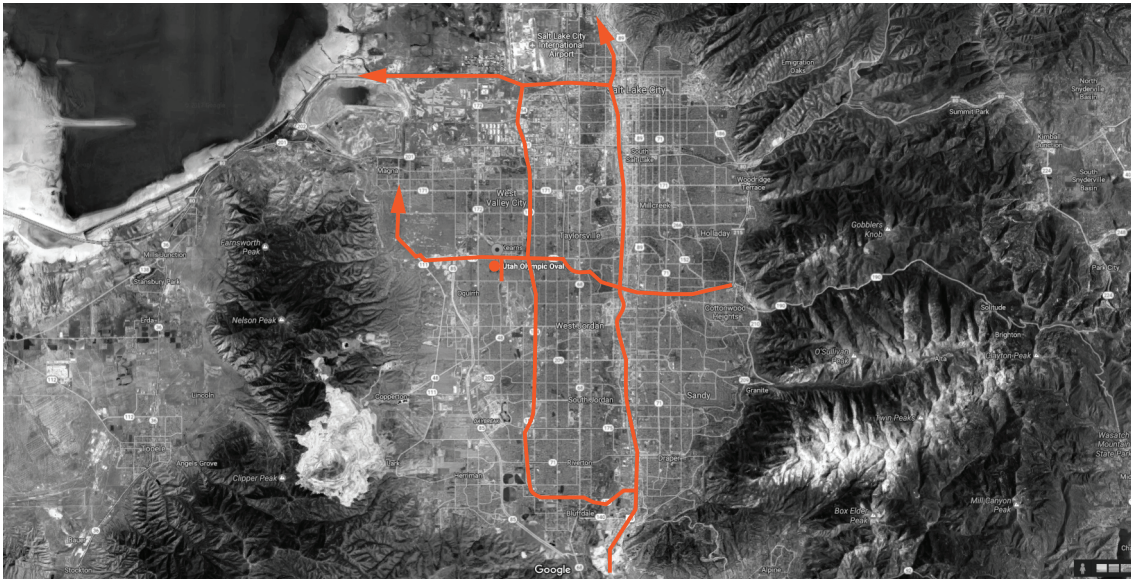


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



VIKINGSKIPET



Owens its name to its shape, which is designed like a turned viking ship. In its time it was the largest sport venue in the world. It is still the national venue of Norway for all important competitions to take place.

The bearing construction of the roof is made from timber trusses, finished with metal plates. The trusses rest on a triangular shaped concrete base, which functions as the "foot" of the bearing construction, and is directly connected to the foundation. Quite remarkable for this construction is the longitudinal timber beams. Which all trusses in one line. The roof has,

Building year:	1990-1992 (Olympics 1994)
Altitude:	125m
World ranking:	6
Architect:	Niels Torp and Biørg & Biørg
Prize:	€25,6 million
Audience places:	2000 seats (10.600 with standing places)

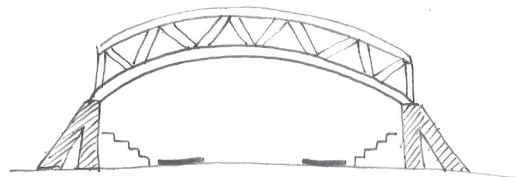
in the longitudinal direction, roofwindows, in line where the relief of the viking ship would be. The daylight entrance it creates is acceptable during broadcasting events.

The hall is used in summer for markets, concerts and other sport events.

Program:
Restaurant, store, ice hockey rink.



Image 1: Outdoor appearance



Sketch 1: Construction Principle

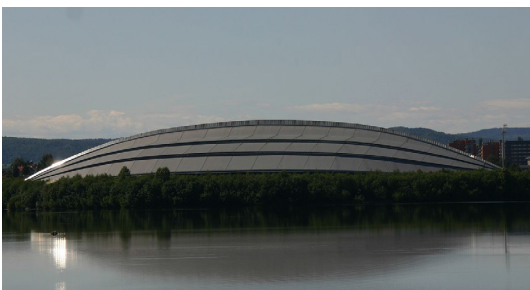
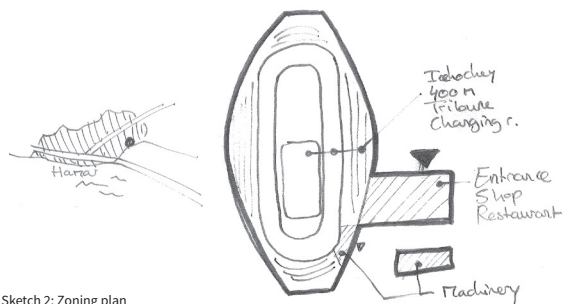


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



ALAU ICE PALACE

Building year:	2007-2011
Altitude:	348 m
World ranking:	10
Architect:	VL Architects/Bertus Butter
Prize:	-
Audience places:	8000

The first oval ice rink in Kazakhstan, the second ice rink, Medeo, an outdoor ice rink high in the mountains was the first. It is seen as the younger brother of the rink in Kolonna, Russia. Also this rink has the recognizable aluminium low-emissivity layer applied, which is applied in every "new generation ice rink". The technical aspects were designed by Bertus Butter, who let the architect do the esthetical part. In its tribune lay out, it is even bigger than kolonna, since it has seats on both side of the ice rink. Of all ice rinks, this rink has the most seats.

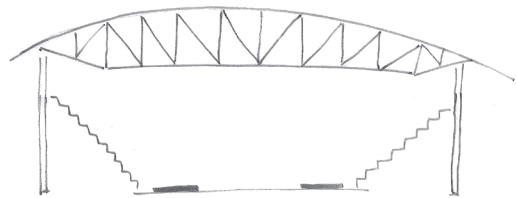
The construction consists of steel columns, which bears a steel truss. This is not visible due to the aluminium layer applied at the ceiling.

Also, the world judo championships were organised in this venue.

Program:
Fitness space, hotel, ice hockey rink, restaurant



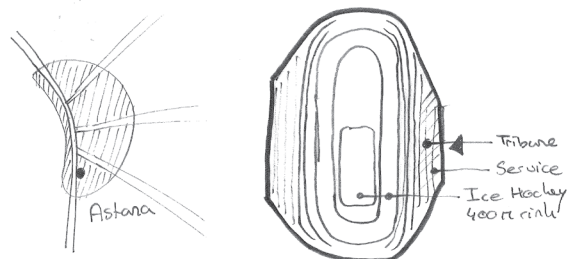
Image 1: Outdoor appearance



Sketch 1: Construction Principle

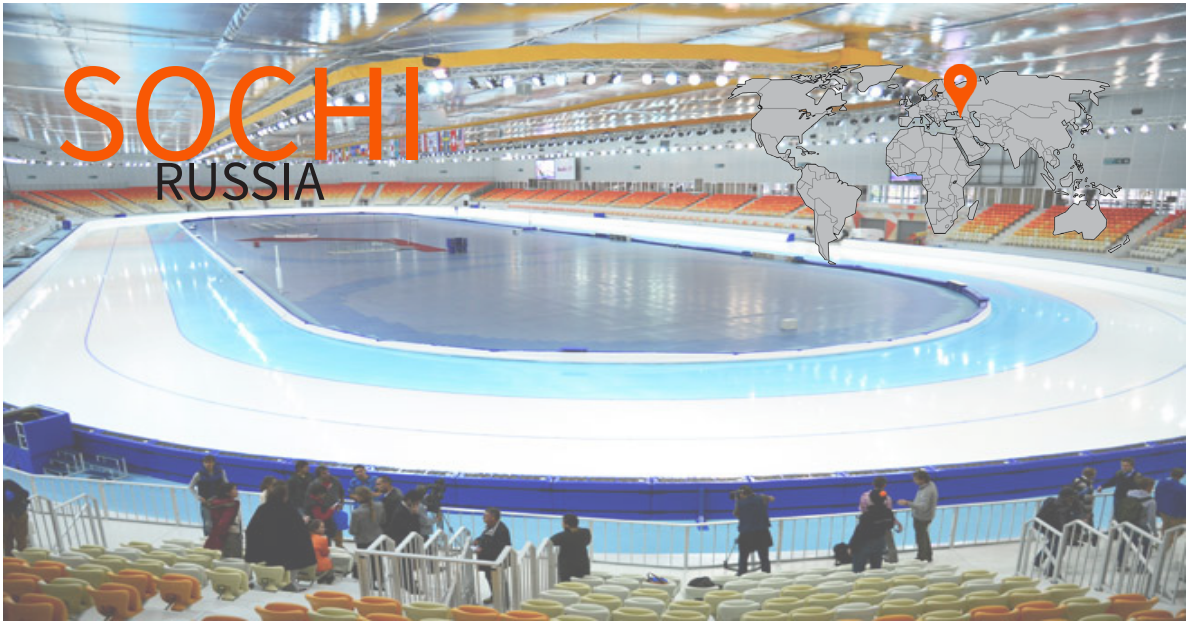


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



ADLER ARENA



Build for the 2014 Olympics the Adler Arena was the most expensive ice rink ever build. It exceeded 2,4 times its budget. Overall, the Olympic Games of 2014 were the most expensive wintergames.

“A crystal face theme is supported by angular walls and triangular stained-glass windows. The gray and white color of the building enhances this impression. The walls along the sides of the skating rink are made transparent so that spectators can look outside. The skating center is designed to make the utmost use of local natural features”.

Building year:	2012 (Olympics 2014)
Altitude:	5m
World ranking:	4
Architect:	Robert J. Johnston (Cannon Design), JSA Sport, Bertus Butter
Prize:	€211,3 million
Audience places:	8000 seats

At the moment the 400 rink has been removed. What functions the building will be hosting next is unclear.

Program:
Restaurant, ice hockey rink

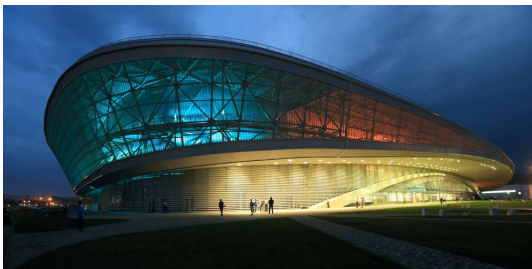
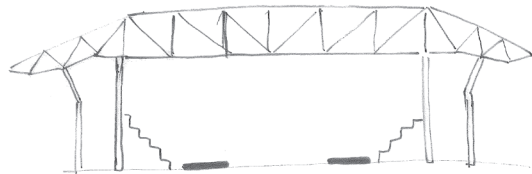


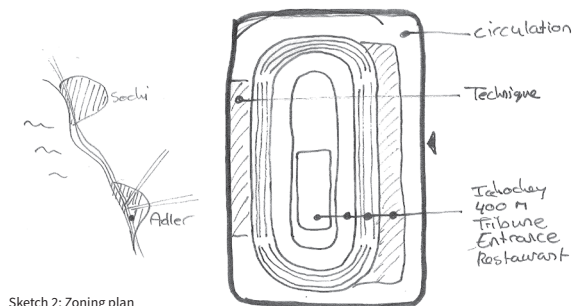
Image 1: Outdoor appearance



Sketch 1: Construction Principle



Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



KOLOMNA

RUSSIA

KOMETA

Building year:	2006
Altitude:	120 m
World ranking:	7
Architect:	Nodar Kantcheliya/ Boris Shavyrin/ Bertus Butter
Prize:	€150 million
Audience places:	6150 seats

Kometa was the third indoor ice rink in Russia. Is about an hour travelling from Moskou. Previously this location was housing a outdoor ice rink with natural ice. This was transformed into an indoor ice rink in 2006. This was the first “new generation” ice rinks, designed by Bertus Butter, later on Astana and Sochi would be added to this list.

with aluminium low-emissive coating. The Russian rink is not informative on its construction, there are no publications about its building process.

Program:
Swimming pool, ice hockey rink, gym and warming up space.

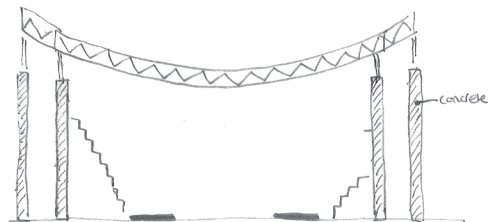
The construction is made from steel columns and beams. The columns are mostly covered with concrete, the roof construction is completely covered



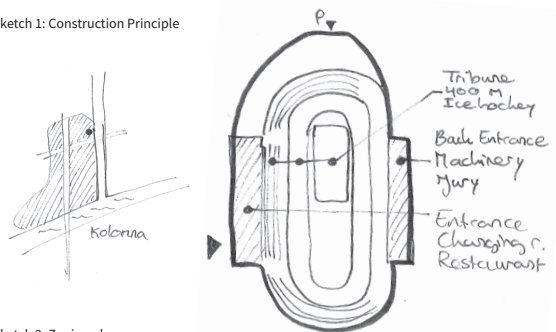
Image 1: Outdoor appearance



Image 2: Impression

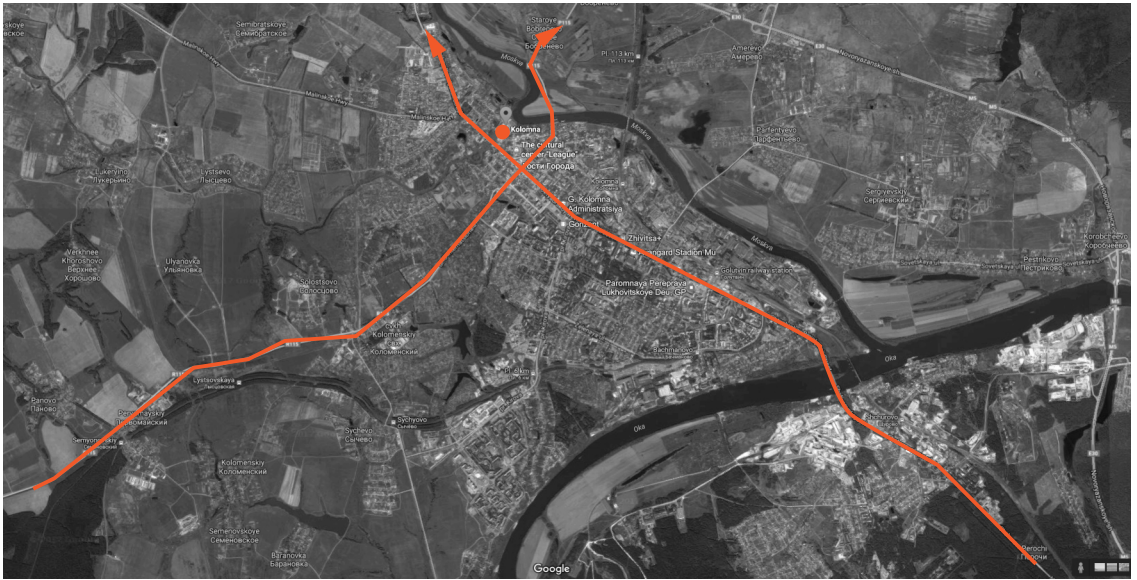


Sketch 1: Construction Principle



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



NAGANO JAPAN

M-Wave



M-wave, owing its name to its shape, which represents the mountain ranges of that area. It was built for the 1998 Olympics. The construction can be described as a steel framed ceiling, which is supported by reinforced concrete. In the vertical direction is one construction plane completely beared with pressure force. The outer construction plane is partly bearing a tensive force. The ceiling is “hanging”, and has the shape of its own momentum. The ceiling is finished with Japanese Larch. As a lot of Olympic ovals, it was made with a multifunctional purpose. The ice layer could be removed, to make place for tennis rinks, or pingpong

http://www.nagano-mwave.co.jp/m_wave/language/en.php
<http://www.shinmal.co.jp/feature/oly-eng/kaijo/m-wave.htm>

Building year:	1996, for the 1998 Olympics
Altitude:	342 m
World ranking:	11
Architect:	Kajima Design, Kume, Kajima, Okumura, Nissan, Iijima, Takagi Design Joint Venture
Prize:	33,7 billion yen, €278 million
Spectator places:	6500 seats, 10.000 during the Olympics

tournaments, trade fairs or large scale shows. During the Olympics the rink contained only a 400 m ice layer and a 30x60 ice hockey rink. The structure is known for its high ceiling, which is guaranteeing that every function is possible inside its hall.

Current program:
 During winter it's still an ice rink, during summer it is a multifunctional entertainment venue.

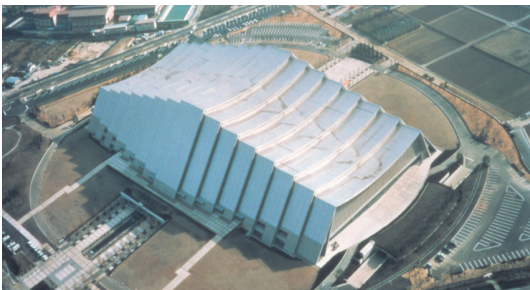


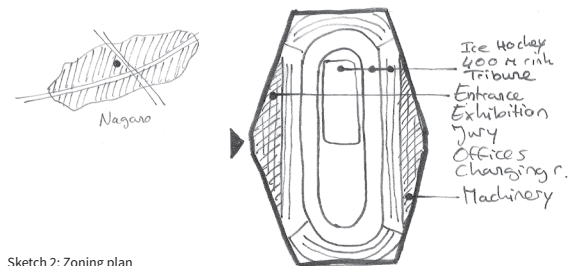
Image 1: Outdoor appearance



Sketch 1: Construction Principle

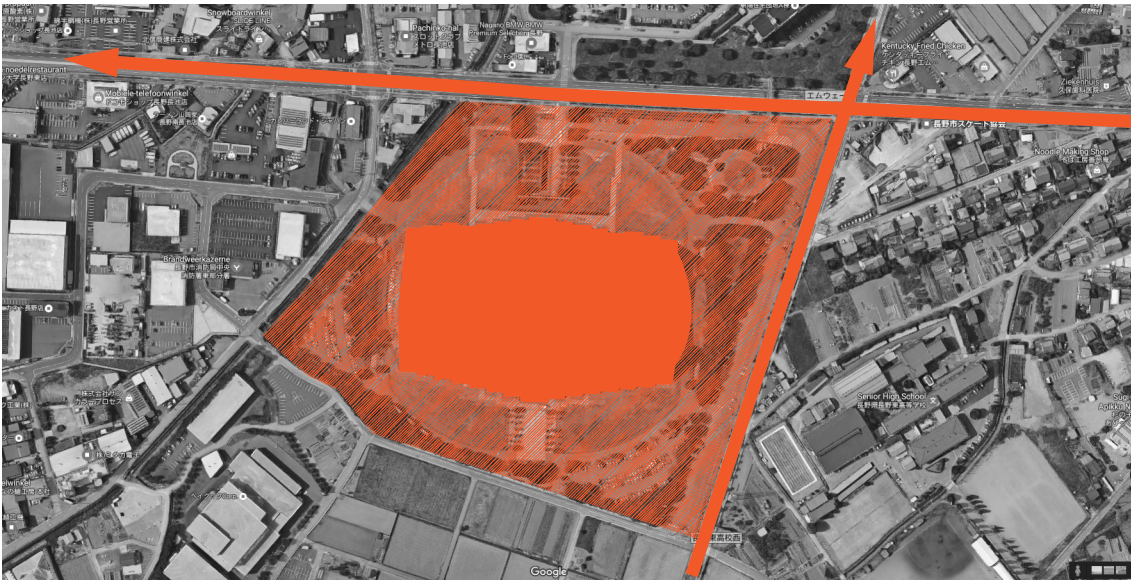


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



VANCOUVER CANADA

RICHMOND OLYMPIC OVAL



Like a lot of Olympic ovals, Richmond was only build to suffice in the Olympic winter Games. It was build 2 years before the event, to provide the local citizens a chance to try long track speed skating.

The construction was made in a way, that the ventilation was integrated in the bearing beams, as well as a drainage system. Which let the water outside of the building. The wooden trusses are made from pine wood, which makes this in 100x200 meter surface the largest building covered with pine wood in the world.

In the floorplan the overall function change was already visible. Instead

Building year:	2008, for 2010 Olympics
Altitude:	4m
World ranking:	14
Architect:	CannonDesign
Prize:	\$178 million Cdn, €127 million
Audience places:	

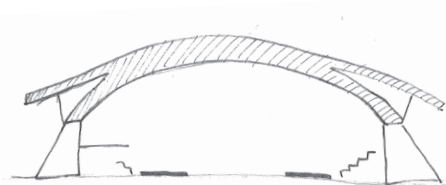
of choosing for a oval shape, the architect decided to make a rectangular floorplan to guarantee flexibility in the years to come. Also, the floor is made of concrete, which was made that it had enough strength to bear different functions.

The building is now used for ice hockey events, (table)tennis competitions, markets, symposia etc.

Program nowadays:
multifunctional sport complex with 2x ice hockey rinks, basketball fields, climbing wall, waterbath to practice rowing.



Image 1: Outdoor appearance



Sketch 1: Construction Principle

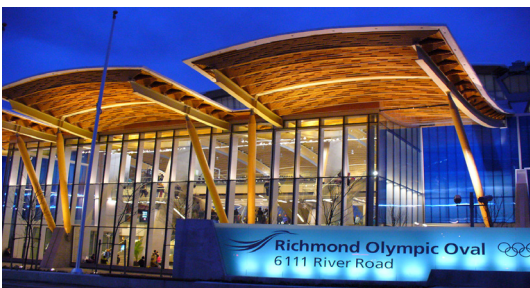
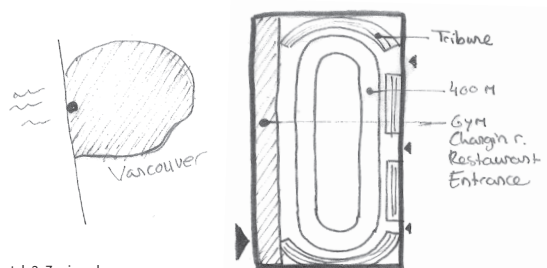


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



OLYMPIC OVAL



Building year:	1987, for 1988 Olympics
Altitude:	1034
World ranking:	2
Architect:	Graham – McCourt
Prize:	\$38.9 million cdn, €27,7 million

Since the rink is built, one season before the Winter Olympics of 1988, it was the fastest ice worldwide. It held its status until Salt Lake City built its oval even 400 m higher in altitude, which brought a lot of air pressure advantages. But it is said to be a more stable ice rink, with faster ice on a daily basis.

The rink is half sunken into the ground. It is surrounded by a continuing layer of glass. The roof won several design awards and has, unlike other rinks, a construction which has a three dimensional grid. Which is why the section of the construction is drawn in a three dimensional way. It contains a rhom-

bush shaped grid, these rhombuses are divided in two, which eventually makes a triangular shaped roof, as shown below. Until this day Calgary is still the second rink on track times ranking.

Program: 2x hockey rinks, changing rooms, gym, running track, half of the 400 m track has a tribune (only in the corners).

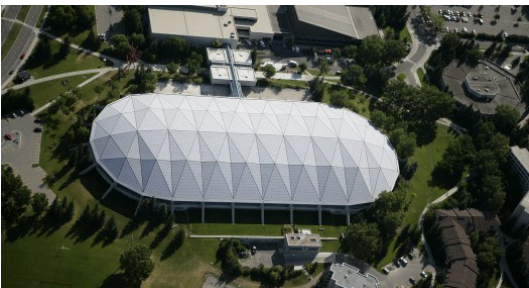
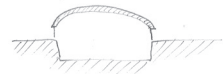
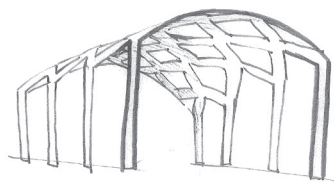


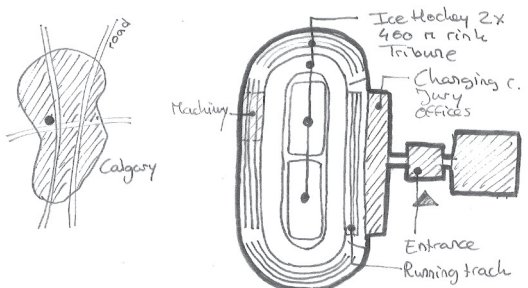
Image 1: Outdoor appearance



Sketch 1: Construction Principle

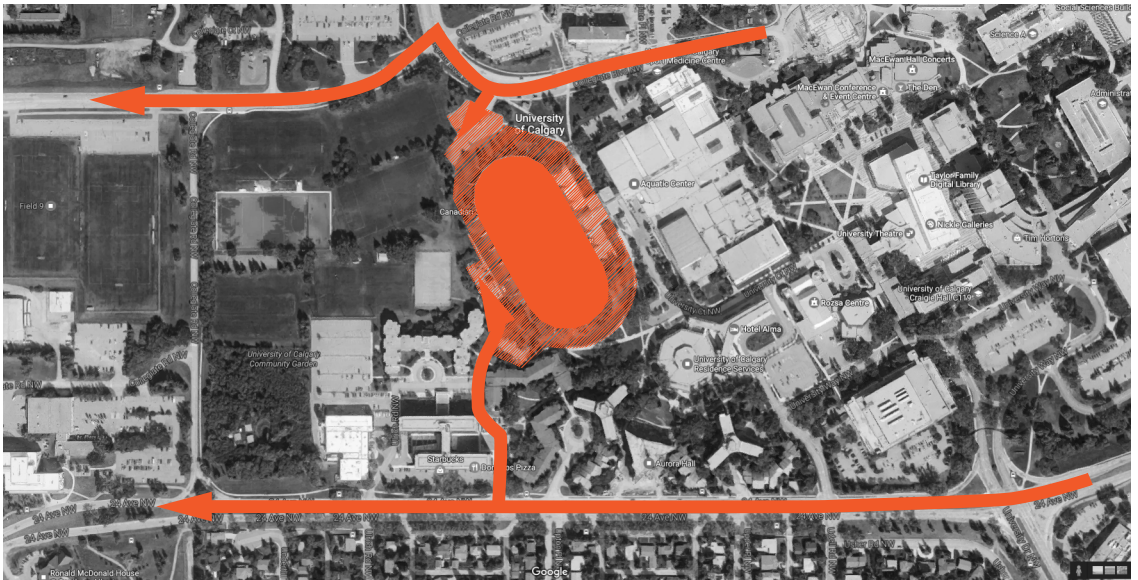
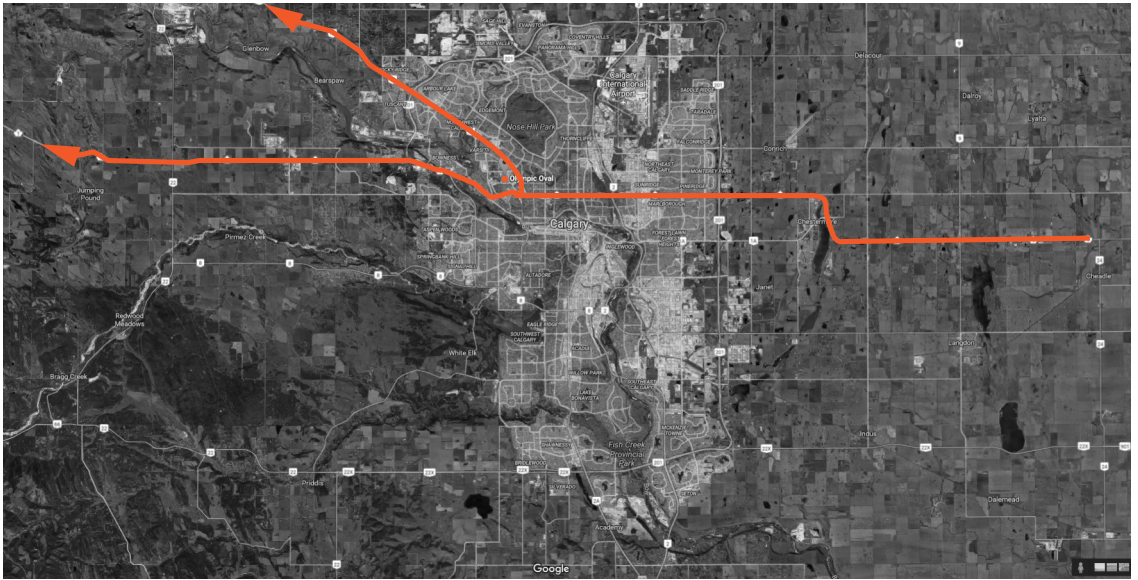


Image 2: Impression



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 4: CASE STUDIES



MAX AICHER ARENA

Building year:	2011
Altitude:	691 m
World ranking:	5
Architect:	Behnisch architekten & Pohl architekten
Prize:	€36 million
Spectator places:	7000 seats

The span of 82,5 meter was made with wooden trusses, made from trees directly in the environment of the ice rink. The trusses have a distance towards each other of 12,65 m, connected with secondary beams. The roof construction is beared by 40 concrete columns. The trusses are cantilevered slightly over these columns, to bring the impression of a "floating" roof. The roof has been finished with a 3mm thick foil placed on the secondary construction. Half of the wooden truss form a hole to provide daylight in the ice rink. The wooden trusses have a steel beam underneath, which is made to bear the tension of the roof structure. Between this steel beam and the wooden truss is a triangle truss structure of steel beams. The inner ceiling is covered with a low-e foil, connected between the steel trusses and the holes of the wooden trusses. The sheet also provides better acoustics in the ice rink and reflects the cold

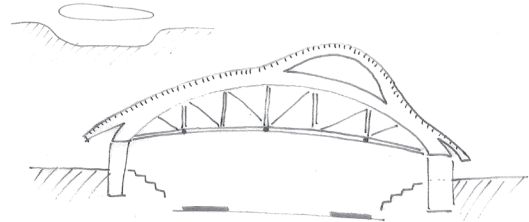
of the ice sheet. Two architectural firms worked together with these requirements: the rink must have the fastest ice in the world, the new construction should cover the rink without completely sealing it. The panorama sight of the environment should be kept. To lower the energy demand the rink has been granted a climatic air system in which the tribune and the ice area have two separate ventilation systems. An "air" curtain prevents the warm humid air from the spectators to flow towards the ice area. The daylight comes in through these 17 "sheds" (Berends, 2011). But only from the north direction. This daylight needs to have the perception of skating outside. (Fuchs, 2011) Interesting fact is that, to heat their inner air, the arena makes use of a wood burning kettle.



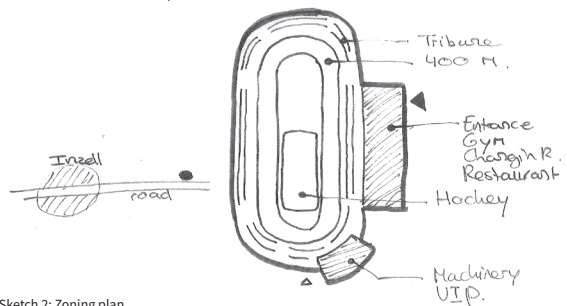
Image 1: Outdoor appearance



Image 2: Impression

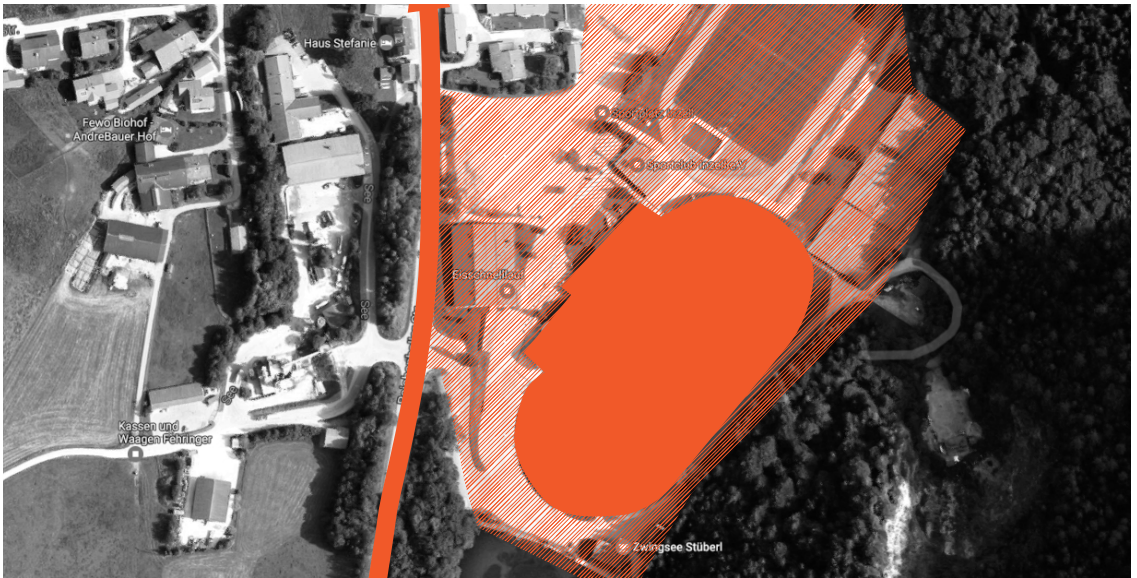


Sketch 1: Construction Principle



Sketch 2: Zoning plan

APPENDIX 4: CASE STUDIES



APPENDIX 5: FLOORPLAN ANALYSIS

TRAFFIC ZONE

Ireen Wüst IJsbaan:

6323,5 m²

Max Aicher Arena:

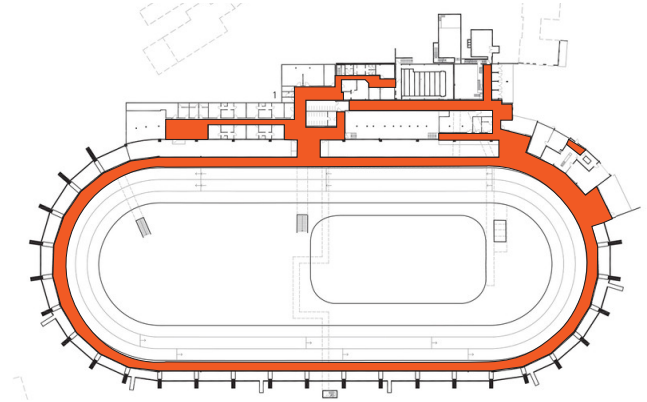
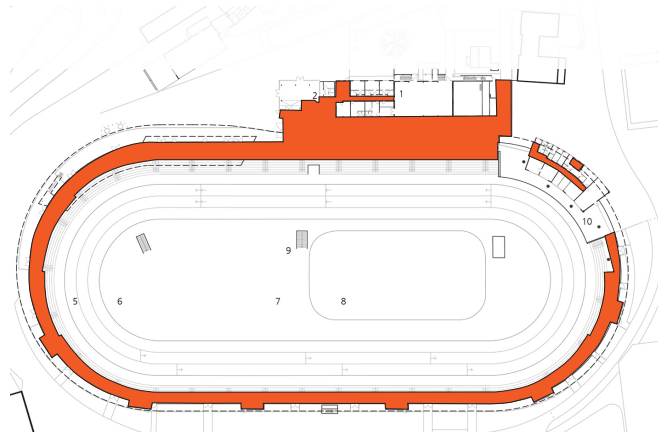
5787,9 m²

Thialf:

4865,5 m²

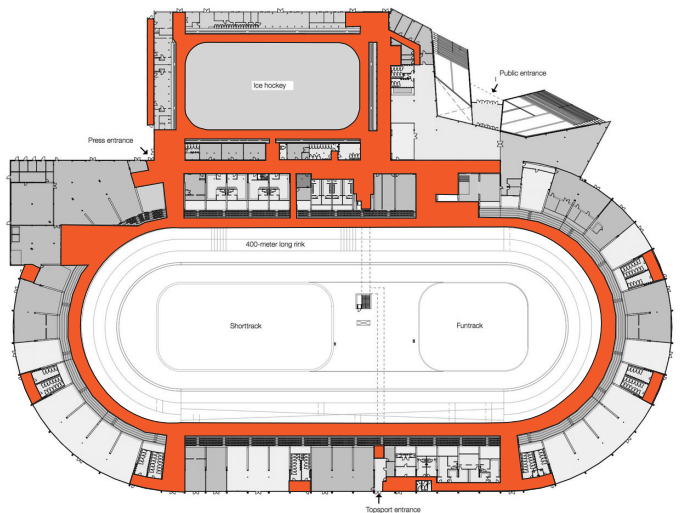
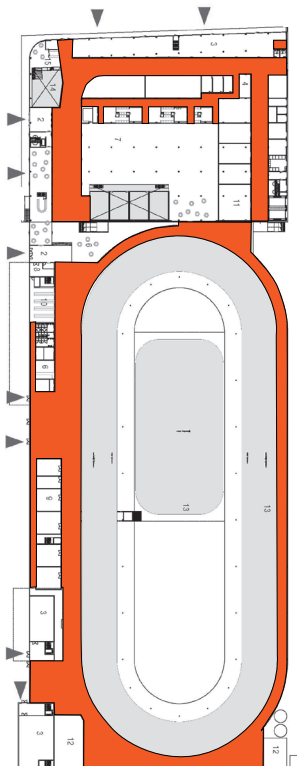
Average:

5658,9 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Ireen Wüst IJsbaan (Sportcomplex T-Kwadrant), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

ENTRANCE

Ireen Wüst IJsbaan:

146,2 m²

Max Aicher Arena:

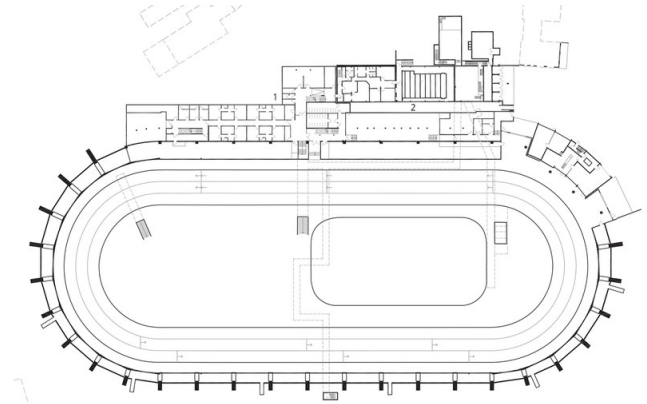
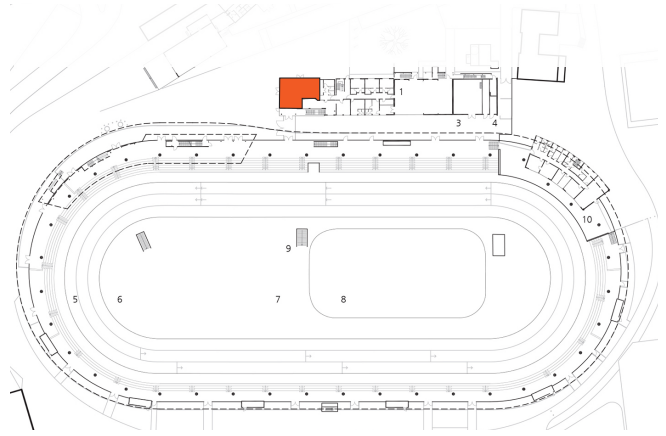
124,1 m²

Thialf:

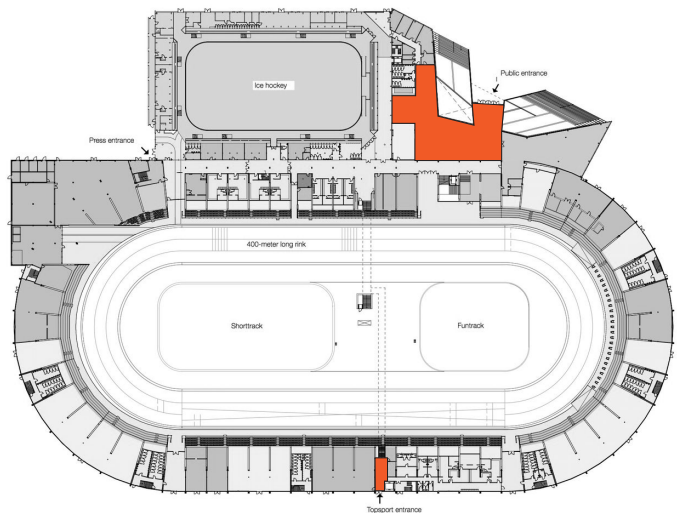
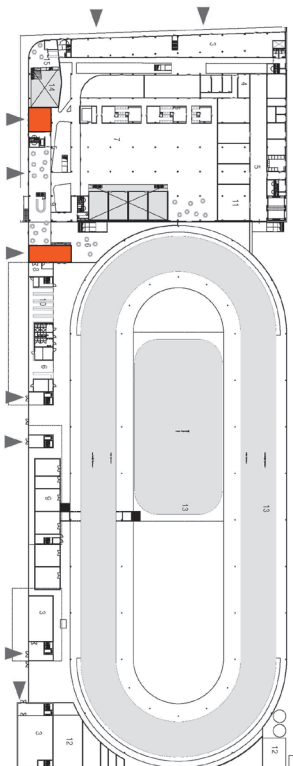
730,9 m²

Average:

333,8 m²



Max Aicher Arena, Inzell, Germany
Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

RENTAL SHOP

Ireen Wüst IJsbaan:

70,8 m²

Max Aicher Arena:

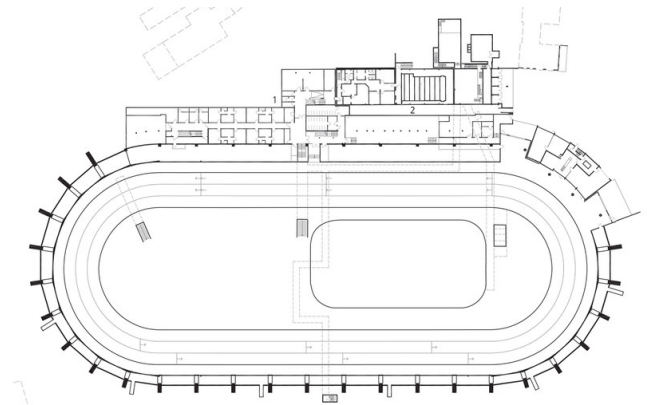
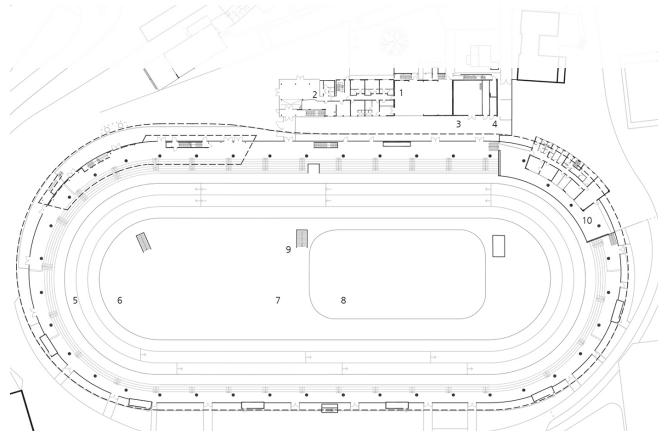
0 m²

Thialf:

100 m²

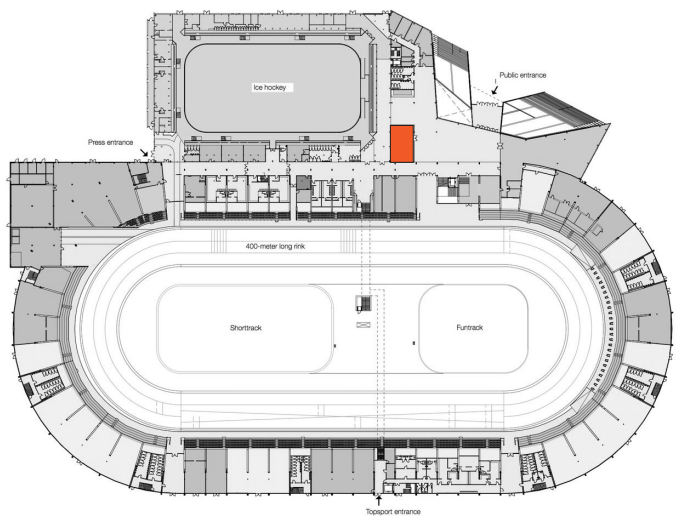
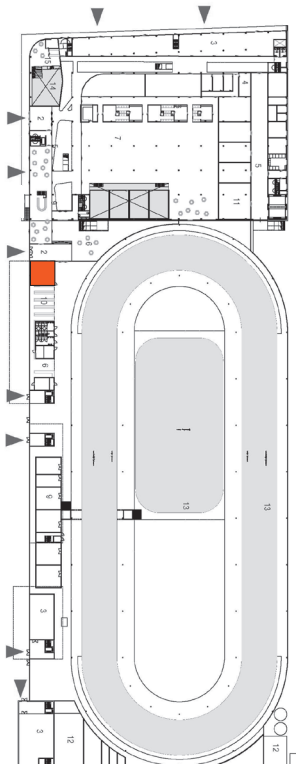
Average:

85,4 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Ireen Wüst IJsbaan (Sportcomplex T-Kwadraat), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

ICE SHEETS

Ireen Wüst IJbaan:

6639,0 m²

Max Aicher Arena:

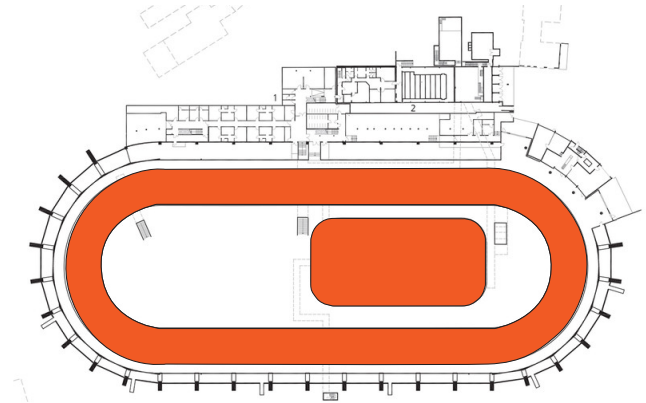
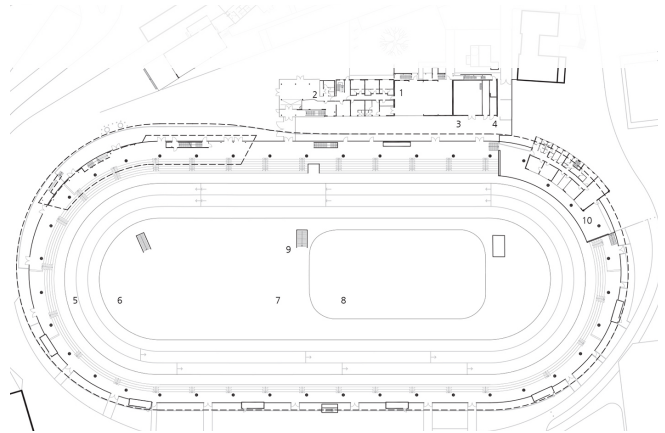
6639,0 m²

Thialf:

11899,0 m²

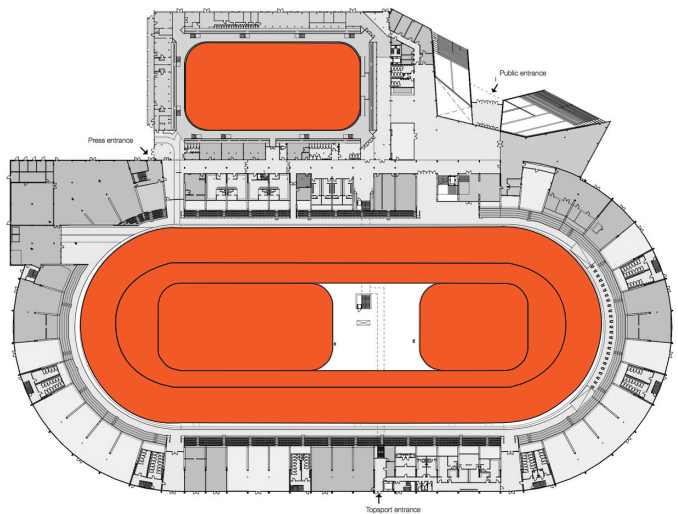
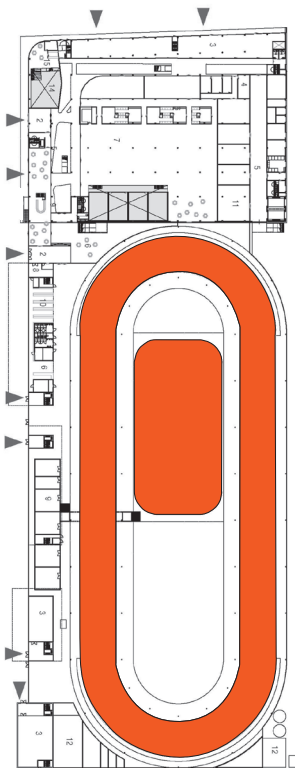
Average:

8392,2 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



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BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

CHANGING ROOMS

Ireen Wüst IJbaan:

581,2 m² (3 rooms)

Max Aicher Arena:

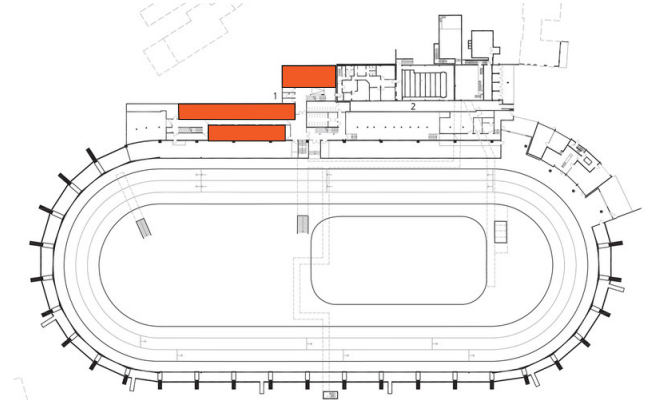
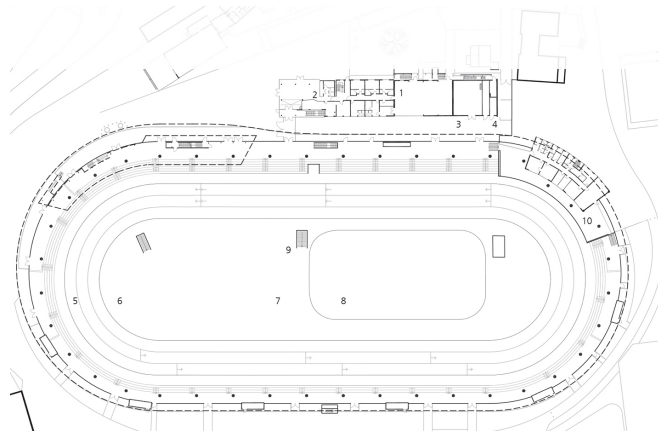
496,3 m²

Thialf:

925,3 m² (3 ice hockey rooms/ 7 ice skating/ 7 pro ice skating)

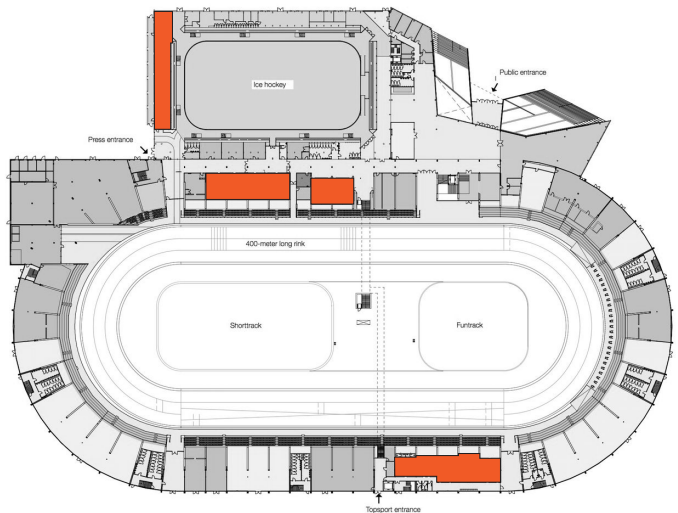
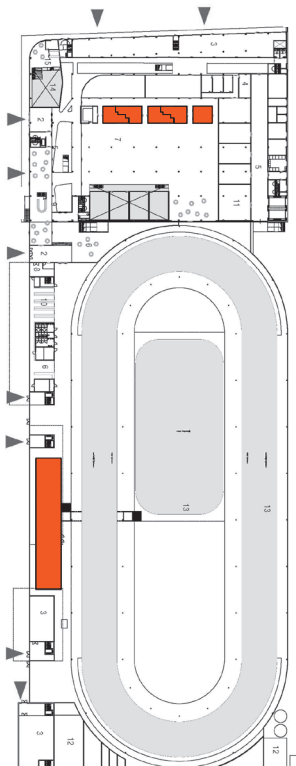
Average:

667,58 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



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BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

FITNESS

Ireen Wüst IJsbaan:

2187,5 m²

Max Aicher Arena:

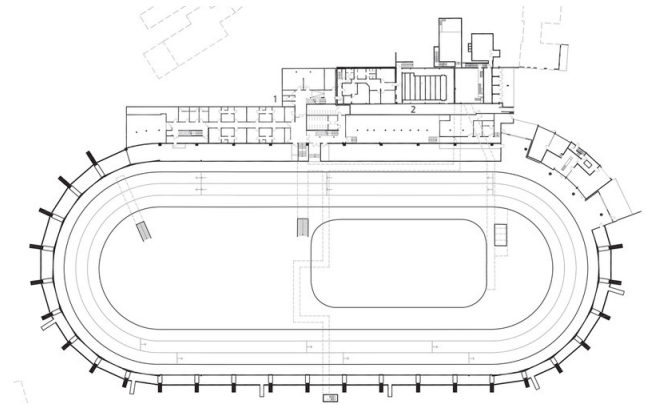
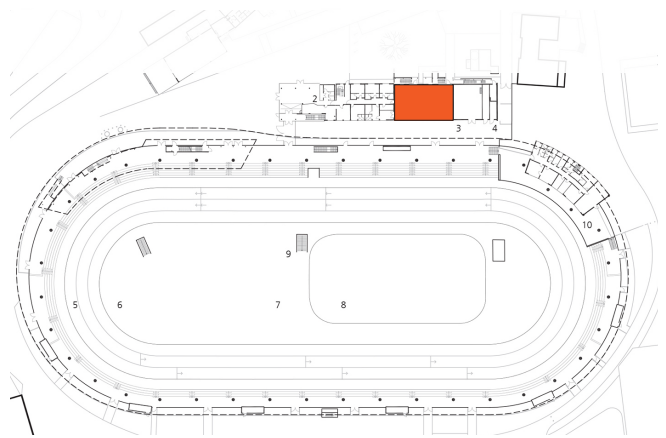
246,6 m²

Thialf:

0 m²

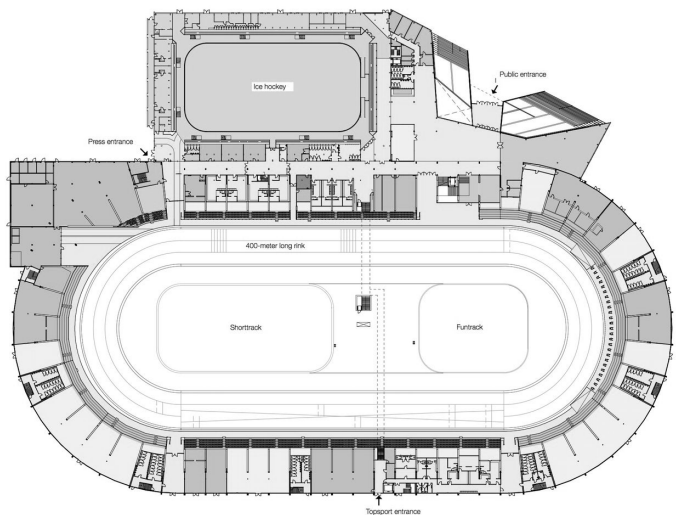
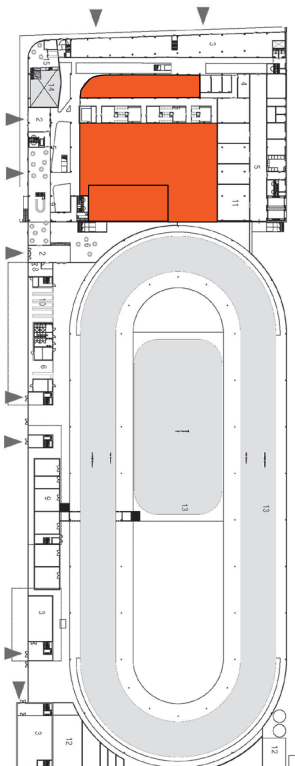
Average:

1217,1 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

COMMERCIAL SPACE

Ireen Wüst IJbaan:

1069,3 m²

Max Aicher Arena:

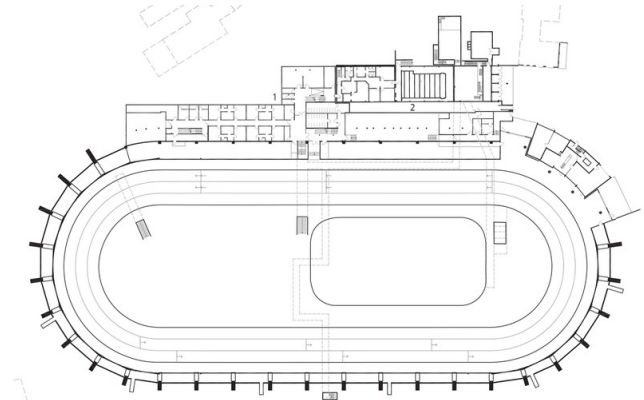
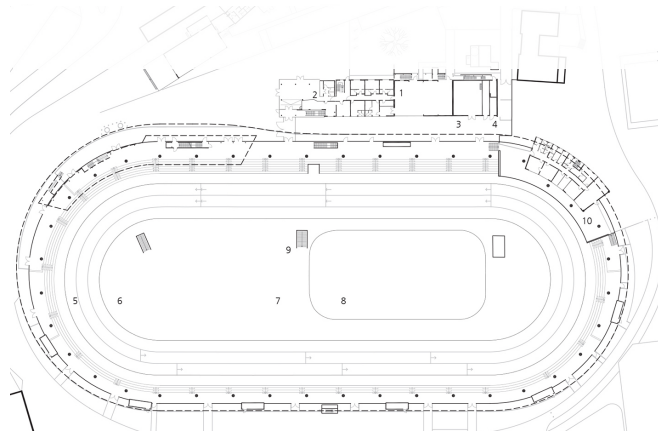
0 m²

Thialf:

2391,6 m²

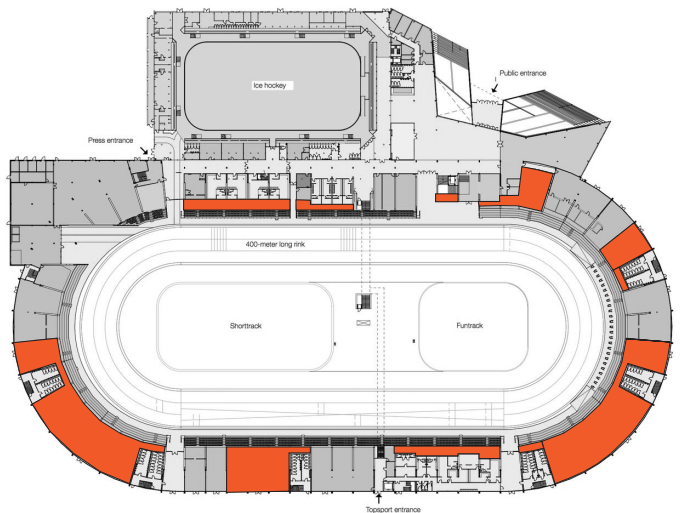
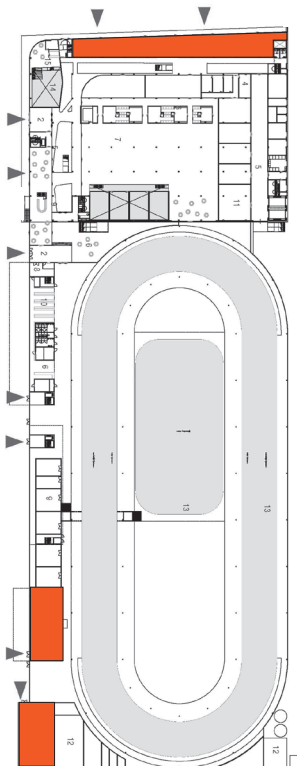
Average:

1730.5 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

GARDEROBE

Ireen Wüst IJsbaan:

100,9 m²

Max Aicher Arena:

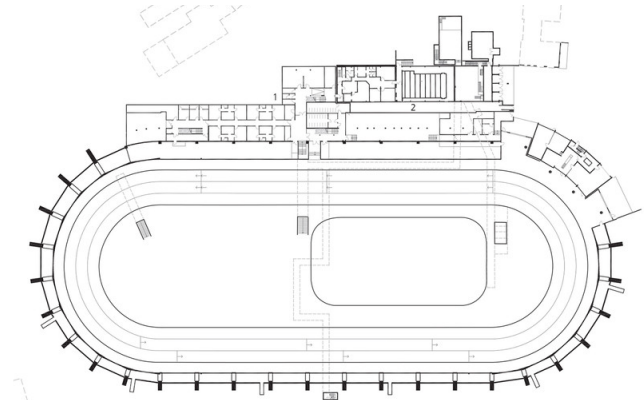
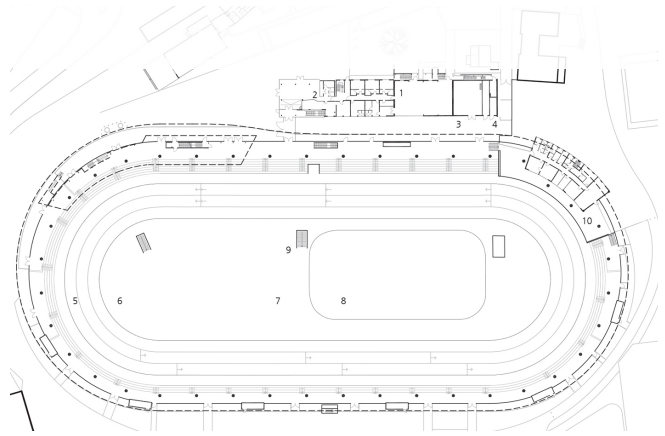
0 m²

Thialf:

21,9 m²

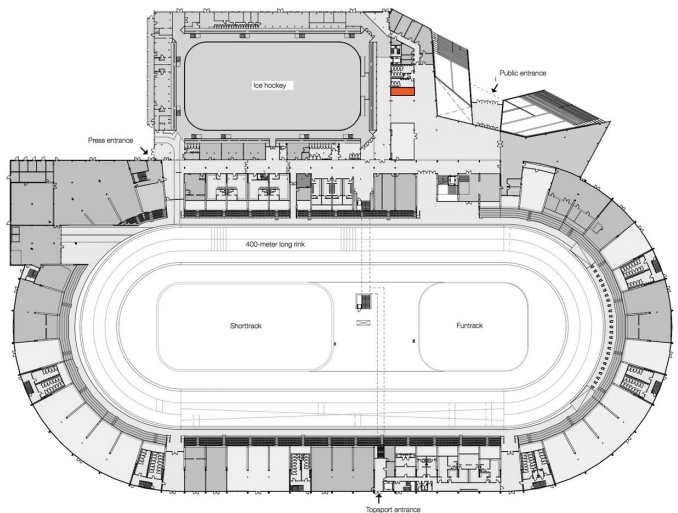
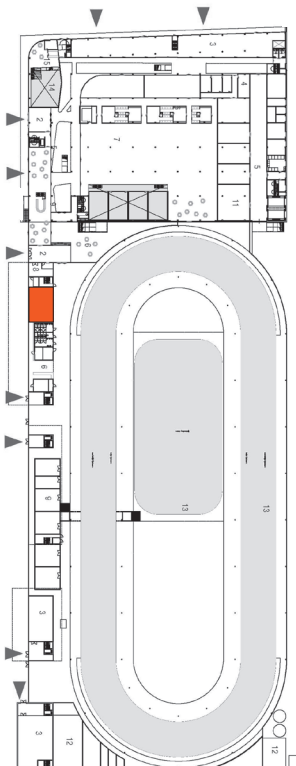
Average:

61,4 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

CAFE

Ireen Wüst IJbaan:

652,5 m²

Max Aicher Arena:

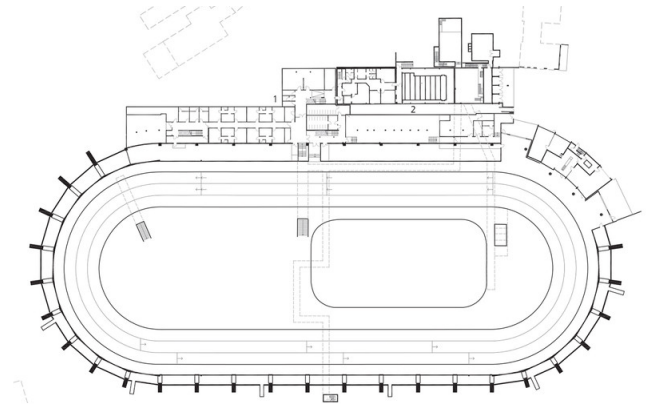
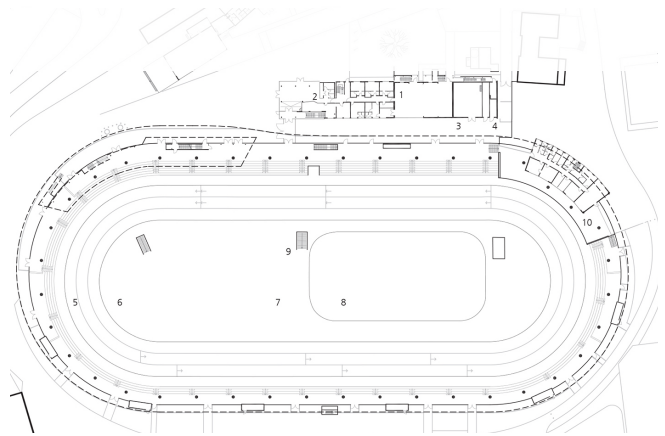
0 m²

Thialf:

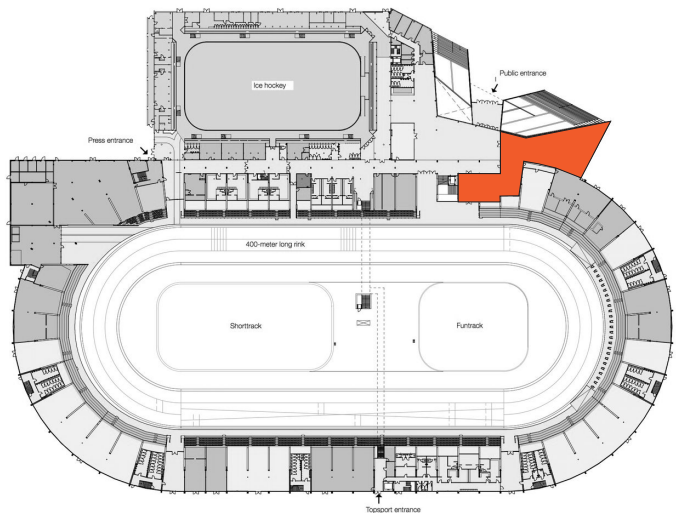
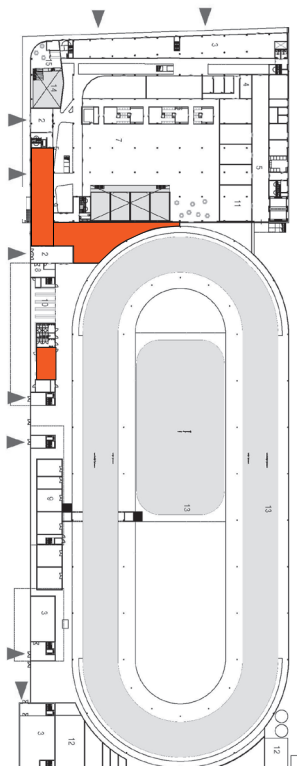
630,5 m²

Average:

641,5 m²



Max Aicher Arena, Inzell, Germany
Behnisch Architekten & Pohl Architekten



Ireen Wüst IJbaan (Sportcomplex T-Kwadrat), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

TECHNICAL SPACE

Ireen Wüst IJbaan:

261,8 m²

Max Aicher Arena:

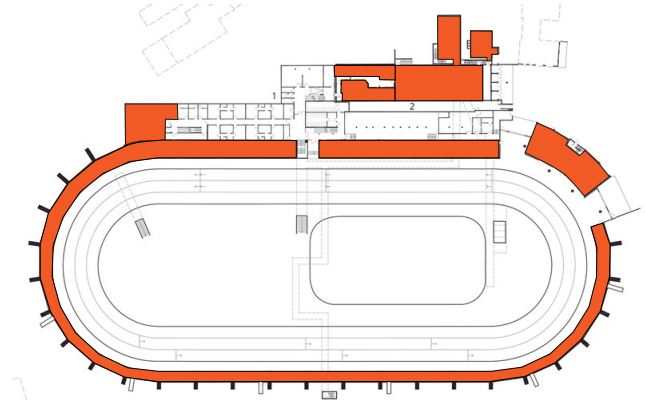
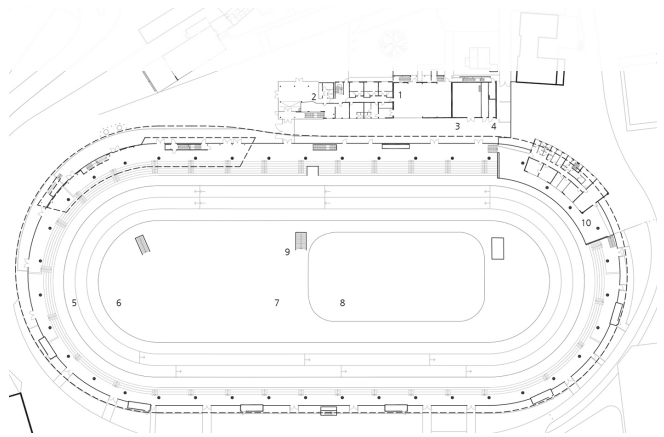
3186,2 m²

Thialf:

2921,6 m²

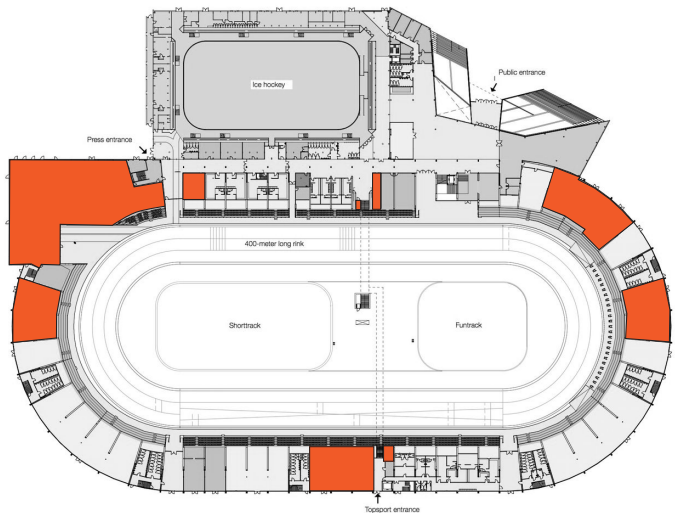
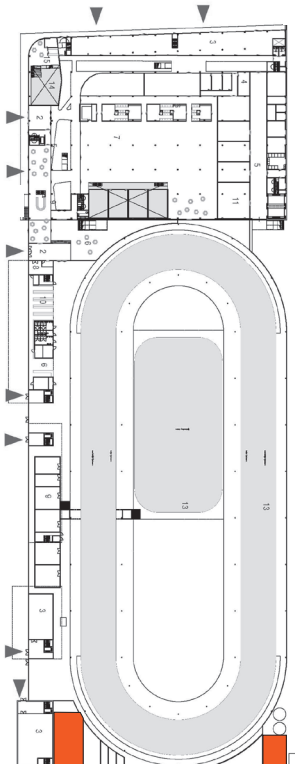
Average:

2123,2 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

TOILETS/SHOWERS

Ireen Wüst IJbaan:

66,5 m² (3 units)

Max Aicher Arena:

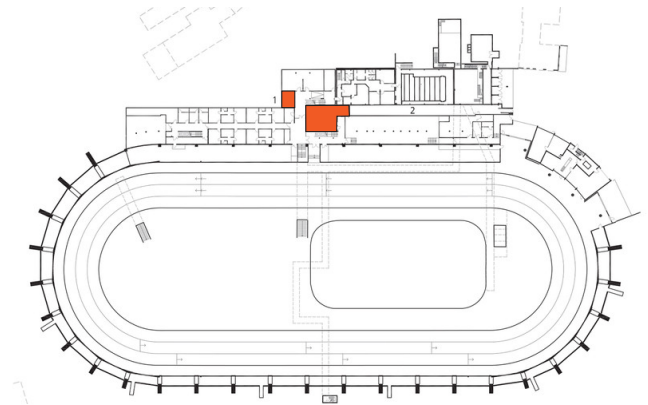
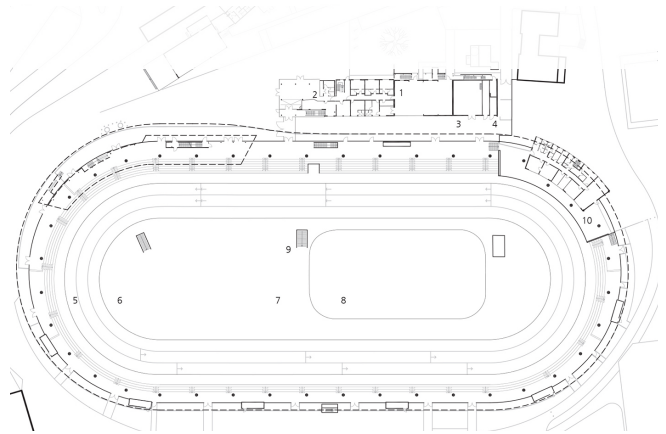
137,1 m² (3 units)

Thialf:

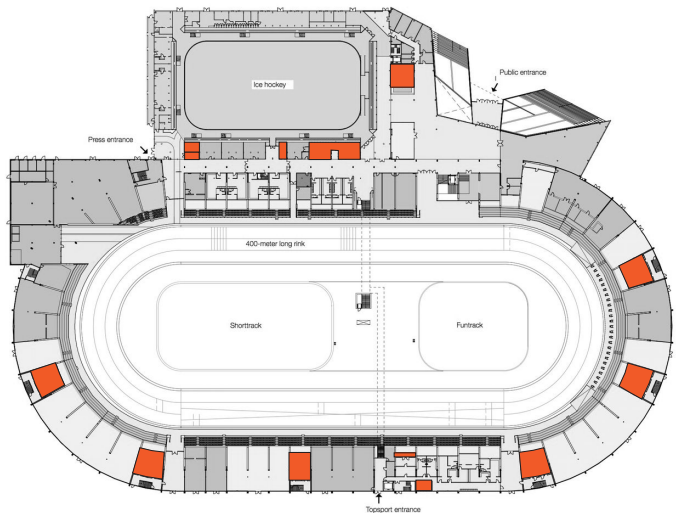
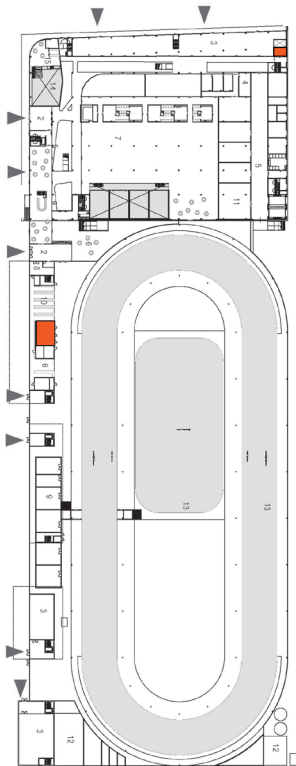
647,0 m² (21 units)

Average:

283,5 m²



Max Aicher Arena, Inzell, Germany
Behnisch Architekten & Pohl Architekten



Ireen Wüst IJbaan (Sportcomplex T-Kwadraat), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

MEDICAL ROOM

Ireen Wüst IJsbaan:

35,5 m²

Max Aicher Arena:

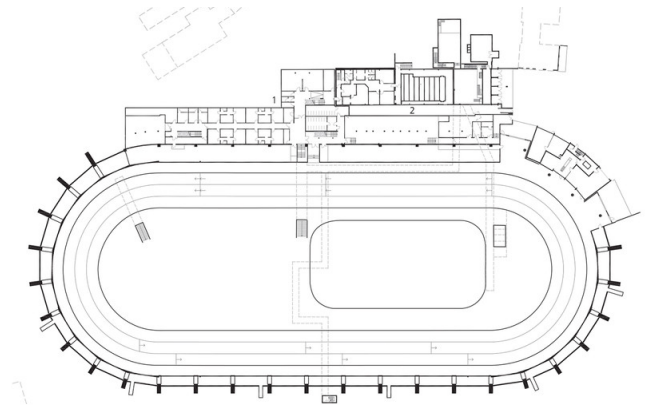
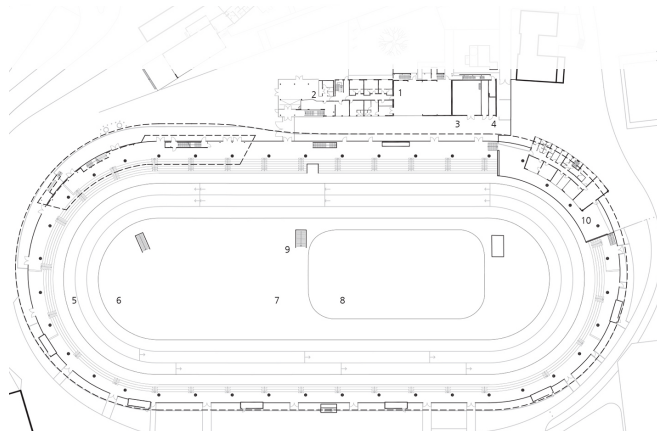
0 m²

Thialf:

25,3 m²

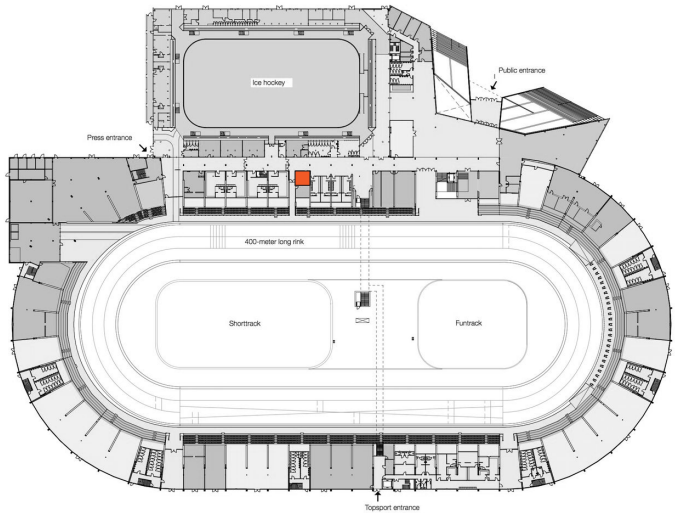
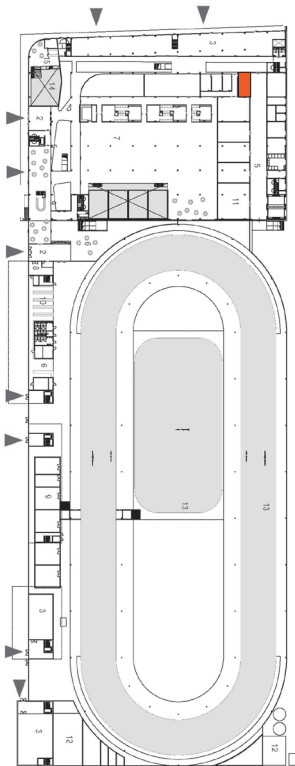
Average:

30,4 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



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BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

STORAGE

Ireen Wüst IJbaan:

973,7 m²

Max Aicher Arena:

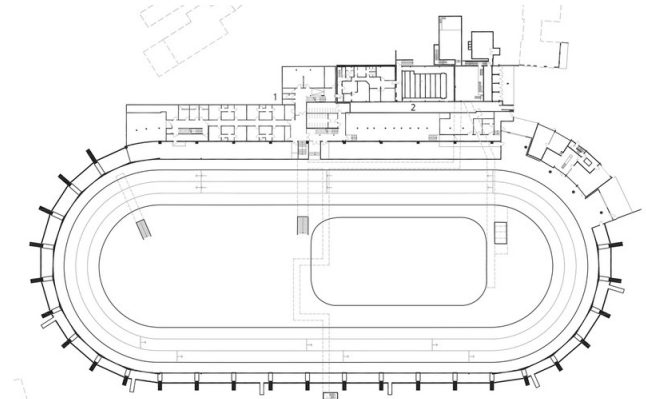
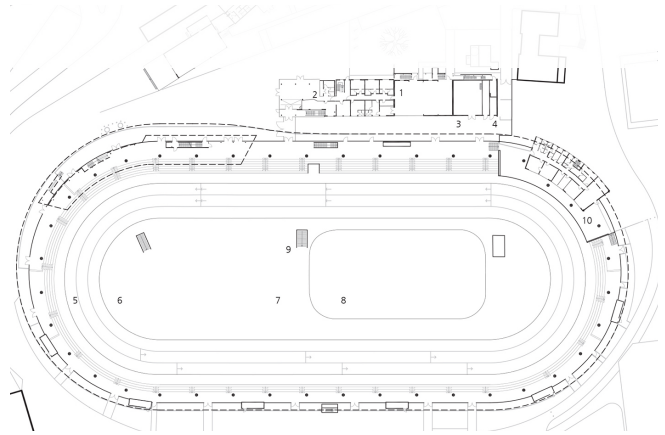
0 m²

Thialf:

1081,4 m²

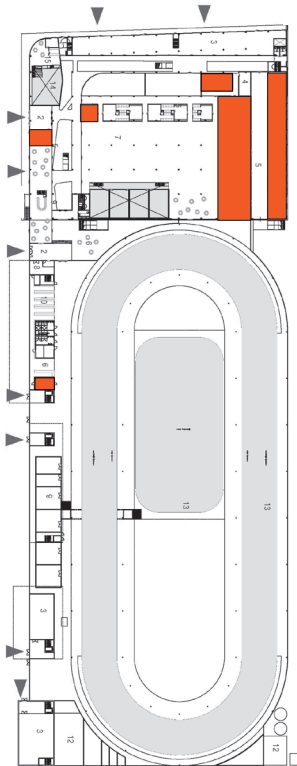
Average:

1027,5 m²

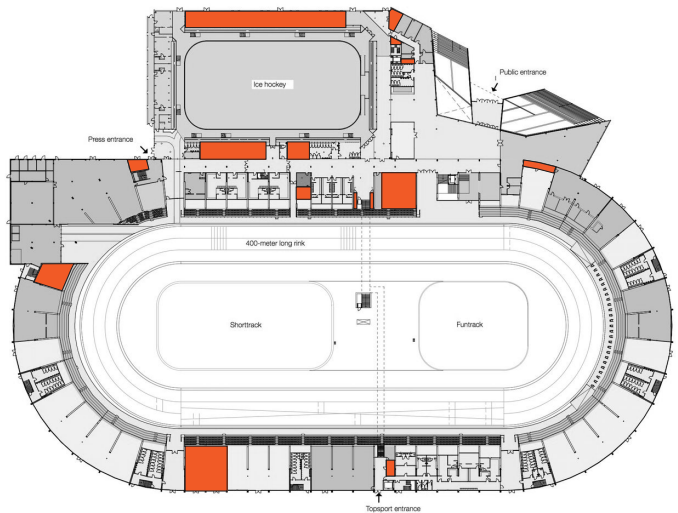


Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Ireen Wüst IJbaan (Sportcomplex T-Kwadaat), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten



Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

SPECTATORS SPACE

Ireen Wüst IJbaan:

0 m²

Max Aicher Arena:

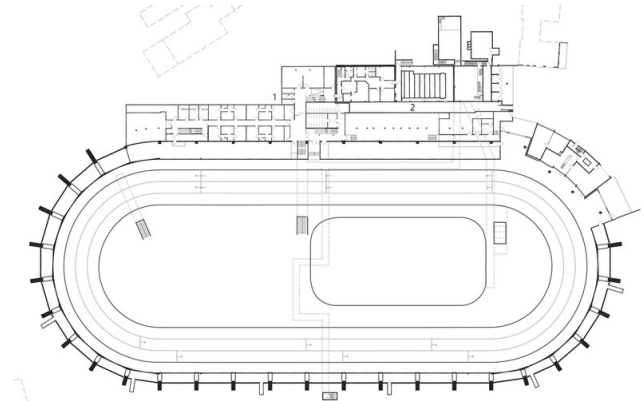
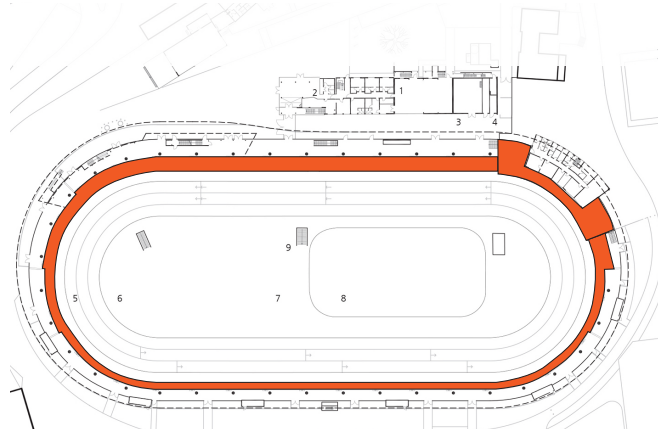
1835,6 m²

Thialf:

1843,5 m²

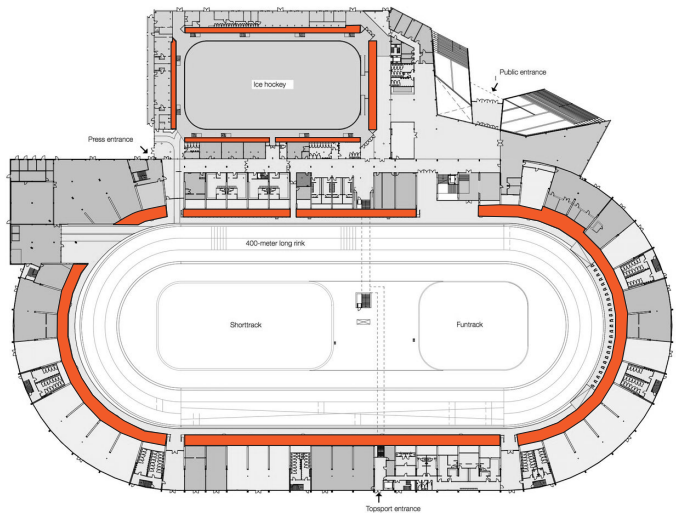
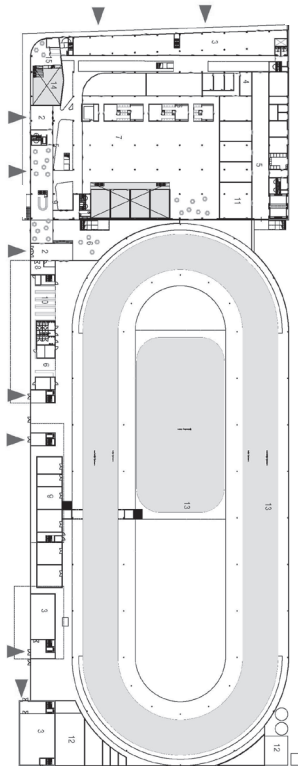
Average:

1839,6 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Thialf, Heerenveen, Netherlands

Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

UTILITY SPACE

Ireen Wüst IJbaan:

0 m²

Max Aicher Arena:

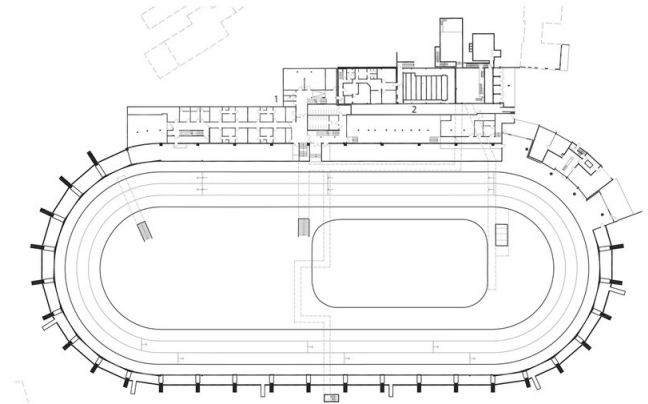
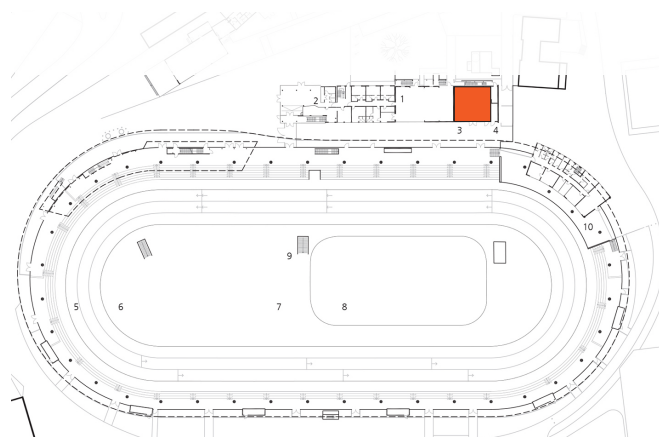
149,5 m²

Thialf:

0 m²

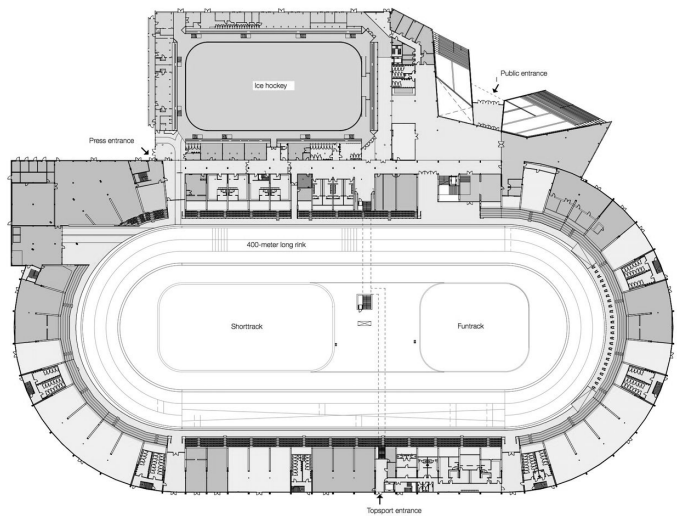
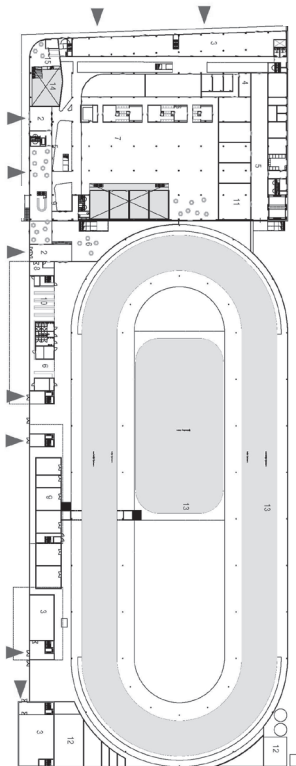
Average:

149,5 m²



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



APPENDIX 5: FLOORPLAN ANALYSIS

MULTIFUNCTIONAL SPACE

Ireen Wüst IJbaan:

957,5 m²

Max Aicher Arena:

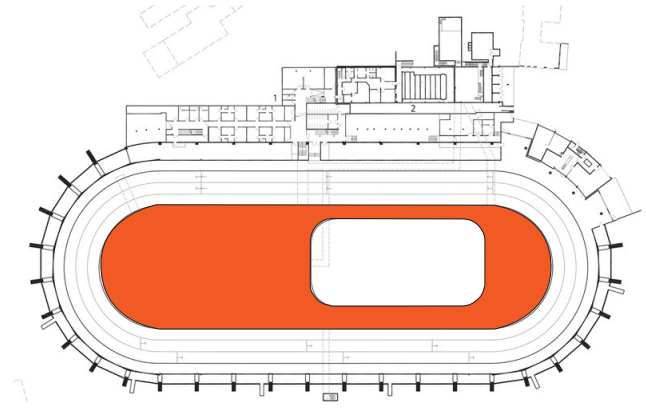
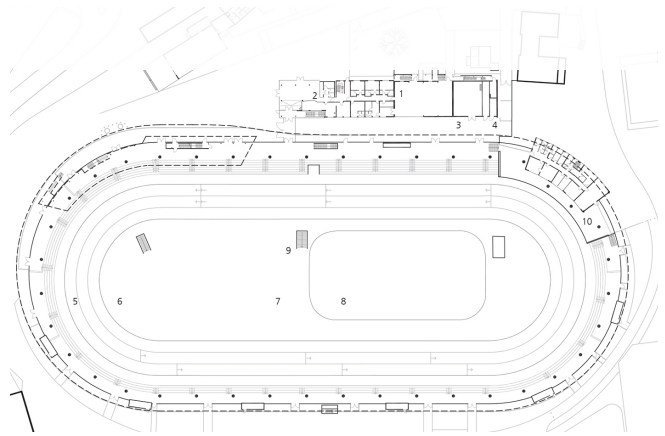
4468,4 m²

Thialf:

4468,4 m²

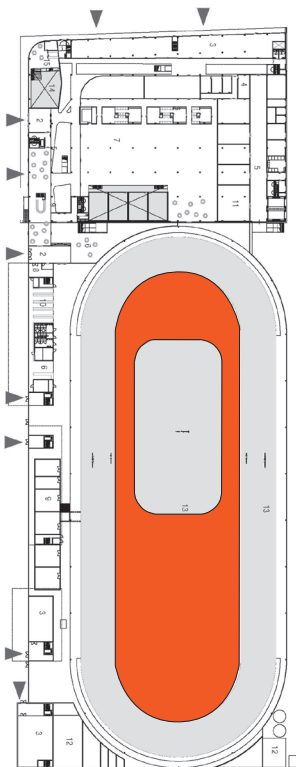
Average:

2712,9 m²

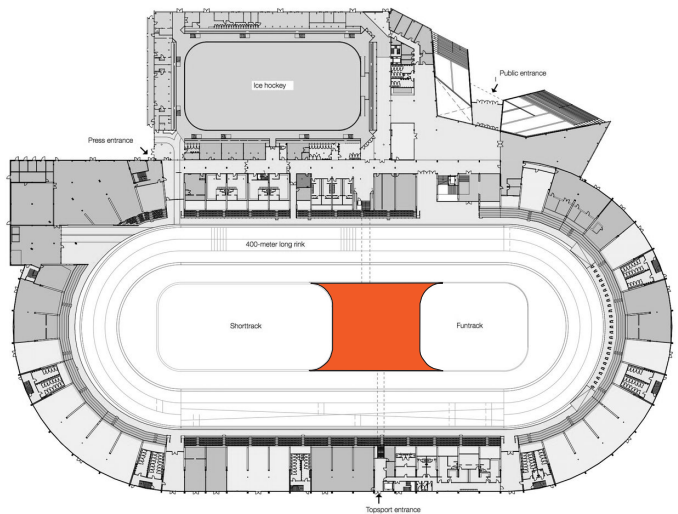


Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Ireen Wüst IJbaan (Sportcomplex T-Kwadaat), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten



Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

OFFICES

Ireen Wüst IJsbaan:

0 m²

Max Aicher Arena:

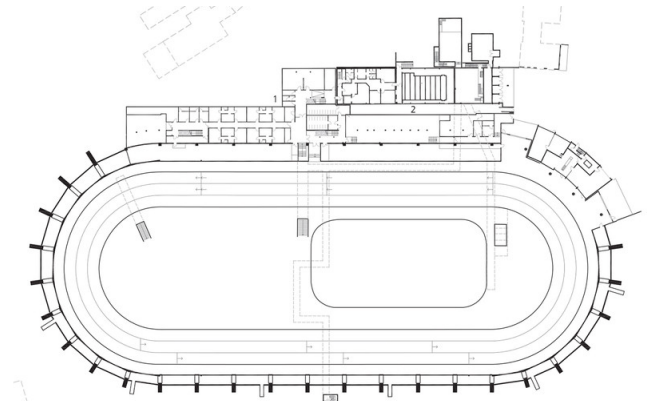
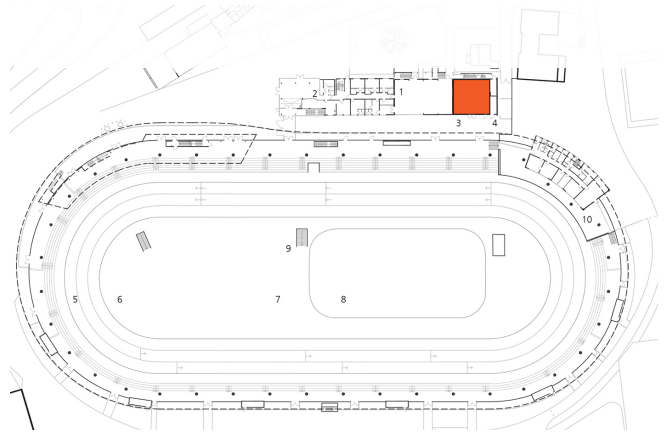
459,6 m²

Thialf:

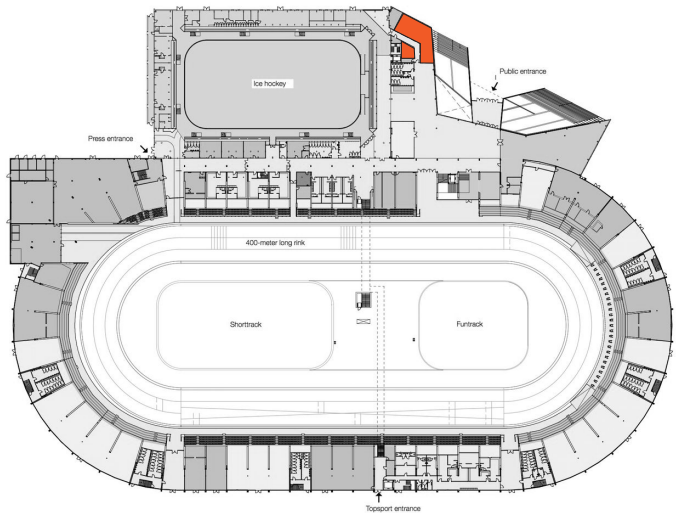
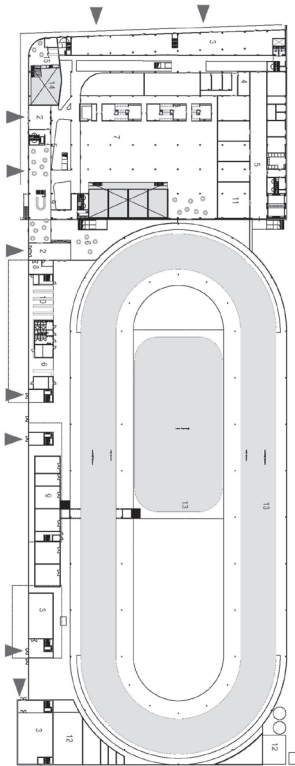
130,7 m²

Average:

295,1 m²



Max Aicher Arena, Inzell, Germany
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Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

OTHER

Ireen Wüst IJsbaan:

222,562 m2 (Climbing hall+cafe)

Max Aicher Arena:

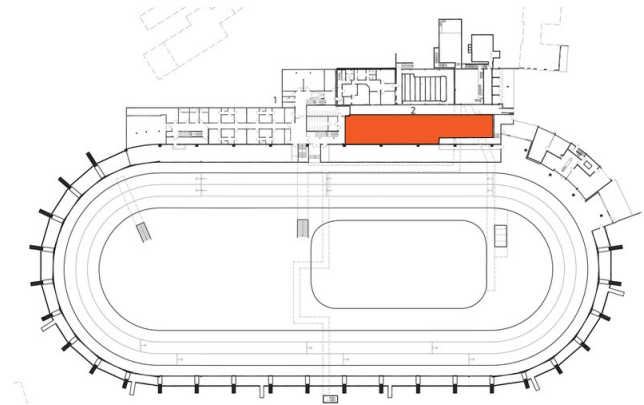
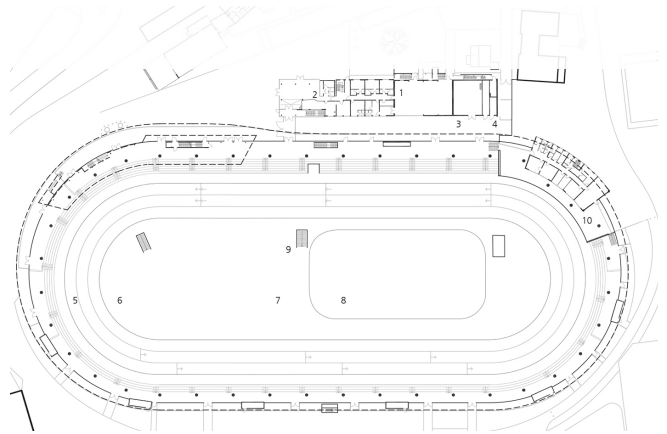
472,1 m2 (probably climatic room)

Thialf:

0 m2

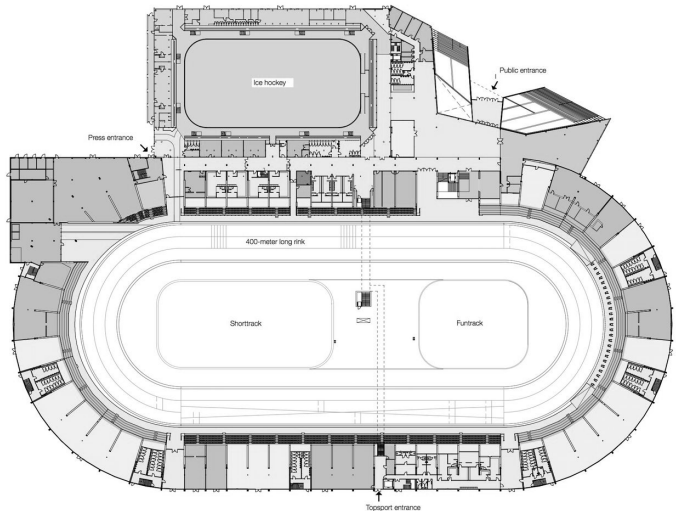
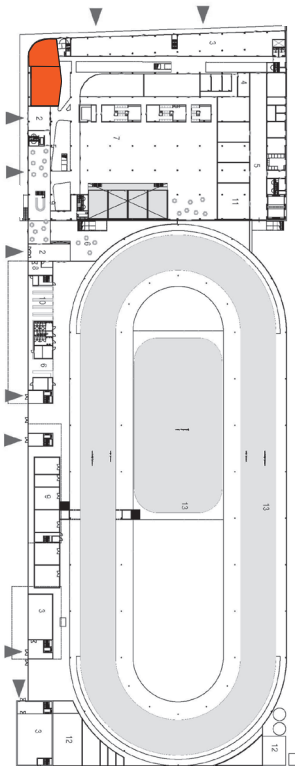
Average:

347,3 m2



Max Aicher Arena, Inzell, Germany

Behnisch Architekten & Pohl Architekten



Ireen Wüst IJsbaan (Sportcomplex T-Kwadrant), Tilburg, Netherlands
BO.2 Architectuur en Stedenbouw & van Hoogmoed architecten

Thialf, Heerenveen, Netherlands
Zwarts & Jansma Architecten

APPENDIX 5: FLOORPLAN ANALYSIS

	Max Aicher Arena		Thialf
Ice sheet 60x30	1756,45		1756,45
Ice sheet 400 rink	4882,52	tot: 6638,97	4882,52
Ice sheet 60x30 separate	0		1756,45
Entrylevel ice lap	0		2437,11
Funrink	0		1066,28
Garderobe	0		21,95
Rental	0		100,06
Techniek	3186,15	Zamboni space: 297,340, Ventilation: 2089,512 (onder tribune), Iceproduction: 799,300	2921,58
Fitness space	246,63		0
Changing rooms	496,26	Toilets 2units: 111,613, Shower 3 units: 25,484	925,27
Toilets separate units	137,10		646,99
Cafe	0		630,54
Commercial space	0		2391,564
Storage	0	Ice floor level: 2578,475, First floor (ground level): 3209,422	1081,36
Traffic space	5787,90		4865,46
Entrance	124,11		730,93
Medical room	0		25,26
Utility room	149,48		0
Spectator stands	1835,64		1843,55
Offices	459,57		130,70
Multifunctional space	4468,36		957,47
Other	472,06		0
Total	24002,231		29171,475

APPENDIX 5: FLOORPLAN ANALYSIS

	Ireen Wüst Ijsbaan	Average
	1756,45	1756,45
	4882,52	4882,52
	0	1756,45
	0	2437,11
tot: 11898,80	0	1066,28
	100,87	61,41
	70,76	85,41
Ice making space: 1255,213, Climate: 1666,367, No cooling room	261,77	2123,17
	2187,54	1217,09
Ice hockey (3 rooms): 235,277, Speed skating (7 rooms): 390,632, Pro Speed Skating (7 rooms): 299,357	581,21	667,58
Public (12 units): 476,196, Topsport (3 units): 30,105, Speedskating (3 units): 140,690	66,48	283,52
	652,54	641,54
	1069,34	1730,45
Ice hockey:311,628, Ice speedskating: 359,483, Offices/cafe: 62,036, Technical: 348,217	973,66	1027,51
	6323,47	5658,94
	146,23	333,76
	35,47	30,37
	0	149,48
	0	1839,60
	0	295,13
	4468,36	2712,91
	222,56	347,31
		climbing hall: 136,176 +Climbing: 86,386
	23799,216	25657,64067

